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Susceptibility analysis for seismically-induced landslides: application to the 2001 earthquakes in El Salvador (C.A.)

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The geodynamic context in which El Salvador is located, made of a convergent structure characterized by the interaction among six different plates, together with the lithological characteristics of the outcropping rocks and soils (mainly corresponding to deeply weathered acid pyroclastites, basic effusive rocks and volcanic ashes), are responsible for the very high seismically-induced landslide susceptibility of the country. These predisposing factors were decisive on the occurrence of thousands of seismically-induced landslides caused by two huge earthquakes on 13th January and 13th February 2001, which triggered thousands of landslides in the country. In particular, the February event (6.6M, onshore and intraplate at a depth of 10 km) triggered 5,371 landslides in an area of around 300km^2. These gravitational phenomena took the form of debris slides, earth slides and debris flows and affected several inhabited areas damaging infrastructures and crops and causing, respectively 844 and 315 fatalities.

Thanks to aerial photos taken soon after the days following both the two earthquakes and made available by the CNR (Centro Nacional de Registros - Instituto Geográfico y del Catastro Nacional), associated landslide maps have been prepared, where each phenomenon is represented by a landslide polygon and its LIP (Landslide Identification Point), located in the crown of the landslide. In particular, static landslide susceptibility models were prepared for the Ilopango (1594 landslides in an area of around 40km^2) and the San Vicente (1602 landslides in an area of around 108 km^2) sectors, by regressing the spatial distribution of the 13th February seismically-induced landslides on a set of explanatory variables obtained by a geologic map and a 10m pixel DTM (Digital Terrain Model). At the same time, shaking-dependent models were prepared by including also PGA (Peak Ground Acceleration) and the epicentral distance (ED) among the predictors.

For both the two areas a marked increase of performance was observed (AUC from 0.70 to 0.75, for Ilopango, from 0.73 to 0.77, for San Vicente) from the static to the shaking-dependent models, highlighting the role of the seismic acceleration in the triggering of the landslides both in activating the susceptible sites and in lowering the score threshold for slope failures occurrences. Besides, for the Ilopango sector, a rainfall-induced susceptibility model was also prepared, exploiting a landslide inventory available for the 2009 IDA/12E storm events. The obtained score was then combined with PGA and ED to predict the spatial distribution of the seismically induced landslides, obtaining a higher performance than the relative basic model (AUC = 0.75).

The results obtained from the research demonstrate suggest the possibility to couple the susceptibility scores obtained from static modelling to the expected mechanical shaking for the seismically-induced susceptibility assessment.

The whole modelling was carried out by applying MARS (Multivariate Adaptive Regression Splines) analysis through RStudio and SAGA GIS freeware software.