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Slope movements in Daunia (Apulia): collecting historical events for the definition of rainfall thresholds

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RIASSUNTO

Movimenti di versante in Daunia (Puglia): raccolta di dati storici ai fini della definizione di soglie pluviometriche d'innesco

L'Appennino Dauno (provincia di Foggia, Puglia) rappresenta la zona di transizione tra il Tavoliere delle Puglie e l'Appennino Meridionale, e costituisce il settore regionale maggiormente interessato da fenomeni di instabilità dei versanti. A partire dai primi risultati di un progetto di ricerca del CNR-IRPI, finalizzato alla definizione di soglie pluviometriche per l'innesco dei fenomeni franosi a scala nazionale, di recente è stata avviata una collaborazione con il Servizio di Protezione Civile della Regione Puglia, per giungere alla individuazione di una soglia pluviometrica di significato regionale. Il presente studio, oltre a descrivere l'area oggetto delle ricerche ed i suoi principali caratteri di franosità, illustra le attività sinora svolte e quelle in essere per la raccolta di dati storici su eventi di frana in Daunia, a partire dai quali saranno eseguite le successive analisi pluviometriche per la individuazione delle soglie pluviometriche da frana.

KEY WORDS: *Daunia, hazard, landslides, historical events, rainfall threshold.*

INTRODUCTION

Landslide hazard is one of the most threatening phenomena causing casualties, homeless, and severe damage to society every year, that national and regional offices of the Civil Protection have to tackle and manage. At the national scale, the present strategy of Civil Protection relies on an early warning system based on development of a national rainfall threshold. This latter is the result of the research project "Rainfall thresholds" financed by the National Department for Civil Protection. In this project, research efforts have been spent by CNR-IRPI (GUZZETTI *et alii*, 2007, 2008; BRUNETTI *et alii*; 2010; ROSSI *et alii*, 2010; PERUCCACCI *et alii*, 2012) to construct an early warning automatic system (SANF, ROSSI *et alii*, 2012) that collects the national rain-gauge network registrations during the rainfall events and compares the cumulated rainfall with the Italian rainfall threshold: whether the antecedent precipitation is higher than the threshold for a given time duration, a warning message is automatically sent to the regional operative offices of the Civil Protection to implement the evacuation plans.

The threshold method has been developed since the initial idea by CAINE (1980), due to the renown role that rainfall of diverse intensity and durations have in triggering landslides. The next step of the SANF system will consist in developing regional rainfall thresholds. However, the first outcomes from studies in central Italy (PERUCCACCI *et alii*, 2012) show low variability among the rainfall thresholds identified for the different regions.

As concerns Apulia, the present cooperation between the Apulian Office for Civil Protection and CNR-IRPI is addressed toward the definition of a regional rainfall threshold for the triggering of slope movements. With respect to the landslide hazard, the Apulian sectors most affected by unstable territories are the Daunia Apennine and, essentially for fall processes and topple failures along the rock cliffs, the Gargano Promontory. The Daunia Apennine is a crucial area for rail transport and communication routes that connect the Apulia to neighbouring regions. Interruption of these routes due to landslides caused several times in the past serious problems, including isolation of several villages. At this regard, the Montaguto landslide has to be recalled: at the boundary between Campania and Basilicata, this slow-moving landslide reached in April 2006 an important State Road, and in March 2010 the railway, thus isolating Apulia for several months, and causing severe economic losses.

In this paper, we present an overview of the activities, both carried out and on going, in Daunia, in order to implement the method to derive the regional rainfall threshold for rainfall-induced landslides.

GEOLOGICAL SETTING

The high landslide frequency in Daunia is related to the geological setting of this sector of Apulia, where slopes are made up of highly tectonised and fissured soils and rocks, with widespread outcropping of the so-called "structurally complex formations". The Daunia Apennine, consisting of a series of allocthonous tectonic sheets, is the area of transition between the Southern Apennine Chain and the regularly bedded carbonate succession belonging to the Apulian foreland. The

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northern portion of the Apulia region underwent considerable uplift, weathering, and erosion, beginning in the middle Pleistocene (DOGLIONI *et alii*, 1994).

The front of the Southern Apennines thrust belt in Daunia consists of the superimposition of a series of tectonic units and by the related thrust deposits having the Varicoloured Clays as a common base. Upward these tectonic nappes are covered by flysch Miocene formations.

Morphologically, the area is characterized by mostly gentle hills, reaching the highest gradients where the more competent rock masses crop out. Notwithstanding the general medium- to low values of slope gradients, landslide features are widespread, as a consequence of the prevailing clay intervals within the stratigraphic successions, and of the high degree of tectonic deformation in the outcropping rocks. The towns are generally located at the top of the hills, and often the peripheral portions of the inhabited areas are affected by retrogressional activity of the slope movements. In addition to rainfall, the main triggering actions are represented by seismic activity (from the nearby seismogenic areas of the Apennine Chain and the Gargano Promontory) and by human actions.

LANDSLIDE HAZARD IN DAUNIA

Extensive research of historical landslides have highlighted the high instability that affects the Daunia Apennines (PARISE, 2000, 2003). In particular, many urban areas of this sector of Apulia appear to have often been involved in re-activation of ancient slope movements. Further, outcomes from the AVI (an acronym for Areas Vulnerated in Italy by landslides and floods) project, that collected at the national scale information about landslides occurred from 1950 to 2001 (GUZZETTI *et alii*, 1994), showed the Daunia Appennine to be the most significant sector in Apulia as regards slope instability.

