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A probabilistic model for assessing debris flow propagation at regional scale: a case study in Campania region, Italy

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Debris flows and debris avalanches are rapid to extremely rapid landslides that tend to travel considerable distances from their source areas. Interaction between debris flows and elements at risk along their travel path may result in potentially significant destructive consequences. One of the critical challenges to overcome with respect to debris flow risk is, therefore, the credible prediction of their size, travel path, runout distance, and depths of erosion and deposition. To these purposes, at slope or catchment scale, sophisticated physically-based models, appropriately considering several factors and phenomena controlling the slope failure mechanisms, may be used. These models, however, are computationally costly and time consuming, and that significantly hinders their applicability at regional scale. Indeed, at regional scale, debris flows hazard assessment is usually carried out by means of qualitative approaches relying on field surveys, geomorphological knowledge, geometric features, and expert judgement.

In this study, a quantitative modelling approach based on cellular automata methods, wherein individual cells move across a digital elevation model (DEM) landscape following behavioral rules defined probabilistically, is proposed and tested. The adopted model, called LABS, is able to estimate erosion and deposition soil volumes along a debris flow path by deploying at the source areas autonomous subroutines, called agents, over a 5 m spatial resolution DEM, which provides the basic information to each agent in each time-step. Rules for scour and deposition are based on mass balance considerations and independent probability distributions defined as a function of slope DEM-derived values and a series of model input parameters. The probabilistic rules defined in the model are based on data gathered for debris flows and debris avalanches that mainly occurred in western Canada. This study mainly addresses the applicability and the reliability of this modelling approach to areas in southern Italy, in Campania region, historically affected by debris flows in pyroclastic soils. To this aim, information on inventoried debris flows is used in different study areas to evaluate the effect on the predictions of the model input parameter values, as well as of different native DEM resolutions.