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Uncertainty on shallow landslide hazard assessment: from field data to hazard mapping

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Shallow landsliding that involve Hillslope Deposits (HD), the surficial soil that cover the bedrock, is an important process of erosion, transport and deposition of sediment along hillslopes. Despite Shallow landslides generally mobilize relatively small volume of material, they represent the most hazardous factor in mountain regions due to their high velocity and the common absence of warning signs. Moreover, increasing urbanization and likely climate change make shallow landslides a source of widespread risk, therefore the interest of scientific community about this process grown in the last three decades. One of the main aims of research projects involved on this topic, is to perform robust shallow landslides hazard assessment for wide areas (regional assessment), in order to support sustainable spatial planning.

Currently, three main methodologies may be implemented to assess regional shallow landslides hazard: expert evaluation, probabilistic (or data mining) methods and physical models based methods. The aim of this work is evaluate the uncertainty of shallow landslides hazard assessment based on physical models taking into account spatial variables such as: geotechnical and hydrogeologic parameters as well as hillslope morphometry. To achieve this goal a wide dataset of geotechnical properties (shear strength, permeability, depth and unit weight) of HD was gathered by integrating field survey, in situ and laboratory tests. This spatial database was collected from a study area of about 350 km2 including different bedrock lithotypes and geomorphological features. The uncertainty associated to each step of the hazard assessment process (e.g. field data collection, regionalization of site specific information and numerical modelling of hillslope stability) was carefully characterized.

The most appropriate probability density function (PDF) was chosen for each numerical variable and we assessed the uncertainty propagation on HD strength parameters obtained by empirical relations with geotechnical index properties. Site specific information was regionalized at map scale by (hard and fuzzy) clustering analysis taking into account spatial variables such as: geology, geomorphology and hillslope morphometric variables (longitudinal and transverse curvature, flow accumulation and slope), the latter derived by a DEM with 10 m cell size. In order to map shallow landslide hazard, Monte Carlo simulation was performed for some common physically based models available in literature (eg. SINMAP, SHALSTAB, TRIGRS). Furthermore, a new approach based on the use of Bayesian Network was proposed and validated. Different models, such as Intervals, Convex Models and Fuzzy Sets, were adopted for the modelling of input parameters. Finally, an accuracy assessment was carried out on the resulting maps and the propagation of uncertainty of input parameters into the final shallow landslide hazard estimation was estimated. The outcomes of the analysis are compared and discussed in term of discrepancy among map pixel values and related estimated error.

The novelty of the proposed method is on estimation of the confidence of the shallow landslides hazard mapping at regional level. This allows i) to discriminate regions where hazard assessment is robust from areas where more data are necessary to increase the confidence level and ii) to assess the reliability of the procedure used for hazard assessment.