Journal of Geology & Exploration
Vol. 4, No. 2, December 2025 : 85 – 92
E-ISSN 2963-2869

Analysis of Landslide Potential Based on Slopes And Rock Weathering Levels in The Mamampang Area, Tombolopao District, Gowa Regency, South Sulawesi Province

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ABSTRACTS

The Mamampang area is composed of the rocks of the Lompobattang Volcano with the dominance of tufa lithology which is fragile and easily weathered. Morphologically, the study area shows the shape of hills to mountains with steep slopes – very steep, so it has a high vulnerability to the movement of soil masses. This study aims to analyze the potential for landslides based on the parameters of the slope and the rate of rock weathering. Slope geometry measurements were carried out using geological compasses and roll meters, then analyzed with the Bermana (2006) classification, while the rate of rock weathering was determined based on the classification of Irfan and Dearman (1978). The results showed that most slopes have a slope angle between 40°–52° with a slope percentage of 50–129% (steep to very steep category), and the weathering rate is at degrees IV–VI (strong weathered to residual soil). The condition of the tufa lithology that has undergone advanced weathering, combined with steep morphology, land use on steep slopes, and intense rainfall, is the dominant factor determining slope instability. The potential for landslides in the Mamampang area is categorized as very high, so mitigation efforts based on geology engineering are needed through land use management and strengthening of slope cover vegetation.

https://doi.org/10.58227/jge.v4i2.340

ARTICLE INFO
Article History:
Received 03 Dec 2025
Revised 04 Dec 2025
Accepted 30 Dec 2025
Available 31 Dec 2025

Keyword:
Landslide, Slope, Rock Weathering, Slope Stability, Gowa

INTRODUCTION

Geological disasters are one of the natural phenomena that can cause great losses to human life. One of the geological disasters that often occur in tropical areas with hilly to mountainous morphology is landslides. Landslides are the movement of rocks, soil, and mixed materials that move down the slope due to an imbalance between the holding force and the pushing force (Hadisantono, 2006; Iovine and Cohen, 2014). The factors that cause landslides are very complex, including geological conditions, morphology, climate, and human activities in utilizing land. In general, geological conditions have an important role in determining the stability of slopes, especially the constituent lithology and the degree of weathering (Dahal and Dahal, 2017; Raja et al., 2017; Roslee et al., 2017). Rocks that have undergone further weathering will lose cohesion strength and have the potential to become slipping fields when affected by rainwater or additional loads. In addition, slope slope is also a major parameter that affects slope stability. Slopes with steep to very steep angles will increase the potential for landslides because the mass of rocks or soil that presses on the slope is getting larger (Anwar et al., 2021; Aswadi et al., 2022; Sulfahmi et al., 2020; Thamsi et al., 2021).

The Mampangs area, Tombolopao District, Gowa Regency, South Sulawesi, is composed of the rocks of the Lompobattang volcano which is dominated by tufa lithology. These rocks are fragile and susceptible to weathering, so they have the potential to reduce slope stability. The morphological conditions of the study area, which are dominated by steep hills and land use in the form of sloped agriculture, further increase the vulnerability to landslides, especially during the high-intensity rainy season (Asmiani et al., 2024; Habibie et al., 2019; Mikoš et al., 2017; Pradhan et al., 2009).

Based on this, this study was conducted to determine the potential for landslides in the Mamampang area by examining the parameters of the slope and the level of rock weathering which are the main controlling factors for slope stability. The purpose and purpose of this study is to determine the landslide potential of the research area based on the slope and the level of weathering of the rocks.

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METHODS

The methods carried out in this study include several stages, namely literature study, data collection stage which includes the stage of field data collection in the Mamampang area, Tombolopao District, Gowa Regency, South Sulawesi Province, and laboratory data collection. The next stage is the data analysis stage, including the field data analysis stage and laboratory data analysis. The last stage is the Report Preparation stage.

