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Geomorphological Study of the Samigaluh Area and Its Surroundings, Kulon Progo Regency, Yogyakarta

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Abstract

Samigaluh District and its surrounding areas, Kulon Progo Regency, Special Region of Yogyakarta, form part of the Kulon Progo Mountains, which lie within the eastern segment of the Southern Serayu Mountains zone. This region exhibits complex geomorphological conditions resulting from the interaction of tectonic activity, volcanism, and ongoing denudational processes. This study aims to provide knowledge and benefits for relevant stakeholders and readers, thereby supporting related scientific fields and areas of expertise. The research method involved field observations combined with analyses using Geographic Information Systems (GIS) and Digital Elevation Model (DEM) data. Geomorphological characteristics were analyzed by correlating drainage patterns, slope gradients, and lithological units to identify landform features within the study area. The results indicate that the geomorphic units in the Samigaluh area consist of Volcanic Denudational High Hills, representing remnants of ancient volcanic edifices that have undergone prolonged weathering and erosion over geological timescales; Intrusive Hills, formed by the intrusion of igneous rocks into surrounding strata and subsequently exposed by erosion; and Karst High Hills, which developed predominantly through carbonate dissolution processes. The diversity of these geomorphic units reflects the strong influence of geological dynamics on the landscape evolution of the study area.

1. Introduction

Geomorphology is the study of the Earth's surface forms. It is divided into four main aspects: morphology, morphogenesis, and morphochronology [1]. The morphological aspect includes morphometry, which concerns the size and shape of Earth's surface, and morphography, which describes surface patterns and structures. Geomorphological studies are essential because landforms not only reflect the geological history and tectonic dynamics of a region, but also directly influence hydrological conditions, slope stability, land use, and natural hazard potential.

The Samigaluh District, Kulon Progo Regency, is part of the Kulon Progo Mountains, located in the southern part of Central Java and included within the eastern segment of the Southern Serayu Mountains zone. The Kulon Progo Mountain range lies within the Southern Zone of Central Java and, overall, constitutes a plateau [2]. The Kulon Progo area has experienced three phases of tectonic activity [2] [3] [4]. The first tectonic phase occurred during the Early Oligocene and was accompanied by volcanic activity. The second phase took place in the Early Miocene and involved subsidence of the Kulon Progo area. Subsequently, the third phase occurred from the Pliocene to the Pleistocene, characterized by tectonic uplift and renewed volcanic activity. The stratigraphic framework of the Kulon Progo Mountains can be divided into sedimentary rock units and volcanic rock units [5]. The sedimentary rocks forming the basement are dominated by claystone, quartz sandstone, and limestone, collectively referred to as the Nanggulan Formation. These sedimentary rocks serve as the basement for the volcanic rocks of the Kebobutak Formation. Both the Nanggulan and Kebobutak formations are intruded by shallow intrusive rocks, including microdiorite, andesite, and dacite, which have generally undergone alteration [6]. Shallow-marine deposits of the Jonggrangan and Sentolo Formations unconformably overlie this volcanic rock assemblage.

The Tertiary volcanic rock units that have undergone uplift and deformation form distinctive structural and denudational relief, expressed as undulating to steep hilly terrain with pronounced elevation and slope contrasts. Variations in lithology and geological structure act as the main controlling factors in the development of landforms, drainage patterns, and the distribution of geomorphological units within the study area. Geomorphological conditions characterized by steep slopes, narrow valleys, and structurally controlled river networks make the Samigaluh area prone to environmental problems, including landslides and land degradation. Therefore, this geomorphological study in the Samigaluh area aims to systematically analyze morphographic, morphometric, and morphogenetic characteristics to identify and classify geomorphological units, determine the dominant geomorphic processes, and identify indicators of active denudation and landslide susceptibility. The results are expected to provide a scientific basis for understanding regional geomorphology and to support hazard assessment, spatial planning, or environmental management.

2. Methodology

This study was conducted through field observations and studio analysis. Geomorphological observations were carried out by taking photographs of field conditions and through direct observation, which were then analyzed and correlated with other supporting variables, including drainage patterns, slope gradients, and the constituent lithology. These geomorphological observations encompass the morphological conditions and landscape characteristics of the study area.

