

GEOMORPHOLOGY OF CISEWU AREA AND ITS SURROUNDINGS, GARUT REGENCY, WEST JAVA, INDONESIA

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ABSTRACT

This study analyzes the geomorphological phenomena of the Cisewu area and its surroundings, Garut Regency, West Java, through an integrated approach encompassing morphographic, morphometric, morphogenetic, and morphotectonic was used to analyze landforms as a basis for establishing geomorphological units. The methods used included mapping the earth's surface, Digital Elevation Model (DEM) analysis, slope gradient measurement, drainage pattern interpretation, and lineament analysis. The results indicate the presence of five distinct geomorphological units, namely an Andesitic Intrusive Dome, very steep structural valley, moderately steep volcanic valley, steep volcanic ridge, and very steep structural ridge. Morphometric analysis shows the dominance of steep (16° – 35°) to very steep ($>35^{\circ}$) slopes, reflecting strong control by geological structures and resistant lithology. Rectangular and trellis drainage patterns indicate control by fault and joint structures. Morphotectonic analysis using geomorphic indices (Bs, Vf, Af, Smf) indicates ongoing Quaternary tectonic activity, particularly in the Cilayu Sub-Watershed. The formation of these geomorphological units is the result of the interaction between volcanism during the Late Miocene–Pliocene and tectonic deformation by northeast–southwest-trending strike-slip faults. The results of this study provide a scientific basis for land-use planning and landslide hazard mitigation in the study area.

Keywords: Cisewu–Garut, geomorphology, morphotectonics, remote sensing, slope gradient, landforms.

INTRODUCTION

From a geological perspective, Java Island was formed as a volcanic arc resulting from the subduction of the Indo-Australian Plate beneath the Eurasian Plate from the Late Cretaceous to Recent (Smyth et al., 2008). This complex and ongoing tectonic interaction has not only produced high volcanic activity and seismicity, but also formed diverse physiographic regions with distinctive morphology, one of which is the Southern Mountains Zone of Java (Van Bemmelen, 1949). Geomorphology is a scientific discipline that studies landforms and landscapes along with the processes that shape them, providing an analytical framework to understand the evolution of the Earth's surface (Tarolli & Sofia, 2021). This study includes analysis of

the influence of endogenic forces (tectonic and volcanic), exogenic forces (fluvial processes, weathering, and erosion), as well as the role of anthropogenic activities in modifying landscapes (Viles, 2022). Modern geomorphological approaches integrate field observations, remote sensing data, and numerical modeling to holistically reconstruct landscape evolution histories and to identify potential resources and geological hazards (Bishop et al., 2020).

The Cisewu area in Garut Regency physiographically belongs to the Southern Mountains Zone of West Java. This region is characterized by hilly to mountainous morphology with steep slopes, deep and narrow river valleys, and structurally controlled drainage patterns. This complex

landscape is the result of prolonged interaction between Tertiary volcanism and Quaternary tectonic deformation associated with regional fault systems, such as the Cimandiri Fault to the north (Martodjojo, 2003). The lithology is dominated by Miocene–Pliocene volcanic and volcanoclastic rocks that have undergone uplift and intensive weathering. Although several regional geological studies have been conducted, detailed geomorphological information integrating morphotectonic aspects for the Cisewu area remains very limited. Therefore, a comprehensive understanding of the geomorphological characteristics and genesis of this region is crucial as a scientific basis for land-use planning, resource management, and mitigation of geological hazards such as

landslides that frequently occur on steep slopes.

Based on this background, this study aims to: (1) identify and classify geomorphological units based on morphographic, morphometric, morphotectonic aspects, and morphogenetic through lithology and geological structure; (2) evaluate indications of relative Quaternary tectonic activity through geomorphic indices analysis (morphotectonic analysis); and (3) interpret the main geomorphological processes that shaped the current Cisewu landscape. Geographically, the study area is located in the Cikarang area and its surroundings, Cisewu Subdistrict, Garut Regency, West Java Province (Figure 1).

