Introduction to local landslide early warning systems

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An introductory guide to local rainfall-triggered landslide early warning systems. This guide includes an overview of monitoring and warning methods, the role of community engagement, and challenges to local landslide early warning systems.

Overview

The Science for Humanitarian Emergencies and Resilience (SHEAR) programme supports world-leading research to enhance the quality, availability and use of risk and forecast information.

This snapshot provides an introduction to Local Landslide Early Warning Systems.

Further information can be found in the two accompanying SHEAR publications: Introduction to landslide early warning systems and Introduction to regional landslide early warning systems.

Summary

- Local landslide early warning systems (LEWSs) monitor a **specific slope** that has been pre-identified as being at risk of failure.
- Changes in slope conditions are **monitored using instruments** to measure the movement of slope materials and/or a proxy for pore water pressure. Often a range of monitoring sensors are used.
- Models are used to link past landslide observations or slope movement with these site-specific conditions to understand the relationship between certain conditions and the likelihood of a landslide occurring, termed as a **threshold** relationship.
- **Warnings are issued locally** when this threshold is passed, i.e. when there is a significant change in the monitored conditions over time which is linked with a greater chance of a landslide occurring.
- Local LEWSs can only provide warning information for the specific instrumented locations (e.g. for a single landslide, for a single hillslopes). **They cannot provide information, forecasts or warnings outside the instrumented area**.
- The landslide forecast information is often **easily interpreted** and can generate an **automatic** warning to the local community or a mandated person to disseminate the warning more widely.
- Typical **responses** include evacuating to pre-identified safe location(s) and closing off roads.
- Best practice of local LEWSs emphasise the **involvement of local communities**, including community awareness, engagement, risk knowledge training, and local early action (e.g. evacuation).

Pore water pressure refers to the pressure of water held within soil or rock, in gaps between particles (pores). When the gaps between particles are filled with water (the pore water pressure changes), the friction and forces acting on the slope change and the slope becomes increasingly unstable and more likely to fail.

Calibration of the forecast model requires detailed local data and knowledge so that the relationship between monitored conditions and warning levels are specifically tailored to the individual slope.

Methods of monitoring

Monitoring methods are typically divided into two main approaches: monitoring proxy indicators of hydrological conditions, or monitoring slope movement. Often multiple monitoring methods are used on a single slope.

Monitoring **hydrological** proxy conditions as an indicator of **pore water pressure** can include using:

- Rain gauges for measuring rainfall.
- Hydraulic sensors to monitor pore pressure, soil moisture content and other factors.

Monitoring **slope movement** as an indicator of change can include using:

- Inclinometers to determine the magnitude, rate, direction, depth, and type of landslide movement.
- Extensometers to determine the active boundaries of the landslide (on the surface and at depth), correlate landslide movements to external environmental factors (e.g., precipitation events), and for early warning of accelerating landslide behaviour. They can be manual or automatic (paper or digital recorders).
- Wooden or metal stakes, posts, battens, or pegs driven into the ground and manually monitored regularly for signs of movement or changes to rate of movement.
- GPS sensors to measure relative movement.
- Remote sensing technology or imagery to compare changes to or movement of the slope over time.

