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Estimating Newmark displacement on a regional basis using GIS: Application to the Lorca Basin (SE Spain)

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The Lorca Basin is located in the Eastern Betic Cordillera (SE Spain). Three seismic series have recently struck this area: 1999 Mula (m_{bLg}=4.8, I_{EMS}=VI), 2002 Bullas (m_{bLg}=5.0, I_{EMS}=V), and 2005 La Paca (m_{bLg}=4.7, I_{EMS}=VI–VII). Despite their small magnitude, these earthquakes produced significant damage on buildings, as well as induced slope instabilities –mainly rock falls. In this work, we present a map of the Lorca Basin and neighbouring areas in terms of Newmark displacement (N_D) as a first step in studying seismically induced slope instabilities at specific locations. The construction of the N_D map is based on GIS technology (ArcGIS) and results from computing several sets of maps in order to: (1) arrive at a critical acceleration map –i.e., the minimum horizontal acceleration to overcome shear resistance and initiate sliding, provided the static safety factor is known and, (2) estimate N_D –i.e., the expected slope displacement due to strong ground motion, combining the critical acceleration map with a seismic input motion map.

To produce the critical acceleration map, a lithological map was firstly arranged from 1:50,000 and 1:200,000 scale digital geological maps from the Spanish Geological Survey (IGME). Strength parameters –specific weight, cohesion and friction angle– were assigned to each lithological unit based on geotechnical bibliography as well as from available geotechnical tests. Then, a map of static safety factors was calculated computing the strength parameters maps with a slope map derived from a 25x25 m

pixel digital elevation model. Finally, the safety factor map was combined with the slope map to produce the critical acceleration map, which can be regarded as a seismic landslide susceptibility index.

To estimate N_D, both probabilistic and deterministic seismic input scenarios have been considered. The former considers three hazard maps in terms of peak ground acceleration (PGA) corresponding to the 475-, 975- and 2475-year return periods. Deterministic scenarios are considered assuming the occurrence of the most probable earthquake for a 475-year return period (M_w=5.0) at every location, or either a complete rupture of the Lorca-Totana (M_w=6.7) or the Puerto Lumbreras-Lorca (M_w=6.8) segments of the Alhama de Murcia fault. Input PGA values are referred to rock conditions, so they were corrected to allow for soil and topographic amplification effects. Soil amplification factors were adopted from a previous study (RISMUR project), while the topographic factor was evaluated considering the slope and relative height of the ridges, following Eurocode-8 provisions. Finally, PGA scenario maps were computed with the critical acceleration map by means of Jibson (2007) regression equation that correlates N_D to the critical acceleration ratio (a_c/PGA).

Estimated N_D from the probabilistic scenarios shows very low values, mostly lower than 2 cm –although at very few locations they are higher than 5 cm. The M_w=5.0 deterministic scenario draws similar results. Spatial distribution of N_D delineates small and scattered areas, which become wider accordingly to the return period considered. On the other hand, deterministic scenarios considering segment ruptures of the Alhama de Murcia Fault produce higher N_D, which are very frequently higher than 2 cm and, locally, higher than 10 cm. Furthermore N_D distributes in much wider areas including embankment slopes of intrabasinal drainage.

In summary, our study suggests that future earthquake-induced slope instabilities in the Lorca Basin would be fundamentally disrupted slides, particularly rock-falls at specific locations. Only the occurrence of a great earthquake (M_w=6,7-6,8) appears to be able to induce widespread instabilities and coherent slides.