GIS-Based Landslide Susceptibility Mapping Using Overlay and Scoring Techniques Along the Nanggulan–Kalibawang Road, Kulon Progo

Rina Eryuliana[1], Rahman Afrinaldi[2]
[1]Geography Teacher, SMA PGRI 2 Padang, West Sumatra, Indonesia
[2]Geography Education Study Program, Faculty of Teacher Training and Education, PGRI University of West Sumatra (UPGRISBA), West Sumatra, Indonesia

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ABSTRACT

Purpose of the study: This study aims to evaluate landslide susceptibility along Nanggulan–Kalibawang road corridor, Kulon Progo, by identifying spatial distribution of vulnerability classes and dominant factors influencing slope instability, providing context-specific information for disaster risk reduction and infrastructure planning.

Methodology: GIS-based spatial multi-criteria analysis (SMCA) was applied using ArcGIS 10.8 software. Primary data included slope measurement, soil depth, and laboratory analysis of soil samples. Secondary data consisted of thematic layers of geology, soil type, landform, land use, and vegetation. Weighted overlay and scoring techniques were used to generate landslide susceptibility index.

Main Findings: Results indicate moderate to high vulnerability dominates hilly zones along the corridor. Very high susceptibility zones are located on steep slopes with sparse vegetation and intensive land use. Slope gradient and land use are the most dominant factors. Five susceptibility classes, ranging from very low to very high, were delineated providing fine-resolution spatial information for prioritizing mitigation measures.

Novelty/Originality of this study: This study introduces corridor-specific landslide susceptibility mapping using integrated overlay and scoring techniques within GIS. Unlike regional assessments, seven terrain parameters are combined into a unified spatial model producing fine-resolution susceptibility zones. Findings provide practical guidance for disaster risk management along strategic road corridors and advance knowledge by offering a replicable framework for localized hazard assessment.

Corresponding Author:
Rahman Afrinaldi,
Geography Education Study Program, Faculty of Teacher Training and Education, PGRI University of West Sumatra (UPGRISBA)
Jl. Gunung Pangilun, Gunung Pangilun, Kec. Padang Utara, Kota Padang, Sumatera Barat, 25111, Indonesia
Email: rahmanaldi50@gmail.com

1. INTRODUCTION

Indonesia is characterized by complex geological conditions due to its position along active tectonic boundaries and subduction zones. These conditions produce diverse landforms dominated by hilly and mountainous terrain that are inherently susceptible to slope instability [1], [2]. Landslides represent one of the most frequent geomorphological hazards in such environments, particularly during periods of intense rainfall.

The interaction between slope gradient, lithology, soil properties, and land cover significantly influences slope failure processes [3]. Therefore, spatial assessment of landslide susceptibility becomes essential to understand terrain stability and potential hazard distribution.

In Kulon Progo Regency, landslides frequently occur in areas with steep topography and intensive land utilization. The Nanggulan–Kalibawang road corridor traverses denudational hills with varying slope gradients and complex geological characteristics. Increasing land-use conversion, vegetation reduction, and infrastructure development along the corridor potentially exacerbate slope instability [4], [5]. Moreover, the road serves as an important transportation link with relatively high traffic intensity, increasing the risk of disruption and material losses when landslides occur. Despite these conditions, comprehensive spatial information regarding landslide susceptibility levels along this corridor remains limited.

Previous studies on landslide susceptibility mapping in Indonesia have applied various approaches, including statistical models, heuristic weighting, and GIS-based multi-criteria analysis. Many of these studies emphasize regional-scale assessment without focusing specifically on transportation corridors [6]. Overlay techniques combined with scoring methods have been widely recognized as practical tools for evaluating terrain-based susceptibility factors. However, their application often varies in parameter selection, weighting schemes, and spatial resolution [7], [8]. Consequently, localized investigations that integrate detailed terrain parameters remain necessary to improve spatial accuracy and contextual relevance.

