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# Geomorphological Study of Lanslide in Sukamulya Village, Tegalwaru Sub-district, Purwakarta

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***Abstract***
*Purwakarta Regency represents one of the areas in West Java Province with high landslide susceptibility. This research aims to analyze geomorphological aspects that influence landslide occurrence in Purwakarta using morphogenetic, morphometric, and morphographic approaches. The data utilized encompass regional geological maps, topographic data, rainfall records, and recurring landslide events in the area, particularly in Tegalwaru District and surrounding areas. The research methodology includes morphometric analysis (slope gradient, elevation, and relief indices), morphographic analysis (landform characteristics and drainage patterns), and morphogenetic analysis (landscape formation processes). Results indicate that steep hilly morphology with slope gradients of 16-35°, expansive claystone lithology of the Subang Formation, and morphogenetic processes controlled by volcanic and tectonic activities constitute the primary factors of landslide susceptibility. Morphometric analysis demonstrates that areas with high relative relief (>200 m) and slope gradients exceeding 25% exhibit very high landslide susceptibility. Morphographically, landforms characterized by moderately steep to steep hills with subradial to subparallel drainage patterns reflect strong structural and magmatic controls. Morphogenetic processes are dominated by intensive weathering and gravitational erosion triggered by high rainfall. The combination of these three geomorphological aspects results in moderate to high landslide susceptibility zones across most of Tegalwaru District, particularly in areas with claystone lithology and steep hilly morphology..*

***Keywords: Geomorphology, Landslide, Morphogenetic, Morphometric, Morphographic***

## INTRODUCTION

Purwakarta Regency, located on the highlands of West Java Province, faces significant challenges related to landslide hazards. Its terrain comprises rolling hills formed by a complex sequence of geological processes, including ancient volcanic intrusions and tectonic deformation. Volcanic activity deposited alternating layers of andesite and tuff, while faulting and folding created structural weaknesses prone to weathering and erosion (Dikau, Brunsden, Schrott, & Ibsen, 1996). The heterogeneous lithology particularly the claystone of the Subang Formation, further exacerbates slope instability due to its pronounced swelling and shrinkage when saturated, which promotes cracking and mass failure (Varnes, 1984).

Precipitation in Purwakarta is high, with rainfall intensities ranging from moderate to heavy during the wet season. Elevated rainfall promotes infiltration into rock fractures and soil layers, accelerating both chemical and physical weathering processes and triggering mass movements through gravitational erosion (Dikau et al., 1996). Meteorological records indicate an average annual rainfall of 2,500–3,000 mm, with monthly peaks often exceeding 300 mm (Badan Meteorologi, Klimatologi, dan Geofisika, 2024). These hydrological conditions compromise slope stability, especially on steep inclines with inefficient surface drainage.

A holistic understanding of landslide causation in this setting requires integrating three geomorphological approaches: morphogenetic, morphometric, and morphographic analyses. Morphogenetic studies examine landscape-forming processes; such as weathering, erosion, and deposition driven by both internal forces (tectonic and volcanic) and external factors (climate and vegetation) (Thornbury, 1969). Morphometric analysis quantifies landform characteristics, including slope gradient, elevation, and relief ratio, which are critical parameters for assessing slope stability potential (Strahler, 1952). Morphographic investigation focuses on surface drainage patterns and landform types; such as valleys, channels, and drainage networks to identify structural and magmatic controls on landslide distribution (Carrara, 1983).

Previous studies in regions with comparable geology and topography have shown that slopes exceeding 25°, relief values above 200 m, and subradial or subparallel drainage patterns correlate strongly with very high landslide susceptibility (Guzzetti et al., 2012). Furthermore, landscapes dominated by intensive weathering particularly of volcanic and clay-rich rocks are more prone to gravitational erosion under high rainfall conditions (Huang & Bradford, 1990). However, empirical research that simultaneously integrates these three approaches at the village or subdistrict scale remains scarce in Indonesia. A focused geomorphological investigation in rural areas such as Sukamulya Village, which exhibits high landslide vulnerability, can yield critical insights into hazard zoning and community-based mitigation strategies.

