

# Remote Sensing and GIS Approaches for Evaluating Landslide Susceptibility in Sumedang Regency

Pradnya Paramarta Raditya Rendra<sup>1</sup>, Nana Sulaksana<sup>1</sup>, Boy Yoseph Cahya Sakti Sunan Syah Alam<sup>1</sup>, Murni Sulastr<sup>2</sup>

<sup>1</sup>Applied Geology Department, Faculty of Geological Engineering, Universitas Padjadjaran, Jatinangor, Indonesia

<sup>2</sup>Polytechnic of Energy and Mining, Bandung, Indonesia

Email address: radityarendra90@yahoo.com

**Abstract**—Landslides are one of the most significant geological hazards in Indonesia, particularly in regions of high relief topography, active tectonics, and high precipitation. Sumedang Regency in West Java Province has complex geological conditions and dynamic land use, and thus it is prone to frequent landslide events. The present research examines landslide susceptibility using the combined remote sensing and Geographic Information System (GIS) method. Slope gradient, lithology, rainfall intensity, geological structure, and land use are assessed for mapping landslide susceptibility spatial zones. ASTER-DEM was used to obtain slope gradients, while Landsat 8 imagery was used for supervised land use classification to determine the spatial coverage and distribution of land use classes in the research area. Geological and rainfall data were combined using a multi-criteria overlay to produce a landslide susceptibility map. The results show that landslides are typically found to occur in steep faulted volcanics with heavy rainfall and disturbed land use. The research demonstrates remote sensing and GIS to be highly effective in regional hazard assessment and allows for more effective land-use planning and disaster risk reduction.

**Keywords**— GIS, Landslide, Land Use, Remote Sensing, Sumedang.

## I. INTRODUCTION

Landslides are the most devastating and widespread geological hazards in Indonesia, especially those areas of rugged terrain, heavy rainfall, and rapidly altering land use [1], [2]. The interaction between natural factors like steep topography, fractured volcanic rocks, and intensive seasonal rainfall and man-induced stress like deforestation and hillside construction have rendered certain areas highly vulnerable. One of them is Sumedang Regency, which is located in the geologically active West Java province [3], [4], [5].

Between 2009 and 2014, rising landslide danger here was recorded in several studies and official reports. In 2009, the Jatinunggal landslide struck residential zones, primarily triggered by inadequate drainage on weathered volcanic slopes [6]. According to [7], 17 of the 26 subdistricts in Sumedang were discovered to be situated in medium to high landslide risk zones, particularly during the wet season. In South Sumedang and North Sumedang, GIS-based research showed that more than 87% of the area was identified as having medium to high susceptibility according to slope feature, geological structure, and land use [8]. Aside from that, in 2014 a study by utilizing the Storie method ended with the conclusion that the southern part of Sumedang, e.g., Rancakalong, Situraja, and Darmaraja subdistricts, were highly to moderately susceptible to mass

movement by virtue of being covered by young volcanic deposits [9]. Overall, the existence of these findings suggests the imperative need for extensive landslide susceptibility and risk reduction planning in Sumedang Regency. They highlight the crucial importance of applying good spatial analysis software to evaluate, monitor, and mitigate landslide hazard.

Traditional ground surveys in landslide hazard areas are time-consuming and localized [10]. Remote sensing and Geographic Information Systems (GIS), on the other hand, provide affordable, large-scale analysis of physical topography, land cover processes, and geologic conditions [11], [12]. DEM-based slope analysis, satellite-based land use classification, and geological mapping can be integrated in a GIS framework to develop landslide susceptibility maps. These maps are crucial for aiding land-use planning and disaster risk management at the local government level.

The current research employs a spatial evaluation framework for application within Sumedang Regency through a case study of 2016 using ASTER-DEM data, Landsat 8 imagery, and geological and rainfall data sets. The generated landslide susceptibility map is designed to delineate various regions of risk and facilitate improved land-use planning and disaster risk management. Thorough compilation and analysis of hazard-prone areas are needed in building evidence-based mitigation strategies, ranking susceptible areas, and guiding decision-making processes in regional planning and disaster readiness [13].

