SUSCEPTIBILITY ANALYSIS OF CO-SEISMIC SLOPE INSTABILITIES IN THE MURCIA REGION (SE SPAIN) CONSIDERING SITE EFFECT

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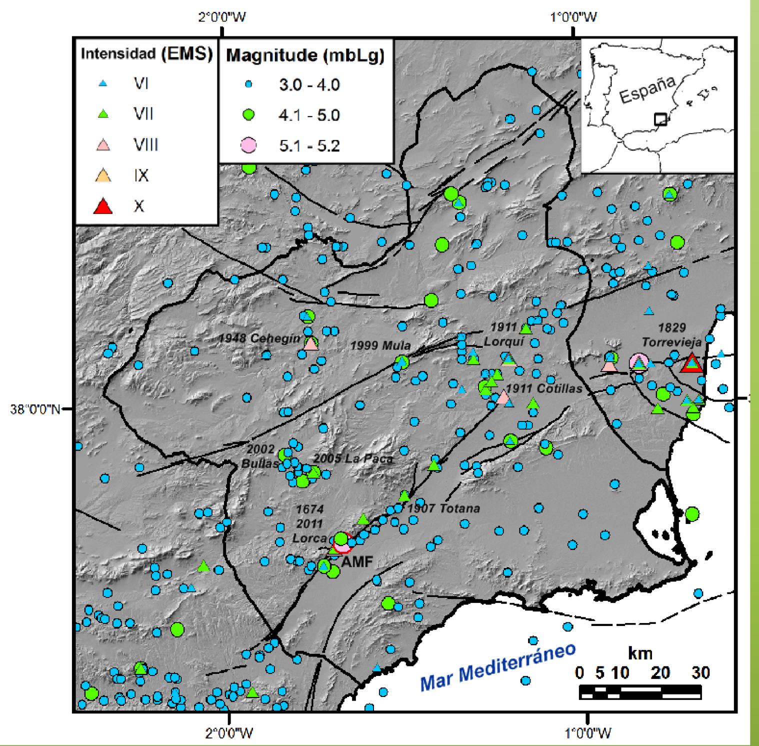
The Murcia Region (SE Spain) is a seismically active zone with several active faults that can potentially generate earthquakes of magnitudes higher than M_w 6.0 (e.g. Alhama de Murcia fault). Considering the geology and topography of the region, there are several prone areas to slope instability processes. These areas comprise soft and poorly consolidated soils (Quaternary sand and gravels), highly fractured and alterable rock masses (limestone and clay marls) that, together with the possibility of an earthquake of sufficient magnitude, can trigger or reactivate slope movements close to some densely populated urban centers. An example of this is the Lorca earthquake of May 11, 2011, with a magnitude of M_w 5.2 and that was preceded by an event of magnitude M_w 4.6, which caused numerous damages in Lorca, as well as great social concern. This earthquake also produced slope instabilities of greater importance, up to a distance of more than 10 km from the epicenter, and which have been varied in their typology and size, reaching sometimes hundreds of cubic meters during the shaking (IGME, 2011; Alfaro *et al.*, 2012; Rodríguez-Peces *et al.*, 2013). These facts justify the need to obtain maps that identify areas that are prone to slope instability.



