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A Perspective of Geomorphology for Landslide Susceptibility and Its Applied in the Taji Village-Malang Regency as Vulcanic Area

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Abstract

Landslides are Indonesia's second-largest disaster during 2020-2022. Many researchers have conducted research related to landslides, i.e., landslide susceptibility with statistical, heuristic, geomorphological approaches and landslide disaster risk. The geomorphological approach is one approach in the study of landslides that can represent morphology, morphostructure, morphochronology, and morphoarrangements. This research aims to explain landslide hazard mapping using a geomorphological approach, evidenced by a case study in the Gede watershed as one of the watersheds in Taji Village. The method used in this research is Geomorphology approach using a systematic literature review. Furthermore, landslide susceptibility analysis has been carried out using a geomorphological approach with topographic position analysis a case study in Taji Village. The results showed that landslides can be more specifically identified through morphology, surface material resulting from morphochronological and morphological processes, and existing and dormant geomorphological processes. These four aspects can be used as the key to the identification of landslide hazards. Based on the geomorphological approach, as much as 52.13% is very high vulnerability located on the upper slope morphology, 25.45% high vulnerability on the middle slope, 10.16% medium vulnerability on the lower slope, and 12.26% low vulnerability on the slope morphology. foot.

Keywords: geomorphology, landslide susceptibility, taji village, perspective.

Introduction

Indonesia is one of the countries that have the potential for natural disasters, this is influenced by geographical location. Indonesia is an archipelagic country with three main plates, namely the Indo-Australian, Eurasian, and Pacific plates which are one of the causes of disaster vulnerabilitysuch as volcanic eruptions, earthquakes, tsunamis, floods, landslides, and so on. East Java Province is one of the provinces that has vulnerability to disasters. East Java as part of Java Island has enormous potential for landslides (Nisa et al., 2019; Putra et al., 2021). Based on (BNPB 2023) in 2022 in East Java there have been 20 landslides with losses of 493 people who were injured and displaced, 112 houses were damaged, 2 bridges and 2 schools were also damaged.

One of the areas in East Java Province that has a high vulnerability to landslides is Taji Village, Malang Regency. Taji Village which is one of the villages located in the Bromo Tengger Semeru Mt. Area. It has a rough morphology with thick soil surface material resulting from the deposition of Bromo Volcano material. The geological structure of this area produces rocks that are not solid and have no strong grain bonds, so it is easily eroded. Based on phenomena related to landslides in this area, it is interesting to learn about landscape which a geomorphological approach cannot separate. The landslide process is understood as the movement of material in the form of land, rock, or mud down to the slope. There is interconnection between the landslide process and the landslide's factors, thus the landslide process is closely related to landscape, landform, morphology, land use, surface, and sub-surface materials.

The landslide process can be studied using a geomorphological approach. Geomorphological approach can represent the shape of the earth's surface. Geomorphology is able to represent morphology ranging from valleys, lands, hills, and mountains (Hooke, 2020; Martínez-Graña et al., 2017). Geomorphology is the study of the earth's physical land surface features such as rivers, hills, plains, beaches, sand dunes, and others (Hutagalung, 1967). Many researchers have developed studies on natural processes with a geomorphology approach. Research on geomorphology used as an approach in environmental and disaster studies has developed very rapidly. This is because the landscape strongly reflects the local community environment.

In addition, the geomorphological approach is an approach that can explain the origin and development of landforms. We can identify the morphology, processes, and materials through a geomorphological approach. Landslides can be understood as the process of moving material down a slope (Crozier, 2010). The process of landslides cannot be separated from the geomorphological conditions of the area. Geomorphological studies can be used to analyze landscapes and their processes. Geomorphological studies also examine the reciprocal relationship between nature and humans so currently the term anthropogenic. Geomorphological studies also examine land surfaces that have a lot of diversity in topographical impressions, rocks/structures, and processes. It gives various traits and characteristics. Therefore, the study of geomorphologyis able to classify the characteristics of groups called landforms (Hutagalung, 1967). The Landform is a real configuration of the earth's surface formed from geomorphological processes, lithology, and arrangements.

Landforms are closely related to geomorphological processes and geological structures (Kinde et al., 2024) . Geomorphology has four main aspects in the composition of landforms, namely morphology, process, morphochronology, and morphostructure. An area's morphology will affect the material's position (soil and rock) because the position of the soil and rock masses will follow the surface topography (Anderson R.S., 2008; Tooth, Stephen, Viles, 2014). The geomorphological process is a process that causes changes in landforms in a short time and the process of landforms includes morphogenesis (Haskins et al., 1999). Rock structure is related to the arrangement, slope, and type of constituent assistance below the surface of the landform. This will affect the direction, velocity of the surface material, position, and the type of soil mass movement that will be generated. Based on this, the geomorphological approach is indeed very suitable in the study of landslide susceptibility.

There have been many studies on landslide mapping and analysis of the factors that influence landslides. (Berhane & Tadesse, 2021a) has conducted a landslide susceptibility study using statistical methods, the landslide parameters used are lithology, aspects, land use, rain, and human activities. In this study, the accuracy of the resulting landslide hazard map was not tested.

Several previous studies using statistical and heuristic methods between researchers used different variables (Chen, 2018; Juliev et al., 2019; Nsengiyumva et al., 2019). Based on research (Juliev et al., 2019) which compares statistical methods in the form of the statistical index (SI), Certainty Factor (CF), and Index of Entropy (IOE) for landslide susceptibility, the accuracy is below 80%. This study uses 12 landslide trigger factors: altitude, slope angle, plan curvature, curvature profile, slope aspect, distance to roads, distance to faults, distance to rivers, rainfall, NDVI, land use, and lithology. Based on previous research, the use of the landslide susceptibility method with statistical methods is still very dependent on the individual and the availability of the data used in the study.

