THE MOUNTAIN-RISKS RESEARCH PROJECT: CHALLENGES IN HAZARD ANALYSIS

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SCOPE: MOUNTAIN HAZARDS ANALYSIS

There are a number of important 'gaps' in the assessment of mountain hazards. In particular, the temporal frequency and magnitude of the processes have to be studied in greater detail to further the assessment of the hazard. Therefore, modern techniques of data collection and analysis, advanced analytical methods, as well as innovative computer simulation results, have to be introduced into the hazard assessment procedures to assess critical triggering thresholds and evaluate return periods.

To develop these techniques, a better understanding of the physics of the processes is crucial, for instance the role of preferential flows and the unsaturated zone in terms of the supply of water to the soil, the mechanisms governing the acceleration of slow-moving landslides or the mechanical behaviour of the material during run-out of rapid processes such as debris flows, rock-falls and snow avalanches.

The themes which will be investigated by the project are detailed hereafter.

➢ Identification of the processes

The project will develop a procedure to analyse the long-term preparatory factors and the short-term, transient, triggering factors that control landslide occurrences. The processes and related factors that will be addressed are:

- chemical and mechanical weathering of the rock and soil material;
- cyclic loading by earthquakes, leading to progressive damage;
- slope evolution and changes in loading on a potential landslide;
- the evolution of the fracture system;
- thermo-mechanical and chemical processes induced by circulating water in preferential fractures and biological processes enhancing the propagation of the fractures.
- the development of long-term hillslope models in order to quantify the temporal evolution of predisposing factors.

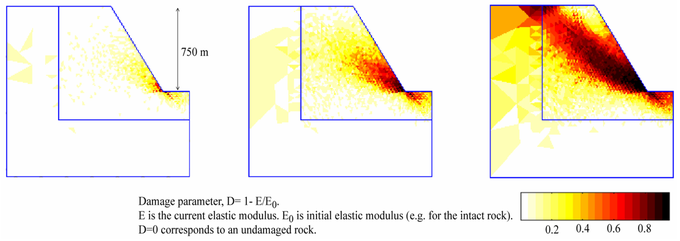

Fig. 1: Modeling of the progressive damage of an idealized rocky slope based on brittle creep theory considering the sub-critical growth of a population of cracks (Amitrano, 2005).

Several investigation and monitoring techniques (near-surface geophysical techniques, remote-sensing techniques like interferometry, Permanent Scatterers, image correlation, and hydro-chemistry) will be used to understand the type and the mechanics of movement. All these techniques will be evaluated against geomorphological observations which may reveal the complexity of real-life landslides and thus the inevitable shortcomings of abstract models. Geomorphological observations will also assist in the conceptualization and evaluation of the process-based models to be developed.

➢ Prediction of hazard spatial extent and intensity

Prediction of spatial extent and intensity of landslides and gravitational flows is still very difficult. For instance, for fast gravitational flows, there are many rheologic behaviours which can even change during the runout. Direct measurements of key variables (yield stress, viscosity, pore-pressure) are difficult to perform in field-scale events, while rheological properties determined from laboratory small-sale samples may not be representative at the slope scale. Moreover, there are still great uncertainties about material amounts from the source area by landsliding, run-off erosion, collapse of gully walls or scouring of *in-situ* channel bed material.

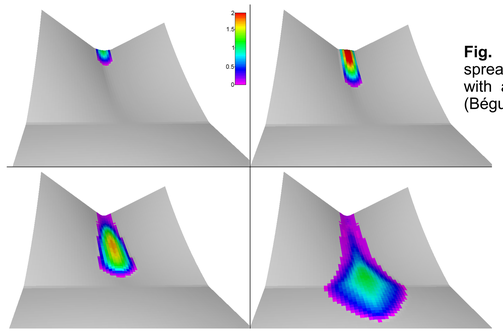

Fig. 2: Modeling of the spreading of a debris-flow with a process-based model (Béguèria-Portuguès, 2007).

The processes and related factors that will be addressed are:

- the development of model able to entrain material within the flow path;
- the development of model able to take into account changes in rheology;
- the development of GIS process-based models to handle more easily pre-and post-processing;
- the development of detailed event databases in order to test the performance of the models, and gain insights from geomorphological observations in the understanding of the processes.

