

# Development of Landslide Monitoring and Early Warning System in Indonesia

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**Abstract.** Landslide is one of most major disasters in Indonesia due to the susceptibility of the region and socio-economical conditions of the country. Since 2007, a community-based early warning system has been introduced in a pilot area at Banjarnegara Regency, Indonesia. Simple extensometers and automatic rain gauge have been installed for landslide monitoring and prediction with the participation of local community. Furthermore the Asian Joint Research Project for Early Warning of Landslides led by International Consortium on Landslides (ICL), in collaboration with Gadjah Mada University (GMU) Indonesia, Disaster Prevention Research Institute of Kyoto University (DPRI/KU) and Asian Institute of Technology (AIT) Thailand have conducted a preliminary investigation and established a real-time monitoring and early warning system. The system consists of a fieldserver as its core component, which collects data from network camera, two long span extensometers, rain gauge and water pressure sensor. The early warning system allows data to be stored locally on the monitor at the site and also sends the data to a web server in AIT for graphs to be published on the internet. There is a necessity for the implementation of this real time landslide monitoring system for contribution towards local community early warning.

**Keywords.** Early warning system, landslide prediction, real-time monitoring, rural community.

## 1. Background of Landslide Early Warning in Indonesia

As the dynamic volcanic-archipelagoes, more than 60 % of Indonesian region are covered by the mountainous and hilly areas of weathered volcanic rocks, which are intersected by faults and rock joints. These geological conditions give rise to the high landslide susceptibility of the region. Moreover, the high rain precipitation which can exceed 2000 mm to 3000 mm per year, frequent earthquake vibrations as well as the extensive landuse changing and deforestation cause the occurrence of landslides frequently increase recently. Since the last 7 years, more than 36 landslide disasters occurred and result in 1226 people died or missing. Urgently, some efforts should be done to avoid or reduce the risk of landslides. Unfortunately, most landslide susceptible areas have very fertile soils and very good quality and quantity of water. This makes the susceptible areas are densely populated, and it create serious inducement to slope instability. Despite an effort to establish slope protection zone, which is restricted for any development and settlement, the relocation program is not easy to be carried out due to socio-economical constrains. Therefore, landslide monitoring, prediction and early warning system are urgently required to guarantee the safety of community living in such area.

## 2. Geological Condition of the Study Area

A pilot area for landslide monitoring, prediction and early warning program has been established in Banjarnegara Regency, Central Java Province. It is clarified that not only the rain intensity but also the morphology and geological conditions of study area significantly control the occurrence of landslides. The unstable zone in the study area is situated at lower slope of mountains with the slope inclination of 20° to 60°. The moving materials consist of colluvial deposits of silty clay overlying the inclined impermeable layer of clay, which is situated at the lower part of the andesitic breccias mountain. The clay layers are inclined at the same direction of the slope (i.e. 85°) and this becomes the sliding failure for the above colluvial soils. The moving zone is saturated at most of the rainy season due to the lower position of the zone comparing to the surrounding mountainous slopes. The existence of impermeable clay layer underneath the colluvial soils creates the saturation condition within colluvial soil gradually increased and maintained during the rainy season, until then the rise of pore water pressure within this soil induces the movement. Therefore, monitoring of the pore water pressure (groundwater table) in response to the rain infiltration should be the main concern in establishing early warning for the slope movement.

## 3. Community-based Early Warning System

At the beginning of year 2007, Gadjah Mada University has developed low-cost equipment for landslide monitoring and early warning, where the rural community can easily operate and maintain the equipment based on their capability. As the initiation of quantitative investigation, two types of simple extensometers and automatic rain gauge were installed at a pilot area in Banjarnegara. The first type of extensometer is a handmade manual reading extensometer. Another type is the automatic extensometer, where the relative movement between two points is mechanically enlarged by 5 times and recorded on a paper continually. The installation of automatic extensometer is shown in Fig.1. Both types of extensometers are connected to the siren system in order to directly warn the local community for taking necessary actions in dealing with landslide disaster.

