Risk level of landslide hazard at Probolinggo district, East Java

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Abstract. Landslide is the third largest disaster in Indonesia, including in Probolinggo. Approximately 50% of Probolinggo regency area is a potential landslide region. This area is located in the southern part of Probolinggo regency with hilly terrain and slopes. The number of landslide events in 2015-2016 is recorded 21 events. Potential landslide hazard was analyzed by SINMAP (Stability Index Mapping) method using physic condition, slope, digital elevation model, and rainfall. The risk level of landslide hazard is derived from the crosstab between landslide hazard potential and vulnerability index covering exposure aspect, sensitivity, and adaptive capacity with variables consisting of population density, livelihood, the proportion of the vulnerable population, building quality, and the number of poor households. The high risk of landslide hazard in Probolinggo regency is found in four districts of Lumbang, Pakuniran, and Kotaanyar sub-district. Potential landslide areas are spread in the south of Probolinggo Regency, especially in Krucil sub-district with 15-40 % slopes. Based on the spread of landslide location, as many as 81% of landslide locations occur in high and medium landslide potential areas.

1 Introduction

Indonesia is a region that has an undulating morphology from coast to mountain. In line with the situation, then Indonesia is a disaster prone area. Disasters that occur not only natural disasters but also non-natural disasters and social disasters. One of the Natural disasters that hit Indonesia is landslide. According to data from the National Disaster Management Agency (BNPB) in 2016, there is 3649 number of landslide events from 1998 to 2016, spread across Indonesia [1]. East Java Province is one of the high potential areas of landslide disaster. This is due to hilly and mountainous of its topography. Besides, it is also caused by the high density of population in the hilly area that causing pressure on the ecosystem. [2]. The landslides are certainly very detrimental to the community because of the resulting loss of life and the destruction of facilities and infrastructure such as road cuts, damage to irrigation channels, settlements, markets and so forth.

Landslide is a general term for a wide blend of downslope advancements of earth materials that result in the distinguishable dropping and outward advancement of soil, rock, and vegetation influenced by gravity. The materials may move by falling, toppling, sliding, spreading, or gushing. A couple of landslides are fast, happening in seconds, while others may take hours, weeks or more [3].

Probolinggo regency is one of the districts in Indonesia that affected by the disaster. Throughout the

year 2016, according to the Regional Disaster Management Agency (BPBD) in Probolinggo District recorded 72 incidents of disaster including landslides, drought, tidal flood, forest fires and others. Landslides dominate throughout 2016 as much as 29 percent, wind 25 percent, flood 17 percent, fire, drought, and eruption as much as 13 percent. While the affected area as much as 66 percent of the 24 districts in Probolinggo District [4].

From the above backgrounds then the research problem to be studied in this paper is: what is the risk level of landslide disaster in Probolinggo regency.

2 Methodology

Identification of potential areas of landslide disaster can be achieved in various ways, such as SINMAP (Stability Index Mapping), Fuzzy Logic, the method of logistic regression, etc [5]. Based on Acharya research, SINMAP model has the best result for identification potential landslide. [6]. This method is used to determine a region with potential or no potential landslide based on geographic information. SINMAP excellence can provide an overview of the potential landslides of a region by combining hydrological elements such as rainfall, soil conditions, and slopes [7]. Then followed by mapping of potential landslide areas, combined with landslide events that occurred in Probolinggo District. This mapping has also been widely used in several countries, such as in Ratnapura City, Sri Lanka by

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Weerasinghe [8], which in its research found as much as 72% of Ratnapura City area of 153 km² categorized to areas with potential landslides.

After obtaining landslide potential data, then analyze data of vulnerability of area based on the social factor, that is from exposure, sensitivity and adaptive capacity against shocks in landslide disasters. The exposure determinant indicator is limited to population density and livelihoods; the sensitivity determinant indicator is limited to the proportion of vulnerable (elderly-old) and quality of the building; as well as adaptive capacity is limited to the number of homes the stairs are poor. The vulnerability criteria used in this study are described in Table 1. While the formulas used are: function $V = f(E, S, A)$, where E is the exposure, S is sensitivity and A is adaptive capacity [9]. The degree of vulnerability is also affected by conditions of community sensitivity and their ability to adapt it [10].

Regional vulnerability data and landslide potential data are created by crosstab to obtain disaster risk level. The level of disaster risk is divided into three classifications: low risk, medium risk, and high risk.

Table 1. Vulnerability criteria

Variable	Assumption	Vulnerability		
		Low	Moderate	High
Population Density	The higher the population density, the higher the vulnerability	<700 person /km ²	700-1300 person/km ²	>1300 person/km ²
Occupation	The population working in the formal sector will have a lower level of exposure compared to those working in the informal sector	Formal	Formal	Informal
Population Proportion Infant-Senior Age	The higher the proportion of infant-senior age then the higher the sensitivity will be	0.11-0.13	0.14-0.16	0.17-0.19
Building Quality	Temporary settlement type will have higher sensitivity	Permanent	Semi-Permanent	Temporary
Poor Household Number	The higher the number poor household the lower their ability to handle disaster	<20%	20%-50%	>50%

Table 2. Landslide hazard risk level

Vulnerability	High			
	Moderate			
	Low			
		Low	Moderate	High
		Hazard		

3 Results

3.1 Area of potential landslide hazard

Potential landslide hazard areas in Probolinggo district are derived from Nanda's research in 2017 [12]. The result of processing SINMAP model, Probolinggo regency has four areas of the potential danger of landslides that is not potential, low potential, medium potential, and high potential. Based on the total area, the potential landslide hazard area in Probolinggo regency is 49.70%. This is an area that does not have landslide potential, so another 50.30% is an area with landslide potential (see Table 3 and Map 1).

