Zonation of Landslide-Prone Using Microseismic Method and Slope Analysis in Margoyoso, Magelang

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Abstract. Margoyoso Village, Salaman Sub-district, Magelang Regency, Central Java is one of the villages that were included in landslide prone areas. The steep slopes and land use in this village were quite apprehensive. There were fractures with 5 cm in width and a length of 50 m. Moreover, these fractures appeared in the home residents. Although the local government has established a disaster response organization, this village is still not getting adequate information about the landslide prone areas. Based on the description before, we conducted research with geophysical methods and geotechnical analysis to minimize the danger of landslides. The geophysical method used in this research was microseismic method and geotechnical analysis. The microseismic measurement and slope stability analysis at Margoyoso village was a step in analysing the landslide-prone zone boundary. The results of this research indicated that landslide potential areas had a low peak ground acceleration values with a range from 36 gal to 46 gal. Measurement of slope stability indicated that a slope angle values between 55°-78° are a potential landslide slope because the soil in this village has very loose properties so it is very easy to move.

1. Introduction
Landslide is one of the most often natural disasters that happen in Indonesia. Almost all regions in Indonesia are risky from the landslide. According to Data dan Informasi Bencana Indonesia 2016-Badan Nasional Penangulangan Bencana (Disaster Data and Information in Indonesia - National Board for Disaster Management) Even until mid-2016, there have been 394 landslides that caused hundreds of victims, dozens of missing people, and up to thousands of people displaced[1]. Therefore, the landslide disaster must be taken seriously and society must be educated about prevention act so that nothing bad happens.

Margoyoso Village, Salaman District, Magelang Regency, Central Java is one of the villages in Indonesia which are included in landslide prone areas. Villagers have complained about lots of fractures that appear in this village, even that fracture also appeared around the villager’s house with an average fracture of 5 cm with a length up to 50 m and also appeared cracks in the wall of villager’s house. This fracture is suspected as a result of land-use change due to the new buildings that not supported by proper construction. Although the local government has established a disaster response organization such as the Tanggap Ing Sasmito forum, this village is still not getting adequate information about landslide prone areas.

Landslide disaster can occur because of many factors, such as geomorphology (slope, height, drainage, etc), geological (soil type, fracture) and seismic activity (earthquakes)[2]. Landslides that caused by earthquakes can increase the shear stress due to horizontal acceleration, or decrease in soil strength. [3]. A microseismic method for zonation landslide prone areas, from this method can be analyzed a
correlation between the thickness and type of the soft sediment cover [4]. In this case, the area with high potential of landslide and low potential of landslide have different seismic vulnerabilities [5]. Slope stability analysis is a geotechnical method that can measure soil safety factors caused by geological aspects such as fractures, pores, and lithology. By conducting this research, it is expected to provide information about landslide-prone zones so that it has an impact on the reduction of potential victims and the loss of the community. This research is also a contribution from the geosciences especially geophysics in its application to the environment.

2. Methods and Materials
This research area located in Margoyoso, Salaman sub-district, Magelang regency. The time of research is about 2 weeks (April 30th - May 9th, 2017). The method used in this research is microcosmic method and slope stability analysis. In general, the research flow diagrams were conducted as follows:

![Research process flow diagram](image)

**Figure 1.** Research process flow diagram. This research was started with surveying of research location and it was finished with data interpretation.

2.1. Microseismic Method
The method used in the study of landslide-prone zonation was microseismic. The microseismic device can identify the vibration decay contained in the medium, along with the broadband seismometer measuring in real time. The main sources of vibrations in microseismic method are ocean wave, traffic, industrial and human activities [6]. Then, the ground movement can be recorded as a function of time in local site [7]. Site response analysis is important in seismic hazard assessment in earthquake prone zones. This research used H/V method, also called the Nakamura technique [8].