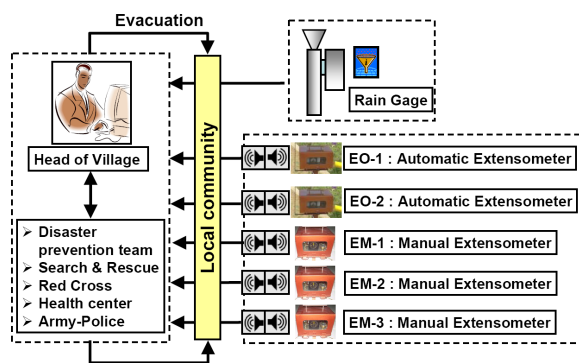
At the same time a simple modified rain gauge has been developed with hourly rainfall intensity recorded on a paper continually. The warning criteria are determined based on topographical, geological and hydrological conditions. During the installment, five local operators have been trained on how to install and operate this equipment (Fathani & Karnawati, 2007). On November 7<sup>th</sup>, 2008, a manual extensometer warned the community just four hours before the landslide occurrence, therefore the community has enough time to evacuate when the landslide destroys 400 m of district road and 10 houses. Due to a very active



movement recorded by these extensometers, recently around 40 houses at the landslide susceptibility area have been relocated to a more stable area provided by local government. Fig.2 shows early warning system and evacuation scheme for local community under the supervision of head of village in coordination with disaster prevention team, Search and Rescue, Red Cross, health center, and other local authorities.



**Fig. 1** Automatic extensometer installed at the upper part of houses at a dangerous zone.

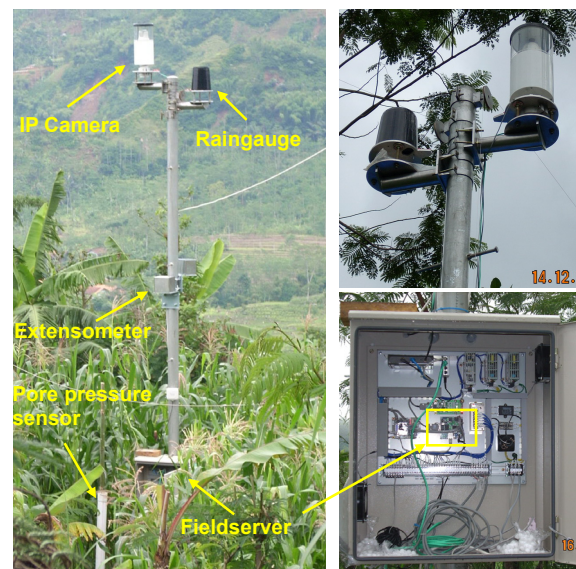


**Fig. 2** Evacuation procedure for local community based on early warning from simple monitoring equipment.

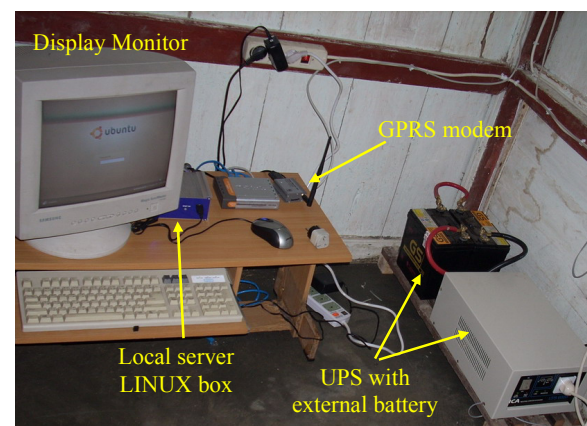
#### 4. Real-time Monitoring and Early Warning System

In line with the installation of simple monitoring equipment, on September 2007, the Asian Joint Research Project for Early Warning of Landslides led by ICL and in cooperation with Gadjah Mada University and Asian Institute of Technology has developed and deployed an early warning system for landslides in Banjarnegara Regency. A fieldserver as a sensing device was used to collect data from several sensors and display the results of monitoring in a web page. This system consists of a network camera, two long span extensometers placed above and below the data collection point in order to check ground displacement, and a rain gauge to constantly check the antecedent as well as current rainfall which affect land movement. Moreover, a water pressure gauge was placed at a depth of 2.5 m to measure the underground water level fluctuation. The data from the sensors and the images from the camera are collected and stored in a database in an embedded Linux system.

The real-time monitoring equipment consists of outdoor unit and indoor unit. Outdoor unit mounted on a fixed center pole consists of fieldserver, two extensometers, rain gauge, network camera and water pressure sensor (Fig.3). The extensometer placed at two positions connected by a pulley and a super invar wire which can measure both extension (+) and compression (-). Indoor unit has two crucial components i.e. processing unit and GPRS modem (Fig.4). The system applies an algorithm based on local observations by landslides experts to provide warning messages at several levels. The warning levels are determined depending on the data collected from two long-span extensometers and the rain gauge. A graphical interface is also provided at the local site for community to observe the movement and the warning level. The data and images collected at the site are also sent to a server at Asian Institute of Technology (AIT) in Thailand, where it is possible to make it publicly accessible through the internet. The system collects data every 5 minutes and sends the collected data to AIT server every 1 hour.