Sukamulya Village in Tegalwaru Sub-district has experienced repeated landslide events over the past decade, causing damage to village roads, irrigation channels, and agricultural land. According to the Regional Disaster Management Agency of Purwakarta (BPBD Purwakarta, 2023), more than fifteen medium-to-large landslides occurred between 2015 and 2022, with peaks in 2019 and 2021. Spatial data indicate that most failures are concentrated in the western and southern sectors of the village, characterized by slopes of 20°–35° and elevations between 150 and 350 m above sea level. This vulnerability reflects the broader pattern of landslide susceptibility in West Java, where 571 landslides occurred between 2012 and 2019 (Center for Volcanology & Geological Disaster Mitigation, 2019), with volcanic-weathered material, steep terrain, and high rainfall serving as primary triggering factors (Mulyasari, 2021).

Implementing geomorphological landslide research at the village scale is increasingly recognized as essential for targeted risk mitigation planning (Hadi, 2020; Zamroni, 2020). Hazard zoning based on morphometric, morphographic, and morphogenetic parameters enables local authorities and communities to identify priority areas for interventions such as reforestation, water retention structures, and slope-supporting infrastructure. Recent studies have demonstrated the effectiveness of this integrated approach: (1) in Bandar Lampung City, geomorphological assessment using morphometry, morphography, and morphogenesis successfully identified landslide-prone zones for spatial planning decisions, with findings supporting the design of targeted development restrictions (Mulyasari, 2021); (2) in Kabandungan District and Salak Geothermal Field, West Java, landslide susceptibility mapping using multi-parameter analysis (lithology, land cover, rainfall, slope, curvature, aspect, distance from river and road) achieved an Area Under Curve (AUC) validation value of 0.89359, demonstrating strong predictive accuracy (Scholarhub UI, 2024); and (3) in East Ungaran, Semarang Regency, comparison of three methods (Weight of Evidence, Logistic Regression, and combined WoE-LR) showed that integrated approaches substantially improved landslide susceptibility mapping accuracy, with the combined method achieving superior performance for mitigation planning (Maulana et al., 2024).

The practical effectiveness of village-scale hazard zoning is further supported by implementation studies: Similar zoning models employed in Cisolok, Sukabumi, and the upstream catchments of Central Java have reduced landslide damage frequency by up to 30% following mitigation measure implementation (Wahyudi, Hadi, & Santoso, 2021; Prasetyo, Ibrahim, & Yulianto, 2022). Furthermore, Indonesia's "Disaster Resilient Villages" program has demonstrated that community-based hazard zoning at the village scale, when combined with risk mapping, analysis, preparation of disaster management plans, early warning systems, and volunteer development, significantly enhances local resilience (Hadi, 2020). However, implementation studies have also identified persistent challenges: despite the availability of geomorphological research results and landslide-prone area maps, local government adoption of these findings remains inconsistent, with gaps between research outputs and policy implementation attributed to inadequate residential development planning and insufficient warning sign placement in high-risk areas (Zamroni, 2020). This implementation gap underscores the importance of conducting village-scale geomorphological research that is explicitly designed to support community engagement and disaster risk reduction education.

Therefore, adapting integrated geomorphological methodologies to Purwakarta, particularly in Tegalwaru Sub-district, is expected to: (1) enhance rural community resilience against landslides through evidence-based hazard identification; (2) support the implementation of Indonesia's disaster resilience framework by providing localized scientific data for planning; and (3) contribute to narrowing the research-to-practice gap through methodologies that are explicitly linked to community-based mitigation and disaster education.

