EXPERIENCES FROM COST-EFFECTIVE INSTRUMENTATION FOR EARLY WARNING SYSTEMS INSTALLED IN SOME HOT-SPOT AREAS IN SOUTH AND SOUTH EAST ASIAN COUNTRIES

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ABSTRACT

The frequency and intensity of landslides in Asia have increased significantly over the past years causing extensive damages to life and property in the affected regions. A key triggering factor for many of the landslides has been extreme precipitation events. Rainfall threshold values vary from region to region due to differences in existing soil characteristics and climatological patterns in different areas. Therefore, a complete study of the rainfall patterns in landslide prone areas and their records of landslides are warranted. This will help predict reasonable threshold values of rainfall and use them as a tool for landslide forecasting. The Norwegian Geotechnical Institute (NGI), in cooperation with various mandated national institutions from Bangladesh, Bhutan, India, Vietnam and Sri Lanka, has installed cost effective instrumentation for landslide early warning systems (EWS) in order to monitor triggering conditions of rainfall-induced landslides. Although the appropriate implementation and operation of a landslide EWS is a complex task, the operation of the installed instruments has proved to be highly effective in limiting the damages to lives and properties especially in the densely populated areas of Bangladesh where scores of lives have been saved. This paper describes the cost effective method for early warning of rainfall-induced landslides in the above countries where instrumentation is performed for monitoring triggering conditions of rainfall-induced landslides.

1 INTRODUCTION

The most common natural landslide triggers for landslides include intense rainfall, rapid snowmelt, water-level change, volcanic eruption and earthquake shaking. Some examples with geological conditions that lead to susceptibility to landsliding caused by these triggers have been described by Turner and Schuster (1996). In addition to rainfall as the main triggering factor, increase in the occurrence of landslides has been associated with a combination of factors and several attributes such as geological, topographic, morphometric, climatic and anthropogenesis nature that directly or indirectly contribute to the phenomena of slope instability. Landslides are often triggered in areas with past landslide history and monitoring of the landslides using community-based approaches are proven to be highly effective. In most areas, development activities seem to be responsible for reactivation of dormant landslides. Hence, communities living in areas with landslide history should be warned in due time through constant monitoring and early warning of potential reactivation. In addition, slow moving slides on hill slopes need constant monitoring as many of developing countries in Asia cannot afford to undertake mitigation measures or to resettle people to safer areas after identification of the potential threat.

Several major studies have revealed a close relationship between rainfall intensity and activation of landslides. The rapid infiltration of rainfall, causing soil saturation and a temporary rise in pore-water pressure is generally believed to be the mechanism by which most shallow landslides are generated during intense rainfall e.g. during storms. With the advent of improved instrumentation and electronic monitoring devices, transient elevated pore pressures have been measured in hillside soils and shallow bedrock during rainstorms associated with abundant shallow landsliding. Loose or weak soils are especially prone to landslides triggered by intense rainfall.
2 DESIGN AND IMPLEMENTATION OF COST EFFECTIVE EARLY WARNING SYSTEMS

Hundreds of people are killed each year by landslides and debris flows in the Asian Region. These recurring events are therefore a serious threat to life, welfare and local economy of the communities residing in the hilly regions, which are prone to landslides.

The appropriate implementation and operation of a landslide EWS is a complex task and only few examples can be found worldwide. Probably the earliest landslide EWS was developed in the San Francisco Bay region (USA) in the mid-1980s and consisted of a real-time network of rain gauges, precipitation forecasts, and relations between rainfall and landslide initiation to define the alert level (Keefer et al., 1987). The relation between rainfall and landslide occurrence, or in more general terms, the understanding when, why, and how large landslides occur is an important basis for an early warning system (EWS). A EWS comprises of four main activities: monitoring, analysis of data and forecasting, warning and response. A block diagram of a typical EWS is shown in Fig. 1.

