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Building Disability-Inclusive Disaster-Resilient Villages: A Spatial Analysis of Vulnerability for People with Disabilities in East Kalimantan, Indonesia

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Abstract Geographical and demographic shifts in East Kalimantan, driven by development and the establishment of the nation's capital, have heightened the region's susceptibility to disasters, particularly among the vulnerable population. Effective disaster management at the village level is essential to foster disaster-resilient communities and protect all population groups, including people living with disabilities. While the National Disaster Management Agency (BNPB) disaster risk index includes data on the ratio of people with disabilities to the population, it lacks specific details on vulnerabilities related to different types of disabilities and disasters. This study aims to assess the vulnerability of villages with people with disabilities (PWD) to floods, forest fires, and landslides in East Kalimantan. Using the 2021 Village Potential Data (PODES), we applied the district social vulnerability index (DSVI), which incorporates 36 indicators of exposure, sensitivity, and adaptive capacity, to determine village vulnerability. Our analysis identified 205 out of 1,036 villages as highly vulnerable (DSVI-5). Spatial mapping revealed that villages most affected by these vulnerabilities (Group 4, which are villages with people living with disabilities and experiencing disasters) are predominantly located in West Kutai, Kutai Kartanegara, and East Kutai, with Samarinda City notably affected by landslides. These findings underscore the importance of developing disability-inclusive disaster-resilient villages (DIDRV) to mitigate disaster risks and impacts. Additionally, tailoring disaster preparedness, response, and recovery efforts to the specific needs of individuals with disabilities and actively involving them in the planning is crucial.

Keywords: disability, disaster, resilient village, spatial analysis, vulnerability

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1. INTRODUCTION

Indonesia faces multiple disaster threats, with a significant portion of its population residing in high-risk areas. According to the National Disaster Management Agency (BNPB), approximately 148.4 million people live in earthquake-prone zones, 5 million in tsunami-prone areas, 1.2 million in volcanic eruption zones, 63.7 million in flood-prone regions, and 40.9 million in landslide-prone areas (BNPB, 2017). Additionally, over 53,000 villages are in disaster-prone zones, making these populations highly vulnerable (BNPB, 2017). This vulnerability is exacerbated by the lack of inclusive disaster planning, adaptation, and mitigation.

In East Kalimantan, disasters have caused substantial damage in recent years, for example, the devastating floods of June 2019 inundated more than 600 houses and affected over 35,600 residents in Samarinda City alone (BNPB & BMKG, 2019). Severity is measured in both human and economic terms. In 2022, the estimated direct losses in Samarinda reached up to IDR 40 billion, with cumulative 20-year flood losses amounting to trillions of rupiah (Satar, 2022). Disasters like these disproportionately affect people with disabilities (PWD), who face challenges such as difficulty evacuating due to mobility or sensory impairments, inaccessible shelters, and limited access to emergency information (CBM & Inclusion Advisory Group, 2024). This heightened vulnerability underscores the urgent need for inclusive disaster planning and targeted mitigation efforts.

Moreover, Indonesia is ranked third globally for disaster risk, with rapid socio-economic and political changes that affect the population's vulnerability (Atwii et al., 2022). The development of the New Capital City in East Kalimantan highlights this issue, as deforestation for development increases risks of floods, erosion, and drought (Safitri et al., 2022). Forestry deficits, particularly related to oil palm plantations, have long been a concern in East Kalimantan, significantly aggravating environmental impacts (Maulidya et al., 2021). The 2021 Village Potential Data (PODES) indicates frequent floods and landslides in this region, underlining the severe impacts of deforestation and land-use changes (BPS, 2021).

Recent evidence indicates that socio-economic disparities critically influence disaster outcomes. For example, a study in Central Java found that lower education and poverty heightened flood exposure, as residents had limited access to hazard information and preparedness resources (Sigit et al., 2023). In urban Indonesia, flood disasters disproportionately harmed the urban poor, resulting not only in higher physical morbidity but also longer-lasting mental health effects compared to wealthier groups (Escobar Carías et al., 2022). Climate-related disasters further aggravate health inequities: a 2021 Lancet report highlighted that the most vulnerable, such as the poor, older people, and those with pre-existing health conditions, bear the brunt of climate-induced health risks (Tipaldo et al., 2024). Additionally, advancing the concept of “adaptive social protection,” Gasior et al. (2023) showed that Indonesia’s current social safety nets insufficiently support vulnerable groups, such as PWD, during disaster-induced income shocks. PWD often face challenges in understanding disaster-related information and evacuating during emergencies. Despite making up approximately one in five people globally, including older people, this group is

frequently underrepresented in disaster management planning (Alexander, 2015; Pertiwi et al., 2019).

A holistic approach that includes both climate and non-climate factors is essential for assessing vulnerability to climate change. Social vulnerability to natural disasters is crucial for effective disaster risk reduction strategies, as it significantly influences policy development. Addressing this vulnerability necessitates a thorough understanding of social, economic, and political contexts that shape and reinforce risk-promoting conditions (Chen et al., 2013). Evaluating social vulnerability across global, regional, and local levels is a fundamental strategy for reducing disaster risk and enhancing climate adaptation.

The BNPB has been issuing a district-level disaster risk index (DRI) since 2021 and has also developed a disaster risk map for the village level in the New Indonesian Capital City (BNPB, 2021, 2022, 2023). However, this map does not prioritize villages for inclusive disaster management for PWD. Therefore, our study aims to (1) assess social vulnerability to disasters at the village level in East Kalimantan Province, Indonesia; (2) identify key indicators contributing to social vulnerability within this context; and (3) map areas based on both social vulnerability and the presence of people with disabilities. To assess social vulnerability to disasters at the village level, this study incorporates disability proportions into the analysis to better map social vulnerability in relation to disability prevalence (Dintwa et al., 2019).

The District Social Vulnerability Index (DSVI) methodology (Cutter et al., 2003), has been widely utilized in various countries (Bjarnadottir et al., 2011; W. Chen et al., 2013; Dintwa et al., 2019; Reimann et al., 2024; Siagian et al., 2014). These studies demonstrate that social vulnerability to natural disasters can be measured at global, regional, national, district, village, and even household levels, contingent on data availability. In communities prone to environmental change and natural disasters, this study is crucial because it aims to provide evidence and scientific data to aid local governments in developing disability-inclusive disaster-resilient village (DIDRV) and disaster risk reduction programs.

