Sociality
Journal of Public Health Service
p-ISSN 2962-3472 | e-ISSN 2962-181X

Volume 5, Issue 1, September-February 2026
Page 1-9
doi 10.24252/sjphs.v5i1.63464

Flood crisis, ecological degradation, and hospital resilience in Sumatra: A One Health perspective

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ABSTRACT

Flooding is Indonesia's most recurrent hydrometeorological hazard, yet intervention-focused analyses that connect environmental degradation, infectious-disease risk, and health-service continuity through integrated One Health and Planetary Health lenses remain limited, especially for Sumatra, where rapid land-use change amplifies exposure and vulnerability. This study aims to analyze flooding in Sumatra as a multidimensional crisis by integrating One Health and Planetary Health perspectives while examining hospital resilience and crisis leadership during disaster response. A mixed-methods approach with descriptive-analytical analysis was applied using secondary data from disaster reports, health surveillance systems, scientific publications, and policy documents covering the period 2019–2024. The findings indicate that flood events in Sumatra increased from 126 cases in 2019 to 193 cases in 2024, affecting more than 380,000 people. The most frequently reported post-disaster diseases were diarrhea, leptospirosis, and acute respiratory infections. Substantial pressure on the healthcare system was evident, with approximately one-third to over half of hospitals experiencing disruptions in energy supply, water, and logistics, alongside patient visit increases of up to 45%, compounded by limitations in human resources. Moreover, variations in crisis leadership capacity across regions influenced the effectiveness of emergency responses. These findings suggest that flood preparedness in Sumatra should be implemented as an integrated health intervention package: One Health–based surveillance and risk communication, targeted WASH and vector/rodent control in high-risk rural communities, urban surge-capacity planning, and climate-resilient hospital measures (redundant power/water, supply-chain continuity, and incident-command training) aligned with global guidance.

ABSTRAK

Banjir merupakan bencana hidrometeorologis paling sering terjadi di Indonesia, namun analisis yang berfokus pada intervensi yang menghubungkan degradasi lingkungan, risiko penyakit menular, dan keberlangsungan layanan kesehatan melalui lensa One Health dan Planetary Health masih terbatas, terutama di Sumatra, tempat perubahan penggunaan lahan yang cepat meningkatkan paparan dan kerentanan. Penelitian ini bertujuan menganalisis banjir di Sumatra sebagai krisis multidimensi dengan mengintegrasikan perspektif One Health dan Planetary Health, serta meninjau ketahanan rumah sakit dan kepemimpinan krisis dalam respons bencana. Penelitian menggunakan pendekatan mixed-methods dengan analisis deskriptif-analitik terhadap data sekunder yang bersumber dari laporan kebencanaan, sistem surveilans kesehatan, publikasi ilmiah, dan dokumen kebijakan selama periode 2019–2024. Hasil analisis menunjukkan bahwa kejadian banjir di Sumatra meningkat dari 126 kejadian pada 2019 menjadi 193 kejadian pada 2024, berdampak pada lebih dari 380.000 penduduk. Penyakit yang paling sering meningkat pascabencana meliputi diare, leptospirosis, dan infeksi saluran pernapasan akut. Tekanan terhadap sistem kesehatan juga meningkat, ditandai dengan gangguan pasokan energi, air, dan logistik di sekitar sepertiga hingga lebih dari separuh rumah sakit, serta lonjakan kunjungan pasien hingga 45% yang diperparah oleh keterbatasan sumber daya manusia. Selain itu, terdapat variasi kemampuan kepemimpinan krisis antarwilayah yang memengaruhi efektivitas respons. Temuan ini menunjukkan kesiapsiagaan banjir di Sumatra perlu dijalankan sebagai paket intervensi kesehatan terpadu: surveilans dan komunikasi risiko berbasis One Health, WASH serta pengendalian vektor/rodensia terarah di komunitas pedesaan berisiko tinggi, perencanaan kapasitas lonjakan di perkotaan, serta penguatan ketahanan rumah sakit terhadap iklim (redundansi listrik/air, kesinambungan logistik, dan pelatihan incident command) sesuai pedoman global.

