
Catalogue of Rainfall Events with Shallow Landslides and New Rainfall Thresholds in Italy

280

Maria Teresa Brunetti, Silvia Peruccacci, Loredana Antronico, Devis Bartolini, Andrea Maria Deganutti, Stefano Luigi Gariano, Giulio Iovine, Silvia Luciani, Fabio Luino, Massimo Melillo, Michela Rosa Palladino, Mario Parise, Mauro Rossi, Laura Turconi, Carmela Vennari, Giovanna Vessia, Alessia Viero, and Fausto Guzzetti

Abstract

In Italy, rainfall-induced shallow landslides are frequent and harmful phenomena. The prediction of their occurrence is of social significance for civil protection purposes. For the operational prediction of rainfall-induced shallow landslides empirical rainfall thresholds based on the statistical analysis of past rainfall conditions that triggered slope failures are commonly used. The paper describes a catalogue of 1981 rainfall events, which caused 2408 shallow landslides in Italy in the period 1996–2012. Information on rainfall-induced landslides was collected searching chiefly online newspaper archives, blogs, and fire brigade reports. For each documented failure, we reconstructed the triggering rainfall conditions (rainfall duration D and cumulated rainfall E) using national and regional rain gauge networks. We analysed the rainfall conditions to determine new ED rainfall thresholds for Italy. The calculated thresholds can be implemented in a landslide forecasting system to mitigate landslide hazard and risk.

Keywords

Shallow landslides • Rainfall thresholds • Italy

M.T. Brunetti (✉) · S. Peruccacci · S. Luciani · M. Melillo · M. Rossi · F. Guzzetti
CNR IRPI, via Madonna Alta 126, 06128 Perugia, Italy
e-mail: mariateresa.brunetti@irpi.cnr.it

M.T. Brunetti · S. Luciani · M. Rossi
Dipartimento di Scienze della Terra, Università degli Studi di Perugia, piazza dell'Università, 06123 Perugia, Italy

L. Antronico · S.L. Gariano · G. Iovine
CNR IRPI, via Cavour 6, 87036 Rende, Italy

D. Bartolini
Formerly CNR IRPI, via Madonna del Piano 10, 50019 Sesto Fiorentino, Italy

A.M. Deganutti
CNR IRPI, corso Stati Uniti 4, 35127 Padova, Italy

F. Luino · M.R. Palladino · L. Turconi · A. Viero
CNR IRPI, strada delle Cacce 73, 10135 Torino, Italy

M. Parise · C. Vennari · G. Vessia
CNR IRPI, via Amendola 122 I, 70126 Bari, Italy

G. Vessia
Dipartimento di Ingegneria e Geologia, Università "G. d'Annunzio" di Chieti-Pescara, via dei Vestini 31, 66031 Chieti Scalo, Italy

280.1 Introduction

In Italy, landslides cause every year severe economic damages and casualties, frequently with loss of life (Salvati et al. 2010). Prolonged rainfall and high intensity precipitation are the main triggering factors of shallow landslides. The prediction of rainfall-induced slope failures is of primary importance for decision makers and for civil protection authorities. At this aim, our Institute (CNR IRPI) is collaborating with the Italian National Department for Civil Protection (DPC) to study the rainfall conditions responsible for the occurrence of shallow landslides in Italy. Our research activity focuses on the definition of empirical rainfall thresholds to be used in a nationwide landslide warning system (Rossi et al. 2012). In the system, the thresholds are compared to rainfall measurements and quantitative rainfall forecasts to estimate the landslide occurrence probability.

280.2 Catalogue of Rainfall Events

Empirical rainfall thresholds can be defined through the statistical analysis of past rainfall events that have caused slope failures (Guzzetti et al. 2008). Reliable rainfall thresholds require collecting a large amount of information (i) on the geographical and temporal location of the slope failures, and (ii) on the rainfall conditions responsible of the observed landslides. We are compiling a catalogue of rainfall events that have resulted in slope failures in Italy. At present, the catalogue lists 1981 rainfall events that triggered 2408 documented shallow landslides in the period from January 1996 to August 2012 (yellow dots in Fig. 280.1). The documented mass movements are distributed in all the 20 Italian regions, with the exception of Liguria, Emilia Romagna and Toscana. For the latter three regions, we collected information on nearly 300 rainfall events with landslides that are under investigation at the date of the paper, and not shown in Fig. 280.1. The catalogue is the single largest collection of information on rainfall events responsible of landslides in Italy in the last 10-year period.