## II. METHODOLOGY

Sumedang Regency occupies West Java Province, 6°44'–7°83' S and 107°21'–108°21' E. It contains 26 districts of diverse physiographic character. The southern region is dominated by steep Quaternary volcanic rock formations comprising breccias, lava flows, and tuffs [14], [15]. These attain heights over 1,000 m. Northern regions are replaced by Tertiary sedimentary land made up of sandstone, claystone, and alluvial deposits. Sumedang is further dissected by several active faults, which introduce structural instability [16]. Together with heavy rainfall and land use conversion, particularly in Sukasari, Jatigede, and South Sumedang, the area is highly susceptible to landslides. Sources of data and tools utilized in this research are:

- ASTER-DEM: utilized in constructing the slope feature.
- Landsat 8 (2016): processed using supervised classification.
- Geological maps [14], [15]

- Rainfall data (1961–1990) [17]
- GIS tools: for spatial analysis, overlay, reclassification, and map creation

The Landsat 8 image was pre-processed with atmospheric correction and false-color composites (bands 7-6-4). Maximum Likelihood Classification or the Supervised Classification algorithm was used [18], [19] to separate four land use classes:

1. Forest area
2. Agriculture and cultivated area
3. Residential, office, and industrial area
4. Paddy field and wetland

The derived land use map was cross-mapped against other thematic variables using Geographic Information Systems (GIS) in order to examine terrain in relation to landslide susceptibility. GIS was a key utility for integrating spatial data such as slope, elevation, lithology, and rainfall. Using overlay analysis and spatial interpretation, GIS allowed the determination of high-risk zones where multiple contributing factors intersect [12]. This approach provided a quantitative framework to assess slope instability across the study area, and this enhanced the precision and accuracy of the landslide susceptibility analysis.

### III. RESULTS AND DISCUSSIONS

#### A. Slope Characteristics

Very steep to steep topography (>25%) dominates southern Sumedang based on the slope map. These are very erosive and commonly proved to be associated with witnessed landslides, especially where forest cover has been removed. The steepness of the slope has a direct correlation with gravitational forces that induce slope instability.

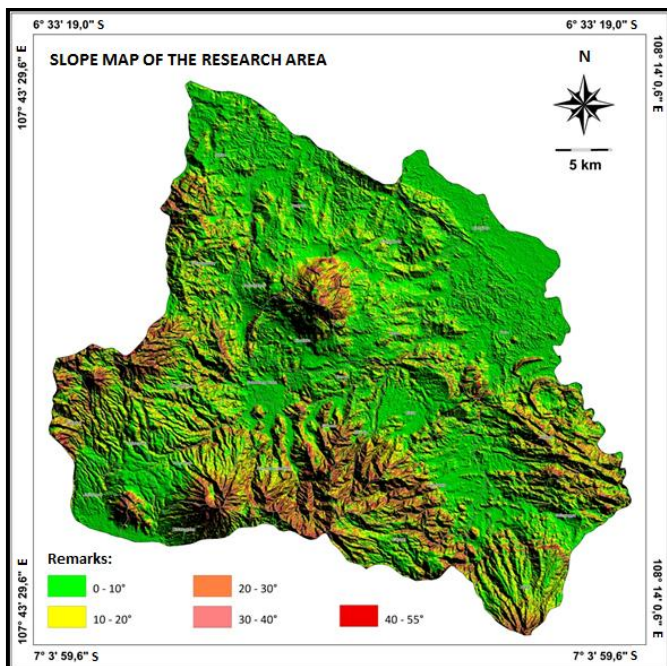


Fig. 1. Slope map of the research area.

#### B. Lithology and Geological Structure

Sumedang Regency is composed of Quaternary volcanic

and Tertiary sedimentary rocks, which exhibit different levels of stability upon being exposed to environmental conditions.

