Smorph application for landslide identification in Kebumen Regency

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Abstract. Indonesia is a country that has natural geological disasters. One of the most frequent geological disasters in Indonesia is a landslide. Landslides are movements of rock or soil mass due to gravitational forces pulling down accompanied by a driving force on the slopes greater than the innate material. Identification and mapping of landslide potential areas has an important role as an effort to overcome and anticipate landslides. One of methods that can be used to determine potential landslides is the SMORPH method. The SMORPH method will produce a landslide classification based on a matrix between slope angle and slope form. This study aims to analyze the landslides potential distribution area in Kebumen Regency. Landslide identification was carried out at 30 locations of landslide events. Spatial analysis of landslide potential is done by overlaying the slope angle with slope form. The potential level for low landslides has a percentage of 79.54% in the southern and central parts of Kebumen Regency, the level of moderate potential level with a percentage of 8.81% randomly scattered over the Kebumen Regency, and 11.65% of high potential level in the north and southwest of Kebumen Regency.

1. Introduction
Indonesia is a country that has natural disasters which consist of hydrometeorology and geological disasters [1]. Landslides are one of the geological disasters which often occur with large number of fatalities and material losses [2]. Landslides are a natural event which is currently increasing [3]. Landslide is the movement of slope-forming material in the form of rocks, materials, soil, or mixed material, moving down or exiting the slope [4]. Geological, topographical and land use factors are some of the things that can cause landslides [5]. The existence of processes that change a slope from vulnerable to critical conditions will cause disturbances in slope stability, resulting in ground movement [6]. Landslides are disasters that emphasize natural and human processes related to geological material that causes disasters either on a local or global scale [7]. Landslides occur because there is a disturbance in the stability of the slope / rock [4]. Apart from natural factors, landslides can also be caused by human activities that affect the landscape, such as agricultural activities, slope loading, and mining [6]. The danger of landslides in Indonesia is increasingly threatening the lives its residents. These include West Java, Central Java, East Java, West Sumatra and East Kalimantan [1].
Out of a total of 497 regency / cities in Indonesia, 176 are at high risk of flooding, 154 are at high risk of landslides and 153 are at high risk of drought [8]. This phenomenon of landslides will be increasingly dangerous in unstable soil conditions with steep slopes and extreme rainfall [8]. According to data and information from the National Disaster Management Agency (BNPB), there were more than 2,000 landslides that occurred in 2011 - 2015 [1]. The results of the disaster risk assessment by BNPB, also shows that 14 million people of the total population of Indonesia is directly exposed to landslide hazards [1].

Based on the data from the Regional Disaster Management Agency (BPBD) in Kebumen, as many as 112 villages within 15 sub-districts were areas with the landslide potential [8]. The slope effect and forms in Kebumen Regency can be analyzed using Geographic Information System (GIS) for mapping areas with potential landslides [9]. Identification and mapping of landslide potential areas have an important role as an effort in overcoming and anticipating landslides [10].

GIS can be used to identify potential landslides in Kebumen Regency. Using GIS can give result, such as various geospatial information related to various factors that cause landslides [11]. One of the methods that can be used to determine potential landslides is the SMORPH method [12]. This method is applied to determine the potential landslide areas by applying slope morphology and slope using a Geographic Information System (GIS) [12]. This method will provide a good level of accuracy due to the use of variable slope and slope forms based on the Digital Elevation Model [13]. The method used in determining the landslide potential area is the SMORPH (Slope Morphology) method developed by Shaw and Johnson in 1995 [15]. SMORPH method has good results than the others methods such as Storie Index and SINMAP. The Storie Index method has a disadvantage if there is a parameter category that has zero value, then the multiplication result (Storie Index) will be zero and the land is considered to have physical limitations and is not suitable for agricultural land needs [5]. SINMAP method has a weakness to be used with a wide area scale, this is because the data used in the SINMAP method in the form of soil type and rainfall is a large and compact polygon scale data. [13].

SMORPH method is a model in GIS that refers to topographic data in the form of slopes such as concave, planar or convex, and to the slope gradients [13]. The SMORPH method uses raster data in processing data [13]. This raster data is suitable to provide a continuous description of the spatial distribution of topographic conditions as important elements in shaping hydrological characteristics and soil properties [13].

The research of the SMORPH method for landslide analysis was carried out previously by Triwahyuni et al (2017) [13]. This research was conducted in Kulon Progo. It compares the SINMAP method with SMORPH. This research uses SRTM 1 Arc data for the SMOPRH [13]. Another study which uses SMORPH method was a study by Harist et al (2018) [12]. This research was conducted in Wonosobo, Central Java. This research uses the SMOPRH method to produce potential landslide areas using SRTM DEM data [12].

This study uses DEMNAS data in the application of the SMORPH method. DEMNAS has a better level of resolution than the SRTM DEM. It has a spatial resolution of 8.5 x 8.5 meters. The aim of this study was to analyze the potential areas of landslides in Kebumen Regency.

