Geophysical Research Abstracts, Vol. 7, 06197, 2005
SRef-ID: 1607-7962/gra/EGU05-A-06197

Earthquake-induced landslide scenarios: a GIS-based application

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Earthquakes trigger several kinds of ground failure phenomena, the most important and hazardous one being sure landslides. The local civil protection agencies need to plan their emergency activities prior the catastrophe occurs, thus to be prepared to promptly bring assistance to the population injured. One of the most or, probably, the most useful tool to do this, is the formulation of scenarios, describing how the dangerous event manifest itself, its consequences in terms of damages and losses and the countermeasures to be adopted to limit such negative effects. The present work deals with an example of earthquake-induced landslide scenarios carried out in an area close to the town of Urbino (Central Italy) where several mass movements affect the landforms even under static conditions. Recent seismotectonic studies pointed out the potential of earthquakes as large as 6 in magnitudes at distances not farer than 11 km. Therefore, a seismic hazard analysis for the area has been performed using two alternatives, mutually exclusive but collectively exhaustive, approaches: a probabilistic one vs. a deterministic one. The first has the potential to investigate a reference time interval, suitable, for instance, for a long-term planning of the land use. The second one is powerful for providing the worst-case scenario or, to borrow a terminology in use in the nuclear siting, the maximum credible earthquake that maximizes the collateral hazards. Both seismic hazard analyses were performed computing expected Arias Intensity's values, as the ground motion parameter recognized to be the better one to represent the effects of seismic excitations on the landslides behaviour. Landslides affecting the study area have been characterized from the geological (lithology and structural setting), geomorphological (kinematics and slope gradient) and geotechnical (physical and mechanical parameters) points of view. All the information have been stored in a spatially-referred database, ready to be analysed by means of a GIS

tool (Arcinfo platform). Two kinds of analyses were performed: one referring to the spatial extent of the whole area (spatial analysis by pixels); the second one referring to the boundaries of the landslide bodies (local analysis). For both the analyses the coseismic displacements according to the Newmark's sliding block model, was assumed as a relative index of landslide performance under the seismic action. Newmark's displacements with a 10% chance to be exceeded as well as probabilities that a threshold displacement of 10 cm be exceeded within a reference time period of 50 years, were computed in the probabilistic analysis. Median, as well as 84-percentile of Newmark's displacements due to the maximum credible earthquake, were instead computed in the deterministic analysis. The probabilistic analysis allows computing the mean return periods of landslide reactivations due to earthquakes, thus providing an insight into the landslide hazard. Moreover, overlapping the coseismic displacements computed for the spatial and local analyses, allows highlighting those areas, bordering the landslide bodies, more prone to be involved in the failure by the occurrence of seismic actions, thus focusing on the evolution of the landslide areas in terms of enlargement, retreating or progressing behaviours. The deterministic analysis allows the formulation of the worst-case scenario of earthquake-induced landslide behaviour and it was used to perform a first-level analysis of risk. This analysis was carried out intersecting the landslide body areas - and a convenient buffer around them - failing under the earthquake with the elements at risk present in the areas themselves. A real estate inventory of the area highlighted the presence of houses, roadways and lifelines; for all of them a qualitative assessment of the risk associated with the slope sliding was performed, expressing it in terms of risk certain or potential to fail or collapse. Finally, the powerful of the GIS shall be stressed not only as a tool to store and display geographic data, but, over all, to analyse and perform logical and mathematical operations; at this scope calculation subroutines and macro instructions were specifically programmed to automates the analyses so that the scenario may be easily updated in real-time every time new data are available.