Constraints used in the use of statistical and heuristic methods in producing landslide hazard maps are very subjective variables used in generating landslide maps, so there is no definite benchmark for the most influential variables on landslides. In addition, statistical and heuristic methods mostly use remote sensing data, which sometimes ignores the suitability between the processed data and the mapping scale, so this causes a low accuracy test.

This paper will elaborate and show that geomorphology and landslides are interrelated and the geomorphological approach can be an effective approach in landslide mapping because the geomorphology approach is able to represent morphology, processes, and materials. The use of geomorphology for landslide studies was tested in the Taji Village area, which is one of the villages located in the Bromo Tengger Semeru area. The Taji Village area has a rough morphology with thick soil surface material resulting from the deposition of Bromo Volcano material.

Methods

This research was conducted in three steps. The first step is to conduct a systematic literature review to understand the geomorphology relationship with the landslide process. To explain in more detail the geomorphological relationship with landslides, an analysis of one catchment area was carried out in Taji Village, Jabung District, Malang. The second step is to process the DEMNAS data with 8 meters to produce a landslide susceptibility map using a geomorphological approach.

Systematic Literature Review (SLR)

The systematic literature review synthesizes the existing information related to the research question. Several stages are carried out in conducting a systematic literature review, namely 1) formulating research questions; 2) finding references related to the research topic; 3) selecting and evaluating literature; 4) analysis and synthesis of results and 5) reporting. In this study, the SLR method used was adopted from (Denyer & Tranfield, 2009; Thomé et al., 2016). The purpose of this study is to explain that there is a link between geomorphological aspects with landslide processes and landslide susceptibility, so that in the search used the keywords "geomorphology and landslides" and "landslide mapping". Our article search process is done through perish software and published with keywords that we have specified (Harzing, 2010). We conducted a search in the metadata section of Google Scholar with a time period of 2015-2020. We have found 2,506 metadata articles for 5 years. From all metadata obtained, screening was carried out based on abstract and title. Furthermore, a quality assessment was carried out for paper selection and a snowballing analysis was carried out on the selected paper. (Fig. 1).

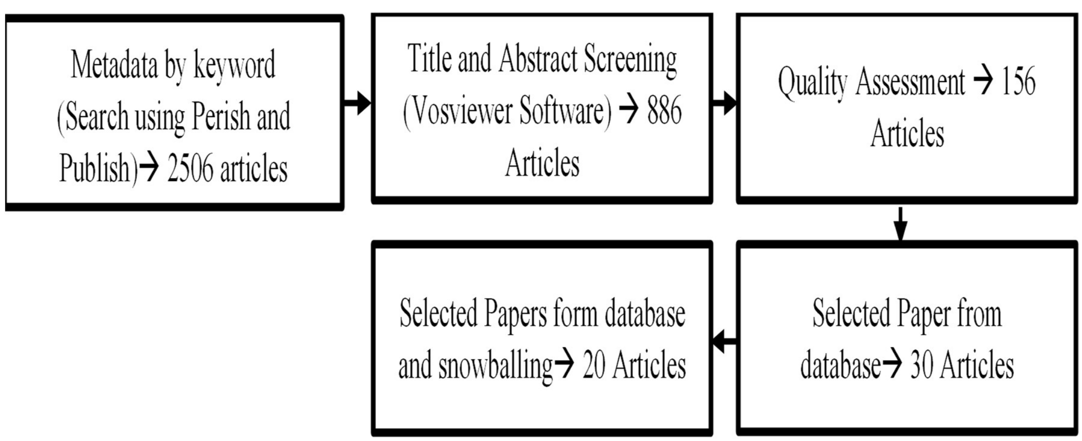

Figure 1. The Systematic Literature Review Step in this Study (Masruroh, 2021).

Based on figure 1, the articles downloaded using perish and published using the keyword "landslide susceptibility". Then a more detailed screening was carried out based on the title and abstract that matched the landslide susceptibility using a geomorphological approach. In more detail, in this research, a quality assessment was also carried out based on geomorphological indicators, and similarities in regional characteristics, namely volcanic areas and a quality assessment was carried out based on detailed information regarding the relationship between geomorphology and landslides.Based on metadata, there have been many studies on landslide studies. Based on

Google Scholar metadata obtained from Perish and Publish, there are 2,506 articles discussing landslides from the 2015-2020 period. Based on the results of metadata processing using vosviewer, it is known that landslide studies in that period were associated with landslide hazard modeling methods using statistical methods, studying landslide volumes, and landslide identification using remote sensing data. Landslide studies that relate to hydrology, geomorphology, and landslide hazard value index are still rarely carried out in 2018 and above (Fig.2)

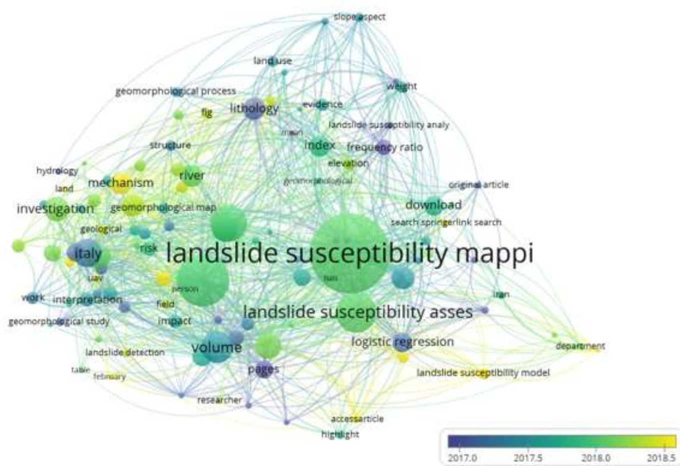

Figure 2. Metadata Analysis of Research Regarding Landslide (Analysis, 2021).