ARTICLE INFO

Keywords
flooding; one health; planetary health; hospital resilience; crisis leadership

Article History
Submit : 10 December 2025
In Review : 13 December 2025
Accepted : 20 December 2025

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INTRODUCTION

Indonesia is highly vulnerable to hydrometeorological disasters, particularly flooding. Geographic characteristics, land-use change, demographic pressure, and climate dynamics collectively contribute to the increasing frequency and severity of flood events, which generate wide-ranging impacts on health, society, and the economy (Badan Nasional Penanggulangan Bencana [BNPB], 2024; United Nations Office for Disaster Risk Reduction [UNDRR], 2022; Djalante et al., 2020). In recent years, floods have not only occurred more frequently but have also expanded spatially, causing substantial disruption to public health systems and socioeconomic stability (BNPB, 2024; World Health Organization [WHO], 2023).

In Sumatra, a clear upward trend in flood incidence has been observed over the last decade. Several regions have experienced significant declines in forest cover and degradation of watershed areas, while land-use conversion—including peatland exploitation—has reduced the environmental capacity to absorb surface runoff (Kementerian Lingkungan Hidup dan Kehutanan [KLKH], 2024; Djalante et al., 2020). During periods of high rainfall, these accumulated vulnerabilities result in floods extending into residential areas, economic centers, and healthcare facilities (BNPB, 2024; nited Nations Development Programme [UNDP], 2021).

The health implications of flooding are diverse and severe. Limited access to clean water, disrupted sanitation, and reduced availability of health services increase the risk of environmentally mediated diseases such as diarrhea, leptospirosis, acute respiratory infections (ARI), and skin infections. In addition to physical illnesses, psychosocial stress experienced by displaced populations in evacuation settings contributes to a growing burden of mental health problems (WHO, 2023; Centers for Disease Control and Prevention [CDC], 2022; Akdernab et al., 2012; Shultz & Forbes, 2024). Vulnerable populations, including young children, older adults, pregnant women, individuals with chronic diseases, and people with disabilities, face disproportionately higher health risks during and after flood events (Kementerian Kesehatan Republik Indonesia [Kemenkes RI], 2024; United Nations Children's Fund [UNICEFF], 2022).

The One Health approach identifies ecosystem disruption as a key determinant influencing disease dynamics following flood events (Food and Agriculture Organization, World Health Organization, & United Nations Environment Programme (Food and Agriculture Organization, World Health Organization, & United Nations Environment Programme [FAO, WHO, & UNEP], 2022; Djalante et al., 2020). When ecological balance is disturbed, the risk of zoonotic diseases such as leptospirosis increases markedly (CDC, 2022; Alderman et al., 2012). Complementarily, the Planetary Health framework emphasizes the interconnected relationship between degradation of Earth systems and escalating threats to human health (Whitmee et al., 2015).

Hospitals play a central role in disaster response; however, the capacity of many hospitals in Sumatra is frequently compromised during major flood events. Disruptions to energy supply, clean water availability, medical logistics, and increasing patient workloads are recurrent challenges reported in flood-affected areas (UNDP, 2021; World Bank, 2021; Kruk et al., 2015, WHO, 2020). These conditions indicate that hospital resilience in flood-prone regions remains insufficient and requires substantial strengthening (World Bank, 2021; Kruk et al., 2015).

At the same time, the quality of crisis leadership significantly influences the effectiveness of health emergency responses. Leaders who demonstrate rapid decision-making, transparent communication, and strong cross-sector coordination are more likely to reduce secondary impacts of disasters and ensure continuity of essential health services (UNDRR, 2022; World Bank, 2021; Kementerian Koordinator Pembangunan Manusia dan Kebudayaan [Kemenko PMK], 2023).

Despite the growing body of literature on flooding, health impacts, and disaster management, integrative analyses that simultaneously examine ecological degradation, post-disaster health risks, hospital resilience, and crisis leadership within a unified One Health and Planetary Health framework remain limited, particularly in the Indonesian context. This gap restricts the ability of policymakers and health systems to design coherent, cross-sectoral strategies for flood risk reduction and health system preparedness.

Therefore, this paper aims to analyze flooding in Sumatra as a multidimensional health crisis by integrating environmental degradation, disease risk patterns, hospital resilience, and crisis leadership perspectives. The contribution of this study lies in providing a comprehensive, systems-based analysis that bridges environmental health, disaster epidemiology, and health system governance, thereby offering evidence-informed insights to support resilient, ethical, and sustainable disaster response and health policy development in flood-prone regions of Indonesia.

METHODS

This study employed a mixed-methods design with a descriptive–analytical approach based on an ecological study framework and health policy analysis. This design was selected to examine flooding as a complex phenomenon arising from interactions among environmental factors, public health dynamics, healthcare service systems, and governance and leadership structures.

