PROCEEDING OF
International Symposium
and The 2nd AUN/Seed-Net
Regional Conference
on Geo-Disaster Mitigation in ASEAN
FEBRUARY 25-26, 2010
BALI, INDONESIA

PROTECTING LIFE FROM GEO-DISASTER AND ENVIRONMENTAL HAZARDS

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Wahyu Wilopo
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The International Symposium and 2nd AUN/Seed-Net Regional Conference on Geo-Disaster Mitigation in ASEAN is done on 25-26 February 2010 at Bali, Indonesia, with a selected theme “Protecting Life From Geo-Disaster and Environmental Hazards”. This event is organized by the Department of Geological Engineering, Faculty of Engineering, Gadjah Mada University in cooperation with the ASEAN Foundation, and AUN/Seed-Net JICA.

The symposium is feature oral and poster presentations, in which conference participants are share their experience on geo-disaster and environmental hazards mitigation including hazard assessment, prediction, reduction of risk and the development of early warning system. In this proceeding, various issues are being analyzed and review, including earthquakes, tsunamis, flooding, typhoons, volcanoes, landslides, disaster mitigation and policies, and groundwater contaminations.

We are indeed most grateful to the conference participants, all of whom promptly send their papers. Without their active collaboration and support, this proceeding simply would not possible. We would also like to express our very special appreciation to all members of organizer committee and organizations, for their support and effort to make this conference successful.

Dr. Doni Prakasa Eka Putra & Dr. Wahyu Wilopo
Editors
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Development of landslide early warning system by online GPS in Central Java, Indonesia

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ABSTRACT

Lack of landslide early warning in a vulnerable area has seriously resulted in poor awareness and preparedness for landslide disasters, and accordingly brings to the increasing numbers of casualties. Therefore this research was conducted with the main purpose to develop landslide monitoring and early warning system which is supported by online GPS (Global Positioning System) and community empowerment in Tengklik Village, Tawangmangu District, Karanganyar Region, Central Java Province. Indeed, this study is very important to support policy decisions related to the early warning to landslide hazards in the community of the village.

Integrated discipline of study is the approach of this research, which includes the study on engineering: geology and geotechnics (civil engineering) to conduct landslide hazard mapping for site selection of early warning installment and understanding the mechanism of landslide that should be monitored. This understanding is important for further development of the design of the appropriate early warning system. Accordingly, the integrated study of geodetic engineering and electrical engineering are responsible for developing the online GPS system which is connected to a website. In line with this integrated study, social mapping for identifying community perception and aspiration were conducted in order to develop an appropriate approach and method to motivate and empower the community living in the installed early warning site, and thus the effectiveness of the operation and maintenance of such system.

Finally, this study has been succeeded to produce a monitoring system to detect ground movement landslides using Internet-based GPS (Online GPS) with a relatively low cost by using the OEM GPS L1. The developed system was built using Matlab Web Server for processing GPS data which was supported by some web programming language. Indeed, the system has been able to indicate the movement of the GPS position on the field and showing landslide risk indicators (green, yellow, red level of warning) graphically for use in a landslide early warning. Obviously, this online GPS system offers such an easy monitoring system in disaster prone areas. The system is equipped with automation facilities of disaster notification and is expected to assist the decision making process for early warning with respect to the landslide disaster risk reduction efforts.

Keywords: Landslide disaster early warning, GSM, GPS, L1, community-empowerment, landslide disaster risk reduction.

INTRODUCTION

Many urban and rural areas in Indonesia are prone to landslide disasters. Lack of landslide early warning in a vulnerable area has seriously resulted in poor awareness and preparedness for landslide disasters, and accordingly brings to the increasing numbers of casualties. This paper aims to present an interdisciplinary research progress undertaken at Faculty of Engineering, Gadjah Mada University involving Department of Geodetic Engineering, Department of Geological Engineering, Department of Electrical Engineering, and Department of Civil and Environmental Engineering in developing a landslide early warning system using GPS (Global Positioning System) sensors and in enhancing community empowerment in Tengklik.
Village, Tawangmangu District, Karanganyar Region, Central Java Province (Figure 1).

The main purpose of the development of GPS sensors for landslide monitoring is to improve effectiveness of landslide monitoring using geotechnical sensors including extensometers and tilt meters (Fathani et al 2008, Fathani 2008). GPS sensors have abilities to provide landslide vectors (magnitude and direction of landslides) on the field, thus provide useful information for positioning extensometers on the field. In this study, GPS L1 sensors are utilized to provide data for online monitoring system for landslide early warning.