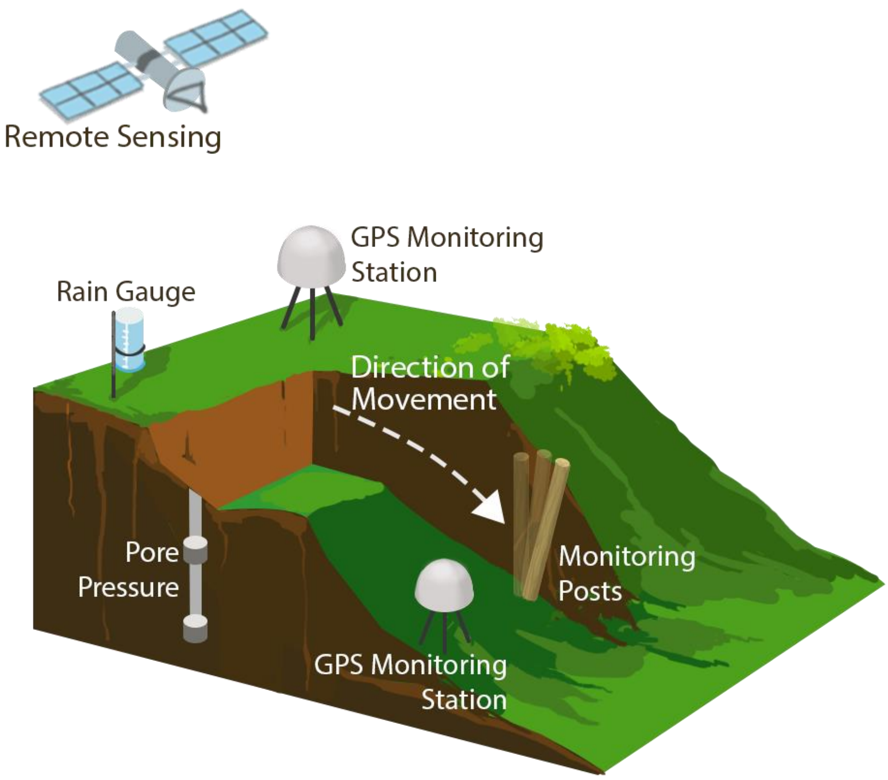

Figure 1. Examples of monitoring methods for local landslide early warning systems.

Examples of warning alerts include:

A flashing light or beeping sound at the central server or operations base.

A daily bulletin and/or an alert SMS are sent to the concerned authorities and experts. In parallel, local people at risk from the landslide are informed via alarms.

At the highest warning level, the local at-risk population are alerted through loud speakers or sirens and asked to evacuate the vulnerable locations and requested to move to safer places.

Task force teams receive alerts and coordinate the overall process of response, early action or further dissemination.

Warning messages are sent to the local bulletin board.

Landslide warning

Local LEWSs can only provide warning information for the activity on specific instrumented locations (e.g. for a single landslide, for a single hillslopes). **They cannot provide information, forecasts or warnings outside the instrumented area.**

Local LEWSs provide **very little warning lead time**, from seconds to minutes, to hours.

Warning levels are typically assigned **automatically** when a pre-determined threshold of monitored conditions passes a certain level, such as a change in the rate of displacement of slope materials, or pore water pressure. Sometimes there are **manual** processes such as opportunities for expert judgement or assessment as well.

For automated systems, data is often transmitted automatically from sensors to a central warning facility or device, and some sensors can contain specific software and automated procedures for both pre- and post-processing of data.

Once a warning threshold level is passed, **alerts** can be sent automatically to key groups, or for public dissemination.

Early action

Early action refers to actions taken in response to the warning information, rather than after the landslide event.

Early action examples include:

- Evacuation of the community to a pre-identified safe location (particularly overnight);
- Closing schools and meeting places; and
- Closing off access to roads and/or rail routes.

Working with the community

In particular, local LEWSs require high levels of community engagement to be effective. Most local LEWS projects include components to focus on this engagement.

Examples of these strategies include:

- Developing community-based **awareness** and **educational** programs about landslides and the early warning system;
- Setting up local, accessible **public communication systems** such as sign boards to facilitate warning and evacuation systems;
- Setting up local **committees and volunteers** and equipping them with knowledge and skills to monitor slopes and communicate warnings;
- Incorporating **local knowledge and skills** into plans;
- Establishing **safe evacuation routes and locations** with the communities;
- Co-developing **preparedness plans**; and
- Conducting **drills to practice** the evacuation process.

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Strengths, limitations and challenges of LEWSs

Strengths:

- They provide locally-relevant warnings to **communities** at risk.
- Forecast information can be **interpreted easily** and it is possible to generate **automatic** warnings.
- Local LEWSs can support **awareness** and interest in landslide risk reduction, engaging the community in hazard mapping and hydro-meteorological data collection, which can be an entry point for longer term risk reduction practices
- There is **community ownership**. Threshold levels can be adjusted as per the communities' requirements.

Limitations:

- **Not applicable to other slopes** beyond the one(s) being intensely monitored.
- Forecast model calibration requires detailed local data and knowledge - it is a very **resource intensive** approach for one slope.
- It is hard to tell when hazard levels have **reduced to a safe level** for people to return to their homes.
- There can be range of **other factors** that might complicate the relationship between monitoring data and landslide occurrences.
- Warnings based on the actual ground movement might not provide sufficient **lead time** to act in advance of a sudden failure.

Challenges:

- **Sustainability of the system**

  Many local LEWSs are set up as pilots by research or development funding. The only way to sustain the system beyond the pilot is for it to be funded and owned long-term by e.g. local government institutions.

- **Forecasting skill**

  The accuracy of the warnings is variable based on the methods used for monitoring. Evaluation of the performance of different approaches to monitoring outlined in this snapshot is currently not known.

- **Not scalable**

  Local LEWSs can only provide warning information for the specific slope it is monitoring. Warnings cannot be applied to un-monitored slopes. Scaling up the system requires monitoring of all slopes. Monitoring all slopes at risk of landslides in mountainous regions is not a feasible approach due to the resource intensity required.

Further reading

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