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Large-area landslide susceptibility with optimized slope-units

Massimiliano Alvioli, Ivan Marchesini, Paola Reichenbach, Mauro Rossi, Francesca Ardizzone, Federica Fiorucci, and Fausto Guzzetti

CNR, IRPI, Research Institute for Geo-Hydrological Protection, Perugia, Italy (massimiliano.alvioli@irpi.cnr.it)

A Slope-Unit (SU) is a type of morphological terrain unit bounded by drainage and divide lines that maximize the within-unit homogeneity and the between-unit heterogeneity across distinct physical and geographical boundaries [1]. Compared to other terrain subdivisions, SU are morphological terrain unit well related to the natural (i.e., geological, geomorphological, hydrological) processes that shape and characterize natural slopes. This makes SU easily recognizable in the field or in topographic base maps, and well suited for environmental and geomorphological analysis, in particular for landslide susceptibility (LS) modelling.

An optimal subdivision of an area into a set of SU depends on multiple factors: size and complexity of the study area, quality and resolution of the available terrain elevation data, purpose of the terrain subdivision, scale and resolution of the phenomena for which SU are delineated.

We use the recently developed r.slopeunits software [2,3] for the automatic, parametric delineation of SU within the open source GRASS GIS based on terrain elevation data and a small number of user-defined parameters. The software provides subdivisions consisting of SU with different shapes and sizes, as a function of the input parameters.

In this work, we describe a procedure for the optimal selection of the user parameters through the production of a large number of realizations of the LS model. We tested the software and the optimization procedure in a 2,000 km2 area in Umbria, Central Italy.

For LS zonation we adopt a logistic regression model implemented in an well-known software [4,5], using about 50 independent variables. To select the optimal SU partition for LS zonation, we want to define a metric which is able to quantify simultaneously: (i) slope-unit internal homogeneity (ii) slope-unit external heterogeneity (iii) landslide susceptibility model performance. To this end, we define a comprehensive objective function S, as the product of three normalized objective functions dealing with the points (i)-(ii)-(iii) independently. We use an intra-segment variance function V, the Moran's autocorrelation index I and the AUCROC function R arising from the application of the logistic regression model. Maximization of the objective function S = f(I,V,R) as a function of the r.slopeunits input parameters provides an objective and reproducible way to select the optimal parameter combination for a proper SU subdivision for LS modelling.

We further perform an analysis of the statistical significance of the LS models as a function of the r.slopeunits input parameters, focusing on the degree of coarseness of each subdivision. We find that the LRM, when applied to subdivisions with large average SU size, has a very poor statistical significance, resulting in only few (5%, typically lithological) variables being used in the regression due to the large heterogeneity of all variables within each unit, while up to 35% of the variables are used when SU are very small. This behavior was largely expected and provides further evidence that an objective method to select SU size is highly desirable.

[1] Guzzetti, F. et al., Geomorphology 31, (1999) 181-216

[2] Alvioli, M. et al., Geoscientific Model Development 9 (2016), 3975-3991

[3] http://geomorphology.irpi.cnr.it/tools/slope-units

[4] Rossi, M. et al., Geomorphology 114, (2010) 129-142

[5] Rossi, M. and Reichenbach, P., Geoscientific Model Development 9 (2016), 3533-3543