Although several assessments have been conducted in landslide-prone districts of Kulon Progo, detailed susceptibility mapping along the Nanggulan–Kalibawang road corridor has not been comprehensively documented. Existing hazard information generally provides broad classifications without explicitly integrating terrain unit analysis derived from systematic overlay procedures [9], [10]. In addition, variations in slope characteristics, soil depth, permeability, and vegetation density along this corridor require more refined spatial evaluation [11]. The absence of corridor-based susceptibility zonation may limit mitigation planning and infrastructure management. This condition highlights the need for a structured GIS-based assessment tailored to the specific geomorphological setting of the study area.

Understanding the spatial distribution of landslide susceptibility is crucial for disaster risk reduction and sustainable land-use planning. Corridor-based mapping provides strategic information for transportation safety management and settlement regulation [12], [13]. By identifying zones of varying susceptibility levels, local authorities can prioritize monitoring, slope stabilization, and vegetation management efforts. Furthermore, spatially explicit information supports evidence-based decision-making in infrastructure development. Hence, producing a detailed susceptibility map along this corridor carries both scientific and practical significance [14].

This study applies a GIS-based overlay and scoring approach to generate landslide susceptibility zonation along the Nanggulan–Kalibawang road corridor. Multiple terrain parameters, including slope gradient, soil texture, solum depth, permeability, degree of rock weathering, land use, and vegetation density, are systematically integrated within a spatial framework. The combination of terrain unit delineation and weighted scoring enables a structured evaluation of susceptibility levels across heterogeneous landscapes [15]. Unlike broader regional assessments, this research emphasizes corridor-scale analysis with detailed terrain characterization. The resulting spatial model contributes to methodological refinement and provides context-specific information for landslide risk management in Kulon Progo.

2. RESEARCH METHOD

2.1. Research Framework

This study applied a GIS-based spatial multi-criteria analysis (SMCA) framework to evaluate landslide susceptibility along the Nanggulan–Kalibawang Road corridor, Kulon Progo. The methodological approach integrates geomorphological assessment, field investigation, laboratory analysis, and spatial modeling within a unified geospatial environment [16], [17]. Landslide susceptibility was conceptualized as the cumulative effect of terrain, soil, geological, and land-use conditioning factors. The analytical workflow consisted of land unit delineation, parameter standardization, weighted scoring, and spatial overlay. This framework ensures reproducibility and spatial consistency in susceptibility mapping.

2.2. Study Area and Spatial Data Preparation

The study area covers a 23-km corridor traversing five villages in Kulon Progo Regency, Special Region of Yogyakarta, Indonesia, characterized by denudational hills and heterogeneous land use patterns. The geomorphological setting is dominated by moderate to steep slopes, weathered volcanic materials, and varying vegetation density. Primary data were obtained through field surveys, including slope measurement, soil depth assessment, and soil sampling for laboratory testing. Secondary spatial data included thematic layers of slope, geology, soil type, landform, and land use acquired from official geospatial sources. All spatial datasets were standardized into a uniform coordinate system and raster resolution prior to analysis to ensure spatial compatibility.

2.3. Landslide Conditioning Parameters

Landslide susceptibility was assessed using seven conditioning parameters: slope gradient, soil texture, soil solum depth, soil permeability, degree of rock weathering, land use, and vegetation density. These parameters were selected based on geomorphological theory and empirical evidence indicating their influence on slope instability. Slope represents gravitational driving force, while soil and lithological characteristics reflect material resistance and hydrological behavior. Land use and vegetation density were incorporated to capture anthropogenic and surface protection effects. Each parameter was reclassified into five ordinal classes to facilitate standardized scoring and integration.

2.4. Multi-Criteria Overlay and Scoring Analysis

Spatial analysis was performed using a weighted linear combination (WLC) approach within a GIS environment. Each parameter class was assigned a score ranging from 1 (least susceptible) to 5 (most susceptible) based on its relative contribution to landslide occurrence. Land units were generated through overlaying slope, soil, geology, and landform maps to serve as analytical units. The total landslide susceptibility index (LSI) for each unit was calculated by summing all parameter scores. The resulting LSI values were classified into five susceptibility categories using equal interval classification to maintain analytical transparency.