## RESEARCH METHODS

This research employed an integrated geomorphological approach that synthesizes morphometric analysis, morphographic analysis, and morphogenetic analysis three complementary methodological frameworks established by leading geomorphologists over several decades. The integrated approach follows the conceptual foundation articulated by Van Zuidam (1985), who demonstrated that holistic landslide assessment requires understanding both the quantitative geometry of landforms (morphometry) and the qualitative characteristics and processes that create them (morphography and morphogenesis). The research was structured in four sequential phases across a 12-week field season during the 2023–2024 wet season: data acquisition and preparation, morphometric analysis with GIS implementation, morphographic mapping and analysis, and morphogenetic process characterization. This hierarchical structure enables systematic synthesis of landscape-forming processes and structural controls on landslide distribution, consistent with the theoretical framework articulated by Thornbury (1969) and more recently operationalized by Carrara (1983) and Guzzetti et al. (2012) in their influential landslide susceptibility studies.

### Preparatory Phase

The preparatory phase incorporated literature review, preliminary field reconnaissance surveys, and administrative permit acquisition. The literature review constituted an initial geological assessment of the research area based on previous scientific publications, topographic map interpretation, and satellite imagery analysis. This preliminary review aimed to establish a comprehensive understanding of the regional geological framework. Pre-field interpretation proved essential for guiding subsequent field data acquisition strategy. Through systematic topographic map and satellite imagery interpretation, the research team identified lithological variations and morphological characteristics within the study area, providing a foundational framework for targeted field observations. This preparatory analysis enabled strategic planning of field data collection locations and methodological focus areas.

### Field Data Acquisition Phase

This phase employed standard geological field methodologies established in the discipline to generate optimal quantitative and qualitative field data. The primary objectives of this phase were to document lithological types, map lithological spatial distribution, characterize rock layer attitudes and structural geometry, and collect representative rock samples for subsequent laboratory analysis. Field mapping methodology employed an orienteering approach based on preliminary interpretative considerations derived from the preparatory phase. The field orientation methodology comprised four sequential procedural steps: (1) position marking using GPS technology to establish precise geographic coordinates; and (2) data transfer from GPS units to field documentation systems. Geomorphological observations characterized surface landform characteristics including hillslope morphology, drainage network patterns, and valley configurations within the research area. These observations provided qualitative documentation of landscape-scale geomorphological features essential for subsequent morphogenetic interpretation.

**Data Analysis and Processing Phase**

Field-collected data underwent interpretative analysis grounded in established geological and geomorphological concepts and theory. Interpretative results were synthesized into thematic maps including geomorphological mapping, structural framework mapping, and geomorphological mapping integrating all observational datasets.

**Geomorphological Analysis**

Geomorphological analysis integrated three complementary analytical approaches: morphometric analysis, morphographic analysis, and morphogenetic analysis. Geomorphological assessment of the research area was supported by construction of three-dimensional digital terrain models derived from topographic map data incorporating elevation and drainage network information. This multi-scale approach follows established geomorphological methodology (Van Zuidam, 1985; Dikau et al., 1996).

**Morphometric Analysis**

Morphometric analysis constitutes quantitative assessment of landform geometry serving as analytical support for qualitative morphographic and morphogenetic interpretations, enabling numerical characterization of landforms described qualitatively through classification schemes (Van Zuidam, 1985; Strahler, 1952). Slope gradient values derived from topographic data and digital elevation models were classified following Van Zuidam (1985) slope classification categories established in Guide to Geomorphologic Aerial Photographic Interpretation and Mapping. This approach provides numerical thresholds for quantifying topographic steepness across the research area.

**Morphographic Analysis**

Morphographic analysis examines descriptive characteristics of Earth surface morphology through systematic interpretation of topographic maps and satellite imagery. This analytical approach involved identifying landform types through analysis of contour pattern density and spacing, enabling discrimination between hilly terrain and plateau morphologies. Contour pattern interpretation also permits identification of slope gradient variations and recognition of structural features including fault-controlled valleys and lithological boundaries reflected in morphological expression (Van Zuidam, 1985; Carrara, 1983).

