Zoning landslide vulnerable area according to geological structure, slopes, and landuse parameters In Trangkil Sukorejo Gunungpati Semarang City’s Residential Area

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Abstract. The condition of the geological structure, land use, and slope in Trangkil Sukorejo Gunungpati Semarang City’s residential area can influence the occurrence of the landslide. In this study zoning is conducted to identifying the landslide vulnerable area and based on three main parameters that affect the occurrence of land movement, i.e., Geological Structure (A), Slope (B), and land use (C) according to weighted formula H (Weight) = (0.24xA) + (0.38xB) + (0.38xC)). The result indicates that the southern part of the settlement is relatively safe than the northern part where the landslide vulnerability point is located, there is a fracture that can trigger the water entry through the weathered breccia.

1. Introduction
A fault geological structure in the Semarang City has been affirmed its existence and cause many problems, notably the land instability and road damage as found in Sekaran. In early 2014, a landslide occurred at those sites include the half part of Sekaran-Sampangan road which resulted in damaged houses, one dead and few residents of the Trangkil residential area must be relocated due to the severely damaged houses.

The landslide may also be referred to as land movements [1]. The land movement (landslide) is a product of a process of the slope balance’s disturbance which causes the movement of soil mass and rock to a lower place. The force that holds the soil mass along the slope is affected by the soil’s physical properties and its angle of slide resistance along the slope.

The geological condition is one of the factors of landslide occurrence, to detect the geologic condition of landslide area, the geophysical method is needed. One of the geophysical methods which can be used is the geophysical resistance method. The mapping method is used to determine the rock resistivity distribution in the lateral direction. From its result will be estimated the rock distribution underneath the soil surface [2].
The 2D resistivity geophysical method is used to detect a slip surface or shear surface. Darsono et al. in his research identifying the landslide’s trigger of slip surface in Pablengan Village, Matesih District, Karanganyar where the slip surface is wet clay with the value of resistivity is 19.3 Ω m- 36.6 Ω m at depth 1.7 m-17 m [3].

Mubekti and Alhsanah, F, developed a spatial model based on Geographic Information System (GIS) to identify the landslide vulnerable areas [4]. The model uses map’s overlay and tabular weighing techniques on its attributes, involving seven variables, i.e., slope, geology, rainfall, groundwater content, infiltration rate, seismic zone, and land cover. The zoning process to identify the vulnerable landslide area is based on three main causes of land movement which are Slope, Geological Structure, and Land Use.

2. Geological Engineering of Research Area
   2.1 Morphology
   Based on the results of the research is known morphology of the research area is a hill area with a slope 15 ° up to 45 °, the natural processes which occur are cliff erosion and rock mass movement. In this area the growing vegetation mainly trees and shrubs. The land use is mostly settlements and fields.

   2.2. Lithology
   In the research area, it is known that there are two types of lithology based on mapping result, they are volcanic breccia and carbonaceous carbonate. The volcanic breccia has a megascopic appearance as described as dark gray color, an andesitic gravel fragment (2 mm - 4 mm) to a lump (> 256 mm), a matrix of a lapilli-size tuff (2 mm - 64 mm) with a bad shortage, moderate to high weathering level. At some observation sites, there is a fracture at the vertical-directed Volcanic Breccian’s outcrop. The fracture is likely to occur due to the imposition of rocks from water that infiltrates within the rock. This fracture has a potential to become a surface water flow’s pathway which can accelerate weathering and erosion. These events can cause rock mass movement that triggers a landslide. These volcanic breccia rocks enter within the Kaligetas Formation (Qpkg) which may be deposited as lava deposits [5]. This rock distribution is almost 90% of the whole research area.

   Clay on the research area has a megascopic appearance as described as a gray color, size of clay-sized grain (<1/256 mm), carbonate cement because when dropped by HCL it was foaming, high weathering level. This rock distributes about 10% which located in the eastern part of the research area. This unit is exposed beneath the volcanic Breccia close to the seasonal river which only filled during the rainy season. Limestone is an impermeable rock because of its inability to escape water which may lead to a landslide.

   2.3. Analyze Influencing Factor to Landslide
   Landslide or land movement is a slope material displacement; they can be rock, soil weathering, piling material or a combination of which moves down and out of the slope [6]. Many factors influenced the emergence of land movement, namely slope, lithology, geological structure, rainfall, and land use.

   The slope is a slanting degree reflected in the morphology. The larger the slope level will generally increase the land movement in the certain area. This is happening because of the gravitational force that attracts rock mass from top to bottom. The higher the slope level its rock will be easier forced downward which resulting in the occurrence of land movement.

   The geological structure is a weak zone in a rock formation or lithology. The occurrence of fracture reduces the rock’s bending power thus reducing its resistance level. Furthermore, the fracture also becomes a path, where the water infiltrate causes the weathering and erosion going more intensive. The rock which exposed to intensive structures has a greater potential for land movement.
Land use is the culture produced by humans. Some of them are a settlement, road, rice field and so on. Land use also affects land movement. Land use can increase the burden of its lithology. If the load is greater than the strength of lithology, there will be a movement. Vegetation is all kind of plants that exist in the region — namely grass and shrubs. Vegetation also affects the degree of slope stability. Some vegetation can improve the slope’s stability because its roots can bind the rock mass to make it more compact. On the contrary, some vegetation with weak roots can actually reduce the level of slope’s stability and cause the occurrence of land movement.