Studio analysis was performed using various Geographic Information Systems (GIS) software. This analysis focuses on the landforms present in the study area, as interpreted from the land surface, and on the processes that influence their development. Geomorphological analysis was carried out by examining the Digital Elevation Model (DEM) of the study area and supported by direct observations of geomorphological conditions at the research location. The Digital Elevation Model (DEM) data used in this study were obtained from the National DEM (DEMNAS) provided by the Geospatial Information Agency of Indonesia, with a spatial resolution of approximately 8 m represented by a cell size of 0.000075° × 0.000075° in the WGS 84 geographic coordinate system. This resolution is considered adequate to support regional-scale geomorphological analysis in the Samigaluh District. This GIS workflow began with a data preprocessing stage that included coordinate system reprojection and DEM clipping within the study area boundaries. Subsequently, DEM-derived analyses were performed, including the generation of contour maps, slope, and hillshade to depict the relief characteristics, elevation, and surface morphology of the study area, which were classified based on specific classification schemes. Slope classification criteria followed the geomorphometric classification proposed by Widyatmanti [7], which divides slope gradients into seven classes: flat (0–2%), very gentle (3–7%), gentle (7–13%), moderately steep (14–20%), steep (21–55%), very steep (56–140%), and extreme (>140%). This classification was applied to identify slope steepness levels and their relationships with geomorphological processes operating in the study area. Morphographic analysis was carried out based on elevation data to group landforms into several classes, namely plains (<50 m), low hills (50–200 m), hills (200–500 m), high hills (500–1000 m), and mountains (>1000 m), following the elevation criteria proposed by Widyatmanti [7]. Drainage pattern analysis was performed through DEM-based hydrological analysis, including the determination of flow direction and flow accumulation. The drainage network was extracted from the flow accumulation results using a threshold value adjusted to the area's morphological conditions. Drainage patterns were then identified and classified visually and analytically based on their geometric characteristics and orientations, referring to the drainage pattern concepts proposed by Twidale [8].