This study offers several novel contributions to the existing literature on disaster risk reduction and disability inclusion. First, it integrates the District Social Vulnerability Index (DSVI) methodology with disaggregated disability data at the village level, a combination not previously applied in the Indonesian context. Unlike national or district-level assessments, this fine-scale analysis enables precise identification of vulnerable villages based on both hazard exposure and the specific types of disabilities present. Second, the approach goes beyond mapping by linking spatial patterns to practical village-level prioritization, thus providing a directly actionable tool for policymakers, local governments, and disaster management agencies to allocate resources efficiently. Third, the study demonstrates a replicable methodology for incorporating multiple dimensions of vulnerability (exposure, sensitivity, and adaptive capacity) into disaster planning for marginalized populations, offering a model that can be adapted to other regions facing similar challenges. By combining geospatial analysis with disability-specific indicators, this research bridges a critical gap between inclusive disaster risk governance theory and its operationalization in rural and peri-urban contexts, particularly in rapidly developing areas like East Kalimantan.

2. THEORETICAL FRAMEWORK

A total of 36 indicators from the social vulnerability index (Cutter et al., 2003), were used to develop the DSVI model. These indicators are organized into three categories: exposure, sensitivity, and adaptive capacity (see Figure 1). This categorization is grounded in the vulnerability theory framework, which defines vulnerability as comprising sensitivity, exposure, and adaptive capacity, all of which reflect societal conditions in shaping community response to hazardous events (Cardona, 2003; Huq et al., 2020). Although the concept of vulnerability is extensively used in disaster research (Cardona, 2003; Frazier et al., 2014; Harrati et al., 2023; Huq et al., 2020), many studies focus primarily on sensitivity, which addresses the impact on social assets, while often neglecting adaptive capacity and exposure or 'the degree of proximity' between social assets and adverse events. This study aims for a more comprehensive measurement of vulnerability by incorporating sensitivity, exposure, and adaptive capacity to assess the level of threat posed to village communities by specific disaster scenarios. Therefore, the theoretical framework used in this study is as follows.

The components of vulnerability, including exposure, sensitivity, and resilience, interact intricately, reflecting the complexity of their relationships. Exposure is a primary vulnerability factor that indicates the extent of changes within a system caused by a disturbance or disaster, particularly physical ones (Huq et al., 2020). This component encompasses various aspects such as human casualties (deaths or injuries), damage to assets (including property and agricultural land), infrastructure, and cultural heritage. Sensitivity, on the other hand, pertains to social dimensions, including social relationships and the capacity of institutions or communities to manage disasters. Additionally, the resilience component refers to a system's and community groups' ability to endure and recover from disasters through effective and efficient strategies. While resilience generally involves long-term processes, this study focuses on adaptive capacity, which involves the immediate and short-term adaptations communities make in response to disasters. The theoretical framework adopted in this study aims to provide insights into the vulnerability of PWD within a village and to identify the factors influencing the village's vulnerability to disasters, specifically floods, land/forest fires, and landslides that are common in East Kalimantan Province.

3. RESEARCH METHODS AND DESIGN

3.1 Data Source

In alignment with the research objectives, this study utilizes a quantitative approach, drawing on secondary data from the 2021 Village Potential Data (PODES), provided by the Central Statistics Agency (BPS) (BPS, 2021). The PODES data encompasses a wide range of characteristics, including general information, demographics and employment, housing and

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environmental conditions, natural disasters and disaster mitigation, education and health, socio-cultural aspects, economic factors, and village finances and assets.

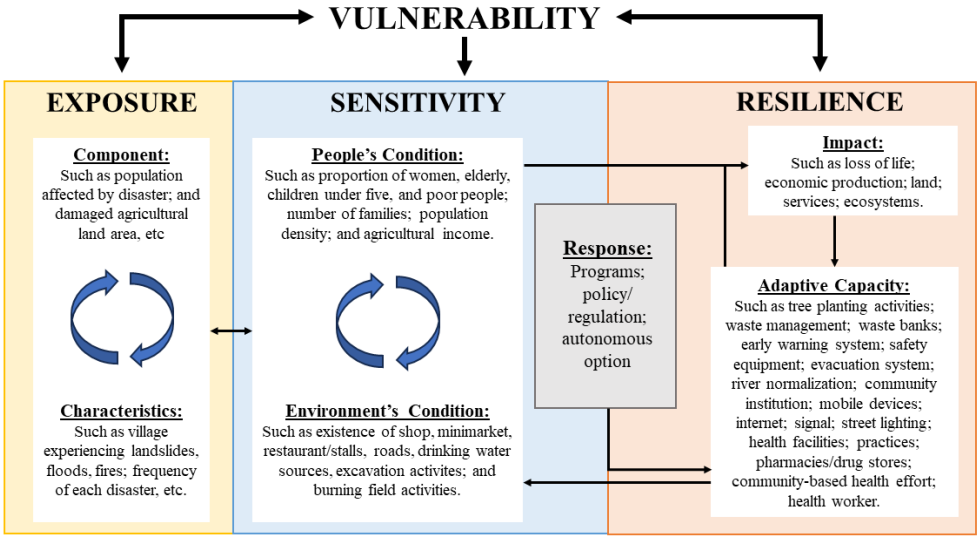

Figure 1. Research framework (Adopted from Cutter et al. (2003), Hug et al. (2020), and Dintwa et al. (2019))

The PODES constitutes a complete enumeration that collects information from all administrative villages (*desa*) and urban wards (*kelurahan*) across Indonesia, rather than from a sample. Accordingly, the dataset used in this study covers the entire population of 1,036 villages and urban wards in East Kalimantan Province, comprising 10 districts/cities and 103 sub-districts (Figure 2). This full coverage ensures that the analysis reflects the actual distribution of disaster exposure, vulnerability indicators, and the presence of people with disabilities across the whole province, thereby eliminating the need for sampling error adjustments.