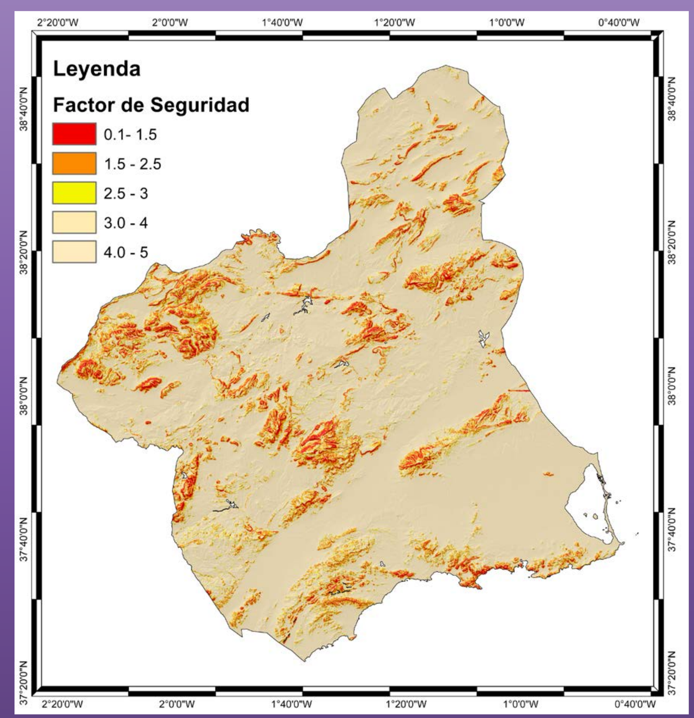
Earthquakes registered in Murcia Region (SE Spain). The thin black lines represent the main active faults in the area (García Mayordomo et al., 2012), highlighting the Alhama de Murcia Fault (AMF).

In this work, we show the result of the regional analysis of susceptibility of slope movements by earthquakes in the Murcia Region using two methodologies: the well-known Newmark displacement (Jibson, 2007) and the Susceptibility Coefficient or $a_{c,efe}$/PGA ratio (Tsige *et al.*,2012) methods. The susceptibility was estimated by comparing the effective critical acceleration ($a_{c,efe}$) with the peak ground acceleration (PGA) obtained from the seismic hazard map for a return period of 475 years in Murcia Region (Benito *et al.*, 2006). The effective shear strength parameters used to obtain the $a_{c,efe}$ were considered for different situations depending on the geological and geotechnical condition of the area. For example, for pre-existing shear surfaces, old landslides, sheared joints or faults, the post rupture or the joint strength parameter was considered. Residual conditions were used in the highly fissured marly clays and shales. In addition, the amplification factor (site effects) was taken into account due to geological materials (Tsige and García Flórez, 2006) and topography (Allen and Wald, 2009). Finally, the susceptibility maps obtained using the two methods were compared with current landslide inventory maps in the region.

