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# Evaluation of spatial and temporal landslide hazard in Northern Apennines flysch deposits

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Landslide hazard mitigation is currently limited by the implementation of monitoring systems. These systems can provide experimental data, which can be usefully applied to the characterization of mass movement and to forecast and manage catastrophic events. A thorough knowledge of the territory is required to produce well-structured, cost-effective monitoring systems. In case of slope movements, an accurate assessment of the intensity (volume or mass and velocity) and state of activity (mean return periods) of potentially damaging events should be considered (Aleotti & Chowdhury, 1999). The landslide intensity can be ascertained using traditional (field surveys, analysis and interpretation of aerial photographs) or advanced methods (GIS techniques, analysis of satellite images). The evaluation of the state of activity is usually carried out by screening historical landslide series or by investigating the temporal occurrence of triggering factors such as rainfall and earthquakes. The scope of this study is the evaluation of the spatial and temporal landslide occurrence (i.e., hazard) in a training area near the town of Urbino (Central Italy), characterized by the extensive outcrops of Cenozoic flysch deposits that reach, in the studied area, the thickness of 350 metres of interbedded arenaceous shale. The first phase of the study was focused at obtaining a thorough knowledge of the landslide susceptibility. Data related to the main geological, geomorphological, geomechanical and hydrogeological characteristics of the investigated area and to the slope movements were collected and stored in a GIS. A univariate statistical analysis (Lee & Min, 2001) was applied to investigate the spatial relationship between the landslide location and each landslide-related factor. Using appropriate GIS-techniques several descriptive layers were produced and combined each other to portrait the Landslide Susceptibility Map. The development of a landsliding index mapping is a useful tool for both territorial planning and design

of monitoring systems, which can be realized through GPS networks or RADAR images (Hilley et al., 2004). The assessment of the state of activity (the second phase of the study) was carried out analysing the frequence of landslides mobilization and the correlation between landslides and rainfall. The frequency of occurrence of the 300 landslides identified in the area was determined through a multitemporal analysis of several timeframed aerial photographs. The interevent time was equalled to the minimum recurrence interval between two reactivations and the probability of landslide occurrence was calculated referring to the Poisson distribution (Crovelli, 2000). Statistical hydrological studies highlighted a cause-effect correlation between rainfall and landslides in the investigated area. Should they be confirmed by the development of coupled hydromechanical models of the slope behaviour, the statistical-probabilistic results might be used to design a landslide warning network based on an "intelligent" monitoring system (Polemio & Petrucci, 2001), able to identify and process rainfall data to be communicated to emergency management centres for the real-time identification of critical conditions threatening the slopes stability.

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