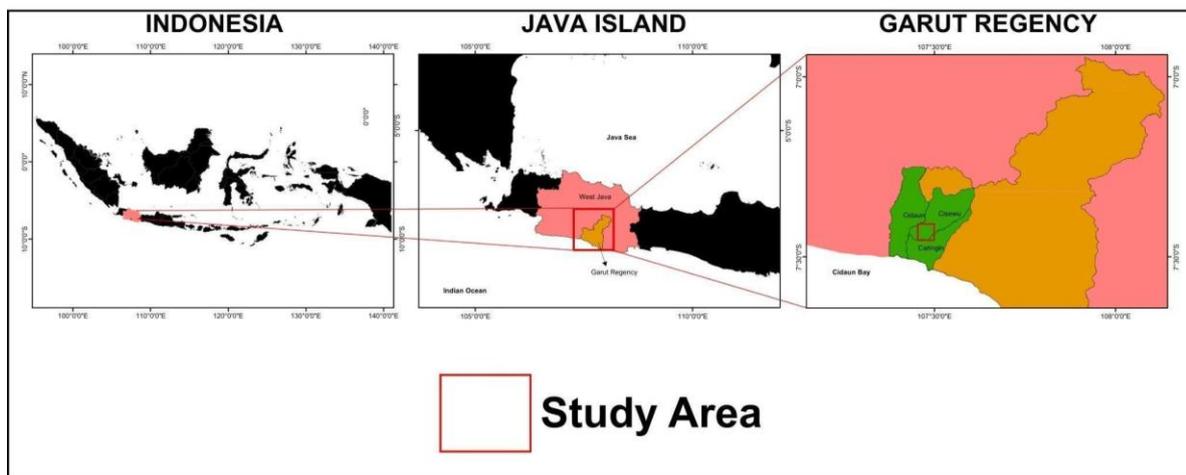


Figure 1. Study area located in Cisewu Subdistrict.

REGIONAL GEOLOGY

Physiography of the Study Area

Physiographically, the study area belongs to the Southern Mountains Zone of West Java (Van Bemmelen, 1949) (Figure 2). This zone extends along the southern coast of Java Island with a width of approximately 50 km and is characterized by highland to steep hilly morphology that has undergone intensive folding and uplift processes since the Miocene. The Cisewu area, as part of this zone, exhibits hilly to mountainous morphology with rugged relief, steep slopes, and deeply incised narrow valleys. These physiographic conditions result from complex interactions between Sunda Arc tectonic activity, volcanism, and denudational processes that have operated intensively since the Miocene to the Quaternary. The development of regional morphology is

strongly controlled by Miocene–Quaternary volcanic and sedimentary rocks that have undergone structural deformation, producing landform units in the form of steep structural ridges and steep structural valleys aligned with regional structural lineaments.

Stratigraphy of the Study Area

The stratigraphy of the study area consists of rock units ranging in age from the Late Miocene to the Quaternary, recording the geological evolution of the Southern Mountains Zone from deep-marine to terrestrial environments with dominant volcanic influence. Based on the Regional Geological Map of the Sindangbarang and Bandarwaru Quadrangles (Koesmono, 1996), the regional stratigraphy indicates that the rocks in this area range in age from the Late Miocene to the Quaternary. Previously identified lithostratigraphic units include the

Bentang Formation (Tmb), the Koleberes Formation (Tmk), the Undifferentiated Older

Volcanic Unit (QTV), and Pyroxene Andesite (pa). The Bentang Formation represents the oldest unit, deposited in a deep-marine environment, whereas the volcanic units reflect intensive magmatic activity during the Late Miocene to Pliocene (Figure 3).

Geological Structure of the Study Area

The study area, particularly in the Cilayu River area located in the southeastern part, belongs to the Margahayu Fault segment. This fault is part of the active fault system in Garut Regency. Based on systematic mapping conducted by the Geological Agency, the Margahayu Fault is classified as a left-lateral strike-slip fault that still shows Quaternary activity (Moechtar et al., 2024).