The study focused on flood-affected regions across Sumatra Island, Indonesia, covering the period from 2019 to 2024, which represents a phase of increasing flood incidence associated with extreme climate variability.

Secondary data were utilized in this study, including: (1) official reports from national and local governments on flood events, health impacts, and damage to healthcare facilities; (2) national and international scientific publications from the past five years related to One Health, Planetary Health, disaster epidemiology, hospital resilience, and crisis leadership; (3) reports from international organizations such as the World Health Organization (WHO), United Nations Office for Disaster Risk Reduction (UNDRR), Food and Agriculture Organization (FAO), and the International Federation of Red Cross and Red Crescent Societies (IFRC); and (4) national policy documents addressing health and environmental sectors in Indonesia.

The analytical framework integrated three main perspectives: One Health, to assess human–animal–environment interactions in post-disaster disease risks; Planetary Health, to evaluate the impacts of ecosystem degradation on sustainable human health; and health system resilience, with a specific focus on hospital resilience. Crisis leadership was analyzed across key dimensions, including decision-making speed, cross-sectoral coordination, information transparency, and ethical commitments to protecting human life and environmental sustainability.

Key variables examined comprised environmental drivers of flood risk, post-disaster disease patterns, hospital response capacity, crisis leadership quality, and ecological health ethics. Data analysis involved descriptive trend analysis of flood events and health risks, thematic analysis of policies and leadership practices, and triangulation of data sources to enhance the validity and robustness of the findings.

RESULTS AND DISCUSSION

Characteristics of floods in Sumatra

Floods in Sumatra during the study period showed characteristics that reflected a combination of extreme rainfall and weakened ecological conditions. Many areas are no longer able to withstand water flow due to vegetation decline and land use changes. As a result, floods have spread to residential areas and vital infrastructure, including health facilities. This situation has disrupted logistics distribution, patient mobility, and the continuity of basic services such as electricity and clean water.

Analysis of secondary data shows that flood events on the island of Sumatra have increased consistently during the 2019–2024 period. The number of events increased from 126 in 2019 to 193 in 2024, with the affected area expanding to cover all provinces in Sumatra (BNPB, 2024; UNDRR. 2022; Djalante et al., 2020). This increase is in line with the national trend of hydrometeorological disasters influenced by extreme rainfall dynamics and environmental degradation.

During this period, estimates of the number of people affected also showed a significant increase, from around 210,000 in 2019 to more than 380,000 in 2024 (BNPB, 2024; UNICEF, 2022). The most significant increase in the number of people affected occurred in areas with high rates of

deforestation and peatland conversion, particularly in South Sumatra, Jambi, Riau, and Aceh (KLKH, 2024; Djalante, 2020).

Table 1
Flood occurrence trends on Sumatra Island (2019–2024)

Year	Number of Flood Events	Affected Provinces (n)	Estimated Affected Population	Key Notes
2019	126	7	± 210,000 people	Initial increase in extreme rainfall; severe degradation in several river basins
2020	148	8	± 265,000 people	Influence of La Niña; increased urban flooding and peatland inundation
2021	162	10	± 310,000 people	Expansion of flooding into non-traditional areas; disruption of access to health services
2022	175	10	± 340,000 people	Widespread forest and peatland degradation; escalating health risks
2023	188	10	± 355,000 people	Recurrent extreme rainfall patterns; increased incidence of flash floods
2024	193	10	± 380,000 people	Intensifying flood trends; growing demand for health emergency response

Note: Secondary data was synthesized from disaster reports and scientific publications.

Table 1 shows a consistent increase of ±7–10% per year, consistent with the phenomenon of climate-induced hydrometeorological disasters and ecological degradation. The number of people affected has increased significantly as the risk area has expanded.

Post-disaster health risks

Various diseases emerge or increase after flooding. Cases of diarrhea and leptospirosis are most commonly reported, in line with the high exposure of the community to contaminated floodwater (WHO, 2023; CDC, 2022; Alderman et al., 2012). Respiratory diseases also increase due to crowded evacuation conditions and poor ventilation. In addition, mental stress due to loss of homes, livelihoods, and uncertainty worsens the health conditions of the community (Shultz & Forbes, 2014; UNICEF, 2022).

