The Power of Openness: Reforming Spatial and Legal Data Integration for Disaster-Resilient Indonesia

Syahrastania Qibti ERTONO and Alief Wiraguna ASERAN, Indonesia

Key words: Climate change, disaster resilience, land administration, open spatial data

SUMMARY

Indonesia's exposure to climate-induced disasters is shaped not only by its geographic and environmental characteristics but also by the effectiveness of its land governance and spatial data systems. This paper argues that disaster risk in Indonesia emerges from the compounded interaction of climate change, land degradation, and weak spatial–legal integration, where fragmented land administration and limited data openness undermine both prevention and recovery efforts. In disaster contexts, insecure land tenure amplifies social and economic losses, complicates resettlement, and enables post-disaster land exploitation. The paper positions open and accessible parcel-based land administration as a foundational pillar of good land governance and disaster resilience. By enabling public scrutiny, reducing overlapping claims, and safeguarding pre-disaster land rights, spatial data openness strengthens tenure security and deters corruption and illicit land grabbing—particularly during post-disaster reconstruction.

Integrating open cadastral data with hazard and spatial planning information shifts land administration from a passive recorder of rights to an active instrument of risk prevention. Aligning land administration reforms with disaster risk reduction frameworks and the Sustainable Development Goals requires not only technical interoperability but also institutional transparency, inclusive participation, and a commitment to spatial data openness as a public good essential for long-term resilience in Indonesia.

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1. INTRODUCTION

Indonesia is one of the countries most vulnerable to the impacts of climate change due to its geographic characteristics as an archipelagic nation, its high dependence on land resources, and the concentration of population in coastal areas and disaster-prone regions. Climate change has led to an increase in the intensity and frequency of extreme weather events, including floods, droughts, landslides, and sea-level rise, which directly amplify disaster risk across various regions of Indonesia.

Previous studies indicate that disaster risk in Indonesia is the result of complex interactions among climate change, land degradation, and governance factors. Limited integration between climate change adaptation policies and disaster risk reduction, particularly at the local scale, remains a major challenge in effective disaster risk management. Therefore, studies that integrate analyses of climate change, land degradation, and disaster risk are crucial to support spatially based planning and the formulation of sustainable mitigation and adaptation strategies in Indonesia.

Over recent decades, the impacts of climate change have been further intensified by land degradation driven by land-use change, deforestation, uncontrolled urbanization, and intensive exploitation of natural resources. Such land degradation reduces the capacity of the environment to absorb and buffer the impacts of extreme climatic events, thereby increasing regional vulnerability to hydrometeorological disasters. Lumban-Gaol et al. (2024) demonstrate that the combined effects of sea-level rise and land subsidence significantly increase flood risk in Indonesian coastal cities, underscoring the close interlinkages between land degradation, climate change, and disaster risk.

Climate change has increased disaster risk in Indonesia through the rising frequency and intensity of hydrometeorological events such as floods, droughts, landslides, and coastal inundation. These impacts are further exacerbated by land degradation driven by unsustainable land-use practices, deforestation, ecosystem degradation, and rapid urbanization. Land degradation reduces soil stability, water infiltration capacity, and the buffering function of ecosystems, thereby increasing exposure and vulnerability to climate-induced hazards. As demonstrated by Shah (2020), disaster risk in Indonesia emerges from a complex interaction between climate change, land degradation, and weak land-use governance. The lack of integration among spatial planning policies, land management, climate change adaptation, and disaster risk reduction has contributed to increasing disaster losses, particularly in coastal areas, river basins, and other hazard-prone regions.

Environmental degradation associated with climate change is not solely driven by natural processes but is also significantly influenced by human intervention. Failures in adapting to climate change, insufficient mitigation efforts, and poor spatial planning and land-use management have undermined society's capacity to respond effectively to climate-related risks, thereby intensifying environmental damage and disaster vulnerability.

2. THE ROLE OF LAND REGISTRATION AND CADASTRAL DATA IN DISASTER RESILIENCE

This part will discuss the importance of cadastre and land registry as a means of safeguarding the rights of disaster victims to land ownership, followed by the current conditions of Indonesian cadastre and land registry interoperability and how it hinders disaster relief efforts.

2.1. Land Security for Disaster Victims and Vulnerable Communities

Land tenure insecurity is the primary amplifier of disaster impact, especially for vulnerable communities. Those who lack a secure tenure, including indigenous and remote groups, smallholder farms, and informal settlers, are often left defenseless when a disaster occurs. The lack of official legal and cadastral records frequently hinders post-disaster recovery efforts. This spatial-legal void exacerbates land loss through environmental degradation, fuels a surge in land disputes, and destabilizes traditional tenure systems, ultimately resulting in poorly coordinated and inadequate resettlement efforts.

