Computers & Geosciences 86 (2016) 146–153

Contents lists available at ScienceDirect

Computers & Geosciences

journal homepage: www.elsevier.com/locate/cageo

Case study

Mimic expert judgement through automated procedure for selecting rainfall events responsible for shallow landslide: A statistical approach to validation

Vessia Giovanna [a,b,*], Pisano Luca [b,c], Vennari Carmela [b,d], Rossi Mauro [e], Parise Mario [b]

[a] Department of Engineering and Geology, University "G. d'Annunzio" of Chieti-Pescara, Chieti Scalo, Italy
[b] Institute of Research for Hydrogeological Protection IRPI, National Research Council CNR, Bari, Italy
[c] Department of Biosciences and Territory, University of Molise, Pesche (IS), Italy
[d] Department of Earth, Environmental and Resources Science, University of Naples Federico II, Napoli, Italy
[e] Institute of Research for Hydrogeological Protection IRPI, National Research Council CNR, Perugia, Italy

ARTICLE INFO

Article history:
Received 25 July 2015
Received in revised form
22 October 2015
Accepted 29 October 2015
Available online 31 October 2015

Keywords:
Rainfall thresholds
Shallow landslide
Automated procedure
Statistical tests
LANDTRAIN code

ABSTRACT

This paper proposes an automated method for the selection of rainfall data (duration, *D*, and cumulated, *E*), responsible for shallow landslide initiation. The method mimics an expert person identifying *D* and *E* from rainfall records through a manual procedure whose rules are applied according to her/his judgement. The comparison between the two methods is based on 300 *D*–*E* pairs drawn from temporal rainfall data series recorded in a 30 days time-lag before the landslide occurrence. Statistical tests, employed on *D* and *E* samples considered both paired and independent values to verify whether they belong to the same population, show that the automated procedure is able to replicate the expert pairs drawn by the expert judgment. Furthermore, a criterion based on cumulated distribution functions (CDFs) is proposed to select the most related *D*–*E* pairs to the expert one among the 6 drawn from the coded procedure for tracing the empirical rainfall threshold line.

1. Introduction

Shallow landslides triggered by rainfalls are a common source of damage to infrastructures, casualties and interruption of functionality of transportation systems worldwide. For this reason early warning systems have been devised to predict their possible occurrence (Baum and Godt, 2010; Rossi et al., 2012; Papa et al., 2013) commonly by means of empirical rainfall thresholds. These have been introduced since several decades (Wieczorek and Guzzetti, 1999; Berti et al., 2012; Peruccacci et al., 2012; Nikolopoulos et al., 2014; Segoni et al., 2014; Zhuang et al., 2015) and represent the minimum rainfall cumulated *E* or intensity *I* vs duration values *D* responsible for landslide initiation. *D*,*E* or *D*,*I* pairs have been selected according to several expert criteria implemented by manual procedures proposed for different geographic and geologic settings (see the works by Caine (1980) and Innes (1983) from worldwide databases, Ceriani et al. (1994) and Bolley and Oliaro (1999) from the Italian Alps, Wilson et al. (1992) from Hawaii, Sandersen et al. (1996) from Norway, Dahal and Hasegaw (2008) from Nepal). Recently, for the Italian territory an expert method has been proposed by Brunetti et al. (2010) and Peruccacci et al. (2012) to select *D*,*I* and *D*–*E* pairs, respectively, aimed at the identification of rainfall threshold for the initiation of shallow landslides. Through the expert method the latest Italian empirical rainfall threshold has been drawn using 2408 landslide events (Brunetti et al., 2015). This method has been used within the early warning system SANF (an acronym for national early warning system for rainfall-induced landslides) devised by the CNR-IRPI research group (Rossi et al., 2012) for the Italian Civil Protection Office (DPC). Within this research project, financially supported by the DPC, some attempts to implement automated procedure that mimic the expert judgement were addressed. Automated procedures are needed from local administrations which employ non-expert users to implement policies against hazards. At this aim, the automated procedure by Vessia et al. (2014) was implemented as a code in R language (R Core Team, 2013). It enables non-expert users to retrieve multiple *D*,*E* or *D*,*I* pairs from an input datasets of shallow landslide events. Comparing expert and automated methods that, starting from an observed shallow landslide event, calculate the event rainfall likely to be responsible for the failure, is not a straightforward task. In fact, there is often the possibility of multiple choices for the rainfall event. This is typically reduced at only one selection in the expert method, based on the user experience. The expert user accomplishes the calculation of *E* and *D* through flexible judgement according to different rainfall patterns in different seasons or climatic

* Corresponding author at: Department of Engineering and Geology, University "G. d'Annunzio" of Chieti-Pescara, Chieti Scalo, Italy.
E-mail address: g.vessia@unich.it (V. Giovanna).

