Dihin Mayang 2019

by Dihin Muriyatmoko

Submission date: 22-Jun-2019 06:05AM (UTC+0900)
Submission ID: 1195004393
File name: Mayang_Phuspa_2019_J._Phys.__Conf._Ser._1175_012223.pdf (759.61K)
Word count: 3465
Character count: 17842

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IOP Conf. Series: Journal of Physics: Conf. Series **1175** (2019) 012223 doi:10.1088/1742-6596/1175/1/012223

Analysis of health risks using geomedical mapping in landslide prone areas in Ponorogo East Java

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Abstract. Ponorogo Regency is an area prone to landslides, as happened on April 1, 2017, which had impacted 28 fatalities, declining public health status, and losses in the economic sector to hundreds of millions of rupiah. This research is a preventive step that aims to analyze the public health risks by geomedical mapping covering 21 sub-districts prone to landslide disasters in Ponorogo Regency. Geomedical mapping is an utilization of Geographic Information Systems (GIS) on disaster mitigation. Health risk analysis is carried out by weighting and scoring methods on variables from the hazard, vulnerabilities, and capacities to obtain the level of risk for each sub-district. The results show that 28.6% of all sub-districts in Ponorogo Regency have a high potential for landslide disasters while 71.4% are potentially moderate. The vulnerability of the community to landslide disasters varies from low (33%), moderate (43%) to high (24%). The capacity of communities facing landslides shows that 19% of all sub-districts are classified as medium and 81% others are low. Based on the identification of hazards, vulnerabilities, and capacities of communities in each sub-district in Ponorogo Regency, it was concluded that only 1 sub-district had a low risk of landslides, 2 sub-districts were at moderate risk, while 18 other sub-districts had a high health risk. The results of the analysis are described in spatial mapping with ArcGIS software. Hopefully, this output can be a reference in setting priority areas for reducing the risk of landslide disasters in Ponorogo Regency.

1. Introduction

Landslide is the 3rd highest frequency of disaster after floods and tornadoes in Indonesia [1]. Ponorogo Regency is one of the regions that has the potential of landslides. Landslides have occurred on April 1st, 2017 in the village of Banaran, Ponorogo which had impacted 28 fatalities, various health problems, and losses in the economic sector to hundreds of millions of rupiah due to land masses hoarding settlements and plantations to 15 hectares area [2].

Landslide is mass movements consisting of soil and rocks from the top of the slope along the sloping plane due to gravity. Generally, landslides are caused by a combination of precondition factors, preparatory factors and trigger factors [3]. Precondition factor is a static factor affecting the limit of slope stability. Preparatory factor is a dynamic factor that changes the stable boundary of the slope. While triggering factor is a variable that directly causes slope failure (landslide).

Indonesia has numerous of landslides because of high rainfall, rock conditions, soil thickness, the impermeable layer (sloping area) of the soil mass and slopes of more than 30° [4]. Especially in Ponorogo, rainfall has become an adequate factor causing the potential for landslides [5]. High risk of

landslides is caused by the high vulnerability of the community [6]. Preventive efforts to minimize the risk of landslides are by mapping the potential hazards, vulnerabilities, and the capacity to face the disaster. This risk mapping is a GIS implementation in disaster mitigation [5]. Mapping is very helpful in improving data visualization and has been widely used by health professionals for planning, monitoring and surveillance [7].

The concept of geomedical mapping is linking the influence of environmental factors and health problems in humans and animals [8]. Specific geographical conditions provide strong information that health professionals can use to monitor public health. Geomedical mapping is prepared to support the implementation of the Integrated Emergency Management System [9]. Geomedical mapping is the result of an analysis based on identification of hazards, vulnerability and capacity to face the threat of disasters.

Geomedical mapping needs to be carried out in the area of Ponorogo Regency because an area that has experienced landslides can be projected to have a landslide again. This is called landslide vulnerability. Landslide vulnerability is a classification, volume and spatial distribution which has the potential to recur [10]. Therefore, this study has the aim to analyze the health risks by geomedic mapping in areas prone to landslide in Ponorogo Regency.

2. Methods

The study was conducted on 21 sub-districts in Ponorogo Regency. Semi-quantitative approach was carried out with descriptive analytic design to provide a systematic, factual and accurate description of health risks and determine the relationship of hazards, vulnerability and capacity to landslide disasters. Health risks analysis to landslide disaster refers to the model below:

$$\text{Risk} = (\text{hazards} \times \text{vulnerability}) / \text{capacity} \quad (1)$$

The model of risk assessment above uses weighting factors and indexing, not a real (numerical) values. The indexation of each variable above consist of: (a) the hazard is calculated based on the probability of occurrence and magnitude of the disaster; (b) vulnerability is assessed based on population density, vulnerable groups, and poverty ratio; (c) capacity is assessed based on Health human resources, focal points and health care facilities [11].

