



**Bulletin of Scientific Contribution  
GEOLOGY**

**Fakultas Teknik Geologi  
UNIVERSITAS PADJADJARAN**

homepage: <http://jurnal.unpad.ac.id/bsc>  
p-ISSN: 1693-4873; e-ISSN: 2541-514X



Volume 24, No.1  
April 2026

**LANDSLIDE VULNERABILITY ZONE USING ANALYTICAL HIERARCHY PROCESS (AHP) METHOD IN BANYURESMI VILLAGE, SUKASARI DISTRICT, SUMEDANG, WEST JAVA**

**Muhammad Ibrahim Ryonaldo Rizqi<sup>1\*</sup>, Teuku Yan Waliana Muda Iskandarsyah<sup>1</sup>, Muhammad Nabel Nahensa Athallah<sup>1</sup>, Raditya Ahmad Renardi<sup>1</sup>, Reza Mohammad Ganjar Gani<sup>2</sup>**

<sup>1,2</sup>Faculty of Geological Engineering, Padjadjaran University, Sumedang, West Java, Indonesia

\*Corresponding author: [muhammad22496@mail.unpad.ac.id](mailto:muhammad22496@mail.unpad.ac.id)

**ABSTRACT**

Landslides are a common natural disaster in Indonesia, especially in Banyuresmi Village, Sukasari District, Sumedang Regency, which is a research area covering 9.58 km<sup>2</sup>. This study aims to identify landslide vulnerability zones using the Analytical Hierarchy Process (AHP) method. This method is used in decision making by compiling a process hierarchy structure, a pairwise comparison matrix, class and subclass weighting analysis, and a consistency ratio (CR) test. The method was applied to evaluate and spatially overlay the controlling factors of landslide vulnerability, namely slope gradient, lithology, aspect (slope direction), land cover, and distance from streams. The results showed that the study area was predominantly classified as having moderate to high vulnerability, with the high vulnerability zone covering 60.94% of the area, the moderate vulnerability zone covering 38.38%, and the low vulnerability zone covering only 0.68%. Slope gradient was identified as the dominant factor, followed by lithology and aspect. Field validation confirmed a strong spatial correlation between the mapped high-risk zones and the actual locations of reported landslides, demonstrating the reliability of the method through field validation. Overall, this study provides a scientific basis and recommendations for land use planning, minimizing the risk of landslides, and mitigation strategies, especially in residential areas in Banyuresmi Village.

**Keywords:** Analytical Hierarchy Process, Banyuresmi, Landslide, Sumedang, Slope

**ABSTRAK**

Tanah longsor adalah bencana alam yang umum terjadi di Indonesia, terutama di Desa Banyuresmi, Kecamatan Sukasari, Kabupaten Sumedang, yang merupakan wilayah penelitian seluas 9.58 km<sup>2</sup>. Studi ini bertujuan untuk mengidentifikasi zona kerentanan longsor menggunakan metode Analytical Hierarchy Process (AHP). Metode ini digunakan dalam pengambilan keputusan dengan menyusun struktur hierarki proses, matriks perbandingan berpasangan, analisis pembobotan kelas dan subkelas, serta uji rasio konsistensi (CR). Ini diterapkan untuk mengevaluasi dan tumpang tindih faktor-faktor yang mengontrol kerentanan longsor, yaitu kemiringan lereng, litologi, aspek (arah lereng), tutupan lahan, dan jarak dari sungai. Hasil penelitian menunjukkan bahwa wilayah studi didominasi oleh tingkat kerentanan sedang hingga tinggi, dengan zona kerentanan tinggi mencakup 60.94% wilayah, zona kerentanan sedang mencakup 38.38%, dan zona kerentanan rendah hanya mencakup 0.68%. Gradien lereng diidentifikasi sebagai faktor dominan, diikuti oleh litologi dan aspek. Validasi lapangan mengonfirmasi korelasi spasial yang kuat antara zona berisiko tinggi yang dipetakan dan lokasi sebenarnya dari laporan tanah longsor, menunjukkan efektivitas metode tersebut, yang divalidasi secara langsung oleh bukti lapangan. Secara keseluruhan, penelitian ini memberikan dasar ilmiah dan rekomendasi untuk perencanaan penggunaan lahan, meminimalkan risiko tanah longsor, dan strategi mitigasi, terutama di kawasan permukiman di Desa Banyuresmi.

**Kata Kunci :** *Analytical Hierarchy Process*, Banyuresmi, Tanah Longsor, Sumedang, Lereng

**INTRODUCTION**

Based on Fauzielly (2018), landslides are among the most common disasters in Indonesia, especially during the rainy season. According to national disaster data, there

were 2,862 disasters in Indonesia, predominantly landslides, tornadoes, and floods, accounting for 89.9% of all disasters (BNPB, 2017). The data shows that landslides

in West Java accounted for 29.7% of all disasters.