![Block diagram of a typical EWS](image)

2.1 Regional and global precipitation thresholds

Depending on the available classes of meteorological events, thresholds can be estimated as follows, (see Fig. 2) according to Cepeda and Devoli (2008):

- Only occurrences of landslides: the threshold is a lower bound to the meteorological events. See Figure 2a. Examples: Crosta (1998) and Guzzetti et al. (2007).
- Only non-occurrences of landslides: the threshold is an upper bound to the meteorological events. See Figure 2b.
- Both, occurrence and non-occurrences of landslides: in this case, the threshold is a boundary separating the two classes. See Figure 2c.

From Figure 2, it can be noted that a threshold may not classify correctly all the meteorological events. Events with observed landslides (“+” in Figure 2) and located below the threshold are missed events, while events with no landslides (“-“ in Figure 2) and above the threshold are false alarms. One of the main challenges in the estimation of thresholds is to achieve an optimum performance such that both missed events and false alarms...
are minimized as much as practical operational conditions allow (i.e., in the framework of an early-warning system).

Figure 2. Types of thresholds based on the available classes of meteorological events: (a) Only landslide occurrences available; (b) only non-occurrences available; (c) both occurrences and non-occurrences are available. For simplicity, a threshold based only on two meteorological elements (ME) is shown. The proportion of “landslide” events in relation to “no landslides” events is usually very small and does not correspond to the proportion shown in (c), which is presented for illustration purposes only. Adapted from Cepeda and Devoli (2008)

3 INSTALLED INSTRUMENTATION FOR EARLY WARNING IN ASIA

The NGI installed instruments for early warning of rainfall-induced landslides comprises of the following components:

• A tipping bucket rain gauge
• An instrument enclosure with solar panel comprising:
• Omni Text – TDP4 GSM logging and alarm unit
• Solar charge controller
• Battery

Figures 3A-D show the various components of the installed rainfall warning system in Bangladesh. The whole system costs around USD 1500. The EWS instrument has the capacity to send alarm messages (via SMS) to up to 10 registered mobile users whose numbers have been programmed in the system. If the rainfall threshold values, (previously set up in the system) are exceeded, the early warnings are sent automatically. In addition, the users can also request status messages, change users and change all other programmable options such as threshold values. Details concerning the system are described in an NGI report (NGI, 2016). In Bangladesh, the fatalities due to landslides in Cox's Bazar, Chittagong and Teknaf area have been significantly reduced after the installation of automatic rain gauges at the sites (Ali and Khan 2014, The Daily Star 2015, Prothom Alo Bangladesh, 2015). Recently, Cepeda (2018) has carried out a preliminary assessment of rainfall thresholds in the Badulla district of Sri Lanka. According to the results, the following generalized threshold has been calibrated for this district:

\[
\text{Rain}_{24h} = 138.5 - 0.2357 \times A_{20d}
\]

Where: \( A_{20d} \) is the antecedent and cumulative 20-day rainfall in mm.

\( \text{Rain}_{24h} \) is the triggering 24-hour rainfall, in mm.

This threshold can be used as a component of an early-warning system as follows:
1. Calculate 20-day precipitation before today using observations from a station.
2. Estimate threshold value using the above equation for \( \text{Rain}_{24h} \) threshold
3. Estimate forecast for the next 24 h, \( \text{Rain}_{24h} \) and compare with \( \text{Rain}_{24h} \) threshold
4. If \( \text{Rain}_{24h} < \text{Rain}_{24h} \) threshold, no warning is issued.
5. If \( \text{Rain}_{24h} < \text{Rain}_{24h} \) threshold, issue of a warning level depending on how far the forecasted value is from the threshold value.
6. If \( \text{Rain}_{24h} \geq \text{Rain}_{24h} \) threshold, a warning level must be issued, but the acute level of the response depends on how far the forecast is from the threshold value.
7. The number and position of the warning levels, both below and above the threshold can be set based on a back-analysis of historical landslides in the region.

REFERENCES
h. NGI report (2016), NBRO-NGI Automatic rainfall station, operation and maintenance manual, prepared by Lloyd Tunbridge, NGI report, June 2016