GEOLOGICAL AND LANDSLIDE CONDITIONS

Karnawati et al (2009a) reported that more than 30% of the region in this regency is susceptible for landslide with various hazard levels, i.e. from moderate to very high (Figure 1). The levels of landslide hazard in this region are mainly controlled by the slope steepness, the loose formation of soils/rocks and also by the inducement of accumulative heavy rainfall as well as the human interfere. The steep slopes (exceeding 50°) covered by thick colluvial deposits or by thick soil (exceeding 4 meters) which was weathered from andesitic breccias, are the most susceptible ones for landsliding. It is also important that the rainfall accumulation for several hours up to several days, which exceeds 100 mm (with the annual rain precipitation exceeding 3000 mm), identified as the triggering process. This is the reason why the distribution of the zone with very high level of landslide hazard is strongly controlled by the distribution of the annual rain precipitation as illustrated in Figure 1. In addition, landuse changing and human interfere such as by uncontrolled slope cutting and deforestation, has also become serious inducement of landslides in this region.

Figure 1: Rain-induced landslide hazard level investigated by Karnawati, et al (2009a), and the location of the installment area of landslide early warning system.
Tengklik Village at Tawangmangu District, in Karanganyar Regency has been selected as the pilot study area (Figure 1). This village is situated at the middle part of western slope of Lawu Volcano, in which the lithology is dominated by colluvial deposits of tuffaceous sand-clay overlying the andesitic breccia. Based on the field investigation and by referring to the landslide classification suggested by Cruden and Varnes (1996), the landslide occurred can be classified as earth slide but with the slow rate mechanism (creeping) as illustrated in Figure 2. This slow rate mechanism is controlled by the relatively gentle slope condition, which is performed by the slope inclination only about 15° up to 20°. It is also suspected that the clay content in the colluvial deposits affect the sensitivity of the slope to slowly move, despite the gentle conditions of the slope. However, more detailed investigation on this soil or clay sensitivity is required.

Karnawati, et al (2009c) reported that since the rainy season in December 2008, this creeping has been resulting in land deformation, such as the land subsidence up to 3 m depth, and some cracks at the land surface which continues up to the depth of 2 m (Figure 3). Such deformation zone has been exceeding up to the area of 50 ha, and accordingly several houses has been damaged. This land movement and deformation continue up to the recent rainy season in 2010, but have not yet reached to the state of rapid movement (rapid landsliding), and this is the important reason for having online slope movement monitoring in this particular site.

WEB-BASED LANDSLIDE MONITORING USING GPS SENSORS

The system is designed to provide periodical report related to landslide disaster potential based on GPS observation sent to the server. For this purpose, two OEM (Original Equipment Manufacturer) GPS L1 sensors were used on the vulnerable area and one GPS L1 sensor was designed to be used as a benchmarking station and to be located on the more stable site. The data gathered from the sensors then processed to provide warning related to ground movement on the field. Figure 4 provides the technical design of the system.

In principal, there are two sub systems of the web-based landslide monitoring have been successfully developed according to the design presented in Figure 4:

1. Data transfer system,

2. GPS data processing and graph visualization.

DATA TRANSFER

To transfer GPS data from the field to the server, the system makes use of GSM (Global Systems for Mobile Communications) network. GSM was chosen as it requires low cost and has reliability to be deployed on the research area. A GSM-based low-cost communication system has been developed. For monitoring geographic phenomena on the field, the communication system allows extensometers, rain gauge, and GPS sensors to send data measurements to the server via SMS (Short Message Services). For this purpose, the sensors are connected to the system through RS-232 ports. The designed communication system is presented in Figure 5. It consist of two main parts: master station and field station

An interruptible battery backup power supply is used in the system. It has abilities to support the system running up to two weeks. As the power needs to be charged, community members in the village can charge the device. This approach is chosen as electricity is available in the village near by the research location and community members are designed as the manager of the device (see next section). For vulnerable sites that have no electricity networks, solar power supply may be used.

GPS DATA PROCESSING AND GRAPH VISUALIZATION

This research develops a system that enables to gather periodic GPS measurements of low-cost GPS (capable of receiving the L1 signal) from the field to be processed for providing landslide early warning. Low-cost GPS devices have been proven to be useful to help monitor ground movement (Aguado et al. 2006; Gasser et al. 2002). Single positioning of each GPS device is gathered periodically (i.e. every 15 minutes) and stored as GPS measurements databases. The collected observation data is then assessed to detect any ground movements by measuring change vectors. The vectors can be obtained by comparing the series of position observations. The vectors are assumed to have significant value to provide initial data on the direction and magnitude of the movements.

