Implementation of the SMORPH method for mapping the susceptibility area of landslide in Bogor City

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Abstract. This study aims to map landslide susceptibility areas in Bogor City. The method used is the modified SMORPH method. The main parameters in this method are the slope angle and slope shape. Calculation of slope shape using curvature algorithm. The results showed that the widest medium and high hazard classes were in the South Bogor Subdistrict with a percentage reaching 46.14%. This is because most of the area is the lower slope of denudational volcanic cones and river cliffs. Medium and high hazards with the lowest area are in East Bogor Subdistrict, where the dominance of the area is the volvio volcanic plain covering an area of 70.41% of the total area.

1. Introduction
A landslide disaster is one of the disasters that often hit Indonesia. Landslides were recorded as the second most frequent disaster in Indonesia after the flood. The recorded data [1] shows that the trend towards catastrophic floods and landslides continues to increase until BNPB releases the highest disaster data in 2016. Disaster events recorded in 2016 were 2,342 events for all types of disasters and were the highest occurrences since the recording of events in 2002. Of all the disaster events, 92% were dominated by hydrometeorological disasters which were generally in the form of floods, landslides, and tornadoes. In the case of landslides, disaster data recorded during 2016 landslides occurred as many as 612 incidents and caused 188 deaths. The high vulnerability of landslides causes landslides to be the most fatal. There are 40.9 million people in Indonesia who are predicted to be exposed to moderate and high risk of landslides.

The increase in landslide disasters is not only caused by extreme climate change. One of the main causes of the increase in the incidence of environmental disasters in Indonesia, among others, is the increasing conversion of land, especially from forests to non-forests. Rapid urbanization causes the need for residential land to increase. This causes changes in land use patterns in the form of land conversion. [2] The pattern of utilization of space in an area is the impact of the interaction of socio-economic factors that take place in line with the development of space and time. In addition, the development of a region also affects the policy of space allocation from a region.

The case of increasing land-use conversion associated with landslide disasters is a serious highlight by researchers, academics, and the government. In response to this, several watersheds are included in the "super-priority" category, which means they must be restored as soon as possible. In the strategic plan of the Directorate General of Watershed and Protection Forests, two watersheds that passed...
through the city of Bogor, namely the Ciliwung watershed and the Cisadane watershed were prioritized for 2015-2019 [3].

The high rate of land conversion to steep areas along the Ciliwung river and Cisadane river in Bogor City is one of the triggers for the landslide disaster. On the other hand, the morphology of Bogor City in the southern region is increasingly bumpy because it approaches Mount Salak, so that the area has a high potential for landslides. As stated in the background, landslides that occurred in the city of Bogor were generally shallow landslides. This landslide occurs in a small area but has a greater frequency of events. Data collected shows landslides ranked first in the most frequent disasters of 6 types of disasters that occurred, in total there were 179 landslide events (40.5%) out of 442 recorded disaster events [4]. So to overcome this, identification of landslide hazard areas and appropriate mitigation directives are needed as input to the local government.

The objectives of this study are (1) to analyze and map landforms as a subset of landslide areas in the city of Bogor, (2) determine and map landslide hazard classes in the city of Bogor using the SMORPH method.

2. Research methods

2.1. Time and Place.
The research was conducted from August 2017 to January 2018. The areas studied included the entire area of Bogor City, namely West Bogor District, South Bogor District, Bogor Tengah District, East Bogor District, North Bogor District, and Tanah Sareal District. Data analysis and processing is carried out in the Remote Sensing and Spatial Information Division, Department of Soil Science and Land Resources, Faculty of Agriculture, IPB.

2.2. Materials and methods.
The material to be used in this study relates to the location literature as well as a study of the landslides that occurred in the city of Bogor. The materials include SPOT 6 satellite imagery, DEM maps, thematic maps, population data, questionnaires and other materials that can support research. The tool that will be used is a laptop with Arcgis 10.2 software, ERDAS Imagine 14, and Microsoft Office. In the field research, the tools used are smartphones with software Avenza Map, digital cameras and stationery. The relationship between objectives, data types, data sources, methods and results used in this study can be seen in table 1.

