

# Landslide Susceptibility and Educational Facility Exposure in Majalengka Regency: A GIS-Based Weighted Overlay Approach

Muhammad Hafidz Aditya Ramadhan

Universitas Islam Negeri Syarif Hidayatullah Jakarta

[hafizaditya75@gmail.com](mailto:hafizaditya75@gmail.com)

Hermawan Setiawan\*

Universitas Islam Negeri Syarif Hidayatullah Jakarta

[hermawan.setiawan@uinjkt.ac.id](mailto:hermawan.setiawan@uinjkt.ac.id)

Andri Noor Ardiansyah

Universitas Islam Negeri Syarif Hidayatullah Jakarta

[andri.noor@uinjkt.ac.id](mailto:andri.noor@uinjkt.ac.id)

## Abstract

Landslides are a significant geomorphological hazard in Indonesia that can damage infrastructure and disrupt social activities. In Majalengka Regency, variations in topographic conditions result in different levels of landslide susceptibility, which may affect public facilities, including educational institutions. This study aims to analyze the spatial distribution of landslide susceptibility and evaluate the exposure of educational facilities using a GIS-based Weighted Overlay method with seven parameters. The results indicate that High and Very High susceptibility areas cover approximately 33,284 hectares and 17,388 hectares, respectively, and are mainly concentrated in the southern part of Majalengka Regency. Of the 672 educational facilities, 162 schools (24.1%) are located within landslide-prone zones, including 47 schools in Very High susceptibility areas. These findings highlight the influence of terrain conditions, rainfall, soil characteristics, and proximity to infrastructure in shaping landslide susceptibility. This study provides a spatially explicit evaluation of educational facility exposure, offering empirical baseline data to support local disaster mitigation strategies and school safety planning.

## Abstrak

Kejadian tanah longsor merupakan salah satu bahaya geomorfologi yang sering terjadi di Indonesia dan dapat merusak infrastruktur serta mengganggu aktivitas masyarakat. Di Kabupaten Majalengka, variasi topografi menyebabkan perbedaan tingkat kerawanan longsor antarwilayah yang berpotensi memengaruhi fasilitas publik, termasuk pendidikan. Penelitian ini bertujuan untuk menganalisis distribusi spasial kerawanan longsor serta mengevaluasi tingkat keterpaparan fasilitas pendidikan menggunakan metode Weighted Overlay berbasis Sistem Informasi Geografis dengan tujuh parameter. Hasil penelitian menunjukkan bahwa wilayah dengan tingkat kerawanan tinggi dan sangat tinggi mencakup sekitar 33.284 hektar dan 17.388 hektar, yang sebagian besar terkonsentrasi di bagian selatan Kabupaten Majalengka. Dari 672 fasilitas pendidikan, sebanyak 162 sekolah (24,1%) berada pada zona rawan longsor, termasuk 47 sekolah pada kategori sangat tinggi. Temuan ini menunjukkan bahwa kondisi topografi, curah hujan, karakteristik tanah, serta kedekatan terhadap infrastruktur berperan penting dalam membentuk kerawanan longsor. Penelitian ini memberikan evaluasi spasial yang spesifik terhadap keterpaparan fasilitas pendidikan serta menghasilkan data dasar empiris yang dapat digunakan untuk mendukung strategi mitigasi bencana dan perencanaan keselamatan sekolah di tingkat lokal.

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## Introduction

Indonesia is highly exposed to natural hazards due to its position at the convergence of the Indo-Australian, Eurasian, and Pacific plates.<sup>1</sup> This tectonic setting generates active seismic and volcanic processes and forms predominantly mountainous and hilly landscapes.<sup>2</sup> Combined with a tropical climate characterized by high rainfall, these conditions increase susceptibility to hydrometeorological hazards such as landslides.<sup>3</sup> In many regions, geological conditions, slope morphology, and prolonged rainfall interact to reduce slope stability and trigger mass movement.<sup>4</sup>

Majalengka Regency in West Java exhibits contrasting physiographic conditions, with lowland areas in the north and hilly to mountainous terrain dominating the southern region. This variation contributes to differences in slope stability and increases landslide susceptibility in several areas.<sup>5</sup> Between 2023 and 2025, multiple landslide events disrupted transportation along the Maja–Talaga corridor, restricted road access in Bantarujeg, and damaged residential areas in Lemahsugih.<sup>6</sup> These events indicate that landslide occurrence is influenced not only by physical terrain characteristics but also by their interaction with infrastructure networks and settlement patterns.<sup>7</sup>

Landslide susceptibility is controlled by the interaction between conditioning factors and triggering mechanisms. Slope failures may develop gradually or occur suddenly when external triggers such as intense rainfall or seismic activity disturb slope stability.<sup>8</sup> Key controlling factors include slope gradient, lithology, soil characteristics, and land use or land

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<sup>1</sup> Afdelia Novianti and Dina Tri Utari, "Implementation of Markov Chain in Detecting Opportunities for Natural Disasters in Klaten (Case Study: Number of Floods, Landslides, and Hurricanes 2019-2020)," *Enthusiastic: International Journal of Applied Statistics and Data Science* 1, no. 2 (October 15, 2021): 58–67, <https://doi.org/10.20885/enthusiastic.vol1.iss2.art2>.

<sup>2</sup> L. Alfaris et al., "Correlation between Seismicity Rates and Earthquake Return Periods in the Southern Offshore of West Java, Indonesia," *Geosfera: Jurnal Penelitian Geografi* 4, no. 2 (2025): 532–42, <https://doi.org/10.37905/geojg.v4i2.36433>.

<sup>3</sup> Ragil A Yuniawan et al., "Revised Rainfall Threshold in the Indonesian Landslide Early Warning System," *Geosciences*, 2022, <https://doi.org/10.3390/geosciences12030129>.

<sup>4</sup> Heni Masruroh et al., "A Spatial Model of Landslides with A Micro-Topography and Vegetation Approach for Sustainable Land Management in the Volcanic Area," *Sustainability*, 2023, <https://doi.org/10.3390/su15043043>.

<sup>5</sup> BNPB, *Indeks Risiko Bencana Indonesia (IRBI) Tahun 2022* (Jakarta: Badan Nasional Penanggulangan Bencana, 2023), [https://inarisk.bnppb.go.id/pdf/BUKU\\_IRBI\\_2022.pdf](https://inarisk.bnppb.go.id/pdf/BUKU_IRBI_2022.pdf).

<sup>6</sup> BPBD, "Jumlah Kawasan Rawan Bencana Tanah Longsor Berdasarkan Kecamatan Di Kabupaten Majalengka (Data Tahun 2018–2024)" (Majalengka: Badan Penanggulangan Bencana Daerah Kabupaten Majalengka, 2025), <https://opendata.majalengkakab.go.id/dataset/jumlah-kawasan-rawan-bencana-tanah-longsor-berdasarkan-kecamatan-di-kabupaten-majalengka>.