The occurrence of environmental degradation has been causing land loss for disaster victims. The most vulnerable are those living in disaster-prone areas, such as coastal areas or riverbanks. In December 2025, the village of Cidadak, Sukabumi regency, West Java, faced a devastating blow when the river eroded and swept away 16 out of 23 homes, while the rest remained hanging on the edge of fragile soil. Moving to Central Java Province, dozens of hectares of farmer-owned rice fields along the Merawu River in Pertambakan Village, Banjarnegara Regency, have been lost due to erosion that has occurred throughout the year. While the erosion occurred during the rainy season, it is also stated that the presence of privately owned sand and stone mines in the area exacerbates the erosion.

After the disaster, physical boundary markers are less reliable than geodetic coordinates, as they are frequently rendered untraceable or lost during the event. These erased markers created a spatial-legal vacuum, triggering a forced displacement. Without a parcel-based registry that survived digitally, victims would often be unable to prove the exact location of their owned land (Martono, 2023). Having only a legal record of ownership without knowing where the land is weakens the chance of a proper resettlement for the victims. A weak land tenure also triggers overlapping claims, land grabs, and exploitation after the event. Communities with a weak tenure face higher risks during resettlement phases.

2.2. Indonesia's Lack of Spatial-Legal Linkage

FIG defines "cadastre" as a unified, parcel-based system linking spatial data with legal interests. In practice, implementation in Indonesia is enriched with traditional land use and tenure

systems, such as customary land title. This historical trace resulted in a separate act of recording the spatial bounds and who owns that boundary. This is what can be described as a “Deed-influenced Title System”.

While the regulatory framework in Indonesia (PP No. 24/1997) establishes a title-based registration, a certificate (Sertipikat) does not guarantee absolute validity if a third party can prove a superior historical right via an older deed or customary record (e.g., Girik or Adat). Consequently, the state often prioritizes the Sales and Purchase Deed (Akta Jual Beli) over the spatial map, resulting in a title-based model that lacks a corresponding title-based cadastral culture.

The consequences of these situations are reflected in the World Bank Business Ready Report 2024, which reveals a stark disparity between the Land Registry disclosure and Cadastre disclosure. While the first received the highest possible rating, the latter appears to be significantly deficient. The reason for this is that Indonesia often uses a “Person” or the “Certificate Number” as the primary key, while the modern Title Cadastre uses “Parcel” as the primary key. This potentially leads to the “Floating Title” phenomenon, where the office knows if a person owns a Certificate without knowing where on earth that Certificate is attached (Zevenbergen, 2002). Without a parcel-based map, one cannot verify if a “Title” actually corresponds to a unique, non-overlapping piece of “Space”.

This spatial-legal gap is further widened by the exclusion of informal and customary land tenure. In Indonesia, the cadastre only records parcels that have reached a “clean and clear” status—meaning legal rights are already finalized and free of conflict. By design, this excludes informal possessions under dispute, as well as communal and customary lands that have not yet been formalized. Because the cadastre acts only as a record of existing formal rights rather than a comprehensive map of all land occupation, it remains a fragmented "island" of data in a sea of unmapped, vulnerable tenure.

2.2.1. Systematic Land Registration Approach

The concept of achieving “clean and clear” status as mandatory based on Government Regulation (PP No. 24/1997) is a barrier to mapping the lands of Indonesia, aside from existing customary and informal lands (Aditya, 2020). The challenge under the current legal and institutional framework includes requiring the active participation of communities, villages, and government officers, leading to uncoordinated and sporadic registration activities (Zevenbergen, 2002).

Accordingly, the Systematic Land Registration or Pendaftaran Tanah Sistematis Lengkap (PTSL) was mandated through the President's Instruction 2/2018. The program is designed to map all land parcels and to certify unregistered land parcels nationwide for rural areas. The program can increase the number of land parcels from one and a half million per year to a staggering five million in its first year and seven million in its second. The program is targeted to register fifty million land parcels by 2025.

The initiative highly accelerates the progress of mapping Indonesian land. However, regulatory frameworks do not always yield the intended outcomes. A significant portion of the mapped parcels remains uncertified due to the ambiguous legal status of claimants, while a notable percentage of existing land titles still lack spatial verification (Aditya, 2020). Furthermore, the system is burdened by thousands of unresolved disputes and ongoing litigations.

