Socio-Technical Approach for Landslide Mitigation and Risk Reduction

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Abstract

This paper highlights the importance of integrating social and technical approaches (which is so called a "hybrid socio-technical approach") as one innovative and strategic program with respect to landslide disaster risk reduction. Such program mainly based on multi-disciplinary action-research to support the community empowerment program through public education. The technical approach was mainly conducted for geological and geotechnical investigation to analyse and predict susceptibility levels of the disaster prone area, as well as to develop an appropriate technology for hazard mapping and disaster early warning. Meanwhile, the social approach was necessary to be undertaken for analysing and mapping the psychosocial conditions of the disaster prone area, and accordingly an appropriate strategy and program to implement the produced technology can be formulated. Moreover, it is also important to establish a "community task force" as the driving power for landslide disaster risk reduction, which can sustain the program at the village level. This chapter describes the achievements and the current activities of IPL-165 "Development of community-based landslide hazard mapping for landslide risk reduction at the village scale in Java, Indonesia".

Keywords
Hybrid socio-technical system, indigenous technology, life and environmental protection, community empowerment

1. Introduction

Situated in such a dynamic geological region, which is occupied by high density of population, Indonesia is frequently struck by various types of geological disasters, which leads to substantial death tolls, casualties and socio-economical loss. According to the Indonesian National Agency for Disaster Management, Indonesia has been struck by 6,632 events of natural disasters (mainly geological disasters), within the period of 1997 to 2009, with the total death tolls of 151,277 people. Therefore, it is very urgent to develop appropriate geo-disaster mitigation for life protection and environmental sustainability, through the improvement of society resilient in such disaster prone area.

2. Socio-technical Challenges for Landslide Disaster Risk Reduction

Landslide is one of the most frequent disasters in Indonesia. Because of the geological conditions and the high rain precipitation, more than 50 % of Indonesian region is prone for this particular disaster. It is commonly found that the soil condition in this area is fertile with significant amount of water resources and the beautiful panorama to stay. That is why, most of the landslide prone areas have been developed as the villages or cities with high population density, such as in Java and Sumatera. As the results, the risk of landslide disasters seriously increases in response to the continuous growing of population and uncontrolled landuse changing. Indeed, it has been thousands of people died, several thousands of houses damages and thousand hectares of land buried due to landslide disasters. Accordingly, the improvement of community resilience in landslide prone area has become critical challenges that should be tackled through the implementation of appropriate approach, technology and capacity development program as suggested by Karnawati et al (2009), Anderson et al (2010 and 2011), and also Holcombe et al (2012), in order to ensure the human survivability and environmental sustainability.

The development of hazard map and the application of an appropriate technology for early warning system are considered as the crucial efforts to reduce the risk of landslide disasters. Unfortunately, the effectiveness in implementing hazard maps and an early warning system cannot be guaranteed due to less consideration on the social-cultural and socio-economical conditions at the disaster prone area. Accordingly, the needs to integrate social considerations into technical system should be addressed in order to assure the effectiveness in the implementation of such hazard map and early warning system for disaster risk reduction.

3. Hybrid Socio-technical Concept for Landslide Disaster Risk Reduction

To ensure the effectiveness in the implementation of any technology for disaster risk reduction, a combined (hybrid) system, which considers both social and technical conditions has been developed by Karnawati et al (2009 and 2011). Such approach mainly consists of the development of technical system for providing community landslide hazard/ risk map and early warning system, and also the social system for developing appropriate community empowerment program.

The technical system is recommended to address the development of the existing indigenous or local knowledge and technology, by considering the simplicity of such system and technology. Moreover, the utilization of the local material is promoted, by encouraging the local knowledge (local experts and local operators) to drive the local participation program. Indeed, it is important that the hybrid system should be performed with a low cost and simple technology, approach and method, so that it can be easily understood, reproduced, operated and maintained by the local community, such as suggested by Karnawati et al (2008, 2009 and 2011). This empowerment program relies on the public education, encouraging community participation in developing and implementing action plan for disaster mitigation and risk reduction. Schematic concept of this approach is illustrated in Fig 1.

All of this concept can be done only if the local community has been empowered. Therefore, process of technology development can be carried out during or as a part of the process of community empowerment.