2.5. Susceptibility Classification and Map Generation

The theoretical LSI ranged from 7 to 35, representing the cumulative minimum and maximum parameter scores. Classification intervals were derived by dividing the score range into five equal classes to distinguish susceptibility levels. The final classes consisted of very low, low, moderate, high, and very high susceptibility. The classified raster was subsequently converted into a thematic susceptibility map representing spatial hazard variation along the corridor. This output provides a spatially explicit decision-support tool for infrastructure planning and disaster risk mitigation.

Table 1. Landslide Conditioning Parameters and Scoring Scheme

No	Parameter	Role in Slope Stability	Score (1–5)
1	Slope Gradient	Controls gravitational driving force	1–5
2	Soil Texture	Influences shear strength and cohesion	1–5
3	Soil Solum Depth	Reflects thickness of weathered material	1–5
4	Soil Permeability	Controls water infiltration and pore pressure	1–5
5	Rock Weathering Degree	Indicates material decomposition level	1–5
6	Land Use	Represents anthropogenic modification	1–5
7	Vegetation Density	Affects root reinforcement and runoff control	1–5

- Total score range: 7–35
- Susceptibility classes: 5

3. RESULTS AND DISCUSSION

3.1. Characteristics of Landslide Conditioning Factors

Spatial analysis shows that the study area exhibits significant variations in geomorphological conditions, particularly in slope gradient and land use. Most areas are dominated by steep to steep slopes, which have the potential to increase soil shear forces. Varied soil textures and relatively deep solum thickness in some land units also influence slope stability. High levels of rock weathering in hilly areas increase the potential for land mass movement. In general, this combination of physical factors indicates the region's sensitivity to slope instability disturbances.

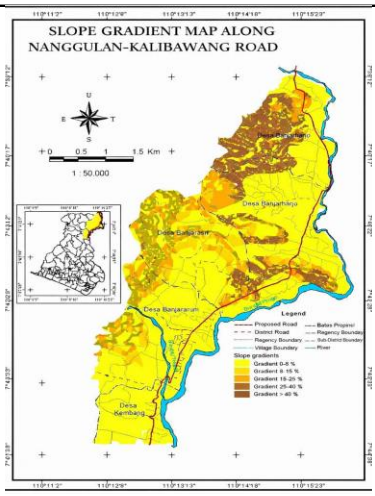

Figure 1. Slope Classification Map of the Study Area

3.2. Scoring and Weighted Overlay Analysis

Vulnerability levels were determined using a weighted overlay approach with a scoring system for each parameter. Each factor was scored based on its contribution to landslide potential, then summed to obtain a vulnerability index value. The total score ranged from 7 to 35, which was then classified into five vulnerability classes. This approach allowed for the quantitative integration of physical parameters into a single integrated spatial model. The analysis yielded distinct vulnerability index distributions for each terrain unit.

Table 1. Landslide Susceptibility Classification

Total Score	Susceptibility Level	Class
7–11	Very Low	I
12–16	Low	II
17–21	Moderate	III
22–26	High	IV
27–35	Very High	V

3.3. Landslide Susceptibility Mapping

The overlay map shows that moderate to high vulnerability classes dominate the hilly zones along the road corridor. Areas with very high vulnerability are generally located on steep slopes with sparse vegetation and land use consisting of dry fields or residential areas. Meanwhile, low vulnerability classes are found in areas with gentle slopes and relatively dense vegetation cover. The spatial distribution pattern indicates a concentration of risk in certain segments that have the potential to disrupt transportation access. This finding confirms the dominant role of topography and land use factors in determining vulnerability levels.

The spatial distribution of landslide susceptibility is presented in Figure 4, illustrating five susceptibility classes ranging from low to very high categories. The map indicates that high and very high susceptibility zones are predominantly located on steep slopes and areas characterized by intensive land use modification.