DEMNAS Processing for Slope Morphology and Landslide Data Analysis

The algorithm generates the slope morphology by processing the topographic position index (TPI). The elevation distribution variabilityincrease with the spatial scale such relief generally increase from smaller to larger neighborhood size and the algorithm of TPI also consists radius. DEV measures the topographic position of local relief normalized to local surface roughness (De Reu et al., 2013; Liu et al., 2009; Sermin & Jeff, 2008). TPI and DEV were automatically calculated using Arc GIS 10.8 tools and using Arc GIS script. TPI and DEV are the most data algorithms for created landform identification.

To produce a morphological form, several stages are carried out, namely DEMNAS download processing; 2) DEMNAS processing; 3) Data processing with Topographic Position Index (TPI) analysis; 4) identification of morphology from the Topographic Position Index (TPI); 5) Field Check and 5) map layout. DEMNAS processing using algorithm analysis with Geographic Information System (GIS) 10.8. The results of TPI processing produce positive (+) and negative (-) values. A positive value in TPI shows the highest topography compared to the surrounding area (ridge) (De Reu et al., 2013). A negative value indicates a low topography compared to its surroundings (valleys) and a TPI value of 0 indicates a plain topography (Weiss, 2001). Calculation of the TPI using the radius circles neighborhood technique. Fig. 3 shows an illustration of the TPI value with topography.

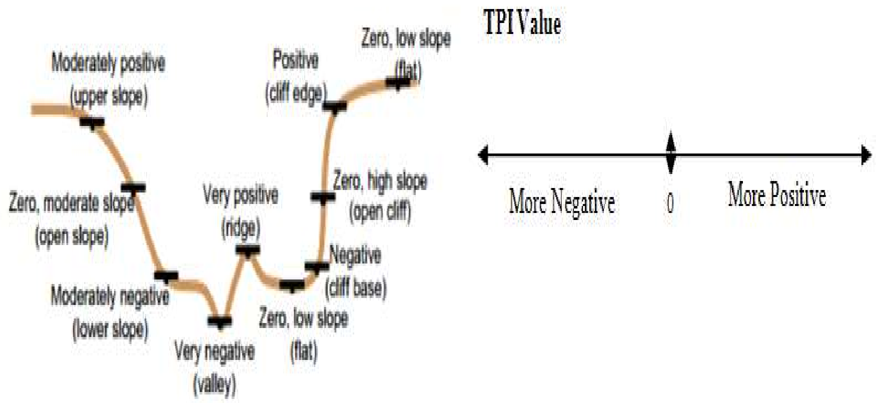

Figure 3. Illustration TPI, Slope and Value of TPI (Weiss, 2001)

Accuracy Test

The interpretation results of visual and digital remote sensing data need to be tested for accuracy through field checking. The accuracy test is used to determine how big the error is in interpreting small format aerial photos with conditions in the field. The method used to test the accuracy of the field test using an error matrix (error matrix). There is no standard reference for the accuracy test reference to determine the number of samples for the accuracy test (Olofsson et al., 2014; Stehman & Czaplewski, 1998). The number of accuracy test samples depends on the area of each class of terrain classification, the level of detail, the percent accuracy, and the minimum area (Minimum Legible Area) based on the mapping scale. To find out the percent error from field tests performed using an error matrix (Congalton, 1991; Olofsson et al., 2014)

Table 1. Interpretation Accuracy Test Matrix.

Test Accuracy		Field Reference Data			
		X	Y	Z	Amount
Classification result data	X	a	b	c	m
	Y	d	e	f	n
	Z	g	h	i	o
	Amount	p	q	r	t

Source: Lillesand dan Kiefer (1994); Sutanto (1986).

The error matrix can calculate the omission and accuracy commission errors in each category and the overall accuracy. The omission error for each category is calculated by dividing the field reference data that is not properly classified by all the reference data for that category. According to Table 3.1, the category X omission error is calculated as follows:

Omission Error $X = (d+g)/p \times 100\ \%$ ....(1)

Commission Error $X = (b+c) / p \times 100\ \%$ ....(2)

User Accuracy X = a / m x 100%...(3)

Overall Accuracy X = (a+ e + i) / t x 100%.

Accuracy test results can be accepted if the accuracy of the classification data with reference data in the field (85%) - (>85%).

Results and Discussion

Geomorphologyand Landslide

Geomorphology, landscape, and erosion are three inseparable parts (Hutagalung, 1967). Geomorphology studies landforms that occur in landscapes. Landscapes are features of the earth's surface that vary from mountains, hills, and plains to valleys (Heckmann, 2015). Through geomorphological studies, it can be identified the origin and development of landforms that occur in the landscape (Hoff, 2018). The morphological condition of the slope will influence the potential for the movement of landslide material. Morphological identification can be done based on slope values, surface roughness, and topographic position. Based on field analysis, it shows that most of the slopes are at 15^0-25^0, amounting to 52%, while the largest landslide incidents occur at slopes of 25^0-35^0.

The origin and development of a landscape cannot be separated from the interaction between endogenous (geological forms and processes) and exogenous (biosphere, hydrosphere, atmosphere) processes. Exogenous factors will affect the geomorphic process, so it is dynamic (Borrelli, 2014; Waele, 2011 Landslides as the movement of soil material will affect the shape of the slope (curvature) in the landscape so through geomorphological approaches it can be used to identify areas where landslides have occurred and have the potential for landslides.