http://dx.doi.org/10.1016/j.cageo.2015.10.015
0098-3004/

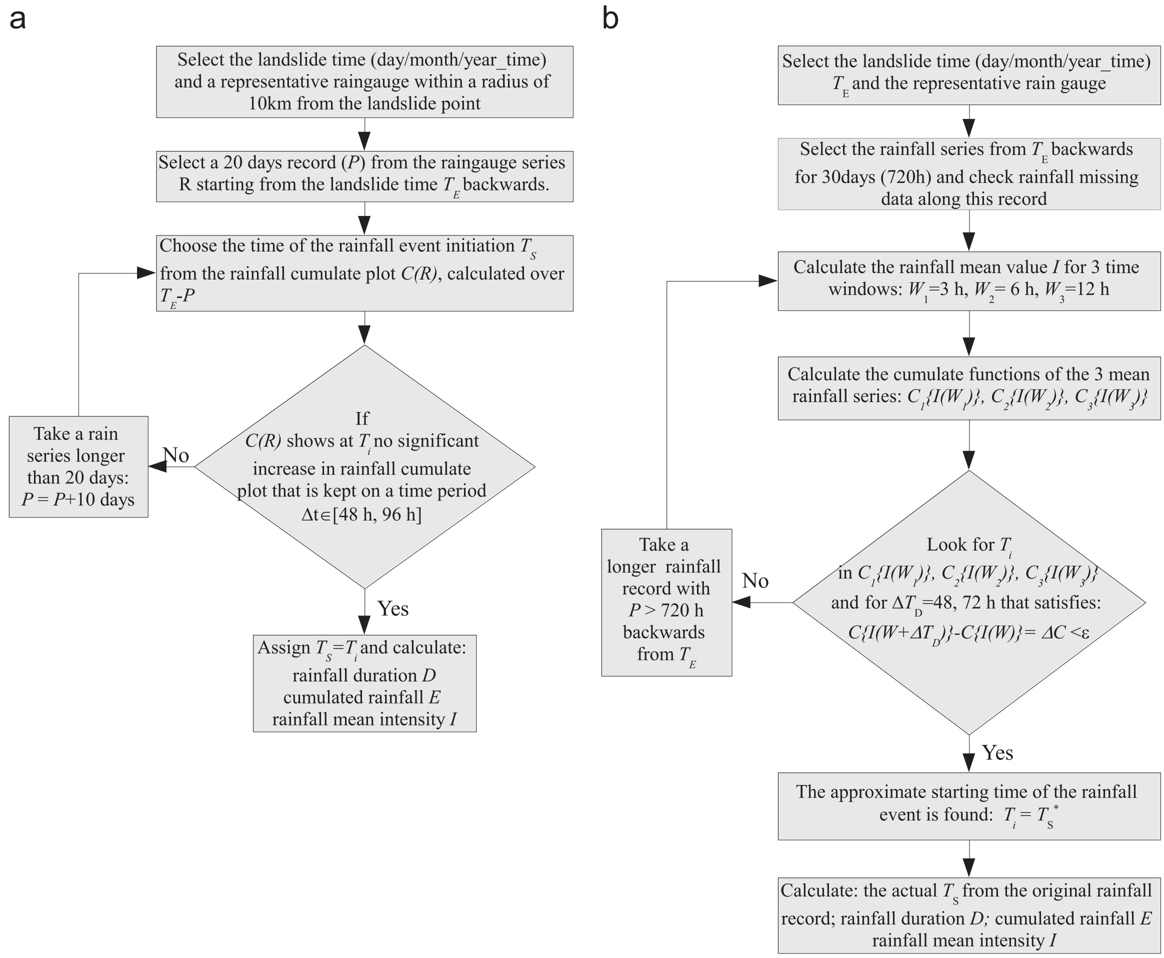

Fig. 1. Logical sequence of the working procedure to calculate (D,E) pairs from rain gage rainfall records: (a) the expert method and (b) the automated method.

conditions. On the other hand, an “automated method” should not depend on the operator, but rather be able to guarantee the repeatability of the working steps, even though with a typically lower degree of flexibility and systematic biases. In the following, the comparison between the preceding two types of methods that independently calculate D–E pairs is undertaken. The comparison between the D–E pairs is addressed through statistical tests. In detail, to make the comparison feasible, two conditions were met: (1) the same sample, consisting of 300 landslide events that occurred in Central-Southern Italy in the time span 2002–2012 was used and (2) the same criteria to define the time of the landslide onset and to derive its geographical location from the sources of information have been adopted. Main objective of the comparison is investigating the sample marginal distribution and moments of E and D to check whether both belong to the same population. If this is the case, the “automated method” can be considered to adequately reproduce the “expert” choice of the rainfall event that likely induced a shallow landslide. This means that the systematic bias introduced by a repetitive procedure does not heavily affect its calculations. In this regard, the automated method shows to be predictive like the expert method. To this end, statistical tests of hypotheses are used for paired and independent samples.

2. Methodological approach

The exhaustive description of the effects of rainfall events as inducing shallow landslides is not feasible due to many uncertain factors that are (1) the landslide initiation time and its location, drawn by reliable sources of information, (2) the number of contemporary landslides and the time delays of multiple landslide initiation, (3) the contribution of evapotranspiration on the moisture conditions predisposing to landslide occurrence. As the sources of information are concerned, the most certain source is the direct observation of witnesses, better if they are landslide experts, which, however, is rarely the case. Thus, the main sources of information for scientists are newspapers or reports from fire fighters. These latter typically refer only to those landslides affecting the main transportation lines or urban centers. When single or multiple landslides occur outside urbanized areas they presumably go undetected. Furthermore, when a shallow landslide occurs along a transportation line, a spatial precision lower than 1 km is easier to be acquired, although it strongly depends on the quality of the information sources. In these cases, it is cumbersome to associate a rain-gage to this landslide. Shallow landslides with geographical precisions lower than 100 km^2 will not be taken into account in this article.

Concerning the evapotranspiration role within soil matrix, it reduces the wet condition of the surficial soil deposits. The magnitude of this contribution over the seasons in Mediterranean climate has been investigated during the last years by means of experimental studies, thus some assumptions can be posed.

Longobardi and Khaertdinova (2015) investigated the evapotranspiration fluxes during inter-storm periods at an experimental site in Southern Italy. Their measures pointed out that evapotranspiration affects the 10 cm depth much more than at 30 cm. Moreover, 15 days seem to be the time span needed for increasing 3–4% the water depletion at 30 cm, both during the wet and the dry seasons. Thus, at a seasonal scale, the rate of depletion