➢ Factors controlling post-failure behaviour

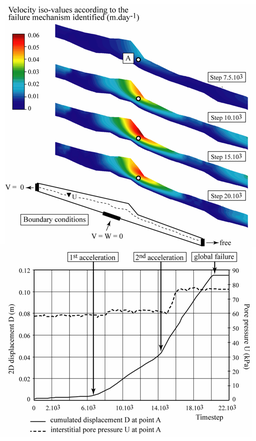

Fig. 3: Modelling of a crisis at the Super-Sauze mudslide (GefDyn finite-element code; Malet, 2003; with EPFL)

Many landslides show complex and transient mechanical and fluid interactions which are very important to predict crises. Non linear intrinsic viscosity of the shear zone, strength regain by consolidation, undrained loading effects leading to the generation of excess pore pressure, or changing fissure systems may drastically change the process behaviour in the post-failure stage.

The processes and related factors that will be addressed are:

- the understanding and modelling of the de- and acceleration phases of slow-moving landslides;
- the understanding of the fluidization of dense material (by undrained loading during movement, presence of an undulating slip surface, or transformation of the material from a dilative to a contractive state).

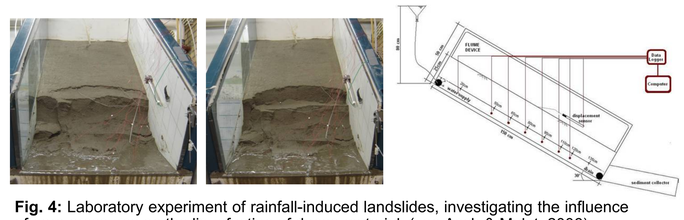

Fig. 4: Laboratory experiment of rainfall-induced landslides, investigating the influence of pore pressures on the liquefaction of dense material. (van Asch & Malet, 2006).

➢ Temporal probability and intensity of the processes

Many hazard assessments lack the support to evaluate temporal probabilities, and intensity of the processes. In that case, the use of deterministic (process-based) methods in combination with probabilistic statistical techniques may deliver good opportunities. Quantitative hazard assessments are rare because of the particular scarcity of information on the meteorologial triggering of landslides, while the temporal probability of landslides is determined worldwide by the hydrological system.

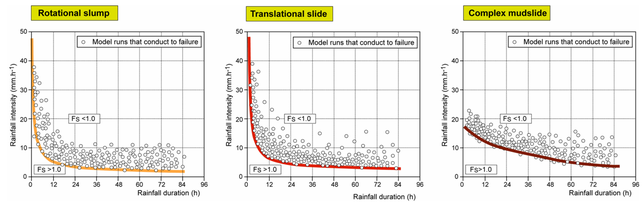

Fig. 5: 'Simulated' rainfall thresholds for some landslide types observed in the Barcelonnette Basin, South French Alps (Malet et al., 2006).

The processes and related factors that will be addressed are:

- the understanding of the coupling between the climate system and the hydrological system controlling landslide occurrences, with a particular focus on the unsaturated zone and on preferentials flows;
- the addition of a temporal dimension and of intensity estimates to the susceptibility assessments, through scenario modelling and probabilistic techniques linked to process-based models;
- the development of simulation techniques (event-tree methods, ANNs, etc…) to estimates occurrence probabilities.

➢ Criteria for early warnings

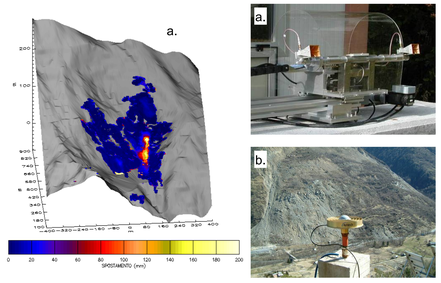

Fig. 6: Monitoring of the Tessina landslide (Italy) with the LISA SAR interferometer (a), and monitoring of the La Clapière landslide (France) with continuous GPS (b).

Criteria for early-warning deduced from a physical understanding of the processes, from model simulations, and from monitored sites will be proposed. Quality standards will be set up with reference to the type of sensors, the type of data collection and analysis, the type of transmission system, the actions following alert and alarm.