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Geomorphological Survey and Mapping Practice for Physical Characteristics at Precet Forest Park Study

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ABSTRACT

Geomorphology is a field of study that focuses on landforms and the natural processes that shape the earth's surface. The physical characteristics of an area are important for determining land use suitability, environmental management, and disaster risk mitigation, especially in volcanic regions. This study aims to carry out a geomorphological survey and mapping of Precet Forest Park, located on the slopes of Mount Kawi, East Java. The research uses a descriptive quantitative approach by combining field surveys and geospatial data analysis. Primary data were obtained from Total Station measurements, GPS tracking, and observations of land use, landforms, and soil characteristics. Meanwhile, secondary data such as DEMNAS, geological maps, and soil type maps from official sources were used to support the analysis. The morphometric data were processed using interpolation methods including Kriging, Minimum Curvature, and Polynomial techniques through Surfer and QGIS software. The results showed that the study area is dominated by volcanic landforms with Cambisol soils that have a silty clay texture. The topography is characterized by steep to undulating slopes with varying soil permeability and saturation levels, which affect slope stability. Mass movements such as slumps were identified in several locations. The findings of this research are expected to support land use planning and environmental management efforts, as well as serve as a learning reference for geography students in applying geomorphological mapping techniques in the field.

INTRODUCTION

Geomorphology is a field of science that studies the shape of the Earth's surface and the geological processes that occur exogenously or endogenously to reveal the characteristics and distribution of specific types of lithology (Firmansyah et al., 2023). The object of study of geomorphology is landforms. Landforms that are the primary concern of geomorphology include their nature, geomorphic processes, constituent materials, genesis (origin), context within the environment, and spatial aspects (Dibyosaputro & Haryono, 2020). A landform is a part of the Earth's surface that exhibits specific characteristics resulting from the action of natural elements on the Earth's surface, commonly referred to as geomorphological processes.

The geomorphological condition of an area is a natural resource because it plays a crucial role in the lives of humans and other living things, as well as in the environment (Askoni & Sarminah, 2018). One of the components of these natural resources is land resources, the utilisation of which must be done optimally to get maximum results. However, this utilisation needs to be done wisely so as not to cause damage to the land. The physical characteristics of land, including relief, soil type, surface rock, and hydrological conditions, must be considered in sustainable land use (Prabaningrum et al., 2019).

Information on the geomorphology of an area is a key foundation for land use planning and management (Amadia et al., 2024). Therefore, geomorphological survey and mapping are necessary to provide accurate spatial information that supports sustainable land use. While previous studies have demonstrated the significance of geomorphological mapping in various contexts, many have relied primarily on either remote sensing or descriptive approaches. This research offers a new contribution by integrating field-based Total Station measurements with DEMNAS and advanced interpolation techniques (Kriging, Minimum Curvature, Polynomial) in Surfer and QGIS to generate both 2D and 3D morphometric visualisations. This integrated approach strengthens slope stability analysis and provides a methodological reference for geomorphological field practice in educational and applied settings.

Wagir District has topographic conditions characterised by foothills, central slopes, and upper slopes, with an undulating and hilly morphology. The Wagir District is located at an altitude of 474 meters above sea level (masl). Part of the area is hills on the slopes. The research was conducted in Precet Forest Park.

Precet Forest Park is one of the natural tourist attractions developed by residents. Precet Forest Park is located on the central slope of Mount Kawi. The morphological condition of the Precet Forest Park area features undulating formations in the field area, with some hills used for vegetable cultivation. The purpose of this research is to conduct a geomorphological survey and mapping, including visualising morphometric data, to facilitate understanding of the research context.

RESEARCH METHODS

Research Location

The research was conducted in Precet Forest Park, Sumbersuko Village, Wagir District, Malang Regency, located at coordinates 112°30'40"E and 7°59'54"S with an altitude of 474 meters above sea level. The study area lies on the slope of Mount Kawi, a volcanic landscape characterised by an undulating to hilly morphology. This location was chosen because it represents a typical volcanic landform system, where geomorphological processes such as erosion, slope instability, and mass movement can be directly observed. For more details, see Figure 1.

