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A GRASS GIS-based deterministic model for shallow and deep-seated landslide susceptibility analysis over large areas

Martin Mergili (1), Ivan Marchesini (2), Mauro Rossi (2,3), Fausto Guzzetti (2), and Wolfgang Fellin (4)

(1) Institute of Applied Geology, BOKU University, Vienna, Austria, (2) CNR IRPI, Perugia, Italy, (3) Department of Earth Sciences, University of Perugia, Italy, (4) Unit of Geotechnical and Tunnel Engineering, University of Innsbruck, Austria

Various deterministic slope stability models, based on the assumption of an infinite slope with a plane, slope-parallel failure plane, have been proposed in the literature. These models are commonly implemented in a GIS environment and are mostly used to model shallow landslides. Other models consider the three-dimensional geometry of possible slope failures and assume an ellipsoidal sliding surface. Such models are best suited to investigate deep-seated landslides. The latter models rely on complex neighbourhood relationships and are difficult to implement in a GIS environment.
Here, we present a GIS-based landslide modelling tool that considers the three-dimensional geometry of the sliding surfaces and is capable of dealing with shallow and deep-seated failures. The model is developed in the GRASS GIS software as the C-based raster module r.rotstab, and adopts a modification of the three-dimensional sliding surface model proposed by Hovland and revised and extended by Xie and co-workers. Given a Digital Elevation Model and a set of thematic layers, the model evaluates slope stability for a large number of randomly selected potential slip surfaces, ellipsoidal in shape. Truncated ellipsoids can be used to model the presence of shallow weak layers in the soil or the bedrock. Any single raster cell may be intersected by multiple sliding surfaces, each associated with a computed safety factor. For each grid cell, the lowest value of the safety factor and the depth of the associated slip surface are stored. This information can be used to obtain a spatial overview of the potentially unstable regions in the study area. In addition, a landslide susceptibility index in the range 0 – 1 is calculated. The index relates the number of unstable slip surfaces to the total number of slip surfaces simulated for each pixel. We tested the model in the Collazzone area, Umbria, Central Italy, which is susceptible to landslides of different types. The presence of both shallow translational and deep-seated rotational landslides, and the availability of reference data allowed for a critical evaluation of the model results. The model successfully predicts most of the observed landslide patterns. However, the results also display a significant number of false positive which we interpret as (i) areas potentially affected by landslides in the future, or (ii) incorrect predictions due to lack of information. Tuning the geotechnical parameters towards a lower number of false positives can only be done at the cost of an increased number of false negatives.