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Natural Hazards and Earth System Sciences

Preface

Landslides can be triggered in several ways, including by intense or prolonged rainfall, by earthquake strong ground motion, by rapid snow melting and by volcanic activity. Mass movements can occur singly or in groups of several thousand. Landslides can involve flowing, sliding, toppling or falling movements, and many landslides exhibit a combination of these types of movements. The extraordinary breadth of the spectrum of landslide phenomena makes it difficult to define a single methodology to evaluate landslide risk.

Slope failures of different type, size and velocity represent a significant threat to the population, structures and infrastructure worldwide. The economical and societal impact of landslides can be tremendous. In many regions casualties and economic losses caused by slope failures are larger than those produced by other damaging natural events, including floods and earthquakes. In various countries landslides kill people every year. Landslide casualties are numerous where population density is high, and where recent urbanization occurred in dangerous areas without proper hazard assessment. Economic losses caused by mass movements can also prove severe. A single storm or earthquake can trigger thousands of slope failures, which can produce a tremendous impact on the built-up areas and the infrastructure, and can severely hamper the economy of a region. Examples exist of single slope failures that have killed hundreds or even thousands of people, that have forced entire communities to be evacuated or relocated, and that have caused direct damage in excess of tens of millions of euros.

The main causes and effects of landslides have long been known and several different methods and techniques have been proposed to identify and map slope failures. Techniques and tools to evaluate landslide hazard are known, and attempts aimed at mapping landslide hazards have been successfully completed at various scales and for different landslide types. It has been recognized that the quality of landslide maps, and the reliability of landslide hazard assessments, depend largely on the skills of the investigators, the quality and quantity of the available data, and on the reliability of the technique used to collect the data and to ascertain the hazard.

In recent years, interest in landslide risk assessment has grown substantially. Administrators, planners and decision makers have become more and more interested in techniques and methods for reliable and comparable landslide risk assessment. Landslide risk evaluation aims to determine the expected degree of loss due to landslides (specific risk) and the expected number of fatalities, people injured, damage to property and disruption of economic activity (total risk). Quantitative and qualitative approaches are possible, and examples of both are becoming available in the literature. A quantitative risk assessment aims to establish the probability of occurrence of a catastrophic event, e.g., the probability of live losses, or the probability of a landslide causing a certain number of casualties. The method requires a catalogue of landslides and their consequences. The completeness and time span of the catalogue greatly affects the reliability of the risk assessment. When attempting to evaluate risk for a site or region where landslides are likely to take various forms or pose various types of threat, the quantitative approach may become impracticable. Indeed, it may not be easy to ascertain the magnitude, frequency and forms of evolution of landslides over large areas, and detailed and reasonably complete catalogues of historical landslide events may not be available. Qualitative approaches can be pursued in such a way as to establish qualitative levels of landslide risk. This involves designing landslide scenarios.

On April 2002, in the framework of the XXVII European Geophysical Society (EGS) General Assembly, we convened a symposium on Landslide Risk Assessment and Mapping. The goal of the symposium was to compare methods and techniques currently available for landslide risk assessment, to establish criteria for ranking risk posed by different types of mass movements, to quantify the impact that mass movements have on population, structures and infrastructures, and to establish and test strategies for avoiding or mitigating landslide risk. Twenty-four contributions were presented at the symposium. The oral and poster presentations discussed various aspects of landslide hazard assessment and, to a lesser extent, of landslide risk evaluation and mapping. In this respect, the symposium only partially met our expectations.

The quality and content of the presentations stimulated us to edit a special issue of the EGS journal Natural Hazards and Earth Systems Sciences. The current issue of NHESS contains papers selected among those presented at the symposium, and reflects the themes and subjects discussed at the symposium. The six papers that constitute the special issue describe hazard posed by different landslide types, including rockfalls, debris flows and complex failures, and discuss attempts at evaluating landslide hazards and risk at different scales, from site specific to regional. Methods and tools to determine landslide hazards and to evaluate the associated risk include a variety of classic and new techniques pertaining to the realms of engineering-geology, geomorphology, mathematical modelling and management of geographic information, including field mapping, interpretation of aerial photographs, GIS technology, and cellular automata. Four papers examine single or multiple landslide events in an attempt to learn from the past to be able to successfully forecast and help mitigate the effects of future landslide occurrences.

We loosely grouped the six papers based on the type of mass movements that are examined and the scale of the investigation. The first three papers examine hazards posed by fast moving rockfalls. The following two papers study hazards posed by rapid moving debris flows and mud flows. In the last paper a regional attempt to evaluate the impact of slides and complex failures is presented.