<sup>7</sup> Masruroh et al., "A Spatial Model of Landslides with A Micro-Topography and Vegetation Approach for Sustainable Land Management in the Volcanic Area."

<sup>8</sup> Aman Ullah, Muhammad Ramzan, and Javed Iqbal, "Landslide Susceptibility Mapping for Hazard Management along Pakistan's Balakot-Naran Route," *Journal of Degraded and Mining Lands Management* 12, no. 3 (April 1, 2025): 7401–16, <https://doi.org/10.15243/jdmlm.2025.123.7401>.

cover.<sup>9</sup> However, landslide occurrence is not driven solely by natural conditions. Human activities, particularly infrastructure development, can significantly alter slope stability. Road construction involving slope cutting may modify slope geometry and drainage systems, while hydrological processes near river corridors can accelerate erosion and increase soil moisture.<sup>10</sup>

Identifying landslide-prone areas therefore requires consideration of both physical terrain characteristics and proximity to infrastructure and hydrological features.<sup>11</sup> However, a key limitation remains: existing landslide susceptibility studies often emphasize biophysical parameters while overlooking the spatial relationship between hazard-prone areas and critical public infrastructure, particularly educational facilities. Previous studies in Indonesia generally rely on standard physical parameters, including rainfall, slope gradient, soil type, lithology, and land use or land cover.<sup>12</sup>

While effective in describing basic biophysical susceptibility,<sup>13</sup> such approaches may not fully capture the influence of anthropogenic disturbances and local hydrological processes, especially in areas with dense road networks and river systems.<sup>14</sup> In particular, proximity factors such as distance to roads and distance to rivers remain inconsistently incorporated into susceptibility models.<sup>15</sup>

This limitation directly affects the effectiveness of disaster risk reduction efforts. Educational facilities are critical public assets whose exposure to landslide hazards requires specific spatial assessment. Without clear and measurable information on the extent of school exposure, local authorities may face difficulties in prioritizing mitigation efforts and planning appropriate risk reduction strategies.

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<sup>9</sup> Chuanmei Cheng et al., "Rain-Induced Shallow Landslide Susceptibility Under Multiple Scenarios Based on Effective Antecedent Precipitation," *Applied Sciences* 15, no. 11 (2025): 6241, <https://doi.org/10.3390/app15116241>.

<sup>10</sup> Md Tanvir Ahsan, Ji-peng Wang, and Abdelali Dadda, "Numerical Analysis of Riverbank Slope Stability Considering Rainfall, Vegetation and Water Level Fluctuation," *Journal of Engineering Research and Sciences* 3, no. 4 (2024), <https://doi.org/10.55708/js0304003>.

<sup>11</sup> Paola Reichenbach et al., "A Review of Statistically-Based Landslide Susceptibility Models," *Earth-Science Reviews* 180 (2018): 60–91, <https://doi.org/10.1016/j.earscirev.2018.03.001>.

<sup>12</sup> Reichenbach et al.

<sup>13</sup> A Brenning et al., "Landslide Susceptibility Near Highways Is Increased by 1 Order of Magnitude in the Andes of Southern Ecuador, Loja Province," *Natural Hazards and Earth System Sciences* 15, no. 1 (2015): 45–57, <https://doi.org/10.5194/nhess-15-45-2015>.

<sup>14</sup> Renhard Haribulan, Pierre H Gosal, and Hendriek H Karongkong, "Kajian Kerentanan Fisik Bencana Longsor Di Kecamatan Tomohon Utara," *Spasial* 6, no. 3 (2019): 714–24, <https://doi.org/10.35793/sp.v6i3.26015>.

<sup>15</sup> Sudaryatno et al., "Evidence Based Landslide Hazard Mapping In Purworejo Using Information Value Model Approach," *Forum Geografi* 33, no. 1 (2019): 25–38, <https://doi.org/10.23917/forgeo.v33i1.7592>.

The objectives of this study are twofold: (1) to analyze the spatial distribution of landslide susceptibility in Majalengka Regency, and (2) to evaluate the exposure of educational facilities within these hazard-prone areas. The results are expected to support spatial planning and disaster risk reduction, particularly in promoting safer school environments.

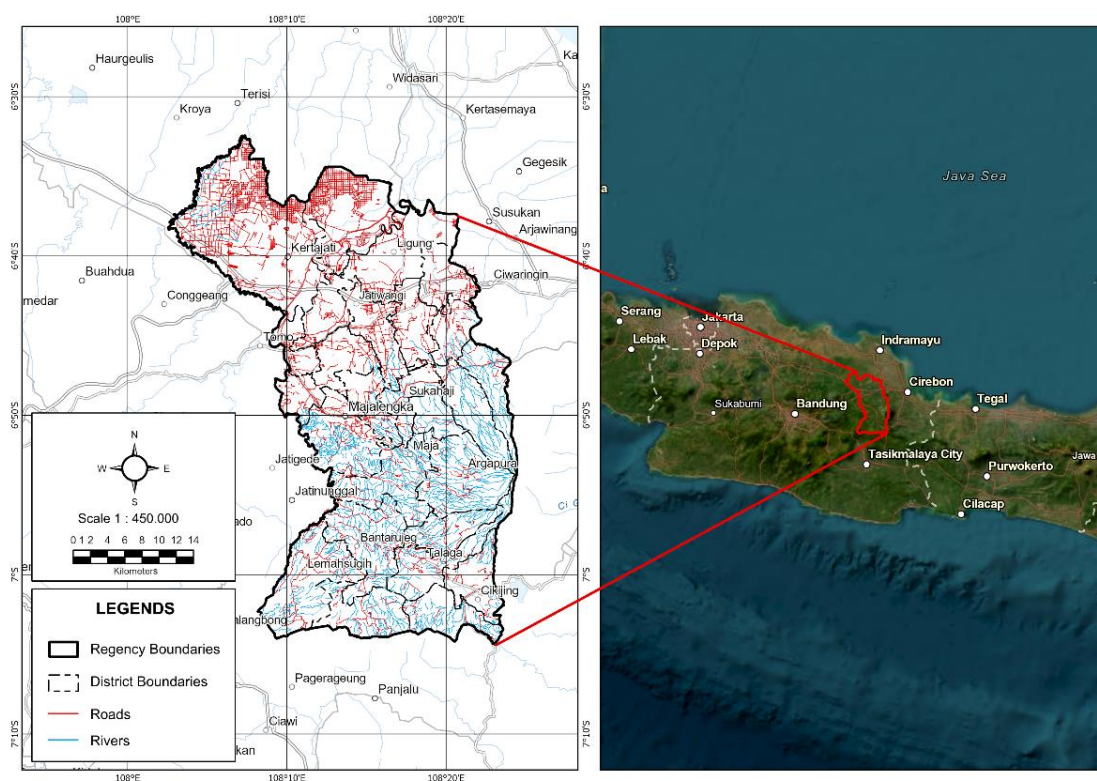
## Methods

### 1. Study Area

Majalengka Regency is located between 108°03'–108°19' East Longitude and 6°36'–7°03' South Latitude, covering approximately 1,204.24 km<sup>2</sup> and consisting of 26 districts. In recent years, development has intensified following the operation of major infrastructure such as BIJB Kertajati and the Cipali Toll Road, accelerating land-use change and human activities.