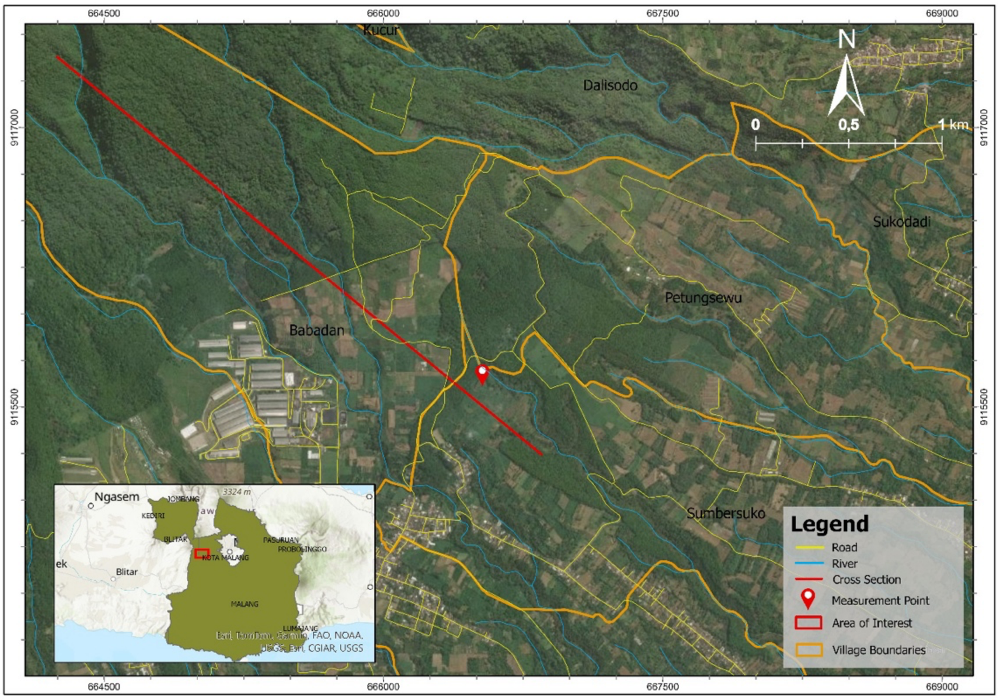


Figure 1. Location Area (Source: Data Processing, 2025)

Data Collection

The data used in this study comprises both primary and secondary data. Primary data were obtained directly from field measurements conducted by researchers, including coordinate data of sampling locations, Total Station measurement data, land use information, and soil chemistry test results. Meanwhile, secondary data is data obtained indirectly and sourced from data providers who have permits, such as DEMNAS obtained through the INAGEO Portal, Land Type Maps obtained from the Sultan of Agriculture's Office, and Google View Images through Google Earth.

Data Processing

Data were processed using QGIS and Golden Surfer software to visualize morphometric characteristics of the study area. Interpolation analysis was applied to estimate values in areas without direct measurement, thereby generating continuous surface data (Sattari et al., 2017; Utomo, 2019). In this study, three interpolation methods were used, namely Kriging, Minimum Curvature, and Polynomial interpolation. The Kriging method was applied to estimate the value of a point by utilising the semivariogram structure model, which reflects the statistical similarity between measured values (Putra et al., 2017; Sabihi et al., 2022). Meanwhile, the Minimum Curvature method was employed to generate surfaces as smoothly as possible, thereby minimising irregular indentations and producing a continuous representation of topographic conditions (Siregar, 2009). Additionally, the Polynomial method was employed to estimate the middle trend of the data with greater precision, yielding sequential input points that enable more accurate interpolation results (Hartomo, 2006).

Data Analysis

Morphometric analysis was performed using the Van Zuidam & Cancelado (1979); Van Zuidam (1985) geomorphological classification system, which categorises landforms based on absolute elevation and slope gradient. Absolute elevation was divided into five classes, ranging from lowland areas to mountains (Table 1). Meanwhile, slope was divided into four classes, from flat terrain to very steep slopes, each associated with a distinct morphological unit (Table 2).

Table 1. Relationship of absolute height with topography

No	Absolute height	Topography Class
1	< 50 meters	Lowland
2	50 meters – 200 meters	Low hills
3	200 meters – 500 meters	Hills
4	500 meters – 1,000 meters	High hills
5	>1000 meters	Mountains

(Source: Van Zuidam & Cancelado, 1979)

Table 2. Morphology classes based on slope and height difference

No	Slope (%)	Slope Class	Morphological Unit
1	0 - 8	Flat	Plain
2	>8 - 15	Sloping	Smooth relief hills
3	15 - 25	A Little steep	Medium relief hills
4	>45	Very steep	The relief hills are very rough

(Source: Van Zuidam, 1985)