4. Implementation of the Hybrid Socio-Technical System

A hybrid socio-technical system has been implemented in one pilot area in Central Java, especially in Karanganyar Regency. This Regency is situated at the western slope of Lawu Volcano, in which 30% of the region is highly risk for landslide due to the high susceptibility condition (indicated by red color in the map of Fig.2), which is controlled by the geology and climate conditions, and also because of the high vulnerability of the socio-economical conditions in the landslide prone area (Karnawati et al 2009 and 2011). Managing the social-conditions for reducing the socio-economical vulnerability in the landslide prone area is considered to be more feasible, instead of changing the natural conditions, such as the geology and climate. Thus, the landslide disaster risk reduction in the pilot study area was conducted by targeting the social conditions through the adaptive management as suggested by Andayani et al (2008), Karnawati et al (2009 and 2011), and also Halcombe et al(2012), which emphasized on the improvement of community resilience by implementing the ***hybrid socio- technical approach.***

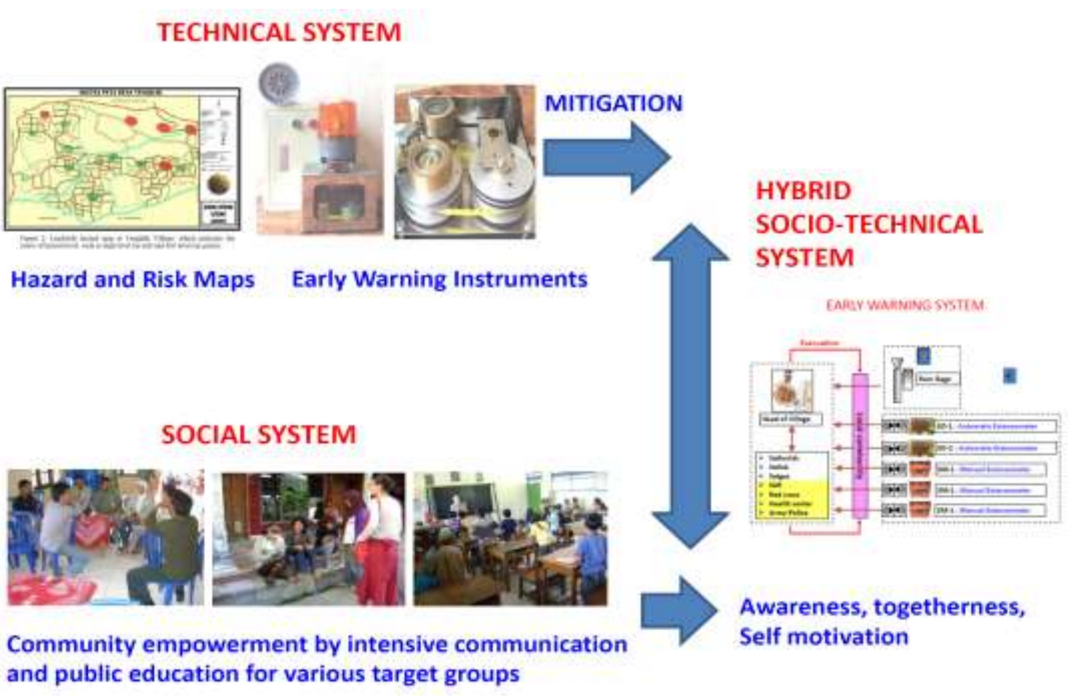

Fig. 1 The concept and key component of a hybrid socio-technical system for landslide mitigation and early warning system (Karnawati et al 2009 and 2011)

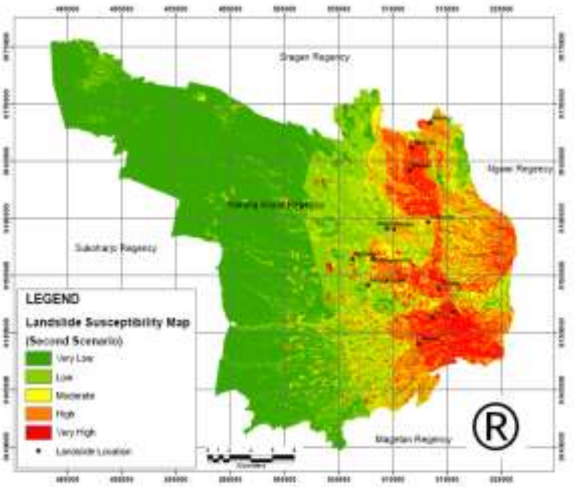

Fig. 2 Landslide susceptibility map of Karanganyar Regency, Central Java, Indonesia, developed in regional scale of 1:100,000 (Karnawati et al 2009 and 2011).