Physiographically, the region shows a clear north–south contrast, with lowland terrain (19–50 m) in the north and mountainous areas exceeding 1,000 m in the south. The region experiences tropical rainfall (2,000–3,500 mm/year), which increases landslide susceptibility, particularly in the southern highlands, further intensified by land-use change and slope modification. The study area is shown in Figure 1.

**Figure 1**  
Location Map of the Study Area, Majalengka Regency



Source : Author, 2025

## 2. Data Collection

This study uses secondary data from government institutions and satellite imagery analyzed within a geospatial framework. The seven variables were selected based on previous studies on slope instability in tropical environments.

### a. Rainfall

Rainfall data were derived from the CHIRPS dataset,<sup>16</sup> and used to map annual rainfall distribution in the study area. Rainfall is a key triggering factor in landslides, as increased infiltration raises pore water pressure and reduces slope stability.<sup>17</sup>

### b. Slope Gradient

Slope gradients were derived from the National Digital Elevation Model (DEMNAS) with a spatial resolution of 0.27 arc-seconds provided by the Geospatial Information Agency.<sup>18</sup> DEM data represent surface elevation and are used to derive slope gradients for stability analysis.<sup>19</sup> Steeper slopes increase gravitational forces on surface materials, enhancing the likelihood of downslope movement.

### c. Land Use / Land Cover

Land use and land cover data were obtained from the Indonesian Topographic Map (RBI) at a scale of 1:50,000 provided by the Geospatial Information Agency,<sup>20</sup> and validated using Sentinel-2A satellite imagery.<sup>21</sup> This parameter represents land utilization and vegetation cover conditions that influence slope stability.<sup>22</sup>

### d. Soil Type

Soil type data were derived from a 1:50,000 scale soil map published by the Indonesian Center for Agricultural Land Resources Research and Development.<sup>23</sup> Soil characteristics,

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<sup>16</sup> Chris Funk et al., "The Climate Hazards Infrared Precipitation with Stations—a New Environmental Record for Monitoring Extremes," *Scientific Data* 2, no. 1 (2015): 150066, <https://doi.org/10.1038/sdata.2015.66>.

<sup>17</sup> Muhammad Farhan Yassar et al., "Penerapan Weighted Overlay Pada Pemetaan Tingkat Probabilitas Zona Rawan Longsor Di Kabupaten Sumedang, Jawa Barat," *Jurnal Geosains Dan Remote Sensing* 1, no. 1 (May 7, 2020), <https://doi.org/10.23960/jgrs.2020.v1i1.13>.

<sup>18</sup> Badan Informasi Geospasial, "DEMNAS: Digital Elevation Model Nasional" (Cibinong: Badan Informasi Geospasial, 2018), <https://tanahair.indonesia.go.id/portal-web>.

<sup>19</sup> Peter L. Guth et al., "Digital Elevation Models: Terminology and Definitions," *Remote Sensing*, 2021, <https://doi.org/10.3390/rs13183581>.

<sup>20</sup> Badan Informasi Geospasial, "Peta Rupa Bumi Indonesia (RBI) Skala 1:50.000 [Wilayah Kabupaten Majalengka]" (Cibinong, Indonesia: Badan Informasi Geospasial, 2018), <https://tanahair.indonesia.go.id/>.

<sup>21</sup> European Space Agency, "Copernicus Sentinel-2A Satellite Imagery [Level-2A Bottom of Atmosphere]" (Paris, France: European Space Agency (ESA), 2025), <https://dataspace.copernicus.eu/>.

<sup>22</sup> Muhammad Iqbal Firdaus and Eppy Yuliani, "Kesesuaian Lahan Permukiman Terhadap Kawasan Rawan Bencana Longsor," *Jurnal Kajian Ruang* 1, no. 2 (2021): 216–37, <https://doi.org/10.30659/jkr.v1i2.20030>.

<sup>23</sup> Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian, "Peta Tanah Semi Detail Kabupaten Majalengka Skala 1:50.000" (Bogor: Kementerian Pertanian, 2016).

including texture and permeability, influence infiltration capacity and soil stability, which are important in landslide analysis.<sup>24</sup> Soils were classified based on their sensitivity to erosion.<sup>25</sup>

#### e. Lithology

Lithological data were obtained from the Geological Maps of the Arjawinangun Sheet (No. 1309),<sup>26</sup> and the Bandung Sheet,<sup>27</sup> published by the Geological Agency, Ministry of Energy and Mineral Resources. These data were used to identify the distribution of rock types. Lithology influences landslide susceptibility through rock properties and geological structures such as faults, fractures, folds, and bedding planes.<sup>28</sup>

#### f. Proximity to Roads and Rivers

Road and river network data were derived from the RBI map produced by the Geospatial Information Agency (BIG). Distance to roads and rivers was calculated using the Euclidean Distance method. These parameters were integrated to represent the combined influence of anthropogenic activities and hydrological processes on slope stability.

Proximity to roads reflects human-induced slope disturbances, such as slope cutting, excavation, and loading, which can alter slope geometry and increase the likelihood of slope failure.<sup>29</sup> Meanwhile, proximity to rivers represents natural fluvial processes, including riverbank erosion and undercutting, which can weaken slope materials and reduce stability.<sup>30</sup> To address limitations in conventional susceptibility models, this study integrates both parameters to better capture the interaction between terrain conditions, infrastructure development, and hydrological processes, particularly in hilly areas where road networks often follow river corridors.

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<sup>24</sup> Arnas Hardianto et al., "Pemanfaatan Informasi Spasial Berbasis SIG Untuk Pemetaan Tingkat Kerawanan Longsor Di Kabupaten Bandung Barat, Jawa Barat," *Jurnal Geosains Dan Remote Sensing* 1, no. 1 (May 10, 2020), <https://doi.org/10.23960/jgrs.2020.v1i1.16>.

<sup>25</sup> Yassar et al., "Penerapan Weighted Overlay Pada Pemetaan Tingkat Probabilitas Zona Rawan Longsor Di Kabupaten Sumedang, Jawa Barat."

<sup>26</sup> Djuri, *Peta Geologi Lembar Arjawinangun, Jawa* (Bandung: Pusat Penelitian dan Pengembangan Geologi, 1995).

