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Landslide Hazard and Community-based Risk Reduction Effort in Karanganyar and the Surrounding Area, Central Java, Indonesia

KARNAWATI Dwikorita[1]*, FATHANI Teuku F[2], IGNATIUS Sudarno[1], ANDAYANI Budi[3], LEGONO Djoko[2], BURTON Paul W[4]

1 Geological Engineering Department, Gadjah Mada University, Yogyakarta, Indonesia

2 Civil and Environmental Engineering Department, Gadjah Mada University, Yogyakarta, Indonesia

3 Faculty of Psychology, Gadjah Mada University, Yogyakarta, Indonesia

4 School of Environmental Sciences, Norwich, UK

**Corresponding author, e-mail:dwiko2007@yahoo.co.id*

Abstract: Karanganyar and the surrounding area are situated in a dynamic volcanic arc region, where landslide frequently occurs during the rainy season. The rain-induced landslide disasters have been resulting in 65 fatalities and a substantial socio-economical loss in last December 2007. Again, in early February 2009, 6 more people died, hundreds of people temporary evacuated and tens of houses damaged due to the rain-induced landslide. Accordingly, inter-disciplinary approach for geological, geotechnical and social investigations were undertaken with the goal for improving community resilience in the landslide vulnerable villages. Landslide hazard mapping and community-based landslide mitigation were conducted to reduce the risk of landslides. The hazard mapping was carried out based on the susceptibility assessment with respect to the conditions of slope inclination, types and engineering properties of lithology/soil as well as the types of landuse. All of those parameters were analyzed by applying weighing and scoring system which were calculated by semi qualitative approach (Analytical Hierarchical Process). It was found that the weathered andesitic-steep slope (steeper than 30o) was identified as the highest susceptible slope for rapid landslide, whilst the gentle colluvial slope with inter-stratification of tuffaceous clay-silt was found to be the susceptible slope for creeping. Finally, a programme for landslide risk reduction and control were developed with special emphasize on community-based landslide mitigation and early warning system. It should be highlighted that the social approach needs to be properly addressed in order to guarantee the effectiveness of landslide risk reduction.

Keywords: Landslide; Risk reduction; Java; Indonesia

Introduction

Rain-induced landslide occurred in Karanganyar Regency, Central Java, Indonesia on December 27, 2007 where 65 people killed and several houses damage. Six more people were also died due to the landslides occurred on February 2008.

In order to reduce the risk of landslides, integrated approach of geological, geotechnical and social investigations were carried out, especially to provide landslide hazard map with respect to the improvement of community resilience as well as to establish community-

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based landslide early warning system at the most vulnerable villages.

1 Method of Investigation

Remote sensing method by utilizing Satellite Image of Karanganyar region was carried out to support the field geological investigation and to evaluate the levels of landslide susceptibility at the study area.

The first investigation was carried out on December 28, 2007. From this investigation it can be identified the mechanism and controlling factors of the landslide occurrence, thus recommendation for the emergency action to anticipate some other potential landslide disaster can be performed.

Series of the second investigation then was carried out in February 2008 by applying the method suggested by Wu, et al (1996) with the aim to provide hazard map (landslide susceptibility map) and to establish the early warning system for the risk reduction efforts.

In addition, community empowerment program was also undertaken with respect to landslide mitigation and improvement of community resilience.

The landslide hazard mapping was carried out by semiqualitative approach, the Analytical Hierarchy Approach suggested by Saaty (1980) was applied to calculate the weighing and scoring of all parameters controlling the landslide susceptibility and hazard. The controling parameters for landslide susceptibility consist of slope inclination, lithology/soil types and structural geology, as well as the landuse. The landslide hazard map then was developed by integrating rain precipitation map into the susceptibility map.

The third investigation was accordingly conducted in August 5, 2008 for the period of one week, in order to define the most appropriate sites to install the early warning system.

2 Geology and Landslide Conditions

It was identified in Figure 1 that the landslide susceptibility zone exceeds 60 % of the study area, with the level of medium to high.

With respect to landslide classification suggested by Crudent and Varnes (1996), the type

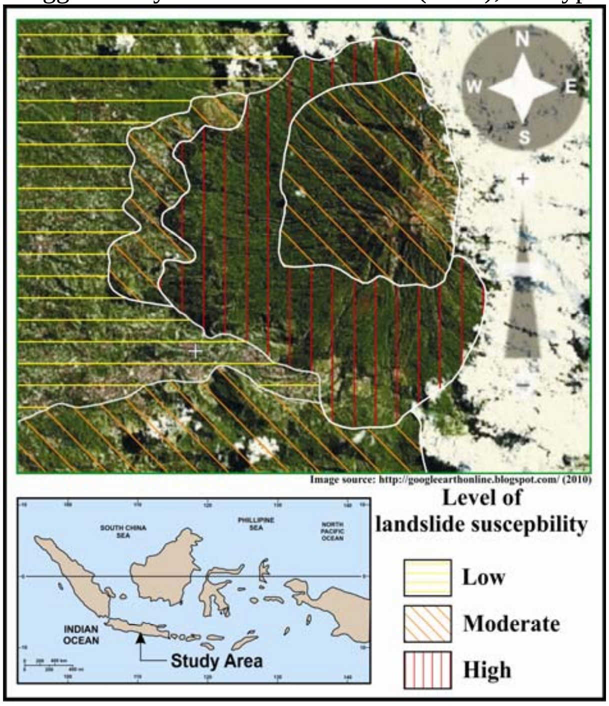

Figure 1 Landslide susceptibility map of Karanganyar Regency, Central Java (developed by Karnawati based on interpretation on the satellite image and field checking in December 2007).