**Morphogenetic Analysis**

Morphogenetic analysis characterizes the landscape-forming processes responsible for generating contemporary surface morphology, encompassing plains, hills, mountains, volcanic features, valleys, hillslopes, and drainage network patterns. Landform expression on the Earth surface results from two complementary process categories: (1) endogenic processes driven by internal crustal forces including tectonism and volcanism; and (2) exogenic processes controlled by external environmental factors including climate, vegetation, fluvial erosion, and gravitational mass movement. Understanding the relative importance and spatial distribution of these processes provides mechanistic explanation for observed landform patterns and landscape evolution trajectories.

Integration of endogenic and exogenic process interpretation enables comprehensive morphogenetic assessment linking structural and climatic controls on landscape development. Morphogenetic interpretation synthesizes morphometric and morphographic observations with geological field evidence (lithological composition, structural orientation, tectonic features) and climatological factors (precipitation, weathering rates, runoff patterns) to develop process-based explanation for observed landform distributions and geomorphological characteristics. This integrated approach follows established methodology in contemporary geomorphological analysis (Sidle & Ochiai, 2006; Dikau et al., 1996).

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# RESULT AND DISCUSSION

## Geomorphological Aspects and Their Relationship to Landslide Susceptibility

Geomorphology is the scientific study of Earth's surface forms and the processes that have shaped them from the planet's formation to the present day (Van Zuidam, 1985). In this research, geomorphological mapping units were defined based on the fundamental conceptual framework of landform genesis, encompassing three complementary facets: morphometry, morphography, and morphogenetics. By integrating these facets, the study area was subdivided into distinct geomorphological units. This investigation reveals the various geomorphological factors that significantly influence landslide susceptibility in Sukamulya Village, Tegalwaru Sub-district, Purwakarta Regency. The analysis centers on three methodological approaches: morphometric analysis (quantitative assessment of landform geometry), morphographic analysis (characterization of surface drainage patterns and landform types), and morphogenetic analysis (interpretation of landscape-forming processes). The synthesis of findings from these three approaches provides a holistic understanding of landslide mechanisms in steep hill terrains underlain by easily degradable claystone lithology.

## Morphometric Analysis of the Study Area

Morphometry involves the quantitative assessment and analysis of landform geometry to support qualitative classifications derived from morphographic and morphogenetic observations. Quantitative parameters, such as slope gradient, lend precision to qualitative descriptors by providing clear numerical thresholds. Using contour lines and elevation data from topographic sheets 1209-241 (Maniis) and 1209-243 (Jatiluhur), the study area's elevations range from 232 to 788 meters above sea level (Figure 1). Morphometric calculations were performed by classifying slope gradients into four dominant categories: flat slopes (<5°), gentle slopes (5°–15°), moderately steep slopes (15°–25°), and steep slopes (>25°). These classifications form the basis for mapping landslide-susceptible zones and inform targeted mitigation measures.