2.1. Research Variables

The dependent variable is health risk analysis of Ponorogo Regency, while the independent variable are hazards, vulnerability and capacity of the community to face landslides. Each index has parameters as described in the table 1.

Table 1. Research variables, parameter of classes, score, weight and index equation

Variables	Parameter of Classes	Score	Weight (%)	Index Equation
Identification of potential hazards to landslides				
Landslide disaster potential is based on analysis using Paimin formula [12]	High: total points ≥3.5 Moderate: total points 2.6-3.4 Low: total points ≤2.5	1 0.667 0.333	50%	(a) Hazard index = (0.5 * potential) + (0.5 * incidence)
The number of landslides in Ponorogo Regency in 2015-2017 [13]	High: ≥ 21 events / year Moderate: 11-20 incidents / year Low: ≤ 10 events / year	1 0.667 0.333	50%	
Identification of the vulnerability of the community [14]				
Population density [15]	High:> 1000 people / km2 Moderate: 500-1000 people / km2 Low: <500 people / km2	1 0.667	40%	(b) Vulnerability index = (0.4 * density) + (0.3 * vulnerable group) +

		0.333		(0.3 * poverty ratio)
Vulnerable group [15]	High : > 40% of population	1	30%	
	Moderate : 20-40% of population	0.667		
	Low : < 20% of population	0.333		
Poverty Ratio [15]	High : > 40% of population	1	30%	
	Moderate : 20-40% of population	0.667		
	Low : < 20% of population	0.333		
Identification of community capacity to face landslide disasters [14]				
Adequacy of health human resources in accordance with SNI which refers to the Vision of Healthy Indonesia 2015: a. 1 doctor for every 2500 population b. 1 pharmacist for every 10,000 population c. 1. Midwives for every 1000 population d. 1 nurse for every 850 population	High : over than National Standards	1	40%	(c) Capacity index = (0.4 * health HR) + (0.3 * Focal point) + (0.3 * health care facility)
	Moderate : sufficient in National Standards	0.667		
	Low : deficient in National Standards	0.333		
The existing of focal point or disaster risk reduction community [9]	High : Exist and doing routine training	1	30%	
	Moderate: Exist but not doing routine training	0.667		
	Low: Doesn't exist	0.333		
Health Service Facilities standardized refers to Healthy Indonesia Vision	High : Exist, standardized and adequate	1	30%	
	Moderate : Exist, not standardized but adequate	0.667		
	Low : Exist, not standardized and not adequate	0.333		

2.2 Data Collection and Analysis Techniques

Primary data and secondary data are collected by interview, observation and literature study. Health risk analysis was carried out by compiling the variables based on the Guidelines for Disaster Risk Assessment of BNPB Regulation No. 2 of 2012 and the Geomedical Map Preparation Guidelines of Ministry of Health, 2005. Furthermore, health risks are analyzed by overlaying with ArcGIS devices in to risk maps.

3. Results and Discussion

3.1 Hazards Identification

The potential of hazards had identified by compiling potential variables based on the prediction results with the Paimin formula [12] and the incidence rate based on the Badan Nasional Penanggulangan Bencana (BNPB) District report of 2015-2017 [13]. Formula Paimin has parameters to predict the potential for landslides, namely: (a) cumulative rain for 3 days; (b) degree of slope; (c) geological conditions; (d) thickness of solum; (e) the existence of a fault; (f) land use, (g) infrastructure and (h) settlement factors [16], as formulated as follows.

$$\text{Total Score} = 0{,}25a + 0{,}10b + 0{,}10c + 0{,}05d + 0{,}05e + 0{,}20f + 0{,}15g + 0{,}05h \quad (2)$$

The results of hazards analysis in all sub-districts of Ponorogo shows that 6 sub-districts (Ngrayun, Slahung, Sawoo, Sooko, Pulung and Ngebel) have a high potential of landslide, while the other 15 sub-districts have a moderate potential. The mapping of hazards analysis in Ponorogo Regency is shown in Figure 1.