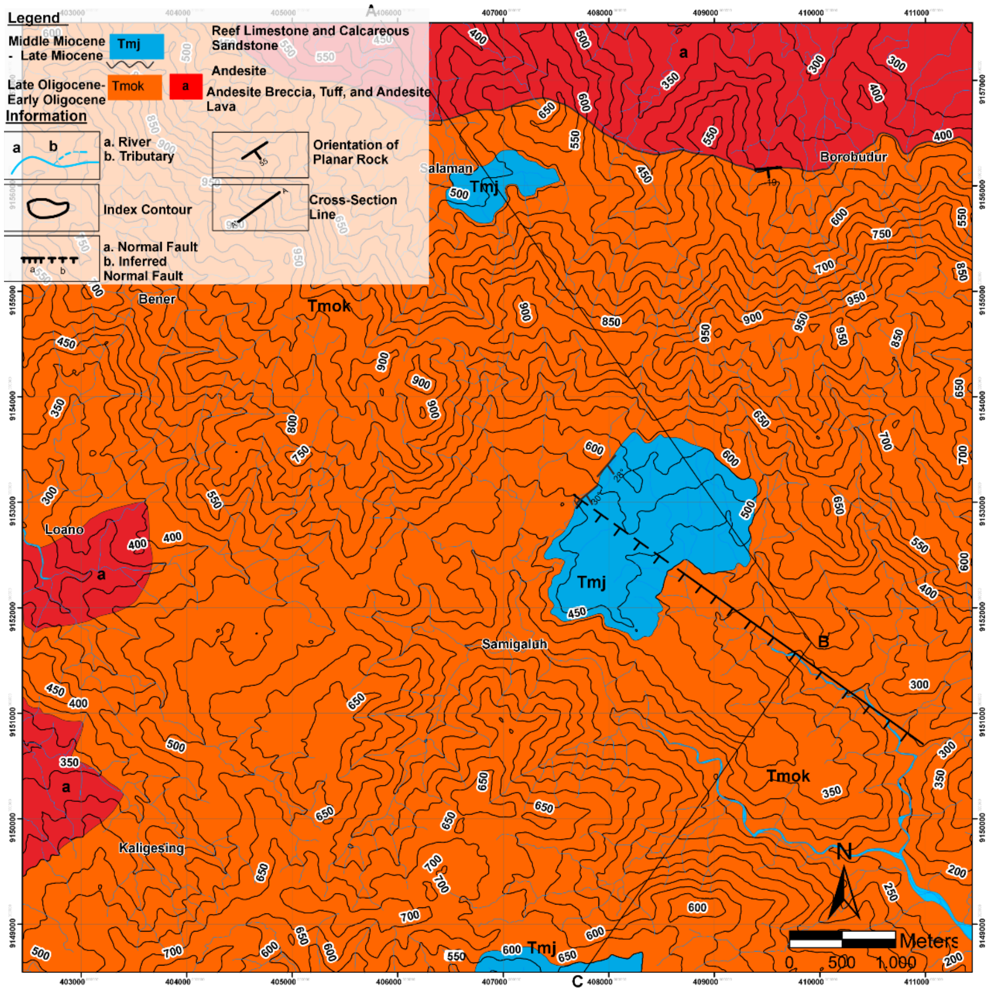

Figure 1. Geological Map of the Study Location

Geomorphological unit delineation was conducted by integrating several parameters, including slope gradient, elevation, drainage pattern, lithology, and geological structures, obtained from field observations and GIS analyses. In addition, the analysis considered the role of denudational processes, including landslide-related denudation, using the mass movement classification proposed by Varnes. The classification of geomorphological units subsequently follows the concepts and terminology proposed by Brahmantyo [9], Charlton [10], and Widyatmanti [7], such that the resulting landform units reflect a combination of morphometric and morphographic conditions and the geological controls of the study area.

3. Results and discussions

This study was conducted in the Samigaluh District and its surrounding areas, Kulon Progo Regency, Yogyakarta Province, covering a research area of 9 × 9 km. Samigaluh District is one of the districts within Kulon Progo Regency, Special Region of Yogyakarta, and is located approximately 40 km from the regency capital. Geographically, Kulon Progo Regency, Yogyakarta Province, is situated between 7°38′42″–7°59′03″ South Latitude and 110°01′37″–110°16′26″ East Longitude.

Geologically, the study area consists of three formations, arranged from the oldest to the youngest: the Kebobutak Formation (Tmok), the Andesite Formation (a), and the Jonggrangan Formation (Tmj) (Figure 1). Based on detailed field observations and lithological identification conducted during the field survey, the Kebobutak Formation (Tmok), dated to the Late Oligocene–Early Miocene, is composed of volcanic breccia units with andesite fragments, tuff, and andesitic lava. This formation was subsequently intruded by the Andesite Formation, which consists predominantly of andesite rocks. The Jonggrangan Formation, dated to the Middle–Late Miocene, is composed of reef limestone and calcareous sandstone.