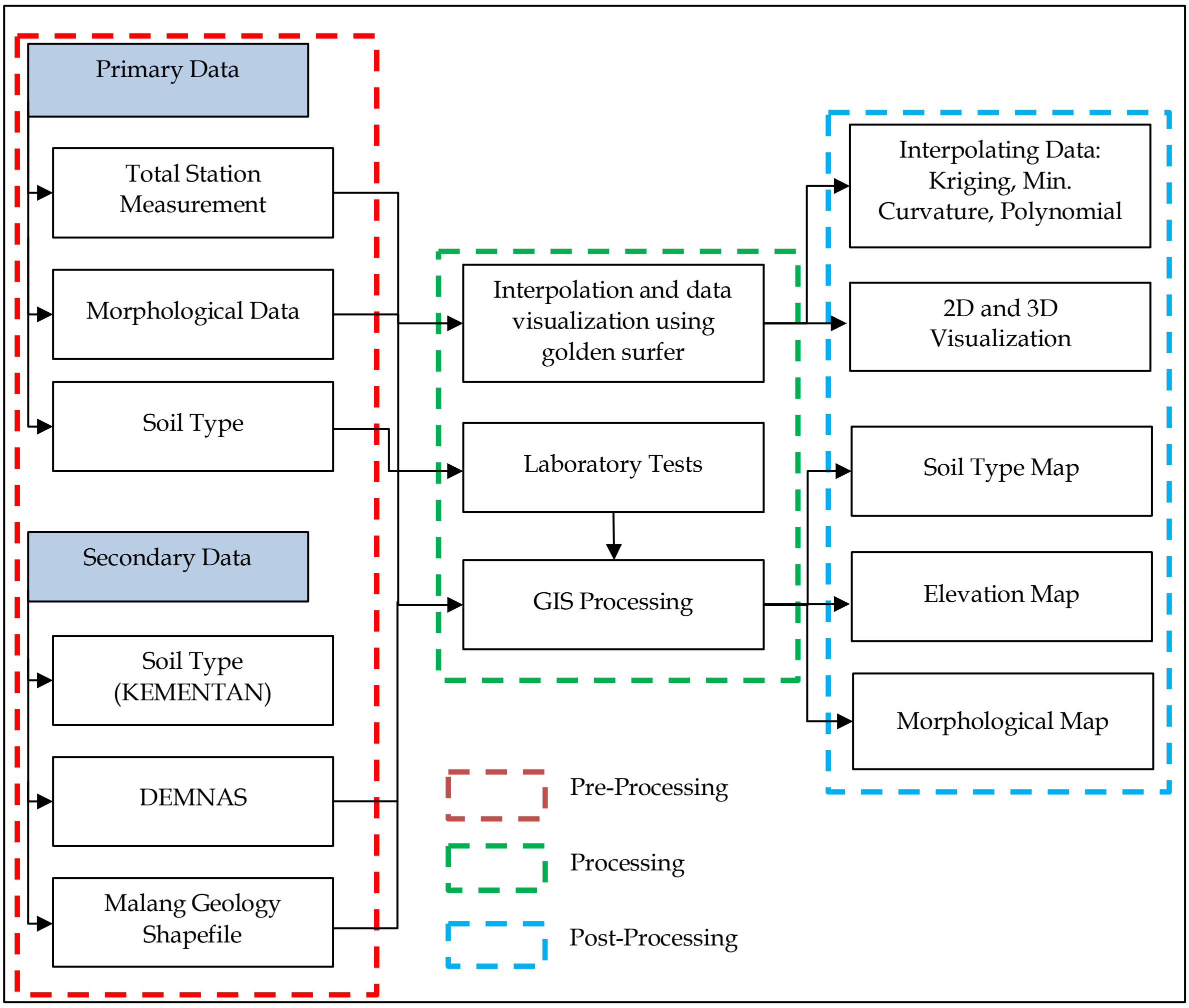


Figure 2. Flow Chart (Source: Author, 2025)

RESULTS AND DISCUSSION

Morphology of Sumbersuko Village Area

The morphological classification of the region was studied based on field observations and GIS analysis, utilising the Van Zuidam classification based on DEMNAS data. DEMNAS was chosen because it has a detailed raster resolution, unlike SRTM, which has a resolution of 30 meters. In contrast, the spatial resolution of DEMNAS is 0.27 arcseconds, or approximately 8 meters (Sulistiana, 2019). DEM is a structured grid of numerical values that represents the spatial distribution of elevations relative to a specific reference datum within a given landscape (Moore et al., 1991). The map created is divided into two parameters, namely: regional morphology and regional topography. Meanwhile, the land shape can be analysed during surveys and field observations. Map creation is carried out using ArcGIS Pro software.

Based on the geological map scale of 1:100,000, Sumbersuko village is composed of the Kawi-Butak Volcanics formation, which consists of constituent materials including andesite-basalt pyroxene lava, breccia, and sandy tuff. The topographic map of the study is classified based on the elevation of the DEM. The classification for topographic maps is divided into two classes: 500-1000 meters above sea level, which is an area with topography located on the middle slope, and at an altitude of > 1000 meters above sea level, it is categorised as the upper slope. The creation of contours is a sign of the division of regional topography. The contour lines have an interval of 20 meters. The research area is situated on the upper slope, with an elevation of 1,060 meters above sea level.