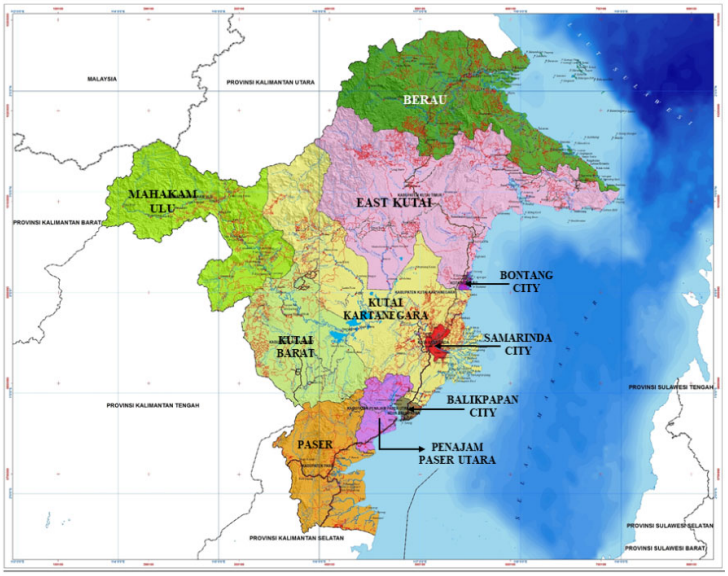

Figure 2. Map of Ten Regencies in East Kalimantan (Source: Indonesian Tematic Map (2013)[2])

[2] This map was obtained from the Indonesian Tematic Map (2013). Available at: https://petatematikindo.wordpress.com/2013/03/31/administrasi-provinsi-kalimantan-timur/

The study categorizes disabilities into four types: mental disabilities (both verbal and intellectual), sensory disabilities (including visual and hearing impairments), motor disabilities (including physical disabilities, mutism, and ex-leprosy conditions), and multiple disabilities (such as combined hearing-speech impairment and physical-mental disability combinations). Additionally, the analysis focuses on three types of natural disasters, landslides, floods, and forest and land fires, due to their high frequency in East Kalimantan during 2021.

3.2 Methods of Data Analysis

3.2.1 District Social Vulnerability Index (DSVI)

The DSVI Model is developed to measure the social vulnerability of different communities within a district to natural hazards by utilizing social vulnerability indicators. This model is grounded in the statistical approach employed in the Social Vulnerability Index (SoVI) methodology. The SoVI model evaluates multiple dimensions, including socio-economic, demographic, and other village characteristics, to assess communities' capacities to manage and recover from environmental hazards (L. Chen et al., 2017; Rufat et al., 2019).

During the data processing phase, we normalized the data to create a standardized scale of 0-10. The normalized data was then used to determine the weight index through Principal Component Analysis (PCA). Before applying PCA, we employed VARIMAX rotation to reduce the number of components and maximize cumulative variance. A VARIMAX orthogonal rotation was applied to simplify the factor structure and enhance interpretability. VARIMAX was selected because it maximizes the variance of squared loadings for each factor, producing components more clearly associated with distinct sets of indicators. Interpreting the rotated results involved examining the highest-loading variables on each principal component to determine which vulnerability dimension they represented.

We also applied the Kaiser criterion (eigen value ≥ 1) to retain factors, as it is a widely accepted rule for identifying components that explain more variance than a single original variable, thereby ensuring that retained factors meaningfully contribute to explaining variation in the dataset. This approach enabled us to reduce the original set of indicators into a smaller set of interpretable components while preserving the multidimensional nature of vulnerability measurement in line with Cutter et al. (2003) and subsequent applications in social vulnerability research. Following the extraction of eigenvalues, variance, and rotated principal components from PCA, we calculated the PCA-based weights using the specified equations:

$$w_i = \frac{\sum_{j=1}^{k}\left(\frac{a_{ij}}{\sqrt{\lambda_j}}\, v_j\right)}{\sum_{j=1}^{n}\left[\sum_{j=1}^{k}\left(\frac{a_{ij}}{\sqrt{\lambda_j}}\, v_j\right)\right]}, i = 1,2,3,\dots n^{th}, j = 1,2,3,\dots,n^{th} \quad (1)$$

where a_{ij} represents the value of the i^{-th} indicator on the j^{-th} rotated principal component, λ_j denotes the total initial eigenvalue for the j^{-th} component, and v_j indicates the variance (%) associated with the j^{-th} rotated principal component. Using these parameters, the weights for each indicator are derived according to the provided equation as follows:

$$w = \left[w_1, w_2, \ldots, w_{n^{th}}\right] \tag{2}$$

The DSVI can be expressed by:

$$DSVI = \sum_{i=1}^{n} x_i \, w_i \tag{3}$$

where x_i and w_i are standardized data and weight of the ith indicator, respectively (Dintwa et al., 2019).

3.2.2 Spatial Map of the DSVI Groups

The DSVI is visualized through spatial maps, utilizing one of the packages available in Stata software. This spatial mapping package is versatile, allowing for the creation of thematic maps ranging from simple to complex configurations. In this study, maps are generated at the village/sub-district level, resulting in a total of 12 maps: three for each type of disaster and four for each type of disability.

To aid in the interpretation of these maps, the DSVI is categorized into five groups based on quantile scores, ranging from least vulnerable (Group 1) to most vulnerable (Group 5). Village grouping also incorporates the presence of PWD (Yes or No) and the experience of natural disasters. The maps will employ a color scheme of 4x5 variations: the four primary colors are gray (indicating no natural hazard and no PWD), green (no natural hazard but PWD present), yellow (natural hazard present without PWD), and purple (both natural hazard and PWD present). Within each category, a gradient of five colors, from light to dark, is applied to represent the level of vulnerability, with lighter shades indicating lower vulnerability and darker shades indicating higher vulnerability.

4. RESULTS

4.1 Descriptive Statistics of the Village's Vulnerability Indicators

This study examined 1,036 villages across ten cities/regencies in East Kalimantan Province, Indonesia. Table 1 summarizes the descriptive metrics related to adaptive capacity, sensitivity, exposure, and the presence of PWD within these villages. Each variable is presented as a percentage or average value to provide an initial overview of village characteristics that inform the construction of the social vulnerability index.

With respect to adaptive capacity, many villages demonstrate notable strengths. A substantial proportion (75.5%) have more than ten community institutions, and nearly all

(99.2%) have access to mobile phones. However, only 27.2% of villages report internet access, indicating persistent digital gaps. Environmental conservation efforts also remain limited: only 20.8% of villages undertake tree-planting activities, and 35.8% engage in river normalization, suggesting that ecological resilience initiatives have yet to be fully optimized at the village level.

