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GIS-based landslide hazard evaluation at the regional scale: some critical points in the permanent displacement approach for seismically-induced landslide maps

Giovanna Vessia (1,2) and Mario Parise (1)

(1) Institute of Research for Hydrogeological Protection, National Research Council, Bari, Italy (m.parise@ba.irpi.cnr.it, +39 080 592 9611), (2) University "G. d'Annunzio", Via dei Vestini 31, Chieti Scalo, 66013, Italy

Landslide susceptibility and hazard are commonly developed by means of GIS (Geographic Information Systems) tools. Many products such as DTM (Digital Terrain Models), and geological, morphological and lithological layers (often, to be downloaded for free and integrated within GIS) are nowadays available on the web and ready to be used for urban planning purposes. The multiple sources of public information enable the local authorities to use these products for predicting hazards within urban territories by limited investments on technological infrastructures. On the contrary, the necessary expertise required for conducting pertinent hazard analyses is high, and rarely available at the level of the local authorities. In this respect, taking into account the production of seismically-induced landslide hazard maps at regional scale drawn by GIS tool, these can be performed according to the permanent displacement approach derived by Newmark's sliding block method (Newmark, 1965). Some simplified assumptions are considered for occurrence of a seismic mass movement, listed as follows: (1) the Mohr-Coulomb criterion is used for the plastic displacement of the rigid block; (2) only downward movements are accounted for; (3) a translative sliding mechanism is assumed. Under such conditions, several expressions have been proposed for predicting permanent displacements of slopes during seismic events (Ambresys and Menu, 1988; Luzi and Pergalani 2000; Romeo 2000; Jibson 2007, among the others). These formulations have been provided by researchers for different ranges of seismic magnitudes, and for indexes describing the seismic action, such as peak ground acceleration, peak ground velocity, Arias Intensity, and damage potential. With respect to the resistant properties of the rock units, the critical acceleration is the relevant strength variable in every expressions; it is a function of local slope, groundwater level, unit weight shear resistance of the surficial sediments, and the assumed depth of the sliding surface. Thus, it is of paramount relevance to correctly understand and describe the dynamic behavior of the lithologies affected by the earthquake. Accordingly, we put here in evidence some critical points in the application of the permanent displacement formulations by considering the case study of Santa Susana Mountains (California, USA) shaken by the Northridge earthquake in 1994. During this earthquake, a high number of registrations has been collected, whilst soon after a careful inventory of the mass movements triggered by the shaking has been produced, together with analysis of the related failure mechanisms. Hence, these data allow to perform a back analysis in order to verify the reliability of some numerical expressions, such as those proposed by Ambraseys and Menu (1988), Romeo (2000), and Jibson (2007), with respect to the possible dynamic behavior of the lithologies affected by landslides. In this sector of California, the following lithologies crop out, that were involved in shallow landslides: (1) Quaternay deposits; (2) Saugus Formation; (3) Towsley Formation; (4) Pico Formation; (5) Topanga Formation; (6) Modelo Formation; (7) Simi Conglomerate; (8) Santa Susana Formation; (9) Llajas and Chatsworth Formations. The surveys carried out after the Northridge earthquake (Harp and Jibson, 1995), and the analysis of landslide distribution (Parise and Jibson 2000) pointed out that the strongest formations with slopes higher than 50° mainly suffered toppling or fall failures: thus, our hazard maps based on permanent displacements did not take into account such range of slopes. Further, areas with slopes lower than 10° were not affected by relevant mass movements. Thus, a limited range of slopes (between 10° and 45°) was considered in the analyses, with depth of the sliding surface varying between 1 and 3 m, and using the resistance parameters of involved lithologies obtained from in situ and laboratory tests performed by local practitioners.

Seismically-induced landslide hazard maps have been drawn using the aforementioned three expressions. The preliminary results show Quaternary deposits (including alluvium deposits, slope wash, and terrace deposits) as the lithologies most affected by permanent displacement. Moreover, Towsley and Modelo formations, that are stiffer than the previous rock units, and consist mostly of shales, siltstones and subordinate sandstones, show high hazard value where the slopes increase. The relevant role of local slope in permanent displacement extent is evident where lithologies are characterized by both cohesive and frictional resistance components. Finally, a comparison among the maps produced by using the three expressions for permanent displacements is discussed.

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