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LEWS2020 workshop on regional Landslide Early Warning Systems – experiences, progresses and needs

Michele Calvello[1], Graziella Devoli[2], Katy Freeborough[3], Stefano Luigi Gariano[4], Fausto Guzzetti[5], Helen J. Reeves[3], Manfred Stähli[6], and all LEWS2020 workshop participants

1) University of Salerno, Italy
2) Norwegian Water Resources and Energy Directorate, Norway
3) British Geological Survey, United Kingdom
4) CNR - IRPI, Perugia, Italy
5) National Department of Civil Protection, Italy
6) Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland

LEWS2020 Workshop

In January 2020, the

- **Research Institute for Geo-Hydrological Protection** of the Italian National Research Council.
- **British Geological Survey**.
- **Norwegian Water Resources and Energy Directorate**.
- **Swiss Federal Institute for Forest, Snow and Landscape Research**.
- **University of Salerno**.

have organised a 3-day workshop on regional Landslide Early Warning Systems (LEWS)

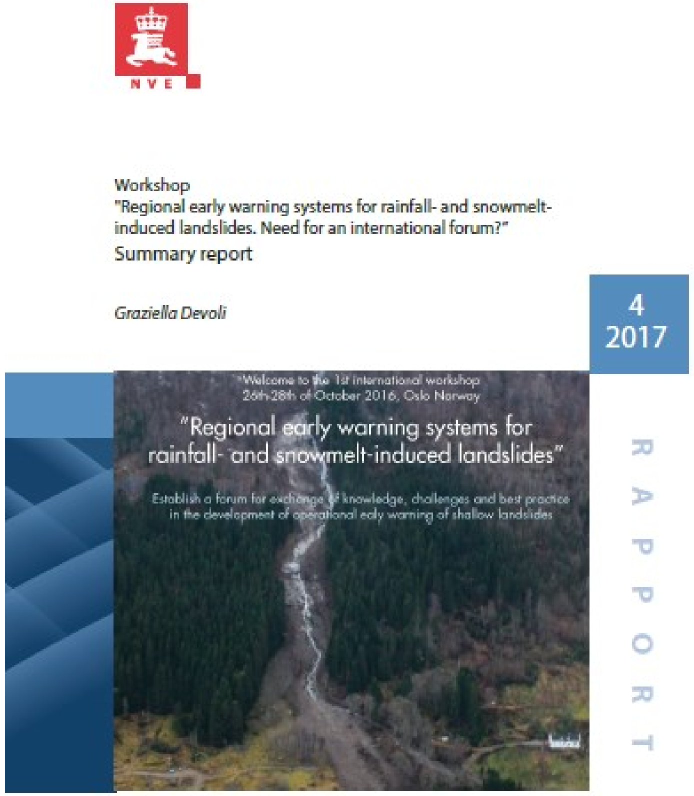
… a bit of history

The workshop follows a previous meeting held in Norway.

On **26-28 October 2016**, the first **International Workshop on Landslide Early Warning Systems** was held in Oslo, at the Norwegian Water Resources and Energy Directorate.

… a bit of history

About **40 people** attended the **3-day** workshop exchanging **experiences** and **ideas**, and **discussing problems** related to **landslide forecasting** and **early warning**.


NVE

Workshop
"Regional early warning systems for rainfall- and snowmelt-induced landslides. Need for an international forum?"
Summary report

Graziella Devoli

4
2017

"Welcome to the 1st international workshop
26th-28th of October 2016, Oslo Norway
"Regional early warning systems for rainfall- and snowmelt-induced landslides"
Establish a forum for exchange of knowledge, challenges and best practice in the development of operational ealy warning of shallow landslides

RAPPORT

LEWS2020 Workshop

The second edition of this **Workshop** on **Landslide Early Warning Systems - LEWS2020** was held in Perugia, Italy.