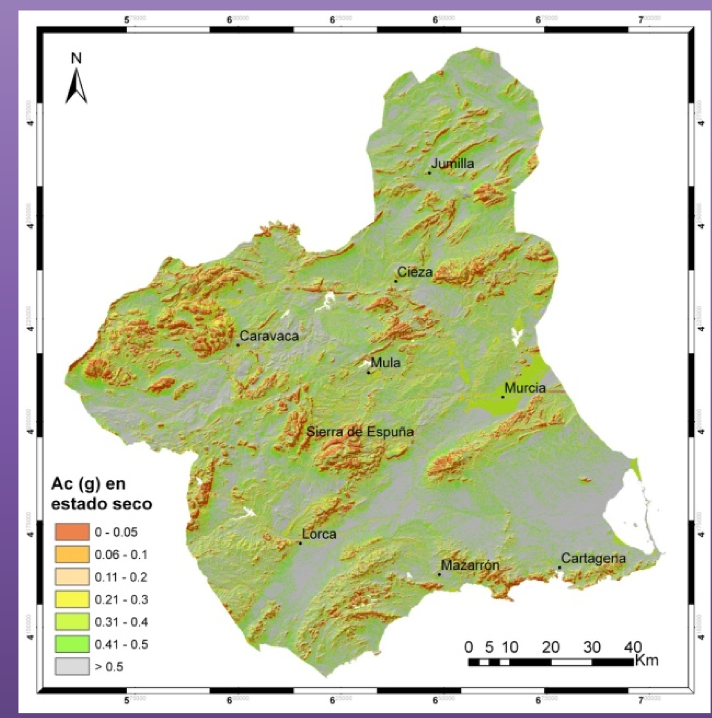
SAFETY FACTOR AND CRITICAL ACCELERATION

GEOTECHNICAL GROUP	Unit weight (kN/m³)	Cohesion (kN/m²)	Friction angle (°)
I: Very hard and low fractured rock	27	150	40
IIa: Hard and fractured rock. Intercalation of very hard and hard rocks	25	50	25
IIb: Very fractured hard-medium rock and intercalation of soft rocks	17	50	20
III: Very fractured medium rock with abundant intercalation of soft rocks (marl and clay)	15	10	20
IV: Soft rocks with expansive clays. Non-cohesive, lightly cemented soils	15	5	20
V: Non-cohesive soils, gravels and sands	14-16	10	15
VI: Soft cohesive soils: clay, silt and loose sands	13-14	0	10