2.1.1. Instrumentation
In this study used seismometer Lennartz Electronic with brand LE-3DLite. This instrument consists of one seismometer unit, one Data Logger unit, also other accessories such as LAN cable and connecting cable. This seismometer unit has an Eigen frequency 1 Hz and the acquired frequency limit is 100 Hz. While data logger is an instrument that can record data within a certain time. This instrument converts the analogue signal into a digital signal that can be processed by laptops. Other equipment required are a 12 volt accumulator, gps handheld, and compass.

2.1.2. Acquisition
In this research, the microseismic method focused on horizontal to vertical spectral ratio (HVSR) method. Ambient seismic noise is a natural vibration arising from nature or commonly referred to as small vibrations of nature (microtremor). Spectral analysis was done to obtain domain frequency of microtremor activity. In this analysis, we used fast fourier transform (FFT) with bandwidth frequency 1 Hz - 10 Hz to obtain natural frequency ($f_0$) and natural amplification ($A_0$) values from the research area [9]. Nakamura [10] explains that the HVSR Method can compare the ratio of spectral amplitudes between vertical and horizontal components. Mathematically, it can be expressed in the equation:
The HVSR method is used on a three-component passive seismic (microtremor). Microzonation can predict the response and behaviour of the soil or sediment layer to external energy that affects the surrounding soils. Microtremor used very small amplitude ranging from 0.1 to 1.0 μm and the period between 0.1 seconds and 1.0 seconds[11]. Peak ground acceleration (PGA) is used to describe strong ground motion. PGA is a parameter that represents the acceleration of earthquake vibration on the ground. The PGA value is not included in the measurement of the energy of an earthquake[12].

2.2. Slope Analysis
Slope stability analysis is an important part to prevent the disturbances that potentially lead to disaster that can endanger the surrounding community. The increased of pore pressure causes decreasing of effective stress on the soil. Afterward, reducing soil shear strength and resulting slope failure[13]. According to Karnawati[14], there are several factors to control the occurrence of slope failure, slope failure with movement of soil mass type has a slope for the range of 20° to 40°.

3. Result and Discussion
3.1. Geological Study
The geological study shows that this area had steep slopes. Those slopes were worsened by poor land use. Moreover, in area with steep slopes there were not planted by plants with strong roots so that potentially occur landslides.

3.2. Microseismic Method Measurement
3.2.1. Natural Frequency (F₀)
Natural frequency characterizes the ground surface character when subjected to external vibrations (such as earthquakes). If the vibrations that hit it have a frequency greater than or equal to the natural frequency then there will be a resonance which will result in the amplification of seismic waves in the area affected by the vibration. The distribution of natural frequency values is shown in Figure 2A. The frequency of the region with blue color will resonate with earthquake frequency and this area is dangerous.

3.2.2. Amplification (A₀)
Amplification is defined as the magnitude of wave reinforcement that occurs in an area. Reinforcement of this wave is proportional to the ratio of the horizontal spectrum and the vertical spectrum of a medium. Soft sedimentary rocks are known to strengthen the movement of the soil during the earthquake and therefore the average damage caused more severe than the hard layer[6]. The distribution of amplification can be seen at Figure 2B. The area with high amplification value is dangerous, because in that area can be earthquake wave strengthening.

3.2.3. Peak Ground Acceleration
The calculation of Peak Ground Acceleration with Kanai method used Yogyakarta earthquake 2006 (6.2 Richter Scale). When the PGA value is smaller, the potential for landslide disaster will be greater.
The observed earthquake should be noted the time range of the earthquake because the frequency of the occurrence of an old earthquake can cause a large earthquake as well. In Figure 2C, the PGA values with a range of 36-52 gal is low enough so that the area is prone to land movement.

\[\text{Figure 2. The result of landslide-prone zonation using microseismic method and slope analysis in Margoyoso, Magelang. A. Distribution map of natural frequency value (F_0). The blue colour indicated low natural frequency value. The read one indicated high natural frequency value. B. Distribution map of amplification value. The violet colour indicated low amplification value. The light green colour indicated high amplification value. C. Distribution map of PGA values. The black colour indicated low PGA value. The white colour indicated high PGA value. D. Distribution map of slope measurement point. The red circle indicated dangerous slopes. The white circle indicated safe slopes.} \]

