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Landslide Prone Maps Using Weighting Parameters in Pulung, Ponorogo East Java

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Abstract. Pulung landslide occurred twice during 2017-2018. The landslide located in the village of Banaran and Wagirkidul, which caused losses. This study aimed to identify the susceptibility level of the landslide in areas of Pulung. This research using four parameters, namely land slope, land use, soil type, and rainfall. This study produces landslide prone maps divided into three levels. It is the level of "very vulnerable" covered area of 3.4% (433.67 ha), level of "vulnerable" covered area of 53.06% (6,767.803 ha), and level of "less vulnerable" covered area of 43.54% (5,553.527 ha). The results are useful for an early warning system in Pulung, especially rainy season. The map presented is also considered as the source for warning landslide system in surrounding Pulung.

1. Introduction

Pulung is included in landslide-prone areas, according to BNPB (National Agency for Disaster Countermeasure) data [1]. April 2017, a landslide occurred in Banaran village [2]. It caused 28 people missing, 32 houses, and five hectares of land destroyed [2]. The landslide is caused by a crack in the upper cliff a few weeks earlier. It causes rainwater to enter the soil and become saturated quickly. So, the weight of the mass and pressure of the pore water increase and the binding capacity decreases. The steep slope, many ginger plants, and lack of firmly rooted plants as slope retaining [2]. On 2018 rainy season, in Banaran were fears for further landslides. As evidenced by the condition of several cracked houses [2]. Another landslide occurred in Wagirkidul. It caused the villagers cannot access the road because almost fifteen-meter had landslides [2].

Previous research has shown that rainfall has an effect on landslides in Ponorogo [3]. Other studies also prove that rainfall, land slope, soil types, and land use also cause landslides in Ponorogo [4]. Three similar studies are using four parameters, namely: land slope, land use, soil type, and rainfall. The first is research in landslide-prone maps in Semarang City produced five classes of vulnerability [5]. The second is research in Ci Tarum river shows that Ci Kondang and Ci Kapundang are the priority in danger of erosion [6]. The third is research in Karang Anyar, Gunung, Semarang City shown that maps can be used as an early warning system [7].

The basic idea behind this research that Ponorogo is the city where the researcher lives. This map design based on four weighting parameters, namely: land slope, land use, soil type, and rainfall. The prone maps are divided into three level areas, namely: less vulnerable, vulnerable, and very vulnerable. This objective research was to determine the susceptibility levels of the landslide in Pulung subdistrict regions.

2. Materials and Methods

2.1 Location and Data Preparation

Pulung is located in Ponorogo City, province of East Java, Indonesia. Pulung also situated between 356 meters to 746 meters above sea level [8]. All data based on Regional Development [8] and Statistic Center of Ponorogo Regency [8]. The data includes Pulung profile, village, land slope, land use, land type, rainfall, etc. Data preparation for draw landslide prone maps is (1) morphology map of Ponorogo with scale 1:25,000 [8], (2) Land type map of Ponorogo with scale 1:100,000 [8], (3) Space pattern map Ponorogo with scale 1:250,000 [8], and (4) Average annual rainfall (mm/years) Pulung, Ponorogo 2017 [8]

2.2 Scoring for Parameters

The parameters choose by UGM (Universitas Gadjah Mada) team, BNPB dan PVMBG when researching in Banaran [2]. It produces four parameters as a cause of landslides, namely land slope, land use, soil type, and rainfall. It is parameter used to this research as a weighting parameter (Table 1-4).

Table 1. The score for land slope

No.	Land slope (°)	Category	Score
1	< 14	Low	1
2	15 - 24	Rather low	2
3	25 - 44	Moderate	3
4	45 - 64	Rather high	4
5	> 65	High	5

Table 2. The score for land use

No.	Land use	Category	Score
1	Secondary dryland forest	Low	1
2	Farm and forest	Rather low	2
3	Settlement	Moderate	3
4	Agriculture, land	Rather high	4
5	Rice fields, grass	High	5