- Interbedded sandstone and claystone outcrops of the Cinambo Formation have been exposed at the cliffs along the Cinambo River in Jatigede.
- Claystone, part of the Upper Halang Formation, is also exposed in the Cijuray River cliff at Darmaraja. It is dark brown in color. Its occurrence is relatively restricted because of local vegetation cover in soil and riverbank. In this location, claystone exposure is not exposed in direct association with landslide hazard.
- Volcanic breccia is dark brown to light gray in color, composed of sub-angular to angular andesitic fragments of small to large size embedded in a sandy tuffaceous matrix. The breccia is compact and massive with weathering that is localized. Although it is compact, this breccia unit has minimal impact on mass movement in the field.
- Andesite lava, interpreted as a product of undifferentiated young volcanic activity, is exposed at the base of the rivers. The outcrop is dark grey to black and locally brecciated by deformation along the Cimuja Fault. It appears in areas of the riverbank where there is no soil cover and vegetation.
- Fine-grained tuffs, interpreted as volcanic deposits, are noticed in several road cuts in the Situraja area. The outcrops feature brown to yellowish-brown coloration and are locally topped by thick weathered units. The lithology is characterized by soft material with fine grain. The comparatively young lithology, combined with intensive weathering in certain areas, indicates high susceptibility to shallow landslides and instability of slope.
- Alluvium: Alluvium is exposed in gently sloping to flat areas and is generally not associated with landslides. It is, however, generally situated in floodplains, river terraces, and valleys and is therefore at risk of flooding. Most alluvial deposits occur in broad river valleys and consist of loose-grained particles of varying sizes that vary from clay, silt, sand, gravel, and rock fragments.

Each lithological unit plays its unique part in slope instability. Volcanic rocks, specifically breccia and tuff, are usually associated with previous landslides, particularly under the influence of human activities and heavy rainfall.

Sumedang is an active tectonic area, traversed by several fault systems, further increasing landslide susceptibility. Structural features consist of:

1. The Pakualam Fault, trending northeast–southwest, traverses a tributary of the Cimanuk River. The fault is confirmed to occur by the presence of slickensides, lithological offsets, and joints.
2. The Cimuja Fault within the Cibugel area trends approximately southwest–northeast. It exists as deduced from linear features observed in ASTER-DEM images, river lineaments, and jointed andesite lava exposures. ASTER-DEM data lineament analysis indicates that the Cimuja Fault is consistent with narrow river valleys and moderately sloping terrain.
3. The Jatigede Fault is one of the structural features, trending northwest–southeast and found near the Cimanuk River.

Linear features detected on ASTER-DEM imagery show the presence of the fault. Rectangular drainage pattern indicates the presence of the fault.

- The Cikandung Fault trends north–south in the Cikandung River. It passes through Wanajaya, Wanasari, and Mekarmukti Villages. Its presence is confirmed by linear features observed in ASTER-DEM imagery, drainage, slickensides, and joint structure.

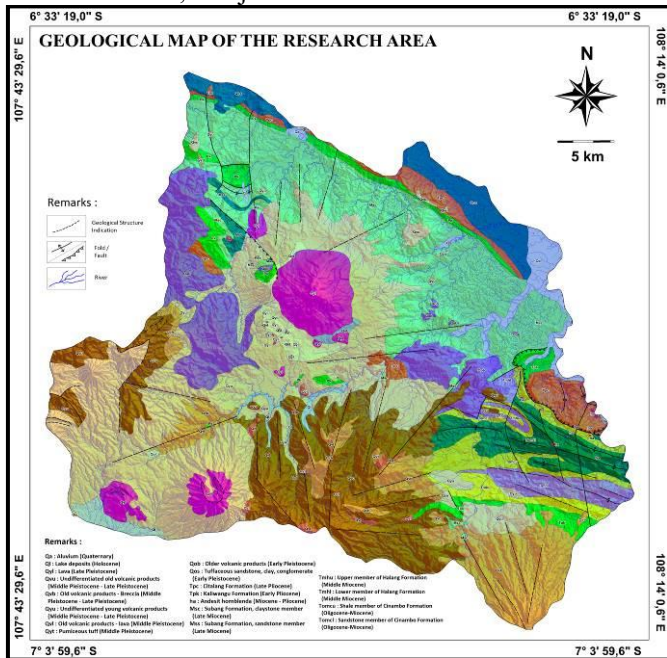


Fig. 2. Geological map of the research area (modified from [14], [15]).