RESULTS AND DISCUSSION

Analysis of the Slope Geometry of Mamampang District

Slope geometry measurements are carried out using a geological compass and roll meter to determine the slope height, slope width, and slope angle. Slope geometry measurements at the research site were carried out to analyze the level of stability of the slope.

The results of observation and data processing show that the higher the slope, the lower the level of stability, this is because the mass of rocks or soil that burdens the slope is greater when the slope is higher. Likewise, if the slope is getting steeper, the level of stability is getting smaller, which is because the load caused by the slope is increasing. Therefore, slope geometry measurements in the field are very important to be carried out in order to analyze the level of slope stability in the research area.

Table 1 Field Data of Research Areas

No	Length (M)	Width (M)	Slope (°)	Directions (N..°E)
ST 1	8.6 meters	21.2 meters	47°	35°
ST 2	9 meters	22 meters	26°	64°
ST 3	12 meters	7 meters	52°	301°
ST 4	7 meters	4 meters	46°	5°
ST 5	6 meters	27 meters	40°	333°
ST 6	9 meters	5 meters	41°	114°
ST 7	6 meters	3 meters	33°	126°
ST 8	18 meters	9 meters	43°	91°
ST 9	9 meters	15 meters	43°	336°

Table 2 Slope Geometry Data The research area

No	Height (H)	Horizontal Distance (D)	Slope (%)	Remarks
ST 1	6 meters	5 meters	120 %	Very Steep
ST 2	4 meters	8 meters	50 %	Steep
ST 3	9 meters	7 meters	128.57 %	Very Steep
ST 4	5 meters	4 meters	125 %	Very Steep
ST 5	4 meters	5 meters	80 %	Very Steep
ST 6	6 meters	7 meters	85.71 %	Very Steep
ST 7	3 meters	5 meters	60 %	Very Steep
ST 8	12 meters	13 meters	92.31 %	Very Steep
ST 9	6 meters	7 meters	93.28 %	Very Steep

Rock Weathering Rate of Mamampang District

From the results of field observations, the Mamampang area is dominated by tufa lithology which is a volcanic rock that is very susceptible to weathering. Based on the classification system of rocks weathering degrees according to Irfan and Dearman (1978) in Setiadji et al. (2006) this research area was identified to have a degree of weathering between IV – VI (Weathered Strong – Residual Soil).

Station 1 (one) as a data collection area representing the degree of weathering IV shows that tufa outcrops that have more than 35% (thirty-five percent) of rock material have been decomposed or disintegrated into soil. There was a weathered appearance from the tufa lithology that showed a change in color from gray to brown. Based on the classification system of the degree of weathering of rocks according to Irfan and Dearman (1978) in Setiadji et al. (2006) this study area was identified as having

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a rate of weathering with a Degree of Weathering IV (Strong Weathering). In this area, biological weathering and chemical weathering have occurred (Figure 1).

Figure 1 Appearance of station 1 represents the degree of weathering IV with a photographic direction N 215° E

Station 3 (three) as a data collection area representing the degree of weathering V shows that all rock material has been decomposed or disintegrated into soil, but the rock mass structure is still mostly intact. Based on the classification system of the degree of weathering of rocks according to Irfan and Dearman (1978) in Setiadji et al. (2006) this research area was identified as having a rate of weathering with a Degree of Weathering V (Perfect Weathering). In this area, biological weathering and chemical weathering have occurred (Figure 2).

Figure 2 The appearance of station 3 represents the degree of weathering V with the photo direction N 141° E caused by biological weathering and chemical weathering

Station 5 (five) as a data collection area representing the degree of weathering VI shows that all rock material has turned into soil. The mass and packaging structure of the rock has been damaged, but the soil has not undergone transportation. Based on the classification system of rocks weathering degrees according to Irfan and Dearman (1978) in Setiadji et al. (2006) this research area was identified as having a weathering level with Weathering Degree VI (Residual Soil). In this area, biological weathering and chemical weathering have occurred (Figure 3).