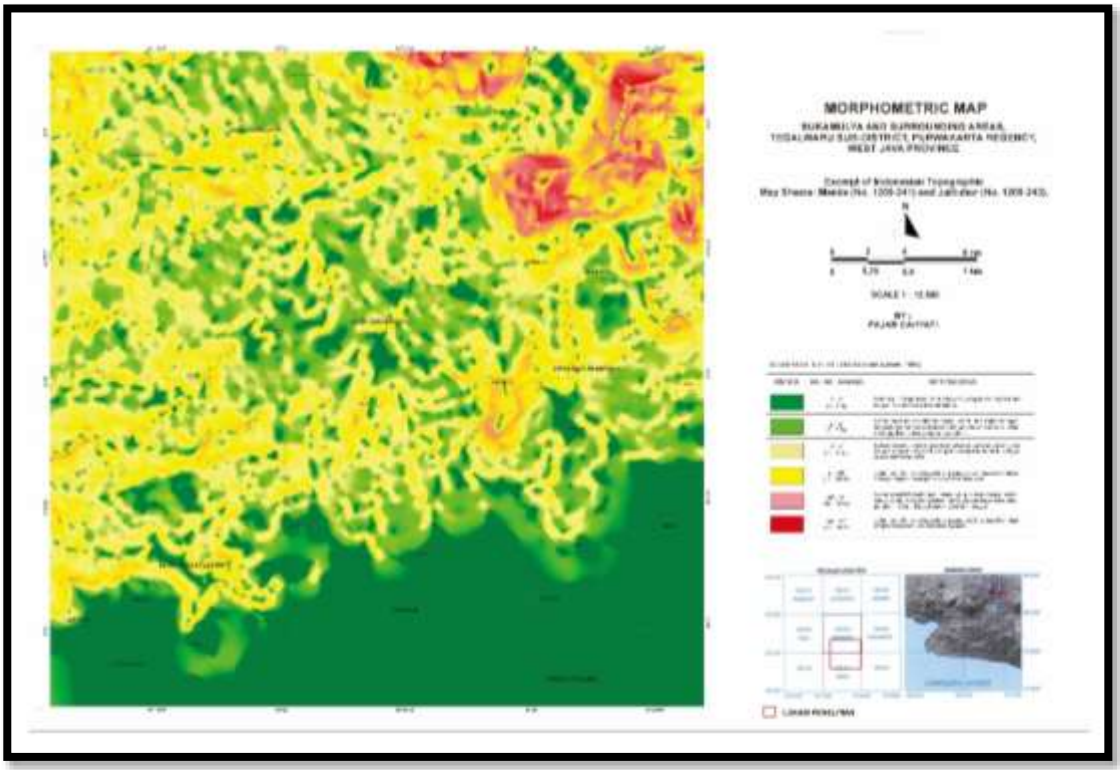


Figure 1. Delineated results of the slope-gradient analysis for the study area (researcher's processing)

The morphometric analysis was conducted using a high-resolution (5 m) Digital Elevation Model (DEM) and GIS software. The parameters computed included slope gradient, elevation, and the Stream Power Index as a proxy for relief complexity. The results are summarized as follows:

a. Slope Gradient
Slopes between 16° and 35° dominate the study area. The very-high-susceptibility zone (slopes ≥ 25°) covers 28.5% of the total area, while moderate slopes (15°–25°) account for 34.2% and correspond to medium susceptibility. Gentle slopes (< 15°) exhibit low landslide susceptibility, comprising 37.3% of the terrain.

b. Elevation and Relief
Elevations range from 150 to 350 m above sea level. Areas above 200 m, representing 42% of the landscape, display a high relief index (> 1.2), indicative of undulating, steep terrain. These high-relief zones coincide spatially with documented historical landslide occurrences.

c. Morphometric Susceptibility Zonation
By integrating slope, elevation, and relief index, a GIS-based susceptibility map was produced categorizing the landscape into four vulnerability classes: very high (12.3%), high (26.7%), medium (31.5%), and low (29.5%). The very-high-susceptibility areas are concentrated in the western and southern sectors of Sukamulya Village, matching the distribution of past landslide events.

These morphometric findings confirm that the combination of steep slopes and high relief serves as a robust indicator of landslide susceptibility, corroborating results from analogous studies in comparable environments.

**Morphographic Analysis of the Study Area**

The study area is characterized by a hilly landscape with elevations ranging from 232 to 788 meters above sea level. Applying Van Zuidam's (1985) classification which relates absolute elevation to morphographic elements the landforms in the research area fall into two morphographic categories: low-plateau gentle slopes and gentle-to-steep hills.

Valley morphology is controlled by slope gradient and inter-ridge spacing, while hillside form is strongly influenced by both slope angle and the vertical configuration of that slope. Based on cross-sectional reconstructions derived from topographic data, the valleys within the study area exhibit both U-shaped and V-shaped profiles.

