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Three-dimensional modelling of slope stability using the Local Factor of Safety concept

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Slope stability is governed by coupled hydrological and mechanical processes. The slope stability depends on the effective stress, which in turn depends on the weight of the soil and the matrix potential. Therefore, changes in water content and matrix potential associated with infiltration will affect slope stability. Most available models describing these coupled hydro-mechanical processes either rely on a one- or two-dimensional representation of hydrological and mechanical properties and processes, which obviously is a strong simplification in many applications. Therefore, the aim of this work is to develop a three-dimensional hydro-mechanical model that is able to capture the effect of spatial and temporal variability of both mechanical and hydrological parameters on slope stability. For this, we rely on DuMux, which is a free and open-source simulator for flow and transport processes in porous media that facilitates coupling of different model approaches and offers flexibility for model development. We use the Richards equation to model unsaturated water flow. The simulated water content and matrix potential distribution is used to calculate the effective stress. We only consider linear elasticity and solve for statically admissible fields of stress and displacement without invoking failure or the redistribution of post-failure stress or displacement. The Local Factor of Safety concept is used to evaluate slope stability in order to overcome some of the main limitations of commonly used methods based on limit equilibrium considerations. In a first step, we compared our model implementation with a 2D benchmark model that was implemented in COMSOL Multiphysics. In a second step, we present in-silico experiments with the newly developed 3D model to show the effect of slope morphology, spatial variability in hydraulic and mechanical material properties, and spatially variable soil depth on simulated slope stability. It is expected that this improved physically-based three-dimensional hydro-mechanical model is able to provide more reliable slope instability predictions in more complex situations.