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Is there predictive power in hydrological catchment information for regional landslide hazard assessment?

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Abstract

Regional landslide hazard assessment is often carried out by means of empirical meteorological thresholds, which reliability is sometimes limited by the lack of information about the hydrological processes which lead to landslide triggering in slopes. Hence, in this paper the inclusion of hydrological information at catchment scale in the definition of landslide triggering thresholds is applied to a catchment in the northern Apennines (Italy). In particular, an hydro-meteorological threshold based on event precipitation and catchment specific storage (*H-S* threshold) is proposed. The performance of the proposed threshold is compared with the one of the usually adopted precipitation Intensity-Duration (*I-D*) threshold. Although most of the landslide recorded in the observed period (2002-2013) were triggered by short and intense precipitation events with little influence of the slope conditions prior the precipitation, the *H-S*threshold performs slightly better than the *I-D* threshold.

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1. Introduction

Rainfall-triggered landslides are among the most widespread natural hazards, and early warning systems are an important way to reduce the deriving socio-economic risk. In this respect, regional hazard assessment is a useful tool for preliminary forecasts. Several approaches have been proposed for assessing the probability of landslide occurrenceatregional scale (see Chacon et al.[1] for a review): heuristic through susceptibility modeling; empirical,

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lumped-statistical, by relating meteorological information to the observed occurrence of landslides; by means of spatially distributed physically-based modeling. However, one of the mostusedapproaches is the regional hazard assessment based on meteorological information[2].

The precipitation-intensity-duration (PID) thresholds, indeed, see widespread applicationfor local, regional or global landslide hazard assessment. The basis of such a methodology is the availability of high quality spatiotemporal landslide inventory database and rainfall time series. The rainfall thresholds are then empirically derived by plotting two variables related to the characteristics of rainfall which have or have not resulted in landslides in a given area. The separation between rain events inducing landslides and events without hazard, which can be a deterministic threshold curve or a probabilistic transition zone, ismade visually or by separator techniques. Due to the spread of rainfall characteristics over several orders of magnitude, the plot is usuallyin bi-logarithmic scale.

Various PID thresholds for landslide initiation have been proposed and applied[2,3,4]. While local thresholds often refer to relatively homogeneous conditions and specific mass movement types, regional and global thresholds encompass landslides with different geo-morphological, environmental and hydrological features, such as lithology, sliding soil depth, slope inclination, land use, and boundary conditions. Hence, to accommodate the latter, which, due to the large heterogeneity in spatiotemporal scales, mass movement types and environmental factors, lack explicit hydrological information, more detailed analysis of PID thresholds was proposed: splitting the records, e.g. for rainfall duration longer/shorter than 48 hours[4], or for winter and summer conditions[5,6];introducing 1D water balance in a slope[7,8,9]; combining an Antecedent Wetness Index withthe PID curve in a decision tree model for a possible early warning system[10]; defining non-dimensional rainfall intensity and duration, accounting for the hydraulic characteristics of a particular slope[11].

The objective of this studyis testing if combining meteorological information with lumped hydrological information at catchment scale will improve the performance of empirical landslide initiation thresholds. To this aim, we studied a small catchment in Emilia Romagna (Italy), for which meteorological and landslide data are available for the period 2003-2013, and applied and compared several possible empirical thresholds. The results indicate that the inclusion of catchment storage can improve the performance of regional landslide hazard assessment.

2. Methods and data

2.1. Description of case study area

The presented application makes use of meteorological and landslide data of the catchment of the river Scoltenna at Pievepelago(Fig. 1). The river is a tributary of river Panaro, in turn flowing into river Po. The catchment area is 130.8km^2 and the mean altitude is around 1450ma.s.l. The concentration time of the catchment is estimated between 2 hours (Kirpich’s formula) and 3.5 hours (Giandotti’s relationship), The prevailing lithology, covering about 80% of the catchment, consists of clay shales (Flysch). Only in the north-western part of the catchment limestone and sandstone emerge. The discharge monitoring station of Pievepelago provides daily discharge data for the period 2003-2013. During the same period, two weather stations operated within the catchment, providing, at hourly time resolution, precipitation, air temperature and relative humidity, mean wind speed and direction. During the considered period, 61rainfall-induced landslides were recorded.

During the monitoring period, the average yearly precipitation was about 1500mm, while the yearly average specific runoff was about 1140mm, corresponding to high mean runoff coefficient of 0.76. Fig. 2 shows the mean monthly precipitation and specific discharge, which exhibit a similar pattern, confirming the direct relationship between precipitation and runoff. The only bias between the distribution of monthly precipitation and runoff can be ascribed to snow accumulation and melting in the highest part of the catchment, which causes a shift of the maximum discharge to the early spring, while the precipitation is maximum in late autumn and early winter. The third panel of Fig. 2 reports the scatter plot of cumulative specific discharge and cumulative precipitation for the monitored ten years, which indicates that the hydrological behavior of the catchment remained fairly stable during the whole considered period.