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A stationary criterion to identify the duration of efficient rainfalls to trigger shallow landslide

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Even though rainfall is considered a well known trigger of natural slope instability, its effective role in initiating landsliding phenomena cannot be easily distinguished due to many time- and space- variable interactions among several factors (i.e. slope geometry, mechanical and hydraulic characters of superficial layers and the basin, etc.). A common approach to relate rainfall to the onset of shallow landslides is to plot effective rainfall intensity vs duration to draw intensity threshold lines. Since the earliest work by Caine (1980) on this topic, several researchers have tried to establish intensity thresholds by means of deterministic and probabilistic approaches from a number of worldwide and regional rainfall-landslide inventories. With respect to this intensity-duration threshold approach, information about rainfall-induced landslides are generally collected from chronicles or historical landslide time series, whilst no data about the hydraulic and geometric features of soils and rocks involved into the natural slope instability is commonly taken into account. On the contrary, rainfall heights at different time lag (even every 30 min) are available at different stations by rain gauges. As rain gauge measurements are concerned, these can suffer many problems such as temporary saturation, temporary lack of data transmission and anomalous geographical distribution of the rainfall. Recently, satellite data have been employed to quantify the rainfall event related to landslide occurrence but their correlation to the effective rainfall height at a site is not guaranteed yet. So far, rain gauge measures still represent the most used option. Moreover, the physical simplification introduced by such "rainfall based" approach on landslide prediction can be accepted due to the assumption that only shallow landslides are considered for drawing a regional intensity-duration threshold from the considered data.

Starting from the above considerations, and within the framework of a nationwide project by CNR-IRPI, under funds from the National Civil Department, the authors propose in this article a new criterion to identify from rain gauge measures the duration of the rainfalls triggering shallow landslides. The new criterion represents an attempt to identify the duration of the "effective rainfall event" responsible for the landslide occurrence, as reported by newspaper clips and/or in real time web newspapers. At this regard, antecedent precipitations are not taken into account, since the model considers only that amount of rainfall that effectively triggers the slope failure. The model analyses the hourly rainfall time series for at least one month before occurrence of the shallow landslide, using a historical landslide archive covering the time range between 2002 and 2011 in the Lazio Region, central Italy. This archive was obtained by a procedure consisting of the following steps: i) critical scrutiny of chronicles, ii) identification of the landslide site, and iii) retrieval of the rainfall data from the nearest rain gauge station within the pluviometric network provided by the National Department of Civil Protection. The proposed method, for each reported landslide, uses the cumulative function of the rainfall heights and rainfall intensity calculated for different time lag. Then, in order to identify the beginning of the effective rainfall event, two conditions have to be satisfied: (1) the difference in rainfall intensity between two adjacent windows must be very low, and (2) the time series of lack of rainfall must be stationary. When these conditions are met, the initial time of the efficient rainfall necessary to trigger the landslide is established. Such criterion is statistically based according to the rainfall time distribution only.

No assumption is needed on the probabilistic distributions of time series of rain/not rain. Such approach has been successfully applied to medium-to-long rainfalls, for which rain/not rain datasets are statistically significant. Very short rainfall durations (i.e. a few hours), due to the small number of data, are not suitable to this approach, but, on the other hand, their onset is generally easily recognizable by visual inspection of the height pluviometric trends.

References

Caine, N., 1980, The rainfall intensity-duration control of shallow landslides and debris flows, Geografiska Annaler, 62A, 23-27.