Table 1. Matrix of relationship objectives, data types, data sources, methods and results

| Aim | Data type | Data source | Method | Result |
|-----|-----------|-------------|--------|--------|
| 1. Mapping landslide susceptibility areas | SRTM (30m medium scale) | United States Geological Survey (USGS) | Digitize on Screen | Landform map as a subset area |
| | SPOT 6 Satellite Image | LAPAN | | |
| 2. Determination of Landslide Hazard Classes | SRTM (30m medium scale) | United States Geological Survey (USGS) | Modify SMORPH using Curvature Tools | Landslide Hazard Classes |
2.3. Making a subset of landslide-prone areas

Analysis of landslide susceptibility areas was carried out by mapping all landforms/landforms prone to landslides in the city of Bogor on a scale of 1: 25,000. The material used in landform mapping is DEM sourced from SRTM. DEM-SRTM data is processed into Hillside and slope so that a combination of the two results in the interpretation of landforms. The results of landform-based landslide susceptibility mapping are then used as a subset of areas for further analysis so that the area analyzed is only in a predetermined subset.

2.4. Determination of landslide hazard class based on SMORPH method

This stage aims to determine the landslide hazard class. At this stage, the slope shape is selected according to the SMORPH method developed by Shaw and Johnson [5] where the shape of the slope influences the process of accumulating soil mass which is influenced by water in the soil. Convex slopes (such as ridges) tend to spread groundwater to eventually prevent the formation of hanging groundwater and reduce the development of high water pressure in the soil pores that contribute to slope instability. Concave slopes (such as valleys) tend to form hanging groundwater and collect groundwater, surface water, sediments, and organic material. In this section, carrying capacity such as gravity, the pressure of the soil pores, and the weight of the soil (including water and plants) can cause mass movements.

Calculation of slope shape (curvature) using slope shape value algorithm. The value of the shape of the minus slope (-) shows the shape of a concave slope, plus (+) shows the shape of a convex slope, and 0 indicates the shape of a straight slope. This study uses CV limits between -0.01 to 0.01. The shape of the slope is concave if the CV value is less than -0.01 and is said to be convex if the CV value is more than 0.01. While the shape of a straight/planar slope has values including [6]. Hazard determination refers to the matrix SMORPH which has modified the slope value and the danger level. The SMORPH matrix can be seen in table 2.

| Table 2. SMORPH Matrix (Modification) |
|--------------------------------------|
| Slope Shape | A (0-8 %) | B (8-15 %) | C (15-30 %) | D (30-45 %) | E (>45 %) |
| Convex     | Low       | Low       | Low         | Medium     | High      |
| Flat       | Low       | Low       | Medium      | Medium     | High      |
| Concave    | Low       | Medium    | High        | High       | High      |

Source: Putra [7]

3. Result and discussion

In this study landforms were interpreted from satellite image data Shuttle Radar Topography Mission (SRTM 30 meter resolution) and SPOT 6 imagery in 2017. Based on the results of interpretation (Figure 2) shows that the widest landform in the study area is the Fluvio-Volcanic Plain with the area reached 7,181.4 ha or 61.47% of the total area of the study area. This landform is spread evenly in almost all districts. Meanwhile, the shape of riverbanks is the second-largest landform with an area of 1,634.5 ha (13.99%) which is found in the South Bogor District. The next landform is the Denudational Volcanic Cone Lower Slope which has an area of 1157.5 ha (9.91%), all of which are in the South Bogor District. The rest is in the form of River Basin and Alluvial Terrace with an area of 802.8 ha, the valley floor with an area of 781.7 ha, and a river channel with an area of 124.5 ha. The description of Bogor City landform can be seen in figure 1 and table 3.
Based on the nature of the landform, both in terms of morphology and geomorphic processes, the landforms prone to landslides are the Lower Denusational Volcanic Cones and River Cliffs, while the Alluvial River and Terrace valleys, as well as the Valley Bases, are associated with River Cliffs and are threatened by Avalanche. Therefore the two landforms were included in landslide susceptibility areas. These areas are then analyzed for vulnerability classes and hazards so that areas in other landforms that are not included in vulnerable areas or are assumed to be landslide safe areas so that they are not analyzed. The area of land chosen for analysis was 4,376.5 ha (37.46%).