SAFETY FACTOR

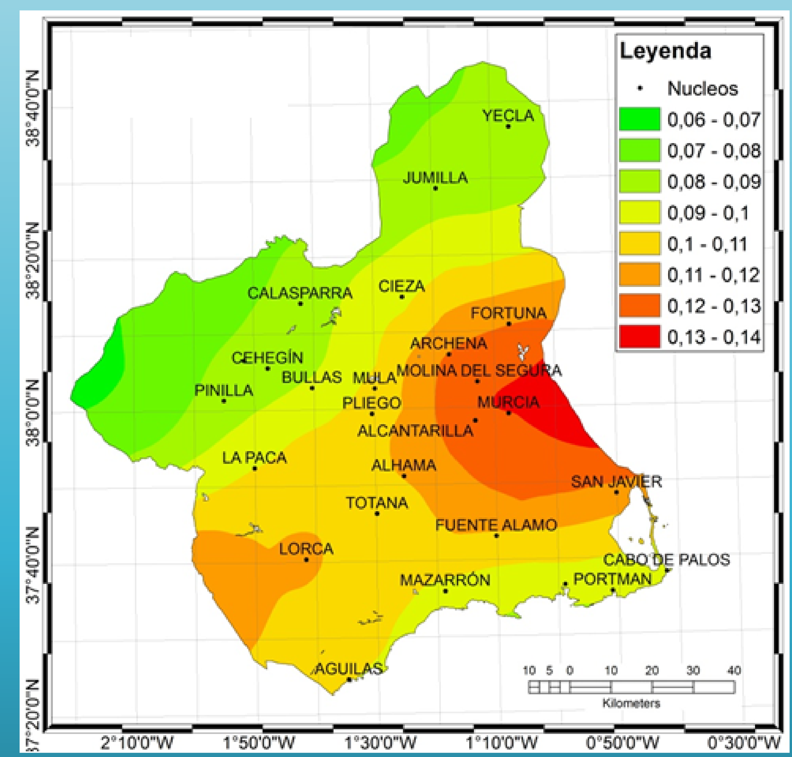


EFFECTIVE CRITICAL ACCELERATION

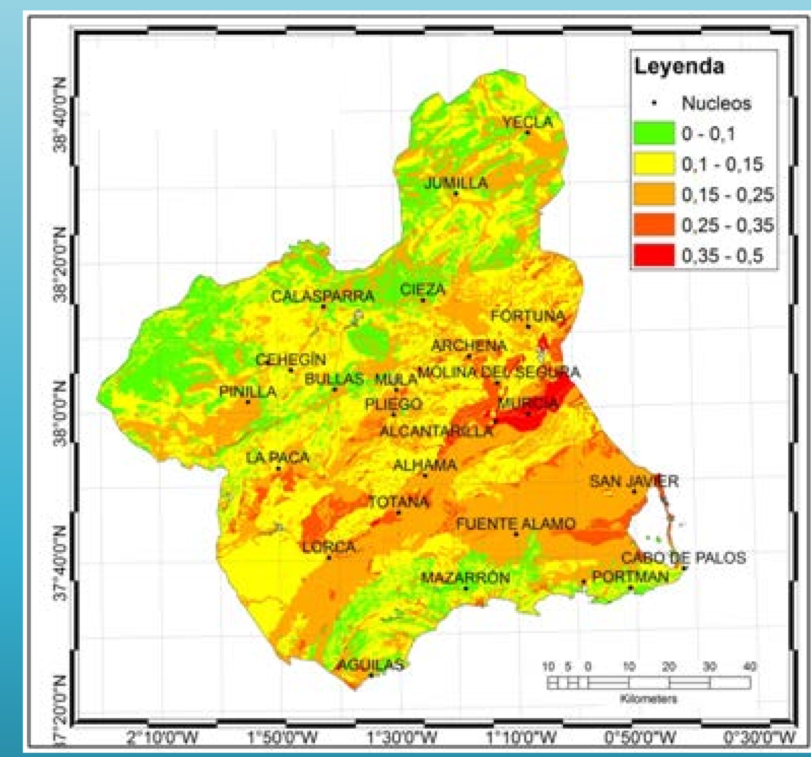


SEISMIC HAZARD

PGA on rock

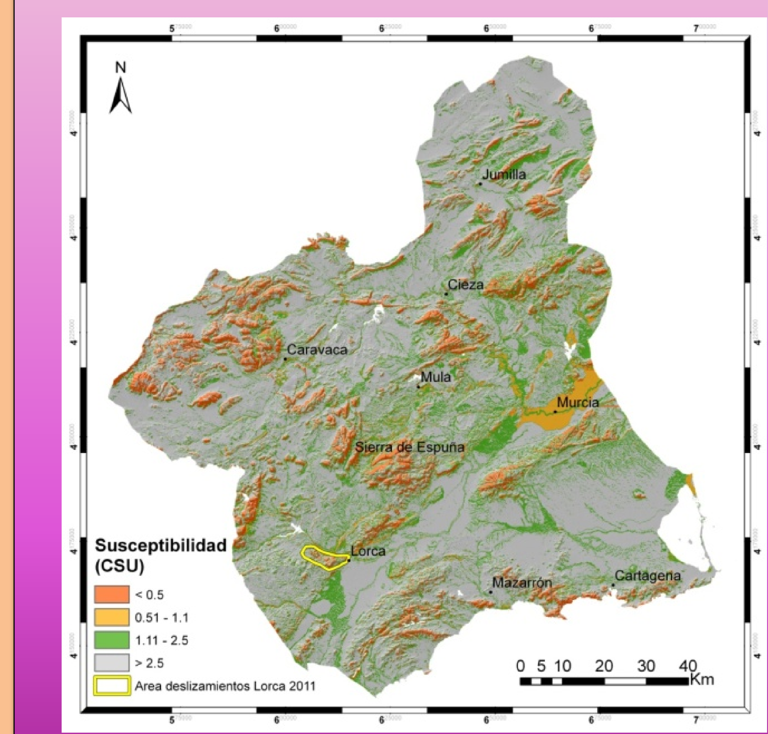


Amplified PGA

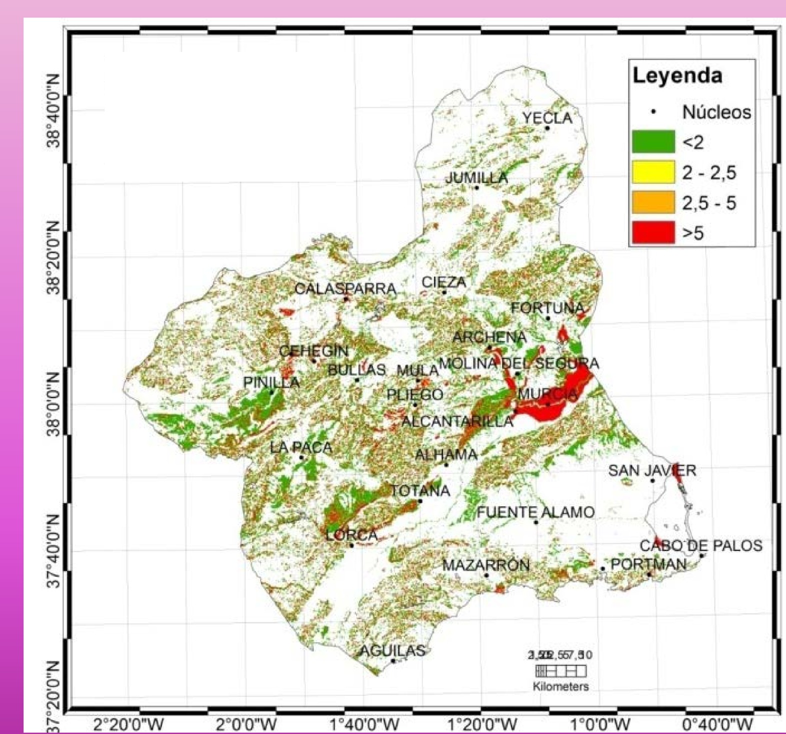


CO-SEISMIC SUSCEPTIBILITY MAPS