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Figure 3 Station 5 appearance represents the degree of weathering V with the photo direction N 149° E caused by biological weathering

Chemical Weathering Process Research Area

Chemical weathering: is a weathering process that can change the chemical composition of rocks and the mineralogy of a rock (decomposition), so that part or all of the composition in the rock becomes damaged or dissolved by water, then reacts with air (O2 or CO2), causing other mineral elements to combine with local elements to form new mineral crystals (Boggs, 1995).

Broadly speaking, geochemical analysis mainly uses the XRF (X-ray Fluorescence) method used to determine the elemental composition of a material. This method was chosen to determine the abundance of chemical elements, including the oxide element in each layer of soil depending on the bedrock, depth and mineralogy. Some chemical weathering indices are: Chemical Index of Weathering (CIW): based on the element aluminum associated with K-feldspar, the presence of this element can be used to determine the rate of weathering that occurs by converting the content of feldspar converted into clay:

$$x = \frac{\text{Al2O3}}{\text{Al2O3} + \text{CaO} + \text{Na2O}} \text{ x } 100\%$$

The role of the chemical weathering index is basically to measure the rate of weathering (Harnois, 1988).

X-Ray Fluorescence (XRF) Analysis Results

Based on the results of the XRF analysis, it can be seen that the highest Al2O3 (Aluminum Oxide) content is in ST 5 with a level of 27.79% while the lowest is in ST 3 with a level of 21.15%. The highest CaO (Calcium Oxide) content was at ST 1 station with a level of 3.37% while the lowest was at ST 5 with a level of 0.06%. The highest Na2O (Sodium Oxide) content was at ST 5 station with a level of 0.23% and the lowest at ST 1 with a level of 0.15%.

Chemical Weathering Index

Based on the results of Geochemical analysis using the XRF (*X-Ray Fluorescence) method*, the level of weathering in the study area can be determined using the chemical weathering index formula of Harnois 1988.The role of the chemical weathering index is basically to measure the level of weathering during the weathering process (Harnois, 1988). This index can then be applied to the material value weathering standards established by a particular weathering classification system that can essentially correlate with the weathering value. The rate of weathering in the study area can be determined using the formula:

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$$Indeks\ Pelapukan\ Kimia\ (Harnois, 1988) = \frac{\text{Al2O3}}{\text{Al2O3} + \text{CaO} + \text{Na2O}} \text{ x } 100\%$$

$$ST1 = \frac{23.6519}{23.6519 + 3.3798 + 0.1016} \text{ x } 100\% = 87.16927\ \%$$

$$ST3 = \frac{21.1456}{21.1456 + 0.1137 + 0.2228} \text{ x } 100\% = 98.43358\ \%$$

$$ST5 = \frac{27.7975}{27.7975 + 0.0686 + 0.2313} \text{ x } 100\% = 98.93264\ \%$$