2.4. Zoning Landslide’s Risk Level
Zoning was conducted based on three main parameters that affect the occurrence of land movement include slope, geological structure, and land use. Field mapping was carried out to collect reference points, including sampling to obtain data which influence the occurrence of land movement. Weighting is done by assigning the value of each factor with a scale of 1 - 5 as listed in Table 1- 3. Then, a quantitative method utilizing Geographic Information System (GIS) program which later calculated using the formula as follows:

$$H (Weight) = (0.24xA) + (0.38xB) + (0.38xC))$$

In this case:
A = Geological Structure   B = Slope   C = Land Use

### Table 1. The Parameters of Geological Structure

| No. | Geological Structure       | Score |
|-----|----------------------------|-------|
| 1   | Safe without fracture      | 1     |
| 2   | Slight fracture            | 3     |
| 3   | Vulnerable to fracture     | 5     |

### Table 2. The Parameters of Slope

| No. | Slope’s Value ( % )       | Score |
|-----|----------------------------|-------|
| 1   | 0 - 8                      | 1     |
| 2   | 8 – 15                     | 2     |
| 3   | 15 - 25                    | 3     |
| 4   | 25 - 35                    | 4     |
| 5   | 35 - 45                    | 5     |
| 6   | > 45                       | 6     |

### Table 3. The Parameters of Land Use

| No. | Land Use                 | Score |
|-----|--------------------------|-------|
| 1   | Natural Forest and Pine  | 1     |
| 2   | Composite Bed            | 2     |
| 3   | Field                    | 3     |
|     | Grassland                | 3     |
|     | Shrubs                   | 3     |
| 4   | Settlement               | 4     |
| 5   | Rainfed Field            | 5     |

Based on the formula above, The Landslide Risk Map is divided into 5 zones, which are:
3. Result and Discussion

The morphology of the research area, which is the Trangkil settlement is part of a corrugated hill slope composed by tertiary sediment deposit and quartz volcanic sediment unit. Based on field observation and shallow drilling, it can be seen there are three lithology units in the area (Figure 1), which are limestone, breccia, and gravel clay sand units. The limestone unit is the lowest stratigraphic rock as described as blackish gray clay, compact, slightly soft, and easily shattered. Breccia unit is dark gray, medium to the fine sand matrix, fragment 5 - 30 cm, slightly angled, overt and andesite packed. The silt-gray silicone unit is composed of sandy silk with gravel and crust content. Based on the drilling data, its lithology appeared in a mild, clunk and gravelly condition alike andesite and limestone, containing a lot of wood, dirt, fractions, red brick remnants of beverage cans and its thickness is thinned to the northeast part as a pattern. According to a geoelectric study conducted by Yulianto, et al. this lithology’s thickness is about 1 - 2 m on the north side and 2 - 15 m on the south side. In accordance with its physical condition and distribution, it is strongly alleged that the silt unit is a soil agglomeration during the settlement’s land preparation. [7]

Figure 1. The Geological Map of Research Area

According to the geological information and subsurface conditions based on the resistance, it can be classified into three classes, namely fractions, slight fracture and vulnerable to fracture class which indicates the potential level of landslide’s trigger as shown in Figure 2.
The information of slope or slope angle is obtained using primary field measurement data using Abney level and secondary data from the result of remote sensing image based on digital elevation model data extraction (DEM) from ASTER GDEM image with spatial resolution of 30 meters with height accuracy of 7 -14 M. The results of the DEM data extraction are then incorporated into the Geographic Information System (GIS) software for 3D spatial modeling to find the expected slope inclination information. The results in the studio are then verified using the Abney level based on each sample points that have been determined using a stratified random sampling method. Data correction is done if there is the difference between DEM and field verification data. The research area has flat to the steep slope as shown in Figure 3.
The land use map (PL) shows the land function on the earth’s surface, whether natural or artificial (the result of human activities). Land use data is obtained from secondary data from Indonesian Topographic Map (RBI Map). The land use information from the RBI map is then updated with a land cover’s visual interpretation using high spatial resolution satellite imagery, Geoeye with its latest acquisition data. This process needed to be done because the RBI Map contains long term data and need to be updated so that the research is valid and based on the real condition. The result of the studio data is then verified by field check based on each predetermined sample points using a stratified random sampling method. The data correction is needed if there is the difference between the land cover and land use interpretation and its real condition data. The result of the land use map, the research area consist of residential building, yard, shrub, open bed and field as shown in Figure 4.

Based on the weighting formula: \( H (\text{Weight}) = (0.24xA) + (0.38xB) + (0.38xC) \) of the geological structure class, slope, and land use map is obtained a landslide zonation class consist of safe class zone, relatively safe zone, moderate zone and zone. The vulnerable to landslide zone is present in the settlement area on slopes 25-45 percent and the fracture rests on the lithology of silt as shown in Figure 5.

![Figure 4. Land Use Class Map in Trangkil Area](image-url)
4. Conclusion
The result of weighting indicates that the Trangkil settlement area is included in safe and vulnerable to landslide zone, there isn’t any highly vulnerable zone. However, almost 60% of vulnerable landslide area is located in a residential area. Its slope is 25-45 percent or more, and there’s a fracture zone that can trigger water infiltration through the weathered breccia.

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