In 2020, Badan Pusat Statistik recorded a landslide in Sukasari District, Sumedang Regency, West Java. The results show the villages that experienced landslides in 2020, one of which was Banyuresmi Village (Table 1).

Field reports from the Banyuresmi Village Office indicated three landslide events in January 2025. On January 26, 2025, landslides occurred at two sites at 06°52'19"S, 107°46'24" E and 06°52'19" S, 107°46'27" E. Then on January 29, 2025, a landslide occurred at 06°52'13" S, 107°46'25" E.

Aruan (2024) discussed ground movement through an evaluation of the physical properties of rocks in Nanggerang Village, Sukasari District. This ground movement was influenced by intensive weathering, the presence of clay minerals, and high rainfall. Previous research conducted in nearby Nanggerang Village provides a relevant geological context and forms a scientific basis for this study.

Table 1. Data on Villages Affected by Landslides in Sukasari District (BPS, 2020)

Villages	Frequency of Landslide
Banyuresmi	7
Sukasari	5
Genteng	2
Nanggerang	1
Sukarapih	0
Mekarsari	0
Sindangsari	0

According to the data described above and previous research, further research is needed to discuss the identification of Landslide Vulnerability Zones in Banyuresmi Village. This aims to map areas prone to landslides and provide recommendations to minimize the impact of landslides on the local community.

**RESEARCH METHOD**

This study focuses on Banyuresmi Village. Administratively, Banyuresmi Village is part of Sukasari District, Sumedang Regency, West Java Province, with an area of approximately 9.58 km<sup>2</sup> (Figure 1).

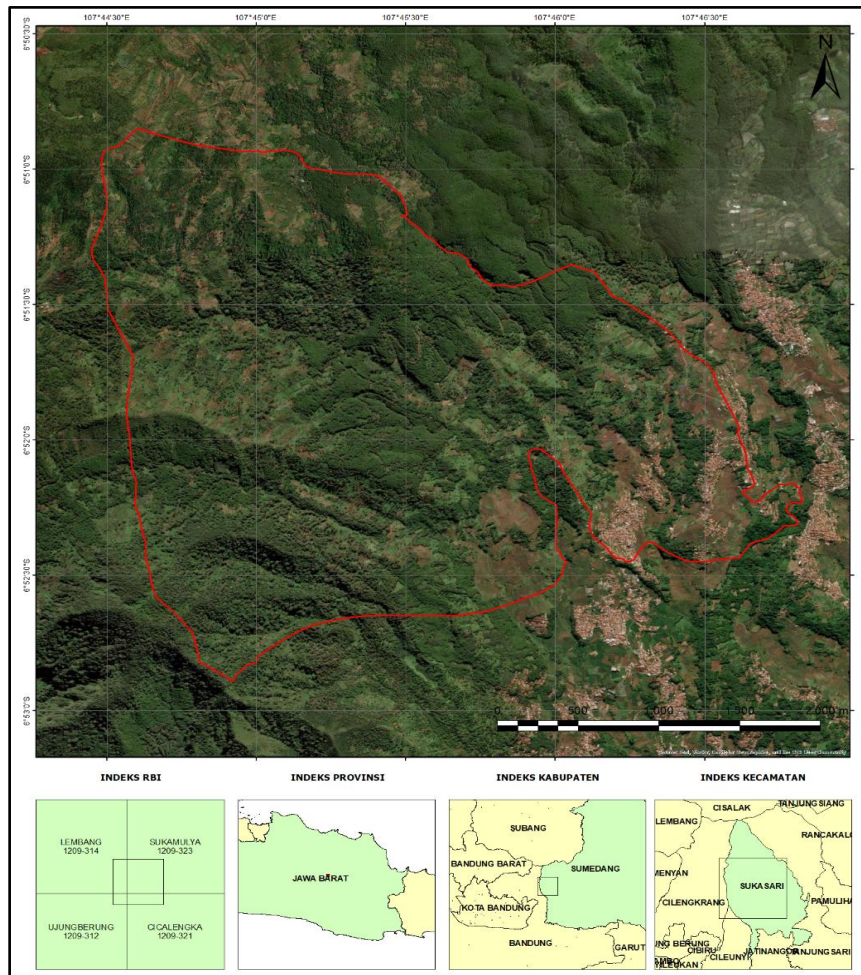
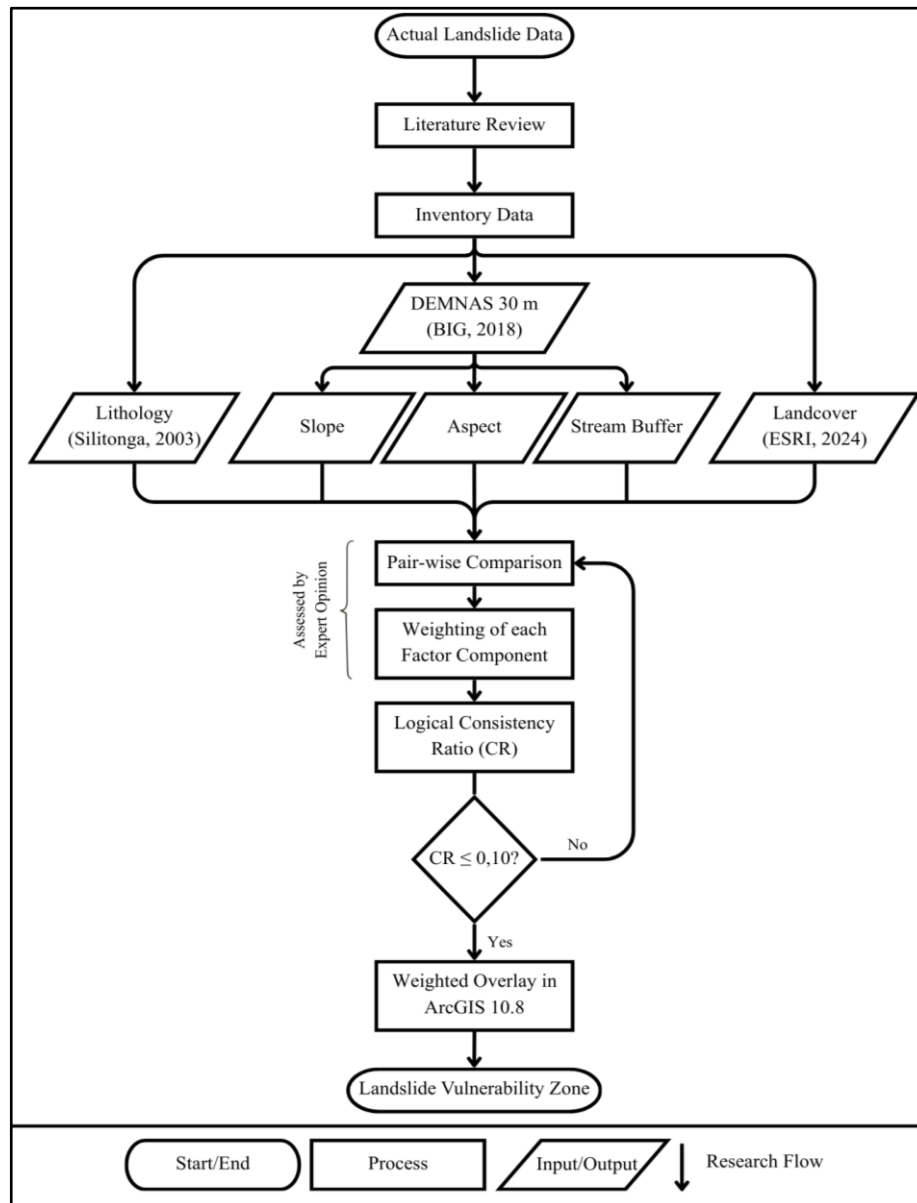


