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Physically-based slope stability modelling and parameter sensitivity: a case study in the Quitite and Papagaio catchments, Rio de Janeiro, Brazil

Carolina de Lima Neves Seefelder (1,2,3) and Martin Mergili (3,4)

(1) National Department of Transport Infrastructure (DNIT), Brasília, Brazil, (2) University of Brasília, Department of Civil Engineering, Brasília, Brazil, (3) University of Vienna, Department of Geography and Regional Research, Vienna, Austria (martin.mergili@univie.ac.at), (4) University of Natural Resources and Life Sciences (BOKU), Institute of Applied Geology, Vienna, Austria

We use the software tools r.slope.stability and TRIGRS to produce factor of safety and slope failure susceptibility maps for the Quitite and Papagaio catchments, Rio de Janeiro, Brazil. The key objective of the work consists in exploring the sensitivity of the geotechnical (r.slope.stability) and geohydraulic (TRIGRS) parameterization on the model outcomes in order to define suitable parameterization strategies for future slope stability modelling.

The two landslide-prone catchments Quitite and Papagaio together cover an area of 4.4 km^2, extending between 12 and 995 m a.s.l. The study area is dominated by granitic bedrock and soil depths of 1–3 m. Ranges of geotechnical and geohydraulic parameters are derived from literature values. A landslide inventory related to a rainfall event in 1996 (250 mm in 48 hours) is used for model evaluation.

We attempt to identify those combinations of effective cohesion and effective internal friction angle yielding the best correspondence with the observed landslide release areas in terms of the area under the ROC Curve (AUCROC), and in terms of the fraction of the area affected by the release of landslides. Thereby we test multiple parameter combinations within defined ranges to derive the slope failure susceptibility (fraction of tested parameter combinations yielding a factor of safety smaller than 1). We use the tool r.slope.stability (comparing the infinite slope stability model and an ellipsoid-based sliding surface model) to test and to optimize the geotechnical parameters, and TRIGRS (a coupled hydraulic-infinite slope stability model) to explore the sensitivity of the model results to the geohydraulic parameters.

The model performance in terms of AUCROC is insensitive to the variation of the geotechnical parameterization within much of the tested ranges. Assuming fully saturated soils, r.slope.stability produces rather conservative predictions, whereby the results yielded with the sliding surface model are more conservative than those yielded with the infinite slope stability model. The sensitivity of AUCROC to variations in the geohydraulic parameters remains small as long as the calculated degree of saturation of the soils is sufficient to result in the prediction of a significant amount of landslide release pixels.

Due to the poor sensitivity of AUCROC to variations of the geotechnical and geohydraulic parameters it is hard to optimize the parameters by means of statistics. Instead, the results produced with many different combinations of parameters correspond reasonably well with the distribution of the observed landslide release areas, even though they vary considerably in terms of their conservativeness. Considering the uncertainty inherent in all geotechnical and geohydraulic data, and the impossibility to capture the spatial distribution of the parameters by means of laboratory tests in sufficient detail, we conclude that landslide susceptibility maps yielded by catchment-scale physically-based models should not be interpreted in absolute terms. Building on the assumption that our findings are generally valid, we suggest that efforts to develop better strategies for dealing with the uncertainties in the spatial variation of the key parameters should be given priority in future slope stability modelling efforts.