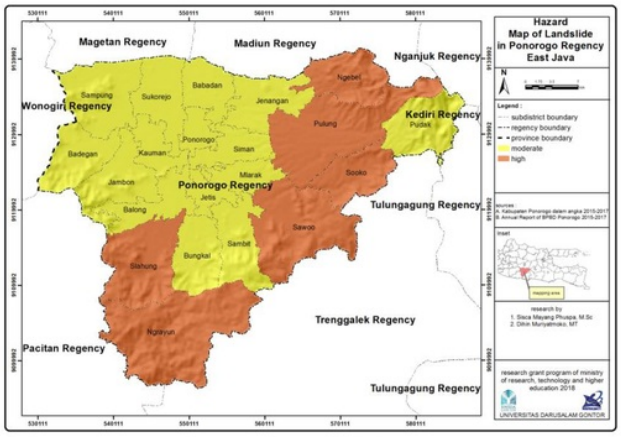

Figure 1. Hazard Map of Landslide in Ponorogo Regency

3.2 Vulnerability Identification

The level of vulnerability had identified by compiling variables of population density, the presence of vulnerable groups and the poverty ratio [14]. Population density become a vulnerability variable because the high population is directly proportional to the high probability of the population affected by disasters. People included to vulnerable groups are a priority to be helped by other because they are considered to be difficult to evacuate themselves when disaster happens [17]. The poverty ratio becomes a variable of vulnerability because poverty is related to the low level of health [7].

The results of the identification of vulnerability to landslide disasters in Ponorogo showed variations from low (7 sub-districts), moderate (9 sub-districts) to high (5 sub-districts). It can be concluded that the growth and distribution of the population in Ponorogo Regency is not equally. It should be taken into consideration in the regional development planning of Ponorogo Regency. The vulnerability mapping of Ponorogo Regency is shown in Figure 2.

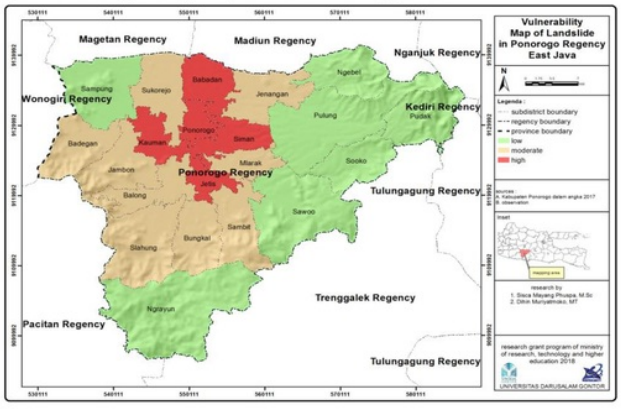

Figure 2. Vulnerability Map of Landslide Disaster in Ponorogo Regency

3.3 Capacity identification

The level of community capacity had identified by compiling the adequacy of health human resources, the existence of focal points and the adequacy health infrastructure [9]. Adequacy of health human resources greatly influences the capacity of the community to face disasters [18]. Adequacy of health human resources refers to the 2015 Healthy Indonesia Vision standards for achieving the Millennium Development Goals (MDGs). In addition to health human resources, the quality of health services should also be supported by adequate and certified facilities and infrastructure [19]. Another strength in dealing with disaster threats is the focal point which actively participates in disaster risk reduction in each region [20].

The results of the identification of community capacity to face landslides showed that only 4 sub-districts were classified as moderate while 17 other sub-districts were low. Community capacity mapping is shown in Figure 3.

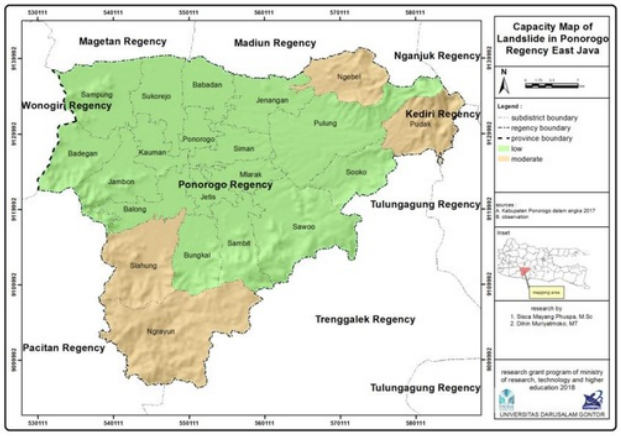

Figure 3. Capacity Map of Landslide in Ponorogo Regency

3.4 *Health Risk Analysis*

Analysis of health risks in each sub-district in Ponorogo Regency based on hazards, vulnerability and capacity as shown in table 2, concluded that only Sampung sub-district had low landslide risk, 3 sub-districts had moderate risk, while 17 other sub-districts had high health risks. Health risk mapping of landslides in Ponorogo Regency is shown in Figure 4.

