Geophysical Research Abstracts, Vol. 7, 06211, 2005
SRef-ID: 1607-7962/gra/EGU05-A-06211

Unraveling hidden landslides in the Arno river basin (Italy) through neural networks

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Catchment scale hazard maps are invaluable tools for landslide pre-disaster planning and mitigation. Their contribution may also be of key importance in optimizing the general costs of implementation of risk management strategies. It is important, however, to adopt specific methodologies, targeting the prevailing types of mass movements in the area of interest. For example, the development of susceptibility models for slow deep-seated landslides at basin-scale requires a fairly different set of assumptions than in the case of prediction of first triggering in shallow landslides. This is the case of the Arno river basin (central Italy, ca. 9000 km^2) where a 2004 inventory project sponsored by the River Basin Authority recognized about 26,000 slow deep-seated landslides out of a total of about 28,000 mapped mass movements. In this context it is clear that, for the spatial prediction of the reactivation of large landslide bodies, inventory maps have a fundamental role and the completeness of the database is a key factor. Prediction methods must primarily be aimed at obtaining or verifying such requirement through techniques able to reveal the position of hidden or not recognized mass movements. This is of paramount importance when using statistical methods that rely on known data to derive weighting factors. A new methodology for the automatic reconnaissance of susceptibility areas and the subsequent detection of possible hidden mass movements is presented here. The method relies upon a statistical weighting of typical landslide preparatory and morphometric factors, such as geomechanical classification, land cover, slope gradient, slope curvature and upslope contributing area. The overlay of preparatory factors generated a large ($> 10^6$) number of unique condition units over the whole catchment. The weighting functions for the combination of the 5 independent variables have been obtained through the generation and validation of a series of neural networks able to predict, for each terrain unit, the degree of belonging to the class “landslide body”. Due to the large dimension and to the physical variability within the basin, the whole area has been split up in five different homogeneous physiographic domains. For each subdivision a different set of artificial neural networks has been prepared and applied. In general, the best predictors were found to be networks of the generalized regression (GRNN) type. Training and testing of the networks were carried out using chosen high-quality subsets of the inventory, in which the accuracy and completeness of the landslide mapping was known to be high (and improved substantially by dedicated field survey campaigns). Afterwards, the best predictors were applied to the whole physiographic domain and the classification results checked against the inventory itself. Average training errors range from 3 to 5%. More than 90% of mapped landslides are correctly classified by the predictors. Post-analysis field surveys showed that negative errors, i.e. mapped landslides not recognized by the method, may be ascribed either to mapping errors (commonly, soil creep or solifluction erroneously interpreted as deep-seated mass movement) or to differences in lithology not adequately reported in the geological maps used for the generation of terrain units. Positive errors (i.e. terrain units with high landsliding probability and no mapped landslides) were generated in many cases, as expected, by the presence of hidden landslide bodies that escaped the aerial mapping. The remaining positive errors most likely represent areas with marginal hillslope stability in which future movements can be expected. The final result of the research is an effective tool that could highly improve the definition of accurate landslide hazard and risk maps at basin scale.