Science for Humanitarian Emergencies & Resilience
SHEAR

July 29, 2022

Introduction to regional landslide early warning systems

Authors:

SHEAR Knowledge Brokers Team

An introductory guide to regional early warning systems for rainfall-triggered landslides. This guide includes an overview of data used, institutional roles, and dissemination and communication approaches.

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 a rapid introduction to regional Landslide Early Warning Systems.

Further information can be found in SHEAR's Introduction to landslide early warning systems and Introduction to local landslide early warning systems.

Summary

- Regional landslide early warning systems (LEWSs) deal with the possible occurrence of **multiple landslides** in a wide geographical area; some regional LEWSs cover national, regional, or municipal areas.
- Regional forecasts rely on historical observations and continuous monitoring of **rainfall** and **landslide** events.
- Regional approaches can provide different types of forecasts with different **lead times**, depending on the rainfall data used. Typically the systems that use rainfall forecasts provide a range of 24-72 hour warnings to 2 week alerts.
- The majority of regional LEWSs are run by **government institutions**, requiring **collaboration** between geological, hydro-meteorological, and disaster risk management departments.
- Most warnings are **manually triggered**, informed by a process of consultation, triangulation, and expert judgement.
- The predominant user groups of regional landslide warnings are **institutional user groups**, with fewer cases of direct dissemination of warnings to the public.
- **Early actions** in response to warnings include closing non-essential services such as schools, road and rail lines; shutdown of essential services such as water, sewage, gas and electricity grids; and pre-positioning response resources.

UKaid
UKRI Natural Environment Research Council

More information

For more information on landslide forecasting and the meteorological and landslide data underpinning India's prototype, experimental regional landslide early warning system, see LANDSLIP resources and publications (publications in review, 2021).

Landslide forecasts

At a very simple level, most landslide early warning systems (LEWSs) for rainfall-induced landslides are based on the assumption that there is a relationship between **environmental conditions** (such as geology, soil type, vegetation cover, and slope angle), a **trigger** variable (such as rainfall amount or duration), and **landslide** occurrence.

Historical datasets on landslide occurrence and rainfall are analysed to model the relationship between rainfall and landslide occurrence in a specific area. LEWS **"thresholds"** determine the minimum amount of rainfall (cumulative rainfall) in a given period (rainfall duration) required for possible landslide occurrence.

Landslide **forecasts** can then be produced using a variety of rainfall data, including rainfall measures from gauge networks, rainfall estimates from radar networks or from satellites, and rainfall forecasts from weather forecast models.

Sometimes other information, such as landslide **susceptibility** or related information, may be used to refine or to support landslide forecasts.

Landslide and rainfall data

Historical landslide observation inventory

A historical database of landslide observations with specific **locations and timings** of the landslide events is needed over multiple years (the longer period, the better) to be able to identify the relationship between triggering factors (rainfall) and landslides occurring.

If this data is not available, there are other methods that can be used to estimate the relationship between triggers and landslide occurrence, but most national systems in operation are built on **good datasets of past landslide occurrences**.

Rainfall and/or weather information

Rainfall is the most monitored variable for LEWSs. Capturing an **accurate representation** of how much water falls where and over what time period is vital in developing forecast models in order to approximate the complex reality.

The **quality** of the rainfall data significantly affects the accuracy of determining rainfall thresholds associated with landslides for the landslide early warning system. The quality of rainfall data can be affected by the abundance, distribution and accuracy of rainfall monitoring methods.

Whilst most LEWSs use **rain gauges**, satellite-based rainfall estimates can be used. However, the thresholds determined from satellite-based rainfall estimates often differ from those prepared using rain gauge data in the same areas.

More information

For further information on institutional roles in India's prototype, experimental regional landslide early warning system, see [LANDSLIP](#) resources and publications.

Roles and responsibilities

Most regional **landslide forecast information** are developed by the mandated national geological government department e.g. British Geological Survey, Norwegian Water Resources and Energy Directorate.

Responsibility for **issuing warnings** is often held by the same department responsible for providing landslide forecasts, however, sometimes the institution that issues warnings is a separate department, such as the hydro-meteorological department (often to centralise early warning systems and communication channels across hazard types).

Because of the multidisciplinary characteristic of landslide forecasts, **cooperation** among government departments is essential to ensure the system is effective.

Figure 1. Examples of stakeholders in a regional landslide early warning system.

Operational systems

Regional LEWSs can operate **continuously**, like a weather forecast system, or **"on demand"**, when the need arises. The majority of active regional LEWSs operate continuously, and provide forecast information at predefined time intervals (typically daily).

Most warnings are **manually triggered**, informed by a process of consultation, triangulation, and expert judgement.

More information

For further information on the prototype landslide forecast bulletin disseminated on an experimental basis to sub-national authorities in India's prototype, experimental regional landslide early warning system, see LANDSLIP resources and publications.

Dissemination and communication

Regional landslide forecast information is often re-packaged into **a hazard or warning map** where the level of landslide hazard or warning is classified by an established scale (e.g. high/medium/low), and illustrated using colour-coding. The hazard or warning map is often provided with administrative boundaries and locations of key towns and cities to guide interpretation. Most maps are accompanied by text to describe the data being represented.

This information (or a version of it) is then typically **disseminated to key individuals or institutions** via an email bulletin, SMS or App alert, or online through a website platform. These key people or institutions include, for example, local authorities, emergency responders, and rail and road network operators.

