Geophysical Research Abstracts
Vol. 17, EGU2015-3660, 2015
EGU General Assembly 2015

Physically-based landslide susceptibility modelling: geotechnical testing and model evaluation issues

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We used the software r.slope.stability for physically-based landslide susceptibility modelling in the 90 km^2 Collazzone area, Central Italy, exploiting a comprehensive set of lithological, geotechnical, and landslide inventory data. The model results were evaluated against the inventory.

r.slope.stability is a GIS-supported tool for modelling shallow and deep-seated slope stability and slope failure probability at comparatively broad scales. Developed as a raster module of the GRASS GIS software, r.slope.stability evaluates the slope stability for a large number of randomly selected ellipsoidal potential sliding surfaces. The bottom of the soil (for shallow slope stability) or the bedding planes of lithological layers (for deep-seated slope stability) are taken as potential sliding surfaces by truncating the ellipsoids, allowing for the analysis of relatively complex geological structures. To take account for the uncertain geotechnical and geometric parameters, r.slope.stability computes the slope failure probability by testing multiple parameter combinations sampled deterministically or stochastically, and evaluating the ratio between the number of parameter combinations yielding a factor of safety below 1 and the total number of tested combinations. Any single raster cell may be intersected by multiple sliding surfaces, each associated with a slope failure probability. The most critical sliding surface is relevant for each pixel.

Intensive use of r.slope.stability in the Collazzone Area has opened up two questions elaborated in the present work:

(i) To what extent does a larger number of geotechnical tests help to better constrain the geotechnical characteristics of the study area and, consequently, to improve the model results? The ranges of values of cohesion and angle of internal friction obtained through 13 direct shear tests corresponds remarkably well to the range of values suggested by a geotechnical textbook. We elaborate how far an increased number of tests may help to further improve the geotechnical parameterization of the model and, consequently, how much effort and resources should be put into geotechnical sampling and testing for physically-based landslide susceptibility modelling.

(ii) What is the spatial unit most suitable to discretize landslide susceptibility maps? Whilst the GIS pixel is the most commonly used level of discretization, slope units represent a valid alternative. Tests have shown that the area under the ROC curve increases significantly when evaluating the slope failure probabilities yielded with r.slope.stability at the level of slope units instead of pixels. At the level of slope units, the physically-based model r.slope.stability outperforms statistical models applied to the Collazzone Area. However, there is good reason to discuss the validity and the usefulness of different levels of discretization.