



CTRL-A: an Algorithm for the Calculation of Thresholds for Rainfall-induced Landslides

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Empirical rainfall thresholds are a tool widely used to predict the possible landslide occurrence in large areas. Review of the literature reveals that most of the thresholds are affected by several uncertainties related to: the rainfall and the landslide data accuracy, the reconstruction of the rainfall amount responsible for the failure, and the method adopted to calculate the thresholds. These uncertainties limit the use of thresholds in operational landslide early warning systems. To overcome the problem, we developed a comprehensive algorithm (named CTRL-A, Calculation of Thresholds for Rainfall-induced Landslides-Algorithm) that automatically and objectively reconstructs rainfall events and rainfall conditions responsible for the failures, and calculates rainfall thresholds at different exceedance probabilities and the associated uncertainties. The algorithm consists of three distinct blocks. The first block operates the reconstruction of rainfall events in terms of duration (D , in h) and cumulated event rainfall (E , in mm) using rainfall series and several parameters to account for different seasonal and climatic settings. Rainfall event parameters were calibrated adopting the monthly soil water balance model and evapotranspiration analysis. The second block performs the selection of the rain gauge representative for the landslide, the modeling of the antecedent rainfall, and the reconstruction of single or multiple rainfall conditions (MRC) likely responsible for the failures (associating a probability to each condition). The third block calculates the rainfall thresholds using the multiple rainfall conditions or the condition with the maximum probability (MPRC) for each failure. CTRL-A uses a set of adjustable parameters to account for different physical and climatic environments.

We tested CTRL-A in Liguria, a northern Italian region highly prone to landslides, exploiting geographical and temporal information on 561 rainfall-induced landslides, occurred between October 2004 and November 2014, and hourly rainfall data measured by 172 rain gauges. The algorithm reconstructed 801 MRC and 440 MPRC associated to the observed landslides and determined ED frequentist thresholds, which may be implemented in an operational regional early warning system for shallow landslide forecasting in Liguria.