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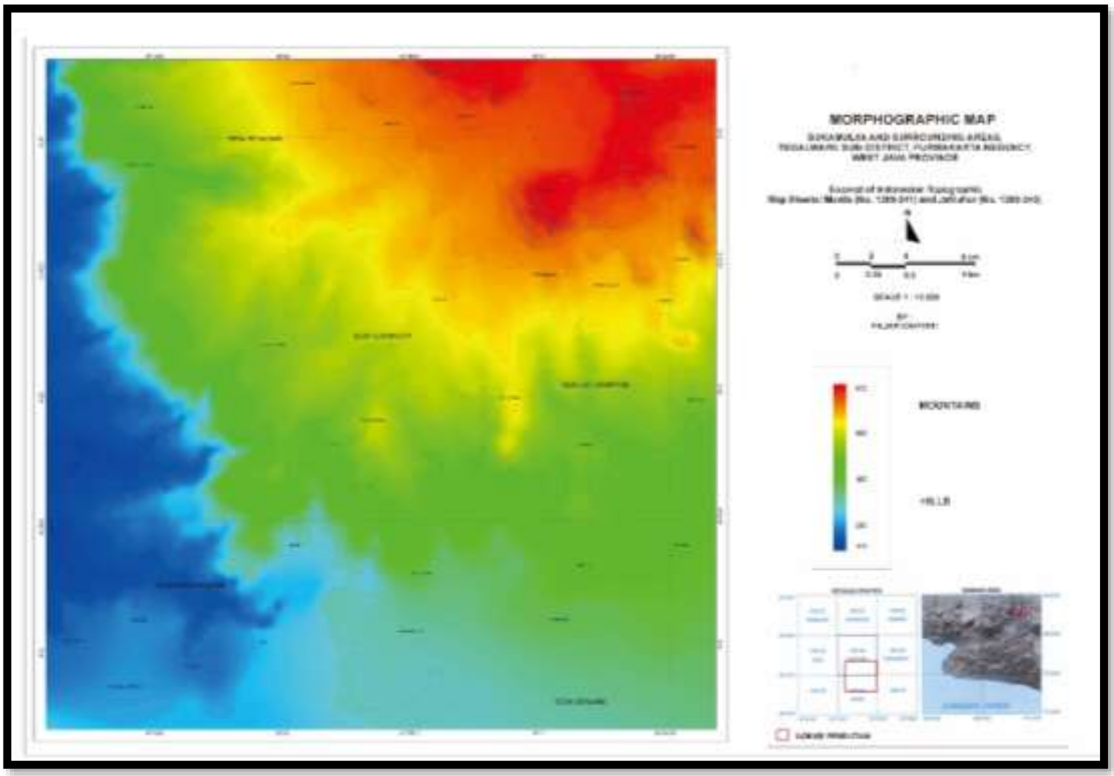


Figure 2. Delineated morphographic map of the study area (researcher's processing)

The morphographic analysis examined drainage patterns, valley shapes, and surface orientation using a morphographic map derived from satellite imagery interpretation and topographic data. The key characteristics are as follows:

a. Drainage Patterns

Two dominant patterns subradial and subparallel are identified (Figure 3). The subradial pattern, which radiates toward multiple centers, reflects magmatic control and ancient volcanic dome structures. The subparallel pattern characterized by nearly parallel stream courses indicates the presence of elongated fault structures beneath the surface.The modified subparallel drainage generally develops on gently to moderately steep slopes and elongated hill–plateau landforms. It covers approximately 70% of the study area, predominantly in the western sector. Streams exhibiting this pattern include the Ci Buluh, Ci Galumpit, Ci Kurutug, Ci Sentul, and Ci Bongkok rivers. The underlying lithologies in these zones are breccia and claystone.

