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Preface

"Landslide hazard and risk assessment at different scales"

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The special issue of Natural Hazards and Earth System Sciences entitled "Landslide hazard and risk assessment at different scales" contains 6 of more than 20 oral and poster contributions originally presented in the session NH3.9 – "Landslide risk assessment methods and strategies" held at the General Assembly of the European Geosciences Union, in Vienna, Austria, on 7 May 2010. Topics discussed in the session included the following: (i) heuristic, statistical, deterministic, and physically based methods and models to evaluate landslide susceptibility and hazard, and (ii) evaluation of qualitative and quantitative vulnerability and risk assessments based on different data. During the session, various contributions were discussed dealing with landslide hazard and risk assessment at local, regional or national scales, in different physiographic, climatic and geological settings.

The meeting proved a valuable opportunity to discuss and compare methods, techniques, and tools for the identification, evaluation, and mitigation of landslide hazards and the associated risks. Despite the large number of contributions presenting case study applications to evaluate landslide hazards and risk, information on the quality, the reliability and the limitations of the applied models was not analyzed in detail and should be considered a major issue for future research. In the following, we summarize the content and the main results of the papers originally presented and discussed at the meeting that are published in this special issue.

Floris et al. (2011) exploit spatial data available in Italian WebGIS portals to evaluate landslide *susceptibility* of the Euganean Hills Regional Park, located SW of Padua, NE Italy. In the paper, quality, applicability and possible analysis scales of the online data were investigated and a susceptibility analysis of the study area was completed using a probabilistic approach that compared landslide distribution and the influencing factors. The input factors used in the analysis include landslide distribution, morphometric data (i.e., elevation, slope, curvature, profile and plan curvature) and non-morphometric data (i.e., land use, distance to roads and distance to rivers). Attention was paid to data pre-processing, in particular to the re-classification of continuous data that was performed following objective, geologic, and geomorphological criteria. The results show that the simple probabilistic approach used for the susceptibility evaluation was accurate and precise (repeatability). Heuristic, statistical, or deterministic methods could be applied to the online data to improve the prediction. The data available online for Italy allow for the assessment of landslide susceptibility at medium to small scales. Morphometric factors, including terrain elevation and slope angle, provide significant information where lithological and structural data are not available. The main drawback of the online data sources was the lack of information on the temporal frequency of landslides. For this reason, a complete hazard analysis is not possible.

Pereira et al. (2012) use a bivariate statistical model to identify a combination of landslide predisposing factors that best predicted landslide *susceptibility* in the Santa Marta de Penaguião study area (70 km^2), northern Portugal. All possible combinations of 7 environmental factors were considered, resulting in 120 predictions that were assessed against a landside inventory listing 767 shallow translational slides. The best landslide susceptibility model was selected according to the model degree of fitness with the inventory data, and on the basis of a conditional independence criterion. The model was developed using only three landslide predisposing factors (i.e., slope angle, inverse wetness index, land use), and was compared with a model developed using seven landslide predisposing factors. Results showed that it is possible

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to produce a reliable landslide susceptibility model using only a limited number of predisposing factors, which contribute towards higher conditional independence of the predisposing factors.

Montrasio et al. (2011) present a regional-scale application of two *physically based stability models*: SLIP (Shallow Landslides Instability Prediction) and TRIGRS (Transient Rainfall Infiltration and Grid-based Regional Slope-stability analysis). A back analysis of recent soil slip events that occurred in the central Emilian Apennines (Emilia-Romagna region, northern Italy) was completed. The paper outlines the main features of the SLIP model and the basic assumptions of TRIGRS. Particular attention is devoted to the discussion of the input data, which have been stored and managed in a GIS. Results of the application of the SLIP model at the regional scale, for a period of one year, are also presented. The predictions obtained by SLIP are analyzed for specific rainfall events, and in terms of time-varying percentage of unstable areas over the considered time interval. The paper also compares observed landslide localizations with those predicted by the SLIP model. A further quantitative comparison between SLIP and TRIGRS, both applied to the most important event that occurred during the analyzed period, is presented. The limits of the SLIP model, mainly due to restrictions resulting from simplification of the mechanical relationships attributed to slope failures, are analyzed in detail. Although an improvement is necessary, mostly in terms of spatial accuracy, the SLIP model proved a valuable tool for regional-scale landslide forecasting.

Quan Luna et al. (2011) apply dynamic debris flow run-out models to develop physical *vulnerability* curves. Dynamic run-out models are able to calculate physical outputs (extension, depths, velocities, impact pressures) and to determine where elements at risk could be impacted. On 13 July 2008, after more than two days of intense rainfall, much debris and several mudflows were released in the central part of the Valtellina Valley (Lombardy region, northern Italy). One of the largest debris flow events occurred in a village called Selvetta. This debris flow event was reconstructed as a numerical problem based on extensive fieldwork and interviews with local inhabitants and civil protection teams. Modeling was performed with the FLO-2D program, an Eulerian formulation with a finite differences numerical scheme that requires the specification of an input hydrograph. The significance of major model output values for flow depth, velocity, and pressure was investigated in terms of the resulting damage to the affected buildings. The physical damage was quantified for each affected structure within the context of physical vulnerability, which was calculated as the ratio between the monetary loss and the reconstruction value. Three different empirical vulnerability curves were obtained, which are functions of debris flow depth, impact pressure, and kinematic viscosity, respectively. A quantitative approach to estimate the vulnerability of an exposed element to a debris flow, which can be independent of the temporal occurrence of the hazard event, is presented.

Jaiswal et al. (2011) present a quantitative procedure for estimating landslide *risk* to human life and property in a mountainous area in the Nilgiri hills, southern India. Direct specific risk was estimated individually for tea/coffee and horticulture plantations, transport infrastructures, buildings, and population both in initiation and run-out areas. Risks were calculated by considering the minimum, average, and maximum landslide volumes in different magnitude classes and the corresponding minimum, average, and maximum run-out distances and vulnerability values, thus obtaining a range of risk values per return period. The results indicate that the total annual minimum, average, and maximum losses are about US$44 000, US$136 000 and US$268 000, respectively. The maximum risk to population varies from 2.1×10^{-1} for one or more lives lost to $6.0 \times 10^{-2}\,\mathrm{yr}^{-1}$ for 100 or more lives lost. The obtained results will provide a basis for planning risk reduction strategies in the Nilgiri area.

Michoud et al. (2012) present an example of a rockfall *hazard and risk* assessment along roads at the regional scale in the Swiss Alps. The authors analyze methods to quantify rock-mass-failure susceptibilities at regional scales and to detect potential rockfall source areas. Slope angle distribution procedure can be exploited to detect potential rockfall source areas and to analyze recent digital elevation models (DEMs) even though this method does not provide information on block-release frequencies inside identified areas. The paper adds its normalized cumulative distribution function to the slope angle distribution of the cliff unit. This improvement is assimilated to a quantitative weighting of slope angles, introducing rock-mass-failure susceptibilities inside rockfall source areas previously detected. Then, rockfall run-out assessment is performed using the GIS- and process-based software Flow-R, providing relative frequencies for run-out. Thus, taking into consideration both susceptibility results, this approach can be used to establish, after calibration, hazard and risk maps at regional scale. As an example, a risk analysis of vehicle traffic exposed to rockfalls is performed along the main roads of the Swiss alpine valley of Bagnes.

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