The morphology of the study area, in the form of a wavy area, can be analysed through a cross-section with a slope of up to 8°, categorised as sloping. The research location has a unique characteristic, namely, a boundary basin between undulating and hilly morphologies.

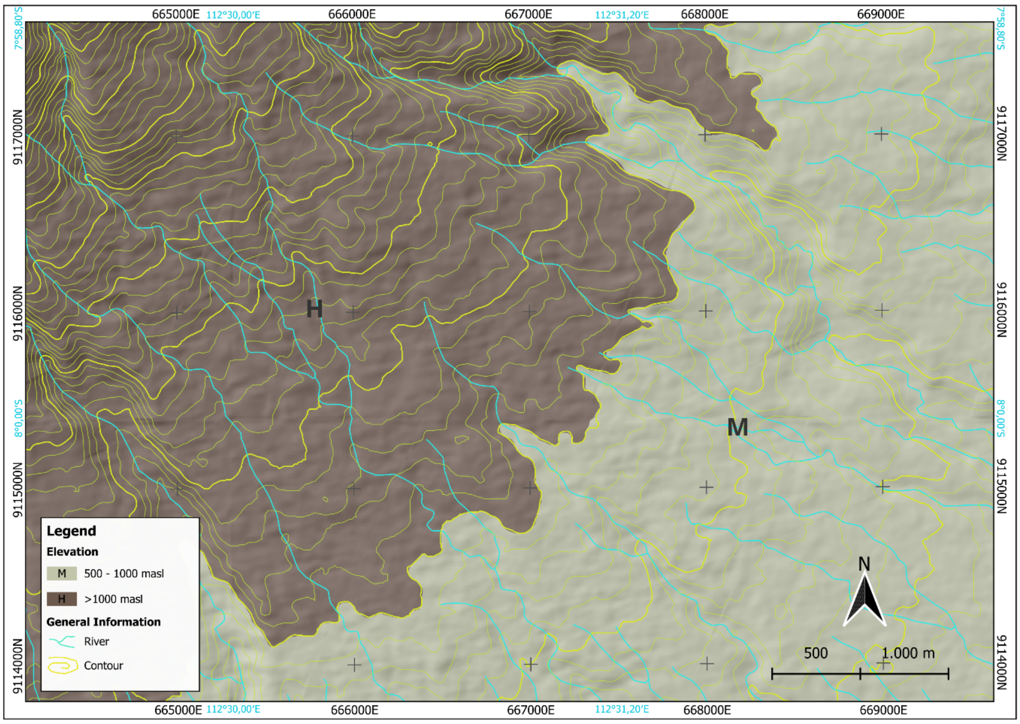


Figure 3. Elevation Map of Sumbersuko Village, Wagir District
(Source: Data Processing, 2025)