<sup>27</sup> P H Silitonga, "Peta Geologi Lembar Bandung, Jawa" (Bandung: Pusat Penelitian dan Pengembangan Geologi, 1973).

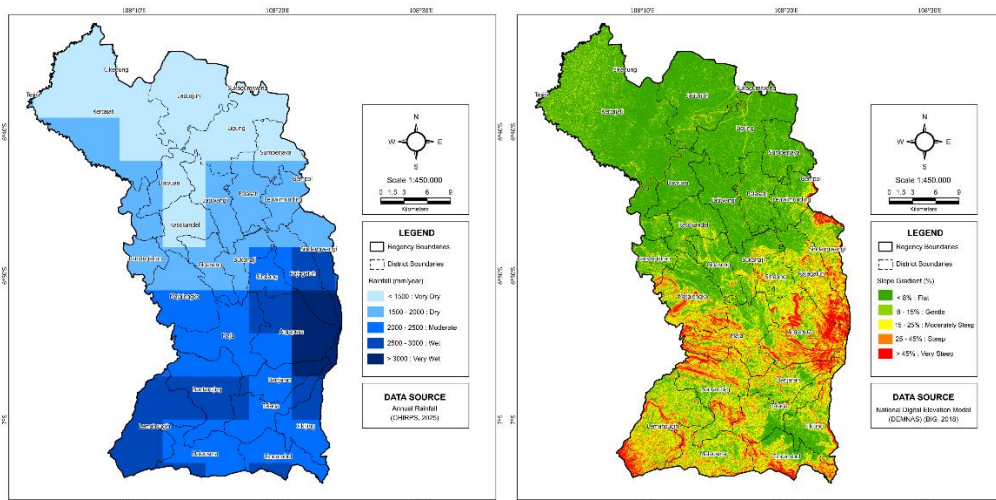
<sup>28</sup> Marlinus Matius Lollong, Tommy Trides, and Windhu Nugroho, "Analisis Kestabilan Lereng Dengan Menggunakan Metode Rock Mass Rating (RMR) Dan Metode Slope Mass Rating (SMR) Pada Penambangan Batupasir Daerah Bukit Pinang Kecamatan Samarinda Ulu Kota Samarinda Provinsi Kalimantan Timur," *Jurnal Teknologi Mineral FT UNMUL* 7, no. 1 (2019): 50–60, <https://e-journals.unmul.ac.id/index.php/TM/article/view/2435>.

<sup>29</sup> Oldrich Hungr et al., *Landslide Risk Management* (Boca Raton, FL: CRC Press, 2005), <https://doi.org/10.1201/9781439833711>.

<sup>30</sup> Bahareh Ghasemian et al., "A Robust Deep-Learning Model for Landslide Susceptibility Mapping: A Case Study of Kurdistan Province, Iran," *Sensors*, 2022, <https://doi.org/10.3390/s22041573>.

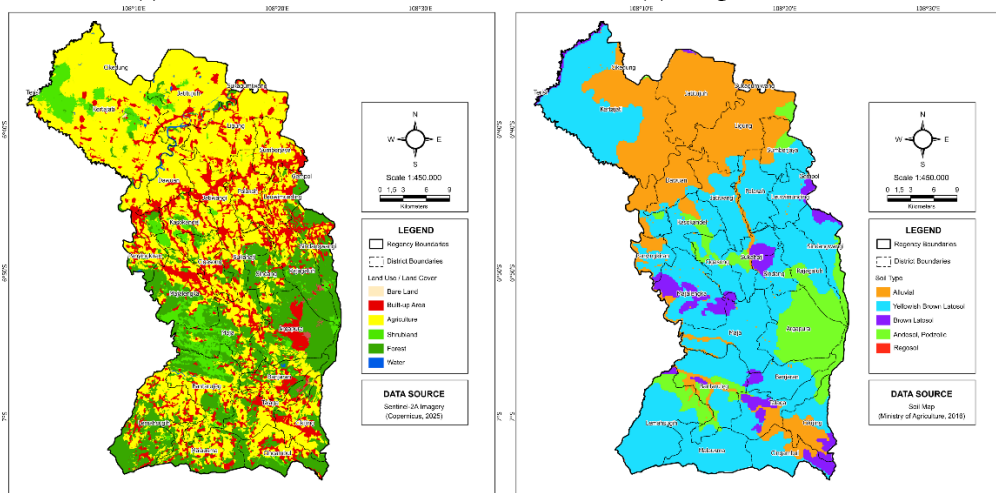
**Figure 2**

Parameter Data : (a) Rainfall, (b) Slope Gradient, (c) Land Use / Land Cover, (d) Soil Type, (e) Lithology, (f) Proximity to Roads, and (g) Proximity to Rivers



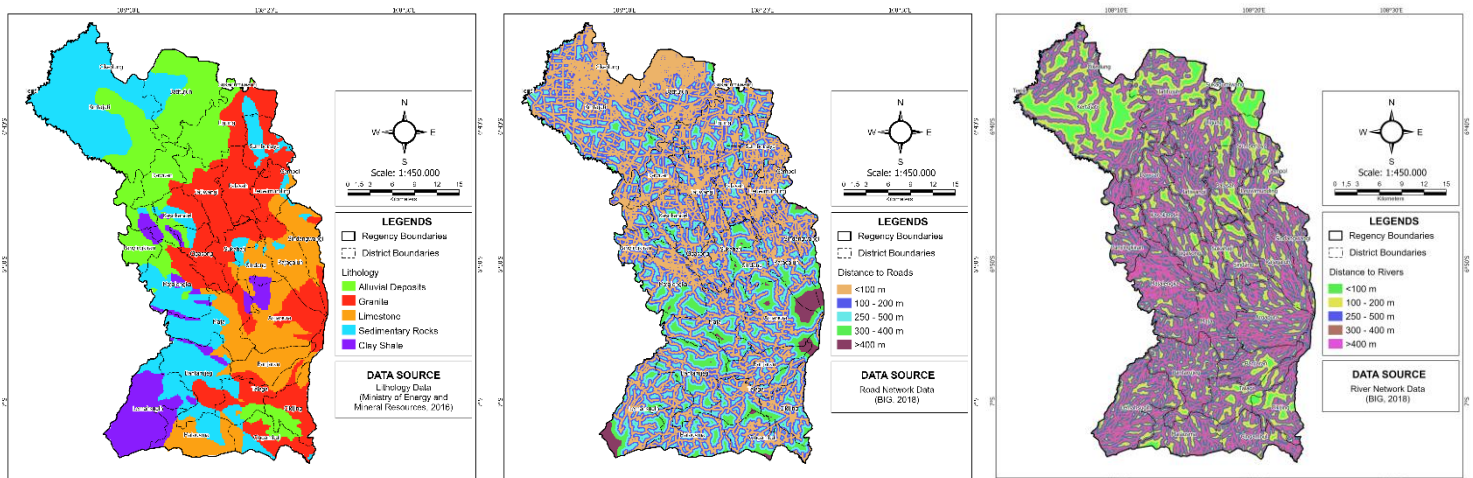
(a) Rainfall

(b) Slope Gradient



(c) LULC

(d) Soil Type



(e) Lithology

(f) Proximity to Roads

(g) Proximity to Rivers

Source : Author, 2025

### 3. Data Analysis

Landslide susceptibility was analyzed using the Weighted Overlay method within a Geographic Information System (GIS). This approach corresponds to the Simple Additive Weighting (SAW) technique, where the final score is obtained by summing the products of parameter scores ( $X_{ij}$ ) and their corresponding weights ( $W_j$ ).<sup>31</sup> In a GIS environment, each parameter layer must be normalized to a common scale before aggregation to maintain consistency in the spatial analysis.<sup>32</sup>

