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A geomechanical approach to landslide hazard assessment: the Multiscalar Method for Landslide Mitigation

Federica Cotecchia[a], Francesca Santaloia[b], Piernicola Lollino[b], Claudia Vitone[a,]*, Francesco Cafaro[a], Osvaldo Bottiglieri[a]

[a]*Politecnico di Bari, DICATECh, Via E. Orabona 4,70126 Bari, Italy*
[b]*IRPI, National Research Council, Via Amendola 122, 70126 Bari, Italy*

Abstract

The landslide hazard assessment, when based on the deterministic diagnosis of the processes, can be pursued only through the interpretation and the geo-hydro-mechanical modelling of the slope equilibrium. In practice, though, landslide hazard assessment is still seldom dealt with slope modelling, in particular when it addresses vast areas, where either heuristic or statistical methods do not entail any geo-hydro-mechanical knowledge of slope features and stability. The Multiscalar Method for Landslide Mitigation (MMLM) is an original methodological approach for intermediate to regional landslide hazard assessment. It is based on the geo-hydro-mechanical knowledge achieved from the application of a stage-wise diagnostic methodology of the landslide mechanism at the slope scale. The paper discusses the main steps of the MMLM aiming at diagnoses of landslide hazard based on hydro-mechanics, for small scale hazard mapping (at the large area).

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1. Introduction

The landslide risk assessment is the necessary premise for the sustainable development of mountainous areas,

* Corresponding author. Tel.:+39-080-5963708.
E-mail address: c.vitone@poliba.it

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where sustainable is any initiative for development “that meets the needs of the present without compromising the ability of the future to meet its own need” [1]. To this aim, a scientifically advanced approach to landslide risk management is required, in order to improve the quality of life and reduce the risk trade-off among different decisional strategies [2,3,4]. This implies that the knowledge about landsliding achieved through the most advanced scientific studies should be transferred to the institutions, industry and civil society, with the aim of developing a deep consciousness of the risk associated to landsliding and of the possibility of identifying adequate mitigation options only through the use these study. The numerous deaths and losses, which are still recorded, despite the improved regional landslide risk mapping [5,6,7], testify that this transfer of knowledge is still limited. 2.620 landslide events were recorded worldwide during 2004 - 2010, causing a total of 32.322 fatalities [8] and, just only in Europe, the material losses amounted to over 1700 Million USD during the 20th century [9]. With reference to the Italian peninsula, the landslide risk is also very high [10,11]: 2.713 landslide events occurred from 1900 to 2008, causing 5.196 deaths, and from 1944 to 2010 the damage due to landslides and floods amounted to over 61 Billions of Euro [12]. It follows that landslide risk characterization should be improved at any scale. This improvement requires a more diffuse application of the procedure nowadays available to achieve the diagnosis of the landslide mechanisms, with the recognition of the landslide causes based on quantitative slope modelling [13,14,15,16,17]. In practice, such a deterministic assessment is commonly considered not feasible at the regional scale, i.e. at the small scale [6], where instead hazard assessment is usually carried out by means of either heuristic or statistical methods [18,19,20]. In the following, an original methodology for intermediate to regional scale quantitative landslide hazard assessment, called the Multiscalar Method for Landslide Mitigation, MMLM [13,14,15,21,22], is briefly presented.

2. The Multiscalar Method for Landslide Mitigation

The MMLM consists of two phases: the first entails the characterization of landsliding in the whole study region (Fig. 1(a)), background of the hazard assessment within any given territorial cell of the region, which is the subject of the second phase (Fig. 1(b)). This paper focuses on the first phase, in order to show how results of quantitative studies at the site scale (i.e. large scale; studies eventually available, or carried out on purpose) bring about the knowledge about the landsliding across the vast area and, as such, support the landslide hazard assessment at the regional scale [13,23,24]. At the base of the MMLM there are two main assumptions (Fig. 1), which have to be fulfilled in order to carry out the assessment of the landslide hazard at the small scale using the knowledge about the hydro-mechanical conditions of single slopes. Hypothesis 1 asserts that, despite the variability of the geological landscape, in any region of given single paleo-geographic origin, a limited number of representative and most recurrent geo-hydro-mechanical set-ups and failure mechanisms can be distinguished for the region. Such hypothesis can be considered plausible, since the variability in the hydro-mechanical properties of soils and rocks, that control the failure mechanisms, is known to be much lower than that of the soil geological features and the characterization of a landscape based on the soil mechanical features may be simpler than its geological characterization. Despite different geological origin and histories, geo-materials can exhibit similar behaviour at the slope scale and, as such, be considered similar with respect to the slope mechanics. They may be considered part of the same class of material in schematic geo-hydro-mechanical set-ups; these set-ups are called GMi in the MMLM. The recurrence of similar geo-hydro-mechanical set-ups in a region implies a limited number of representative set-ups, GMi, for the region, and a corresponding limited number of landslide mechanisms representative for the region, which are referred to as Mi (hypothesis 2). The first phase of the MMLM (Fig. 1(a)) is intended to sort out which are the GMi and the Mi of the region, through a reductionist approach [25]. To this aim, work is extensively devoted to the creation of a regional database of both the internal (e.g., geological, mechanical and hydraulic properties) and external (e.g., climatic, anthropic, seismic actions) slope factors [26]. The generation of such database requires extensive surveying of the slopes across the region [14], with the acquisition of both small scale study data and site scale data at diverse locations in the region. The database could be implemented in a regional GIS [27]. The study of this database should allow the sorting out of the GMi classes of the region that could be reported in a Regional Landslide Manual (RLM). This represents the handbook gathering the geo-hydro-mechanical knowledge about the slopes of the region, of reference for all the operators involved either in the slope management, or in the construction of operas interacting with the slopes.