More than 40 worldwide invited experts involved in the design, the development, the operation or the analysis of LEWS were invited to attend the workshop

Scope of LEWS2020

- Focus on:
  - **regional** to **global** landslide early warning systems.
  - **operational** systems.
- Facilitate the **interaction** among **people** & **organizations** that design, develop, and manage **operational** systems.
- Discuss **openly** and **critically** all parts and **aspects** of the systems.
- Exchange **knowledge**, **experiences**, **challenges** and **best practices**.

Format of LEWS2020

- A small number of **invited** and **guided** talks
- Plenty of time for **discussion**
- A set of guided **discussion tables** on **data**, **forecast models**, **warning models**, **communication**
- **Rapporteurs** to report the outcomes of the **discussion tables**
- A **plenary discussion**

Schedule of LEWS2020

1st Day, 28 January: Presentations and discussion

- **presentations** on specific topics relevant for the optimal design, implementation, and operation of global, national and regional LEWS.
- **discussion**, aimed at addressing many of the issues that are relevant for regional LEWS, including system performance, warning communication and involvement of the stakeholders.

2nd Day, 29 January: Four round Tables

I. Data

II. Landslide forecast models

III. Warning models

IV. Scope, management structure, stakeholder involvement, and communication

3rd Day, 30 January: Discussion and Follow up

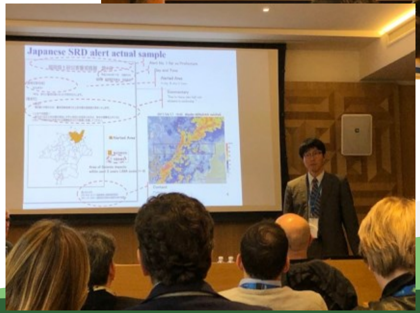
- **Summarizing**
- **formalizing** the main issues discussed in an open document to be later shared with colleagues interested in LEWS.

Day 1 - Presentations

Day 1 - Presentations





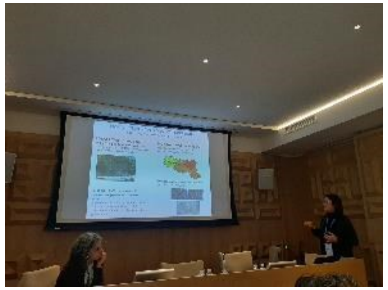


28 January: Presentations

- **Scopes, advantages and limitations of global LEWS**
  D. Kirschbaum (NASA - USA)
- **The Norwegian landslide forecasting and warning service**
  M. Sund (NVE - Norway)
- **Landslide early warning system in Switzerland: a project for future**
  H. Raetzo (FOEN - Switzerland) & *M. Stähli* (WSL - Switzerland)
- **Scope and needs for a national landslide early warning system in Japan**
  Hiroaki Nakaya & Joko Kamiyama (NILIM – Japan)

Day 1 - Presentations



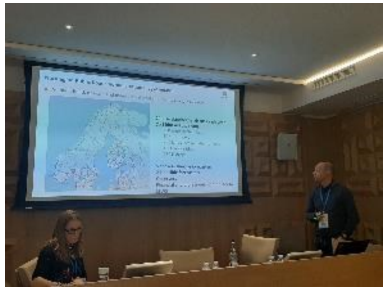


28 January: Presentations

- **National systems: an Italian experience** *Mauro Rossi* (CNR IRPI – Italy)
- **Scopes, advantages and limitations of regional LEWS: Emilia-Romagna and Valle d'Aosta experiences** *Sara Pignone* (Emilia-Romagna region - Italy) & *Sara Ratto* (Valle d'Aosta region - Italy)

- **Advanced LEWSs: the role of monitoring and modelling** *Dennis Staley* (USGS – USA)
- **Geographical landslide early warning systems: a review** *Fausto Guzzetti* (Italian National Civil Protection Department)

Day 1 - Presentations



28 January: Presentations

- **From landslide forecasts to landslide warnings** *Joanne Robbins* (MetOffice - United Kingdom)
- **Assessing warning models: issues and perspectives** *Michele Calvello* (University of Salerno - Italy)
- **Communicating weather-related warnings: issues and perspectives** *Claudia Adamo* (RAI Italian National Television – Italy)
- **Stakeholder's perspective** *Tore Humstad* (Norwegian Public Road Administration - Norway)
- **Presentation of LEWS managed by CNR IRPI** *Ivan Marchesini* (CNR IRPI - Italy)

Day 2 - Round tables

Day 2 - Round tables

Four discussion sessions and **four discussion table topics**.