Mathematically, the landslide susceptibility index can be expressed as follows:

$$S_i = \sum(W_j \times X_{ij})$$

Where :

$S_i$  = Total susceptibility score for the  $i$ -th land unit

$W_j$  = Weight of the  $j$ -th parameter (percentage of relative importance)

$X_{ij}$  = Classification score of the  $j$ -th parameter for the  $i$ -th land unit

Prior to the overlay process, data coding was performed through spatial reclassification. Each parameter was standardized into a common evaluation scale by assigning discrete susceptibility scores ( $X_{ij}$ ) ranging from 1 (Very Low) to 5 (Very High). In this study, parameter weights ( $W_j$ ) were not determined solely based on the standard proposed by Puschittanak.<sup>33</sup> The weighting scheme was adjusted by incorporating proximity parameters, namely distance to roads and distance to rivers, to better represent localized anthropogenic and hydrological influences. Seven parameters were used in the analysis: (a) rainfall, (b) slope gradient, (c) land use/land cover, (d) soil type, (e) lithology, (f) distance to roads, and (g) distance to rivers. The weight values were derived from a comparison of several previous studies and are presented in Table 1.

After all parameter layers were integrated, the resulting cumulative scores were directly classified into five landslide susceptibility levels (Very Low to Very High). This classification corresponds to the predefined evaluation scale (1 to 5) applied during the reclassification and weighting process, where each spatial unit is assigned to a susceptibility class based on its aggregated parametric score.

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<sup>31</sup> Jacek Malczewski, *GIS And Multi-Criteria Decision Analysis* (New York, NY: John Wiley & Sons, 1999).

<sup>32</sup> J Ronald Eastman, *IDRISI Selva Tutorial* (Worcester, MA: Clark Labs, Clark University, 2012).

<sup>33</sup> *Laporan Akhir Pengkajian Potensi Bencana Kekeringan, Banjir Dan Longsor Di Kawasan Satuan Wilayah Sungai Citarum-Ciliwung, Jawa Barat Bagian Barat Berbasis Sistem Informasi Geografi* (Bogor: Pusat Penelitian dan Pengembangan Tanah dan Agroklimat, 2004).

**Table 1**

Weighting and Scoring of Landslide Conditioning Factors

Parameter	Classification	Weight	Score	Source
Rainfall (mm/year)	Very Wet (>3000)	30%	5	Puslittanak, 2004. <sup>34</sup>
	Wet (2500–3000)		4	
	Moderate (2000–2500)		3	
	Dry (1500–2000)		2	
	Very Dry (<1500)		1	
Slope Gradient (%)	Very Steep (>45)	25%	5	
	Steep (25–45)		4	
	Moderately (15–25)		3	
	Gentle (8–15)		2	
	Flat (<8)		1	
LULC	Dryland Farming, Paddy Fields	10%	5	
	Shrubland		4	
	Forest / Plantation		3	
	Settlement / Built-up Area		2	
	Water Bodies		1	
Soil Type	Regosol	10%	5	
	Andosol, Podzolic		4	
	Brown Latosol		3	
	Yellowish Brown Latosol		2	
	Alluvial		1	
Lithology	Basaltic Rock (Clay Shale)	15%	5	Reichenbach et al., 2018. <sup>35</sup>
	Sedimentary Rock		4	
	Granite		3	
	Limestone		2	
	Alluvial Deposits		1	
Distance to Roads and Rivers (meters)	<100	10%	5	Ghasemian., et al, 2022. <sup>36</sup>
	100–200		4	
	200–300		3	
	300–400		2	
	>400		1	
	>400 m	1		

*Source: Adapted from Puslittanak (2004), Reichenba et al. (2009), and Ghasemian et al. (2022), with modifications by the author.*

<sup>34</sup> Puslittanak.

<sup>35</sup> Reichenbach et al., “A Review of Statistically-Based Landslide Susceptibility Models.”

<sup>36</sup> Ghasemian et al., “A Robust Deep-Learning Model for Landslide Susceptibility Mapping: A Case Study of Kurdistan Province, Iran.”

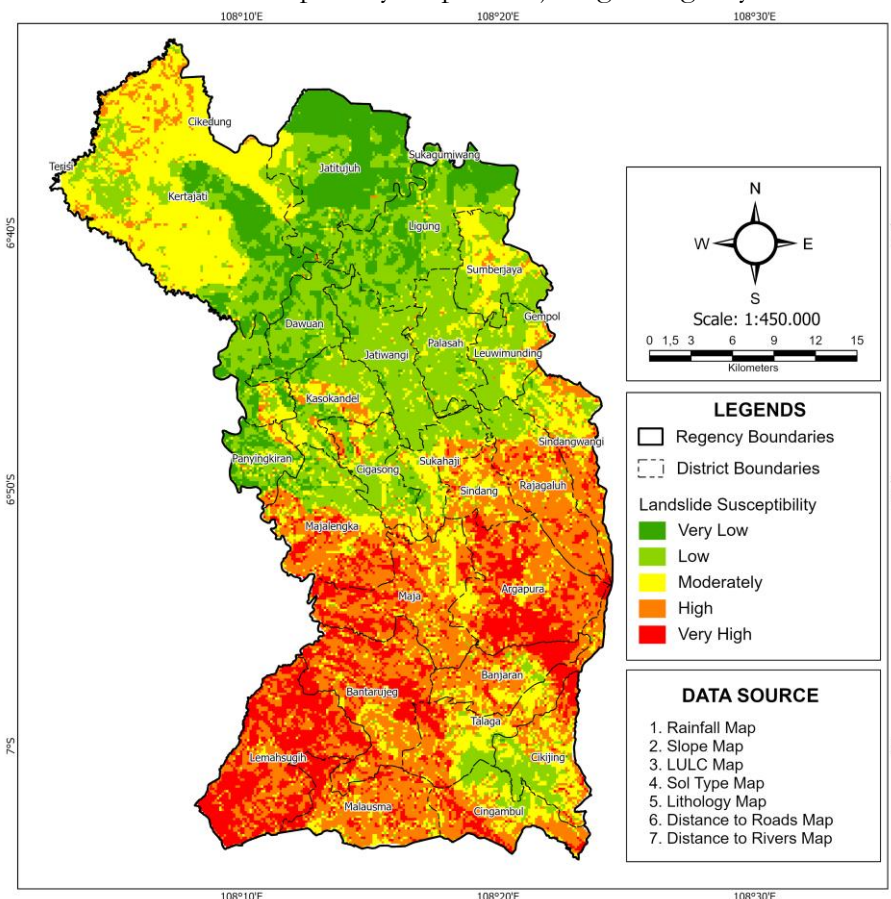
## Results and Discussion

### 1. Research Results

#### a. Spatial Distribution of Landslide Susceptibility

The weighted overlay of the seven parameters produced a landslide susceptibility map for Majalengka Regency (Figure 3). The results show a clear contrast between the northern and southern regions.