To compile the catalogue, we started searching for information on rainfall-induced shallow landslides chiefly in digital or printed newspapers, in blogs, and in technical

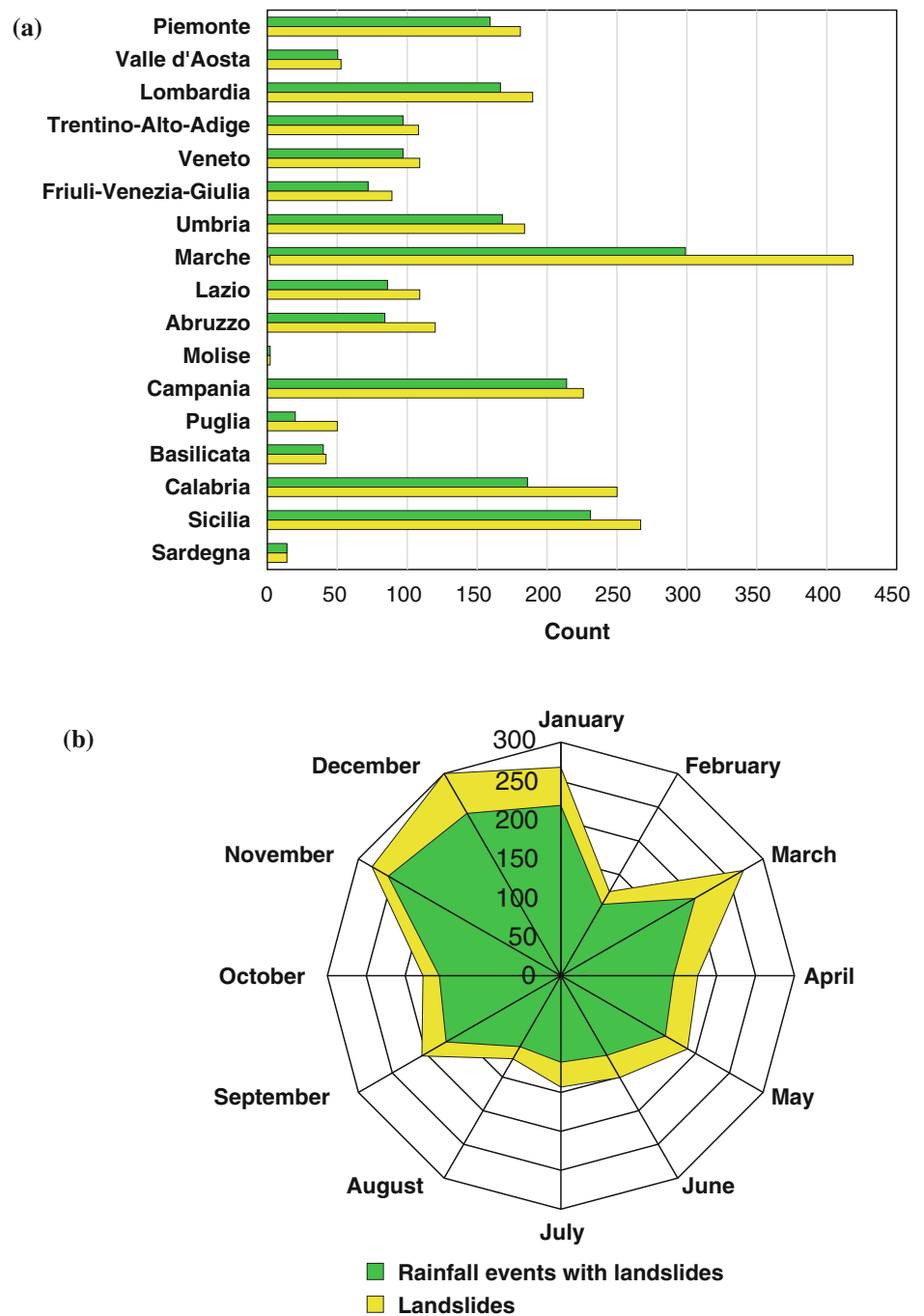
documents, in particular fire brigade reports. Additional sources of information were historical databases and scientific journals. To reconstruct the rainfall conditions responsible for the mass movements, the information must contain the location and the time, or at least the day, of the failure. About half of the documents collected during the search were discarded, because the location and/or the occurrence date were missing. When only the day or part of the day of occurrence was known, the time of failure was inferred using predefined values. The geographical position and the time of the failure are affected by uncertainty. Depending on the quality of the available information, we attributed to each failure a level of mapping accuracy P , in four classes: high, $P_1 < 1 \text{ km}^2$; medium, $1 \leq P_{10} < 10 \text{ km}^2$; low, $10 \leq P_{100} < 100 \text{ km}^2$; and very low $100 \leq P_{100} < 300 \text{ km}^2$ (Peruccacci et al. 2012). Three classes of increasing temporal accuracy for the failures (day, period of the day, and time) were also adopted.