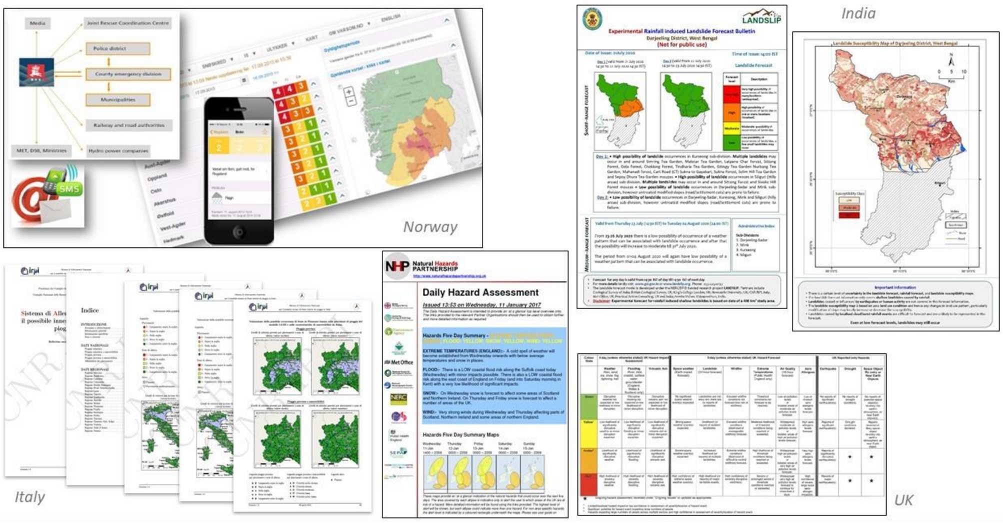

Figure 2. Examples of landslide forecast information products by Norway, Italy, UK and India.

In some (rarer) instances, **advice on actions** to be taken based on the level of warning is also provided. This information is often co-created with key stakeholders to determine the most appropriate actions to be taken for each level of warning.

However, LEWSs are usually used as **decision-support systems** rather than advisories; the issued warning messages are typically evaluated by key institutions and further actions are decided locally. In most cases, the LEWS is integrated into national or subnational Disaster Management Plans with defined roles and responsibilities for the authorities and agencies involved.

The **public** very rarely receive landslide warning information directly from the central warning institution in current operational regional LEWSs. Typically, with the exception of passive information accessible to the public, messages are not disseminated to the public unless a certain threshold of hazard is reached. The media is a key information source for the public.

The most common approach to communicating warnings to the public is delegated as a responsibility to the key responders or local authorities to take action or issue further warnings, using existing methods of communication (often existing disaster management structures).

Science for Humanitarian Emergencies & Resilience
SHEAR

Early action

Landslide forecasts can provide an opportunity to reduce the risks either through preparation activities or through organising earlier response. Examples include:

- **Further dissemination:** informing municipal management and relevant authorities and organisations; if there is a risk of explosion or an emission of hazardous substances, contacting technical or environmental experts; organising media information as needed; and/or issuing a public advisory statement e.g. “be alert”, “be prepared” alongside risk-minimising advice.
- **Closing services:** requesting shutdown of water/sewage systems, gas and electricity grids as needed; and closing vulnerable or non-essential services such as schools, rail services, roads.
- **Planning for earlier response:** pre-positioning resources such as mechanical equipment for removing debris, first aid kits, water, and shelter in safe locations near to at-risk areas for earlier response; securing people-related resources in advance, such as ensuring sufficient numbers of response staff are on standby for high-risk time periods; requisitioning search dog teams.
- **Evacuation planning:** planning for the possible rescue of personnel in higher risk areas from safer areas; evacuating people in the most vulnerable areas to safer locations.
- **Securing essential resources:** ensuring back up electricity sources are prepared in essential resource locations (e.g. hospitals, response centres) and essential tools are charged (e.g. mobile phones).

Strengths and limitations

Strengths

- Regional LEWSs can give a **longer lead time** for decision makers because it is linked to weather forecast data.
- This allows time for taking **early preparedness actions** which can increase the effectiveness and time-and cost-efficiency of response. This is of particular use for national and municipal authorities.
- They cover a **wide area**, providing warnings for a larger population.
- They **do not require pre-existing knowledge of a specific at-risk slope**.
- Regional LEWSs are **scalable** to national level.

Limitations

- Regional landslide forecasts often do not give high levels of specific **detail**. This means it may be less useful for the public compared to local LEWSs.
- Wide areas are often given the same level of warning, but in reality, there is **variation** in the likelihood of landslide occurrence within the area.
- They cannot predict **where** the landslide(s) will occur.
- They require a **significant amount of data** over a wider geographical region to generate reliable and accurate forecasts.
- There are **large modelling uncertainties** that need to be dealt with and communicated effectively.
- There is often difficulty **translating** complex forecast information into useful warnings.
- It is very difficult to implement meaningful automatic warnings; most systems are manually generated, which are **time and resource intensive**.

Further resources

Guzzetti, F., Gariano, S., Peruccacci, S., Brunetti, M., Marchesini, I., Rossi, M. and Melillo, M. 2020. Geographical landslide early warning systems. Earth-Science Reviews, 200, pp. 1-91.

Norwegian Water Resources and Energy Directorate, 2017. Regional early warning systems for rainfall- and snow melt induced landslides. Need for an international forum? Workshop.

Piciullo, L., Calvello, M., Pecoraro, G., 2017. Components and characteristics of territorial landslide early warning systems (Te-LEWS) operational worldwide.

Thiebes, B., 2017. Landslide early warning systems - Challenges, opportunities and status of regional cooperation for landslides, and recommendations on the establishment of new regional cooperation mechanisms and networks.