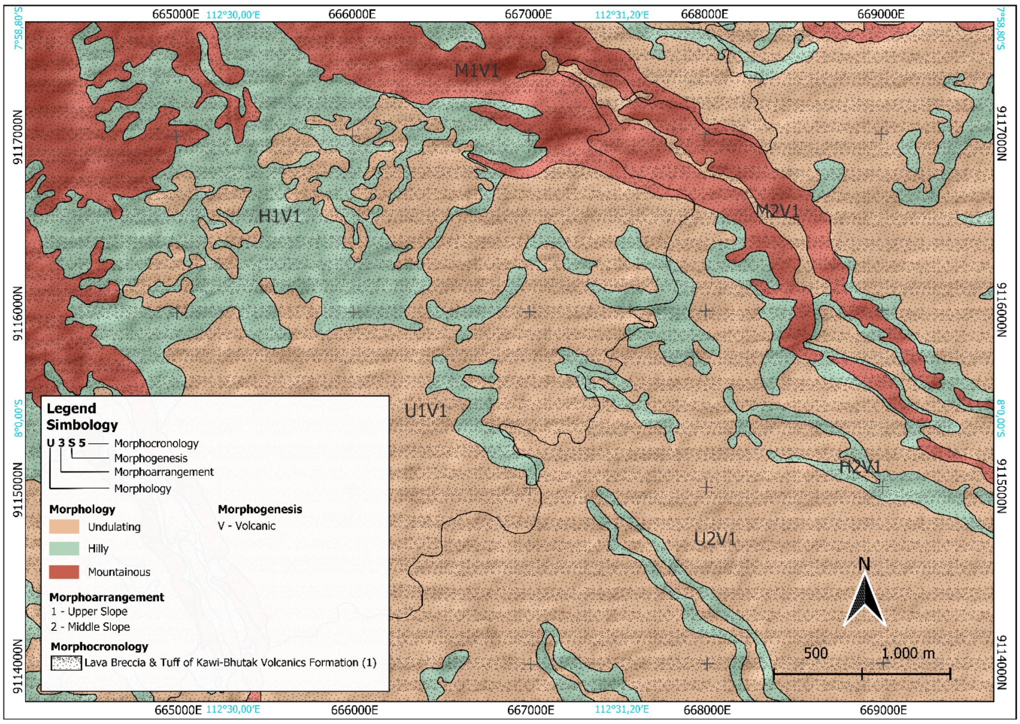
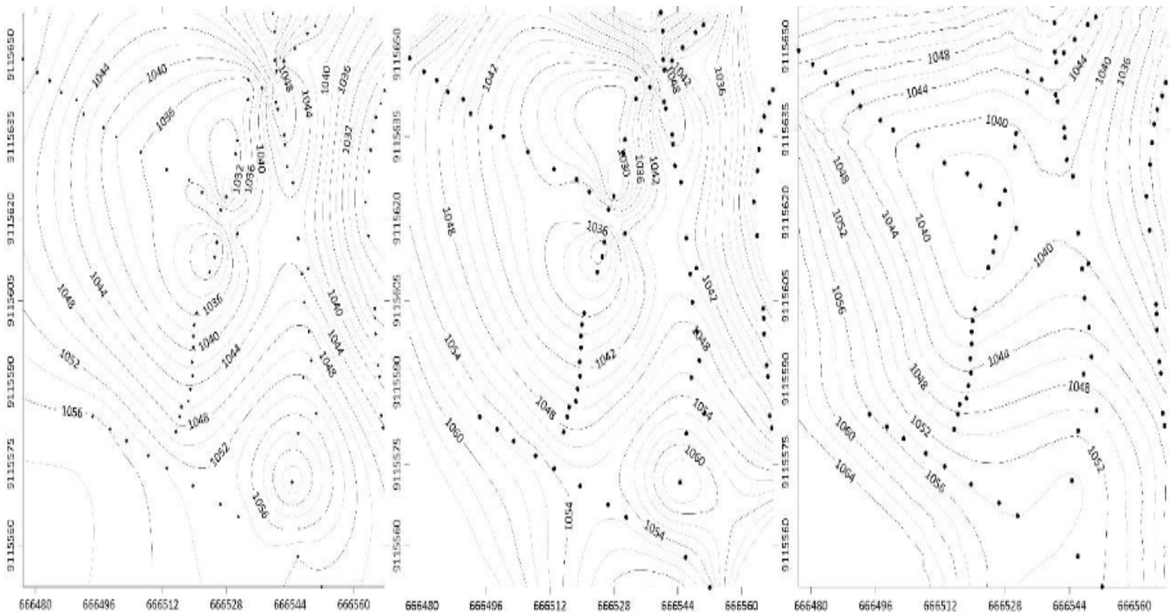


Figure 4. Morphological Map of Sumbersuko Village, Wagir District
(Source: Data Processing, 2025)

Visualisation of morphometry data

The primary aspects of geomorphology comprise morphology (including morphography and morphometry), morphogenesis, morphochronology, and morpho-arrangement. In this study, particular emphasis is placed on the morphometric aspect, which was measured directly through field surveys. (E Prasetyo et al., 2022). Morphometry is a quantitative geomorphological aspect of an area, including slope, height, direction, and roughness (Bermana, 2006). The morphometry visualisation of the study was analysed using the interpolation method from the measurement data points. The creation of morphometry maps was processed using the Golden Surfer application. Golden Surfer is a mapping program that can produce interpolated maps through measurement Points using a systematic method. The results obtained can be modified in 2D and 3D as shown in Figure 5.

The contour map is made based on measurement data marked with a dot symbol, and then a systematic calculation is carried out through three interpolation methods. The interpolation methods used are the kriging method, the minimum curvature method, and the local polynomial. Through contour map analysis, the kriging method has similarities with the minimum curvature method. However, on the contour map of the minimum curvature interpolation, it can be seen that the distance between the contours is tighter and has finer details than the kriging or local polynomial method. The results of the local polynomial method can be seen to form a rounded contour in the basin.



(a) (b) (c)

Figure 5. Contour Map of the results of interpolation of field data by method a) Kriging, b) minimum curvature, c) local polynomial (Source: Research Result, 2024)

To determine the results of the contour map, it is necessary to identify the optimal interpolation value. The results of the three interpolations were tested for accuracy using statistical analysis to determine the number of errors that occurred. Statistical analysis is used with the help of Surfer software. The process involves detecting the data values of each grid on each map. The statistical analysis produces variables, namely, standard deviation, skewness, kurtosis, data variation, and error values. The values of each interpolation are presented in Table 3.

Through the interpretation of statistical results, it can be observed that the kriging interpolation method yields the smallest error value. The standard value of the allowed error is 0.1, which means that the data is acceptable. If there is an error value < 0.1, then the data is normal and acceptable. The lower the standard error value, the more accurate the distribution data will be.