Table 3. The score for land type

No.	Land type	Category	Score
1	Regosol, lithosol, organosol, rendzina	Very sensitive	1
2	Andosol, laterite, grumusol, podzol, and podzolic	Sensitive	2
3	Brown forest land, mediteran land	Moderate sensitive	3
4	Latosol	A little sensitive	4
5	Alluvial, planasol, gray hydro morph, laterit groundwater	Not sensitive	5

Table 4. The score for annual rainfall

No.	Annual rainfall (mm/years)	Category	Score
1	< 500	Low	1
2	500 - 999	Rather low	2
3	1000 - 1999	Moderate	3
4	2000 - 2999	Rather high	4
5	> 3000	High	5

2.3 Weighting Parameters

Weighting parameter based on previous research by Kusratmoko [6] and Purba [5]. Table 5 is the parameter weighting classification.

Table 5. Weighting parameters

No.	Parameter	Weight
1	Land slope (LS)	40%
2	Land use (LU)	30%
3	Land type (LT)	20%
4	Annual rainfall (AR)	10%

The result of four parameter weighting will get the cumulative score shown in the formulation (1):

$$\text{Cumulative score} = (40\% \times \text{LS}) + (30\% \times \text{LU}) + (20\% \times \text{LT}) + (10\% \times \text{AR}) \quad (1)$$

The vulnerability level of a landslide is categorized by three types, shown in Table 6 [5], [6]:

Table 6. Vulnerability level for landslide

No.	Cumulative score	Vulnerability level
1	≤ 2.5	Less vulnerable
2	2.6 - 3.6	vulnerable
3	≥ 3.7	Very vulnerable

2.4 Draw Maps

All map in this research was built by four software. ArcGIS is used to create spatial data, layered map, and fundamental analysis for spatial. Map Server for Windows as a server to for allows a map data to be accessed via the web. PostgreSQL use for manipulates a database. The pmapper framework used as visualization to build the geographic information system via internet. Then the map results from exporting using pmapper plugins.