The subradial pattern represents a modification of primary radial drainage. True radial networks typically form on uniform, resistant lithologies with steep slopes, radiating from a central point such as an intrusion dome, volcanic cone, or erosional remnant. In the study area, slopes range from moderately steep to gentle, and the relief does not form a distinct cone, distinguishing these networks from classic radial systems. Subradial drainage occupies about 20% of the region, primarily in the central–eastern sector. Rivers demonstrating this pattern include the Ci Akar and Ci Salak, underlain predominantly by porphyritic diorite and tuff.

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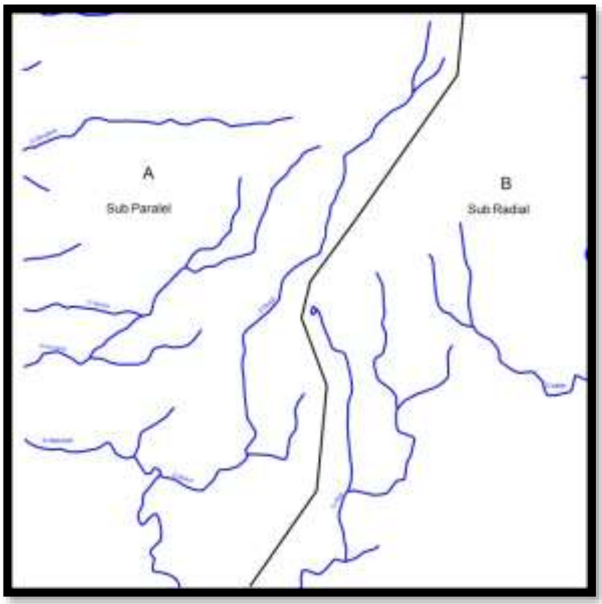


Figure 3. Delineated drainage pattern of the study area (researcher's processing).

b. Landform Types

Moderately steep to steep hills with sharp crests dominate the western and southern sectors of the study area (Figure 2). Narrow, V-shaped valleys indicate deeply incised fluvial erosion that directly cuts into the slopes. Relationship to Landslides: The majority of historical landslide occurrences align with the intersection of subradial and subparallel drainage sectors, where geologic structural frameworks concentrate surface runoff and water infiltration into zones of weakness. Areas characterized by narrow valleys and steep slopes exhibit high susceptibility due to focused water flow and the accumulation of shear stress. These morphographic findings confirm that structural and magmatic controls on drainage patterns play a critical role in shaping landslide distribution, consistent with structural geomorphology theory.

**Morphogenetic Analysis of the Study Area**

To identify the dominant morphogenetic processes, the drainage network development was compared against the region's geological structure and rock lithology. A drainage network consists of a main river and its tributaries within a single catchment. The evolution of these drainage patterns is influenced by factors such as slope gradient, lithological resistance contrasts, structural controls, mountain or hill formation, and Quaternary geological processes. From these considerations, the study area is characterized by both volcanic and structural morphogenetic influences. Morphogenetic investigation examines landscape-forming processes, including weathering, erosion, and deposition. The methodology integrated a review of local geological literature, laboratory analyses of Subang Formation claystone samples, and historical rainfall records. Intensive weathering of Subang Formation claystone, with clay contents exceeding 45%, yields high water retention capacity and elevated pore pressures upon saturation. Laboratory testing confirmed that both mechanical and chemical weathering rates in these claystones surpass those of other sedimentary rocks in West Java.

Gravitational erosion is accelerated by the combination of steep slopes and an average annual rainfall of 2,500–3,000 mm. The interaction of rill and interrill erosion mechanisms rapidly mobilizes slope material. Furthermore, ancient volcanic and tectonic activity produced andesitic intrusions that are more erosion-resistant, juxtaposed against more easily weathered claystone layers. Both thrust and normal fault systems within the study area generate discontinuities that serve as preferred pathways for mass movement. This morphogenetic analysis confirms that intensive weathering and rainfall-driven gravitational erosion are the primary drivers of landslide processes, while the volcanic-tectonic structural framework provides the spatial control for mass movement initiation.