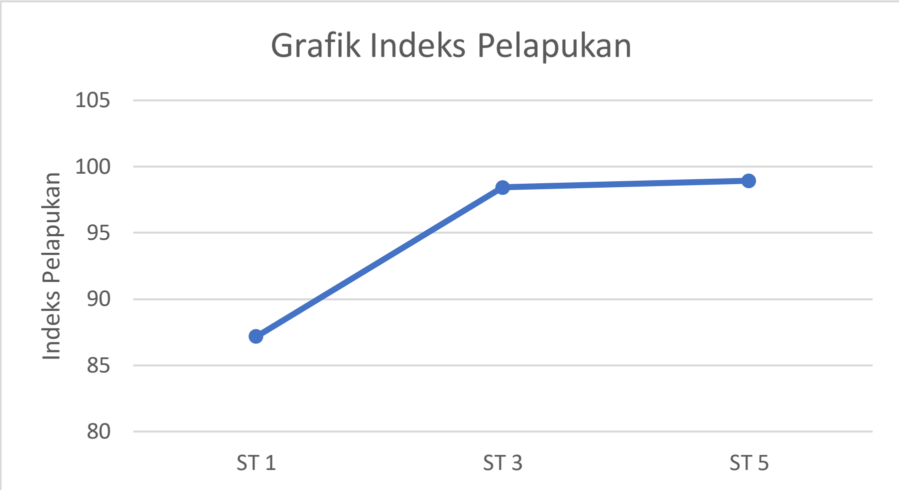

Figure 4 Graph of the chemical weathering index of the research

Based on the results of the calculation using chemical elements obtained from XRF Analysis, it can be seen that the highest to lowest weathering rate is in ST 5 where the weathering rate is known to reach 98.9%. Furthermore, it is located in ST 3 with a weathering rate of 98.5%. The lowest rate of weathering occurred in ST 1 with a weathering rate of 87%.

Based on the results of the analysis of the Chemical Weathering Index and the comparison with the results of direct observations in the field, it is known that the Station 5 area as a station that represents the area with the level of weathering with Weathering Degree VI (Residual Soil) has the highest percentage of weathering.

Supporting Factors for Landslides

Based on the results of field observations and referring to several researchers, the factors that cause landslides in the Mamampang area are divided into several types, including:

Factor Geology

Geological factors are one of the causes of landslides in an area. An area composed of a compact and resistant lithology will certainly reduce the possibility of landslides and vice versa. Avalanches generally occur in volcanic rock lithology. This is due to its nature that has not been properly consolidated. high erodibility, as well as high porosity and permeability (Sutikno, 1999).

Regional geology shows that the study area is composed of the volcanic rocks of Lompobattang (Sukamto and Supriatna, 1982). Based on the results of the field survey, it shows that the rocks that make up the observation location are generally composed of fine tufa. The constituent rocks have undergone physical and chemical weathering to form soil. In general, the research area is dominated

Morphology (Slope Slope)

Morphological conditions can be a parameter in determining landslide-prone areas because morphology can indicate the state of the slope, the higher the slope level, the greater the likelihood of landslides. The morphological state of the research area consists of hills to mountains that have a varied

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E-ISSN 2963-2869

slope shape ranging from Flat to Very Steep (Figure 5). The classification of slope slope used in this analysis uses the classification of Van Zuidam (1985).