Standard deviation is a value that describes the level of variation or degree of spread in a group of data, and shows how far the data deviates from the average value (Febriani, 2022). The larger the standard deviation, the greater its impact on the variation in data values. Variation itself is a comparison value between the standard deviation and the average value of the distributed data, allowing it to show the diversity of the data (Anas, 2009). Meanwhile, the values of skewness are a variable that produces skewed data visualisation, while kurtosis is a variable that produces pointed data visualisation (Uhland & Alfred, 1951). If the skewness of the data is negative, then the data tends to tilt to the left and yield a more positive result. The results of the statistical interpretation for the contour map were chosen by the Kriging method. Kriging interpolation was selected because it received a score with a standard deviation that was not too large, ensuring that the variation of each data point had minimal potential for error.

A closer look at the quantitative results reveals that Kriging interpolation yielded the lowest standard error (0.091), compared to Local Polynomial (0.095) and Minimum Curvature (0.111). This means that Kriging reduced the error by approximately 18% compared to Minimum Curvature and about 4% compared to Polynomial Interpolation. Likewise, the standard deviation in Kriging (8.54) was markedly lower than Minimum Curvature (10.38), confirming its stability. These numbers indicate that although Minimum Curvature generates finer visual detail, its accuracy is weaker, while Polynomial interpolation tends to smooth out slope variation. Kriging thus provides the best trade-off between detail and Reliability.

Table 3. Results of statistical tests and data grouping based on interpolation

Interpolation	Standard Deviation	Variations	Skewness	Kurtosis	Standard Error
Kriging	8.54	73.04	-0.315	2.25	0.091
Minimum Curvatur	10.38	107.91	-0.134	2.18	0.111
Local Polynomial	8.87	78.78	0.055	2.43	0.095

(Source: Research Result, 2024)

The selected contour map is then converted into a cross-section, with a reference point indicated by a soil sampling location. The slope of the soil sampling has a varied class. Through field observations, it is evident that morphological characteristics differ significantly from those depicted in the existing morphological maps. The high slope level, categorised as steep at 45 °, is located in segment one, utilising Napier grass fields. The formation in segment one occurs due to the transportation process in the form of a slump, where the characteristics of the movement of soil masses are evident in the avalanche crowns. If interpreted through 3D visualisation, the remnants of the avalanche crown can be seen. Meanwhile, the slope is relatively flat, with segments two and three sloping. The formation of ramps in segments two and three is caused by the processes of erosion and mass wasting, which are agents in the form of water.

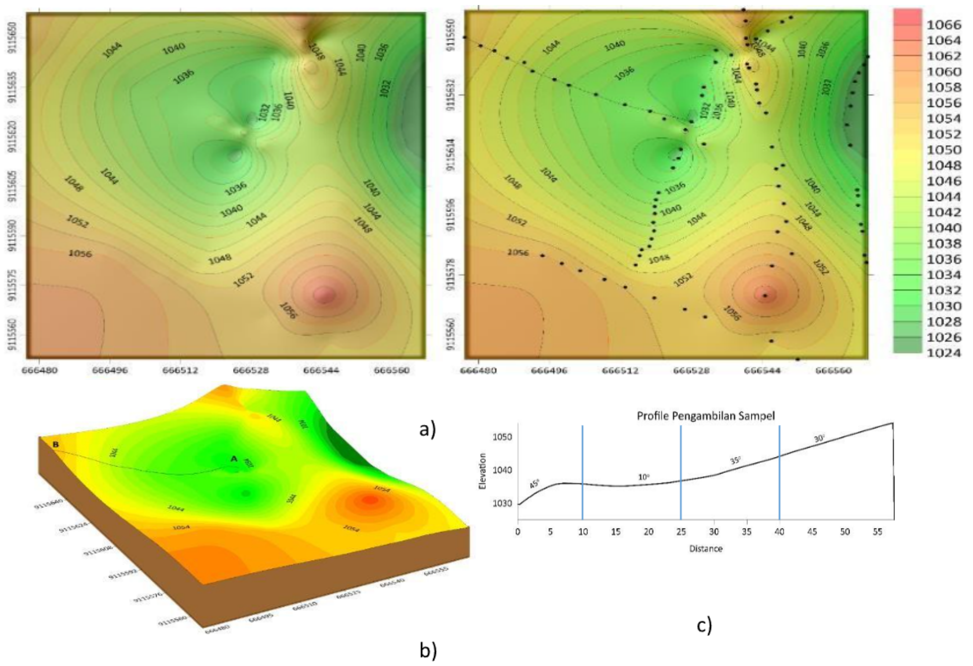


Figure 6. Visualisation of contour maps, a) contour maps of kriging interpolation, b) 3D visualisation of contour maps, c) 2D visualisation of cross-sections
(Source: Research Result, 2024)

From a policy perspective, the preference for Kriging has practical implications. More accurate interpolation not only ensures reliable morphometric maps but also provides technical support for conservation and land management strategies. For example, managers of Precet Forest Park and its surrounding areas can use Kriging-based contour maps to delineate hazard-prone slopes for conservation, identify stable land units for agricultural or eco-tourism development, and incorporate slope hazard information into local disaster risk reduction policies. This reinforces the link between technical geomorphological research and its application to sustainable land use planning in volcanic regions.