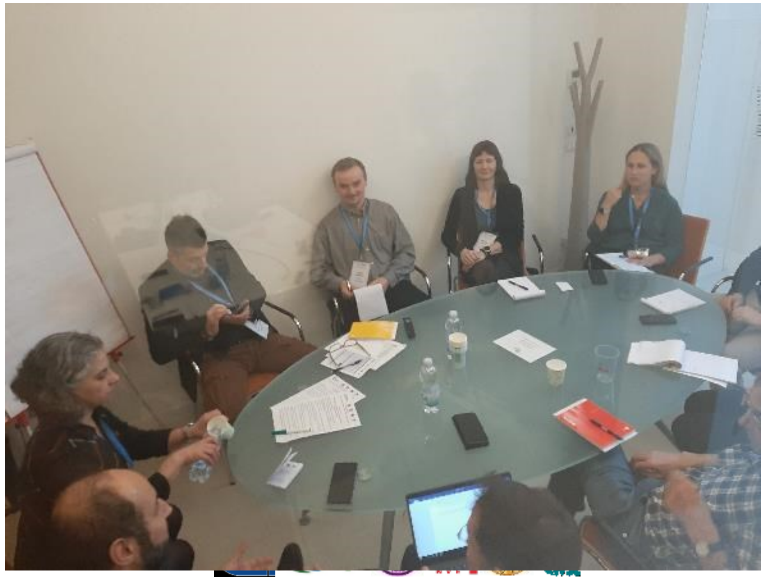
- Roundtable **1 - Data**
- Roundtable **2 - Landslide forecast models**
- Roundtable **3 - Warning models**
- Roundtable **4 - Scope, management structure, stakeholder involvement and communication**

Attendees were divided into groups and rotated through one table at each session. All attendees visited all tables in the course of the day.

Two rapporteurs were assigned **for each table topic.**

Day 2 - Round tables




Roundtable 1 – Data

Questions to discuss

- Reliability of weather data (experience in each Country)
- The role of soil information in LEWS
- Example of methods to ensure and understand the accuracy/quality of data used for modeling
- Share knowledge on economical and effective real-time data collections for the use in LEWS, strengths and limitations
- Coordination, sharing and quality control of inventories across regions and for different purposes

Roundtable **1 – Data**

Main weaknesses of LEWSs

- Spatial resolution
- Lack of landslide information (inventories, databases) for the creation of landslide forecast models
- Amount and quality of data (landslide inventories, hazard maps, susceptibility maps) insufficient
- Limited evaluation of the forecasted precipitation product
- A sparse real-time data network

Roundtable 2 – **Landslide forecast models**

Questions to discuss

- Expected near-future innovations on rainfall forecasts
- Most appropriate method to generate a landslide forecast model according to the available information
- The accuracy of prediction models, especially physical based models
- How applicable are LEWS for everyday disposition evaluation (Role: pure practitioner)
- How to improve the accuracy of LEWS (forecast models)

Roundtable 2 – Landslide forecast models

Main weaknesses of LEWSs

- Spatial resolution
- The estimation of actual field infiltration/runoff/ET vs model- or satellite-based forecasts, including spatial variation of soil/vegetation properties
- Lack of a "protocol" for the performance evaluation of landslide forecast models
- Difficulty to accurately predict "where" for shallow landslides and "when" for deep-landslides
- Limited transferability (of forecast models)
- Evaluation of models, forecasts and early warnings