2. Method
Kebumen Regency is located in Central Java Province. The area is located at 7° 27’ - 7° 50’ South Latitude (LS) and 109° 33’ - 109° 50’ East Longitude (BT). Kebumen Regency administratively consists of 26 sub-districts with an area of 128,111.50 hectares or 1,281.115 km².

There are some material used in determining the landslide potential area, which are the slope and slope form. These materials are obtained from Digital Elevation Model (DEM). The DEM used in this study is DEMNAS. This data is obtained from the Geospatial Information Agency (BIG). In addition, a field survey was conducted in Kebumen Regency. This is aimed to observe and validate the results of the SMORPH method by taking samples based on landslide events in Kebumen Regency.
The sample points in this study amounted to 30 sample points [Figure 1]. This sample data was obtained from the landslide point by the Kebumen Regional Disaster Management Agency (BPBD). The survey was conducted for validation and documentation regarding the condition of the sample location.

SMORPH method will produce a landslide classification based on the matrix between the slope angle (in percentage) and the slope form [12, 13]. The identification matrix is used to produce potential landslide areas. This matrix is formed by combining the slope angle (in percentage) and the slope form [15]. This SMORPH method uses DEM data to generate topographic data sources, this is because DEM is the most commonly used data and is also available in a GIS system [15]. Slope form can be classified into 3 values as in table 1 below.

![Location of Landslide Sample In Kebumen Regency](image)

**Figure 1.** Map of Sample Landslide in Kebumen Regency.

| No. | Slope Form | Value   |
|-----|------------|---------|
| 1.  | Concave    | < -0.1  |
| 2.  | Planar     | -0.1 – 0.01 |
| 3.  | Convex     | > 0.01 |

The processing of slope angle and form are carried out using ArcGIS software, which was then classified in percentage using tool slope in ArcGIS and the slope form are classified in the form of convex, planar, and concave using tool curvature in ArcGIS.

| No. | Slope Form | Slope Gradient (%) |
|-----|------------|--------------------|
| 1.  | Convex     | 0 – 8% 8 – 15% 15 – 25% 25 – 45% 45 – 65% >65% |
| 2.  | Planar     | Very Low Low Low Low Moderate |
| 3.  | Concave    | Very Low Low Moderate Moderate High High |
The next step is to overlay the slope data and slope form based on the SMORPH matrix [table 2]. The results of the overlay are classified according to the SMORPH matrix table, producing potential landslide areas in Kebumen Regency.

3. Result and Discussion

3.1 Altitude Area

Based on Altitude map [Figure 2], Kebumen Regency can be divided into 4 regions. The altitude of <50 meters above sea level, is found in the southern coastal part of Mirit sub-district, Puring, to the central part of Kebumen and Sruweng sub-districts. This region has an area of 724,971 km².

The altitude of 51-100 meters above sea level is found in the north to the border of Wonosobo Regency and Banjar negara Regency. The area in the southwest also has the same altitude as the area in the north which is located in the sub-district of Ayah and Buayan. This region has an area of 135,226 km².

Areas with an altitude of 101 - 250 meters above sea level are located in parts of northern Kebumen Regency. This region has an area of 142,97 km². This area is located along the border between Kebumen Regency and Banjar negara Regency.

The area with an altitude of 251 - 500 meters above sea level is in the northern part of Kebumen Regency. This region is located along the border between Kebumen Regency and Banjar negara Regency. This region has an area of 305.3 km².

Areas with an altitude of > 500 meters above sea level, are located in the northwestern part of Kebumen Regency, within Rowokele sub-district. It is also found in the border area of Kebumen Regency with Wonosobo Regency. This region has an area of 5.96 km².

From the elevation area, the topography can be divided into 3 classes in Kebumen Regency. In the northern and southwestern regions of Kebumen is a mountainous and hilly region. In the central part of Kebumen Regency is a lowland area that is widely used for agricultural activities. The southern region is a coastal region.

3.2 Slope Area
Based on slope map in Kebumen [Figure 3], areas with a slope of 0-8% are the widest slope area. These areas are almost evenly distributed from the southern coast to the northern part of Kebumen Regency. This region has an area of 437.21 km². Areas with a slope of 8-15% and 15 – 25% are spread randomly in the middle of the Kebumen Regency.

Areas with a slope of 25 - 45% dominate the north and southwest of Kebumen Regency. This region has a moderate steep and very steep slope. This region has an area of 245.54 km².

Areas with a slope of 45-65% has an area of 77.79 km² and for areas with > 65% slope has an area of 13.5 km². They have a small area, which is only a small part in the north and southwest.