**Table 3. Landform distribution in the research area**

| Landform                        | West Bogor | South Bogor | Central Bogor | East Bogor | North Bogor | Tanah Sareal | Total Area (ha) |
|---------------------------------|------------|-------------|---------------|------------|-------------|--------------|-----------------|
| River Flow                      | 31.9       | 26.6        | 27.9          | 19.8       | 13.0        | 5.3          | 124.5           |
| Elementary Valley               | 134.9      | -           | 28.1          | 45.3       | 253.8       | 319.6        | 781.7           |
| Fluvio Volcanic Plain           | 1,582.9    | 1,275.2     | 554.8         | 741.8      | 1,306.2     | 1,720.5      | 7,181.4         |
| River valleys and Alluvial Terraces | 98.9    | 347.6       | 116.8         | 99.9       | 92.2        | 47.4         | 802.8           |
| Denudational Volcanic Cone      | -          | 1,157.5     | -             | -          | -           | -            | 1,157.5         |
| Lower Slope                     | -          | -           | -             | -          | -           | -            | -               |
| River Cliffs                    | 353.1      | 488.5       | 203.5         | 146.6      | 230.6       | 212.1        | 1,634.5         |
| **Total Area (ha)**             | 2,201.7    | 3,295.5     | 931.1         | 1,053.4    | 1,895.9     | 2,304.9      | 11,682.4        |
From the subset of regions, the hazard level analysis is based on the slope parameters and slope shape (SMORPH method). The tool used to detect the shape of the slope is curvature. Slope shape data is then combined with angle slope to produce landslide hazard classes according to table 1. The results of a spatial hazard analysis can be seen in figure 2 and table 4.

![Figure 2. Landslide Hazard Class](image)

**Table 4.** Distribution of landslide hazard areas in each sub-district in Bogor City

| Administrative area | Area of Landslide Hazard Area (ha) |
|---------------------|------------------------------------|
|                     | Medium | High | Total |
| West Bogor          | 222.15 | 69.08| 291.23|
| South Bogor         | 732.26 | 206.98| 939.24|
| Bogor Tengah        | 135.65 | 32.00| 167.64|
| East Bogor          | 125.49 | 19.96| 145.46|
| North Bogor         | 232.49 | 15.29| 247.78|
| Tanah Sereal        | 229.06 | 15.03| 244.09|
| **Total**           | **1677.10** | **358.34**| **2035.44**|

There are 3 hazard classes produced from the analysis. However the lowest hazard class is not calculated with the assumption that the area is safe because the dominance of the slopes is below 30%.

The result of the landslide hazard analysis (Figure 3) shows that the medium and high hazard areas are widest in South Bogor subdistrict with the percentage reached 46.14%. high hazards in the South
Bogor region are caused by landforms, which are mostly areas with steep slopes. Based on the results of the Landform mapping (Figure 1), the total denudational cone slope of 1,157.5 ha is entirely in the South Bogor Subdistrict area, the river cliffs in this region are also the largest with an area of 488.5 ha or 29.9%. This means that the South Bogor Subdistrict area does have the potential for natural landslides that are very high from other regions in the city of Bogor.

Medium and high landslide hazard class with the lowest percentage in East Bogor sub-district with a percentage of 7.15%. although it is the lowest, geographically this sub-district borders the Bogor Selatan sub-district which has the widest landslide hazard area. When viewed from the distribution of existing landforms, the dominance of the landform is the fluvi-volcanic plain which tends to be sloping with a percentage reaching 70.41%.

4. Conclusion
In accordance with the conditions of the Bogor City landform, the area designated as an area susceptibility to landslides is in the form of denudational volcanic cone slopes, river cliffs, and alluvial valleys and terraces. The area with the highest medium and high hazards are in South Bogor District with a percentage reaching 46.14%. East Bogor sub-district becomes the lowest with a percentage of 7.15%. This is because 70.41% of the area is a fluvi-volcanic plain.

References
[1] BNPB 2016 Kejadian Bencana Selama 2016
[2] Ramlan A, Solle M s and Seniarwan 2015 Dinamika dan Proyeksi Perubahan Penggunaan Lahan di kawasan Peri-Urban Kota Makassar (Kawasan Mamminasata) (Makassar: Universitas Hasanuddin)
[3] Kementerian L H dan K 2015 Rencana Strategis Direktorat Jenderal Pengendalian Daerah Aliran Sungai dan Hutan Lindung tahun 2015-2019 (Jakarta: KLHK)
[4] BPBD 2017 Data kejadian bencana Kota Bogor (Bogor)
[5] Shaw J 1987 Slope Morphology Model Derived From. Washington (US: Department of Natural Resources)
[6] Zevenbergen L W and Thorne C R 1987 Quantitative analysis of land surface topography Earth Surf. Process. landforms 12 47–56
[7] Putra H 2014 Identifikasi Daerah Rawan Longsor Menggunakan Metode SMORPH-Slope Morphology di Kota Manado J. Wasian 1 1–7