Roundtable **3 – Warning models**

Questions to discuss

- Definition of threshold for landslide early warning in each Country
- Warning model for deep-seated landslides
- Relationship between the output of the model and the predicted scenario associated to the alert level zone
- How to include other information, such as soil wetness and precursors of landslides, in purely rain-based regional LEWSs
- What do we want LEWS to do so that they are useful to different stakeholders
- How to indicate impact (rather than the probability of occurrence)
- Methods, tools and concepts for the validation of operational landslide early warning systems

Roundtable 3 – Warning models

Main weaknesses of LEWSs

- Spatial resolution
- False alarms
- Threshold values
- LEWS are very site specific and often not very well validated
- Evaluation of models, forecasts and early warnings
- Value of expert judgement in model output communication

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

Questions to discuss

- How to convince the society and administration of the need of LEWS
- How to implement LEWS and to build people-centered approaches
- How can LEWS really save lives? Practically: what can we really predict? How can we set or assist appropriate expectation levels?
- How to set up a reliable LEWS
- How to prove LEWS reliability/usefulness for technical-social aspects
- How to develop a community of practice around publicly sharing landslide inventories and landslide model codes for communal use
- How to maintain the LEWS in each country
- How best do we visualize this information and communicate the model uncertainties in an effective way?

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

Main weaknesses of LEWSs

- Continuous securing of reliable information and accuracy of forecast model/warning
- Interaction between different levels of government and people living in landslide prone areas
- Communication of probabilities and uncertainties in the warning advisories
- Warnings/evacuations lacking or poorly understood by public/emergency management (When to return after evacuation warning?)
- Announcing warning information for landslides does not lead to residents' evacuation behavior
- User-orientated evaluation of warning issuance (objective and/or subjective)
- Variability in terminology – prediction / forecast / assessment/ warning

Day 3 - discussion

Rapporteurs summarized and reported the main issues discussed.

All the participant discussed the main findings of the workshop.

The main outcomes of the workshop, the most debated issues, and the key recommendations are here presented and shared.

Roundtable 1 – Data: Landslide Inventories

Challenges

- Unreliability and variable quality in landslide databases
- No control with what goes into the database
- Different terminologies
- Uncertain event times and locations
- Insufficient information for effective use
- Data sharing between groups, regions, countries, etc.
- No global, consistent standards for landslide data reporting
- Language barriers with reports

Roundtable 1 – Data: Landslide Inventories

Potential innovations

- Crowdsourcing and citizen science
- Social media mining (e.g. Twitter) – worthwhile and a good source of data
- Satellite detection with optical imagery (change detection, etc.)
- Satellite monitoring with InSAR

Roundtable 1 – Data: Weather Data

Challenges:

- How much you trust the information?
- Temporal resolution of gauge data for some information (e.g. daily) is hard/impossible to use (depending on forecast outlook)

Opportunities

- Rainfall ensembles from different weather models may help to provide better information on uncertainties
- Uncertainty estimation using *a priori* databases of "trusted" rainfall data for different types of precipitation regimes to inform probabilistic error/uncertainty estimates.

Roundtable 1 – Data: Weather Data

Potential innovations

- NETATMO in Norway (citizen science approach) – useful for heavy rain in summer to identify hotspots that aren't apparent from the gauge network
- Multi-model ensemble can give better skill in the forecast because it can give spread. Incorporating weather forecast ensembles or probability distribution of errors into LEWS may help to inform and better define uncertainties
- Improved satellite resolutions and model data are on the horizon (real-time)
- Can we better use ground-based radar within LEWS systems (merged radar/gauge data)?