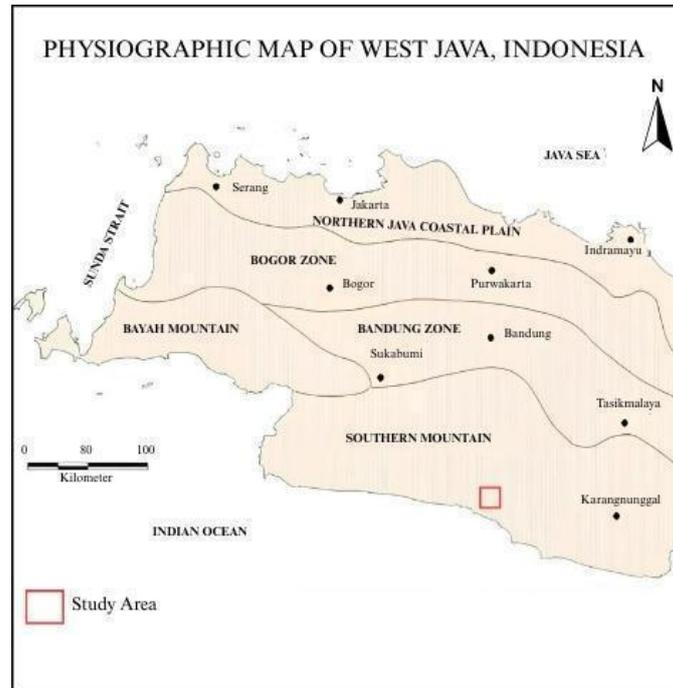


Figure 2. Modified illustration of the Physiography of Western Java, Indonesia.

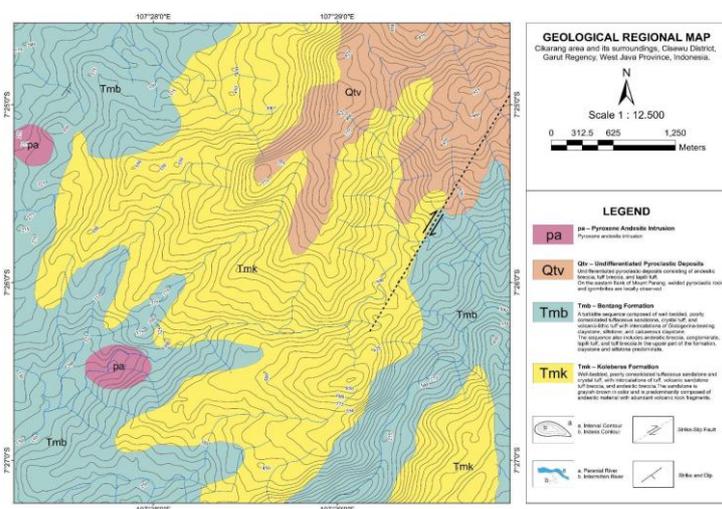


Figure 3. Geological map of the study area. Modified from the Geological Map of the Sindangbarang and Bandarwaru Quadrangles (Koesmono, 1996).

RESEARCH METHOD

This study integrates field methods and spatial data processing. Field data collection includes surface geological mapping at a scale of 1:12,500, outcrop observations, geological structure measurements, and rock sampling. Morphographic analysis was conducted by classifying landforms based on absolute elevation and valley morphology (Van Zuidam, 1985). The morphographic map was prepared using DEMNAS data processed with GIS software.

Drainage pattern analysis was carried out based on river pattern forms following the classification of Howard (1967). The river data used were obtained from RBI data of Garut Regency.

Morphometric analysis focused on slope gradient, which was classified into six classes: flat (0° – 2°), gentle (2° – 8°), moderately steep (8° – 16°), steep (16° – 35°), very steep (35° – 55°), and extremely steep ($>55^{\circ}$). Slope gradient values were obtained through GIS processing using the Slope function. This classification refers to a modification of Van Zuidam (1985) with adjustments for volcanic-structural terrains.

Morphogenetic analysis was conducted by identifying endogenic processes (volcanism and tectonics) and exogenic processes (weathering, erosion, and mass movement) based on lithology and geological structures.

Morphotectonic analysis was conducted by calculating four quantitative geomorphic indices (El Hamdouni et al., 2008 in Nugraha, R.P.D., 2023). The indices calculated include the Basin Shape Index (Bs), Valley Floor Width-to-Height Ratio (Vf), Asymmetry Factor (Af), and Mountain Front Sinuosity (Smf). The Valley Floor Width-to-Height Ratio (Vf) and Mountain Front Sinuosity (Smf) indices were calculated for the study area at a scale of 1:12,500, while the Basin Shape Index (Bs) and Asymmetry Factor (Af) were measured following the sub-watersheds included in the study area, which are Cilayu, Ciawi, and Cilaki, at a scale of 1:100,000.