2.2.2. One Policy Map

Indonesia's One Map Policy (OMP) is a national program designed to integrate and synchronize thematic maps across Indonesia under a single reference system, a unified standard, a single database, and one geoportal. The program is regulated by Presidential Regulation No. 9 of 2016, which mandates the acceleration of One Map Policy implementation at a mapping scale of 1:50,000, enacted on 4 February 2016. This policy integrates data from 19 ministries and national agencies and consolidates 85 thematic maps covering the entire territory of Indonesia (Abidin, 2021).

However, the study notes that the One Map Policy faces fundamental challenges, as thematic maps are integrated on top of an incomplete base map. In practice, thematic maps are often produced after base maps and are generated by various actors, including ministries, government agencies, non-governmental organizations, and community groups. These conditions result in inconsistencies in reference systems and non-uniform standards, varying levels of accuracy due to the use of different base maps, outdated data, limited public accessibility to datasets managed by multiple custodians, and frequent deadlocks in data sharing caused by institutional coordination failures and other constraints (Abidin, 2021).

In the context of land registration, the One Map Policy has demonstrated positive contributions, particularly through the standardization of spatial data via a geoportal-based system capable of providing comprehensive information on land tenure and land rights. OMP is expected to reduce future land conflicts arising from overlapping land tenure and ownership claims (Sanjaya, 2023). Nevertheless, a major weakness of OMP lies in disagreements among key stakeholders, particularly between the National Land Agency (BPN) and the Geospatial Information Agency (BIG), primarily due to differences in georeferencing systems. Early policy analyses indicate that non-uniform reference systems and mapping standards across government institutions directly contribute to boundary overlaps in the field. Because each institution applies its own baseline and map projection, spatial datasets often fail to align when overlaid, complicating the resolution of spatial disputes and land-use conflicts (Shahab, 2016).

2.2.3. Integrated Land Administration and Spatial Planning Project

The Integrated Land Administration and Spatial Planning Project (ILASPP) is a strategic initiative developed to strengthen land administration systems and spatial planning in Indonesia through the integration of spatial data, institutional frameworks, and cross-sectoral policies. The project aims to address structural challenges in land governance, including overlapping land claims, inconsistencies among thematic maps produced by different institutions, and differences in geospatial reference systems that hinder interoperability between land administration data and spatial planning information (World Bank, 2019; Abidin et al., 2021). By enhancing spatial data infrastructure, standardizing georeferencing systems, and integrating land information systems with spatial plans, ILASPP supports the implementation of the One Map Policy (OMP) as a national geospatial reference framework. This approach contributes to improved legal certainty of land tenure and more accurate, risk-based spatial planning, thereby indirectly strengthening disaster resilience and supporting sustainable development in Indonesia (World Bank, 2020; BNPB, 2021).

3. BENEFITS AND RECOMMENDATIONS OF SPATIAL DATA OPENNESS

This part discusses the advantages of transparent and accessible complete land administration. The general public has a better understanding and trust in a transparent government and its efforts regarding the people's rights. With a better public understanding, a collective effort of safeguarding the wellness and the rights of disaster victims has gained greater momentum, subsequently leading to better policy-making based on evidence and data.

3.1. Increased Transparency and Public Participation

3.1.1. Community-Participation Land Administration and Enhance Resilience

In Honiara, the capital city of the Solomon Islands, the Fit-For-Purpose Land Administration (FFPLA) concept was utilized to enhance resilience by ensuring that informal settlers are not excluded from the process. This increases the security of tenure and trust of vulnerable communities, leading to a higher public participation rate in land administration efforts and strengthening the government's role in disaster resilience (Mitchel, 2021). A project in Nepal following the 2015 earthquake demonstrated the use of the Social Tenure Domain Model (STDM), an FFPLA tool, allowing the government to recognize informal land rights to inform both land administration and disaster reconstruction activities (Baiocchi, 2021).

In Indonesia itself, the "Complete Cadastre" program aims for a higher public participation by utilizing aerial imagery rather than a high-quality terrestrial survey. The public participation rate increases in the rural context as village residents deem high accuracy as something less important (Martono, 2021).