Once the location and the time (known or inferred) of initiation of the failure were established, rainfall information was obtained from a national network of 2228 rain gauges with hourly and sub-hourly data provided by DPC. Additional data from regional rain gauge networks were also available to us. The rain gauge used to reconstruct the

Fig. 280.1 Map showing the location of 2408 rainfall-induced shallow landslides (yellow dots) in Italy between 1996 and 2012. The map shows the 20 Italian administrative regions



Fig. 280.2 a Number of rainfall events (*green bars*) and landslides (*yellow bars*) in the 17 Italian regions for which information is available in the catalogue. **b** Number of rainfall events (in *green*) and landslides (in *yellow*) subdivided by month



rainfall event that caused the failure (i.e., rainfall duration, D , and cumulated event rainfall, E) was selected considering the distance from the landslide, and the relative elevation. In places (e.g., in the complex Alpine orography), the local morphological setting was also considered.

We define a rainfall event as a period or a sequence of periods of continuous precipitation separated from previous events by dry periods. The length of the dry periods can vary, depending e.g., on seasonal, meteorological, and climatic conditions. The rainfall duration D was determined as

the time between the rainfall event starting time and the time (known or inferred) of the landslide initiation. Once the rainfall duration D was determined, the cumulated event rainfall E was obtained from the selected rain gauge record.

In the catalogue, for each rainfall event that triggered one or more landslides the information includes: (i) rainfall event identification (code number, reference source), (ii) landslide location (place, municipality, province, region, geographical precision), (iii) landslide classification (if available from the source of information), (iv) temporal information (day,

Fig. 280.3 **a** Number and percentage of landslides of different types in the catalogue. **b** Number and percentage of landslides with different level of temporal accuracy. **c** Number and percentage of landslides with different level of mapping accuracy

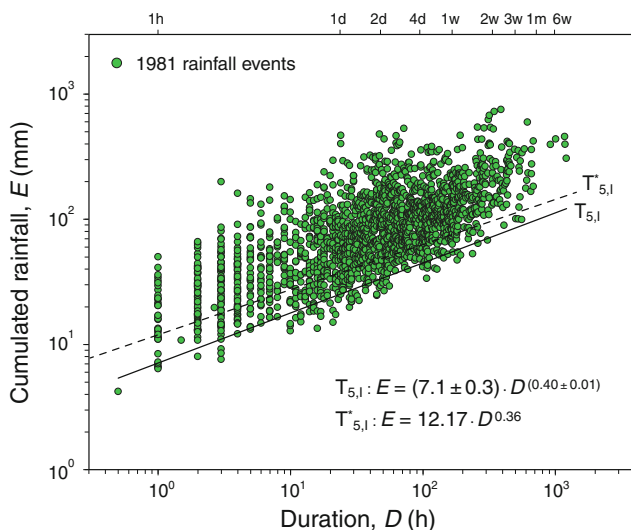
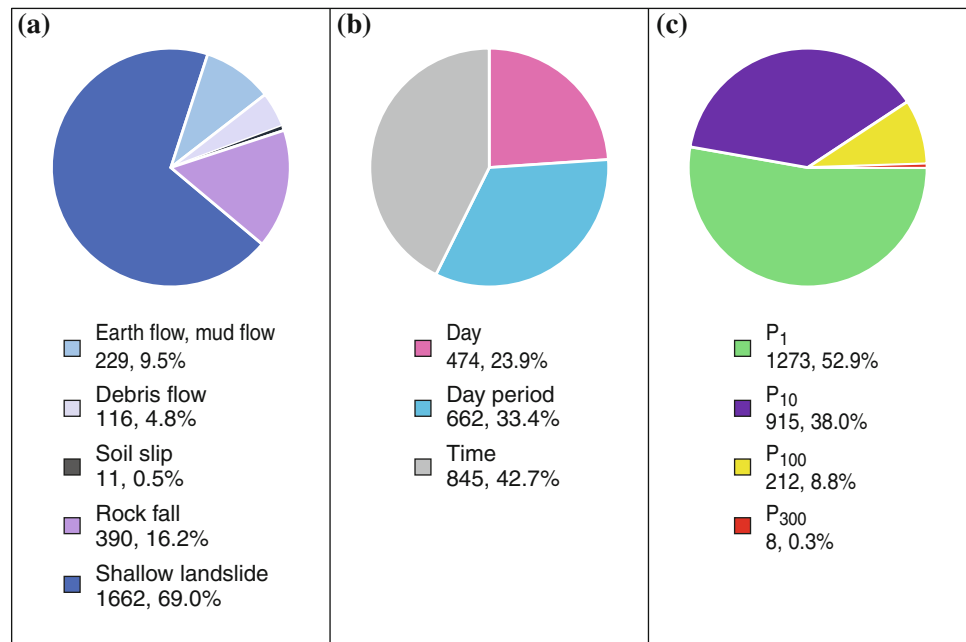


