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Populating a catalogue of rainfall events that triggered shallow landslides in Italy

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INTRODUCTION

In Italy, rainfall induced landslides - including soil slips and debris flows - occur every year, claiming lives and causing severe economic damages. In the 61-year period 1950-2010, such phenomena have caused more than 6400 casualties (SALVATI *et alii*, 2010). During 2011, 25 people have been either killed or wounded by landslides. As a result, the prediction of slope failures triggered by rainfall is of primary importance for decision makers and civil protection authorities.

The predictive ability for rainfall induced landslides is still limited due to the complexity of the problem, to the number of the involved variables, and to the methodological approaches that are not always rigorous.

As regards shallow landslides, a team of researchers working at CNR-IRPI (Italian National Research Council, Institute of Research for Geo-Hydrologic Protection) is carrying out a research project funded by the Italian national Department for Civil Protection (DPCN), aimed at defining regional and sub-regional rainfall thresholds.

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METHOD

A hydrological approach has been adopted to evaluate the dependence of landslide occurrence on rainfall values. The method is based on a statistical-probabilistic analysis of rainfall series and dates of occurrence of landslides (see, among the others: CAMPBELL, 1975; CAINE, 1980; WILSON & WIECZOREK, 1995; SIRANGELO & VERSACE, 1996; ALEOTTI, 2004; GUZZETTI *et alii*, 2007; 2008).

Empirical thresholds may define the rainfall conditions (e.g. cumulated event rainfall, mean rainfall intensity vs. rainfall duration, cumulated event rainfall vs. rainfall duration) that, when reached or exceeded, are likely to trigger landslides (REICHENBACH *et alii*, 1998). Landslide rainfall thresholds can be defined through the statistical analysis of past rainfall events that resulted in slope failures. They can be classified based on the geographical extent of the study area for which they are determined (i.e., global, national, regional, or local), and on the type of rainfall information used (GUZZETTI *et alii*, 2007, 2008).

Reliable regional and local rainfall thresholds require the collecting of large amount of information on geographical and temporal location of the slope failures, and on rainfall amounts responsible of the mass movements. For this purpose, the team is compiling a catalogue containing information about rainfall events that have resulted in landslides in Italy in the 10 year period 2002-2011.

The catalogue contains 2318 rainfall events that triggered single or multiple landslides in Italy. Figure 1 portrays the abundance of rainfall events that triggered landslides in the 20 Italian regions. The collected events are distributed almost equally between Northern, Central and Southern Italy (Fig. 2).

Information on rainfall events that resulted in landslides in Italy has been searched on (*i*) newspapers, in particular those available on line (actually the main source of information), (*ii*) blogs, (*iii*) historical databases, (*iv*) event reports and information provided by DPCN, and (*v*) recent publications and other technical reports. In particular, among technical reports, an important source of information is given by the reports of landslide events compiled by local fire brigades. Currently, fruitful collaborations exist with fire departments in Basilicata, Calabria, Campania, Marche, Sicilia, and Umbria.

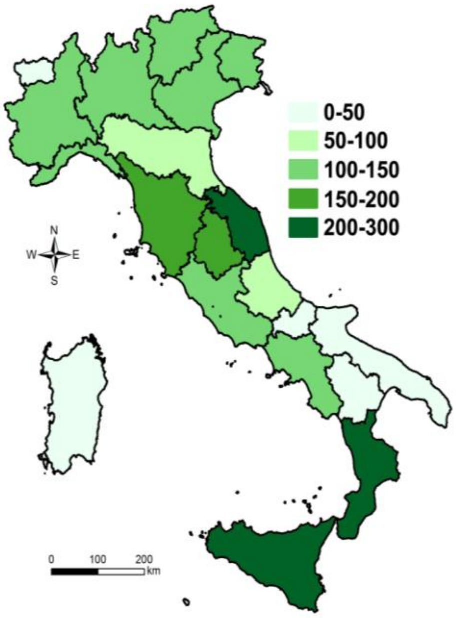

Fig. 1 – Classes of the number (*N*) of rainfall events that triggered landslides in the Italian regions.

In the catalogue, for each rainfall event that triggered one or more landslides, the information includes:

a) event identification (ID number, reference source);
b) landslide localization (place, municipality, province, region, geographical precision);
c) landslide classification;
d) temporal information (day, month, year, time, date, temporal precision);
e) rainfall information (representative rain gauge, rainfall duration, *D*, mean intensity, *I*, cumulated event rainfall, *E*).

The geographic coordinates of the documented slope failures have been obtained using Google Earth®. Different levels of uncertainty can characterize landslide locations, so four classes of geographic precision have been adopted.

In order to reconstruct the rainfall conditions responsible of the mass movements, the precise occurrence date must be known. Time of the failure can be also affected by some uncertainty, thus three classes of temporal precision have been adopted.

Once location and (known or inferred) time of initiation of the failure(s) are established, related rainfall information from the DPCN national network of 1950 rain gauges are analysed (Fig. 3). Additional data from regional rain gauge networks have also been used.