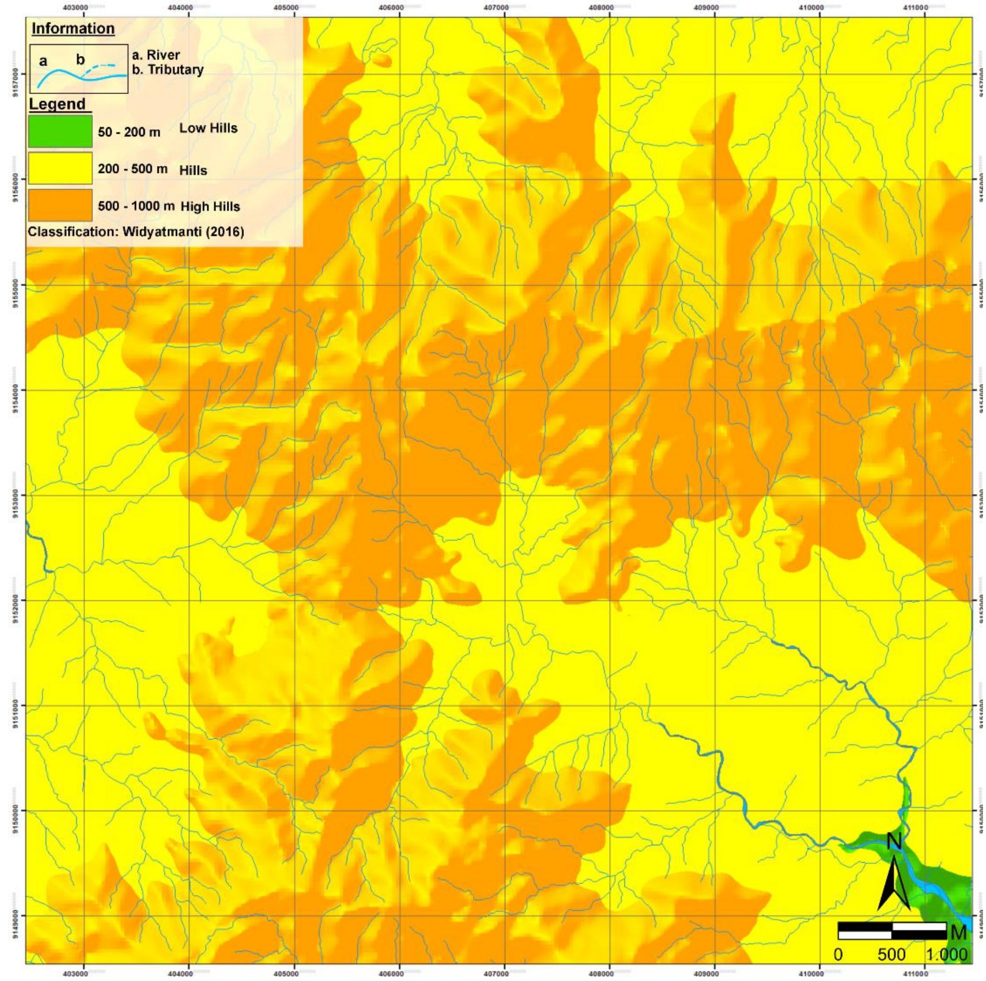

Figure 2. Morphological Elevation Map of the Study Location

The geomorphological aspects analyzed in the study area are generally divided into three main components: morphography, morphometry, and morphogenesis, along with the dynamic element, which describes the processes responsible for the formation and evolution of landforms or morphological features. Based on these aspects, several thematic maps were produced, including morphological elevation maps, slope gradient maps, drainage pattern maps, and geomorphological modelling outputs.

3.1. Morphographic Analysis

Morphography is a geomorphological aspect defined by the landform types present within the study area. This study indicates variations in landscape forms, ranging from lowlands to mountainous regions, each characterized by distinct topographic features and elevation ranges. Morphographic analysis was conducted to identify and describe the landform units present within the study area, including lowlands, hills, and mountains. Morphography is classified into five categories, namely lowland (<50 m), low hills (50–200 m), hills (200–500 m), high hills (500–1000 m), and mountains (>1000 m) [7]. The study area comprises three landform classifications: low hills with elevations of 50–200 m above sea level, covering 5% of the study area and represented by green color; hills with elevations of 200–500 m above sea level, covering 45% of the study area and represented by yellow color; and high hills with elevations of 500–1000 m above sea level, covering 50% of the study area and represented by orange color. The morphological elevation map and 3D elevation model are shown in Figure 2. The distribution of landforms in the Samigaluh area, which is dominated by hilly to high-hilly terrain, indicates the strong influence of the Kulon Progo Mountains' tectonics on the region's geomorphological development. This condition makes the area vulnerable to landslides and land degradation, particularly in high-elevation, steep-slope areas.