**Fig. 3** Outdoor unit of real-time monitoring equipment



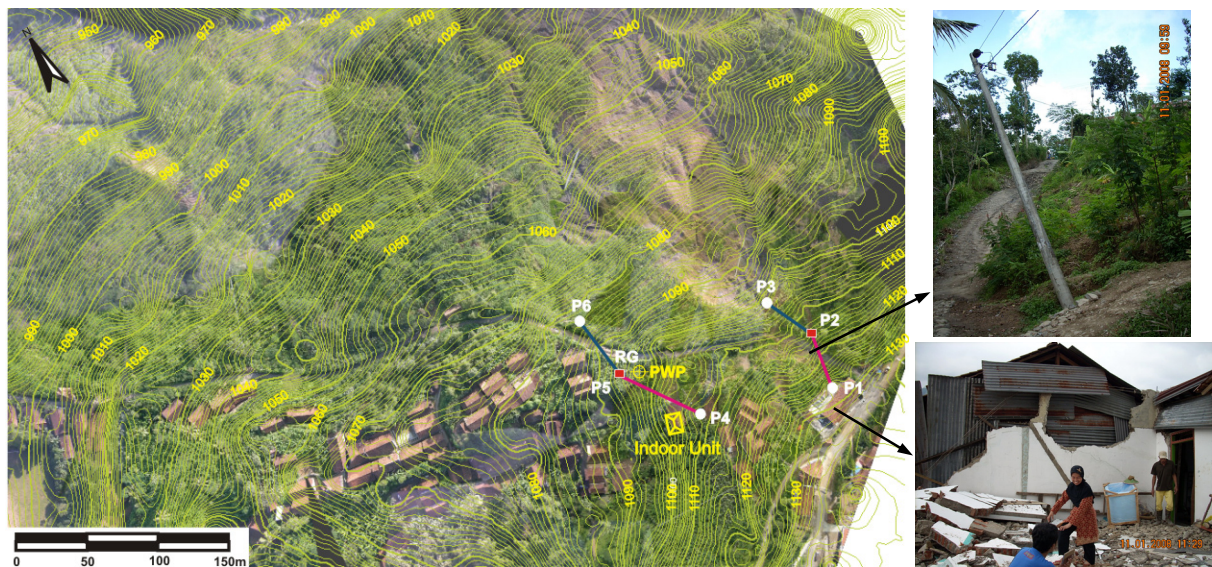
**Fig. 4** Indoor unit of the real-time monitoring equipment placed inside a volunteer's house.



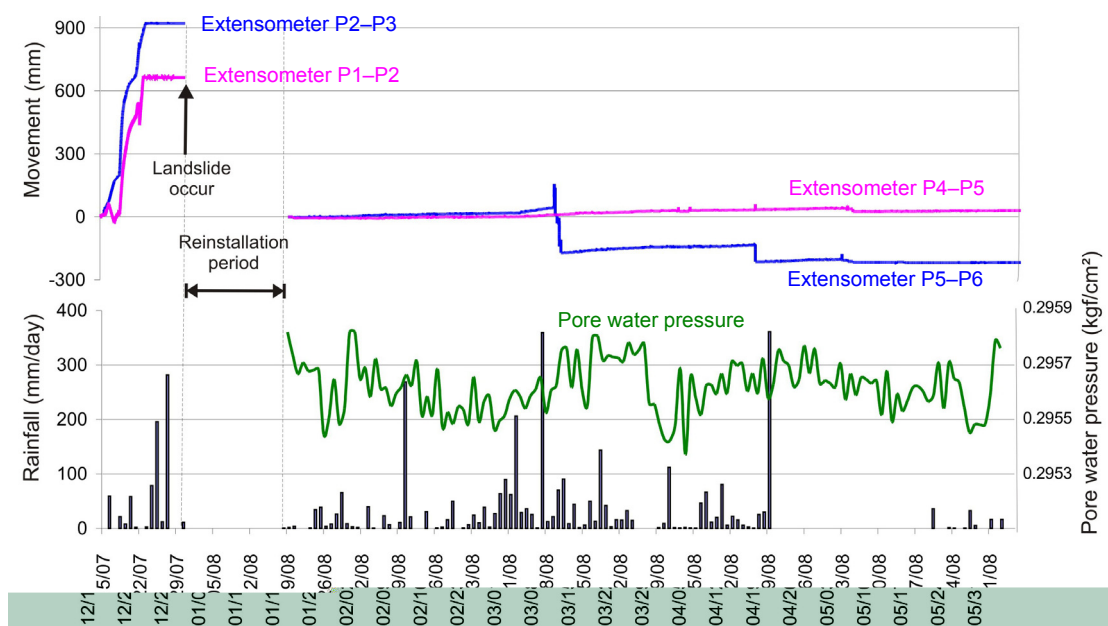
Fig.5 shows the aerial photo and topography map of the landslide area plotted by Balloon Photogrammetry System. This system combines the balloon aerial photography and digital photogrammetry for low-altitude aerial mapping. The balloon carries out a digital camera up to 400 m above the ground level and takes aerial photographs in appropriate viewing angle. The digital photogrammetry processes the photo-restitution to produce 3D model from the multi-view aerial photograph (Rokhmana, 2007).