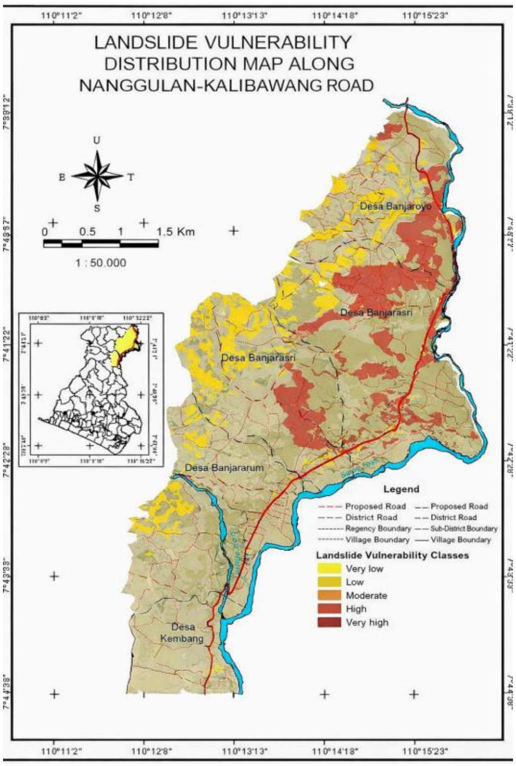

Figure 2. GIS-Based Landslide Susceptibility Map Along the Nanggulan–Kalibawang Road, Kulon Progo

3.4. Dominant Contributing Factors

Frequency score analysis indicates that slope gradient and land use are the most dominant factors in determining vulnerability class. Slopes with a gradient greater than 25% consistently fall into the high to very high vulnerability class. Land use, such as dry fields and settlements on steep slopes, increases the potential for soil instability. Advanced rock weathering and thick soil layers also increase the likelihood of landslides. This combination of factors suggests that the interaction between natural conditions and human activities is the primary driver of increased vulnerability.

3.5. Spatial Implications for Road Corridor Risk

The high vulnerability distribution across several road corridor segments indicates potential disruptions to regional connectivity. The Nanggulan-Kalibawang route, which serves as an alternative access point between regions, has a significant level of exposure to landslide risk. Highly vulnerable zones should be prioritized in mitigation and slope strengthening planning. Spatial information generated through GIS provides a scientific basis for infrastructure planning that is more adaptive to disaster risks. Therefore, the results of this study are not only academic but also applicable in supporting spatially-based disaster risk reduction.

The spatial analysis of the study area reveals significant variation in geomorphological and land-use conditions along the Nanggulan–Kalibawang road corridor. Steep slopes dominate most segments, increasing the gravitational driving forces for potential landslides. Soil texture, solum depth, and degree of rock weathering also contribute to slope instability in several hilly zones. Areas with sparse vegetation and intensive land utilization are particularly susceptible. Figure 1 (Slope Classification Map) effectively illustrates these physical characteristics across the study corridor.

The weighted overlay and scoring approach generated a detailed landslide susceptibility map that integrates seven conditioning parameters. The results indicate that moderate to high vulnerability classes are widespread, while very high vulnerability zones are concentrated on steep slopes with anthropogenic land use. The calculated Landslide Susceptibility Index (LSI) ranges from 7 to 35, corresponding to five distinct susceptibility classes. Table 1 summarizes the scoring system and classification intervals, supporting quantitative assessment. Figure 4 (GIS-Based Landslide Susceptibility Map) clearly visualizes spatial risk distribution along the corridor.

Although previous studies have mapped landslide susceptibility in Kulon Progo, most focus on regional-scale assessment without detailed corridor-based analysis. Existing hazard maps provide broad classifications but often omit terrain unit delineation and parameter integration [18], [19]. This study confirms earlier findings that slope gradient and land use are dominant factors while providing more localized spatial insight [20], [21]. The detailed corridor-level assessment helps bridge the knowledge gap for transportation planning. Consequently, the findings complement and refine prior regional studies.

This research offers novelty by combining corridor-specific mapping with a systematic overlay and scoring technique within GIS. Unlike regional assessments, the study integrates seven terrain parameters into a unified spatial model, producing fine-resolution susceptibility zones [22], [23]. The approach highlights the interaction of natural and anthropogenic factors along a strategic road corridor. It aligns with the background discussion emphasizing the need for location-specific hazard assessment [23], [24]. Therefore, the study introduces methodological and practical advancements for landslide susceptibility mapping.