The occurrence of a geomorphological process in the form of a landslide will affect the surface configuration such as the shape of the slope which was initially convex due to a landslide then turned into a concave shape (Bishop et al., 2018; Sofia, 2020). On the other hand, convex and concave slopes in areas that both have the potential to be prone to landslides will be more prone to convex slopes, so in the study of derivatives of slopes it is known as plan curvature and profile curvature. The derivative of this slope shape will affect the acceleration and deceleration of the movement of landslide material. The configuration of different slope shapes will also affect the speed and deceleration of the water. The difference in the configuration of the slope shape will also affect the soil moisture. In this case, landslides as the geomorphological process will affect and be influenced by their geomorphic shape.

Active landslides and dormant landslides that occur in the study area are located in the peak to lower slope morphological units with a maximum slope of 28^0 for rotational type landslides, while the slope is between 28^0-32^0 for translational type landslides. Landslide morphology in the research area is divided into landslide morphology units in the form of landslide crowns, landslide scarp areas (Scarp), landslide heads, landslide bodies which are mostly upslope and downslope morphological units, and landslide feet, namely toe slopes. Each landslide morphological unit has unique geomorphological characteristics (Figure 4). These characteristic differences can be identified through slope angle, elevation, and geomorphological processes. Landslides in the research area are generally divided into two, namely 1) rotational landslide (slump) typology which is identified based on the shape of the landslide body, landslide area, and the shape of the slip plane which forms a semicircle and the presence of a break below the landslide scarp, 2) translational landslide typology (translational) which is identified through a planar-shaped landslide body that has a steeper slope compared to translational landslides.

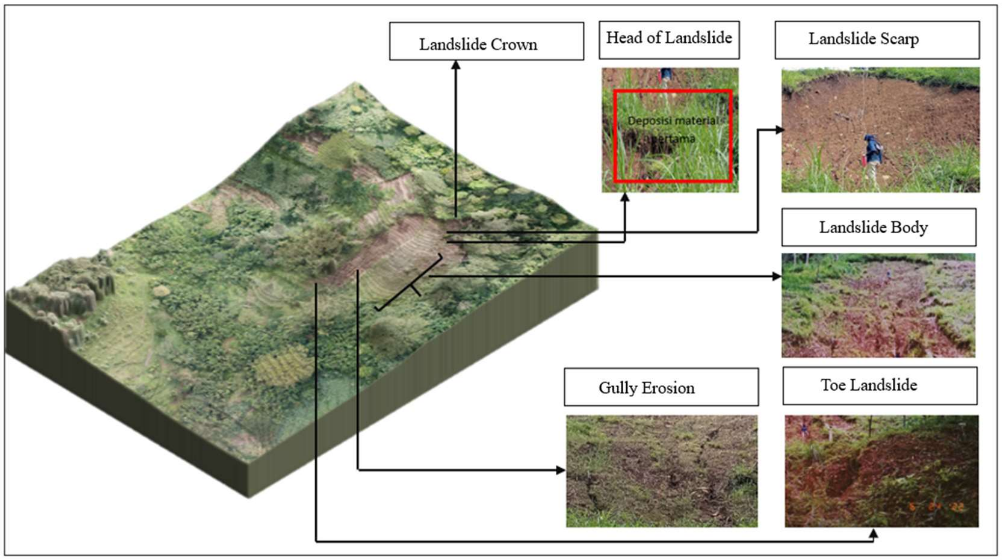

Figure 4. Landslide Morphology in the Research Area.

Landslides as one of the geomorphological processes are strongly influenced by landscape configuration where this landscape configuration is influenced and influenced by exogenous and endogenous factors studied in a geomorphological approach consisting of morphology, morphochronology, morphoarrangement, and morphogenesis (Hutagalung, 1967). The interaction between exogenous and endogenous factors can be seen in (Fig.4). The existence of interrelated interactions between landslide processes that affect the shape of the surface and the shape of the surface formed is influenced by endogenous and exogenous processes is the core discourse of geomorphological studies. Several geomorphologists have studied landscapes using three approaches, namely 1) an evolutionary approach to landforms that has its roots in the science of geological history (geo history); 2) An approach that focuses on the characterization of landforms and landform systems derived from geographic spatial science and 3) An environmental approach that focuses on the study of landforms and landscape systems on a regional to global scale.

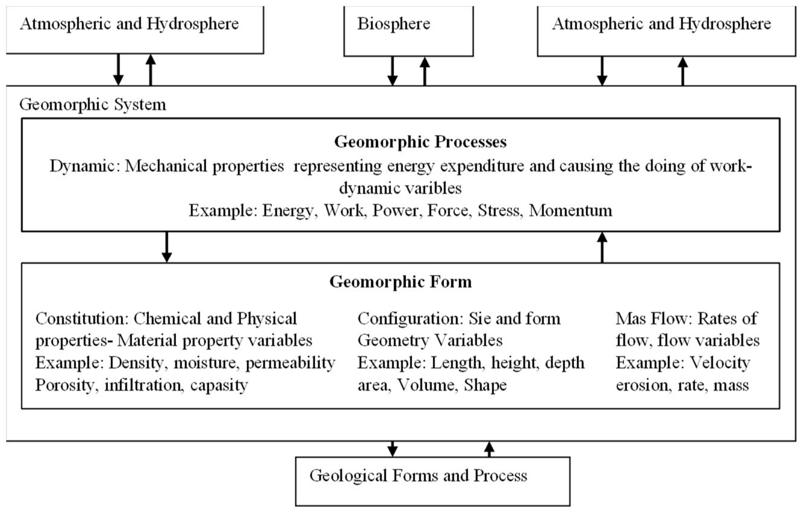

Figure 5. Exogenous and Endogenous Interaction Diagram in Geomorphic Process.