**Practical Implications**

The findings of this study offer several practical measures to reduce landslide risk in Sukamulya Village and its surroundings. First, targeted reforestation is essential for enhancing slope stability. Planting deep-rooted species such as Albizia and Gliricidia in very-high and high vulnerability zones will increase soil cohesion and reduce surface erosion. The root networks act as natural soil binders, slowing overland flow during heavy rainfall and significantly limiting water infiltration into the slope mass.

Second, implementing terracing techniques combined with an effective drainage system is necessary to minimize concentrated runoff that can trigger slope failure. Constructing level terraces along steep slopes reduces the effective gradient, thereby lowering the gravitational force acting on the soil mass. In addition, installing diagonal open channels to convey runoff in a controlled manner to designated discharge points prevents direct flow accumulation along the slope. Together, these measures decrease pore-water pressure, reduce slope failure potential, and slow erosion rates.

Third, developing and deploying an early-warning system based on high-intensity rainfall data will strengthen community preparedness. Installing automated rain gauges at critical locations particularly in the western and southern sectors of Sukamulya Village enables real-time monitoring and forecasting of soil saturation conditions. Warnings can be disseminated via mobile applications or village sirens, prompting preventive evacuations and road closures before critical thresholds are reached. Training local volunteers to operate the equipment and respond quickly will further enhance system effectiveness.

Fourth, land-use planning and building regulations must be revised to restrict human activity in high-risk areas. The local government should designate buffer zones within the very-high vulnerability areas, prohibiting residential developments, public facilities, or critical infrastructure therein. These buffer zones can also serve as green open spaces or vegetation conservation areas, thereby minimizing potential loss of life and property damage while preserving slope ecosystem functions.

Fifth, a community-based mitigation approach must be strengthened through intensive outreach and stakeholder participation in all planning stages. Regular workshops and disaster drills organized by the Purwakarta Disaster Management Agency (BPBD) in collaboration with village volunteers will improve residents' understanding of the vulnerability map and recommended mitigation actions. Empowering local groups; such as farmer cooperatives or youth organizations ensures that technical recommendations like reforestation, terracing, and drainage installation are not only understood but also maintained over the long term. Through this participatory approach, landslide mitigation becomes a shared responsibility engaging the entire community.

## CONCLUSION

Morphometric, morphographic, and morphogenetic approaches collectively elucidate landslide susceptibility in Purwakarta Regency. Morphometric analysis quantifies landform geometry-slope gradient, elevation, and relief index-revealing that steep slopes between 16° and 35° accumulate higher gravitational stresses, thereby innately exhibiting greater landslide potential. Morphographic assessment of drainage patterns and surface landforms uncovers structural and magmatic controls on landslide distribution; narrow, V-shaped valleys accelerate channel incision into slopes, progressively undermining slope stability. Concurrently, morphogenetic processes emphasize the long-term dynamics shaping rock and soil characteristics in Purwakarta, including intensive weathering and gravity-driven erosion. The claystone lithology of the Subang Formation, with its high clay content, retains significant moisture, elevating pore-water pressures upon saturation and triggering slope-material failure.Implementing targeted reforestation using deep-rooted species markedly enhances soil cohesion and reduces surface erosion within high-vulnerability zones. Terracing and effective drainage systems reduce the effective slope gradient and regulate runoff, thereby lowering subsurface pore-water pressures. A rainfall-based early-warning system further strengthens community preparedness and enables timely preventive evacuations. Land-use planning revisions that establish buffer zones in very-high-risk areas mitigate potential loss of life and infrastructure damage while preserving slope ecosystem functions. Finally, a participatory approach combining public outreach, training, and collaboration with local stakeholders ensures the sustainability of landslide mitigation measures by framing risk reduction as a shared, integrated responsibility.

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