The position of long-span extensometer poles (P1 to P6), rain gauge, pore water pressure gauge and indoor unit are

shown in Fig.5. The installation of three extensometer poles (P1 to P3) was conducted on December 15<sup>th</sup>, 2007. The installation process had faced some problems since the slide occurring also on day of the system set up. As shown in Fig.6, starting from December 23<sup>rd</sup>, 2007, the extensometer has been saturated (up to 660 to 920 mm of displacement), therefore it cannot measure the movement when the landslide occurred on December 30<sup>th</sup>, 2007, which destroyed the center pole (P2), buried the lowest pole (P3) and also attacked several existing houses, farm land and district road (Fig.7).



**Fig.5** Aerial photo, topography map and position of real-time monitoring equipment. Landslide fatalities are shown on the right.



**Fig.6** The results of measurement by two extensometers, rain gauge and pore water pressure sensor.





**Fig. 7** Center pole (P2) was destroyed by landslide movement on December 30<sup>th</sup> 2007.

On January 19<sup>th</sup>, 2008, the monitoring system has been reinstalled at a new location about 150 m below the previous destroyed place (Fig.5). Three new poles (P4 to P6) were erected with two long-span extensometers, rain gauge and network camera mounted on the fixed center pole (P5). Pore water pressure sensor is placed inside a well near P5, whereas the indoor unit located in a house belongs to a volunteer resident near P4. The result of measurement of two extensometers, daily rainfall and pore water pressure fluctuation are shown in Fig.6. The accumulated movement of extensometer starting from January 19<sup>th</sup> until May 31<sup>st</sup> 2008 reaches of about 30 and 220 for Extensometer P4–P5 and P5–P6, respectively. Meanwhile the maximum rate of rainfall could reach 200 – 360 mm/day. It can be seen that the extensometer movements on March 7<sup>th</sup> and April 13<sup>th</sup>, 2008 were strongly related to the rainfall occurrence.

## Discussion

Some lesson learned can be derived from this program that this real time landslide monitoring system can be a model for implementation at landslide prone rural community worldwide. Likewise, the early warning system of landslide should be based on the involvement of community participation. Therefore, both technical skill and communication skill are the main requirements to achieve the success of early warning system program. The system should include some technical aspect such as the geological surveys and site selection, development of equipment design which is simple (low cost) but effective, determination of early warning levels, installment and operation/maintenance at the field site, as well as include the social aspect such as social mapping and evaluation, public consultation and dissemination of program, community empowerment (including the technical training and evacuation drill) for landslide hazard preparedness and operational system of the early warning. Moreover, the communication with all stake-holders such as local, regional and national authorities, local leaders, local youth communities, and local non government organization should be established and maintained. The role of scientist or researcher is more like to be the motivator and facilitator, instead of the instructor or manager of program.

## References

- Fathani TF and Karnawati D (2007) Community-based early warning system at Central Java and East Java Province Indonesia, EWS Project - Final Report.
- Karnawati D and Fathani TF (2008) Mechanism of earthquake induced landslides in Yogyakarta Province Indonesia, *The Yogyakarta Earthquake*, Star Publishing, California pp 8-1–8-8.
- Karnawati D, Ibriam I, Anderson MG, Holcombe EA, Mummery GT, Renaud JP, and Wang Y (2005) An initial approach to identifying slope sStability controls in Southern Java and to providing community-based landslide warning information, *Landslide Hazard and Risk*, Ed; John Wiley & Sons, pp 733–763.
- Rokhmana CA (2007) The low cost monitoring system for landslide and volcano with digital photogrammetry, *Proc. Joint Convention HAGI-IAGI-IATMI*, Bali.