Table 1. Percentage and mean of original social vulnerability variables

Variable	Percentage (%) or mean
Adaptive Capacity	
1. Villages with tree planting activities	20.8
2. Villages with waste management	15.7
3. Villages with waste banks	16.7
4. Villages with early warning systems for disaster emergencies	8.6
5. Villages with safety equipment	18.5
6. Villages with evacuation systems	9.4
7. Villages with river normalization	35.8
8. Villages with more than 10 community institutions	75.5
9. Villages where most residents have cellphones/telephones	99.2
10. Villages with internet	27.2
11. Villages with a strong signal	64.7
12. Villages with the most main street lighting	39.2
13. Villages with health facilities	94.5
14. Villages with health practices	59.4
15. Villages with pharmacies and drug stores	27.5
16. Villages with a ratio of community-based health efforts of more than 2.36 per 1000 residents	75.3
17. Villages with a ratio of health workers of more than 2.23 per 1000 residents	75.9
Sensitivity	
1. Villages with agricultural income	81.3
2. Villages with at least 1 shop	11.9
3. Villages with at least 1 minimarket	22.2
4. Villages with at least 4 restaurants/stalls	53.4
5. Villages with roads that can be passed all year round	76.9
6. Villages with drinking water sources	67.8
7. Villages with excavation activities	30.3
8. Villages with the burning of fields	57.1
9. Population density per village	771
10. Proportion of women per 100 residents	47.21
11. Proportion of older people per 100 residents	7.37
12. Proportion of children under five per 100 residents	8.1
13. Number of families per village	1,143
14. Proportion of poor per 100 residents	4.32
Exposure	
1. Villages whose population is affected by disasters is more than 100	8.1
2. Villages whose agricultural land area is damaged is more than 10 Ha	8.1
3. Villages that have experienced landslides	7.0
4. Villages that have experienced floods	32.5
5. Villages that have experienced fires	4.9
6. Landslide frequency per 100 villages	4.6
7. Flood frequency per village per 100 villages	31.2
8. Fire frequency per village per 100 villages	1.4
Disability	
1. Villages with mental disabilities	35.1
2. Villages with sensory disabilities	47.0
3. Villages with motor disabilities	30.8
4. Villages with multiple disabilities	60.2

Regarding sensitivity, 81.3 % of the villages rely on agriculture, yet only 11.9 % have at least one shop, indicating a significant dependence on agriculture and limited access to trade facilities. Despite this agricultural reliance, the proportion of poor individuals is relatively low, with an average of 4.32 poor persons per 100 residents. The average population density across

village is 771, with an average of 1,143 families per village. On average, there are 47 women for every 100 residents. The proportion of elderly individuals is 7.37 per 100 residents, while the proportion of children under five is 8.1 per 100 residents, reflecting a relatively modest older people and child population.

In terms of exposure, 32.5 % of the villages reported experiencing flooding, although only 8.1 % experienced impacts affecting more than 100 residents were affected by such disasters. From the perspective of disability, 60.2 % of the villages have residents with multiple disabilities, highlighting the need for enhanced health and social services.

4.2 Measuring The District Social Vulnerability Index (DSVI)

The first stage in the formation of DSVI involves conducting PCA to obtain eigenvalues, variances, and component matrix, which are needed to calculate the weights. After performing PCA, 11 components with eigenvalues greater than 1 were extracted with the variance of each component. The cumulative eigenvalues obtained were 22.763 with a cumulative variance of 58.371%. These values demonstrate that the information of the extracted principal components captures a moderate proportion of the variance in the initial indicators.

The 11 initial eigenvalues and their corresponding variances were utilized to compute PCA-based weights (see Table 2). From Table 2, it is apparent that the indicators contributing most significantly to the DSVI include the number of pharmacies, presence of waste management systems, mutual cooperation, river normalization, prohibition on field burning, existence of waste banks, availability of safety equipment, and disaster evacuation systems. These indicators are associated with adaptive capacity. Conversely, indicators such as the number of households, minimarkets, shops, restaurants, and population density show the lowest weights among the variables. This indicates that, irrespective of a village's exposure and sensitivity to disasters, a strong adaptive capacity tends to lower the DSVI.

Table 2. PCA-based weights for each indicator

No	Variable	Weight	No	Variable	Weight
1	Number of Families (S)	0.0185	19	Excavation Activities (S)	0.0264
2	Number of Minimarket (S)	0.0188	20	Proportion of Children Under Five (S)	0.0265
3	Number of Shops (S)	0.0192	21	Internet Ownership (AC)	0.0266
4	Population Density (S)	0.0193	22	Number of Health Practices (AC)	0.0266
5	Number of Restaurants (S)	0.0206	23	Number of Health Facilities (AC)	0.0267
6	Number of Health Efforts (AC)	0.0220	24	Street Lighting (AC)	0.0273
7	Number of Health Workers (AC)	0.0224	25	Tree Planting Activities (AC)	0.0274
8	Proportion of Women (S)	0.0231	26	Strong Signal (AC)	0.0275
9	Number of Landslides (EX)	0.0232	27	Agricultural Land Area Damaged (EX)	0.0276
10	Number of Floods (EX)	0.0251	28	Proportion of Elderly (S)	0.0276
11	Population Affected (EX)	0.0253	29	Evacuation System (AC)	0.0278
12	Number of Forest Fires (EX)	0.0254	30	Safety Equipment (AC)	0.0279
13	Cell phone Ownership (AC)	0.0256	31	Waste Management (AC)	0.0281
14	Number of Community Institutions (AC)	0.0260	32	Burning of Fields Activities (S)	0.0282
15	Drinking Water Sources (S)	0.0262	33	River Normalization (AC)	0.0285
16	Roads (S)	0.0262	34	Waste Bank (AC)	0.0289
17	Proportion of Poor (S)	0.0264	35	Number of Drug Stores (AC)	0.0291
18	Early Warning System (AC)	0.0264	36	Agricultural Income (S)	0.0297

Based on the DSVI values, we categorized the 1,036 villages in East Kalimantan into five groups according to quintiles, as shown in Table 3. Overall, the DSVI for East Kalimantan is classified as moderate, with a mean value of 0.599 (standard deviation = 0.045). The average DSVI for each quintile group varies slightly, ranging from 0.564 in Group 1 to 0.697 in Group 5.

City areas such as Balikpapan, Bontang, and Samarinda are represented in Groups 1 and 2, indicating that these urban areas are generally less socially vulnerable to disasters compared to districts. Conversely, districts such as West Kutai, Mahakam Ulu, and Paser exhibit a higher proportion of their villages/sub-districts in Groups 4 and 5, signifying a greater degree of social vulnerability in these areas. Meanwhile, districts like Berau, North Penajam Paser, Kutai Kartanegara, and East Kutai have a higher proportion of their villages/sub-districts in Groups 1 through 3, reflecting lower social vulnerability levels in these regions.