Crosta and Agliardi describe an attempt to evaluate rockfall hazards using a three dimensional, physically based computer model. Detailed maps showing the simulated maximum frequency of rockfall trajectories at each grid cell, the maximum computed rockfall velocity, and the maximum rockfall travelling distance to the ground, are combined in a GIS to obtain different rockfall hazard maps. Levels of hazard are expressed and ranked using a rockfall hazard index and a rockfall hazard vector. Examples of rockfall hazard zoning are shown for an area in the Lecco municipality, northern Italy, where catastrophic rockfall events have occurred in the past, and the spatial variation of rockfall hazard along a road is discussed. Sartori, Ballifard, Jaboyedoff and Rouiller investigate the 18 April 1991 and the 9 May 1991 rock slides at Randa, Switzerland, which involved 22 millions and 7 millions m^3 or rock, respectively. The authors propose a three-dimensional kinematical model of the pre-failure geometry of the slope to interpret the available structural, lithological, hydrological and chronological information. Slope steepness, local topographic setting, lithology, and the occurrence of pre-existing slope failures are identified as the main pre-factors that set the propensity for large rock failures. An attempt is made to generalize the findings in order to predict the location of sites where future rock slides may occur. Baillifard, Jaboyedoff and Sartori describe a similar approach to investigate a rock slope instability near Sion, Switzerland, where a rockfall involving 2000 m^3 of rock occurred on 9 January 2001. Five criteria are examined in a GIS to determine the probability of rockfall hazard and to identify areas potentially susceptible to rockfalls. Applied along a four kilometres long section of a road, the method revealed that considerable rockfall hazard exists at two sites where rock slope failures similar to that experienced in January 2001 can be expected.

Delmonaco, Leoni, Margottini, Puglisi and Spizzichino describe a physically based, distributed model to determine debris flow hazard conditions in the Vezza River basin, in the Alpi Apuane region, central Italy. On 19 June 1996, the 52 square kilometre catchment was affected by an extremely severe rainfall event, with cumulative rainfall exceeding 300 mm. The high intensity storm triggered hundreds of debris flows, which killed fourteen people and caused widespread destruction. The authors investigate the rainfall event, determine the extent of the ground effects through interpretation of aerial photographs, propose a method to identify the potential source areas of debris flows, and establish rainfall thresholds for the initiation of widespread debris flows for different return periods ranging from 10 to 100 years. Iovine, Di Gregorio and Lupianov investigated selected areas of Campania Region, southern Italy, affected by the 15–16 December 1999 rainfall event, which resulted in abundant mud flows and debris flows. In the study area, the authors ascertain mud and debris flow susceptibility using a combination of field data, GIS modelling and an innovative cellular automata model specifically developed for simulating the spatial evolution of debris flows. Results of the numerical simulation are compared to existing, detailed landslide maps prepared immediately after the event.

In the last paper, Guzzetti, Reichenbach, Cardinali, Ardizzone and Galli discuss an original attempt to estimate the impact of different types of landslides in Umbria region, central Italy. The attempt is based on the combined analysis of the available historical information on landslide events, a detailed regional landslide inventory map prepared through the interpretation of aerial photographs, and three landslide event inventories compiled after major landslide triggering events through extensive field surveys and the interpretation of aerial photographs flown after the events. The impact of slope failures on the population, the transportation network and the built-up areas is ascertained within a GIS environment. An attempt is made to estimate the number of people exposed to landslide risk in the Perugia municipality.

As a final remark, we would like to point out that the symposium and the resultant special issue have indicated the clear need for objective, reliable, comparable, properly formalized and scientifically based methods for landslide risk assessment and mapping. In this respect, it seems that landslide experts lay behind the expectations of land planners and decision makers. To better protect our communities and to respond to the requests of concerned citizens, we need to improve our ability to forecast the effects of damaging landslide events, to prepare reliable and realistic landslide scenarios, and to ascertain landslide risk. We anticipate that landslide risk assessment and mapping will become a new frontier of landslide studies.

We acknowledge all our authors, whose contributions make this volume worthwhile, and we thank them for accepting the work load that the preparation of the special issue has meant for them. We are grateful to the referees for careful and sometimes severe comments on individual papers. Everyone benefited from their suggestions. We thank the European Geophysical Society for providing the opportunity to convene the symposium from which this special issue was derived. Lastly, we would like to acknowledge the efforts of the editorial and production staff at the EGS.

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