The monitoring program was developed as a web application that makes use of GPS measurements databases stored in the server. First, the monitoring program produces the change vector of observation data series. In so doing, it took
into account the predefined coordinate of GPS stations in the field and compared the incoming coordinate values against the predefined coordinates. Subsequently, it continues to calculate the 3D vector at any observation epoch by comparing the incoming observation against the previous ones. It calculates the 3D vector as:

$$|R| = \sqrt{(\phi_1 - \phi_0)^2 + (\lambda_1 - \lambda_0)^2 + (h_1 - h_0)^2}$$  (1)

where,

$|R|$ = 3D vector at observation $i$

$\phi_1, \lambda_1, h_1$ = Incoming coordinates at observation $i$

$\phi_0, \lambda_0, h_0$ = Predefined coordinates

As the value of 3D vector gained, the next step the program does is to provide graph visualization of the vector value against time observation. Threshold values were defined and drawn as green, yellow and red lines indicating warning levels from prepared, alert, and danger. The green level ("prepared") has threshold of 20 cm (20 cm within 10 hours), 30 cm for yellow level ("alert"), and 40 cm for red level ("danger"). The threshold values are based on assumptions from geotechnical investigation and previous landslide events on the area. The GPS processing and graph visualization were done according to routine programs presented in Figure 6.

Figure 2: Schematic diagram of landslide model at the study area.

These positions were situated at the same level

Figure 3: Land subsidence up to 3 m depth (left) and surface cracking up to the depth of 2 m (right) have destroyed houses and main road at the village (Karnawati, et al, 2009c).
Figure 4: The technical design of the landslide early warning system.

Figure 5: The designed communication system for landslide monitoring.
The GPS sensors used were Garmin OEM 18x devices. Two devices were designed to be located on the vulnerable sites to help detecting landslide direction and magnitude for further investigation and dealings. At the moment, the GPS data used was only NMEA (National Marine Electronics Association) format, so only vector measurements from absolute data positioning was resolved.

**COMMUNITY-BASED LANDSLIDE DISASTER RISK REDUCTION**

This research also addresses the importance of community empowerment for landslide disaster risks reduction as suggested by Andayani, et al (2008) and Karnawati et al (2008, 2009a and 2009b). For that reason, the activity to establish a community task force was also undertaken, in order to ensure the effective warning provided by the landslide detection devices. Indeed, the community involvement is crucial for ensuring the sustainability of this warning system. The process for developing the community-task force for maintaining the respective warning system has been reported in Karnawati et al (2009c), and those include:

1. social survey through interviews and questionnaire to gain community perception and understanding on landslide disaster risks and community capacity to cope with the risks,
2. focus group discussion on the use and maintenance of landslide monitoring system.

It is interesting that such activities were carried out through a Student Community Service (KKN) program for community-based disaster risk mitigation that was supported by Gadjah Mada University in coordination with the local Government of Karanganyar.

From the investigation done it is clear that community-based landslide monitoring is feasible to be installed on the field. Community involvement in maintaining landslide early warning system must be simple, user-friendly, and related to their need to cope with landslide disaster risk. The design of the community involvement on the monitoring system is given in Figure 7.

The mechanism to develop community capacity to reduce landslide disaster risk were divided into four stages: community resilience development, preparation, coordination, and evacuation, which can be proceeded as an iterative and backward or forward mechanism.

1. **Community Resilience Development**

In developing community resilience, through Community Services assistances, community leaders at neighborhood levels (i.e. sub-village, Rukun Warga (RW) and Rukun Tetangga (RT)) initiate Community Communication Forum, which consist of community members that have capacity and abilities to get involved as core teams in community-based landslide disaster risk reduction team. Through the Community-
Communication Forum, the team discuss and share strategies to develop preparedness and coordination in anticipating landslides. One of the issues to be resolved is their awareness and willingness to voluntarily maintain and make use of an early warning system. For example, they need to check the battery status, the GSM connection, etc. For this reason, they gain assistance from students involved in Community Services. In order to provide good understanding on the characteristics and risks caused by landslide disasters, socialization activities targeted to a wider audience of community members were also done. In this stage, training on the team to respond to the warning notification needs also to be done. Scenarios for green, yellow, and red warnings and their consequences (including possibilities of false warnings) must be understood for the community leaders. For this reason, the community needs to develop a simple protocol on how to deal with warnings.