3.1.2. Open Parcel-Based Land Administration as a Foundation for Good Land Governance

Having an open and accessible parcel-based land administration is a foundational practice of spatial data openness. It can eliminate overlapping claims by becoming the single source of truth for a national reference map. In the Indonesian context, these overlaps frequently arise from institutional silos, where different ministries—operating with disparate priorities and conflicting datasets—issue licenses for mining, forestry, and infrastructure within the same geographic area. These administrative overlaps often occur on lands inhabited by local or indigenous communities, leading to protracted legal battles and tenure insecurity. Initiatives such as the One Map Policy (Kebijakan Satu Peta) are designed to synchronize these fragmented maps; however, without an open-access parcel-level cadastre, the resolution of these conflicts remains obscured from public oversight.

Beyond technical synchronization, an open parcel-based registry acts as a critical deterrent against corruption and illicit land grabbing. In a standard administrative scenario, transparency allows for public scrutiny of land transactions, making it significantly harder for "land mafias" to manipulate records. This safeguard becomes even more vital in post-disaster resettlement scenarios. When the landscape is altered and communities are displaced, the "data vacuum" often created by closed or destroyed registries provides an opportunity for land exploitation. An open, cloud-based cadastral system ensures that the pre-disaster rights of victims are visible and verifiable by all parties, preventing the opportunistic seizure of "abandoned" land during the reconstruction phase.

In the context of disaster risk reduction (DRR), land administration contributes to long-term security by facilitating hazard-sensitive spatial planning. A precise parcel-based registry allows authorities to identify properties situated in high-risk zones—such as floodplains, landslide-prone slopes, or seismic fault lines—with granular accuracy. However, parcel-level cadastral data are often considered sensitive and therefore restricted from public access. To address this tension between transparency and confidentiality, Arribas-Bel et al. (2021) propose the concept of Open Data Products (ODP), which enables analytical outputs to be shared openly without exposing raw or personally identifiable data. By publishing analysis-ready, well-documented derivative datasets—such as risk classifications, zoning constraints, or exposure indices—governments can maintain data protection while still enabling public scrutiny and evidence-based decision-making. Integrating cadastral information with hazard data through such open products allows authorities to implement restrictive zoning and prevent new development in dangerous areas, shifting land administration from a reactive recorder of rights to an active instrument of risk prevention.

3.2. Basis for Evidence-Based Policy Making

3.2.1. Implementation of No-Build Zones and Technical Guidelines

In Indonesia, disaster management and the regulation of no-build zones in hazard-prone areas are formally addressed through the National Disaster Management Master Plan (Rencana Induk Penanggulangan Bencana/RIPB) 2020–2044, which is enacted under Presidential Regulation No. 87 of 2020. This document adopts the priorities and objectives of the Sendai Framework for Disaster Risk Reduction into national policy. The Sendai Framework provides a global action agenda for disaster preparedness and post-disaster recovery, structured around four priority actions: (1) understanding disaster risk, (2) strengthening disaster risk governance, (3) investing in disaster risk reduction for resilience, and (4) enhancing disaster preparedness for effective response (BNPB, 2022).

Within this framework, the establishment of no-build zones serves as a key risk reduction measure aimed at preventing the escalation of disaster risk by limiting prolonged human exposure in hazardous areas. Such zones are intended to reduce potential loss of life and economic damage in the event of major disasters, such as landslides (Matti et al., 2022). In practice, no-build zones are often enforced for extended periods—sometimes exceeding two years—until comprehensive risk assessments are conducted and formal decisions are made regarding their continuation or revocation. One of the critical datasets used in delineating no-build zones is land-use and spatial planning data, which plays a central role in reducing future disaster risk and losses associated with natural hazards (King et al., 2016; UNDRR, 2015).

Spatial planning measures for disaster risk reduction may include building standards, hazard-based zoning, protective infrastructure, as well as retreat and relocation policies (Burby et al., 2000). Among these, risk zoning functions by regulating or prohibiting development—such as through the designation of no-build zones—in areas assessed to be exposed to specific hazards (Henstra & McBean, 2005). However, empirical evidence from other countries highlights the complex social consequences of implementing such policies. For example, in the Philippines, no-build zones were introduced following Typhoon Haiyan in November 2013, but their implementation disproportionately affected informal, unregistered, and illegal landholders (UN-Habitat, 2003).

The underlying causes of these impacts are complex and often indirect, particularly due to the reciprocal relationship between land tenure status and location. Informal or unregistered landholders are more likely to reside in disaster-prone areas, either because zoning restrictions limit formal development options or because wealthier groups tend to avoid hazardous land (Dilling et al., 2014). After Typhoon Haiyan, the Philippine government and international actors envisioned risk reduction through the relocation of informal

settlements. Nevertheless, the absence of a comprehensive policy re-evaluation led to the reoccupation of no-build zones. Rather than acknowledging the structural inevitability of informal settlements, policy responses framed these communities as illegal, resulting in the denial of housing assistance to households with limited alternatives but to remain in hazard-prone locations (Fitzpatrick & Compton, 2019).