RESULT AND DISCUSSION

Based on the integration of morphographic, morphometric, and morphogenetic analyses conducted on field data and remote sensing data, the geomorphological characteristics of the Cisewu area can be systematically described and interpreted. The following discussion presents the results of each analytical aspect and their synthesis into coherent geomorphological units. Morphographic analysis reveals variations in

landforms and drainage patterns that reflect lithological and structural control.

Landforms

Based on elevation classification, the study area is dominated by two main landforms: high hills (500–925 m a.s.l.) and hills (200–500 m a.s.l.). High hills occupy the northeastern part (Gunung Tumpeng complex) and the southeastern part (along the Cilayu River), formed by resistant volcanic and intrusive rocks. This morphology is the result of tectonic uplift and magmatic intrusion followed by intensive denudation. Meanwhile, hills with moderate elevation dominate the central part of the study area, composed of more erodible volcanoclastic rocks, forming gentler morphology. Low hills (100–200 m a.s.l.) are only locally present in the southern and northeastern parts, generally associated with alluvial plains or rock bodies that have undergone very intensive weathering. The distribution of these landforms shows a strong correlation with lithological distribution and the presence of major fault structures (Figure 4).

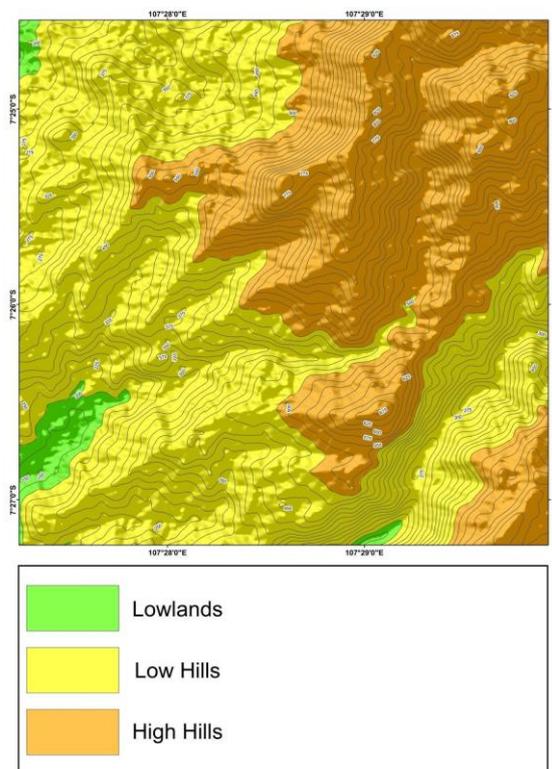


Figure 4. Landform map of study area showing low and high hills dominated (Scale 1:12.500)

Drainage Pattern

The drainage patterns developed in the study area are strongly influenced by geological structures and rock resistance (Howard, 1967; Van Zuidam, 1985). Rectangular and trellis drainage patterns dominate the study area, particularly in the southern and southeastern parts. These patterns are characterized by tributaries joining the main streams at near right angles, indicating strong control by joint and fault systems (Figure 4). Such patterns commonly develop in relatively homogeneous rocks that are dissected by discontinuous structures. In contrast, sub-dendritic drainage patterns are found around the andesite intrusive body (e.g., Gunung Tumpeng). This pattern indicates stronger lithological control than structural control, where massive and homogeneous intrusive rocks cause tributaries to join at more acute angles. The diversity of drainage patterns records the history of tectonic deformation and lithological variation within the study area (Figure 5).

