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Empirical thresholds for precipitation-induced landslides in Europe

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The characterisation of precipitation conditions for triggering of landslides is a key component in the design and implementation of early-warning systems and in the estimation of hazard maps for current and future climate scenarios. Physical modelling of those triggering conditions may be usually feasible for individual slopes, but not for local or regional scales, where practical difficulties generally arise due to the lack of estimates of spatially distributed hydraulic and mechanical parameters, and to complexities of ground conditions on susceptible slopes. In those situations, where the implementation of a physical model is not feasible, the preferred approach is to formulate empirical relationships between measurements of precipitation and slope movements or landslide occurrence. This paper presents 6 different empirical models applied to 7 landslide datasets from Italy, France, Norway and Switzerland. The main aim of this contribution is to summarize the experiences of Work Package 1.3 "Statistical studies for precipitation-induced landslides" as part of the SafeLand project funded by the European Commision.

The implemented empirical models were: intensity-duration power law forms, classification tree analyses, discriminant analyses, the Forecasting-of-Landslides-Induced-by-Rainfall (FLaIR) model, the AutoRegressive-with-eXogenous-inputs (ARX) model, and the Neural-Network-AutoRegressive-Moving-Average-with-eXogenous-inputs (NNARMAX) model. The landslide datasets included inventories of movements as well as hourly or daily observations of precipitation. The types of events predominating in the inventories were soil slides and debris flows, and a few rock slides and rock falls. The locations of the datasets were: Satriano, Verzino and Sarno (Italy), the Barcelonnette basin (France), the Norangselva catchment (Norway), the Nedre Romerike region (Norway) and the La Frasse landslide (Switzerland).

The results indicate that the occurrence of soil slides and debris flows can be predicted using precipitation observations. On the other hand, models fail to predict rock falls and rock slides, presumably due to the predominant influence of other triggering factors (e.g., wedging of vegetation, influence of freeze-thaw cycles on fractures). Soil slides are controlled by a combination of short-duration precipitation (less than 24 hours) and antecedent precipitation ranging from 20 to 50 days, respectively. On the other hand, debris flows are controlled by instant precipitation characterised by durations of less than 12 hours. In this case, real-time monitoring is required for a successful implementation in practice. Finally, two main challenges were identified for a reliable calibration of thresholds: inventories should be complete in order to identify at least the time and location of initiation, as well as the type of landslide according to international conventions; and the selection of locations for rain gauges should ensure that the monitored values are representative of precipitation conditions in initiation areas.