Geophysical Research Abstracts
Vol. 18, EGU2016-14612, 2016
EGU General Assembly 2016
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Challenges and limitations of a statistical Pan-European landslide susceptibility evaluation

Marta-Cristina Jurchescu (1,4), Andreas Günther (1), Jean-Philippe Malet (2), Paola Reichenbach (3), and Mihai Micu (4)

(1) Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany (Andreas.Guenther@bgr.de), (2) School and Observatory on Earth Sciences, CNRS – University of Strasbourg, France (jeanphilippe.malet@unistra.fr), (3) Research Institute for Hydrogeological Protection, CNR-IRPI, Perugia, Italy (paola.reichenbach@irpi.cnr.it), (4) Institute of Geography, Romanian Academy, Bucharest, Romania (marta_jurchescu@yahoo.com, mikkutu@yahoo.com)

In the framework of the European Thematic Strategy for Soil Protection, landslides are regarded as one of the several soil threats which need to be considered in view of a sustainable soil use. With the aim of identifying landslide priority areas in Europe, research related to the Pan-European landslide susceptibility assessment is progressing on a second version of the map (ELSUS v2) which bases upon a heuristic spatial multi-criteria evaluation (SMCE).

In the context of an enriching continental landslide inventory from various European countries, this study aims at exploring the degree to which statistical and typologically-differentiated European-wide landslide susceptibility modeling can be conducted, while looking into the challenges and limitations raised by spatial analyses at small scales (1: 1Mill.). Despite the efforts put into collecting a continent-wide dataset of landslides, the present data is still characterized by large incoherencies. In order to comply with the current assessment requirements for objectivity and typological differentiation, the European landslide database is analyzed and classified according to the main quality indicators (completeness and spatial accuracy) as well as landslide categories (topple/falls versus slide/flows). The selected thematic environmental input data (lithology, slope angle and land cover) are classified separately according to their relevance for the occurrence of the landslide types.

Statistical assessments, using modern multivariate data mining techniques like Classification and Regression Trees (CART) and Multivariate Adaptive Regression Splines (MARS), are attempted separately for each of the seven climate-physiographic zones used for the preparation of ELSUS, distinguished on the basis of morphometric and climatic data. To ensure that information is collected in an objective and unbiased manner, a sampling strategy is proposed for each zone. Accordingly, areas for sampling landslide absences are restricted to complete inventories characterized by "good" spatial accuracy, while those for sampling landslide presences are determined by landslides characterized by both a "good" spatial accuracy and the presence of typological information. The sampling areas are further reshaped in order to well-balance all parameter classes characterizing the respective zone. Finally, a random and equal number of pixels with information associated to landslide presences and absences is sampled. The sample-constructed models are then applied to the entire climate-physiographic zones. Validity of the models within the representative sample areas is verified using V-fold cross-validation technique and the receiver operating characteristics. Reliability of the models outside the sample areas is checked through comparisons with the Pan-European semi-quantitative SMCE map, comparisons with national and regional susceptibility maps, as well as national expert knowledge.

While yielding highly improved results in the well-balanced, zone-representative sample areas, as confirmed by the applied validation, the statistical models emphasize large uncertainties in areas for which no landslide information is yet available. Through the revealed uncertainties, this data-driven modelling attempt proves to be efficient in defining areas, further narrowed down by a unique-conditions-units map to some representative perimeters, where there would be an acute need for accurate, complete and typological landslide inventory data. Additionally, the statistical modelling strategies proposed in this paper allows for the detection of data inconsistencies and biases in the spatial predictors used, namely the lithological information.