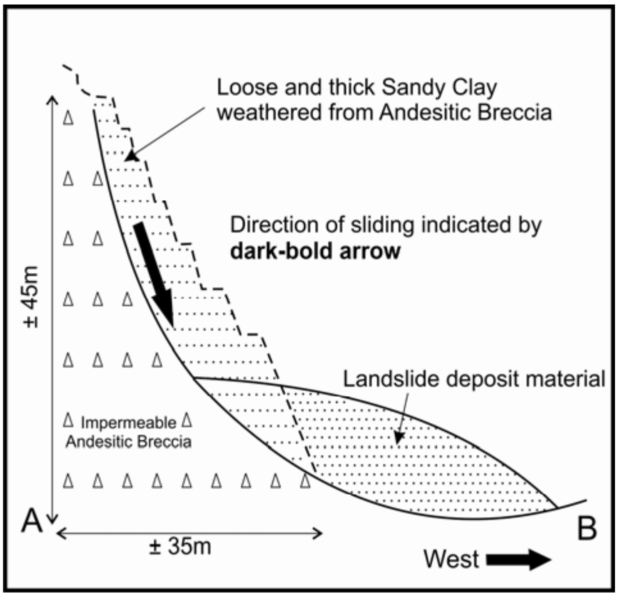

Figure 2 Mechanism of earth slide in Ledoksari Village occurred last December 27, 2007 with the width of sliding crown approx. 50 m.

of landslide was identified as the earth slide (Figure 2). It was apparent that the failure surface was the contact between andesitic breccias and the moving mass of loose sandy clay weathered from the underlain andesitic breccias (Figure 3).

Figure 3 Bedrock of jointed andesitic breccia covered by the weathered material of sandy clay (exposed at the foot of susceptible mountain slope). Contact between the breccia and sandy clay performs as the sliding surface.

Figure 4 Un-appropriate landuse management, where many houses of situated immediately at the lower part of susceptible slope.

This landslide occurs mainly due to the conditions of slope steepness (exceeding 50o in association with a break-slope) and the inducement of heavy rainfall exceeding 100 mm precipitation. Uncontrolled landuse management at the lower part of susceptible slope, which was developed as settlement area, seriously increased the risk of landslide (Figure 4).

Based on landslide hazard mapping which was conducted by overlying the annual rain precipitation map (recorded in the last 10 years) into the analyzed susceptibility map, zones of landslide hazard level in the Regency of Karanganyar can be identified (Figure 5). It was

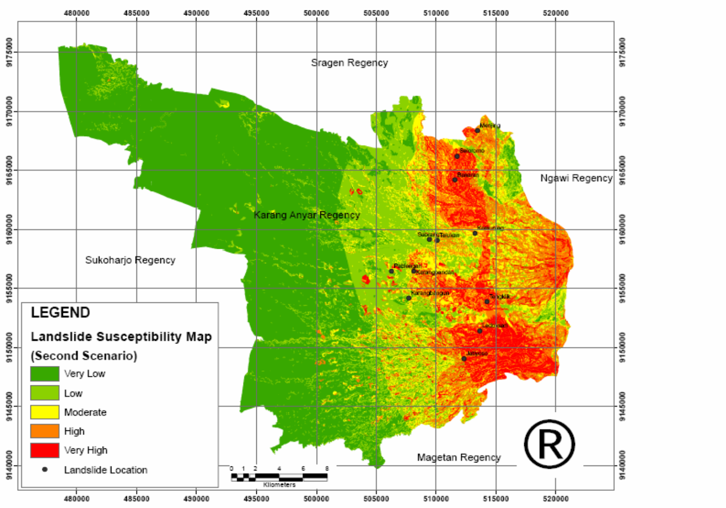

Figure 5 Landslide hazard map of Karanganyar Regency, Central Java, Indonesia, which was developed based on the regional scale of 1 : 100,000.

Figure 6 Selected sites for the installment of early warning system.

apparent that the highest level of landslide hazard was mainly concentrated at the middle part of the west-slope of Lawu Volcano, illustrated as the red zone in the map. In fact, the field survey proved that most landslides occurred within this highest level of hazard zone.

3 Support for Landslide Early Warning System

Considering that the landslides still potentially occur in the region of Karanganyar

Regency, which is densely populated and such population was not easy to be relocated, on August 6, 2008 one most susceptible and vulnerable sites were selected to be installed with the early warning system equipment.