Figure 1. Research Location Map

The process of identifying landslide-prone zones involves several steps, including a literature review, data inventory, weighted analysis incorporating expert opinions, consistency ratio (CR) testing, and overlay analysis in ArcGIS 10.8. These steps are clearly illustrated in the research flowchart below (Figure 2).



Gambar 2. Research Flowchart

### GIS-based Mapping

The parameters analyzed in this study include lithology, land cover, distance from streams, slope aspect, and slope gradient. The data used include the 1:100,000 scale Bandung Geological Map (Silitonga, 1973), Sentinel-2 10 m Land Use/Land Cover (ESRI, 2024), and DEMNAS\_1209 with a resolution of 30 m (Badan Informasi Geospasial, 2018). The method used in this study was the Analytical Hierarchy Process (AHP) with data and research processes as presented in the research flowchart.

In a similar study, Faizana (2015) explains that GIS-based mapping is carried out by compiling and integrating various types of data. In this context, the data mentioned above are organized into a systematic framework based on their functions, classifications, and applications, along with their respective weights. This parameter analysis then serves as the foundation for the Analytical Hierarchy Process (AHP) method.

### Analytical Hierarchy Process (AHP)

According to Saaty (2008), the Analytical Hierarchy Process (AHP) is a decision-making

method through pairwise comparison calculations and weighting or priority scales based on expert opinion. The basic principles in the AHP method include problem decomposition, pairwise comparison matrix, priority determination, and consistency test (Saaty, 1980, cited in Isneni, 2020). Problem decomposition is visualized in the form of a systematically arranged structure to achieve goals rationally (Figure 3). The pairwise comparison matrix is obtained by normalizing the matrix (Equation 1) (Table 2), calculating the Eigen Factor (Equation 2), and testing the consistency ratio (Equation 3) (Saaty & Vargas, 2012; Nurjaman, 2023).