Geomorphological Approach for Landslide

Morphology

Morphology is part of the landscape analysis that affects the potential for landslides. The morphological parts that affect the potential for landslides are the slope, elevation, direction of the slope, and shape. The morphology section based on research achievements mostly emphasizes slope analysis as part of the morphology that affects landslide potential (Cardinali et al., 2002; Keller et al., 2020; The et al., 2013). The Slope is an important factor that triggers landslides. This has an impact on the movement of the ground which is influenced by the force of gravity. If the slope angle is greater, then the movement of soil material will be greater. Slope is related to morphological units because both of them act as landslide initiators. Slope assessment and classification of morphological units are between flat to steep slopes which are located in alluvial and colluvial morphology units. The effect of slope on the potential for material movement is described according to Fig.5.

The slopes in the study area are divided into five classes, namely gentle ($<15^0$), slightly sloping (15^0-25^0), sloping (25^0-35^0), steep (35^0-45^0), and very steep (>450). The greatest intensity of landslides occurs on slopes of 25^0-35^0 degrees because on this slope a lot of slope cutting is carried out for roads which causes the slopes to be unstable. At this slope value, many translational and rotational landslides are found.The sloping areas with the greatest angles are mostly on the middle slopes above hilly or mountainous areas. According to Samodra, (2015); Weiss, (2001); Hugget, (2007); and Dalrymple et al, (1968) morphological units can be classified into seven parts such as peak interfluve, upper slope, middle slope, down slope, colluvial toe slope, and colluvial plain. Based on Fig. 5 landslides are potentially influenced by morphological units. The peak interfluve is located in a flat area, so there is no force to move the soil material. The slope angle of the deep slope is the interfluve peak of about 0%-3%. The upper slope to the middle slope is the most gentle area with angles ranging from 26% to more than 45%. Geomorphological processes and landslide movements usually begin at the top of the slope/shoulder (Samodra, 2015)The geomorphological process that develops on the upper/shoulder slope is a fracture area that can trigger landslides if the soil resistance is less than the soil mass load (I). The middle slope becomes a transportation zone when a landslide occurs. This occurs in a slightly inclined slope class with a slope angle of about 9% to 15% (II) . The lower slope, colluvial toe slope, and colluvial plain are zones of accumulation of landslide material (III). The force of material movement in this area is smaller, so this morphological unit is safer against landslides than the upper/shoulder and middle slopes with slope angles ranging from 4% to 8%. The relationship between morphological units and slope class is especially for mountainous areas.

Surface Material

Internal and external factors greatly affect the condition of the surface material. The structure and arrangement of surface materials affect the potential for material movement, namely accelerating, slowing, and controlling various types of landslides. One of the processes of internal factors that affect the surface material is the intrusion process, namely the process of breaking through magma that hits the source rock, thereby causing the acceleration of the weathering process of the parent rock. The result of the intrusion process will produce an alteration material with high clay content characteristics. High clay content will increase the potential for landslides. The structure and arrangement of surface materials control various types of landslides in hilly and mountainous areas (Bievre et al, 2015);

Surface materials can be divided into consolidated and unconsolidated materials. Both of these materials play a role in the movement of materials, the difference is that unconsolidated material has a greater potential to be transported if there is a kinetic energy force in the form of rain. Unconsolidated material is easier to transport because the material has a slip rupture or slip plane. In this condition, most types of landslides are translational and translational. In a solid material, the potential for transported material is smaller than that of unconsolidated material. The material resulting from landslides has the characteristics of being easily moved if there is kinetic energy that hits it.

Geomorphic Process

Endogenous processes influence the composition of the material and the morphology of the surface so that it affects the movement of the material. Many mountainous areas are prone to landslides. The occurrence of earthquakes in landslide-prone areas will increase the possibility of landslides because the shaking of the soil or the widening of the soil material caused by the shaking allows water to infiltrate quickly. Volcanic materials such as rock, sand, and ash become debris flows after mixing with water from rain or crater water which accelerates rapidly on steep mountain slopes. Hot lava flows can destroy any landscape in its path.

All exogenic geomorphic processes include denudation, weathering of rock material, and mass movement on slopes. The parent rock formed from weathered volcanic processes has the characteristics of a high clay content, thus causing an increase in the potential for movement of soil material starting from the process of erosion/landslide, transportation, and deposition on the earth's surface. Of course, this material's movement process is influenced by gravity's force. The surface material and topography strongly influence the process of material going down the slope. The slope's shear strength determines the material's ability to resist deformation and fracture. Differences in constituent materials result in differences in resistance to deformation and motion. The erosion, transportation, and deposition processes occur simultaneously by natural factors of lithology, geological structure, climate, and relief morphometry, forming different morphogenic systems (Baron et al., 2024)

Landslide Identification and Mechanism based on Geomorphological Approach

Identification of landslide hazards can be done based on a geomorphological approach. Data acquisition using geomorphology for landslide susceptibility studies can be done terrestrially and interpretation of satellite images and maps with a landscape approach. A Landslide is the movement of soil material in a massive volume and the process occurs very quickly, so the identification of areas prone to landslides is a very important part of reducing the risk of landslides. Landscape analysis is the key to interpreting and identifying hazard vulnerability, including landslides. The occurrence of landslide hazards cannot be separated from natural factors that exist on the earth's surface. These factors can be identified by identifying the components of the earth's surface, such as natural processes at work (Fang et al., 2023; Du et al., 2023) Endogenic and exogenous forces cause landslides. Landslide areas can be identified from the shape of the earth's surface which can be approached by landscape analysis.