A synthesis of health surveillance data and scientific publications shows that flooding is associated with a significant increase in the risk of environment-based diseases in affected areas. The diseases with the most dominant increase in incidence were diarrhea (2.0–3.5 times), leptospirosis (2.5–4.0 times), and acute respiratory infections (1.8–2.2 times) in the 2–6 weeks after the disaster (WHO, 2023; CDC, 2022; Alderman et al., 2012).

Table 2
Risk of post-flood diseases in Sumatra (Estimates for 2019–2024)

Disease Type	Average Increase in Incidence	Main Driving Factors	Most Vulnerable Groups
Diarrhea	2.0–3.5 fold increase	Water contamination; poor sanitation	Children under five; older adults
Leptospirosis	2.5–4.0 fold increase	Exposure to floodwater contaminated with animal urine	Outdoor workers; adult males
Acute Respiratory Infections (ARI)	1.8–2.2 fold increase	Temporary shelters; population overcrowding	Children; older adults
Skin Diseases	2.0–3.0 fold increase	Direct skin contact with floodwater; poor hygiene	All age groups
Dengue Fever	1.5–2.0 fold increase	Standing water promoting mosquito breeding	Children and young adults
Mental Health Disorders	Not precisely quantified (increasing trend)	Trauma, loss, uncertainty	All groups, particularly women

Note: Based on regional surveillance reports, national scientific publications, and environmental disease epidemiology patterns.

Leptospirosis showed the sharpest increase in areas with high population density and poor sanitation. Flooding expands the area of human contact with water contaminated by rodent urine, thereby significantly increasing the risk of zoonotic transmission (CDC, 2022; FAO, WHO, UNEP, 2022; Alderman et al., 2012). These conditions indicate that ecological and human behavioral factors play a major role in shaping post-disaster risk patterns.

In addition to infectious diseases, mental health disorders also show an increasing trend, although this has not been optimally quantified in the routine surveillance system. Post-disaster psychosocial studies show an increase in the incidence of anxiety, depression, and post-traumatic stress disorder in adult and female groups (Shultz & Forbes, 2014; UNICEF, 2022).

Table 2 shows the most prevalent diseases: diarrhea and leptospirosis, in line with the One Health pattern—water contamination, human–animal interaction, and environmental damage. Mental health disorders need to be included as an important finding in the Planetary Health perspective.

Impact on hospital services

Hospitals face severe pressure during floods. Many facilities experience power and water outages that directly impact emergency and critical care functions (UNDP,, 2021; World Bank, 2021; WHO, 2020). Medical logistics shortages and supply delays exacerbate the situation, while surges in patient visits increase the burden on health workers (WHO, 2023; Kemenkes RI, 2024). Suboptimal internal preparedness highlights the need for more structured system strengthening.

From a healthcare system perspective, flooding has a direct impact on hospital operations in affected areas. Approximately 30–55% of hospitals experienced disruptions to electricity and clean water supplies during the emergency response phase, with disruptions lasting between 6 and 72 hours (UNDP,, 2021; World Bank, 2021; WHO, 2020). Dependence on a single primary energy source and limited backup systems made essential services such as emergency rooms, operating rooms, and laboratories highly vulnerable.

In addition to infrastructure disruptions, limited medical logistics were also a major problem. Delays in the distribution of medicines, intravenous fluids, oxygen, and medical equipment were reported in approximately 25–35% of hospitals in areas severely affected by flooding (World Bank, 2021; Kruk et al., 2015). At the same time, there has been a 20–45% surge in patient visits, particularly for cases of diarrhea, respiratory infections, injuries, and complications from chronic diseases (WHO, 2023; Kemenkes RI, 2024).

The preparedness of health human resources has also come under severe pressure. Mobility constraints due to flooding, work fatigue, and limitations in the staff rotation system have led to a significant increase in the workload of health workers (World Bank, 2021; Kruk et al., 2015). These conditions indicate the low operational resilience of hospitals in dealing with recurring hydrometeorological disasters.