Table 2. Comparison Matrix

Alternative / Criteria	1	2	3	n
1	1	C12	C13	C1n
2	C21	1	C23	C2n
3	C31	C32	1	C3n
n	Cn1	Cn2	Cn3	1

$$C_{ij} = \sum_{i=1}^n C_{ij} \quad \dots (1)$$

$$X_{ij} = \frac{C_{ij}}{\sum_{i=1}^n C_{ij}} ; \quad \dots (2)$$

$$W_{ij} = \frac{\sum_{j=1}^n X_{ij}}{n} \quad \dots (3)$$

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{1n} \\ C_{21} & C_{22} & C_{23} & C_{2n} \\ C_{31} & C_{32} & C_{33} & C_{3n} \\ C_{41} & C_{42} & C_{43} & C_{4n} \end{bmatrix} \begin{bmatrix} X_{11} & X_{12} & X_{13} & X_{1n} \\ X_{21} & X_{22} & X_{23} & X_{2n} \\ X_{31} & X_{32} & X_{33} & X_{3n} \\ X_{41} & X_{42} & X_{43} & X_{4n} \end{bmatrix} \begin{bmatrix} W_{31} \\ W_{41} \\ W_{41} \end{bmatrix} \begin{bmatrix} C_{v1} \\ C_{v1} \\ C_{v1} \\ C_{v1} \end{bmatrix} \quad \dots (4)$$

$$\lambda = \left( \frac{C_{v1}}{W_{11}} ; \frac{C_{v2}}{W_{12}} ; \dots \frac{C_{vn}}{W_n} \right) \quad \dots (5)$$

$$\lambda_{max} = \lambda \quad \dots (6)$$

$$CI = \left( \frac{\lambda_{max} - n}{n - 1} \right) \quad \dots (7)$$

$$IR = \left( \frac{1.98(n-2)}{n} \right) \quad \dots (8)$$

$$CR = \left( \frac{CI}{IR} \right) \quad \dots (9)$$

Where:  
 CI = Consistency Index  
 IR = Index Random Consistency  
 CR = Consistency Ratio

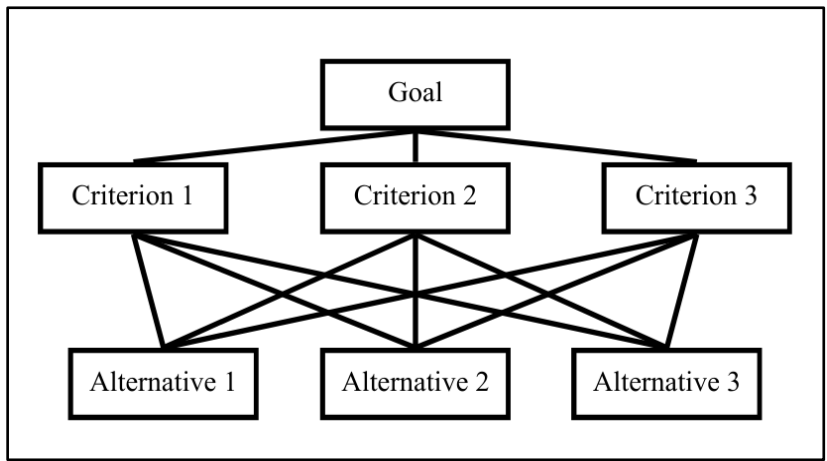


Figure 3. Process Hierarchy Structure (Saaty & Vargas, 2012)

**RESULT & DISCUSSION**

The slope gradient in the study area is divided into six types, namely flat slopes (0-2%), very gentle slopes (2-7%), gentle slopes (7-15%), moderately steep slopes (15-30%), steep slopes (30-70%), and very steep slopes (70-140%) (Van Zuidam, 1985). Flat slopes account for 0.1% of the area, very gentle slopes 1.25%, gentle slopes 6.97%, moderately steep slopes 31.63%, steep slopes 56.41%, and very steep slopes 3.64% (Figure 4a). Slope aspect or slope direction affects slope stability, which plays a role in vegetation growth, rainfall patterns, and discontinuity orientation (Bobrowsky, 2008; Pourghasemi et al., 2013; Devkota et al., 2011; cited in Paudyal et al., 2021). Slope aspect is divided into several orientations, namely North (0 - 22.5°), Northeast (22.5 - 67.5°), East (67.5

- 112.5°), Southeast (112.5 - 157.5°), South (157.5 - 202.5°), Southwest (202.5 - 247.5°), West (247.5 - 292.5°), Northwest (292.5 - 337.5°), and North (337.5 - 360°). In the research area, the dominant aspect was in the NE - S direction with a total percentage of 78.06% (Figure 4b). Based on geological factors identified by Silitonga (1973), the study area has two rock units, namely undecomposed old volcanic rock (Qvu) and undecomposed young volcanic rock (Qyu). Qvu is located in the northern to central parts of the study area, covering an area of approximately 3.94 km<sup>2</sup>, while Qyu dominates the southern part of the study area from west to east, covering an area of approximately 5.64 km<sup>2</sup> (Figure 4c). According to Mersha & Meten (2020), water flow in the study area plays a role in increasing the degree of saturation of

materials or lithology, thereby reducing friction. Water flow in rivers was identified at 100 m intervals, resulting in five categories and their percentages, starting from 100 m (64.05%), 200 m (27.88%), 300 m (6.97%), 400 m (1.00%), and 500 m (0.10%) (Figure 4d).