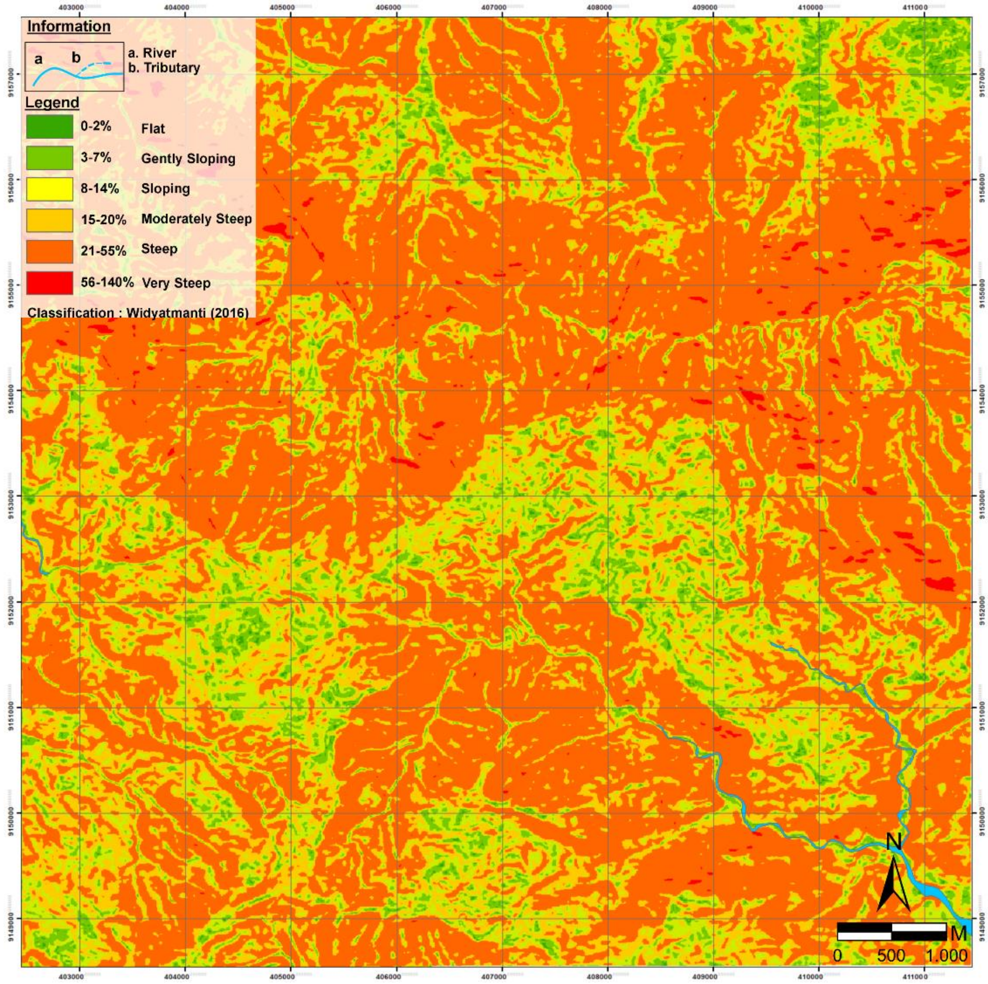

Figure 3. Slope Gradient Map of the Study Location

3.2. Morphometric Analysis

Morphometry represents the quantitative aspect of landforms and surface relief. Morphometric analysis of the study area was conducted using quantitative landform parameters, including elevation, slope gradient, and river drainage patterns, which influence the region's morphological development. Slope classes were classified based on Widyatmanti [7], consisting of seven categories: flat (0–2%), very gentle (3–7%), gentle (7–13%), moderately steep (14–20%), steep (21–55%), very steep (56–140%), and extremely steep (>140%).

In the study area, six slope classes were identified: flat slopes (0–2%) covering 15% of the study area and represented by dark green color; very gentle slopes (3–7%) covering 10% and represented by green color; gentle slopes (7–13%) covering approximately 7% and represented by light green color; moderately steep slopes (14–20%) covering approximately 8% and represented by yellow color; steep slopes (21–55%) dominating the study area with 55% coverage and represented by orange color; and very steep slopes (56–140%) covering approximately 5% of the study area and represented by red color. The slope gradient map of the study area is presented in Figure 3.

3.3. Morphogenesis Analysis

Morphogenesis is the study of how landforms on the Earth's surface develop and change over time. Landforms result from geomorphological processes acting on Earth's materials [11]. These landforms are influenced by internal (endogenic) forces, such as tectonic activity and volcanism, as well as external (exogenic) forces, including weathering, erosion, and sedimentation. Geomorphic processes are physical and chemical processes that alter landforms through changes in Earth's surface configuration.

Figure 4. (a) Translational landslide in Purwoharjo Village, (b) Translational landslide in Purwoharjo Village, and (c) Translational landslide in Pagerharjo Village.

Geomorphic processes are influenced by morphostructural conditions, which comprise three key aspects: active morphostructure, passive morphostructure, and morphodynamic processes. Active morphostructure refers to endogenic processes that directly modify the Earth's crust, such as volcanism, tectonic uplift, folding, and faulting, which establish the primary structural framework of a landscape. Passive morphostructure is associated with lithological characteristics and pre-existing geological structures that influence how the landscape responds to surface processes, particularly denudational processes such as weathering and erosion. Morphodynamics focuses on the physical and chemical processes that actively operate at the Earth's surface, controlling the rates and mechanisms of landform modification under the influence of climate, hydrology, and gravity.

Within the study area, evidence of denudational processes was identified in the form of landslides occurring in several villages. Three landslide locations were identified in Purwoharjo Village and Pagerharjo Village. Based on the classification system proposed by Varnes [12] and later adopted by Highland and Bobrowsky [13], the landslides observed in the study area are categorized as translational landslides (Figure 4). Translational landslides are a type of mass movement in which soil or rock masses move downslope along a relatively planar or gently inclined slip surface, with little rotational movement or backward tilting. This type of landslide commonly occurs on relatively gentle slopes.

River morphogenesis can be interpreted across multiple spatial scales, ranging from detailed channel-reach morphology to broader regional drainage network configurations. At the reach scale, river channel form and behavior are governed by the interaction between flow energy, sediment supply, channel gradient, and boundary conditions such as bank material and vegetation. Variations in these controlling factors result in the development of distinct channel types, including straight, meandering, braided, or anabranching systems, each reflecting the dominance of specific fluvial processes such as erosion, transportation, and deposition [14]. These fluvial processes are integrated into drainage networks whose spatial arrangement is expressed through drainage patterns.