3.3 Slope Form Area
The form of convex slope has the most extensive area in Kebumen Regency which is equal to 647.26 Km² or 49.2% of the total area of Kebumen. Regions with concave slope forms have an area of 586.25 Km² or 44.6%. The area with a flat slope has the smallest area, which is 80.93 Km² or 6.2%. The slope form is a visual form of a slope on a slope sequence. Usually, slopes consist of crest, convex, concave and lower slope. Areas with convex and concave slope forms are dominating areas that spread evenly throughout Kebumen Regency.
Based on figure 4, it can be seen the distribution of slope forms in Kebumen Regency. In general, all types of slopes are spread evenly. From the figure, the regions with convex and concave slopes dominate while, for the form of flat slopes, only a small part of the Kebumen Regency area. One area with a flat slope that is clearly visible on the map is the Sempor reservoir area.

### 3.4 Landslide Potential Area

The potential landslide area produced by the SMORPH method is divided into 4 classes: very low, low, moderate, and high potential. In Kebumen Regency, the potential for low landslides is dominated by convex slope class. These results illustrate that the higher the slope accompanied by the formation of increasingly steep slopes will cause a high potential for landslides.
Based on the landslide potential map [Figure 5], it gives the result that Kebumen Regency is dominated by 2 landslide potentials that are moderate and high potential. For regions with high and moderate landslide potential they have the same distribution. The area is in the north and southwest of the district of Kebumen. The northern part of Kebumen has a topography in the form of hills and mountains which can affect the level of potential landslides.

Areas with moderate potential tend to spread around areas with high potential Kebumen Regency. The topography in the moderate potential landslide area is similar to the potential for high landslides in the form of hills and mountains, while for regions with very low and low landslide potential dominating the southern and central regions of Kebumen Regency. In the southern region of Kebumen it has topography in the lowlands and coastal areas.

According to the Table 3, the area with moderate potential is greater than the area with high potential. From the results of the analysis of landslide point data in Kebumen Regency, it shows that landslide events generally occur in areas with high landslide potential with a percentage of 80% of the total 30 landslide events (Table 3). Some of the regions that have the most landslide events are Ayah and Karangsambung sub-districts. The area of Ayah Sub-district is dominated by very steep slopes with concave as the dominant slope. The area in Karangsambung Sub-district has the same physical conditions as in Ayah Sub-district. In addition, in some areas in Karangsambung Sub-district, there are several dredged slopes that reduce slope stability. The dredging of these slopes is caused by the road widening in the Karangsambung Sub-district, which if in case a landslide happens, it will disrupt the road access in the area.

### Table 3. Landslide Potential Areas.

| No. | Landslide Potential Area | Area (km²) | Percentage of Area | Landslide Events | Percentage of Landslide Events |
|-----|--------------------------|------------|--------------------|-----------------|-------------------------------|
| 1.  | Very Low                 | 589,40     | 44.84%             | 0               | 0%                            |
| 2.  | Low                      | 30,97      | 2.36%              | 1               | 3.33%                         |
| 3.  | Moderate                 | 544,45     | 41.42%             | 5               | 16.67%                        |
| 4.  | High                     | 149,50     | 11.38%             | 24              | 80.00%                        |
| 5.  | Total                    | 1314,32    | 100%               | 30              | 100%                          |

Table 3 shows data on the results of processing potential landslide areas. The results in the table are in the form of each potential landslide area. The largest area is a region with very low area, which is equal to 589.40 km² or amounting to 44.84%. Based on the conditions of the existing sample point, in areas with low potential landslides, the slope conditions tend to be flat and dominated by the convex slope form. The very low and low potential area dominates the southern and central regions of Kebumen Regency.

Regions with moderate potential landslide have an area of 544.45 km² or 41.42%. This area with moderate potential has quite steep slope conditions. Based on sample points in regions with moderate landslide potential, the slope form encountered tend to vary from concave, convex and flat. Areas with moderate potential tend to spread around areas with high potential.
Based on figure 6, the slope form will greatly affect the slope balance. Concave slopes are the most unstable than the others. Meanwhile, slopes with planar form have better stability than concave slopes. Regions with convex slopes tend to be stable.

Based on figure 6, it shows the effect of the form of the slope on landslide events in Kebumen Regency. From the table it show that many landslide events are found in the form of concave and convex slopes. In these conditions there were 12 landslide events in the form of a concave slope and 11 landslides were in the form of convex slopes in Kebumen Regency. Of the 30 landslide occurrence points, the form of the flat slope is the least number of landslide events compared to the flat and concave form which is as many as 7 points of occurrence. The middle part of a convex or concave slope can result in relatively large erosion by surface flow so that the potential for landslides increases.

4. Conclusion

The SMORPH method that was applied to identify the distribution of potential landslides in Kebumen District resulted in 4 levels of potential landslides, there are very low, low, moderate and high. Areas with high potential for landslides dominate the northern and southwest regions of Kebumen Regency with a predominantly concave slope. The area has a hilly and mountainous topography with a steep slope. For the region with very low landslide is dominate in the middle to the southern part of Kebumen Regency. The condition of the region is in the form of lowland and coastal areas. From the results of the SMORPH method, it can be illustrated that the higher the slope of the slope accompanied by the formation of a convex or concave slope, the higher the potential for landslides in the area.

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