Changes in land cover can cause open, degraded, critical, and eroded land, among others (Salim, 2019). Based on the analysis of land cover results in 2021 (ESRI, 2024), the study area was divided into four categories, namely Forest (73.44%),

Cropland (13.07%), Built-up (3.85%), and Grassland (9.64%) (Figure 4e).

Paudyal (2021) in his study discussing landslide zoning, as in this study, used five elements that are factors in the occurrence of ground movement, namely slope, aspect, lithology, distance from stream, and land cover. These five elements and sub-elements ultimately became criteria and sub-criteria in the hierarchical structure of the process to produce ground movement vulnerability zoning (Figure 5).

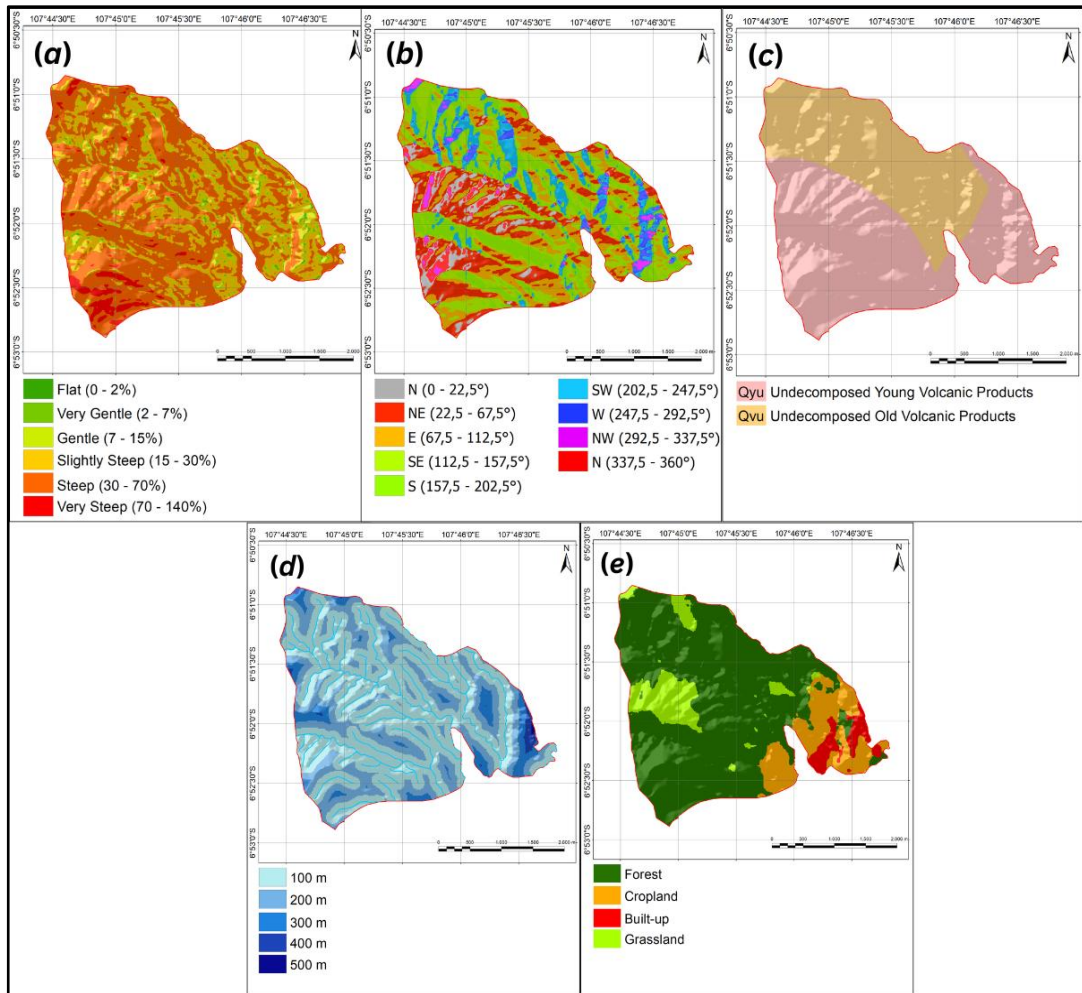


Figure 4. (a) Slope Map; (b) Aspect Map; (c) Lithology Map; (d) Distance from Stream Map; (e) Landcover Map