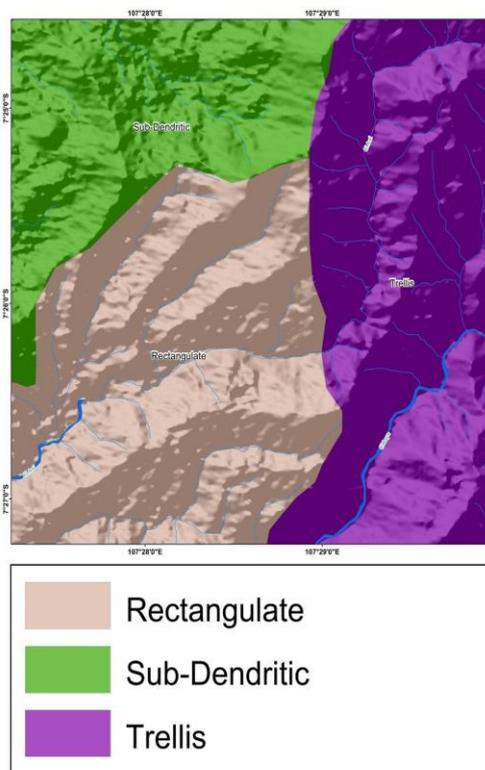


Figure 5. Drainage pattern map of study area (Scale 1:12.500)

MORPHOMETRY

Quantitative slope gradient analysis provides an overview of topographic steepness and its relationship with exogenic processes.

Slope Class Distribution

The DEM processing results show that more than 60% of the study area has steep (16° – 35°) to very steep ($>35^{\circ}$) slopes. These steep to very steep slopes are concentrated in the northern and southeastern parts. This distribution directly reflects the influence of resistant rocks such as andesite and volcanic breccia, as well as the influence of tectonic deformation that created uplift zones. Slopes with slightly steep (8° – 16°) generally dominate areas undergoing moderate vertical erosion (depression) by river systems. Meanwhile, slopes that are flat to slightly sloped (0° – 8°) only occupy very limited areas, mainly in the western part, which is dominated by tuff that is more easily eroded. The dominance of steep slopes has significant implications for landslide susceptibility if the constituent lithology is weathered rock and rainfall patterns are significant (Figure 6). weathered rock and rainfall patterns are significant (Figure 6).

MORPHOGENESIS

The development of the Cisewu landscape is the result of dynamic interactions between endogenic and exogenic processes.

Endogenic Processes

The most influential endogenic processes are volcanism and tectonics. Volcanic activity during the Late Miocene–Pliocene formed the main rock bodies, including andesite lava, volcanic breccia, and tuff. These volcanoclastic materials constitute the primary components in landform development. Subsequently, compressional tectonic activity associated with subduction generated northeast–southwest-trending strike-slip faults. Uplift along these fault zones formed elongated structural ridges and steep fault-controlled valleys, particularly along the Cilayu River. These tectonic

processes are still relatively active during the Quaternary, as indicated by sharp geomorphological features and morphotectonic analysis results.

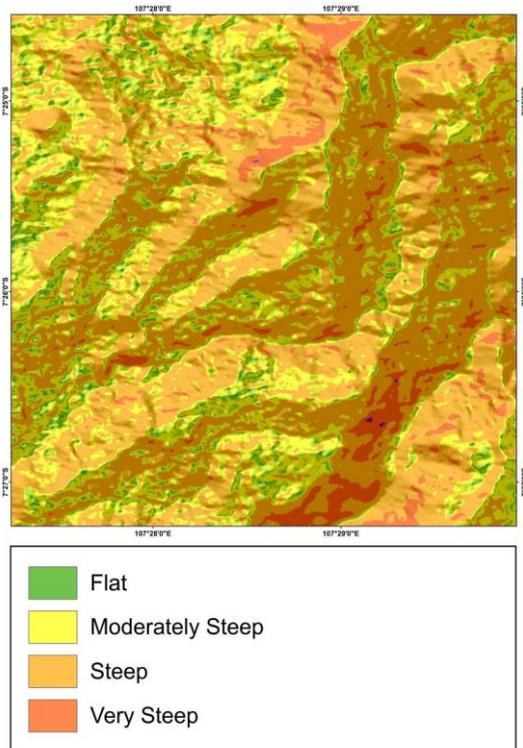


Figure 6. Slope Gradient Map of study area showing the dominance of steep to very steep slopes (Scale 1:12.500)

Exogenic Processes

Exogenic processes act as the main sculpting agents of the uplifted landscape. Chemical and physical weathering occur intensively in volcanoclastic rocks, producing thick soil mantles and loose materials that are easily eroded. Fluvial erosion is the most dominant exogenic process, forming deep V- and U-shaped valleys. Major rivers such as the Cilayu River undergo rapid downcutting in response to tectonic uplift. In addition, mass movement processes such as creep and landslides are very common on steep slopes composed of unconsolidated materials, widening valleys and narrowing ridges.

