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Probabilistic forecasts of debris-flow hazard at the regional scale with a combination of models.

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Debris flows are one of the many active slope-forming processes in the French Alps, where rugged and steep slopes mantled by various slope deposits offer a great potential for triggering hazardous events. A quantitative assessment of debris-flow hazard requires the estimation, in a probabilistic framework, of the spatial probability of occurrence of source areas, the spatial probability of runout areas, the temporal frequency of events, and their intensity.

The main objective of this research is to propose a pipeline for the estimation of these quantities at the region scale using a chain of debris-flow models. The work uses the experimental site of the Barcelonnette Basin (South French Alps), where 26 active torrents have produced more than 150 debris-flow events since 1850 to develop and validate the methodology.

First, a susceptibility assessment is performed to identify the debris-flow prone source areas. The most frequently used approach is the combination of environmental factors with GIS procedures and statistical techniques, integrating or not, detailed event inventories. Based on a 5m-DEM and derivatives, and information on slope lithology, engineering soils and landcover, the possible source areas are identified with a statistical logistic regression model. The performance of the statistical model is evaluated with the observed distribution of debris-flow events recorded after 1850 in the study area. The source areas in the three most active torrents (Riou-Bourdoux, Faucon, Sanières) are well identified by the model. Results are less convincing for three other active torrents (Bourget, La Valette and Riou-Chanal); this could be related to the type of debris-flow triggering mechanism as the model seems to better spot the open slope debris-flow source areas (e.g. scree slopes), but appears to be less efficient for the identification of landslide-induced debris flows.

Second, a susceptibility assessment is performed to estimate the possible runout distance with a process-based model. The MassMov-2D code is a two-dimensional model of mud and debris flow dynamics over complex topography, based on a numerical integration of the depth-averaged motion equations using shallow water approximation. The run-out simulations are performed for the most active torrents. The performance of the model has been evaluated by comparing modelling results with the observed spreading areas of several recent debris flows. Existing data on the debris flow volume, input discharge and deposits were used to back-analyze those events and estimate the values of the model parameters.

Third, hazard is estimated on the basis of scenarios computed in a probabilistic way, for volumes in the range 20'000 to 350'000 m3, and for several combinations of rheological parameters. In most cases, the simulations indicate that the debris flows cause significant overflowing on the alluvial fans for volumes exceeding 100'000 m3 (height of deposits > 2 m, velocities > 5 m.s-1). Probabilities of debris flow runout and debris flow intensities are then computed for each terrain units.