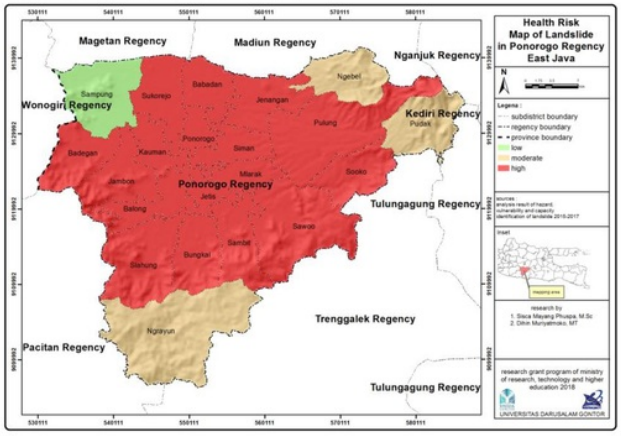

Figure 4. Health Risk Map of Landslide Ponorogo District

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Table 2. The results of data collection and analysis in 21 sub-districts in Ponorogo Regency

Sub-districts	Prediction Score	Frequency Score	Hazard Index (a)	Density Score	Vulnerable group Score	Poverty Score	Vulnerability Index (b)	Health HR Score	Focal point Score	Health facility score	Capacity Score (c)	Risk = (a*b)/c	Risk Level
Ngrayun	1	1	1	0.333	0.333	0.333	0.333	0.667	0.333	0.667	0.5668	0.587509	Moderate
Slahung	1	0.667	0.8335	0.667	0.333	0.667	0.5668	0.667	0.333	0.667	0.5668	0.8335	High
Bungkal	0.667	0.333	0.5	0.667	0.333	0.667	0.5668	0.333	0.333	0.333	0.333	0.851051	High
Sambit	1	0.333	0.6665	0.667	0.667	0.333	0.5668	0.333	0.333	0.333	0.333	1	High
Sawoo	1	1	1	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	1	High
Sooko	1	1	1	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	1	High
Pudak	1	0.333	0.6665	0.333	0.333	0.333	0.333	0.667	0.333	0.667	0.5668	0.391575	Moderate
Pulung	1	0.667	0.8335	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.8335	High
Mlarak	1	0.333	0.6665	0.667	0.667	0.333	0.5668	0.333	0.333	0.333	0.333	1	High
Siman	0.667	0.333	0.5	1	0.667	0.667	0.8002	0.333	0.333	0.333	0.333	1	High
Jetis	0.667	0.333	0.5	1	0.667	0.667	0.8002	0.333	0.333	0.333	0.333	1	High
Balong	0.667	0.333	0.5	0.667	0.667	0.333	0.5668	0.333	0.333	0.333	0.333	0.851051	High
Kauman	0.667	0.333	0.5	1	1	0.667	0.9001	0.333	0.333	0.333	0.333	1	High
Jambon	0.667	0.333	0.5	0.667	1	0.333	0.6667	0.333	0.333	0.333	0.333	1	High
Badegan	0.667	0.333	0.5	0.667	0.667	0.667	0.667	0.333	0.333	0.333	0.333	1	High
Sampung	0.667	0.333	0.5	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.5	Low
Sukorejo	0.667	0.333	0.5	0.667	0.667	0.667	0.667	0.333	0.333	0.333	0.333	1	High
Ponorogo	0.667	0.333	0.5	1	1	0.333	0.7999	0.333	0.333	0.333	0.333	1	High
Babadan	0.667	0.333	0.5	1	1	0.667	0.9001	0.333	0.333	0.333	0.333	1	High
Jenangan	1	0.333	0.6665	0.667	1	0.667	0.7669	0.333	0.333	0.333	0.333	1	High
Ngebel	1	1	1	0.333	0.333	0.333	0.333	0.667	0.333	0.667	0.5668	0.587509	Moderate

Referred to table 2, proved that health risk level of landslide prone in Ponorogo regency have three sub-district area with moderate risk, one sub-district area with low risk, seventeen sub-district area with high risk. So, for the next step we can discuss that the geomedical mapping method is ably to applied for elsewhere area and to mapping risk analysis of landslide prone area, can used an others method like statistical based geospatial model [21] and spatial analysis of landslide inventory maps [22]

4. Conclusion

Geomedical mapping is an utilization of GIS in disaster mitigation. Geomedical mapping can be a method for analysing the risk of a health crisis due to a disaster. An important note as the results of this analysis is the extent high risk area for the threat of landslides. The low capacity of the community must be immediately addressed to reduce the potential risk of disasters due to landslides.

Acknowledgement

The research reported in this publication is supported by the Research Grant Program of the Republic of Indonesia Ministry of Technology and Higher Education in 2017. This content is entirely the responsibility of the author and does not always represent the official view of the Ministry of RI Technology and Higher Education.

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