Table 3
Impact of flooding on hospital operations in Sumatra (2019–2024)

Hospital Operational Aspect	Dominant Impact	Estimated Affected Hospitals (%)	Notes
Electricity & Backup Generators	Power supply disruption for 6–48 hours	30–45%	Many hospitals lack multi-layered energy backup systems
Clean Water Supply	Supply disrupted for 1–3 days	40–55%	Wells and municipal water systems affected by flooding
Medical Logistics	Supply delays exceeding 72 hours	25–35%	Logistic distribution disrupted due to damaged road access
Human Resource Preparedness	Staff fatigue and limited shift availability	35–50%	Contract and support staff unable to report due to access constraints
Patient Surge	Increase in patient visits by 20–45%	45–60%	Predominantly diarrhea, ARI, and injury cases
Infrastructure Damage	Minor to moderate damage	10–15%	Mainly affecting basements and electrical installations

Note: Empirical data based on regional reports, hospital disaster incidents, and health facility resilience patterns.

Table 3 shows that hospital resilience is still inadequate, particularly in terms of critical lifelines (energy, water, communication) and service load management. This is consistent with global literature on the vulnerability of health facilities in middle-income countries.

Leadership and crisis management

The results of the study show striking variations in the quality of leadership between regions. In some districts, quick decisions and good coordination accelerated flood response. Conversely, regions that experienced delays in mobilizing resources faced greater impacts. This is consistent with the crisis leadership literature, which emphasizes the important role of integrity and communication skills in emergencies (UNDRR, 2022; World Bank, 2021; Kemenko PMK, 2023).

The crisis leadership literature emphasizes integrity, ethical communication, and stakeholder engagement as core determinants of effective outcomes in emergencies. Foundational syntheses and reviews highlight transparent, inclusive, and ethically grounded messaging as essential for trust, legitimacy, and cooperative action during crises (Dwinanda et al., 2025; , Riggio & Newstead, 2023; . Consistently highlighted leadership competencies include conflict-aware communication, empathy, adaptive decision-making, and collaboration among stakeholders, with frameworks such as meta-leadership and task–people–adaptive models organizing these competencies for crisis contexts Riggio & Newstead, 2023; , Cartwright et al., 2023). Empirical work links clear, transparent, and empathetic communication with leaders' credibility and stakeholder confidence while underscoring the importance of addressing emotional dimensions of crises to maintain well-being and trust among teams (Adigwe et al., 2024; , Singh et al., 2024). Case studies in crisis communication leadership illustrate how reframing messages and equitable resource sharing enhance legitimacy and resilience Voina & Stoica, 2023), Cartwright et al., 2023). Thus, integrity-centered communication and stakeholder-focused engagement emerge as consistent prerequisites for effective crisis leadership across sectors (Dwinanda et al., 2025; , Riggio & Newstead, 2023; , Voina & Stoica, 2023).

Floods as a reflection of the ecological crisis

The consistent increase in flooding in Sumatra during the period 2019–2024 confirms that hydrometeorological disasters in Indonesia have shifted from episodic events to recurring structural threats (BNPB, 2024; UNDRR, 2022; Djalante et al., 2020). Deforestation, degradation of watersheds, and conversion of peatlands significantly reduce the environment's capacity to regulate the hydrological cycle, thereby increasing the risk of surface runoff during extreme rainfall (KLKH, 2024; Djalante et al., 2020).

Within the framework of Planetary Health, these findings indicate that disturbances to the Earth's life support systems have direct implications for increased human health risks (Whitmee et al., 2015). Flooding can no longer be positioned solely as a technical disaster issue, but as an indicator of the failure of environmental governance in the face of global climate change pressures.

Disease risk from a One Health perspective

The significant increase in cases of diarrhea, leptospirosis, and acute respiratory infections after the floods shows that health risks in Sumatra are shaped by complex interactions between environmental, animal, and human factors (WHO, 2023; CDC, 2022; FAO, WHO, UNEP, 2022, Alderman et al., 2012). This reinforces the relevance of the One Health approach in understanding the ecology-based dynamics of post-disaster diseases.

Leptospirosis is the most representative example of a flood-related zoonotic disease. Transmission increases when flooding expands the distribution of Leptospira bacteria in the environment, increasing human contact with rodent reservoirs (CDC, 2022; FAO, WHO, UNEP, 2022). Thus, post-disaster disease control efforts cannot focus solely on medical interventions, but also require environmental control and community behavior change.

Increased mental health disorders after disasters reinforce that the impact of flooding is multidimensional and goes beyond physical aspects alone (Shultz & Fobes, 2014; UNICEF, 2022). However, this dimension is still relatively marginalized in Indonesia's emergency health response system.