**Figure 3.**  
Landslide Susceptibility Map of Majalengka Regency



Source : Author, 2025

High to Very High susceptibility zones (orange–red) are concentrated in the southern mountainous areas, particularly in Lemahsugih, Malausma, Bantarujeg, Talaga, Maja, Cikijing, and Argapura. This pattern aligns with rainfall distribution, where higher precipitation in the southern region accelerates soil saturation on steep slopes, increasing the likelihood of landslides.<sup>37</sup>

Field observations support these results, showing that landslides occur more frequently during the wet season, particularly along the Maja–Talaga corridor and in settlements in

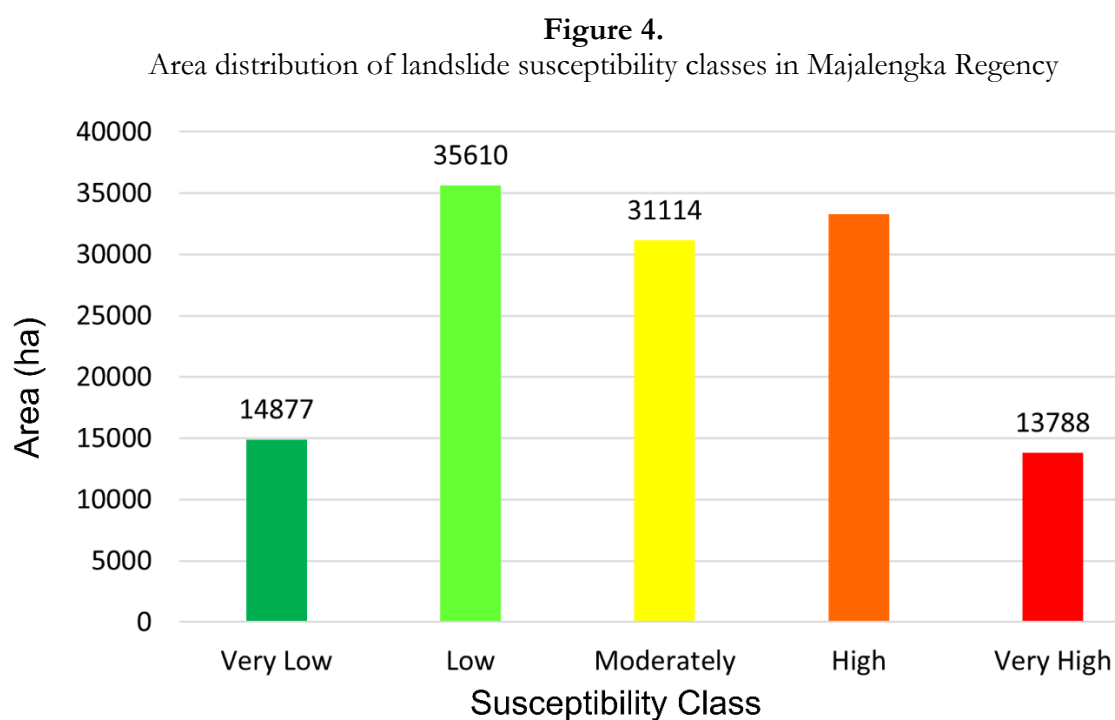
<sup>37</sup> L Agustina, A Syawreta, and A M Irawan, “Analisis Ambang Batas Hujan Untuk Pengembangan Sistem Peringatan Dini Tanah Longsor: Studi Kasus Kecamatan Pejawaran, Kabupaten Banjarnegara, Provinsi Jawa Tengah,” *Jurnal Dialog Penanggulangan Bencana* 11, no. 1 (2020): 75–81.

Lemahsugih and Malausma.<sup>38</sup> This indicates a strong influence of soil moisture conditions on slope failure.<sup>39</sup>

Human activities further increase slope instability. Road construction involving slope cutting disturbs slope equilibrium and promotes water infiltration, increasing pore-water pressure.<sup>40</sup> This is reflected in the concentration of landslides near road corridors, particularly within 100 m of the road network.<sup>41</sup> In contrast, low susceptibility zones (green) are mainly found in the northern lowlands, such as Kertajati, Jatitujuh, Ligung, and Sumberjaya. These areas are characterized by gentle slopes and lower rainfall, resulting in more stable conditions.

#### b. Area Statistics of Landslide Susceptibility

Area statistics were calculated to quantify the extent of each landslide susceptibility class in Majalengka Regency presented in Figure 4.



*Source : Author, 2025*

<sup>38</sup> BPBD, "Jumlah Kawasan Rawan Bencana Tanah Longsor Berdasarkan Kecamatan Di Kabupaten Majalengka (Data Tahun 2018–2024)."

<sup>39</sup> Binru Zhao et al., "Probabilistic Thresholds For Landslides Warning By Integrating Soil Moisture Conditions With Rainfall Thresholds," *Journal of Hydrology* 574 (2019): 134–47, <https://doi.org/10.1016/j.jhydrol.2019.04.062>.

<sup>40</sup> PVMBG, "PVMBG: Longsor Di Solok Akibat Penggalan Lereng Dan Curah Hujan Tinggi," 2024, <https://esdm.go.id/id/media-center/arsip-berita/pvmbg-longsor-di-selok-akibat-penggalan-lereng-dan-curah-hujan-tinggi>.

<sup>41</sup> Ghasemian et al., "A Robust Deep-Learning Model for Landslide Susceptibility Mapping: A Case Study of Kurdistan Province, Iran."