Roundtable 1 – Data: Topography

Challenges

- SRTM was developed in 2001 so it is almost 20 years old and doesn't account for recent development in the Anthropocene
- 30m resolution may not be good enough for some weather forecast models or landslide models
- High resolution DEMs/DTMs are not available everywhere and can be expensive

- **Opportunities**
  - Commercial options such as Digital Globe can provide stereo imagery that can be used to create very high res DEMs
  - SAR-based DEMS are also becoming available but have holes and are expensive (right now) (e.g. TanDEM-X)
  - LiDAR is becoming more pervasive but still limited and expensive

Roundtable 1 – Data: Soils, Geology, Land Cover

- **Challenges**
  - Hard to get
  - Mapping surveys are expensive and time consuming
  - Limited accuracy over large areas that isn’t well constrained
  - Representativeness of soil surveys

- **Opportunities and Innovations**
  - Soil moisture could be an important metric but satellite retrievals remain problematic
  - Land Cover can be somewhat reliably obtained from satellites (e.g. Sentinel, Landsat)
  - There may be other proxies for rock characteristics relevant to LEWS but
  - Can take advantage of recycled data from boreholes, private companies
  - New soil maps being developed

Roundtable 1 – Data: Exposure data

Opportunities

- Accurate information on population, roads, critical infrastructure may not be sufficient for local analyses but has really promising applications for LEWS exposure assessment
- Open datasets such as OpenStreetMap is used routinely by organizations around the world and is growing in accuracy and size of variables considered
- Openlandmap

Roundtable 1 – Data: Remaining Needs

- Improving monitoring of soil moisture and water content (satellite? In situ?)
- Being aware of what weather forecast data is being used (raw vs post-processed) within the model and provide two-way feedback on the relevance and improvements
- Improving communication
- Data quality assessment and standards (or metadata) for landslide inventories
- Representativeness of data and characterization of variability accurately

Roundtable 1 – Data: Innovation and opportunities

- Global open platform to share landslide information & inventories
- Open platform for multiple model (regional, global) sharing
- Place to share open data sources relevant for landslides
- Leveraging cloud environments to:
  - Run physically-based models over large areas
  - Landslide mapping/detection
- Mapping areas of impact – gets back to physics of event and impact-risk question

Roundtable 2 – Landslide forecast models

Most important questions to discuss

- How applicable are LEWS for everyday disposition evaluation

A proper way to combine of warning and hazard maps is needed

Evaluation of days of red and orange warnings affordable by the society is a relevant information

A tailored communication is relevant

Roundtable 2 – Landslide forecast models

Most important questions to discuss

- How to improve the accuracy of LEWS (forecast models)

Shared networks and databases from different authorities

Few data → sharing → More data

Use of soil water content

Improve stations densty selecting proper locations in relevant geomorphological conditions (eg Different fixed warning zones, alert as a function of weather forecast, 90 min nowcast)

Regional model may assimilate information for local models

Roundtable 2 – **Landslide forecast models**

Main weaknesses of LEWSs

- Spatial resolution

High resolution could create problems for public, limiting products resolution could be beneficial for the public

High resolution for calibrating is mandatory

Temporal resolution rather then spatial resolution is limiting the forecast

High resolution rainfall intensity data is really important

Intensity over time is needed rather that instant intensity

Data aggregation at lower resolution may be relevant to improve model accuracy

Roundtable 2 – Landslide forecast models

Main weaknesses of LEWSs

- The estimation of actual field infiltration/runoff/ET vs model- or satellite-based forecasts, including spatial variation of soil/vegetation properties

Hydrological pathways are important, but really difficult to have proper data

Hydrogeological (rainfall and runout) model plus geotechnical model (infinity slope stability, unsaturated model) doable in some contexts where data are available (need to invest on measuring stations)

Satellite soil moisture monitoring not very useful (and used) at the present

Roundtable 2 – Landslide forecast models

Main weaknesses of LEWSs

- Lack of a "protocol" for the performance evaluation of landslide forecast models

Protocols but also **standards** for documentation of forecast models needed

Test and intercomparison studies are relevant to **assess model performances**

Roundtable 2 – Landslide forecast models

Main weaknesses of LEWSs

- Limited transferability (of forecast models)