MORPHOTECTONICS

Quantitative morphotectonic analysis is an approach to determine the relative level of tectonic activity in a region that can be observed through the topography of an area (Nugraha, R.P.D., 2023). In this study, the analysis was carried out by calculating four main geomorphological indices following the

methodology of El Hamdouni et al. (2008), which was applied to three sub-river basins for the Valley Shape (Bs) and Asymmetry Factor (Af) indices, namely the Cilayu River Basin in the east, the Ciawi River Basin in the centre, and the Cilaki River Basin in the west. The Valley Floor Width-Height Ratio Index (Vf) and Mountain Front Sinuosity Index (Smf) were also calculated for the study area. These four indices complement each other in providing an overview of relative tectonic dynamics and identifying active deformation zones. The values of these indices can also be influenced by lithological factors and valley filling processes, in addition to tectonic factors.

Basin Shape Index (Bs)

The Basin Shape Index (Bs) was calculated for the three sub-watersheds (Figure 7a.). The results show that the Cilayu and Ciawi sub-watersheds have a moderate tectonic class, while the Cilaki sub-watershed has a low tectonic class.

Asymmetry Factor (Af)

The results of the Asymmetry Factor (Af) calculation for the three sub-watersheds (Figure 7b.) show varying values but are classified as low tectonic class (Class 3) according to the criteria of El Hamdouni et al. (2008), with values ranging from 46 to 56.2.

Valley Floor Width-to-Height Ratio (Vf)

Based on the calculation of the valley floor width-to-height ratio, values ranging from 0.44–0.50 fall into the active tectonic class, values of 0.85–0.95 into the moderate tectonic class, and values of 1.06–1.61 into the low tectonic class. Areas with active–moderate tectonic classes are distributed in the eastern part, while moderate–low tectonic classes occur in the western part of the study area (Figure 7c.).

Mountain Front Sinuosity (Smf)

The results of mountain front sinuosity calculations show active tectonic class values ranging from 1.07–1.14, moderate tectonic from 1.10–1.40, and low tectonic from 1.60–1.75. Areas with active–moderate tectonic classes are distributed in the eastern part,

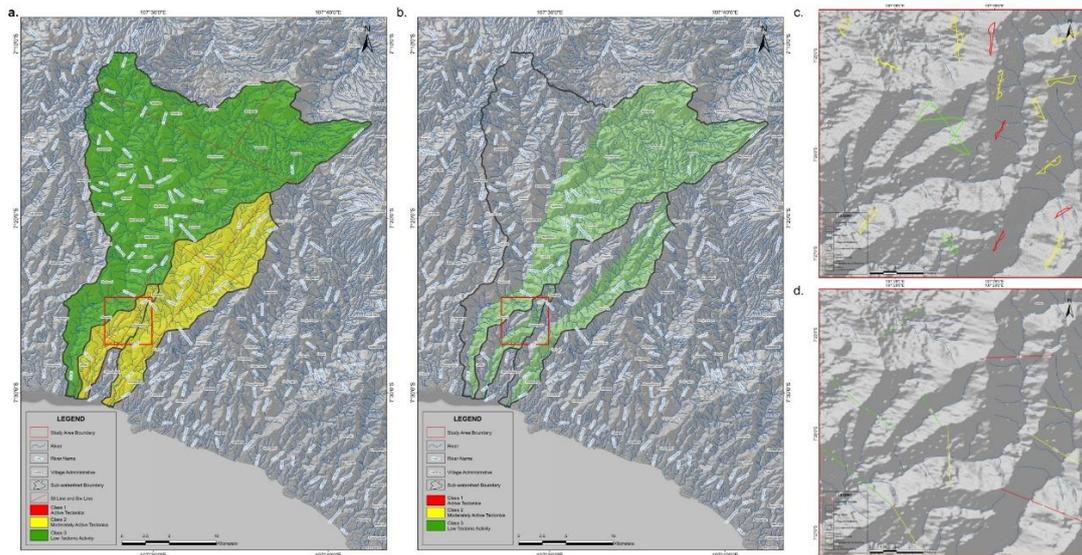


Figure 7. Maps of Geomorphological Indices of the Study Area Showing Bs index (a), Af Index (b), Smf Index (c), and Vf index (d).

whereas moderate–low tectonic classes are found in the western part of the study area (Figure 7d.).