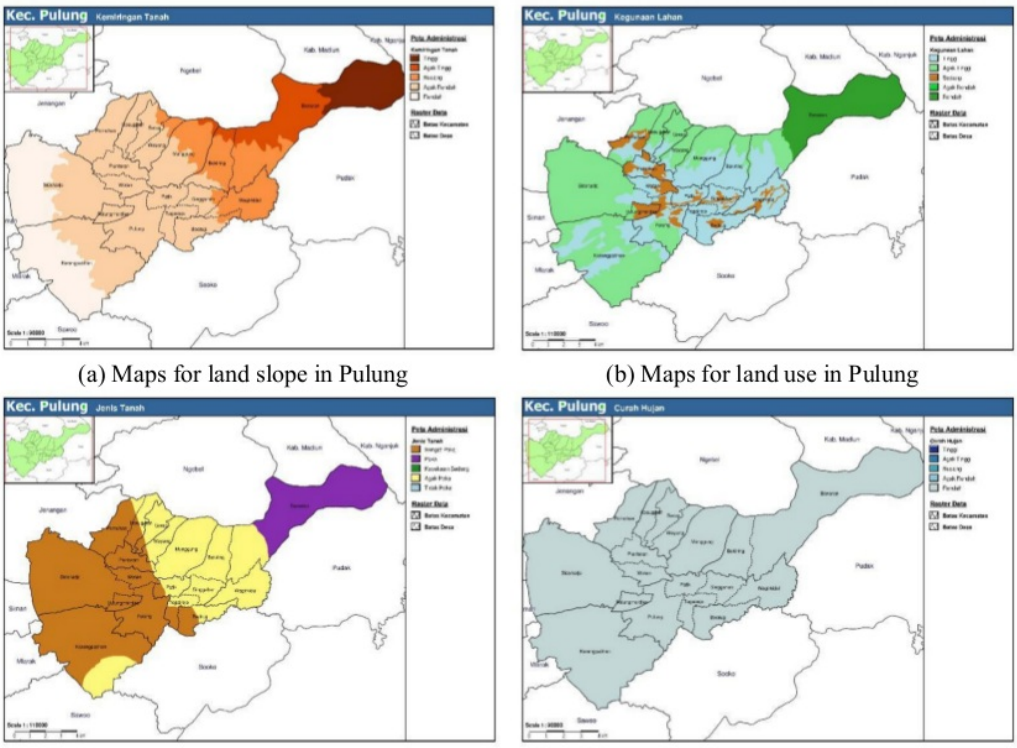
3. Result and Discussion

Figure 1 is the result of researcher draw maps based on is (1) morphology map of Ponorogo with scale 1:25,000 (2) Land type map of Ponorogo with scale 1:100,000 (3) Space pattern map Ponorogo with scale 1:250,000 [14], and (4) Average annual rainfall (mm/years) Pulung, Ponorogo 2017 [8]. At figure 1 (a) land slope is divided by five (Table 1): (1) high category level is located at the northern of Banaran. (2) rather high level is located at a middle of Banaran, northern of Bekiring and Munggung. (3) A moderate level is located at southern of Banaran, Wagirkidul, middle of Bekiring and Munggung, northern of Wayang and Serag. (4) Rather low level is located at all village except Banaran. (5) low level is located at Sidoharjo and Karangpatihan.

At Figure 1 (b) land use is divided by five (Table 2): (1) high level is rice fields and grass are located spread in all regions except most of the Banaran region. (2) The rather high level is farming and the land is located at all village except Plunturan, Wotan, Patik, Singgahan, Tegalrejo, Bedrug, and Wagirkidul. (3) A middle level is settlement is located at Pomahan, Plunturan, Wotan, Pulungmerdiko, Pulung, Patik, Singgahan, Bedrug, and Wagirkidul. (4) The rather low level is farm and forest are located at all village except Plunturan, Wotan, Patik, Singgahan, Tegalrejo, Bedrug, and Wagirkidul. (5) The low level is dryland forest is located at only the northern of Banaran.

At Figure 1 (c) land type is divided by five (Table 3): (1) The very sensitive level is regosol, lithosol, organosol, rendzina located at southeast of Pulung. (2) A sensitive level is Andosol, laterite, grumusol, podsol, podsolic is located spread in almost all Banaran regions. (3) No region is on a moderate level. (4) a little level is Latasol is located in the middle of Pulung. (5) No region is on the insensitive level. Figure 1 (d) is divided by five (Table 4) and all annual rainfall in Pulung is included in low levels.

Figure 2 shown map of susceptibility landslide level based on cumulative score formulation (1) and using weighting four parameters (Table 5). The vulnerability level based on Table 6. The first parameter is land slope based on Table 1. The second parameter is land use based on Table 2. The third parameter is land type based on Table 3. The fourth parameter is the annual rainfall based on Table 3.