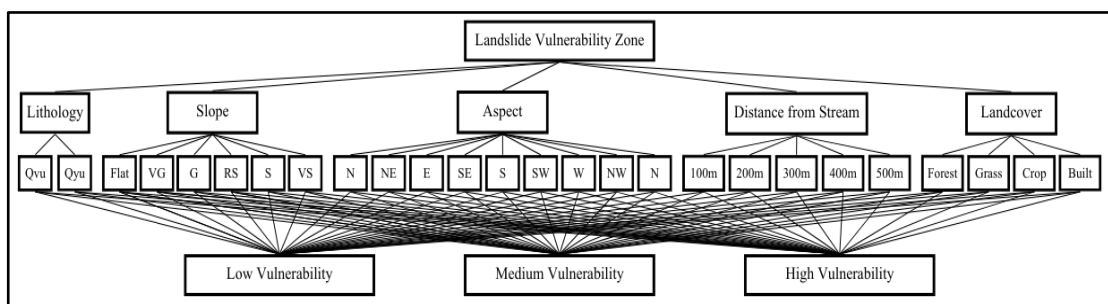


Figure 5. Process Hierarchy Structure of Banyuresmi Village's Landslide Vulnerability Zone

**Weightage Analysis with AHP Method**

The landslide threat criteria classes and subclasses are weighted using a pairwise comparison matrix (Paudyal et al., 2021). This pairwise comparison matrix uses a scale of 1-5, with class values (slope, aspect, lithology, distance from streams, and land cover) determined based on expert opinion (Saaty, 2008), as presented in Table 3. To obtain the weights, it is necessary to normalize the matrix using equations (1), (2), and (3).

The result shows that the factor weight of slope acts as the dominant factor with a

percentage weight of 4.65%. The weights of other factors show the following results: lithology 26.19%, aspect 16.08%, landcover 9.85%, and distance from stream 6.23% (Table 4).

Then, qualitative weighting is performed to assess the subclasses on a scale of 1-5, with 5 indicating the highest priority or weight of the subclass. These weightings are also determined based on expert opinion consultation (Paudyal et al., 2021) (Table 4).

Table 3. Weightage of class's landslide factors using pairwise comparisons.

Factors	Slope	Geology	Aspect	Landcover	Distance from Stream
Slope	1	2	3	4	5
Geology	0.5	1	2	3	4
Aspect	0.33	0.5	1	2	3
Landcover	0.25	0.33	0.5	1	2
Distance from Stream	0.2	0.25	0.33	0.5	1
<b>Total</b>	<b>2.28</b>	<b>4.08</b>	<b>6.83</b>	<b>10.5</b>	<b>15.00</b>

Table 4. Matrix Normalization of Landslide Factor Class based on Table 3.

Factors	Slope	Geology	Aspect	Landcover	Dist. Stream	Weight Avg.
Slope	0.4386	0.4902	0.4392	0.3810	0.3333	0.4165
Geology	0.2193	0.2451	0.2928	0.2857	0.2667	0.2619
Aspect	0.1447	0.1225	0.1464	0.1905	0.2000	0.1608
Landcover	0.1096	0.0809	0.0732	0.0952	0.1333	0.0985
Distance from Stream	0.0877	0.0613	0.0483	0.0476	0.0667	0.0623
<b>Total</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>	<b>1.000</b>

Table 5. Weightage of each sub-class's landslide factor using expert opinion.

Class	Sub-class	Weight
<b>Slope (percentage)</b>	0 - 2	1
	2 - 7	1
	7 - 15	2
	15 - 30	3
	30 - 70	4
	70 - 140	5
	<b>Geology</b>	Qyu
Qvu		4
<b>Aspect (degree)</b>	N	1
	NE	2
	E	3
	SE	4
	S	4
	SW	3
	W	2
	NW	1
<b>Landcover</b>	N	1
	Forest	1
	Grassland	1
	Cropland	4
<b>Distance from Stream (m)</b>	Built-up	5
	0 - 100	4
	100 - 200	4
	200 - 300	2
	300 - 400	2
400 - 500	1	

**Logical Consistency Ratio (CR)**

The weights obtained previously were then validated through Consistency Ratio (CR) calculations before all results were visualized using spatial analysis (Sari, 2025). Several equations (Eq. 4 - 9) were also described earlier to produce CR values, which are used to validate the pairwise comparison matrix in Table 4.

The calculation of the maximum eigenvalue (Eq. 4 - 6) resulted in  $\lambda_{max}=5.0853$ , and the Consistency Index (CI) (Eq. 7) was also obtained, which is  $CI=0.0213$ . Before calculating CR, the Random Index (IR) (Eq. 8) must also be calculated, which is  $IR=1.12$ , so that the CR value of the AHP method in this study has a value of  $CR=0.019$  (Eq. 9). Since  $CR < 0.1$ , the pairwise comparison matrix is considered consistent and acceptable.