5. Development of Technical System

The technical system for landslide disaster risk reduction was developed by Karnawati et al (2009, 2011 and 2012), consisting of several technical components such as the instruments for landslide early warning system recommended by Fathani et al (2008) and also Fathani and Karnawati (2009), supported by the smart-grid for landslide hazard communication, monitoring and early warning developed by Karnawati et al (2012) as well as the community-based landslide hazard map suggested by Karnawati et al (2010).

5.1. Early warning instruments

The early warning instruments was designed by relying on the manual extensometers connected with the alarm generated by dry battery as illustrated in Fig.3a. Each of these instruments is facilitated with the automatically pull able wire installed across the progressive crack, so that the progress of crack development due to the slope movement can be monitored. The instalment of extensometers was also supported by the rain-gauge as illustrated in Fig.3b and solar panel; so two different stage of warning levels can be defined. The first threshold of warning was set-up by setting the ON alarm in response to the rain precipitation of 70 mm/hour or the accumulative rain precipitation of 100 mm, whilst the second threshold was defined when the extension of pull able wire reached the distance of 5 cm. The function of first alarm was used for raising the community alert, and the second alarm was set-up for starting the evacuation process in the landslide prone zone.

It was also crucial that all of the alarm warning instruments were also manually backed-up by a traditional tool "kentongan" made by bamboo or wood (Fig. 3b-right). Therefore, this mechanism of combining the developed early warning instruments and the traditional or local warning system allowed the larger spread of the warning sound. Admittedly, the numbers of early warning instruments are limited which were not sufficient to cover the large area of prone zone. Therefore, a smart grid for landslide early warning has been developed by Karnawati et al (2012).

Figure 3. Early warning instruments consisting of (a) the extensometer and (b-left) the rain gauge, which also manually linked to the traditional "kentongan" (b-right).

5.2. Smart grid for landslide hazard monitoring and early warning

Smart Grid is a participatory cyber-based communication and information system, developed as a system of handling networks of information nodes consisting of local experts, local surveyors, or selected members of local task force and the contact person in the local communities. The information is sent to the 'online' web or cyber system, with the specific functions to facilitate the participatory data reporting via the online web, mobile phone (text message), or other various social media, and also to store and analyse those participatory input-reports (related to the geological/ geotechnical conditions and process, which considered as the symptoms or early indications of landslides), for defining the landslide hazard and risk level in any particular site or zone.

Results of the analyses are required to provide the emergency-decision supports, which relate to the information of the zone and level of landslide hazard/ risk, evacuation route and shelter, and the recommendation of method or approach for mitigation, preparedness and emergency actions. All of the information about hazard/risk and the guidance for response will be blasted/ transmitted back to the respective-reporting node as well as to the other relevant registered nodes. This participatory system can also be connected to various types of social media (mobile phone call/text, Twitter, Facebook, Google+, Yahoo, etc.).

It is also important that the multi-two way direction facilitates the communication flow in this participatory smart grid system. Such system can also be linked to the existing community-based landslide early warning instruments developed in parallel with this smart grid system. Concept of the smart grid design is illustrated in Fig.4, whilst the example to the web performance of smart grid is displayed in Fig.5.