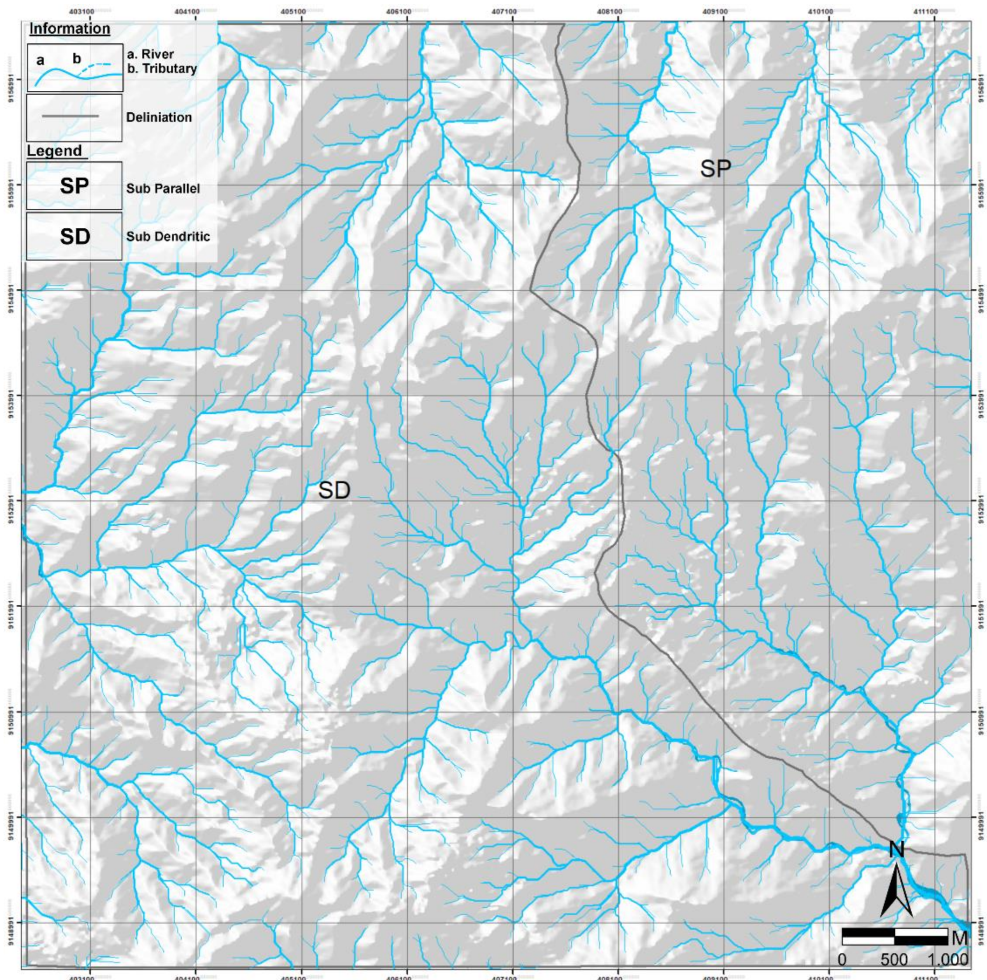

Figure 5. Map and Rose Diagram of Drainage Patterns in the Study Area [8] [15].

River drainage patterns represent the spatial arrangement of main rivers and their tributaries within a region. These patterns evolve due to erosional processes and the characteristics of the underlying rock formations [10]. Drainage pattern development is influenced by several interrelated factors, including geological structures (e.g., faults, folds, and joints), lithological contrasts, initial land surface morphology, and inherited features from past geological and geomorphological processes. Consequently, drainage patterns can be used as indicators of structural control and landscape stability.

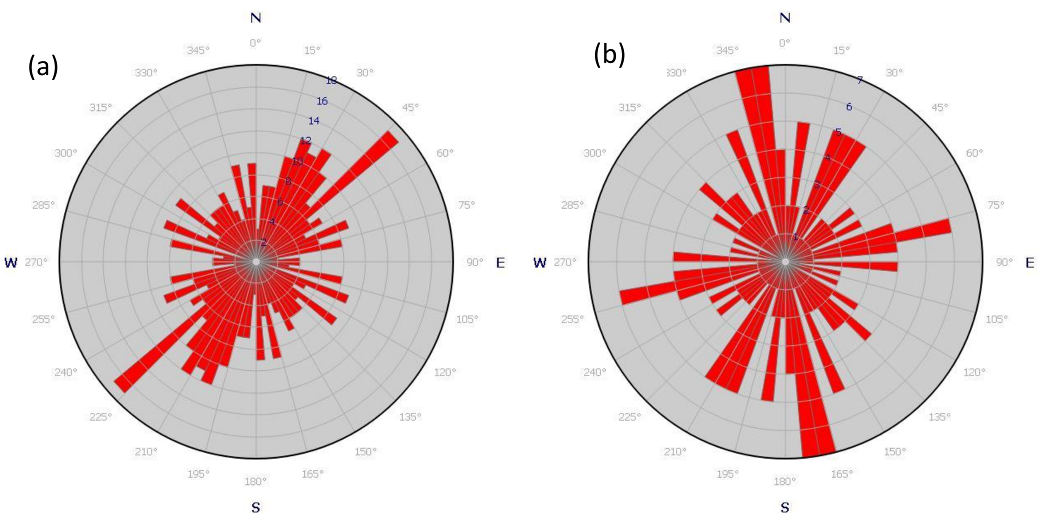

Figure 6. (a) Rose Diagram of Sub Dendritic Patterns and (b) Rose Diagram of Sub Paralel Patterns