The selection of the "representative" rain gauge used to reconstruct the rainfall event (rainfall duration, *D*, rainfall mean intensity, *I*, and cumulated event rainfall, *E*), responsible of the individual failure, is based on *(i)* the geographical distance between the rain gauge and the landslide, *(ii)* the comparison between the elevation of the rain gauge and of the landslide, and *(iii)* other local topographical and morphological settings.

The rainfall duration *D* is determined as the time elapsed

Tab. 1 – Number of landslides and of rainfall events collected for each region. Density: number of detected landslides per thousand of square km. Source: C = Chronicle; FB = Fire Brigades.

Region	Number of landslides	Density	Number of events	Source
Abruzzo	120	11.1	84	C
Basilicata	42	4.2	40	C - FB
Calabria	312	20.7	232	C - FB
Campania	133	9.8	125	C - FB
Emilia - Romagna	87	3.9	79	C
Friuli - Venezia Giulia	158	20.1	116	C
Lazio	122	7.1	101	C
Liguria	143	26.4	141	C
Lombardia	148	6.2	132	C
Marche	418	44.6	300	C - FB
Molise	2	0.5	2	C
Piemonte	123	4.8	109	C
Puglia	2	0.1	2	C
Sardegna	19	0.8	18	C
Sicilia	236	9.2	219	C - FB
Toscana	211	9.2	155	C
Trentino - Alto Adige	161	11.8	147	C
Umbria	186	22.0	170	C - FB
Valle d'Aosta	33	10.1	32	C
Veneto	137	7.4	114	C

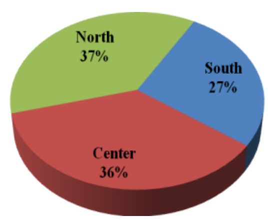

Fig. 2 – Percentages of rainfall events that have resulted in landslides identified in Northern, Central and Southern Italy.

between the rainfall starting time, and the time (known or inferred) of landslide initiation. The definition of the rainfall starting time is not trivial. Two rainfall events are considered separated when a minimum period without rain exists. A four-day period without rainfall is selected for the late autumn and winter (October to April), and a two-day period without rainfall was selected for other seasons (May to September). Furthermore, "frontal" from "convective" type of rainfall events should also be distinguished. Recently, a stationary criterion to identify the effective rainfall responsible of shallow landslides has been proposed by VESSIA & PARISE (2012). Finally, once the rainfall event is identified, the rainfall duration *D* [h], the corresponding cumulated event rainfall *E* [mm], and the mean rainfall intensity *I* [mm h^{-1}] can be calculated.

The catalogue represents the single largest collection of information on rainfall induced landslides in Italy (Fig. 4), and will be exploited to determine empirical rainfall thresholds for the possible initiation of shallow slope failures. To define objective rainfall thresholds and associated uncertainties, two consolidated statistical methods, including a *Bayesian* inference method and a *Frequentist* probabilistic approach, can be adopted

(Brunetti *et alii*., 2010, Peruccacci *et alii*, 2012).

The final aim of the research project is the definition of reliable rainfall thresholds for each of the 20 Italian regions, for the 129 alert zones (established by DPCN), and for homogeneous contexts (i.e. lithological, pedological, climatic) (Peruccacci *et alii*). The obtained thresholds could be implemented in a landslide warning system to forecast the possible occurrence of rainfall-induced shallow landslides in Italy.

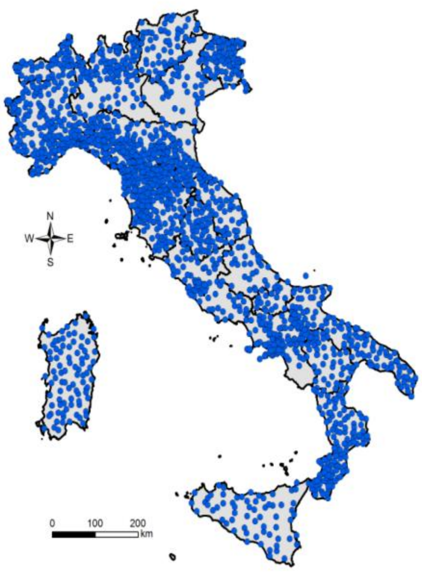

Fig. 3 – Location of the 1950 rain gauges of the DPCN network.

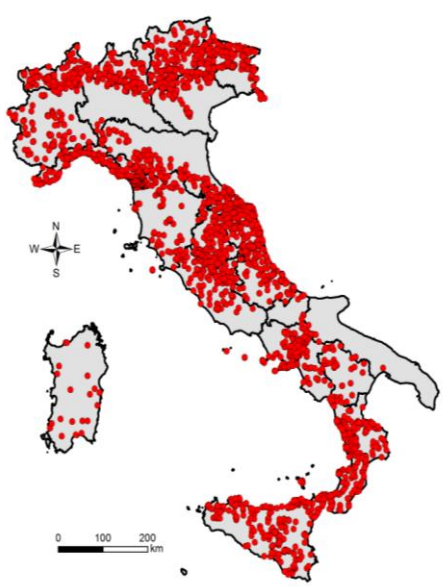

Fig. 4 – Localization of the landslides detected.

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