The resulting susceptibility map has direct implications for disaster risk reduction and infrastructure management. High and very high vulnerability segments can be prioritized for slope stabilization, vegetation management, and monitoring activities [25] [26]. The spatially explicit information supports evidence-based decision-making for road maintenance and regional connectivity. Authorities can allocate resources more efficiently and implement targeted mitigation strategies. Overall, the study contributes to both scientific knowledge and practical disaster management along the corridor.

Despite its detailed analysis, this study has several limitations that should be considered. The assessment relies on available spatial data, which may not capture temporal variations such as rainfall intensity or seasonal vegetation changes [27], [28]. Ground-truthing was limited by accessibility constraints along some steep segments. Anthropogenic factors beyond land use, such as road drainage or excavation, were not fully incorporated [29], [30]. Future research could integrate dynamic environmental variables and more frequent field validation to enhance predictive accuracy.

CONCLUSION

GIS-based landslide susceptibility assessment along Nanggulan–Kalibawang road corridor demonstrates that slope gradient and land use are the dominant factors controlling terrain instability. Overlay and scoring techniques integrating seven terrain parameters effectively delineate five susceptibility classes, from very low to very high, providing fine-resolution spatial information. Findings confirm that steep slopes with sparse vegetation and intensive land utilization are most vulnerable, aligning with the initial objective of identifying corridor-specific hazard zones. Results support practical applications, including prioritization of slope stabilization, vegetation management, and monitoring to reduce disaster risk. Future studies can expand this framework by incorporating temporal environmental variables, dynamic land-use changes, and more frequent field validation, enhancing predictive accuracy and applicability for infrastructure planning.

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REFERENCES

[1] A. Dongzagla, I. Baddianaah, F. A. Avogo, J. Tengbane, and J. Tengbane, “Conformity of filling stations to safe distance guidelines in urban Ghana: A case study of the wa municipality,” *Cogent Soc. Sci.*, vol. 9, no. 2, pp. 1–18, 2023, doi: 10.1080/23311886.2023.2282473.

[2] B. Gweshengwe and N. H. Hassan, “Defining the characteristics of poverty and their implications for poverty analysis,” *Cogent Soc. Sci.*, vol. 6, no. 1, pp. 1–10, 2020, doi: 10.1080/23311886.2020.1768669.

[3] N. D. Nghiep, L. M. Chien, N. Van Hoang, and P. H. Hai, “Perception and adaptation to climate change of the K’Ho people related to coffee production in Lâm Đồng province, Vietnam,” *Cogent Soc. Sci.*, vol. 11, no. 1, pp. 1–17, 2025, doi: 10.1080/23311886.2025.2454345.

[4] Z. A. Tilahun, Y. K. Bizuneh, and A. Gelaw, “The combined effects of LULC changes and climate change on hydrological processes of Gilgel Gibe catchment, Southwest Ethiopia,” *Cogent Soc. Sci.*, vol. 11, no. 1, pp. 1–39, 2025, doi: 10.1080/23311886.2025.2473644.

[5] M. A. Samad, K. Arifin, and A. Abas, “A systematic literature review on the challenges of Southeast Asian countries in natural disaster management,” *Cogent Soc. Sci.*, vol. 11, no. 1, pp. 1–21, 2025, doi: 10.1080/23311886.2024.2435590.

[6] G. Erima, Y. Bamutaze, A. Gidudu, A. Egeru, and I. Kabenge, “Dimensions and drivers of social vulnerability to flood risk in Manafwa catchment, Eastern Uganda,” *Cogent Soc. Sci.*, vol. 11, no. 1, pp. 1–30, 2025, doi: 10.1080/23311886.2025.2493353.

