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Active tectonics as determinant factor in GIS landslides susceptibility mapping: application to the SW border of Sierra Nevada (Granada, Spain)

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In the SW border of Sierra Nevada (Granada, Spain) metamorphic materials of the Alpujarride and Nevado-Filabride Complexes are cropping out as also Neogene and Quaternary post-orogenic deposits. Landslides of different types are abundant and damages to local and regional roads and other infrastructures, villages, cultivations and private properties are yearly considerable. Also there is a widespread regional active tectonics with earthquakes and fault deformation expressed in a particular geomorphic evolution of the landscape developed since Late Miocene times, when the main Alpine tectonic deformations in the Betic Cordillera occurred. This paper presents results obtained to assess the influence of active tectonics as one of the different determinant factor to be accounted for GIS landslide susceptibility mapping. This is made by an approach based on using different active tectonics geomorphic indexes related to the river drainage network, river basins and mountain front, as the stream gradient-length ratio (SL), the basin asymmetry factor (AF), the hypsometric curve and its integer (HC-IH), the valley height-width ratio (Vf), the index of form of the basin (Bs) and the index of mountain-front sinuosity (Smf). These indexes are assessed in a GIS application and supported by field observations of linearly shaped mountain front, fault scarps on recent deposits, alluvial fan deformations, triangular fault-sides, subsiding basins, changes in slope angle of alluvial fans, hanged or under excavated valleys, featuring of slopes flattened by erosion, etc, all of them indicating variable intensity of active tectonics.

A GIS landslide susceptibility modelling and mapping is made based in an inventory

of 980 landslides (71 complex movements, 157 soil flows and shallow soil flow areas, 198 slides, 323 debris flows and 231 rock falls) affecting to 7.4% of the total surface of the study zone. The relationships between each type of landslide and the different determinant factors are analysed in the GIS, including the active tectonic geomorphic indexes, using cross tabulation of landslide distribution (by types) and determinant factors. The assessment of the degree of correlation is made by statistical coefficients (contingence, Goodman-Kruskal and Kolmogorov-Smirnov).

Regarding the active tectonic factor, the GIS analysis showed a significant correlation is observed with the different type of landslides, excepting for soil and debris flow with correlations much less obvious for classes high and very high of active tectonics, explained by its very shallow nature more controlled by soil and debris development, slope steepness and amount of rainfall. In general the observed instable zones are related to steep slopes in under excavated rivers resulting from deforestation, soil erosion and active tectonics. A higher frequency of landslides is related to areas with higher indexes of active tectonic in the southern slopes of Sierra Nevada and also in the northern Sierra of the Guajares, with high to very high values of the active tectonic indexes, until there is a limited frequency of landslides in areas with low values of the active tectonic indexes, as in the north of Sierra de Albuñuelas, and the southwest of Padul village. These correlations between density of landslides and active tectonics intensity, expressed by geomorphic indexes, suggest the usefulness of the integration of the active tectonics between the main determinant factors in landslide susceptibility assessment of mountain alpine areas as it is the case of the Betic Cordillera which may be applied to similar areas around the world.

Finally the landslide susceptibility map for each landslide type are presented. Following the GIS matrix method, these maps were validated both internally, checking out degree of adjustment between landslide inventories and resulting susceptibility classes, and also externally, using inventories of new landslides which occurred afterward during more recent rainfall events. This external validation showed high correlations between new landslides and the available landslide susceptibility classes (G-K$>$0.7) and degree of adjustment above 68% for high to very high susceptibility classes and below 7% for low to very low susceptibility classes, showing the usefulness of these landslide susceptibility maps to forecast future landslide areas.