Model transferability is difficult because data availability, and because model are calibrated/derived in different geo-environmental conditions and climatological settings

Proper model calibration may limit model transferability

Intercomparison studies relevant to evaluate single models transferability

Methods rather than rainfall threshold equations are transferability

Transferability limited by the variables employed

Same colors not solve the problem

Roundtable 2 – Landslide forecast models

Main weaknesses of LEWSs

- Evaluation of models, forecasts and early warnings

Uncertainty should be evaluated and communicated, even if from the system users and managers cannot properly deal with uncertainty

Intercomparison of models can be done, but need to define specifically how those need to be properly compared

Some models cannot be evaluated because producing different outputs, but in these cases timing of failure can be considered

Model calibration is ok, but validation with independent data its still weak

Importance of evaluating model functioning in normal conditions (e.g. low rainfall intensities)

Roundtable 2 – **Landslide forecast models**

Main weaknesses of LEWSs

- Evaluation of models, forecasts and early warnings

More important to know model fails and in particular false negative assessment rather than successful cases

Model functioning perception can be really different when not having model fails analysis or validation

Good landslide data and data collection is relevant for evaluation

Expert-based judgment of model fails rather than numerical metrics is relevant for proper model usage

Hindcasting and model sensitivity analyses are relevant

Important to have standard for model evaluations

Roundtable 3 – Warning models

Most important questions to discuss

- Definition of threshold for landslide early warning in each Country

Key points:

- Landslide database for determining the forecast model threshold – time, location, types and trigger.
- Minimum number of landslides required for determining the forecasting threshold
- National level forecast thresholds are not applicable for all situations (seasons etc.) so suggest that you could use specific thresholds for some local situations
- Warning thresholds different to forecast threshold.

Roundtable 3 – Warning models

Most important questions to discuss

- Methods, tools and concepts for the validation of operational landslide early warning systems

- Landslide Database used for evaluation. Data collected via field teams, stakeholders or WebApp (authorities can put data on landslides in) who capture the landslides that have occurred after an event.
- Is it appropriate/possible to use number of landslides for evaluation of the warning?
- Feedback on warning levels based on the user perception (A yellow warning but no landslides, might still be correct from the stakeholder perspective).
- If the forecast model uses threshold probability of 1 or more landslide; its not appropriate to then evaluate using number of landslides for the warning levels
- Evaluation Types – forecast or warning (can/should these be de-coupled):
  - Number of landslides per category
  - Evaluation of whether the action warning level was correct. What is the validity of the warning being issued.
  - Back-analysis of what happens.
  - Duration matrix (EDuMaP Method) – groups of landslide events compared against warning levels (applied in Brazil, West Norway, Piedmont - Italy). Work out if the warning levels are appropriate and alter thresholds if needed.

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

Most important questions to discuss

- How to convince the society and administration of the need of LEWS
  - *Better than nothing*
  - It might be mandatory / you need it by law thus this might help you if you do not have anything else
  - Events and fatalities drive the need for EWS

  - A good concept to talk and present is to show what the others are doing and compare
  - Tell success stories
  - Use case studies
  - Support your case with statistics (compare earthquake fatalities with earthquake fatalities)
  - Infrastructure owners might be more easier convinced that LEWS are needed

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

How to implement LEWS and to build people-centered approaches?