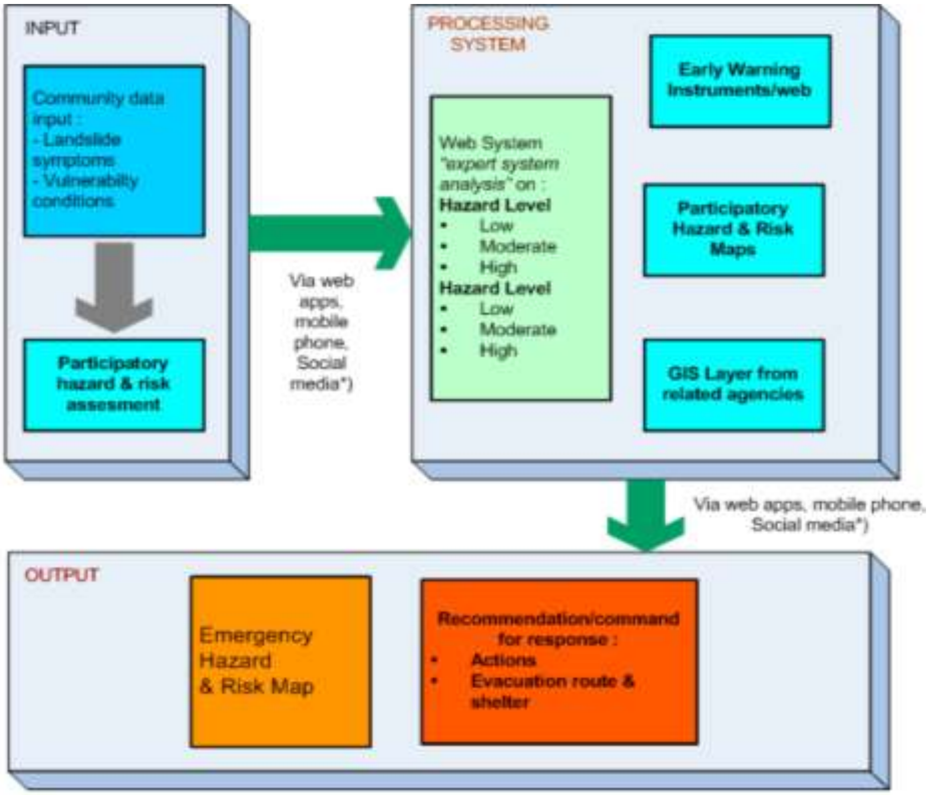

Fig.4 Concept of expert system in the smart grid design developed by Karnawati et al (2012).

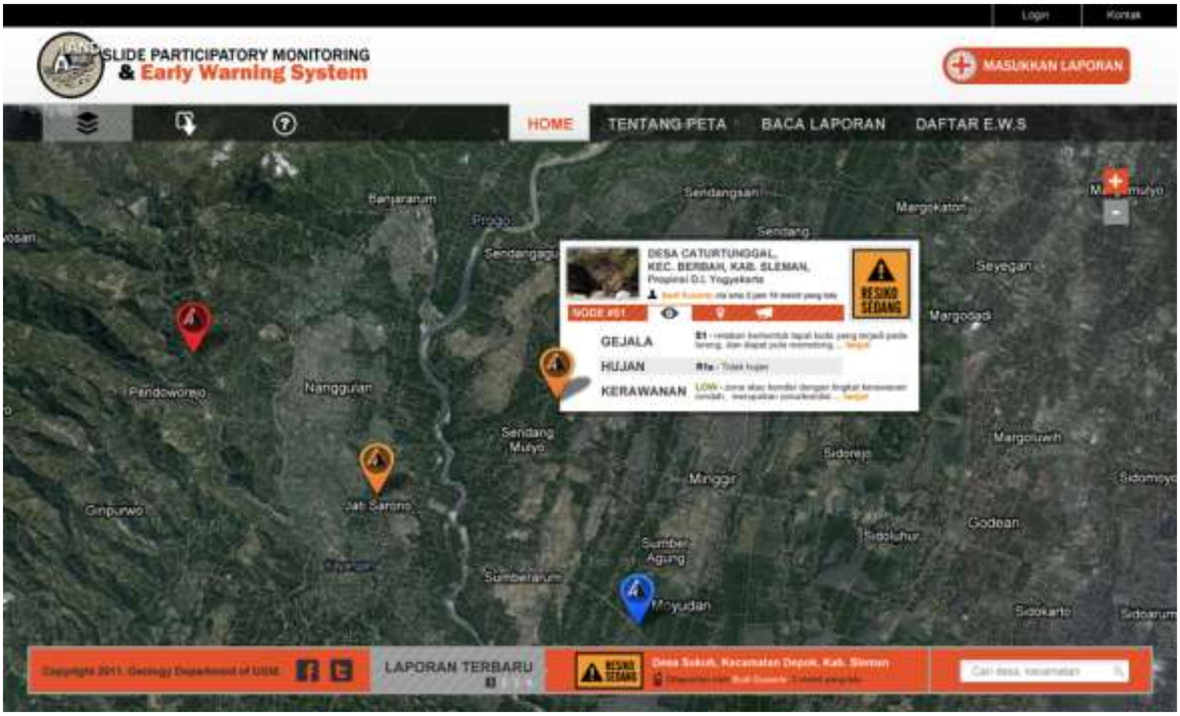

Fig. 5 Web performance showing the geographical position of the reporting nodes

5.3. Community-based hazard map

The understanding and simplicity of the approach and method of mapping is the most critical part to guarantee the effectiveness of disaster risk reduction program.