The geomorphological approach can be applied to identify landslides by taking into account the four important components of the analysis that cause landslides, namely morphology, morphogenesis, morphochronology, and morphoarrangements. Surface morphology that has the potential to become a landslide point is an area that has a significant difference in altitude, such as mountainous and hilly areas. Morphochronology, arrangement, and genesis will affect the constituent materials, both surface and sub-surface materials, and the potential for geomorphological processes. The surface material of the soil or rock is also responsible for the occurrence of landslides. The composition of soil and rock allows it to be transported in large quantities, besides the high elevation driving factor causes the area concerned to be prone to landslides. Three main processes work in the formation or change of an area, namely erosion, transportation, and sedimentation, all of which are the subject of landscape analysis. Identification of landslide susceptibility detached from the earth's surface requires further understanding of the characteristics of the landscape.

Observations in the Middle Part of Bromo Tengger Semeru Region

Taji Village as a village located on the southwest upper slope of the Bromo Mountain System has a high landslide potential. Taji Village is one of the villages included in the Bromo Tengger Semeru (BTS) area. Based on morphological analysis with a topographical approach, most of the morphology of this area are hills from the top of the hill (0.6%), upper slope (10%), middle slope (9.49%), lower slope (39.36%), and bad channel (40.49%). The top of the hill has a flat morphology, so there is no potential for material movement at the top. Most of the hilltops in this area are used for roads and people's houses. At several observation points found between the top of the hill and the upper slope, soil cracks were found as the beginning of the movement of soil material. The upper slope is a morphological area with a greater potential for soil material movement than the middle and lower slopes. In this morphology, geomorphological processes are found in the form of landslides and erosion. Based on observations, the community uses the upper slopes to the lower slopes of former landslides or dormant landslides for cultivating agricultural land with a terraced system with plant species of cassava, carrots, apples, and coffee. Utilization of dormant landslides (inactive landslides) are lands where landslides have occurred for a very long time with the type of material movement in rotation referred to as rotational erosion. Using ex-slide land is part of the community's local wisdom to continue using land to meet their daily needs. This is because the Taji Village community's main income source is agricultural products (Interview, 2021).

Surface material

Taji Village as part of the Bromo Tengger Semeru (BTS) area as a whole is a volcanic area, so its geological formation consists of volcanic activity in the young quarter and old quarter volcano. The surface lithology of this area consists of andesite, basalt, and mostly volcanic tuff. The constituent materials are divided into base material (bedrock) and surface covering material. The basic material in the research area generally comes from volcanic material from Keciri Volcano (30.80%) and Old Temugiri Volcano (31.72%). The dominance of bed material is spatially distributed on the upper slopes of the watershed. Most landslides occur in the basic materials of both. The geological structure of this area produces rocks that are not solid and have no strong grain bonds, so they are easily eroded.

The surface materials in each landslide morphology have different characteristics based on analysis of structure, texture, Cole index, permea, and porosity. At the crown of the landslide to the scarp area, this is the original soil, while at the head of the landslide, the body of the landslide to the foot of the landslide is the deposition of material resulting from landslide breakdown. The material resulting from landslide destruction (colluvial material) is more erodible than original soil because the material resulting from landslide destruction is soil that has been disturbed (soil disturbance). Soil texture is one of the most important physical properties of soil regarding the potential for soil movement. Soil texture affects soil moisture retention, adhesion ability between soil particles, and response to water.

Soil analysis was carried out in 2020 with 3 sampling points, namely on land with pre-onion plants, cabbage, and carrots as the types of plants widely planted in the research area. Based on the analysis results indicate that the dust content in this area is very high, the soil texture is dusty clay, and the soil structure is granular (Table 1). In general, soils with high dust content and low organic matter are most easily eroded (Heckman et al., 2021; Wang et al., 2021) . Based on laboratory data shows that there is a relationship between the proportion of sand, dust, and permeability values. The greater the content of dust and clay, the smaller the permeability ability, so that when there is kinetic energy in the form of rain, it increases the movement of soil material through increased runoff flow.

Table 2. Physical Characteristics of Soil in Taji Village.

No	Soil Characteristic	Cover Crops		
		Pre-Onion	Cabbage	Carrot
1	Sand	46,15%	19,83%	56,34%
2	Dust	48,10%	64,71%	31,34%
3	Clay	5,74%	15,46%	12,07%
4	Texture	Silty loam	Silty loam	Silty loam
5	Permeability	34,893 cm/hour	28,076 cm/hour	40,063 cm/hour
6	Specific Gravity	0,772 g/cm^3	0,823 g/cm^3	0,871 g/cm^3
7	Structure	Granular	Granular	Granular

Source: Muddarisna et al, 2021.