Fig. 280.4 Distribution of the cumulated rainfall (E) as a function of the rainfall duration (D) for 1981 rainfall events (green dots) that triggered 2408 landslides in Italy. The *black solid curve* is the national rainfall threshold at 5% ($T_{5,1}$) of exceedance level. The *black dashed curve* is the previous national rainfall threshold at 5%

month, year, time, date, temporal precision) and (v) rainfall information (representative rain gauge, rainfall duration, D , cumulated event rainfall, E and rainfall mean intensity, I). Figure 280.2a summarizes the total number of rainfall events (green bars) and the total number of landslides (yellow bars) in the 17 Italian regions for which information is available in the catalogue. Variability in the number of events in each region is due to the incompleteness of the catalogue. Figure 280.2b portrays the monthly distributions of rainfall

events (in green), and of landslides (in yellow), and reveals that rainfall induced failures in Italy occur mostly between November and January, but are also frequent in March.

Figure 280.3a shows the number and percentage of each landslide type listed in the catalogue. Most of the slope failures (1662, 69.0%) are classified as generic shallow landslides, due to a lack of a detailed description of the mass movement type in the source of information. The time of the failure is available for a large portion (845, 42.7%) of the rainfall-induced landslides in the catalogue (Fig. 280.3b). The majority of the landslides (1273, 52.9%) are located within an accuracy of 1 km² (Fig. 280.3c).

280.3 National Rainfall Thresholds

We exploited the catalogue to define the new cumulated event rainfall-rainfall duration (ED) thresholds for the possible initiation of shallow landslides in Italy. For the purpose, we analysed the distribution of the rainfall ED conditions responsible for the failures using a statistical frequentist method (Brunetti et al. 2010; Peruccacci et al. 2012). The method allows defining objective probabilistic rainfall thresholds, and the associated uncertainties. Figure 280.4 shows, as an example, the new ED national rainfall threshold (black solid curve) at 5% of exceedance level ($T_{5,1}$). The equation and the statistical uncertainties associated with the threshold parameters are also shown. As a comparison, in the same Fig. 280.4 we show the previous national rainfall threshold (black dashed curve) at 5% ($T_{5,1}^*$) derived from Brunetti et al. (2010). The new threshold is

lower than the previous and this is mostly ascribed to the different sources of information used to collect the two data sets. The main sources of landslide and rainfall information used for this work were news and fire brigade reports. Brunetti et al. (2010) used chiefly information collected from the scientific literature, which usually reports large (i.e., rare, catastrophic) rainfall events that have triggered abundant and widespread landslides. Using the frequentist method large rainfall events in the data set result in higher rainfall thresholds.

The new rainfall thresholds can be implemented in a nationwide landslide warning system.

Acknowledgments Research conducted with funding provided by the Italian National Department for Civil Protection (DPC).

References

- Brunetti MT, Peruccacci S, Rossi M, Luciani S, Valigi D, Guzzetti F (2010) Rainfall thresholds for the possible occurrence of landslides in Italy. *Nat Hazards Earth Syst Sci* 10:447–458
- Guzzetti F, Peruccacci S, Rossi M, Stark CP (2008) The rainfall intensity-duration control of shallow landslides and debris flows: an update. *Landslides* 5(1):3–17
- Peruccacci S, Brunetti MT, Luciani S, Vennari C, Guzzetti F (2012) Lithological and seasonal control of rainfall thresholds for the possible initiation of landslides in central Italy. *Geomorphology* 139–140:79–90
- Rossi M et al (2012) In: Eberhardt E et al (eds) *Landslides and engineered slopes: protecting society through improved understanding*, ISL NASL 2012, Banff, Alberta, Canada, June 2012, vol 2. Taylor & Francis Group, London, pp 1895–1899
- Salvati P, Bianchi C, Rossi M, Guzzetti F (2010) Societal landslide and flood risk in Italy. *Nat Hazards Earth Syst Sci* 10:465–483