By focusing on the end-users' need for ***relevant information*** (only) and provide ***decision basis*** so that ***they*** may take ***relevant action*** according to their responsibilities. The most relevant stakeholders for regional LEWS would be personnel responsible for:

1. Infrastructure network owners (road, rail, power plants/lines.)
2. Municipalities/counties
3. Civil protection (first responders, police, fire brigade, mountain rescuers)
4. Tourist operators and other event organizers
5. Each citizen

Priority 1, 2, 3 and 4 also have the citizens in focus (however indirectly through intermediate units)

Roundtable 4 – Scope, management structure, stakeholder involvement, communication

Most important questions to discuss

- How can LEWS really save lives? Practically: what can we really predict? How can we set or assist appropriate expectation levels?
  - Tolerance of false alarms of different groups might vary, depending on application and country.
  - In India more trust in authority, but in Europe probably less trust in authorities
  - In poor country the tolerance might be more open for false alarm. For example in Nicaragua good response to warnings.
  - Save lives – evacuation: Is the system good enough to allow decisions on evacuation? In Norway it is not seen that even with a red warning whole villages will be evacuated.
  - Impact based warning? Integration of free available information like road network ?
  - Combine the forecast with landslide susceptibility but with other local information.
  - In order to deal with impact we have to deal with fragility curves. In reality this is not really possible
  - Impact scenarios.

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

How to set up a reliable LEWS?

- ***Validate*** your warnings systematically (quantitatively and qualitatively)
- ***Communicate*** mainly to *those you want to reach* (people you don't need to reach will think that all alerts are "false"
- ***Educate*** the end users; what can they expect (and not) from the service?
- Find (or deal with) the "missing link"; the ***emergency/action plans*** used after the warning is issued and before the action taken (the LEWS gives more sense if it is associated with reasonable actions)

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

How to prove LEWS reliability/usefulness for technical-social aspects?

- **Show the public**:
  - Events that actually happened
  - Events that were avoided because of actions taken (because of the warning/knowledge)
  - Tell success stories about actions taken by the society to evacuate form the right place at the right time

- **Tell the politicians** how much money we saved by being prepared to save lives, health and property

- **Evaluate continuously** and use the results

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

Main weaknesses of LEWSs

Communication of probabilities and uncertainties in the warning advisories?

- This is most relevant for internal use.
- The public needs to know that there are always some uncertainties. However, it could be helpful to tell which conditions the warnings are based on.

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

Main weaknesses of LEWSs

- Warnings/evacuations lacking or poorly understood by public/emergency management (When to return after evacuation warning?)
- **How early** is an early warning? What if we don't have time to react? The time needed to take action must bed realistic.
- The speed at which an event develops is important for how you communicate the actions required (e.g. tsunami is an example where you need direct communication to the citizens)

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

Main weaknesses of LEWSs

Announcing warning information for landslides does not lead to residents' evacuation behavior?

Paradox: Regional warnings are “always” false alerts: How do you deal with “false alarms” by definition? Only few areas will be affected within the region. Combine the warning with good zonation. Some areas could be excluded.

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

Main weaknesses of LEWSs

Announcing warning information for landslides does not lead to residents' evacuation behavior?

This may imply that we are not directing our warnings to the *relevant* user group…

Is it a good solution that warnings that are meant for regions are used in weather forecasts for specific locations?

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

User-orientated evaluation of warning issuance (objective and/or subjective)?

- *Feedback* from at least *professional users* (for instance geologists in municipalities and road/railway administration) would be helpful in addition to only landslide/events data:
  - Establish some sort of professional crowdsourcing on danger level?
  - This may prove that a certain level was correct, even though the number of registered landslides is low

Roundtable **4 – Scope, management structure, stakeholder involvement, communication**

Variability in terminology – prediction / forecast / assessment/ warning?

- It is important to communicate what the different colors mean, and also what they mean across:
  - natural hazard
  - regions
  - countries?
  - cultures and languages
- The less variability the better
  - → national and even international standards would be interesting to look at (if possible)

Day 3 - discussion

Final remarks

The **final purpose** of the workshop is to establish and consolidate a **community of experts in LEWS** and to build relationships with other communities (e.g., meteorologists, climate scientists, communications scientists).

This will help to level up the quality of both theory and practice, and to **define standards** in early warnings in order to provide **timely advisories** and to initiate emergency responses to landslides (particularly rainfall-induced) avoiding or reducing life and economic losses.

Looking forward to the third edition