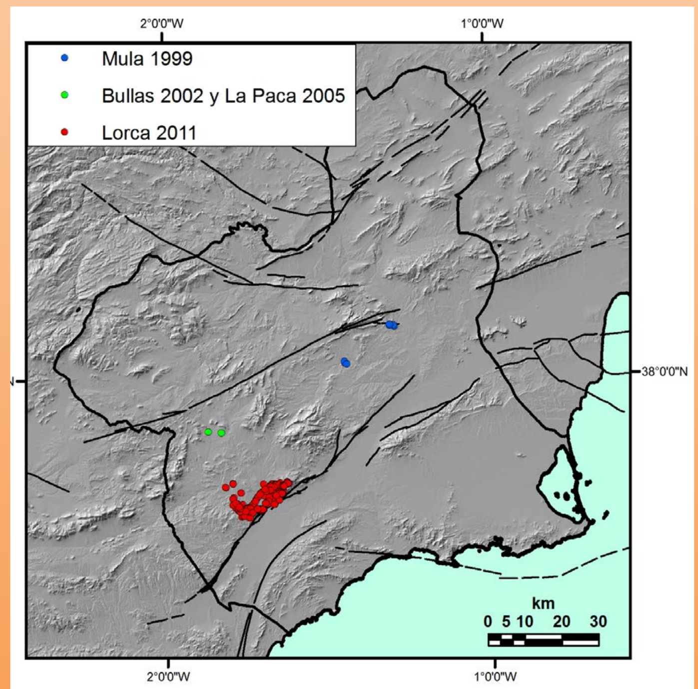
Based on $a_{c,efe}$/PGA

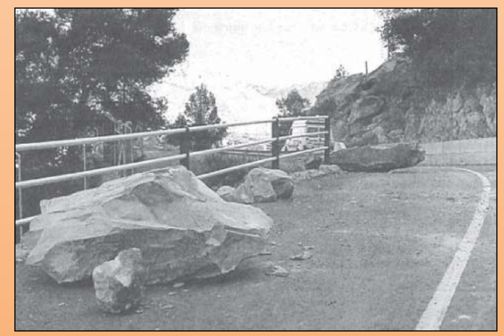


Based on Newmark displacement



EARTHQUAKE-TRIGGERED SLOPE INSTABILITIES IN MURCIA REGION





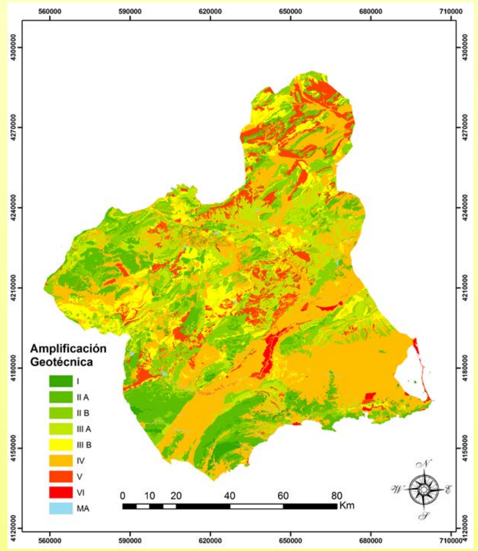
1999 Mula earthquake (M_w = 4.8)
(Mulas et al., 2016)