Unfortunately, it is apparent that most of the technical landslide hazard map was not easy to be understood by the local community. That is why a simple participatory hazard mapping method was developed by Karnawati et al 2010, to facilitate the community landslide hazard mapping, which also addressing the Landslide Risk Assessment and Mitigation Strategy suggested by Lacasse and Nadim (2008). Therefore, the standard technical method for landslide hazard mapping was simplified to prepare a simple landslide hazard map which can be conducted by the local community on the existing village base-map (i.e. the village "situation" map), through the participatory mechanism. Such map was presented without any contour, but mainly showing the layout of roads, rivers, houses and land farming areas which were very easy to be identified by the local community. Identification of the high susceptible zone (red zone) and low susceptible or safe zone (green zone) for landslides was carried out by the community task force through public participation, which is advised by the local expert. Fig. 6 shows the landslide hazard map and evacuation route which was develop by the local community in Koripan Village, Karanganyar Regency, Central Java.

This map is also very important to decide where the early warning instruments should be installed and how the evacuation route should be decided.

6. Development of Social System

Development of the social component in the hybrid system was initiated by social survey, to identify the existing knowledge about the landslide hazard, which will affect the community's perception about landslide risk and their expectation on the proposed developed

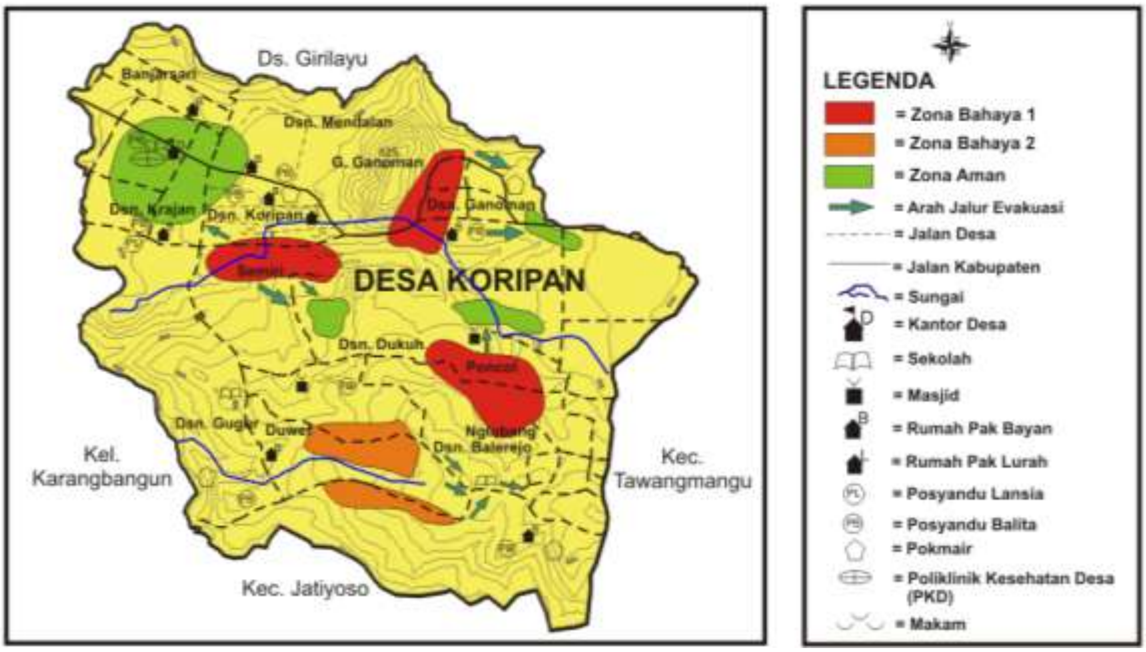

Fig. 6 Community-based landslide hazard map and evacuation route of Koripan Village, Karanganyar Regency, Central Java, indicating zones of hazard level (red is high level and green is low level).

technology for landslide disaster risk reduction. Identification on all of those aspects significantly control their motivation or willingness for actively participating in any disaster risk reduction program. Results of this social survey will be crucial to formulate the appropriate and effective strategy for public education related to the effort for raising the community awareness and also for conducting community empowerment program.