In comparison to previous studies, the novelty of this research lies in its methodological integration. Unlike studies by Parry (2011), Theler & Reynard (2011), Pain et al. (2011), and Dunlop et al., (2011), which focused mainly on specific geophysical or remote sensing methods, this study combines field-based Total Station surveys with DEMNAS and advanced interpolation techniques to deliver high-resolution morphometric visualisation. This integrative approach not only enhances the accuracy of geomorphological mapping but also provides a replicable framework for similar volcanic landscapes in Indonesia, directly linking geomorphological findings to practical conservation and land use policy.

Soil Characteristics and Permeability

The soil type in the study area is predominantly Cambisol, with eutrophic subgroups. Cambisol soil has the characteristics of horizon A with a solum thickness of >25 cm and horizon B in the form of a thick soil solum with a silty clay texture, and is quite fertile. During the rainy season, the soil expands laterally, creating a morphology of small mounds (hills) (25-75 cm wide, 10-15 cm high) called 'gilgey'. In contrast, during the dry season, the soil shrinks sideways (stretches), resulting in cracks 2-10 cm wide and more than 60 cm deep (Priyono et al., 2019). The depth of horizon B ranges from 60-80 cm, with a dark reddish brown soil colour (5YR3/6) based on the results of the Munsell colour test. This soil has an angular, lumpy structure with weak characteristics that is easily destroyed when twisted and has a loose soil consistency with a fine root zone.

Meanwhile, the electric subgroup has soil characteristics with a soil pH value greater than 5.5, which falls within the category of fertile soil. In the study area, the soil has a texture resembling silty clay.

Vitric and Tyvic Andosols are other soil types present in the study area. Andosol is a type of soil formed from volcanic material (Aditya & Wijayanti, 2023), such as volcanic ash, tuff, and lapilli, which undergoes a weathering process. This soil is widespread in areas with a history of volcanic activity, such as the study area, which is located within the Kawi-Butak Volcanics formation. The formation consists of constituent materials, including andesite-basalt pyroxene lava, breccia, and sandy tuff.