In the study area, drainage patterns are classified into two types by Twidale [8] and Howard [15]: sub-dendritic and sub-parallel (Figure 5). The sub-dendritic drainage pattern occupies 71% of the study area. This pattern is characterized by irregular, relatively complex tributary branching, indicating limited structural control over channel orientation. Sub-dendritic drainage commonly develops in areas dominated by relatively homogeneous lithology and gentle topographic gradients, where surface slope rather than geological discontinuities primarily dictate river flow directions. Rose diagram analysis indicates that the dominant orientations of the sub-dendritic pattern are N–S and W–E (Figure 6).

The sub-parallel drainage pattern covers 29% of the study area. This drainage type typically develops on moderately inclined slopes or in areas where subtle structural or lithological controls influence channel alignment. Although the channels are not perfectly parallel, the overall uniformity in flow direction reflects the combined influence of topographic gradients and structural lineaments. Rose diagram analysis shows that the dominant orientations of the sub-parallel drainage pattern are SW–NE or SE–NW, indicating the influence of structural and topographic controls (Figure 6).

3.4. Geomorphic Units

The determination of geomorphic units is the process of identifying and classifying landforms into distinct units based on their morphological characteristics, formative processes, and other controlling factors. The delineation of geomorphic units in the study area was based on elevation, lithological units, contour patterns, drainage patterns, and slope gradients, following the approaches of Brahmantyo [9], Charlton [10], and Widyatmanti [7]. Based on the results of these analyses and field observations, the geomorphic units in the study area were classified into Volcanic Denudational High Hills (PTDG), Volcanic Residual Hills (PSV), Intrusive Hills (PI), and Karst Hills (PK).

3.4.1 Volcanic Denudational High Hills

Volcanic Denudational High Hills are relief forms characterized by hilly to upland terrain that represent a district geomorphic unit within the study area [9]. These landforms originally constituted parts of ancient volcanic edifices, which have undergone prolonged erosion and weathering over geological timescales. This geomorphic unit occupies approximately 31% of the study area (Figure 7). It is characterized by elevations ranging from 500 to 1000 m above sea level and slope gradients classified as steep to very steep [7]. The landforms within this unit are predominantly composed of volcanic breccia.

Figure 7. Volcanic Denudational High Hills in Ngargosari Village

Figure 8. (a) Karst cave in Purwoharjo Village and (b) karst cave ornament in the form of stalactite

3.4.2 Karst High Hills
Karst high hills represent a distinctive geomorphological unit within the study area, characterized by steep hills, caves, and closed depressions [9]. These landforms develop through the dissolution of carbonate rocks, primarily limestone and dolomite, by acidic water. Karst typically develops in areas with high rainfall and complex subsurface drainage systems. The main characteristics of karst hills include irregular landforms, rocky, sharp surfaces (lapies), and limited surface runoff due to rapid infiltration of water into subsurface fractures and conduits.

In the study area, karst high hills are characterized by karst caves formed by dissolution processes that create subsurface tunnels, as well as stalactites that form when water percolates through the cave ceilings (Figure 8). This geomorphic unit occupies approximately 16% of the study area. It is characterized by elevations of 500–1000 m above sea level and slope gradients ranging from gentle to steep [7]. The landforms in this unit are dominated by reef limestone lithology.

Figure 9. Intrusive Hills in Borobudur Subdistrict

3.4.1 Intrusive High Hills

Intrusive hills are landforms characterized by hilly relief that represent a distinct geomorphic unit within the study area [9]. These landforms are formed from intrusive igneous rocks that penetrated the surrounding rock layers beneath the Earth's surface and were subsequently exposed by the erosion and weathering of the overlying materials. This geomorphic unit occupies approximately 21% of the study area. The landform expression of this unit is shown in Figure 4.9. It is characterized by elevations ranging from 200 to 500 m above sea level and slope gradients from flat to steep [7]. The landforms in this unit are composed predominantly of andesite.