Various target groups were defined, and those comprise the group of women (as the key person in the family), teachers, children as well as the young and senior leaders. The local government of Karanganyar Regency also continuously and actively supported this social development program.

Results of the social survey indicated that most of the community members had been quite aware with the potential occurrence of landslides at the rainy season, because the landslide disasters have quite frequently struck their living area, especially under the heavy or long continuous rainfall. Nevertheless, most of the community members preferred to remain living in their vulnerable region, instead of being relocated to the other safer areas. Obviously, the fertility of soil, the abundance of water resources, the beauty of mountainous panorama and the strong psychological engagement with their homeland or home-heritage, strongly prevented their willingness to leave their dangerous homeland. Unfortunately, they did not have enough knowledge, skill and capacity to decide about “what should” and “what should not do” for preventing the landslide as well as for protecting their life and environment from the landslide occurrences. Eventhough, they had not yet been capable to identify the sites (slopes), which were susceptible for landsliding, and to recognize the initial symptoms of landsliding. Therefore, the hybrid socio-technical approach for community-based landslide early warning was applied to develop their capacity for implementing the appropriate landslide disaster risk reduction program, which will support the improvement of the community resiliency in this landslide prone area.

A community task-force for disaster risk reduction at the village level was also established under the coordination with the Agency for Disaster Management at the Regency level (Fig. 7). This network is also linked to the local hospital (health centre), the local army and police, and also the Search and Rescue Team (SAR team) at the local Regency. Indeed, this task force played an important role as the driving power for the disaster risk reduction program, and also to effectively implement and sustain the technical system for landslide risk reduction.

7. Discussion

It was apparent that the existence of a community task force for landslide disaster risk reduction at each village level was the most important factor to ensure the affectivity and sustainability of landslide mitigation and risk reduction program. This task force had an important role as the driving agent in the empowerment and mitigation program. In fact, since this proposed hybrid socio-technical approach implemented in several pilot areas in Karanganyar Regency, such as in Ledoksari Village in 2008, Tengklik Village in 2009, Matesih Village in 2010, Koripan Village 2010 and also Gempolan and Plosorejo Villages in 2011, the community resilience for landslide disasters has gradually increased, the socio-economical losses due to landslides can be minimised and the numbers of landslide victims have been dropped to zero. It seems that this approach could effectively empowered to local community to mitigate the landslides. Eventhough, the key person who is also the member of the community task force and was in charged for the mitigation program, was also invited to share their experiences in facilitating the community empowerment actions to tackle the landslide problems in another landslide disaster area in Tanjungsani Village at Agam Regency, West Sumatera.

Fig. 7 Activities to develop and empower the community task force at Tengklik Village which were facilitated by the student community service program conducted by UniversitasGadjahMada

Therefore, the Hybrid Socio-Technical approach is also very applicable to be developed in several other disasters area in developing countries, although several adjustments may be required to address the social and environmental characteristics at the specific site. Moreover, the importance of commitment and leadership of the local Agency for Disaster Management at the Regency and District levels to support the effectiveness of the disaster management program at the village must be highlighted.

It was also obvious that the socio-cultural and socio-economical constrains during the mitigation program can be minimized by implementing the hybrid socio-technical approach. Indeed, the introduction and implementation of a new technology for early warning and disaster management system can be conducted more effectively through the public participation actions. That is why more enthusiastic response of the local community and local authority to actively participate in the landslide disaster risk reduction program can be performed as illustrated in Fig. 7.

8. Conclusion

One of the most critical considerations on disaster risk reduction in Indonesia is the assurance for the effectiveness and sustainability of the disaster management program. It is apparent that the proposed model, which is so called as the combined (hybrid) socio-technical approach has been quite effective and strategic to improve the community resilience at the landslide vulnerable village. It is also crucial that the system should be developed through community participation and the provision of simple and low cost technology for landslide hazard mapping and early warning. Indeed, the establishment of community task force at the village level is very important to ensure the effectiveness, continuity and sustainability of this proposed system. This approach may also be applicable to tackle similar problems for landslide risk reduction in other developing countries in Asia.

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