Geophysical Research Abstracts,
Vol. 10, EGU2008-A-00000, 2008
EGU General Assembly 2008

Landslide susceptibility zonation in the Flemish Ardennes, Belgium, using multiple statistical models and different mapping units

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We describe an attempt to determine landslide susceptibility using multiple statistical models and different terrain partitioning units. The study area extends for 277 km^2 in the Flemish Ardennes, Belgium. For this study area, a landslide inventory map showing 158 landslides is available. The inventory map was prepared through field surveys and the analysis of LIDAR-derived hillshade maps. For the study, two terrain subdivisions based on different mapping units (i.e. slope units and grid cells), and four statistical models (i.e., linear discriminant analysis in R, canonical discriminant analysis in SPSS, logistic regression in R, and rare events logistic regression in R) were prepared. Slope units were obtained using specialised software that generated drainage and divide lines from a 10 m x 10 m DEM and a map showing the location of main rivers. For the raster analysis, the same 10 m x 10 m pixel resolution was adopted. As independent variables for the susceptibility zonation, geomorphological, lithological and soil parameters were used.

Exploiting the terrain subdivision into slope units, four statistical models were constructed, calibrated and critically evaluated. The model prepared adopting canonical discriminant analysis was selected for comparison with the grid-based landslide susceptibility model. For the grid-based analysis, the environmental characteristics shown by a single, central pixel located in the depletion area of each landslide were used. The

resulting susceptibility map portrays the propensity to failure of the source (depletion) area of the mapped landslide. This is different from the slope-unit based model, which shows the propensity of an individual slope unit to contain one or more of the know landslides, and - by inference - the propensity of the mapping unit to generate future slope failures.

The two discriminant models (based on slope units and on grid cells, respectively) were tested using a dataset of 34 recent landslides, produced or reactivated during the 1990-2006 period. These landslides were not use for the production of the susceptibility models. Since many of these recent landslides are located within the older landslides used to prepare the models, the quality of the obtained susceptibility maps was further investigated. Fifty model runs were prepared, each using 80% mapping units for model production and 20% mapping units for model validation. The large ensemble of models allowed for the quantitative evaluation of the relevance of the independent variables (predictors), the estimation of the average probability of landslide susceptibility for each mapping unit, and the estimation of a model prediction error in each slope unit.

An attempt was made to combine the results obtained with the different landslide susceptibility modelling. For the purpose, a multi-level landslide susceptibility map was prepared. The map was obtained by superimposing in a GIS (i) the landslide inventory map, (ii) the grid-based susceptibility map, and (iii) the slope-unit based susceptibility map. A table showing landslide susceptibility using a three-digit code complements the map. For each code, the three digits allow for the identification of the propensity to landslide failure shown in the three original maps. Given the high number of combinations, a simplified scheme of landslide susceptibility is proposed. The multi-level landslide susceptibility map and the associated table, aided by field surveys, can support planners and decision makers in the delineation of zones where landslide measures are required to mitigate the risk of landslide damage.