Finally, one site was selected at Ledokasari

Figure 7 Early warning system equipments consisting of a) manual extensometer with the control panel and sirene and b) rain gauge, developed by Fathani et al. in 2008.

Village in Tawangmangu area (Figure 6).

The early warning system consists of several sets of equipment listed below (Figure 7):

1. Rain gauge (1 set).

Manual extensometer (5 set) with the sirene alarm worked based on dry battery (accu)

2. Solar panel (2 set) to recharge the dry battery.

The rain gauge was installed in the open space to record the rain precipitation which may induce landsliding. The alarm warning was also set to start if the accumulative rain infiltration exceeds 100 mm. This threshold of rain infiltration was defined based on the previous research conducted by Karnawati (1996) and Su Su Ky (2007). The alarm due to rain gauge warning was designed to raise community alert to be ready to move any time when the alarm of extensometer had been on.

The extensometers were designed to be pulled that can be automatically across the crack in response to the extension of crack induced by the slope movement (Figure 8). The crack-extension is the indicator of initial slope movement just before landslide occurs.

Thus, this early warning system is designed to minimize the potential numbers of victim by raising the community alert.

Accordingly, if the wire of extensometer is pulled up to 4 cm length (this length was defined based on the previous empirical investigation at

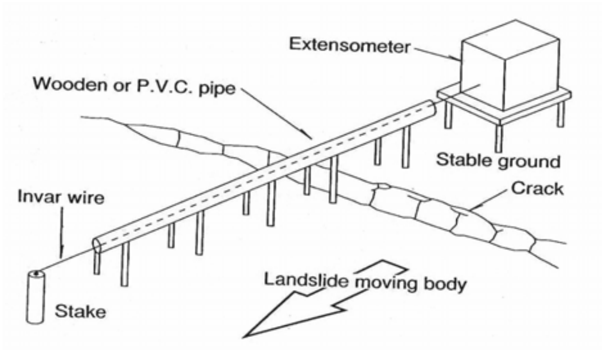

Figure 8 Schematic performance of extensometer installed across the crack (Japan Landslide Society 1996).

similar susceptible landslide area), the connected alarm will be on as the early warning to the community, so they have to start to move away from the respective slope.

The installment of early warning system in Ledoksari Village was carried out in parallel with the community empowerment program for landslide hazard preparedness, as discussed in the following section.

4 Community Empowerment and

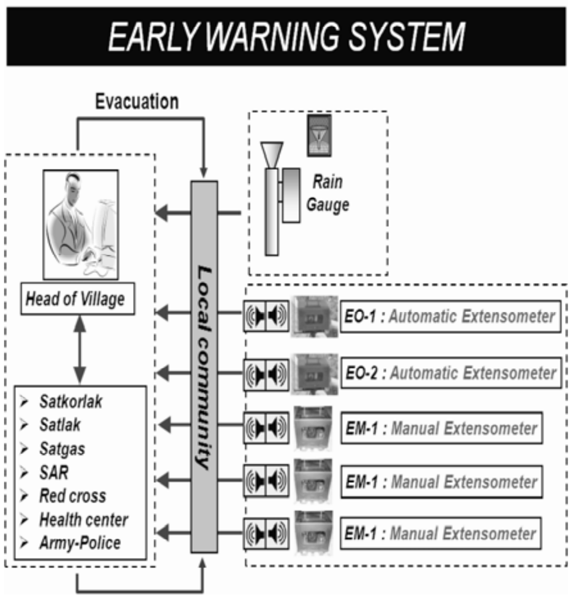

Figure 9 Integration of technical and social system of landslide early warning and disaster risk reduction in Ledoksari Village, Karanganyar Regency, Indonesia (Karnawati et al. 2009 and Karnawati et al. 2010).

Public Education

Based on social survey and mapping, the strategic program for community empowerment has been implemented by conducting partnership between the University and the key person in the local site, under the coordination of Local Authority in the respective Regency. Through this approach, transfer of information can effectively improve the community understanding and stimulate the willingness to build the culture for disaster prevention and preparedness. Indeed, community-based landslide mitigation and early warning system can be established, as illustrated in Figure 9 (Karnawati 2009 and Karnawati 2010). Such system was developed by integrating the technical system of equipment network (Figure 7) and the social network. This social network is supported mainly by the Task Force Team for disaster mitigation at the village level, under the coordination of the Local Agency for Disaster Management at the Regency level. This network is also linked to the local hospital (health center), army and police, and also SAR team.

5 Conclusion

More than 60 % of Karanganyar Regecy Area is susceptible for landslide, because of the morphological and geological conditions. High precipitation and uncontrolled landuse management seriously increase the level of landslide hazard in this region. Community-based landslide early warning and mitigation system is therefore urgently required in order to minimize the potential socio-economical risks. Such system should be simple and practical which can be operated and maintained by the local community.

Indeed, the social survey as well as community empowerment and public education program should be integrated to the geological and geotechnical investigations, to guarantee the effectiveness of early warning system installed and the overal landslide disaster risk reduction program.

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