[7] I. A. Idris, E. Adam, K. Abubakr, A. Abutaleb, and O. I. Abaker, “Analysing four decades of urban growth in Greater Khartoum, Sudan, using Earth observation data and Google Earth Engine,” *Cogent Soc. Sci.*, vol. 11, no. 1, pp. 1–20, 2025, doi: 10.1080/23311886.2025.2555384.

[8] M. H. Thulare and I. Moyo, “COVID-19 and street traders in the City of uMhlathuze, KwaZulu-Natal, South Africa:

On responses and adaptation mechanisms," *Cogent Soc. Sci.*, vol. 7, no. 1, pp. 1–13, 2021, doi: 10.1080/23311886.2021.2006392.

[9] F. Bin Sulaiman, "Striding towards sustainable urban livability: Evaluating walkability efficiency vis-a-vis population dynamics in Saudi Arabia cities," *Cogent Soc. Sci.*, vol. 10, no. 1, pp. 1–19, 2024, doi: 10.1080/23311886.2024.2340428.

[10] N. Sultana, "Analysis of landslide-induced fatalities and Analysis of landslide-induced fatalities and injuries in Bangladesh: 2000-2018," *Cogent Soc. Sci.*, vol. 6, no. 1, pp. 1–27, 2020, doi: 10.1080/23311886.2020.1737402.

[11] R. Tutu, D. Ottie-boakye, and H. N. N. Bulley, "Rethinking and mapping environmental health literacy and contaminants in Old Tulaku, greater Accra region of Ghana," *Cogent Soc. Sci.*, vol. 11, no. 1, pp. 1–21, 2025, doi: 10.1080/23311886.2025.2513465.

[12] F. Baye, "Informal land market mechanisms for accessing and securing land for housing development: The case of peri-urban areas of Woldia Township, Ethiopia," *Cogent Soc. Sci.*, vol. 11, no. 1, pp. 1–30, 2025, doi: 10.1080/23311886.2025.2482115.

[13] A. Armaw and M. B. Molla, "Assessing the trend and magnitude of land cover dynamics and its major driving forces in Omo National Park, Southern Ethiopia," *Cogent Soc. Sci.*, vol. 8, no. 1, pp. 1–18, 2022, doi: 10.1080/23311886.2022.2042055.

[14] N. Nzuzo, X. Sifiso, and N. N. Precious, "Land use and land cover change dynamics and local perception in the Dolphin Coast, KwaZulu-Natal," *Cogent Soc. Sci.*, vol. 11, no. 1, pp. 1–22, 2025, doi: 10.1080/23311886.2025.2563785.

[15] H. J. Jumaah *et al.*, "Assessment of corona virus (COVID-19) infection spread pattern in Iraq using GIS and RS techniques," *Cogent Soc. Sci.*, vol. 9, no. 2, pp. 1–16, 2023, doi: 10.1080/23311886.2023.2282706.

[16] H. Susiati *et al.*, "Criteria and methods in nuclear power plants siting: A systematic literature review," *Cogent Soc. Sci.*, vol. 10, no. 1, pp. 1–20, 2024, doi: 10.1080/23311886.2024.2354976.

[17] S. Rusadi, R. Mulyawan, U. Suwaryo, and N. Yani, "Bibliometric analysis of abrasion and erosion disaster mitigation: Trends, key themes, and potential for global policy development," *Cogent Soc. Sci.*, vol. 10, no. 1, pp. 1–15, 2024, doi: 10.1080/23311886.2024.2430451.

[18] J. He, T. Wang, and H. Zhu, "The logic of recreation space governance in forest parks based on the theory of space production," *Cogent Soc. Sci.*, vol. 8, no. 1, pp. 1–16, 2022, doi: 10.1080/23311886.2022.2137315.

[19] E. A. Muhtar, A. Abdillah, and I. Widianingsih, "Smart villages, rural development and community vulnerability in Indonesia: A bibliometric analysis," *Cogent Soc. Sci.*, vol. 9, no. 1, pp. 1–25, 2023, doi: 10.1080/23311886.2023.2219118.

[20] V. Delauer *et al.*, "The impact of natural environments and biophilic design as supportive and nurturing spaces on a residential college campus," *Cogent Soc. Sci.*, vol. 8, no. 1, pp. 1–19, 2022, doi: 10.1080/23311886.2021.2000570.

