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Mapping rainfall triggered soil slips at the hillslope scale: a case study in the Bernese Oberland (Switzerland)

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Rainfall induced soil slips are among the most dangerous natural hazards acting on hillslopes, leading to structural damage and casualties. Triggered by intense precipitation, in most cases the failures can be considered translational mass movements that occur suddenly. The best available prevention tool for large areas must therefore rely on the ability to predict the timing and location of these natural hazards well in advance.

Switzerland is particularly prone to rainfall triggered soil slips, given the steep nature of many of its alpine and pre-alpine slopes. A series of natural disasters involving soil slips affected several areas in the country in the last decade, among these are the ones occurred in the region around Napf (Bernese Oberland) in July 2002. The event was accurately documented by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL). The site was chosen here with the aim of assessing the predictive capability of a time dependent slope stability model.

The model, TRIGRS (Transient Rainfall Infiltration and Grid-based Slope-stability), is a coupled hydro-mechanical slope stability assessment tool, working at a regional scale. Infiltration is modelled through a simplified analytical solution of Richards' equation, which requires a shallow, quasi-saturated soil cover at the beginning of a simulation. The built-up pore pressure is used as an input to a slope stability model, based on the infinite-slope approach. The assumption that the soil must be quasi-saturated at the beginning of a simulation can be viewed as a limitation of the model for deep soils, but is not an issue in the case examined. The soil cover in the test area does not exceed 3 meters even in the flatter regions.

The main problem in applying TRIGRS over large areas is the lack of detailed input data for topography and soil. A new high-resolution DTM (Digital Terrain Model) with an average density of 0.5 points/m^2 was made available by the Bernese cantonal authorities, and converted into a grid with a resolution of 3 meter using ArcGIS. TRIGRS proved to be very sensitive to the slope angle, making the availability of a precise DTM a primary need, but also presenting the problem of choosing a reliable routine to determine the slope angle for each cell of the raster.

A series of hypotheses were made to model the variation of some selected TRIGRS input parameters. These conceptualizations were necessary due to the lack of information about the variability of these parameters in the study area. Soil cohesion was made dependent on altitude, and root cohesion was added to the model. Soil depth was defined as a decreasing exponential function of the slope angle, ranging from about 1 meter on the steeper slopes to about 3 meters in the valley. The initial water table depth was described using the Topographic Index approach. Average values, computed from the few available data, were used for the friction angle, and the saturated hydraulic conductivity. The hydraulic diffusivity was calibrated starting from a range of reasonable values. Hourly rainfall data for the meteorological station Napf was obtained from MeteoSwiss and distributed uniformly over the basin.

The assessment of the model performance was carried out by taking into consideration the uncertainty in the location of the mapped landslides. The results show the ability of the model to capture as many as 68.6% of the occurred slides by destabilizing 11.6% of the entire basin. A simple slope map would need to destablize 44.9% of the entire basin to match the result. The tendency to overestimate instabilities on steep areas is still present, and seems rather unavoidable with the available data. An improvement in this sense can be expected if additional information on landuse for the area under investigation could be obtained.

Nevertheless TRIGRS holds good promises as a prediction tool for rainfall induced soil slips, but needs to be further tested in other areas, with special attention devoted to the conceptual assumptions mentioned above.