**Landslide Vulnerability Zone**

Zonation was carried out using spatial analysis with the weighted overlay method. The weights obtained and validated in the previous AHP method were finally used in the visualization stage, which combined the five maps above, namely the slope map, lithology

map, aspect map, land cover map, and distance from stream map, to produce the Landslide Vulnerability Zone Map (Figure 6). The results show that Banyuresmi Village has three (3) levels of landslide vulnerability, including low vulnerability in green (0 - 33.33%), moderate vulnerability in yellow (33.33 - 66.67%), and high vulnerability in red (66.67 - 100%). The low vulnerability zone occupies a minor area of the study area, covering only 0.072  $km^2$  or 0.68%. The moderate vulnerability zone occupies an area of 3.67  $km^2$  or 38.38%. The high vulnerability zone dominates the study area, covering 5.838  $km^2$  or 60.94%.

Banyuresmi Village is declared as an area with a moderate to high vulnerability level, especially in the built-up area, precisely in the southeastern part. These residential areas spatially correspond to documented landslide occurrences, as mentioned in the previous introduction. Through validation or direct visits to the actual location (Figure 7 (a), (b), (c)) and its suitability with the landslide vulnerability level, this certainly strengthens the validity of the map results and the methods used.

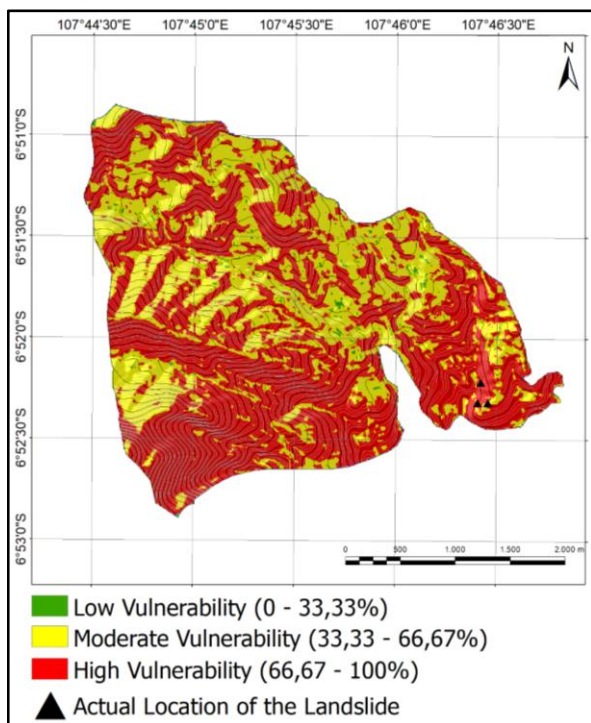


Figure 6. Landslide Vulnerability Zone Map in Banyuresmi Village

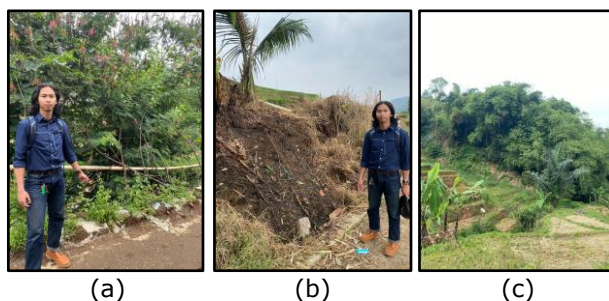


Figure 7. Actual Location of Landslides at (a) 06°52'19\"S, 107°46'24\" E; (b) 06°52'19\" S, 107°46'27\" E; (c) 06°52'13\" S, 107°46'25\" E.

## CONCLUSION

This study successfully identified and mapped landslide vulnerability zones in Banyuresmi Village, Sukasari District, Sumedang Regency, using the Analytical Hierarchy Process (AHP) method integrated with spatial analysis. The results of the study show that Banyuresmi Village is dominated by high landslide vulnerability zones with a percentage of 60.94%, followed by moderate vulnerability zones of 38.38%, and low vulnerability zones of 0.68%. Slope gradient is the most influential parameter affecting landslide potential, with a weight of 41.65%, followed by lithology, slope aspect, land cover, and distance from stream.

The study successfully determined landslide vulnerability levels and generated a zoning map using the AHP method, which showed a high level of logical consistency (CR = 0.019). Field validation confirmed that high-vulnerability zones align with actual landslide locations, thereby strengthening the reliability of both the method and the resulting map.

This study contributes to GIS-based, multi-criteria landslide vulnerability assessment at the village scale and can support spatial planning as well as structural and non-structural mitigation efforts. For further development, it is recommended to include additional parameters such as rainfall, geological structure, and soil properties, along with higher-resolution data to improve accuracy. The resulting zoning map is expected to serve as a practical reference for local governments and communities in reducing landslide risk in Banyuresmi Village.