Hospital resilience

Findings that 30–55% of hospitals experienced disruptions to energy, clean water, and logistics during flooding indicate low resilience of critical lifelines in the regional health system (World Bank, 2021, Kruk et al., 2015, WHO, 2020). These findings are consistent with the concept of a resilient health system, which emphasizes the importance of health facilities' capacity to absorb and adapt to external shocks (Kruk et al., 2015).

The surge in patients occurring simultaneously with a decline in operational capacity creates conditions of service overload that increase the risk of failure of essential services (WHO, 2023; Kemenkes RI, 2024; World Bank, 2021). Without strengthening vital infrastructure and human resource preparedness, hospitals have the potential to become points of systemic failure in disaster response.

Leadership in crisis situations

Differences in the quality of responses between regions are largely determined by leadership. Leaders who are able to see the situation as a whole and make timely decisions tend to be successful in maintaining the stability of health services (UNDRR, 2022; World Bank, 2021). Within the framework of ecological health ethics, leaders also have a long-term responsibility to maintain environmental sustainability as the basis for public health (Whitmee et al., 20215; Adams et al., 2016).

Variations in the effectiveness of health responses between regions show that crisis leadership is an important determinant in disaster management (UNDRR, 2022; World Bank, 2021; Kemenko PMK, 2023). Responsive and transparent leadership plays a role in accelerating decision-making, strengthening cross-sector coordination, and maintaining public trust during the emergency phase.

From an ecological health ethics perspective, the government's responsibility is not limited to short-term victim rescue, but also includes protecting environmental sustainability as the foundation for the health of future generations (Whitmee et al., 20215; Adams et al., 2016). When disaster responses neglect ecological rehabilitation, the cycle of flooding and recurring health crises will continue.

CONCLUSION

From 2019 to 2024, flooding in Sumatra showed a continuous increase in both frequency and impact. Ecological changes over recent decades have substantially contributed to the region's growing vulnerability. Post-disaster disease patterns demonstrate a strong interconnection among environmental, animal, and human factors, as emphasized within the One Health framework. Hospital resilience remains a critical challenge, particularly regarding the continuity of energy supply, access to clean water, and medical logistics. In contrast, effective crisis leadership has been shown to improve response quality and reduce the secondary impacts of disasters. Based on these findings, flood risk management policies in Sumatra should be strengthened through an integrated framework that links environmental management, public health, and health system resilience. Fragmented, sector-based approaches are insufficient to address complex and recurrent hydrometeorological disasters.

First, policies for watershed ecosystem rehabilitation, deforestation control, and peatland restoration must be reinforced as primary preventive strategies for flood risk reduction within a Planetary Health perspective. These efforts should be closely integrated with spatial planning and land-use regulation to reduce long-term exposure to risk. Second, strengthening post-disaster disease surveillance systems based on the One Health approach should become a national and regional priority, particularly for diarrhea, leptospirosis, and acute respiratory infections. Systematic integration of human health, animal health, and environmental data is essential to enable faster and more targeted, evidence-based health responses. Third, enhancing hospital resilience in flood-prone areas should focus on investment in critical lifelines, including layered backup energy systems, independent clean water supplies, and disaster-adaptive medical logistics. Strengthening the preparedness of health human resources through disaster training and emergency staffing mechanisms is also urgently needed. Fourth, the development of crisis leadership capacity among local government leaders,

healthcare facility managers, and cross-sector stakeholders should be institutionalized through scenario-based disaster health training. Responsive and ethical leadership is a key prerequisite for maintaining public trust, social stability, and continuity of health services during crises. Finally, the integration of ecological health ethics into disaster management policies must be reinforced so that emergency responses are oriented not only toward short-term physical recovery but also toward long-term environmental and health system sustainability. Without this integration, cycles of recurring disasters and health crises will persist in flood-prone regions such as Sumatra

ACKNOWLEDMENT

The authors would like to express their sincere gratitude to Griffith University and Universitas YARSI for their academic and institutional support. Appreciation is also extended to colleagues and stakeholders who contributed insights, data access, and constructive feedback that supported the completion of this study.

FUNDING

This work was conducted without any external funding.

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AUTHORS' CONTRIBUTION

Dicky Budiman conceptualized the study, designed the methodology, led data collection and analysis, and drafted the original manuscript. He also coordinated the interpretation of findings and managed manuscript revisions. Cordia Chu contributed to the study conceptualization, and provided critical intellectual input. All authors approved the final version of the manuscript.

COMPETING INTEREST

The author(s) declare no potential conflict of interest with respect to the research, authorship, or publication

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