Geomorphological Units

Based on the synthesis of all aspects discussed above, the study area can be divided into five geomorphological units, each of which has distinctive genesis, morphology, and dominant processes (Table 1).

Steep Volcanic Ridge Unit

This unit occupies the northern to northeastern part of the study area (Figure 8a.). It is composed of volcanic rocks (tuff, breccia, and andesite lava) resulting from Miocene–Pliocene volcanic activity. The main forming processes are volcanic accumulation and uplift, followed by denudation that shapes ridge morphology. Steep slopes (16° – 35°) are controlled by rock resistance and jointing. Trellis to rectangular drainage patterns indicate the influence of secondary structures. This unit is relatively stable; however, it is susceptible to surface erosion and landslides in areas with weathered or brittle rocks.

Very Steep Structural Ridge Unit

The constituents of resistant rocks such as andesite, allowing the development of very steep slopes (35° – 55°). Very deep and narrow V-shaped valleys are characteristic of this unit, indicating intensive fluvial downcutting that keeps pace with tectonic uplift. Trellis drainage patterns are well

developed and reflect strong structural control. This unit represents the most tectonically dynamic unit and is located in the southeastern part along the Cilayu River (Figure 8b.). Its formation is primarily controlled by uplift along northeast–southwest-trending strike-slip faults. This unit has very high susceptibility to mass movement hazards and riverbank erosion.

Moderately Steep Volcanic Valley Unit

Occupying the southwestern and northwestern parts of the study area, this unit is composed of less resistant pyroclastic materials such as tuff and lapilli breccia (Figure 8c.). Gently sloping valley morphology with slope gradients of 8° – 16° is formed through dominant lateral fluvial erosion acting on relatively soft and weathered rocks, resulting in wider U-shaped valleys. Structural control in this unit is not as strong as in the structural ridge unit. Exogenic processes such as weathering and sheet erosion are more dominant.

Very Steep Structural Valley Unit

Located within the Cilayu River, this unit is part of an active fault zone (Figure 8d.). Very steep slope gradients (35° – 55°) result from concentrated vertical river erosion within weak zones (fault zones). Rocks along valley walls are composed of andesite. Trellis drainage patterns indicate almost absolute structural control. This unit is highly susceptible to mass wasting processes and riverbank erosion.

Intrusive Dome Unit

This unit is represented by a pyroxene andesite intrusive body that intrudes surrounding rocks, forming a positive dome morphology such as Gunung Tumpeng (Figure 8e.). The main forming processes are magmatic intrusion and exhumation through

denudation. Steep slopes (16° – 35°) develop due to the high resistance of intrusive rocks. Sub-dendritic drainage patterns radiating from the dome summit reflect the massive and homogeneous nature of the intrusive rocks. This unit is geomorphologically stable; however, weathering processes along its margins may generate debris.



Figure 8. Appearance of geomorphological units in the study area, such as Steep Volcanic Ridge Unit (a), Very Steep Structural Ridge Unit (b), Moderately Steep Volcanic Valley Unit (c), Very Steep Structural Valley Unit (d), and Intrusive Dome Unit (d).