Table 3. Members and statistics for each DSVI Group

District/City	DSVI Group					Total
	1	2	3	4	5	
Berau	25	38	25	17	5	110
Balikpapan City	32	2	-	-	-	34
Bontang City	12	3	-	-	-	15
Samarinda City	52	6	1	-	-	59
Kutai Barat	11	24	41	44	73	193
Kutai Kartanegara	44	60	51	41	40	236
Kutai Timur	14	31	35	35	26	141
Mahakam Hulu	1	7	12	14	16	50
Paser	8	24	34	38	40	144
Penajam Paser Utara	11	17	9	12	5	54
Statistics						
Maximum	0.564	0.597	0.618	0.636	0.697	0.697
Minimum	0.453	0.565	0.598	0.619	0.637	0.453
Mean	0.528	0.583	0.609	0.627	0.653	0.599
Standard Deviations	0.027	0.009	0.006	0.005	0.013	0.045
Grand Total	**210**	**212**	**208**	**201**	**205**	**1,036**

4.3 Spatial Mapping of the DSVI and PWD at the Village Level

The spatial analysis categorizes villages into four groups based on the presence of natural hazards and PWD. Group one includes villages with neither natural hazards nor individuals with disabilities. Group two consists of villages with PWD but no experience of natural hazards. Group three encompasses villages that have experienced natural hazards but do not have PWD. Finally, Group 4 comprises villages with both PWD and a history of exposure to natural hazards.

4.3.1 Landslide

According to Figure 3, landslides occurred in 7% of villages, with Bontang and Mahakam Hulu being the only districts without any villages in Group 4, indicating vulnerability to either natural hazards or the presence of PWD, but not both. In contrast, Samarinda City had the highest number of villages lacking adaptive capacity, particularly in early warning systems, tree planting, safety equipment, and evacuation procedures. Despite this, all districts showed strong health sector capacity, with available health facilities, programs, practices, and personnel. However, in Samarinda City, 2–6 villages in Group 4 (experiencing landslides and

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housing PWD) still lacked certain health adaptations. Specifically, six villages lacked health initiatives, and seven lacked sufficient health workers, despite facing landslides and housing residents with multiple disabilities.

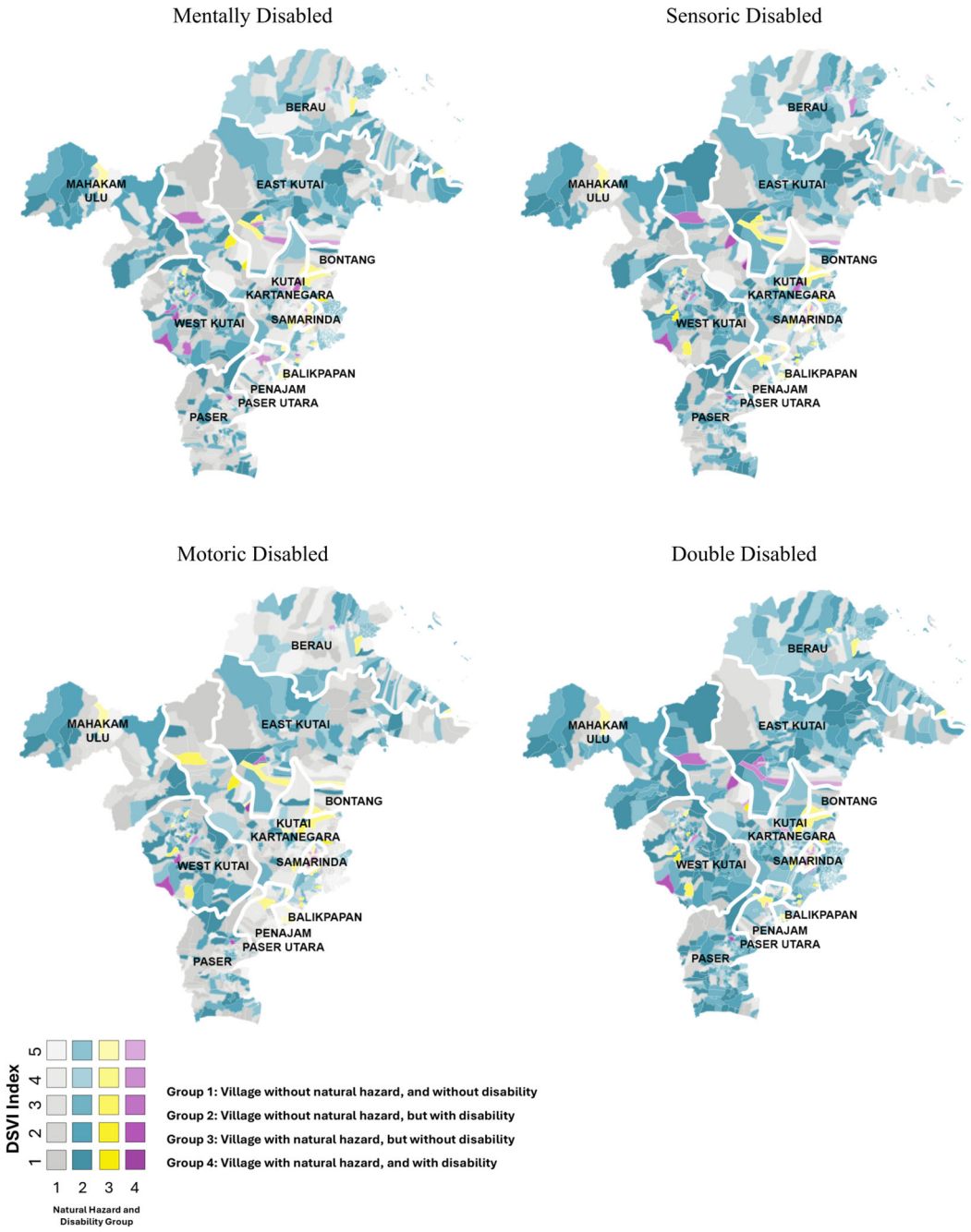

Figure 3. Spatial analysis of villages with landslides and residents with disability

Twenty-five villages with residents with mental disability fell into Group 4, located in Berau (1), Samarinda City (9), West Kutai (6), Kutai Kartanegara (4), East Kutai (3), Paser (1), and North Penajam Paser (1). None were in DSVI-5; instead, classifications included DSVI-4 (3 villages), DSVI-3 (5), DSVI-2 (4), and DSVI-1 (13). All Samarinda City villages were in

DSVI-1, with seven lacking early warning systems. Six villages in West Kutai also lacked such systems.

Twenty-seven Group 4 villages had residents with sensory disabilities, located in Berau (3), Samarinda City (12), West Kutai (3), Kutai Kartanegara (6), East Kutai (2), and Paser (1). These included 2 in DSVI-5, 3 in DSVI-4, 3 in DSVI-3, 2 in DSVI-2, and 17 in DSVI-1. In Samarinda City, 11 of 12 villages were in DSVI-1, with seven lacking safety equipment.