Similar challenges have been observed in Iceland, where residents eventually returned to no-build zones due to psychosocial factors related to housing security, employment, and future prospects (Matti et al., 2022). While there is broad consensus in disaster risk management literature regarding the importance of post-disaster psychosocial support, the psychosocial impacts of pre-disaster risk mitigation measures, including hazard zoning and no-build policies, remain insufficiently understood. Moreover, land-use policies implemented after disasters have been associated with increased social tension, distrust toward authorities, and perceptions of discrimination among affected communities (Santos et al., 2015).

3.2.2. Downstreaming National Geospatial Data

The National Land Agency initiates a program to open the national thematic geospatial information stored in its database. This includes land rights information, disaster risk, topography, spatial planning, and more. The program aims for an open schema where the general public can understand their rights, restrictions, and responsibilities for their land better. Moreover, this schema encourages practitioners and researchers to produce more analysis-ready Open Data Products (ODPs) derived from authoritative cadastral and hazard datasets, rather than disseminating raw or sensitive records (Arribas-Bel et al., 2021).

Following the framework proposed by Arribas-Bel et al. (2021), these ODPs can take the form of parcel-level risk classifications, zoning compliance indicators, or aggregated exposure indices that preserve confidentiality while remaining transparent, reproducible, and policy-relevant. By standardizing documentation, metadata, and methodological disclosure, the program ensures that analytical outputs are traceable and verifiable, thereby strengthening trust in government-produced spatial information.

Such an approach bridges the long-standing tension between data openness and data protection in land administration. While individual ownership details may remain restricted, the resulting open products enable meaningful public oversight, support evidence-based spatial planning, and facilitate cross-sectoral coordination among disaster management, infrastructure, and environmental agencies. Ultimately, the adoption of an ODP-oriented open schema positions land administration not merely as a data custodian but as an active platform for risk-informed governance and resilient development.

3.2.3. Policy Sustainable Development Goals Alignment

The integration of land administration, spatial planning, disaster risk reduction, and data openness in Indonesia demonstrates a strong alignment with multiple Sustainable Development Goals (SDGs), particularly SDG 11.b (Sustainable Cities and Communities), SDG 13.2 (Climate Action). Initiatives such as the One Map Policy (OMP), Systematic Land Registration (PTSL), and the Integrated Land Administration and Spatial Planning Project (ILASPP) contribute to SDG 11 and SDG 13 by enabling hazard-sensitive spatial planning, regulating development in disaster-prone areas through no-build zones, and supporting evidence-based disaster risk reduction strategies consistent with the Sendai Framework.

Strengthening parcel-based cadastral systems and improving spatial–legal linkages also enhance tenure security and reduce land-related conflicts, directly supporting the promotion of transparency, accountability, and inclusive institutions. Furthermore, integrating land-use data with environmental and hazard information supports sustainable land management and ecosystem protection. However, persistent challenges—such as limited public participation, restricted access to cadastral data, fragmented georeferencing standards, and the exclusion of informal and customary tenure—constrain the full realization of these goals. Addressing these gaps through greater spatial data openness, inclusive land administration approaches, and participatory governance mechanisms is therefore essential to translating national geospatial and land policies into measurable SDG outcomes and long-term disaster resilience.

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BIOGRAPHICAL NOTES

Syahrastania Qibti Ertono is a Geospatial Operations Specialist and a graduate of Geodetic Engineering from Universitas Gadjah Mada, with academic interests in spatial–legal integration and digital cadastre. She has professional experience in land administration, geospatial product development, plantation mapping, and navigational charting through roles at GeoSquare, the National Land Agency, Esri Indonesia, and the Indonesian Navy Hydro-Oceanography Center. Her research on CityGML and CityJSON for 3D cadastre development has been presented at the Annual Scientific Forum of Ikatan Surveyor Indonesia (ISI) 2025. She currently serves as Research Division Lead at ISI and actively contributes to geospatial outreach and disaster-related initiatives.

CONTACTS

Syahrastania Qibti Ertono
Ikatan Surveyor Indonesia
East Jakarta
Jakarta
Indonesia
+62 812-3554-7045
syahrastaniaertono@gmail.com
www.isi.or.id