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Landslide activity in Fogo Volcano (S. Miguel, Azores) resulting from the 2005 seismic crisis: susceptibility assessment based on statistical and deterministic models

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Since May 10th 2005 a seismic crisis, with more than 46000 registered earthquakes between May and September, started in Fogo-Congro seismogenic region (S. Miguel Island, Azores) with some periods of increasing seismic activity as it is the case of the 20th and 21st September. During this two days, two earthquakes (Ml=3.9 and Ml=4.3 respectively) occurred and were responsible for extensive slope failure in the central part of São Miguel Island, triggering more than 100 slope movements, mainly debris flows and shallow soil slips usually evolving downslope into debris flows. Some rural roads were temporarily closed and dams were formed due to landslides.

The earthquake-triggered landslides were identified and mapped through systematic field surveys, and latter integrated into a GIS for landslide susceptibility modelling purposes. The landslide susceptibility associated with the earthquake-triggered event was assessed at a regional scale using both statistical and deterministic methods taking in consideration the rupture zones of slope movements.

Assessment of landslide susceptibility is based on the assumption that future landslides can be predicted by statistical relationships between past landslides and the spatial data set of relevant predisposing factors. In the present work, we use Spatial Data Analysis (SDA) techniques to evaluate the likelihood of future landslide occurrence, adopting both bi-variate (Weighs of Evidence, WofE) and multivariate (logistic regression) methods. Considered variables include: landslide distribution, slope angle,

slope aspect, transversal slope profile, lithology, land use and distance to earthquake epicenter.

Data integration of variables is made over unique condition sub-areas obtained by the overlay of the considered thematic layers allowing the definition of susceptibility scores for each variable case, and the computation of favourability values (susceptibility indicators) for each pixel of the study area. Results of the statistically based landslide susceptibility assessment are validated through an independent cross-validation technique. The original landslide data set is split in two comparable groups using a random criterion. The first sub-set (landslide estimation group) is used to obtain a new prediction map, and the second sub-set (landslide validation group) is compared with the prediction results for validation through the computation of prediction-rates curves and of the correctly classified pixel index.

Landslide susceptibility is also evaluated through the application of the 2D deterministic infinite slope model. This method allows the computation of a Factor of Safety (FS) for each 10x10m pixel combining lithological and morphometric characteristics. Geotechnical properties of volcanic materials (cohesion and angle of internal friction) were derived for each pixel from regional standard values, using the database of the Regional Civil Engineer Laboratory (LREC) obtained by shear strength tests. The dynamic effect of the earthquakes in the slopes FS was computed through the earthquakes seismic acceleration peaks.

Obtained results on landslide susceptibility assessment based on statistical and deterministic models are critically compared in order to better define the probable locations of future earthquake-triggered landslides in the context of a seismic crisis similar to the one verified in 2005. Results of the present work can be used to mitigate the landslide risk, namely concerning future land use and emergency planning measures.