3.3. Slope Analysis

There were 22 observed slopes. 14 of 22 (63.63%) observed slopes have potential of landslides. The distribution of slope stability analysis point was shown in Figure 2D. There are several areas that vulnerable because the slope is unstable. The red circle indicated dangerous slopes. The white circle indicated safe slopes.
4. Conclusion
Zonation of landslide-prone with microseismic method and analysis of slope stability in Margoyoso Village, Salaman sub-district, Magelang had quite dangerous landslide potential. This research was a step in analysing the limits of landslide prone zone based on predetermined parameters. Based on the parameters that have been described in this study (natural frequency, amplification, peak ground acceleration, and stability analysis of slope), it was found that the potential landslide area is in the eastern and western of the research area that had a low peak ground acceleration value with a range of 36-52 gal and slope failures.

5. References
1. Data dan Informasi Bencana Indonesia [Internet]. 2016 [cited 2017 Feb 5]. Available from: http://dibi.bnpb.go.id/data-bencana
2. Arnous MO 2011 Integrated remote sensing and GIS techniques for landslide hazard zonation: a case study Wadi Watter area J Coast Conserv. 15(4) 477–97.
3. Lei CI 2012 Earthquake-Triggered Landslides 1st Civil and Environmental Engineering Student Conference (London; Imperial College London) p. 1–6.
4. Torgoev A, Lamair L, Torgoev I, Havenith H 2013 A Review of Recent Case Studies of Landslides Investigated in the Tien Shan Using Microseismic and Other Geophysical Methods Earthquake-Induced Landslides (Berlin: Heidelberg) p. 285–94.
5. Gallipoli MR, Mucciarelli M, Vona M 2009 Empirical estimate of fundamental frequencies and damping for Italian buildings Earthq. Eng. Struct. Dyn. 38(8) 973–88.
6. Tuladhar R, Yamazaki F, Warnitchai P, Saita J 2004 Seismic microzonation of the greater Bangkok area using microtremor observations Earthq. Eng. Struct. Dyn. 225(October 2002) 211–25.
7. Sulistiawan H, Supriyadi, Yulianti I 2017 Seismic Hazard Analysis based on Earthquake Vulnerability and Peak Ground Acceleration using Microseismic Method at Universitas Negeri Semarang Journal of Physics p. 1–6.
8. Kind F, Kohler A, Ohmberger M, Richter G, Savvaidis A, Scherbaum F, et al 2002 Site Effects Assessment Using Ambient Excitations SESAME.
9. Sabrianto L, Awali A 2017 Seismic Microzonation Using Microtremor Measurement for Natural Disasters Mitigation of Earthquake at Regions Singaraja City the Province of Bali Indonesia J Earth Sci. 6(1):1–6.
10. Nakamura Y, Nakamura T 1998 Stiffness Design for Specified Nonexceedance Probability of Seismic Response J. Earthq. Spectra 14(1) 165–88.
11. Ishiyama Y, Hasanuddin 2006 Mikrotremor Antologi Paper Pusat Vulkanologi dan Mitigasi Bencana Geologi.
12. Douglas J 2003 Earthquake ground motion estimation using strong-motion records: a review of equations for the estimation of peak ground acceleration and response spectral ordinates J. Earth-Science Rev 61 43–104.
13. Regmi RK, Lee G, Jung K 2013 Analysis on Failure of Slope and Landslide Dam J. Civ. Eng. 17 1166–7.
14. Karnawati D 2007 Mekanisme Gerakan Massa Batuan Akibat Gempabumi; Tinjauan dan Analisa Geologi Teknik Din. Tek. Sipil 7(2) 179–90.
15. Firmansyah, Feranie S, Tohari A, Latief F D E 2016 Prediction of landslide run-out distance based on slope stability analysis and center of mass approach IOP Conf. Ser. Earth Environ. Sci 29 1–6.

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