4. Conclusion

The geomorphological study in Samigaluh District, Kulon Progo Regency, indicates that tectonic history, volcanic activity, lithological variations, and ongoing denudational processes strongly influence the regional landscape's development. The study area is dominated by hilly to high-hill landforms with elevations ranging from 200 to 1000 m above sea level, reflecting the uplift and deformation of Tertiary volcanic rocks associated with the tectonic dynamics of the Kulon Progo Mountains. Morphographic and morphometric analyses show that steep to very steep slopes dominate more than half of the study area, while river drainage patterns are generally sub-dendritic and sub-parallel, indicating the combined influence of relatively homogeneous lithology, slope gradients, and geological structural control.

Morphogenetic analysis reveals that landform development in the study area is controlled by endogenic processes, such as tectonic uplift, volcanic activity, and igneous intrusions, as well as exogenic processes including weathering, erosion, and mass movement. The presence of active denudational processes is evidenced by several occurrences of translational landslides, particularly in steep and high-elevation zones, indicating a high susceptibility of the area to landslide hazards and land degradation. Based on the integration of DEM analysis, GIS-based interpretation, and field observations, the geomorphic units in the study area can be classified into Volcanic Denudational High Hills, Volcanic Residual Hills, Intrusive Hills, and Karst Hills, each characterized by distinct elevations, slope gradients, lithology, and formative processes.

References:

[1] N. Nasrudin, A. R. Nugroho and Nurlina, Buku ajar geomorfologi: Konsep dan implementasi, Banjarmasin : Universitas Lambung Mangkurat, 2020, pp. 1-8.

[2] I. Syafri, E. Budiadi, and A. Sudradjat, "Geotectonic Configuration of Kulon Progo Area, Yogyakarta," *Indonesian Journal of Geology*, vol. 8 (4), pp. 185-190, 2013, doi : 10.17014/ijog.8.4.185-190.

[3] W. Rahardjo, S. Rumidi and H. Rosidi, "Geological map of the Yogyakarta Quadrangle, Java, skala 1 : 100.000," Geological Survey of Indonesia, 1977.

[4] A. Pulonggono and S. Martodjojo, "Perubahan Tektonik Paleogen-Neogen merupakan Peristiwa Tektonik Terpenting di Jawa," in *Geologi dan Geoteknik Pulau Jawa sejak Mesozoik Akhir hingga Kuarter*, Yogyakarta, 1994.

[5] M. Zakaria, S. Kusumayudha, I. Mutoriz and B. Wijaya, "Stratigraphy of the Kulon Progo Zone, Yogyakarta, Indonesia," *Iraqi Geological Journal*, vol. 58 (2C), pp. 202-214, 2025.

[6] H. Pringgoprawiro and B. Riyanto, "Formasi Andesit Tua suatu Revisi," *Inst.Technologi Bandung, Dept.Geology, Contr*, pp. 1-29, 1988.

[7] W. Widyatmanti, I. Wicaksono and P. D. R. Syam, "Identification of topographic elements composition based on landform boundaries from radar," *IOPScience*, p. 4, 2016.

[8] C. Twidale, "River Patterns and Their Meaning," *Earth-Science Reviews*, vol. 67, pp. 159-218, 2004, 10.1016/j.earscirev.2004.03.001.

[9] B. Brahmantyo and Bandono, "Klasifikasi Bentuk Muka Bumi (Landform) untuk Pemetaan Geomorfologi pada Skala 1:25.000 dan Aplikasinya untuk Penataan," *Jurnal Geoaplika*, vol. 1 (2), pp. 71-78, 2006.

[10] R. Charlton, "Fundamentals of Fluvial Geomorphology," *Routledge*, 2008.

[11] R. J. Huggett, Fundamentals of Geomorphology (4th ed.), Newyork: Routledge, 2017.

[12] D. Varnes, "Slope Movement and Typea of Processes," in *Landslides, Analysis and Control Transportation Research Board, National Academy of Science*, 1978.

[13] L. M. Highland and P. T. Bobrowsky, "The Landslide Handbook: A Guide to Understanding Landslides," *U.S. Geological Survey Circular 1325,* p. 129, 2008.

[14] J. M. Buffington and D. R. Montgomery, "Geomorphic classification of rivers," in *J. F. Shroder Jr. & E. Wohl (Eds.), Treatise on Geomorphology,Academic Press*, 2013, doi : 10.1016/B978-0-12-374739-6.00263-3.

[15] A. Howard, "Drainage Analysis in Geologic Interpretation: A Summation," *The American Association Of Petroleum Geologist Bulletin*, vol. 51(11), pp. 2246-2259, 1967.