Notwithstanding the significant geological complexity of Daunia, within the framework of a recent research project co-financed by Apulia Region (PST 2004-2009) COTECCHIA *et alii* (2009) made an effort to identify a limited number of landslide types in the area, based upon both representative geo-morpho-hydromechanical settings and failure mechanisms. The three possible slow sliding mechanisms that can take place in the flyschioid and chaotic clay deposits of Daunia can be described as follows (COTECCHIA *et alii*, 2009, 2010): L1-type is represented by medium to deep-seated compound landslides with failure surface deeper than 30 m, and width comparable to the length. These landslides have been often found to present retrogressive and multiple states of activity (WP/WLI, 1993). The second typology, L2, corresponds to mudslides, commonly either lobate or elongate, of shallow to intermediate depth (≤30 m). Locally, the retrogressive failure surface may also result deeper (30÷40 m). The third typology, L3, is represented by deep-seated to intermediate depth rotational landslides evolving into either mudslides or earthflows downslope.

The above Authors also stated the prominent role of the rainfalls on the onset of landslides due to the increasing groundwater level (COTECCHIA *et alii*, 2009), but their perspective did not cover the construction of rainfall thresholds.

HISTORICAL DATA

Several sources have been investigated in order to collect data useful for the definition of a rainfall threshold for the occurrence of landslides in Daunia. The required data are represented by detailed information about time and site of occurrence of each event, together with availability of pluviometric data from rain gauges located nearby the landslides, or (within a certain distance) in orographic conditions similar to those of the site affected by the landslide occurrence.

The investigated sources consist of:

- reports from experts of the Gruppo Nazionale per la Difesa dalle Catastrofi Idrogeologiche (GNDCI);
- data from studies carried out by the Civil Defense Office of Apulia;
- a collection of chronological data on landslides in Daunia (PARISE, 2000);
- preliminary outcomes from the project "Rainfall thresholds" in Apulia and Molise regions.

Analysis of these sources, and their critical comparison, allowed to collect about 200 events of landslides for which a temporal reference was found (Fig. 1). Unfortunately, the reference was incomplete (only limited to month and year) in 13% of the cases, which made these information not useful for the definition of a rainfall threshold.

As for the rest of the data, corresponding to 168 landslides,

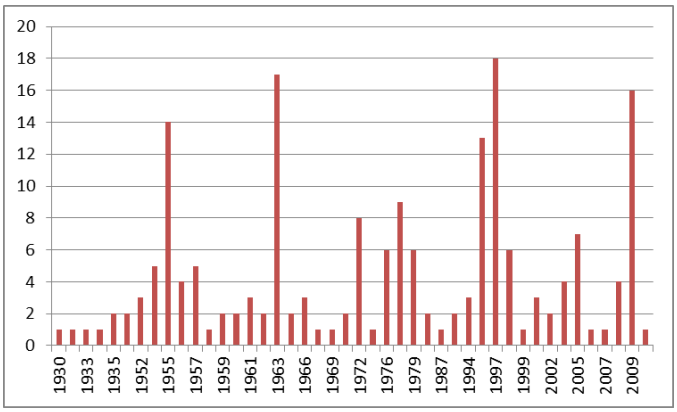

Fig. 1 – Chronological distribution of landslides in Daunia (sample of 191 events).

at present a thorough work of selection of the most proper rain gauge, and the control of availability of the rainfall registration, is being carried out, in order to proceed to the next step in the definition of the rainfall threshold.

RAINFALL THRESHOLD

In the last years, CNR-IRPI developed an effective method for identifying and characterizing the rainfall event causing shallow landslides in terms of time duration and rainfall

intensity (BRUNETTI *et alii*, 2010). The method is shown in Figure 2 and is followed for collecting each landslide event populating CNR-IRPI database (ROSSI *et alii*, 2010; PERUCCACCI *et alii*, 2012). In this procedure, the landslide event is carefully described in time and place by the chronicles or the inventories. This requires that both the day of the landslide must be certain and its location precisely identifed: this is needed for choosing the nearest rain gauge (far less than 10 km from the landslide). The whole procedure needs a trained operator to correctly identify the landslide and the rainfall event. Furthermore, the cumulative amount of precipitation calculated relates to hourly measures of rain gauges; this means that only digital rain gauges can be suitable for the study.

The selective character of the CNR-IRPI method reduces the number of the landslide events to be considered but, conversely, it allows to select rainfall events that have effectively resulted in triggering landslides, and to plot the intensity vs duration, or cumulative rain vs duration thresholds, at different spatial scales, including the regional and sub-regional. This is exactly the on-going work undertaken in cooperation with the Apulia Region, and which outcomes will be presented in the near future.

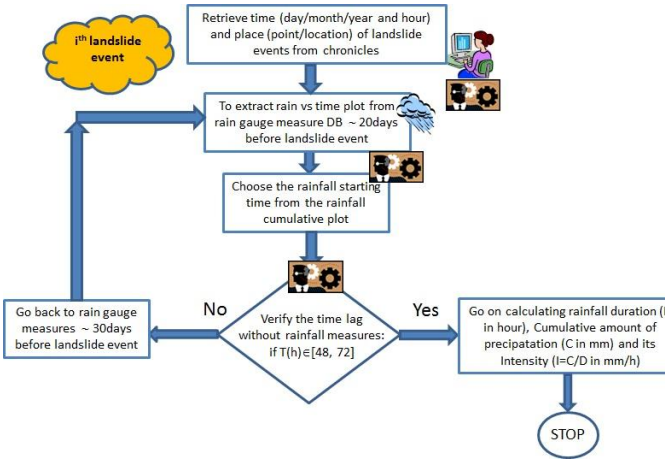

Fig. 2 – Flowchart of the method for the identification of the rainfall-inducing landslides.

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