[21] H. S. Naryanto and Q. Zahro, "Penilaian risiko bencana longsor di wilayah Kabupaten Serang [Landslide disaster risk assessment in Serang Regency]," *Maj. Geogr. Indones.*, vol. 34, no. 1, pp. 1–10, 2020.

[22] F. Ulfa, E. Kusratmoko, and A. Wibowo, "Risiko kerugian akibat longsor di Desa Cibanteng, Kecamatan Sukaresmi, Kabupaten Cianjur, Jawa Barat [Risk of loss due to landslides in Cibanteng Village, Sukaresmi District, Cianjur Regency, West Java]," *Maj. Geogr. Indones.*, vol. 29, no. 2, pp. 139–148, 2015.

[23] E. Febriarta, D. Susanto, A. P. Wicaksono, and A. Larasati, "Kajian metode deterministik untuk zonasi kerawanan gerakan tanah di Labuan Bajo Nusa Tenggara Timur [Study of deterministic methods for landslide vulnerability zoning in Labuan Bajo, East Nusa Tenggara]," *Maj. Geogr. Indones.*, vol. 36, no. 1, pp. 41–50, 2022, doi: 10.22146/mgi.63231.

[24] J. C. E. Talakua and V. V. Tuerah, "Analisis spasial ketersediaan dan keterjangkauan fasilitas kesehatan untuk mendukung kesehatan wisata di Kecamatan Kuta [Spatial analysis of the availability and affordability of health facilities to support tourism health in Kuta District]," *Maj. Geogr. Indones.*, vol. 39, no. 1, pp. 91–100, 2025, doi: 10.22146/mgi.70636.

[25] N. M. Sari, "Analisis sebaran bangunan dan kesesuaian dengan rencana tata ruang wilayah (RTRW) Provinsi DKI Jakarta [Analysis of building distribution and conformity with the regional spatial planning (RTRW) of DKI Jakarta Province]," *Maj. Geogr. Indones.*, vol. 35, no. 2, pp. 133–141, 2021.

[26] L. Somantri, "Pemetaan mobilitas penduduk di kawasan pinggiran Kota Bandung [Mapping population mobility in the suburbs of Bandung City]," *Maj. Geogr. Indones.*, vol. 36, no. 2, pp. 95–102, 2022, doi: 10.22146/mgi.70636.

[27] I. Ardiansyah and S. Wagistina, "Pola spasial dan keputusan keluarga bermukim di permukiman kumuh pusat Kota dan Wilayah Pinggiran Kota Malang, Jawa Timur [Spatial patterns and family decisions to settle in slum settlements in the city center and suburbs of Malang, East Java]," *Maj. Geogr. Indones.*, vol. 35, no. 1, pp. 64–74, 2021.

[28] M. Farizki and W. Anurogo, "Pemetaan kualitas permukiman dengan menggunakan penginderaan jauh dan SIG di Kecamatan Batam Kota, Batam," *Maj. Geogr. Indones.*, vol. 31, no. 1, pp. 39–45, 2017.

[29] T. Aprilliyanti and M. Zainuddin, "Pemetaan potensi kekeringan lahan se-pulau Batam menggunakan Teknik sistem infor- masi geografis (SIG) dan penginderaan jauh [Mapping the potential for land drought across Batam Island using geographic information systems (GIS) and remote sensing techniques]," *Maj. Geogr. Indones.*, vol. 31, no. 1, pp. 91–94, 2017.

[30] F. A. Ikhsan, S. Utaya, S. Bachri, A. Sugiarto, and A. E. Sejati, "Paradigma filsafat penduduk geografi kontemporer: kajian ontologi, epistemologi, aksiologi, dan keterampilan sainstifik [Contemporary geographic population philosophy paradigm: study of ontology, epistemology, axiology, and scientific skills]," *Maj. Geogr. Indones.*, vol. 38, no. 1, pp. 25–34, 2024, doi: 10.22146/mgi.70636.