## ACKNOWLEDGEMENT

Gratitude is extended to the Faculty of Geological Engineering, Universitas Padjadjaran, for academic support and facilities. Appreciation is also given to the Author's Parents, Reezi Renaldo and Yuliana, for continuous support and encouragement.

## REFERENCES

Aruan, I.H., Yuniardi, Y., Khoirullah, N. and Sophian, R.I., 2024. Analysis of landslide causes in Nanggerang Village, Sukasari Sub District, Sumedang Regency through identification of landslide slope material characteristics. *Journal of Geological Sciences and Applied Geology*, 8(1).

Badan Informasi Geospasial, 2018. DEM Nasional (DEMNAS) resolusi 0.27 arc-second (~30 m). Badan Informasi Geospasial, Cibinong. Available at: <https://tanahair.indonesia.go.id/portal-web/unduh/demnas> (Accessed: 23 January 2026).

Badan Nasional Penanggulangan Bencana (BNPB), 2018. Data Bencana Indonesia 2017. Pusat Data, Informasi dan Humas BNPB, Jakarta. ISBN 978-602-5693-04-5.

Badan Pusat Statistik Kabupaten Sumedang, 2020. Banyaknya Kejadian Bencana Alam Menurut Desa dan Kelurahan dan Jenis Bencana Alam di Kecamatan Sukasari, Tahun 2020. Badan Pusat Statistik Kabupaten Sumedang, Jawa Barat. Available at: <https://sumedangkab.bps.go.id/id/statistis-table/1/NDA5IzE=-/banyaknya-kejadian-bencana-alam-menurut-desadan-kelurahan-dan-jenis-bencana-alam-di-kecamatan-sukasari-tahun-2020.html> (Accessed: 23 January 2026).

ESRI. 2024. Sentinel-2 Land Cover Explorer. Available at: <https://livingatlas.arcgis.com/landcoverexplorer/> (Accessed: 23 January 2026).

Faizana, F., Nugraha, A. L., & Yuwono, B. D. (2015). Pemetaan risiko bencana tanah longsor Kota Semarang. *Jurnal Geodesi Undip*, 4(1), 223-234.

Fauzielly, L., 2018. Sosialisasi mitigasi bencana longsor di daerah Hambalang, Kecamatan Citereup, Kabupaten Bogor. *Dharmakarya: Jurnal Aplikasi Ipteks Untuk Masyarakat*, 7(1), pp.11-13.

Isneni, A.N., Putranto, T.T. and Trisnawati, D., 2020. Analisis sebaran daerah rawan longsor menggunakan remote sensing dan Analytical Hierarchy Process (AHP) di Kabupaten Magelang Provinsi Jawa Tengah. *Jurnal Geosains dan Teknologi*, 3(3), pp.149-160.

Mersha, T. and Meten, M., 2020. GIS-based landslide susceptibility mapping and assessment using bivariate statistical methods in Simada area, northwestern Ethiopia. *Geoenvironmental disasters*, 7(1), p.20.

Nurjaman, I. and Listyantoko, R.A., 2023. Analytic hierarchy process for determination of decision making in the selection of contractors. *Jurnal Industry Xplore*, 8(1).

Paudyal, K.R., Devkota, K.C., Parajuli, B.P., Shakya, P. and Baskota, P., 2021. Landslide susceptibility assessment using open-source data in the far western Nepal himalaya: Case studies from selected local level units. *Journal of Institute of Science and Technology*, 26(2), pp.31-42.

Saaty, T.L., 2008. Decision making with the analytic hierarchy process. *International Journal of Services Sciences*, 1(1), pp.83-98.

Saaty, T.L. and Vargas, L.G., 2012. The seven pillars of the analytic hierarchy process. In *Models, methods, concepts & applications*

- of the analytic hierarchy process (pp. 23-40). Boston, MA: Springer US.
- Salim, A.G., Dharmawan, I.W.S. and Narendra, B.H., 2019. Pengaruh luas tutupan lahan hutan terhadap karakteristik hidrologi DAS Citarum Hulu. *Jurnal ilmu lingkungan*, 17(2), pp.333-340.
- Sari, M.I., Bachri, S., Utaya, S., Suharto, Y. and Masruroh, H., 2025. Analisis Spasial Kerawanan Longsor Dengan Metode AHP dan SIG Kajian Mitigasi Bencana di Mojo, Kabupaten Kediri. *Ganaya: Jurnal Ilmu Sosial dan Humaniora*, 8(3), pp.11-24.
- Silitonga, P.H., 1973. Peta Geologi Lembar Bandung, Djawa. Direktorat Geologi.
- Zuidam, R.V., 1985. Aerial photo-interpretation in terrain analysis and geomorphologic mapping. ITC, Smits Publ., Enschede, The Hague.