Landslide Characteristics in Taji Village

Landslides are an environmental problem in the research area. There have been several landslides that caused losses in the form of damage to houses and losses in agriculture. The morphology and constituent materials in the study area are factors that cause this area to have the potential for landslides. In addition, the potential for landslides is increasing due to human activities in the form of cutting slopes used for roads and houses. Landslides in the study area are categorized as shallow and deep landslides because the landslide depth (Dd) exceeds 3 meters (Vandromme et al., 2020; Zêzere et al., 2005). The occurrence of deep landslides in the study area is caused by tectonic control. The occurrence of shallow, deep landslides, and complex landslides cannot be separated from the geological and geomorphological setting (Nguyen et al., 2020). Based on the Malang Sheet Geological Map at a scale of 1:100,000, it shows that the Jabung area, which is the research area, contains a fault from the Keciri Volcano which runs from the northeast towards the southwest (Figure 6). The geological age of the research area is the Pleistocene quarter (Qpv) with the parent material being interbedded lava, breccia, volcanic, and tuff. The Qpv material also contains anglomerate breccia and pumice. Shallow landslides in the research area can be initiated due to land use that is not in accordance with its suitability, thus initiating landslides. The change in plants which were originally standing plants and then changed to horticultural plants in the form of cabbage and spring onions also initiated shallow landslides in the research area. The landslide deposition zone has more erodible soil than the landslide crown because the deposition zone is an accumulation of colluvial material resulting from landslide collapse. In the deposition zone, there is a lot of splash erosion and reel erosion.

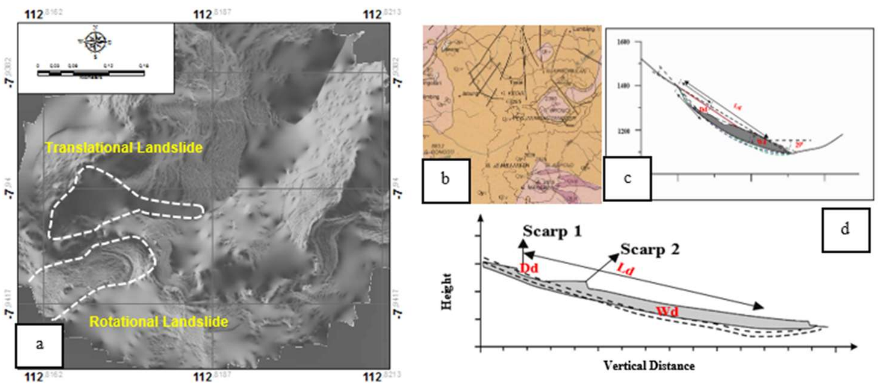

Figure 6. Landslide Cross Section a) Rotational X: 700396; Y: 9120505 and Translational X: 700790; Y: 9120356; b) Geological Setting; c) Rotational landslide cross-section; d) Rotational landslide cross-section.

The basic difference between avalanches with rotational and translational is in the shape of the landslide body. The rotational type has a curve-shaped landslide body and usually has a major and minor landslide escarpment plane. The translational type of landslide has a planar landslide body shape and only has a major landslide escarpment area. These two landslides include active and inactive (dormant) landslides that are used by the community for agricultural land with local agroforestry plantations. Each type of landslide has different site characteristics. Most of the rotational type landslides occur in mixed gardens with a gentler slope than the translational type landslides. Most of the translational type landslides occur in association with roads. The community does not use former landslides with the translational type because this type of avalanche has a planar and steep body shape. The people of Taji Village already understand the strategies for reducing the risk of landslides in each characteristic. In the type of translational landslide, the community does not carry out processing because it can trigger another landslide (reactivation) so that the former avalanche with the translational type is overgrown with grass species (Interview, 2021). Analysis of morphology, constituent materials, and geomorphological processes in the form of existing and dormant landslides is a landslide study with a geomorphological approach. The existing constituent materials in Taji Village are the result of morphogenetic and mofochronological processes. Fig.7 shows the landslide susceptibility analysis based on geomorphological analysis.

