GHZ-05 Remote sensing and GIS technologies for geohazard monitoring

Simulation of debris flows based on open source GIS

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A GIS-based model framework, designed as a raster module for the Open Source software GRASS, has been developed for simulating mobilization and movement of debris flows triggered by heavy rainfall. Designed for study areas of up to few square kilometers, the tool includes the following modules:

(1) Infiltration and surface runoff: water input from rainfall is distributed among the pools vegetation (interception), soil (Green-Ampt infiltration model), and surface runoff, which is calculated using the Manning-Strickler formula;
(2) Sediment transport: detachment of soil by surface runoff is estimated using a sediment transport model;
(3) Slope stability: an infinite slope stability approach is applied for detecting locations of potential slope failures which may contribute to debris flows;
(4) Debris flow mobilization: rules based on sediment concentration or water content and cohesion are applied to identify if detected areas of potential slope failure and erosion tend to produce a debris flow;
(5) Runout and deposition: a numerical model based on the Savage-Hutter theory for granular flow was implemented into GRASS and applied for estimating the runout distance of the identified debris flow material as well as the patterns of deposition. The results are compared to those yielded by empirical rules and equations.
The model framework was applied to some selected study areas along the international road from Mendoza (Argentina) to Central Chile. All necessary parameters were investigated on a local scale: Soil samples were taken in the field and analyzed for their mechanical characteristics. Hydrological characteristics were derived using pedotransfer functions. High-resolution terrain models were generated from stereo imagery.
The model was evaluated using field observations, historical archives, meteorological data, and the results of previous investigations in the area. Worst case scenarios and rainfall thresholds were worked out for the study areas as far as possible. The model output is quite sensitive to a number of parameters which are hard to capture (e.g. preferential flow through soil macropores, bed friction angle for debris flow runout), leading to uncertainties in the results which were quantified by an analysis of sensitivity.
The model framework as described above is mainly suitable for rainfall events of high intensity and short duration: the infinite slope stability model yields realistic results for shallow translational failures mainly connected to such events, but large uncertainties remain in the case of debris flows deriving from deep-seated rotational failures which are rather triggered by rainfall of long duration; therefore a better suited model approach for such failure mechanisms shall be added in the future; also more sophisticated approaches for soil water movement would be required for modelling the initiation of debris flows triggered by rainfall events of long duration.