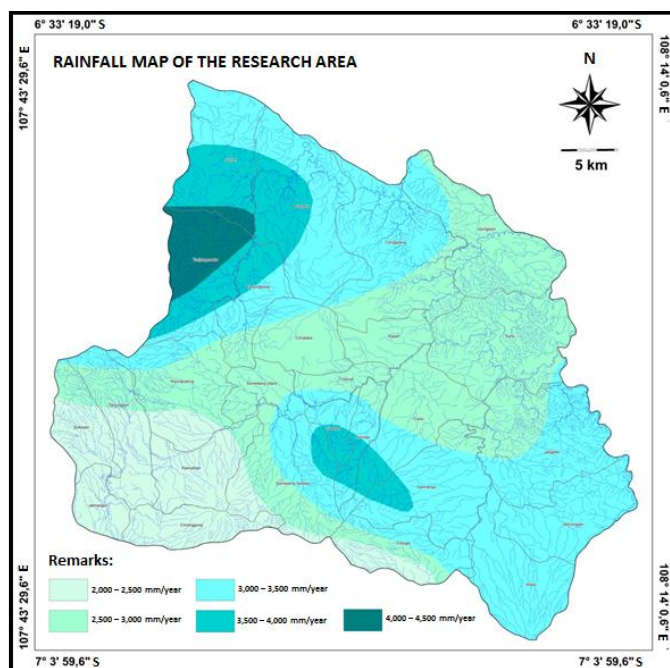


Fig. 3. Rainfall map of the research area.

### C. Rainfall

Sumedang Regency rainfall ranges from 2,000 to 4,500 mm annually. The southern highland region experiences the most rain, primarily due to topographic elevation that promotes

moisture condensation and precipitation. Maximum precipitation occurs between the months of October and April, increasing the likelihood of landslides. Prior landslide occurrence is strongly correlated in space with those areas of high precipitation. Rainfall is widely employed as a principal landslide cause, particularly in tropical regions and mountain terrain, where heavy or sustained rain has the potential to rapidly increase pore-water pressure and reduce slope stability [20].

### D. Land Use Dynamics

Land use transformation in Sumedang Regency has intensified landslide risk over the past two decades. Analysis of Landsat 8 imagery reveals several key patterns:

- Forest degradation: Once-dense upland forests, particularly in Sukasari, South Sumedang, and Jatigede, have been significantly reduced due to shifting cultivation and the increase in human settlements.

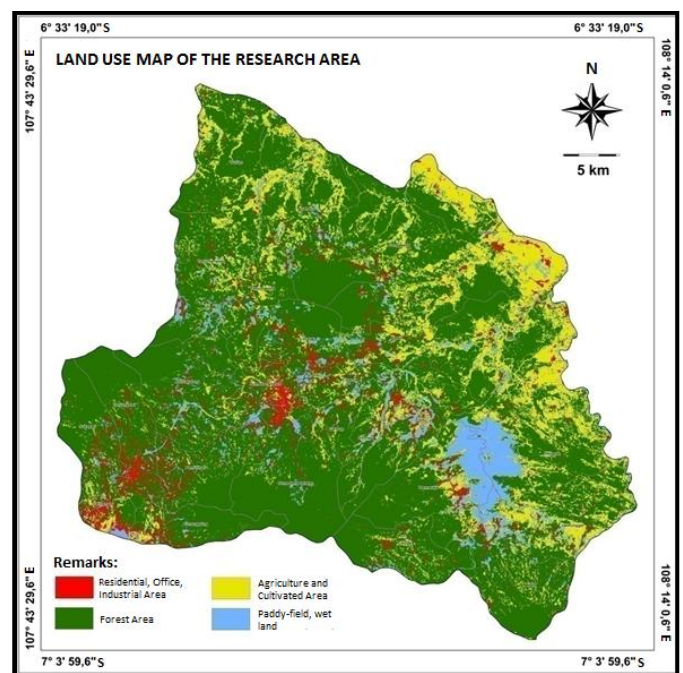


Fig. 4. Land use map of the research area [3].

- Agricultural encroachment: Farming, often conducted on steep hillsides without terracing or conservation practices.
- Urban and peri-urban growth: Housing settlements are encroaching on main roads and adjacent hillslopes, particularly in the areas of Cimanggung, Tanjungsari, and Rancakalong. In many cases, these developments lack adequate slope stabilization.
- Open and bare lands: Areas cleared for construction or abandoned after cultivation are highly sensitive to erosion and runoff concentration.