![Diagram of stages required to develop community resilience for reducing landslide disaster risk.](image)

**Figure 7. Schematic view of stages required to develop community resilience for reducing landslide disaster risk.**

2. Preparation

As the Communication Forum and socialization activities have been successfully done, evacuation simulation was also done to raise their awareness and improve their preparedness. Before and after the simulation, community members can do self-evaluation which aspects and what resources need to be improved and whether after the evacuation their preparedness can be enhanced. Another activity in the preparation stage is to develop a community induced evacuation plan facilitated by students involved in Community Services.

3. Coordination

Once the landslide early warning system is deployed and working properly, on specific circumstances especially when warning is leveled higher, the community needs to have a good coordination with local agencies, for example District and Village officials and Agency for Community Protection that is responsible for disaster responses.

4. Evacuation

When ground movements happen and warning indicator is becoming red, then real evacuation shall be executed to community members and villagers who are in danger.

**RESULTS**

**GPS-Based Landslide Monitoring**

The system that consists of communication system and GPS data processing and graph visualization has been developed successfully. The data sent to the server through SMS messages then stored as tables in the measurement databases (other sensor data can also stored in the databases). The data sent from the server also include battery health status report. Figure 8 shows the communication system developed while Figure 9 shows the data received as rows in the databases to be processed for measuring 3D vector of ground movement in the field.

The data is then used to measure 3D vector change, subsequently the result is processed using AJAX (Asynchronous Javascript and XML) technology to display the graph visualization using PHP web page. For this purpose, the application makes use of MATLAB and MATLAB server to measure the vector and display the graph on the web.

**Community-Based Landslide Risk Reduction**

Integrated discipline of study is the approach of this research, which includes the study on engineering geology and geotechnics (civil engineering) to conduct landslide hazard mapping for site selection of early warning installment and understanding the mechanism of landslide that should be monitored. This understanding is important for further development of the design of the appropriate
early warning system. Accordingly the integrated study of geodetic engineering and electrical engineering has been done to develop early GPS online system which is connected to website.

In line with this integrated study, social mapping for identifying community perception and aspiration were conducted. The results from the study provide useful foundation to build the Communication Forum within the community that is essential to motivate and empower the community living in the installed early warning site. In this setting, informed decision on warning can be gained as community provide local knowledge based on their experiences living in vulnerable sites in dealing with indicators leading to landslide disasters as well as cause and effects of landslide events. Through the dialogue during the research period community not only gain new information on landslide disaster risks but also they have opportunity to share their aspiration and local knowledge that is important for defining levels of warning including the threshold values.

The four stages of community preparedness were well recognized by the community's Communication Forum and implemented through Community Services' activities. Some tangible outcomes include agreements and coordination with local agencies to do landslide evacuation simulation and the developed community-based evacuation map. In relation to this, the effectiveness of the operation and maintenance of the landslide early warning system can also be assured to be sustainable.

Figure 10 exemplify the visualization of graph representing vector changes for each 15 minutes on top of warning level lines (green, yellow, red levels).

CONCLUSION
This research study has successfully delivered two outcomes: low cost GPS-based landslide early warning system intended to provide initial data for further investigation on landslides and secondly, a community-based landslide disaster risk reduction activities to enable community resilience and community involvement in operating and maintaining the early warning system.

Figure 8. GSM-based communication system unit developed for sending measurement data to the server.
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<th>data_nmea</th>
</tr>
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<td>7</td>
<td>$GPGGA,012052,0745.6742,S,11022.9826,E,1,08,1,1,17...</td>
</tr>
</tbody>
</table>

Figure 9: Observation data sent to the server and managed as MySQL databases.

Figure 10: Ground movement is monitored through online landslide detection system.

The early warning system is set as a web application making use of GSM network. The GPS sensors used are low cost GPS L1 type OEM (Garmin 18x) that is installed into the communication system unit located in the field. On the server side, there are two main programs working out to provide ground movement information: GPS data transmission and storage and GPS data measurement and graph visualization. Although the system is working well, the system is unable to provide position information with sm up to dm accuracies due to its current limitation on the use of NMEA format only. The RINEX format was planned to be processed as well but the communication system at the moment has limitation to provide power supply and to accommodate mini computer to convert Garmin Binary Format into RINEX format. Thus the plan to provide double differencing solution for each measurement before processed as the graph has not been achieved. This drawback motivates us to further improve the prototype system developed. In addition, the integration of GPS data and other sensor data for improved and more accurate warning decision will be also our next research focus.

The study has also been successfully developing a Community Forum that is useful to improve
community resilience in anticipating landslide disaster risks and to maintain the system installed on the site. The community preparedness include community leaders and members’ abilities to act during four stages of preparedness i.e. resilience and awareness, preparation, coordination and evacuation stage.

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REFERENCES