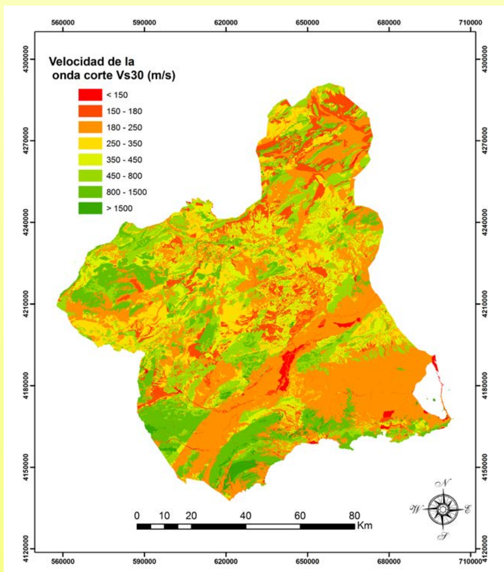
2005 La Paca earthquake (M_w = 4.8)
(Rodríguez-Peces et al., 2008)

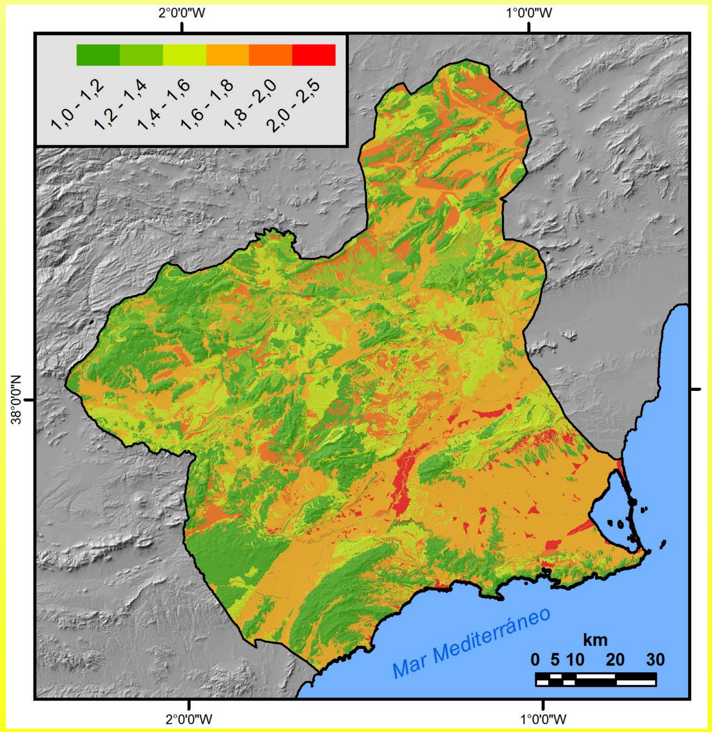
2011 Lorca earthquake (M_w = 5.1)
(Martínez-Díaz et al., 2012; Alfaro et al., 2012)