Conversion of vegetated land to agricultural or built-up land reduces the infiltration capacity and increases surface runoff, also exacerbating surface erosion [21], [22], [23], with a tendency to concentrate water at slope breaks. All this exacerbates the susceptibility to landslide.

### E. Integrated Susceptibility Mapping

The landslide susceptibility mapping within this research was conducted through a qualitative overlay method in a GIS environment. The thematic layers covering the most significant landslide-contributing elements were cross-matched and integrated visually to indicate zones of various susceptibilities.

1. Slope gradient: Higher slopes (>25%) were assigned greater weights due to gravitational force and erosion potential.
2. Lithology: Unconsolidated volcanic breccia, tuff, and pyroclastics received higher susceptibility ratings due to the physical nature.
3. Geological structure: Such as faults and lineaments, were considered as contributing factors to structural instability.
4. Rainfall: Areas with >3,000 mm/year were considered high-risk due to increased saturation and infiltration.
5. Land use: Forested areas were considered less susceptible, whereas agricultural and built-up lands were identified as high-risk due to surface disturbances and lack of ground stability.

Each factor was classified as low, moderate, and high susceptibility based on its contribution to slope instability. The superposition of the layers allowed visual identification of zones where multiple risk factors converge. The research area can be bounded into:

1. High susceptibility zone: Found in the Sukasari, Jatigede, and South Sumedang areas with steep slopes, weak volcanic rocks, high rainfall, and disturbed land cover.
2. Moderate susceptibility zone: Mid-slope terrain with mixed lithology and land use.
3. Low susceptibility zone: Northern lowlands with flat terrain and consolidated sedimentary rocks.

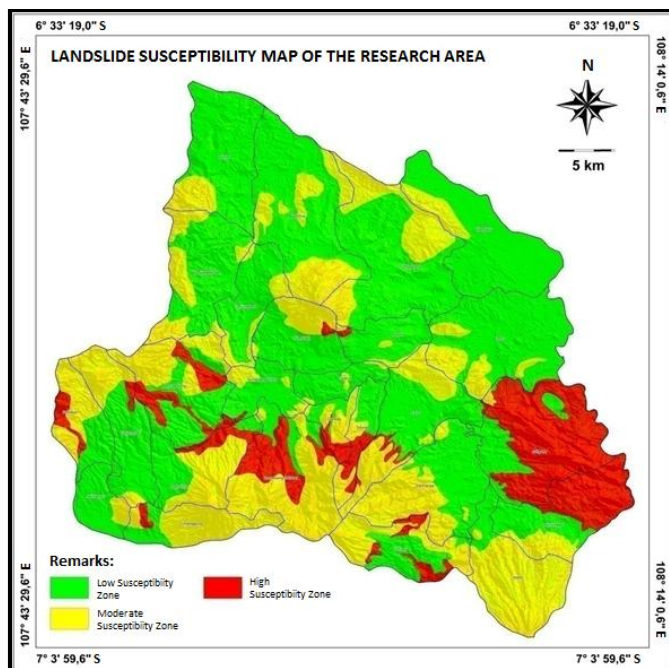


Fig. 5. Landslide susceptibility map of the research area.

This overlay technique of spaces facilitates an applied understanding of landslide hazard zones and provides a scientific basis for land use planning, infrastructure

construction, and community-based disaster risk reduction. Although qualitative, the technique is suitable for regions like Sumedang, where various natural and human aspects must be interpreted together.

### IV. CONCLUSION

This research demonstrates that landslide susceptibility in Sumedang Regency is influenced by steep topography, unconsolidated rocks, active geological structures and fault zones, high rainfall, and anthropogenic land disturbance. Use of remote sensing (ASTER-DEM, Landsat 8) and GIS overlay techniques is an affordable and scalable technique for hazard mapping where limited instrumentation is available. The final susceptibility map is a valuable asset for regional land use planning, infrastructure planning, disaster risk reduction policy, and community preparedness and awareness.

### ACKNOWLEDGMENT

The author extends sincere gratitude to the Faculty of Geological Engineering, Universitas Padjadjaran, and all supporting colleagues for their contributions during research and fieldwork.

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