Nineteen Group 4 villages had residents with motor disabilities, distributed across Berau (1), Balikpapan (1), Samarinda City (10), West Kutai (4), Kutai Kartanegara (1), East Kutai (1), and Paser (1). These included 1 in DSVI-5, 3 in DSVI-4, 2 in DSVI-3, 1 in DSVI-2, and 12 in DSVI-1. In Samarinda City, most were in DSVI-1, with only a single village in DSVI-3.

There were 27 Group 4 villages with residents experiencing multiple disabilities, located in Balikpapan (2), Samarinda City (12), West Kutai (2), Kutai Kartanegara (4), East Kutai (5), Paser (1), and Penajam Paser Utara (1). Among these, 3 villages, 1 each in West Kutai, Kutai Kartanegara, and Paser, were in DSVI-5. Of the 12 Samarinda City villages, 11 were in DSVI-1; however, 8 lacked early warning systems and 9 lacked safety equipment.

4.3.2 Flood

Floods were the most frequent natural hazard in East Kalimantan, affecting 32.5% of villages (Figure 4). This high incidence placed villages across all districts into Group 4, marked by a high prevalence of disabilities. Compared to landslides, flood-affected villages exhibited weaker adaptive measures, including limited tree planting, waste management, early warning systems, safety equipment, evacuation systems, and river normalization. Most of the villages were in West Kutai, Kutai Kartanegara, and East Kutai. Health-related adaptive capacities were also lacking, with deficiencies in facilities, services, practices, and personnel, particularly in Samarinda City, West Kutai, Kutai Kartanegara, and East Kutai.

Figure 4 shows 112 Group 4 villages with residents who have mental disabilities, concentrated in West Kutai (32), East Kutai (20), and Kutai Kartanegara (18). These included 16 villages in DSVI-5, 27 in DSVI-3, 23 in DSVI-2, and 30 in DSVI-1. The DSVI-5 villages were in West Kutai (7), Paser (4), Kutai Kartanegara (2), East Kutai (2), and Mahakam Hulu (1). All Group 4 villages in Samarinda City were in DSVI-1.

Villages with residents who have sensory disabilities were mainly in West Kutai (33), East Kutai (30), Kutai Kartanegara (31), and Berau (23), comprising 21 in DSVI-5, 29 in DSVI-4, 35 in DSVI-3, 29 in DSVI-2, and 39 in DSVI-1. The DSVI-5 group included villages in West Kutai (7), East Kutai (6), Paser (4), Mahakam Hulu (2), Kutai Kartanegara (1), and North Penajam Paser (1).

For motor disabilities, 99 Group 4 villages were identified, primarily in West Kutai (31), East Kutai (20), and Kutai Kartanegara (14). These included 11 in DSVI-5, 19 in DSVI-4, 22 in DSVI-3, 19 in DSVI-2, and 28 in DSVI-1. DSVI-5 villages were in West Kutai (5), Kutai

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Kartanegara (1), East Kutai (2), Paser (2), and Mahakam Hulu (1). Of the nine Group 4 villages in Samarinda City, eight were in DSVI-1.

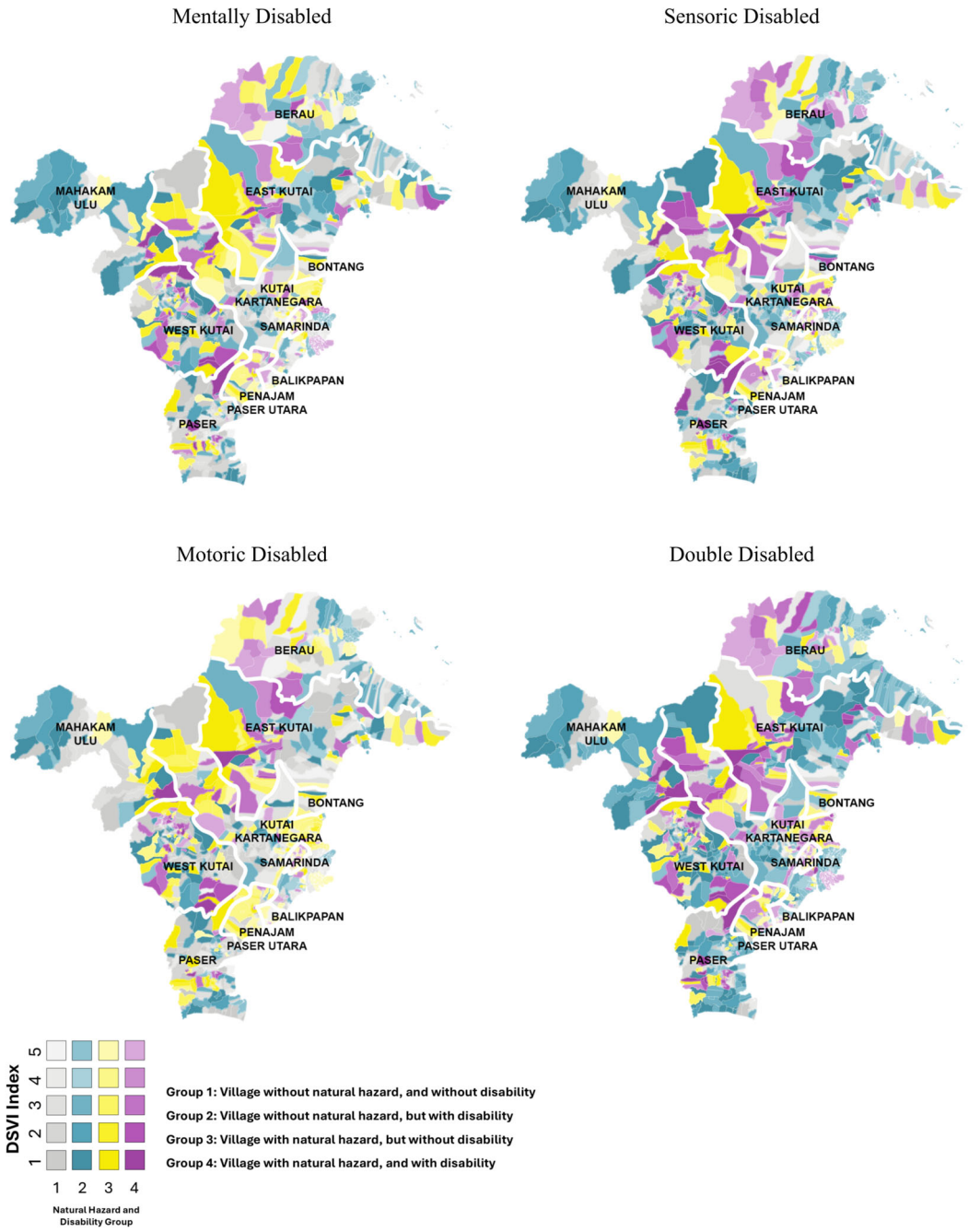

Figure 4. Spatial analysis of villages with floods and residents with disability

A total of 178 Group 4 villages had residents with multiple disabilities, primarily located in West Kutai (35 villages), East Kutai (34 villages), and Kutai Kartanegara (37 villages). Within this group, 23 villages were classified as DSVI-5, 21 as DSVI-4, 38 as DSVI-3, 36 as DSVI-2, and 50 as DSVI-1. The 23 villages in DSVI-5 were located in West Kutai (8 villages), Kutai Kartanegara (2 villages), East Kutai (5 villages), Paser (5 villages), and Mahakam Hulu (3

villages). Notably, 15 of the 17 villages in Samarinda City within Group 4 were classified as DSVI-1.