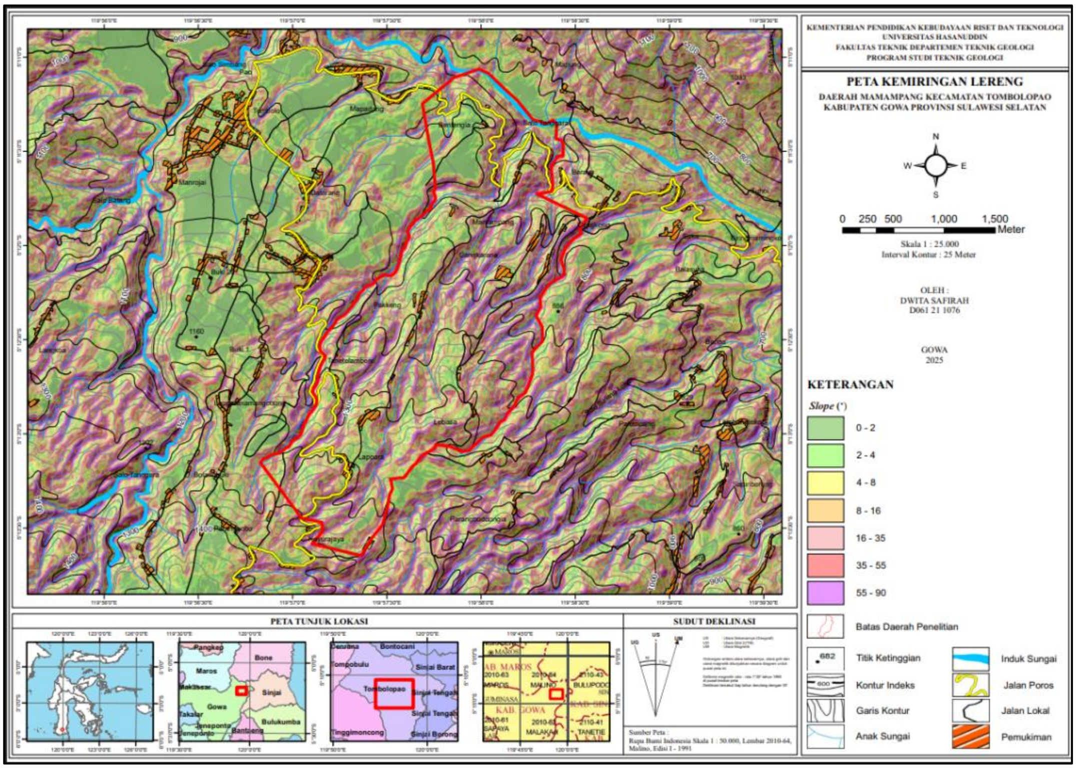

Figure 5 Slope Map of the Research Area

Land Use Planning

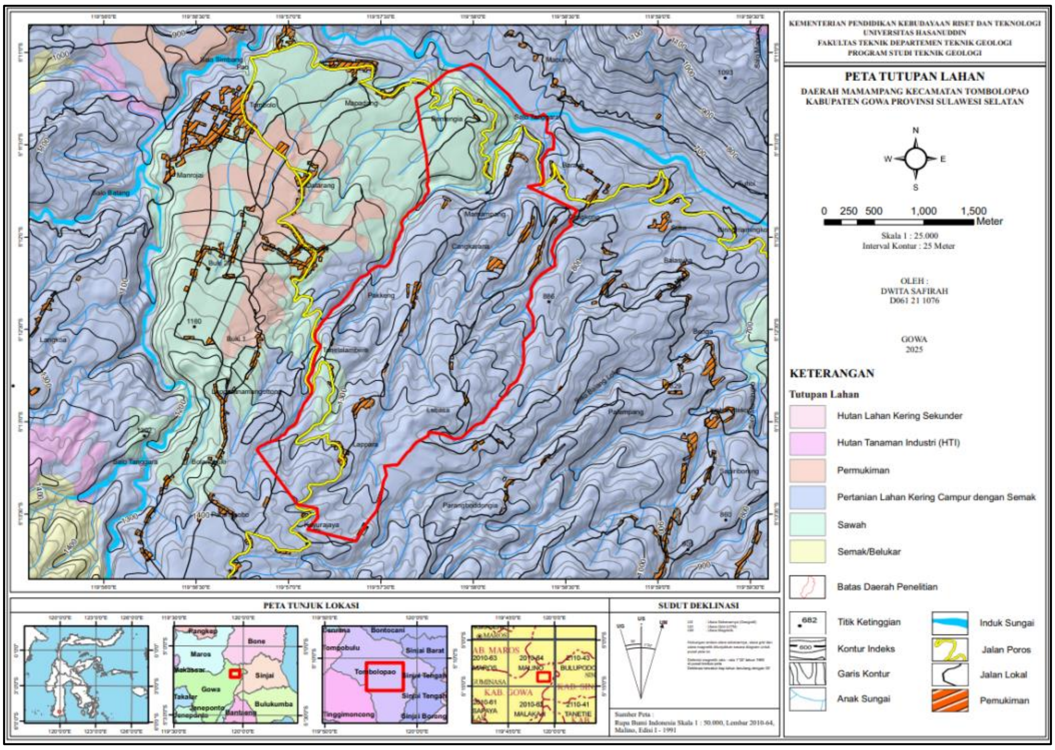

Figure 6 Land Cover Map of the Research Area

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E-ISSN 2963-2869

Based on the results of land cover digitization obtained from the interpretation of image data, the research area is divided into dry land and rice field agricultural land use. Therefore, land use in an area plays an important role in affecting the level of landslide vulnerability in the research area. The following is a map of the distribution of land cover in the research area (Figure 6).