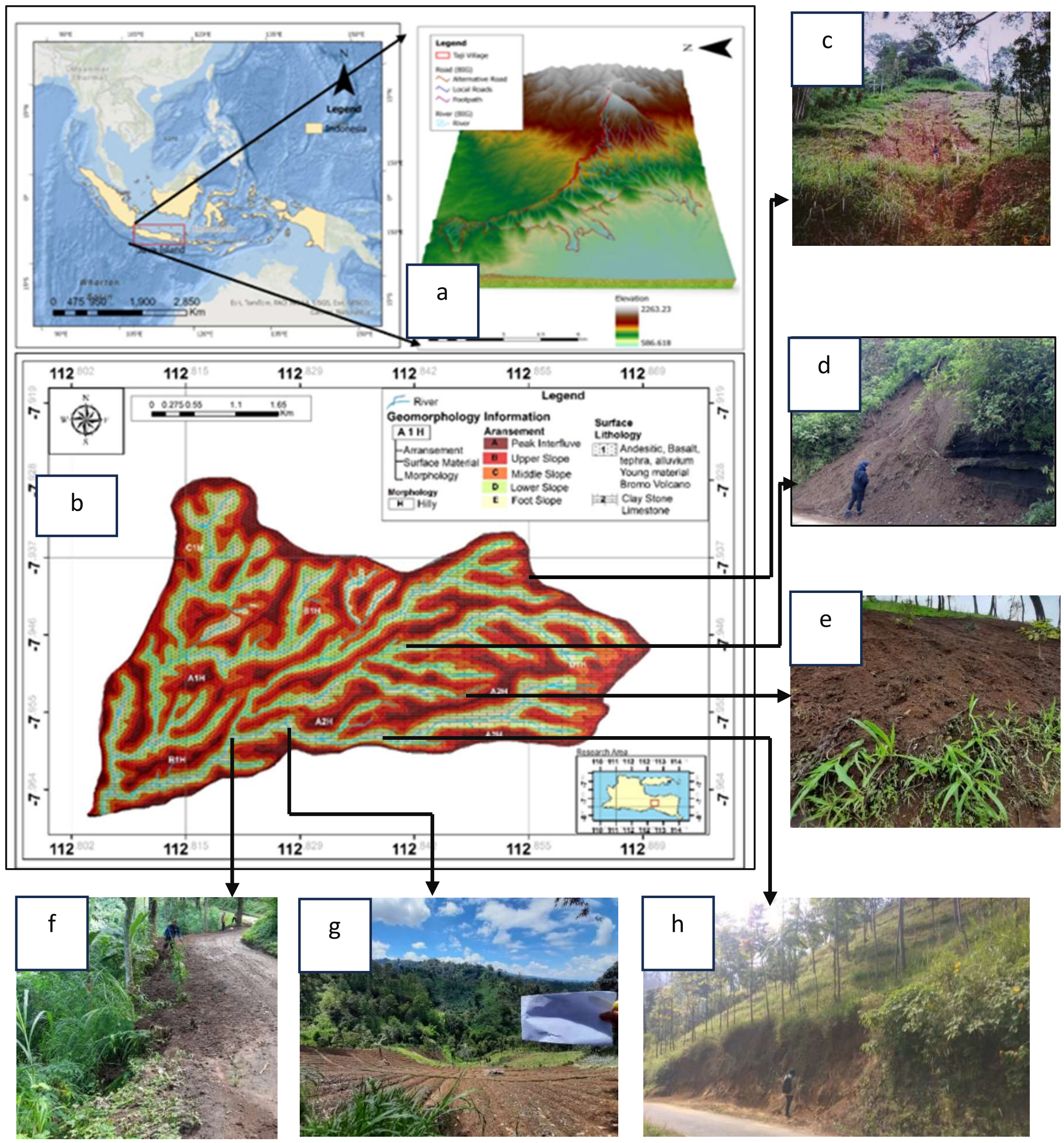

Figure 7: a) 3D of Taji Village; b) Geomorphological Map; c-d) translational landslides on upper to middle slope morphology; f-h) rotational landslides on the middle slope, lower slope and toe slope.

Landslide Accuracy

In this research, accuracy tests were carried out based on comparative values of landslide susceptibility maps with actual active landslides in the field. Vulnerability map validation test using the success rate method. The number of actual landslide events was 15 areas taken randomly in the research area. Table 2 shows the interval probability classes for landslide susceptibility classes and actual landslides. The concept of calculating the success rate is to sort the landslide susceptibility map values from high to low. Based on Table 2, it shows that interval class no. 1-5 is an area that has a high to medium vulnerability class value which has a larger number of pixels compared to the interval class value 6-10.

Table 3. The interval probability classes for landslide susceptibility classes and actual landslides.

No.	Class Interval	NPix Probability	NPix Landslide	Comulative Landslide	Percentages Landslide Area
1.	0-10	2182	150	150	31.33%
2.	10-20	3267	100	250	50.20%
3.	20-30	3094	83	333	66.87%
4.	30-40	5074	70	403	80.92%
5.	40-50	5112	45	448	89.96%
6.	50-60	6098	23	471	94.58%
7.	60-70	4474	9	480	96.39%
8.	70-80	4322	11	491	98.59%
9.	80-90	2427	7	498	100.00%
10.	90-100	252	0	498	100.00%

The percentage accuracy of the landslide hazard map according to the success rate curve, namely the area under the curve (Area Under Curve) is 74%. The landslide susceptibility value indicates that there is more than a 50% probability of landslide susceptibility in one watershed in Taji Village. The landslide hazard accuracy value of more than 50% can be used as a reference for predicting the potential for landslides and priorities for landslide disaster mitigation in Taji Village. Fig. 9 shows the AUC value of the accuracy test.

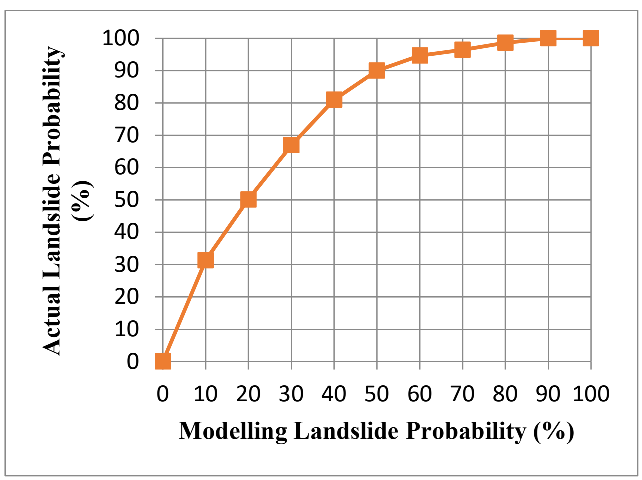

Figure 8. Accuracy Value.

Conclusions

Geomorphology can be used as a landslide susceptibility mapping approach. Four geomorphological aspects, namely morphology, morphogenesis, morphochronology, and morphoarrangement, greatly influence the process of landslides. The occurrence of landslides causes changes in the shape of the land surface to become concave. However, on the other hand, the landslide process will affect the geomorphological characteristics of the landscape. The morphogenic aspect in the form of volcanic material causes the research area to have very erodible soil characteristics. The basic material in the research area generally comes from volcanic material from Keciri Volcano (30.80%) and Old Temugiri Volcano (31.72%). The dominance of bed material is spatially distributed on the upper slopes of the watershed. The characteristics of landslides in the study area are dominated by translational and rotational landslide types. Translational landslides occur on slopes >280, while rotational type landslides occur with a maximum slope of 280. Based on landslide susceptibility mapping using a geomorphological approach, it shows that 52.13% are at very high susceptibility located on the upper slope morphology, high susceptibility is 25.45 % on the middle slope, 10.16% medium vulnerability on the lower slope, and 12.26% low vulnerability on the foot slope morphology.

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