Table 3. Landslide hazard potential area Probolinggo district (Ha)

Landslide Hazard Potential	Width (ha)	Percentage
Non-Potential	84.302	49,70
Low Potential	17.663	10,41
Moderate Potential	36.105	21,29
High Potential	31.541	19,60
Total	169.610	100

Source : [12]

Fig. 1. Landslide hazard potential of Probolinggo district [12]

Low level of potential landslide areas in Probolinggo District are spread over the northern part of the Regency, especially in coastal areas bordering the Madura Strait.

Conversely, the area that has a landslide potential in Probolinggo regency is widely spread in the southern part of the district. Potential landslide area in Probolinggo regency is dominated by moderate landslide hazard areas with an area of 36.105 Ha or equal to 21.29% of the total area of Probolinggo Regency. Subsequently, the high landslide hazard potential area with a total area of 31,541 ha or 19.60%, and the area of low landslide hazard potential has the smallest area of 17,663 ha or 10.41% of the total area of Probolinggo Regency. If assessed by its sub-district, the landslide potential areas are spread over several districts in Probolinggo District. Based on the results of processing using SINMAP model, there are 13 districts that have a low potential area, 12 subdistricts with the medium potential area and 10 districts that have high potential area. Distribution of landslide potential area by sub-district in Probolinggo regency is shown in following Table 4.

Table 4. The potential landslide area by subdistrict (Ha)

Subdistrict	Potential Landslide Area		
	Low Potential	Moderate Potential	High Potential
Tiris	4.453,54	4.319,75	1.932,71
Krucil	3.962,01	10.472,65	8.571,67
Sumber	2.057,11	3.439,28	4.555,28
Sukapura	1.660,00	4.268,37	4.886,51
Kuripan	1.458,36	2.485,84	1.907,78
Gading	1.381,81	4.455,64	3.725,20
Lumbang	1.202,27	2.557,67	952,22
Pakuniran	817,27	3.236,31	4.282,86
Kotaanyar	382,97	396,28	600,61
Bantaran	210,92	329,56	125,70
Tongas	66,34	140,88	0,00
Maron	5,43	0,00	0,00
Besuk	4,96	3,05	0,00
Total	17.662,96	36.105,28	31.540,55

Source : [12]

3.2 Landslide incident location

The location of the landslide in Probolinggo Regency, mostly in Subdistrict Tiris (low and medium potential), whereas in Sukapura District which is included in the high potential there are 7 incidents, as presented in Table 5.

Table 5. Landslide incident number per sub district

Landslide Potential Level	Subdistrict	Landslide Incident Number	Total
Non-Potential	Dringu	1	1
Low Potential	Tiris	3	3
Moderate Potential	Tiris	6	6
High Potential	Gading	1	11
	Pakuniran	2	
	Sukapura	7	
	Sumber	1	
Total			21

Source: [12]

3.3 The social vulnerability of landslide hazard

The vulnerability of landslide hazard in this paper is based on social factors in Probolinggo District as shown in Table 1, from the level of exposure with variable population density and livelihood. Population density in Probolinggo district are as follow. Two districts with high population density while the livelihood of the population is dominated by non-formal livelihoods. The level of sensitivity is measured from the age and the quality of the building. In Probolinggo Regency the proportion of toddler-old age is the highest in the medium classification of 0.14-0.16. While for the quality of the building, 19 sub-districts of 24 districts are dominated by the quality of permanent houses. Adaptive capacity, analyzed by poor households, it revealed that only 5 districts have a value above 50% (See figure 2).

Fig. 2. Social vulnerability landslide hazard

3.3 Level of risk of landslide hazards

Risk level of landslide hazard in Probolinggo Regency, which has high risk are found in District Pakuniran, Lumbang, and Kotaanyar. Those sub-districts are at varying heights as well as its slopes and hilly terrain (See

Table 6). In addition to the sub-districts in Table 6, the potential for a high social vulnerability are found in Sumberasih, Gending and Dringu districts.

Table 6. Landslide hazard risk level

Subdistrict	Landslide Hazard	Vulnerability	Risk
Tiris	L	L	L
Krucil	M	M	M
Sumber	H	L	M
Sukapura	H	L	M
Kuripan	M	M	M
Gading	M	M	M
Lumbang	M	H	H
Pakuniran	H	M	H
Kotaanyar	H	M	H
Bantaran	M	M	M
Tongas	M	H	M
Maron	L	M	L
Besuk	L	L	L

L= low, M=moderate, H=high

Observation on Table 7 shows landslide events that occurred in Probolinggo District in 2015-2016, Sub-District Dringu has a high vulnerability to landslide hazard, the number of incidents 1, while Sukapura District with the most incidents, has vulnerability with medium potential.

Table 7. Risk level

Landslide Potential Level	Subdistrict	Incident Total	Vulnerability
Non-Potential	Dringu	1	High Potential
Low Potential	Tiris	3	Low Potential
Moderate Potential	Tiris	6	Low Potential
High Potential	Gading	1	Medium Potential
	Pakuniran	2	Medium Potential
	Sukapura	7	Low Potential
	Sumber	1	Low Potential

4 Conclusion

Potential landslide areas are spread in the south of Probolinggo Regency, especially in Krucil Sub district with 15-40% slopes. Based on the spread of landslide location, as many as 81% of landslide locations occur in high and medium landslide potential areas. The high-risk level of landslide hazard in Probolinggo regency are found in three districts of Lumbang, Pakuniran and Kotaanyar sub-districts. Meanwhile, the moderate risk of

landslide hazard occurs in Krucil, Sumber, Sukapura, Kuripan, Gading, Bantaran and Tongas sub-district.

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