SEISMIC AMPLIFICATION

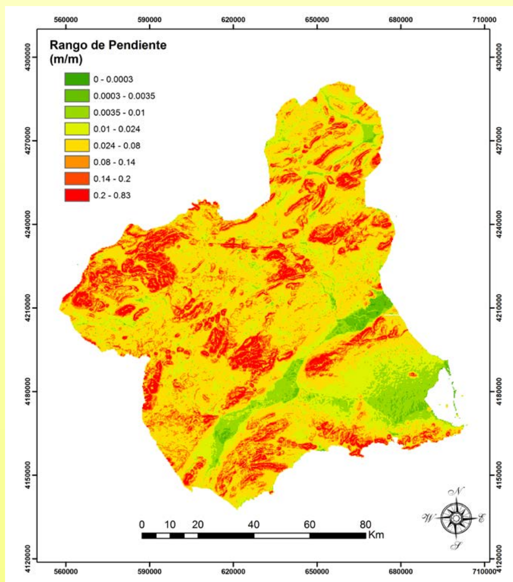
BASED ON GEOLOGY

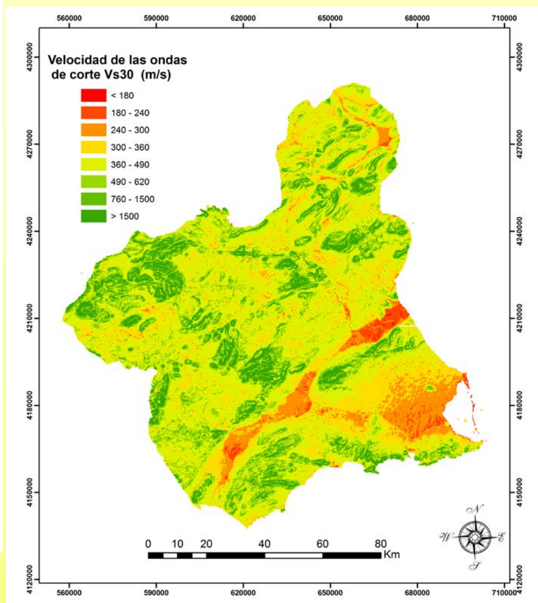


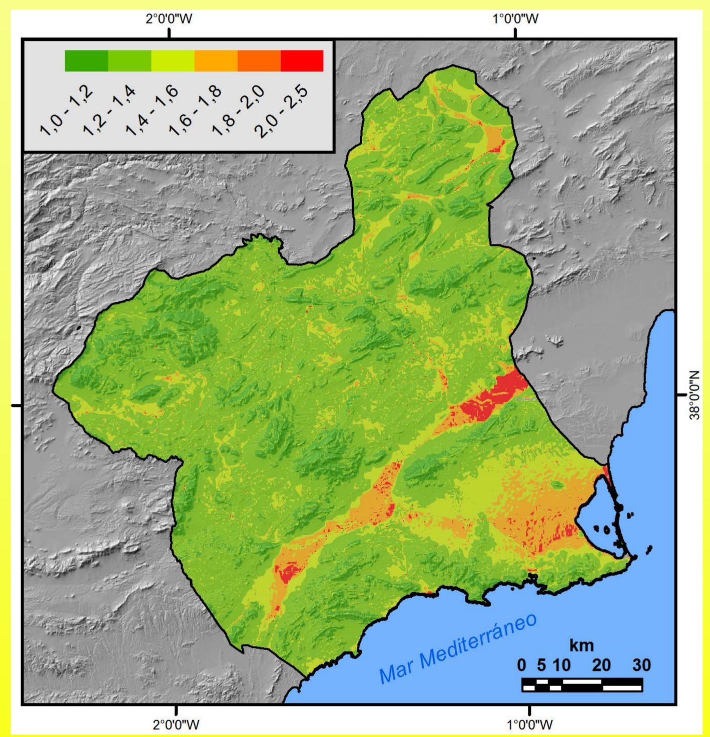




BASED ON TOPOGRAPHY







CONCLUSIONS

The most relevant factor in the co-seismic susceptibility maps (particularly in estimating the safety factor) is a suitable adjustment of the strength parameters in real field conditions. Results show large susceptible areas in which some type of slope instability could take place for the seismic scenario considered. These zones are related to rock falls in outcrops of fractured rocks, with slopes between 20°-30°. There were identified also as susceptible areas with low slopes (< 10°) and recent soft deposits of colluvio-alluvial type, where there is a possible high seismic amplification by lithology (site effect), being able to trigger shallow soil slides and lateral spreading.