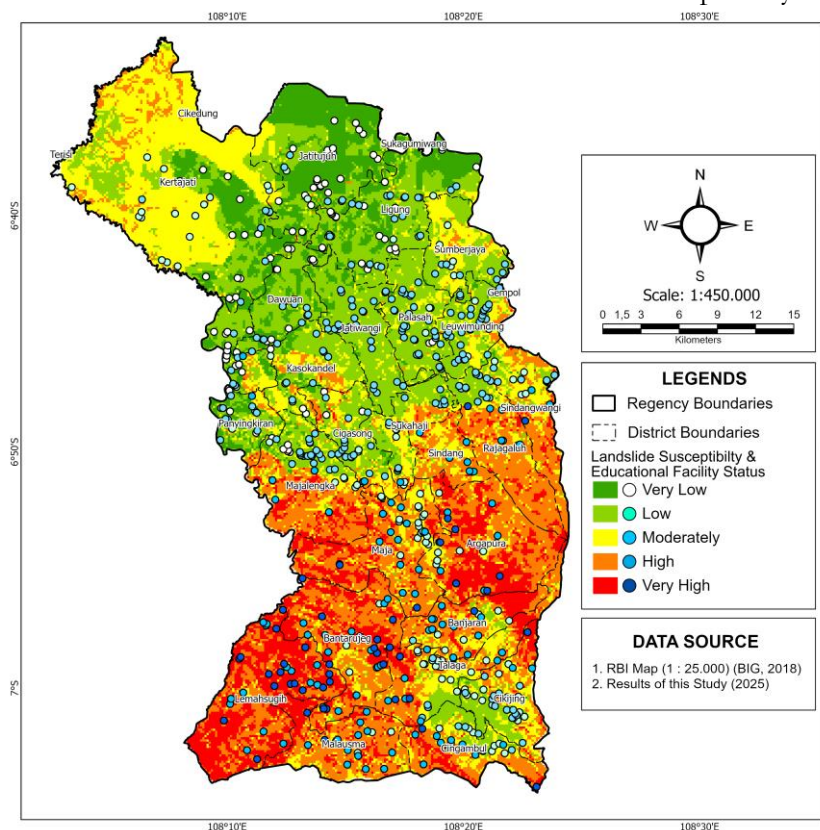
Figure 4 shows clear variation in landslide susceptibility across the study area. The Low class dominates (35,610 ha), followed by High (33,284 ha) and Moderate (31,114 ha), indicating that much of the region falls within intermediate susceptibility levels.

High and Very High classes together cover about 50,672 ha and are mainly concentrated in the southern mountainous districts, such as Argapura, Banjaran, and Lemahsugih, where steep slopes and high rainfall prevail. In contrast, the Very Low class (14,877 ha) is primarily distributed in the northern lowlands, which are characterized by gentle slopes and lower rainfall, resulting in more stable conditions.

**c. Analysis of Landslide Susceptibility on Educational Facilities**

This section evaluates the exposure of educational facilities to landslide hazards. Spatial data on 672 school locations were obtained from the Geospatial Information Agency (BIG),<sup>42</sup> and were overlaid with the landslide susceptibility map to determine their distribution across susceptibility classes presented in Figures 5.

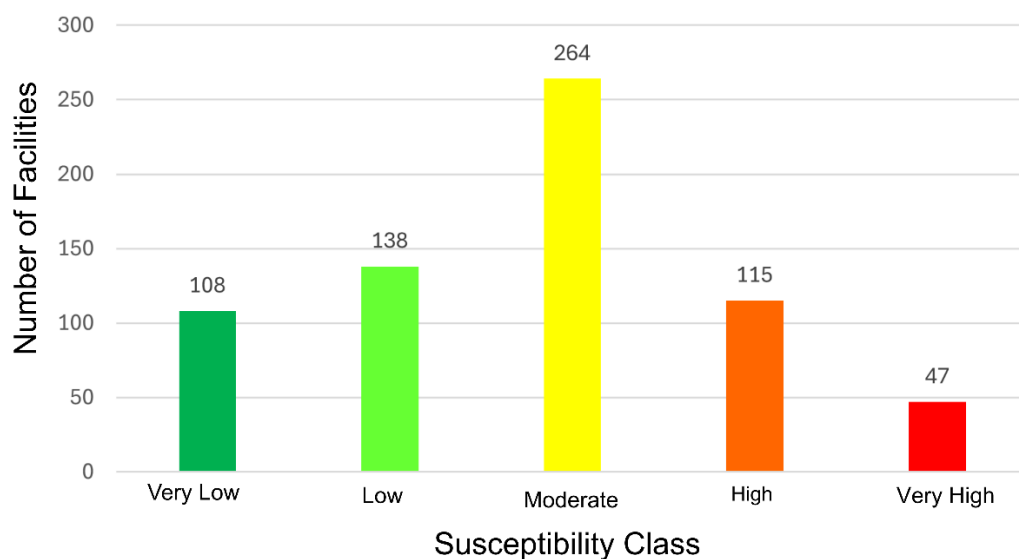
**Figure 5**  
Number of Educational Facilities Based on Landslide Susceptibility Levels



Source : Author, 2025

<sup>42</sup> Badan Informasi Geospasial, “Peta Rupa Bumi Indonesia (RBI) Skala 1:50.000 [Wilayah Kabupaten Majalengka].”

**Figure 6**  
Distribution Of Educational Facilities By Landslide Susceptibility In Majalengka Regency



Source : Author, 2025

The distribution of educational facilities across susceptibility classes is presented in Figure 6. Most schools are located in the Moderate class, while a considerable proportion (24.1%) falls within High to Very High susceptibility levels.

Spatially, these exposed schools are concentrated in the southern part of Majalengka Regency, particularly in Argapura, Banjaran, and Lemahsugih. In contrast, northern districts such as Kertajati and Ligung are generally associated with lower susceptibility levels and fewer exposed facilities.

The higher risk in the southern region is related to steep slopes and high rainfall intensity. Mountainous areas such as Argapura, with slopes exceeding 45% and high annual rainfall, are more prone to slope instability. These conditions are further intensified by human activities, including road construction and riverbank erosion, which weaken slope stability.

**Table 2**  
Distribution of educational facilities by landslide susceptibility in Majalengka Regency

Susceptibility Level	Number of Facilities	Percentage (%)
Very Low	108	16.07
Low	138	20.54
Moderate	264	39.29
High	115	17.11
Very High	47	7.00
<b>Total</b>	<b>672</b>	<b>100</b>

Source : Author, 2025

**d. Validation of Landslide Susceptibility Model**

The reliability of the generated susceptibility model was evaluated using a spatial accuracy assessment. This approach quantifies the proportion of historical landslide occurrences that spatially intersect with the highest susceptibility classes of the model.

A validation dataset comprising  $n = 6$  recent landslide events (2023–2025) was compiled from the Regional Disaster Management Agency (BPBD) reports. The spatial distribution of these validation points is presented in Table 3.