(a) Maps for land slope in Pulung

(b) Maps for land use in Pulung

(c) Maps for land type in Pulung

(d) Maps for annual rainfall in Pulung

Figure 1. Result of researcher draw maps with four parameters in Pulung areas

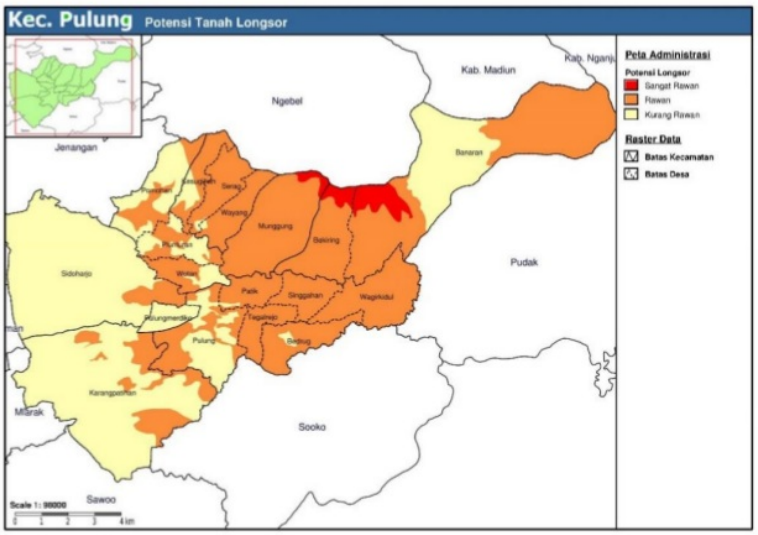
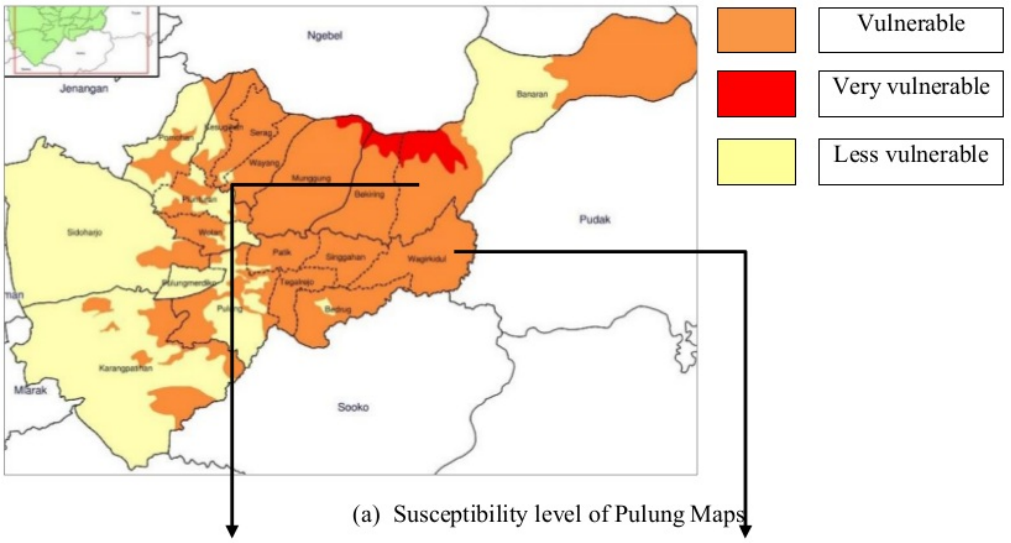


Figure 2. Landslide-prone maps of Pulung areas using weighting four parameters calculate by cumulative score in formula (1)

The research (Figure 2) prove that the village is included very vulnerability levels (red color) of the landslide in western of Banaran, northern of Bekiring, and Munggung. The vulnerability level (orange color) is located in middle and northern of Pulung. The less vulnerability level (low orange color) landslide is located at the southeast of Pulung subdistrict and middle of Banaran village.



(a) Susceptibility level of Pulung Maps

(b) Location 1. Tangkil hamlet, Banaran village [2]

(c) Location 2. Bangunsari hamlet, Wagirkidul village [6]

Figure 3. The landslide occurred in Banaran and Wagirkidul village

Figure 3. shows the location 1. the landslide happened in the village of Banaran, Pulung subdistrict on April 1, 2017. Among the causes of this landslide was due to the steep slope of the land (40º). The location in Banaran includes as a potential level of "vulnerable". In location 2. The landslide occurred in the village of Wagirkidul, Pulung subdistrict on December 3, 2018. The landslides triggered by heavy rain within four hours. The location in Wagirkidul also includes as a potential level of "vulnerable". This research proves that the percentage accuracy of the weighting parameter in the cumulative score is not yet accurate. So those landslides have occurred in Pulung are not included in “very vulnerable” levels.

4. Conclusion

Based on Landslide prone maps of Pulung areas using weighting four parameters (Figure 2), the susceptibility level was divided into three categories. The first level is "very vulnerable" covered 3.4% (433.67 ha) is located in village of Banaran, Bekiring, and Munggung. The second level is "vulnerable" covered 53.06% (6,767.803 ha) is located in middle and northern of Pulung. The third level is "less vulnerable" covered 43.54% (5,553.527 ha) is located at the southeast of Pulung subdistrict and middle of Banaran village. The prone map shows that landslides occurred in Pulung including the level of "vulnerable" and are not in the level of "very vulnerable". This research proves that the percentage accuracy of the weighting parameter in the cumulative score is not yet accurate. It can be used by the next study to improve the accuracy of the weighting parameter. The advised for villagers, to be alert when the rainy season has arrived.

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