4.3.3 Forest Fire

Forest fires were the least frequent natural hazard in East Kalimantan, occurring in only 4.9% of villages. Despite the low occurrence, all districts had villages classified in Group 4 (see Figure 5). Compared to landslides, a smaller number of villages exhibited low adaptive capacity to forest fires, with the most affected villages located in West Kutai (4-6 villages). Deficiencies were observed in critical adaptive components, including early warning systems, tree planting, safety equipment, and evacuation systems which were frequently absent.

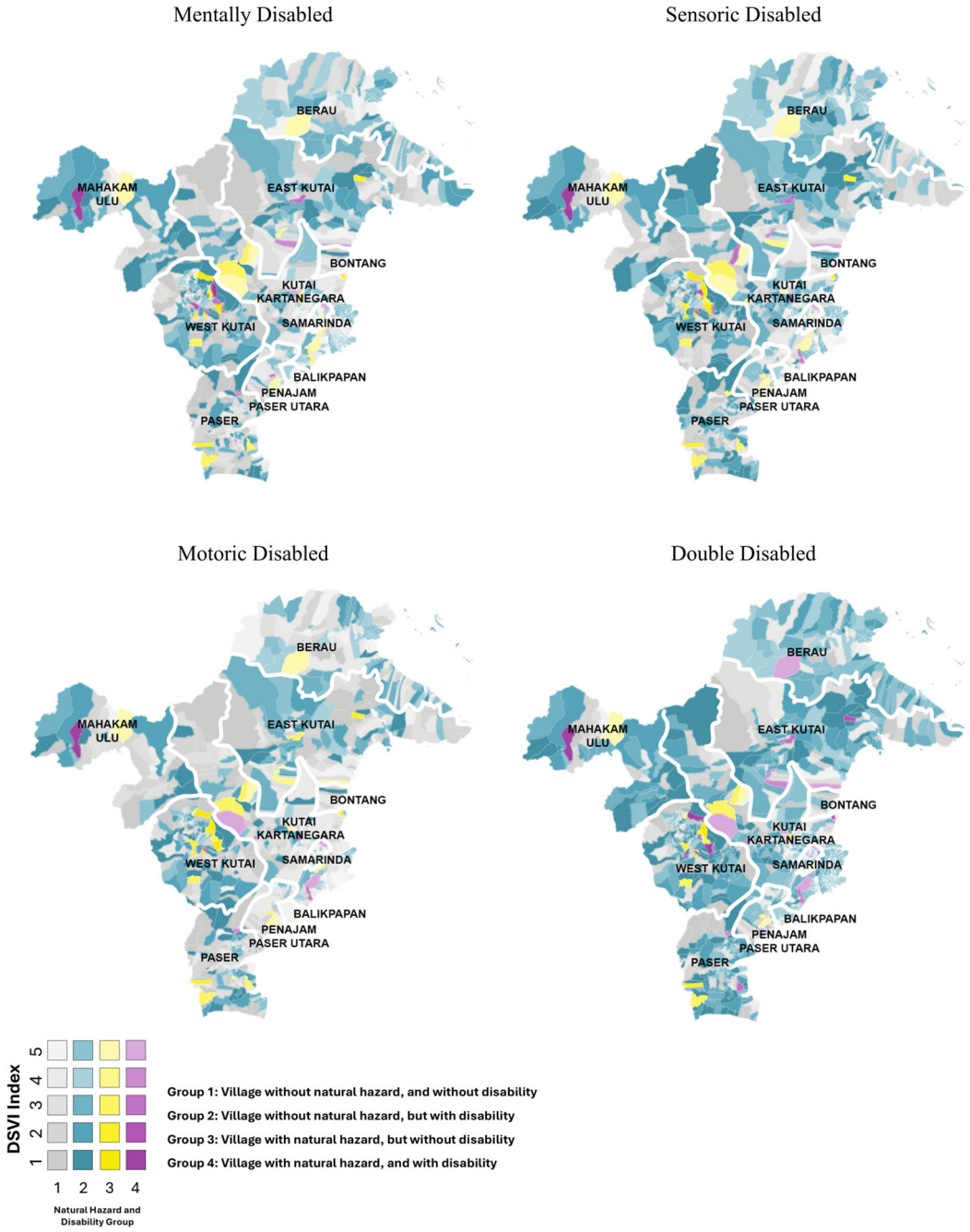

Figure 5. Spatial analysis of villages with forest fires and residents with disability

Even so, villages in Group 4 generally demonstrated strong health-related adaptive capacity, with most having health facilities, ongoing health programs, established health practices, and available health personnel. Only a limited number of villages, primarily in West Kutai (4–5 villages), lacked adequate health practices, regardless of whether they housed residents with sensory, mental, or multiple disabilities. Additional gaps were identified in the availability of health workers. In Kutai Kartanegara, three villages lacked sufficient health personnel despite having residents with motor or multiple disabilities. Samarinda City and East Kutai likewise had three villages each with inadequate health worker capacity, even though they housed residents with multiple disabilities.

For villages having residents with motoric disability, there were 11 villages in East Kalimantan included in Group 4 (experiencing forest fires and having residents with motoric disability). These villages were distributed across West Kutai (13 villages) and Kutai Kartanegara (11 villages). Among the 11 villages, one village was included in the DSVI-5 group (in Mahakam Hulu), two villages in DSVI-4, two villages in DSVI-3, two villages in DSVI-2, and 4 villages in DSVI-1.

For villages having residents with multiple disabilities, there were 28 villages in East Kalimantan included in Group 4 (experiencing forest fires and having residents with multiple disabilities). These villages were located in West Kutai (6 villages), Kutai Kartanegara (6 villages), East Kutai (4 villages), and Samarinda City (4 villages). Among the 28 villages, 4 villages were included in DSVI-5 group (three villages in West Kutai and one in Mahakam Hulu), 4 villages in DSVI-4, 5 villages in DSVI-3, 5 villages in DSVI-2, and 10 villages in DSVI-1.