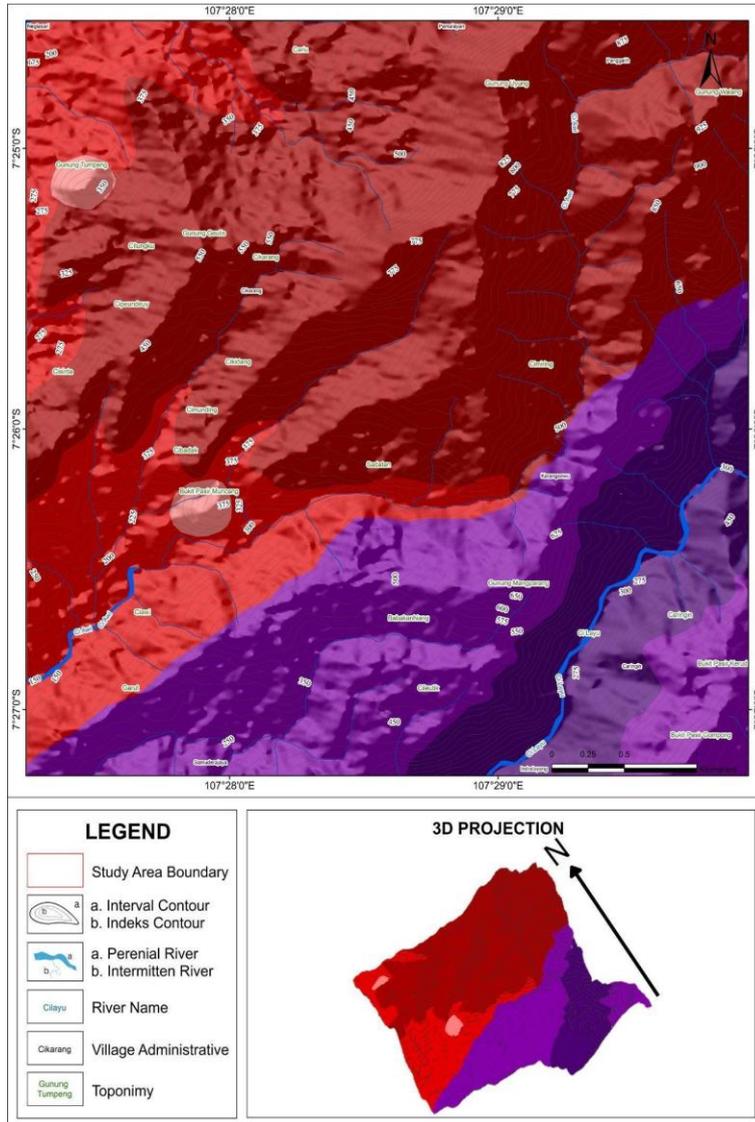


Figure 9. Geomorphological map and 3D projection of the study area

Table 1. Geomorphological units explanations

No	Geomorphological Unit	Symbol	Geomorphological Aspects						
			Morphography			Morphometry		Morphogenetic	
			Landform (masl)	Valley Shape	Drainage Pattern	Slope Class (°)	Endogenous	Exogenous	Constituent Lithology
1	Steep Volcanic Ridge		High Hills (500-925)	V	Trellis-Rectangular	Steep (16-35)	Volcanism	Tuff, Lapilli, and Andesite Lava	
2	Very Steep Structural Ridge		High Hills (500-675)	V	Trellis-Rectangular	Very Steep (35-55)	Tectonics & Volcanism	Andesite Lava and Tuff	
3	Moderately Steep Volcanic Valley		Hills (150-500)	U	Rectangular	Moderately Steep (8-16)	Volcanism	Erosion & Weathering	Tuff, Lapilli, and Breccia
4	Very Steep Structural Valley		Hills (275-500)	V	Trellis	Very Steep (35-55)	Tectonics & Volcanism		Andesite Lava
5	Intrusive Dome		Hills (300-375)	V	Sub-Dendritic	Steep (16-35)	Volcanism		Pyroxene Andesite

CONCLUSION

Based on the integrated analysis of morphography, morphometry, morphogenesis, and morphotectonics, this study concludes that the geomorphology of the Cisewu area consists of five main units formed by the interaction between Late Miocene–Pliocene volcanism and northeast–southwest-trending strike-slip fault tectonic deformation. The drainage pattern is rectangular and trellis-shaped, with steep slopes forming a sharp V-shape on relatively hard andesite rock. This is interpreted as having resulted from geological structural control and is supported by geomorphic indices (Bs, Vf, Af, Smf) indicating relative Quaternary tectonic activity in the Cilayu River, located in the eastern part of the study area. The dominance of steep to very steep slopes and active tectonic conditions increases the susceptibility of the area to landslides. The results of this study can serve as a scientific basis for spatial planning and disaster mitigation in southern West Java.

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