If we compare these results with the current co-seismic instabilities inventories, a coincidence of more than 80 % is observed in the Susceptibility Coefficient map while 44 % in the Newmark displacement map. In this sense, the Susceptibility Coefficient method seems to be more suitable to predict areas with a certain level of susceptibility combined with a concrete lithology and topography conditions.

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References

Alfaro, P., Delgado, J., García-Tortosa, F.J., Lenti, L., López, J.A., López-Casado, C., Martino, S., 2012. Widespread landslides induced by the Mw 5.1 earthquake of 11 May 2011 in Lorca, SE Spain. Engineering Geology, 137-138: 40-52.
Allen, T.I., Wald, D.J., 2009. On the Use of High-Resolution Topographic Data as a Proxy for Seismic Site Conditions (VS30). Bulletin of the Seismological Society of America, 99: 935-943.
Benito, B., Gaspar-Escribano, J.M., García-Mayordomo, J., Jiménez, M.E., García Rodríguez, M.J., 2006. Proyecto RISMUR: Evaluación de la peligrosidad sísmica. IGN y Protección Civil de Murcia, Madrid.
García-Mayordomo, J., Insua-Arévalo, J., Martínez-Díaz, J., Jiménez-Díaz, A., Martín-Banda, R., Martín-Alfageme, S., Álvarez-Gómez, J., Rodríguez-Peces, M., Pérez-López, R., Rodríguez-Pascua, M., Masana, E., Perea, H., Martín-González, F., Giner-Robles, J., Nemser, E., Cabral, J., & QAFI compilers, 2012. The Quaternary Active Faults Database of Iberia (QAFI v.2.0). Journal of Iberian Geology, 38: 285-302.
IGME, 2011. Informe Geológico Preliminar del Terremoto de Lorca del 11 de mayo del año 2011, 5.1 Mw. Instituto Geológico y Minero de España, Madrid. 35 pp.
Jibson, R.W., 2007. Regression models for estimating coseismic landslide displacement. Engineering Geology, 91: 209-218.
Martínez-Díaz, J.J., Álvarez-Gómez, J.A., García-Mayordomo, J., Insua-Arévalo, J.M., Martín-González, F., Rodríguez-Peces, M.J., 2012. Interpretación tectónica de la fuente del terremoto de Lorca de 2011 (MW 5,2) y sus efectos superficiales. Boletín Geológico y Minero, 123: 441-458.
Mulas, J., García-Davalillo, J.C., Sanabria, M., García-Mayordomo, J., Aragón, R., Rodríguez-Peces, M.J., Delgado, J., 2016. Puntos y zonas susceptibles a movimientos de ladera por terremotos en la Comunidad Autónoma de la Región de Murcia (CARM). Información de base para Protección Civil. Geo-Temas, 16 (1): 677-680.
Rodríguez Peces, M.J., García Mayordomo, J., Azañón, J.M., Jabaloy Sánchez, A., 2008. Evaluación regional de inestabilidades de ladera por efecto sísmico en la Cuenca de Lorca (Murcia): Implementación del método de Newmark en un SIG. Boletín Geológico y Minero, 119: 459-472.
Rodríguez-Peces, M.J., García-Mayordomo, J., Martínez- Díaz, J.J., 2013. Slope instabilities triggered by the 11th May 2011 Lorca earthquake (Murcia, Spain): Comparison to previous hazard assessments and proposition of a new hazard map and probability of failure equation. Bulletin of Earthquake Engineering, 12: 1961-1976.
Tsige, M., García-Flórez, I., 2006. Propuesta de clasificación geotécnica del "Efecto Sitio" de las formaciones geológicas de la Región de Murcia. Geogaceta, 40: 39-42.
Tsige, M., García-Flórez, I., Rodríguez-Peces, M., Solano, V., Calderón, N., 2012. Análisis de Susceptibilidad de movimientos de ladera co-sísmicos en la Región de Murcia. Geotemas, 13.