5. DISCUSSION

This study demonstrates that integrating the District Social Vulnerability Index (DSVI) with spatially disaggregated disability data provides valuable insights into prioritizing villages in East Kalimantan for inclusive disaster risk reduction (DRR) interventions. Previous studies have emphasized that vulnerability to disasters is shaped not only by physical exposure but also by socio-economic and demographic conditions, as well as the capacities of communities to prepare for and respond to hazards (Cutter et al., 2003; Kelman, 2015; Stough, 2015). Our findings extend this body of work by linking vulnerability levels with the prevalence and type of disability at the village level, thereby enabling more context-specific policy recommendations.

The results reveal significant spatial disparities, with high-DSVI villages concentrated in rural and hazard-prone areas such as Mahakam Ulu and parts of Kutai Kartanegara, where infrastructure limitations exacerbate the challenges faced by PWD. Disability represents a critical dimension of social vulnerability because it intersects with other factors, including poverty, education, and access to essential services, shaping both disaster preparedness and

recovery capacity (Stough, 2015; Kelman, 2015; BNPB, 2021). Therefore, DRR strategies must address both the hazard environment and the functional needs of PWD.

Based on the combined analysis of DSVI quintiles and disability type, we propose targeted interventions for each vulnerability group:

Group 1 (Least vulnerable, DSVI 1–2): These villages are typically urban or peri-urban with relatively strong infrastructure but still hosting PWD. For individuals with mental disabilities, simple symbol-based disaster messages and low-stress preparedness drills should be implemented in collaboration with local disability organizations. For those with sensory disabilities, the early warning system must incorporate visual, auditory, and tactile alerts, and public awareness campaigns should ensure active participation of PWD. For individuals with motoric disabilities, maintaining accessible public spaces and involving PWD in preparedness exercises is essential. For residents with multiple disabilities, interventions should combine communication adaptations with accessibility enhancements, ideally in partnership with urban disability-focused NGOs to maximize effectiveness (Kelman & Stough, 2015; BNPB, 2021).

Group 2 (Moderate vulnerability, DSVI 3): These villages consist of a mix of rural and peri-urban areas where adaptive capacity is moderate, but gaps persist. For mental disabilities, volunteer training in cognitive assistance and installation of clear evacuation signage is critical. Sensory disability measures should include accessible shelters, tactile maps, and the provision of sign language interpreters during emergencies. For motoric disabilities, evacuation transport must be adapted, and priority facilities should be upgraded with ramps, handrails, and other accessibility features. Villages with residents who have multiple disabilities should employ multi-sensory alert systems and develop inclusive evacuation plans that explicitly address varied functional needs (Cutter et al., 2003; Stough, 2015; Kelman, 2015).

Group 3 (High vulnerability, DSVI 4): These villages are predominantly rural and hazard-prone, often with a higher concentration of residents with mental and multiple disabilities. For mental disability, community-based buddy systems and mental health first aid training for disaster volunteers should be implemented. For sensory disabilities, information should be provided in Braille and large print, and tactile indicators should be in shelters. For motoric disabilities, manual handling equipment should be pre-arranged, and mobility aids distributed. Residents with multiple disabilities require a combination of all these measures, with trained caregivers assigned during evacuation and shelter phases (BNPB, 2021; Kelman, 2015; Stough, 2015).

Group 4 (Highest vulnerability, DSVI 5): These villages are rural, hazard-prone areas, and characterized by low adaptive capacity and a high prevalence of multiple disabilities, representing the highest priority for intervention. For mental disabilities, local registries should be established, and personal support staff deployed during hazard seasons. For sensory disabilities, multi-modal early warning devices should be installed in homes and public spaces. For motoric disabilities, adapted transport should be pre-positioned, and barrier-free shelters made available. For residents with multiple disabilities, interventions should prioritize resource

allocation, provide one-to-one assistance, and implement multi-modal communication strategies (Cutter et al., 2003; Stough, 2015; Kelman, 2015; BNPB, 2021).

By aligning DSVI groupings with disability type-specific needs, these recommendations translate spatial and statistical findings into actionable local strategies. This approach operationalizes the principle of "leaving no one behind" embedded in the Sendai Framework for Disaster Risk Reduction (UNDRR, 2015) and Indonesia's national disaster management policy, while ensuring that interventions address both structural vulnerabilities and functional diversity among at-risk populations. The findings also offer a replicable methodological framework for other provinces seeking to integrate disability considerations into disaster resilience planning.

6. CONCLUSION

Our analysis reveals that, of 1036 villages examined, 205 are classified as highly vulnerable (DSVI-5). Many of these highly vulnerable villages are concentrated in West Kutai, Kutai Kartanegara, and Paser. In contrast, urban areas such as Samarinda City, Bontang, and Samarinda predominantly contain villages categorized as least vulnerable (DSVI-1 and DSVI-2). Spatial mapping indicates that villages hosting PWD and exposed to disasters are mainly located in West Kutai, Kutai Kartanegara, and East Kutai across all disaster types. Notably, Samarinda City exhibits the highest number of villages in group 4 for landslides. Regarding landslide vulnerability, although many villages in Samarinda City are classified as least vulnerable (DSVI-1), some remain in Group 4 due to lower adaptive capacity and the presence of PWD. The distribution of disabilities among villages in Group 4 shows that multiple disabilities and sensory impairments are most common, while motor disabilities are least frequent. The variation in vulnerability across districts for different types of disabilities is minimal, with West Kutai, Kutai Kartanegara, and East Kutai consistently appearing.

Floods, the most frequent natural hazard, significantly affect villages, with many in Group 4 and a notable proportion exhibiting low adaptive capacity. Here again, multiple disabilities are most prevalent among affected villages, while motor disabilities are least common. Although forest fires occur less frequently, they still impact villages across all districts, with West Kutai having fewer villages in Group 4 compared to other hazards. Multiple disabilities remain the most common, and motor disabilities the least represented.

These findings highlight the necessity of developing disability-inclusive disaster-resilient villages (DIDRV) to mitigate disaster risks and impacts. Implementing DIDRV involves three key stages: data-driven advocacy, addressing stigma through leveraging power and influence, and securing funding. Effective disaster preparedness, response, and recovery must be tailored to the special needs of individuals with disabilities and incorporate their input in planning. Achieving this effort requires collaboration and support from various stakeholders, including local authorities, disaster management agencies, social services, and other relevant organizations.

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