Rainfall

The results of rainfall data processing in ArcGIS software in the study area were dominated by low to moderate rainfall intensity (Figure 7).

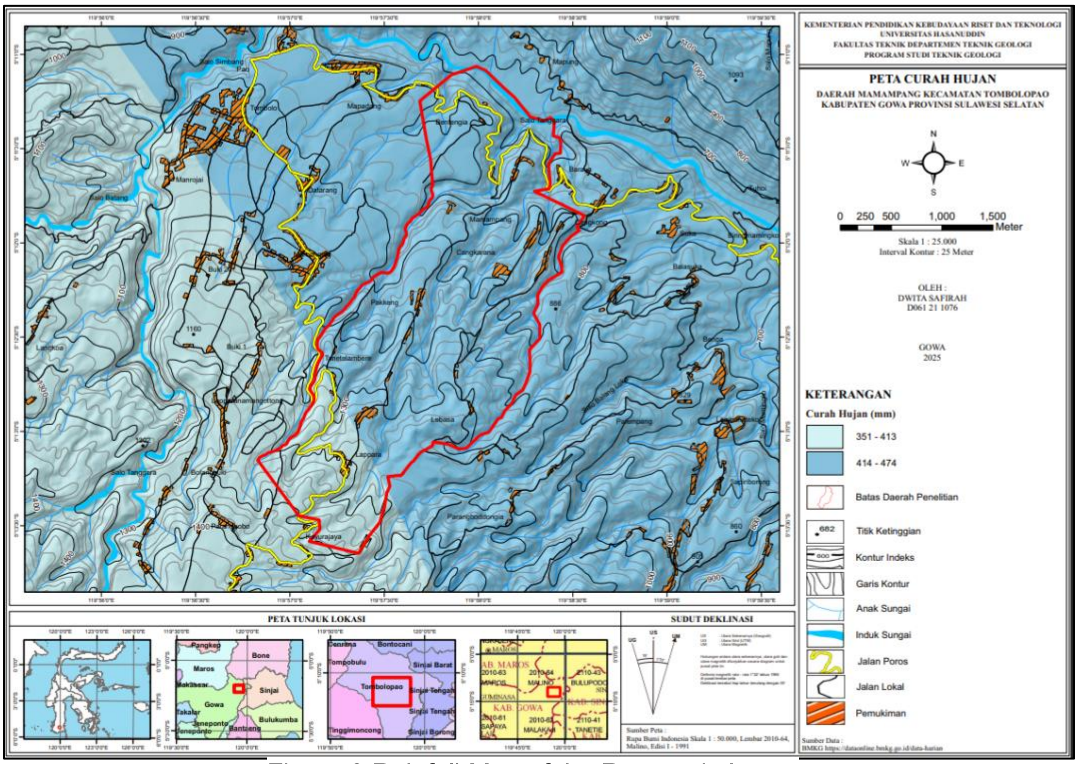

Figure 9 Rainfall Map of the Research Area

CONCLUSION

Based on the analysis of slope geometry and rock weathering levels, the Mamampang area is classified as having a very high potential for landslides**.** The majority of measured slopes are categorized as steep to very steep, while the tuffaceous rock units show advanced weathering levels of IV–VI**,** reflecting substantial material degradation. This combination of steep slope conditions and intense weathering greatly decreases slope stability. Furthermore, land use on sloping terrain and rainfall act as additional controlling factors that intensify landslide susceptibility. Accordingly, the research objective has been achieved, demonstrating that slope gradient and rock weathering are the main parameters controlling landslide potential in the study area. These findings highlight the need for geotechnical and land-management-based mitigation efforts in the Mamampang area.

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