**Table 3**

Landslide occurrence points used for model validation in Majalengka Regency

No.	District	Date	Event Description	Validation
1	Bantarujeg	06 November 2025	Subsidence of a provincial road along the Bantarujeg–Sumedang corridor, disrupting vehicle access	Consistent (Very High)
2	Maja	02 February 2023	Landslide on the Maja–Talaga road slope partially covering the road surface	Consistent (High)
3	Lemahsugih	11 May 2025	Ground movement in Kalapadua Village causing structural cracks in residential buildings	Consistent (Very High)
4	Malausma	06 March 2025	Landslide along the Sukamantri route blocking road access.	Consistent (High)
5	Argapura	25 November 2024	Failure of a steep slope partially burying residential areas	Consistent (Very High)
6	Talaga	24 November 2025	Landslide debris blocking inter-village connecting roads	Consistent (High)

*Source : BPBD Kabupaten Majalengka.*

The spatial validation results show that all  $n = 6$  recorded landslide events are located within the ‘High’ and ‘Very High’ susceptibility classes, resulting in a 100% spatial agreement rate. This indicates a strong correspondence between the modeled susceptibility zones and the observed landslide occurrences.

Although the number of validation samples is limited, the use of spatial overlay accuracy is an appropriate and commonly applied validation approach for heuristic Multi-Criteria Decision Analysis (MCDA) models such as Weighted Overlay. The results suggest that the

selected parameters and weighting scheme are able to represent the general distribution of landslide-prone areas in Majalengka Regency.

## 2. Discussion

The results indicate that Majalengka Regency has a relatively high level of landslide susceptibility, with high-risk areas concentrated in the southern region. High and Very High susceptibility zones cover 33,284 ha and 17,388 ha, respectively. In addition, 24.1% of educational facilities (162 schools) are located within landslide-prone areas, including 47 schools in Very High susceptibility zones. These patterns are most evident in Argapura, Banjaran, and Lemahsugih, where steep terrain and high rainfall strongly influence landslide occurrence.<sup>43</sup>

The high susceptibility in the southern region is primarily controlled by topographic and climatic conditions. Steep slopes increase gravitational forces and slope instability,<sup>44</sup> while annual rainfall exceeding 3,000 mm enhances soil saturation and triggers mass movement. These conditions are further intensified by human activities, particularly slope cutting for settlements and road construction, which reduce slope stability.<sup>45</sup>

Similar findings have been reported in other highland regions of West Java, where slope gradient and rainfall are dominant factors controlling landslide occurrence.<sup>46</sup> Comparable patterns are observed in areas such as West Bandung and Cianjur, where land-use changes on steep slopes significantly increase landslide potential. This highlights that landslide hazards in Majalengka are primarily governed by geomorphological and site-specific conditions rather than general environmental factors.<sup>47</sup>

The findings provide a spatial basis for prioritizing landslide risk mitigation in Majalengka Regency. Overlaying landslide susceptibility with educational facility locations identifies priority areas for mitigation. In particular, the 47 schools located in Very High

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<sup>43</sup> Fausto Guzzetti et al., "The Rainfall Intensity–Duration Control of Shallow Landslides and Debris Flows: An Update," *Landslides* 5, no. 1 (2008): 3–17, <https://doi.org/10.1007/s10346-007-0112-1>.

<sup>44</sup> Lynn M Highland and Peter Bobrowsky, *The Landslide Handbook—A Guide To Understanding Landslides* (Reston, VA: U.S. Geological Survey, 2008), <https://pubs.usgs.gov/circ/1325/>.

<sup>45</sup> Masruroh et al., "A Spatial Model of Landslides with A Micro-Topography and Vegetation Approach for Sustainable Land Management in the Volcanic Area."

<sup>46</sup> Ana Mariana Ulfah Rahayu, Andri Noor Ardiansyah, and Neng Sri Nuraeni, "Wilayah Kerawanan Longsor Di Kecamatan Pamijahan Kabupaten Bogor," *Jurnal Geografi Gea* 19, no. 1 (2019): 1–8, <https://doi.org/10.17509/gea.v19i1.13862>.

<sup>47</sup> Heru Sri Naryanto et al., "Analisis Penyebab Kejadian Dan Evaluasi Bencana Tanah Longsor Di Desa Banaran, Kecamatan Pulung, Kabupaten Ponorogo, Provinsi Jawa Timur Tanggal 1 April 2017," *Jurnal Ilmu Lingkungan* 17, no. 2 (September 2019), <https://doi.org/10.14710/jil.17.2.272-282>.

susceptibility zones should be prioritized for risk reduction measures. These results can support spatial planning policies, including restrictions on development in high-risk areas.<sup>48</sup>

In terms of practical implementation, the susceptibility map can be utilized as a decision-support tool for local governments and educational authorities. Schools located within High and Very High susceptibility zones may require site-specific mitigation measures, such as slope stabilization, drainage improvement, and the development of evacuation routes. In areas where structural mitigation is not feasible, relocation planning may be considered as a long-term risk reduction strategy. These measures should be implemented based on site-specific assessments to ensure their effectiveness under local terrain conditions.

Furthermore, the integration of susceptibility maps into regional spatial planning (RTRW) can help prevent the establishment of new educational facilities in high-risk zones. The results can also support the implementation of the Disaster-Safe School Program (SPAB) by identifying priority schools for preparedness training, risk awareness programs, and emergency response planning at the local level.

This study has several limitations. The susceptibility model is static, as it is based on the Weighted Overlay method and does not incorporate temporal factors such as rainfall variability or changes in soil pore-water pressure.<sup>49</sup> In addition, parameter weights were derived from literature-based approaches. Future research could improve model robustness by applying more systematic weighting methods, such as the Analytic Hierarchy Process (AHP) with expert input,<sup>50</sup> as well as incorporating detailed geotechnical data at local scales. This limitation may affect the model's ability to capture short-term triggering mechanisms of landslides.

## Conclusions

The results reveal a clear contrast in landslide susceptibility between the northern and southern parts of Majalengka Regency. High to Very High susceptibility zones are concentrated in the southern districts, where steep slopes and high rainfall increase the likelihood of slope failure.

Educational facilities are notably exposed to landslide hazards, with 24.1% of schools located in landslide-prone areas, particularly in the southern region. This condition highlights the need for targeted mitigation measures, especially for schools situated in high-risk zones.

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<sup>48</sup> BNPB, *Rencana Nasional Penanggulangan Bencana 2020-2024* (Jakarta: Badan Nasional Penanggulangan Bencana, 2020), <https://bnpb.go.id/buku/rencana-nasional-penanggulangan-bencana-20202024>.

<sup>49</sup> Malczewski, *GIS And Multi-Criteria Decision Analysis*.

<sup>50</sup> Thomas L. Saaty, *The Analytic Hierarchy Process: Planning, Priority Setting, Resources Allocation* (New York, NY: McGraw-Hill, 1980).

Model validation indicates that recorded landslide events generally occur within areas classified as High to Very High susceptibility, suggesting that the model is able to represent the spatial pattern of landslide hazards in the study area.

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