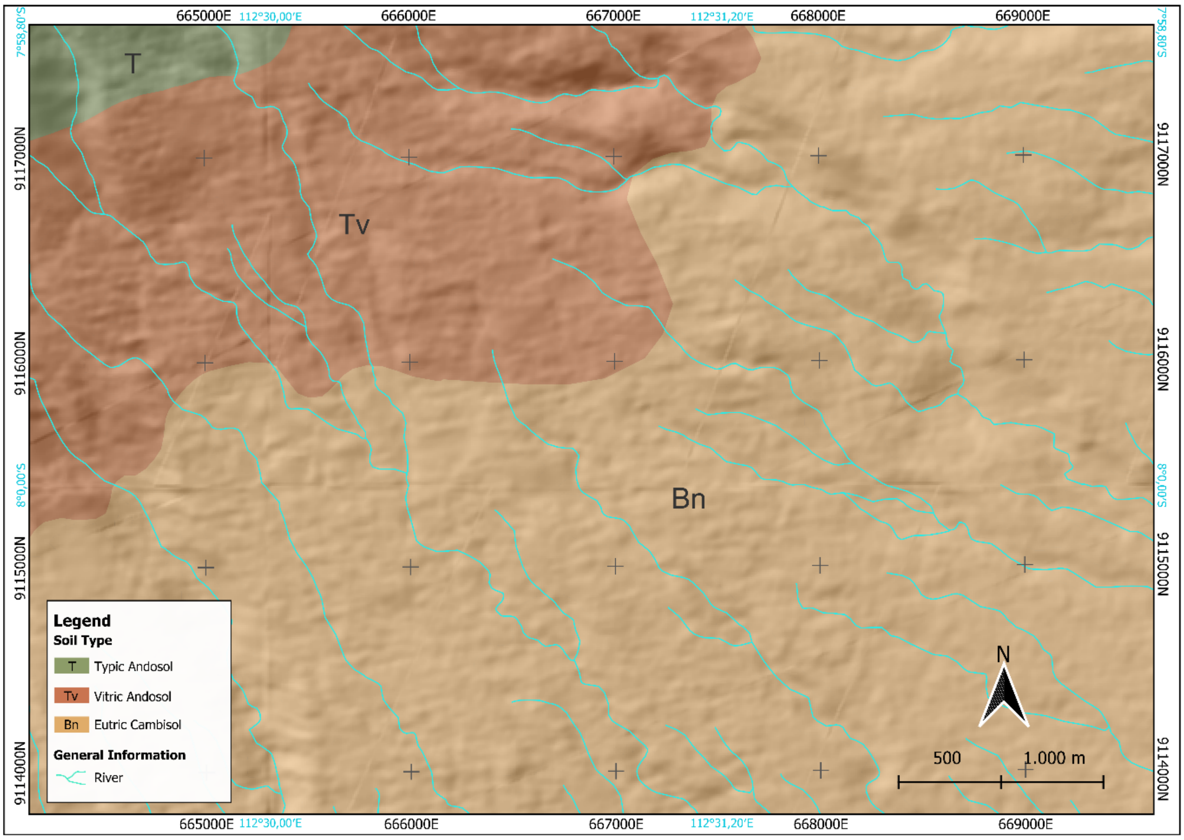


Figure 7. Map of Soil Types of Sumbersuko Village, Wagir District
(Source: Data Processing, 2025)

Soil permeability refers to the ability of soil to allow water to pass through it. The texture of the soil affects the rate of permeability, so that the water entering the pores at least transports the texture of the soil and closes the pores. The composition of the clay texture strikes a balance between coarse and fine fractions, allowing the clay to pass water quickly. The texture of the clay affects the slope stability and soil permeability. This is because the texture of clay generally has a greater capacity to pass water and affects saturation on each horizon. The silty texture is the result of precipitation from ancient eruptions. The silty texture tends to have a high fertility rate, so it has the potential to be planted with a variety of plant types. Through laboratory tests, the permeability value of each segment can be determined. Based on the Uhland and O'Neill (1951) classification, the permeability level of the four segments is categorised into the fast class.

Table 4. Classification of morphometry and physical properties of soil for each segment

Soil Sample Segment	Dominant Land use	Slope Degree	Dominant Soil Type	Morphology	Permeability	pH	Saturation	Texture
1st Segment	Napier grass (Pennisetum purpureum)	45°	Cambisol	Steep (Volcanic Slope)	18.38 cm/h	5.5	6	Silty Clay
2nd Segment	Napier grass (Pennisetum purpureum)	10°	Cambisol	Flat to Undulating (Volcanic foot slope)	14.98 cm/h	5.3	5	Silty Clay
3rd Segment	Napier grass (Pennisetum purpureum)	35°	Cambisol	Steep (Volcanic Slope)	14.37 cm/h	6	5	Silty Clay
4th Segment	Pine Forest	35°	Cambisol	Steep (Volcanic Slope)	16.85 cm/h	6	7	Silty Clay

(Source: Research Result, 2024)

Segment one with land use in the form of Napier grass has a low level of slope stability. This is due to the Influence of the steep slope, characterised by high permeability, coupled with a high level of saturation. The Influence of these three factors has an impact on the increase in the mass load of the slope. It can be observed that a landslide crown occurred in segment one due to the slump avalanche. Segments two and three have slope classes that range from gentle to steep, utilising Napier grass fields. The permeability of both segments has almost the same value. The saturation level in segments two and three is relatively the same as the somewhat wet category. This is influenced by the density of vegetation that is not dense. The Influence of slope factors, permeability, and soil saturation tends to have a relatively moderate effect on stability. Still, the combined Influence of these three factors can result in erosion in segment three and precipitation in segment two. Land use in segment four tends to be planted with pine trees. In this segment, the soil saturation level is very high with fast permeability and relatively steep slopes. The level of slope stability in this segment is prone to soil movement. However, the type of pine plant has high stability to soil movement. The roots of large stands tend to bind the soil, so the level of soil stability is higher than that of segments with fine roots.

CONCLUSION

This study applied geomorphological survey and mapping methods in the Precet Forest Park area through several stages, namely preparation, field data collection, and data processing and analysis. During the preparation stage, a literature review and the collection of secondary data were conducted, including geological maps, DEMNAS, soil type maps, and satellite imagery. Meanwhile, primary data collection in the field was performed using a Total Station for measuring distances and angles, a GPS for determining locations, as well as direct observations of land morphology, land use, and soil sampling.

The survey data were then processed using QGIS and Surfer software, employing morphometric interpolation methods, including Kriging, Minimum Curvature, and Polynomial Interpolation. These three methods were effective in producing accurate contour maps and elevation distribution maps, each with advantages in estimating spatial values, generating smooth interpolation surfaces, and identifying trends in data distribution. The mapping results revealed detailed and representative geomorphological characteristics of the area's physical conditions, making this method a reliable basis for preparing spatial-based land management recommendations in Precet Forest Park.

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