



## Empirical rainfall thresholds for landslide occurrence in Portugal

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Rainfall is the most important physical process responsible for the landslide triggering in Portugal. Following the work of Zêzere et al. (2014), we present the state of the art concerning the proposition of empirical rainfall thresholds in Portugal for different types of landslides observed in different zones of the country: the Lisbon region, the Douro Valley and the NW Mountains, and the Povoação Municipality in São Miguel Island (Azores). The empirical thresholds applied in Portugal are based on the identification of 120 landslide events and include (i) the computation of antecedent rainfall threshold defined by linear regression, (ii) the normalization of rainfall by the mean annual precipitation, (iii) the definition of combined rainfall thresholds, which integrates the rainfall event and the antecedent rainfall for different time periods, and (iv) the definition of lower limit and upper limit rainfall thresholds.

The intensity–duration (ID) threshold is the empirical rainfall threshold more used worldwide. In mainland Portugal, the highest ID rainfall threshold is registered in the NW Mountains, which is the rainiest zone of the country. The Lisbon Region typically receives less rain per year and the corresponding ID threshold is lower than that obtained in the north part of the country. The Povoação study area evidence a contrasting situation, which is associated to the highest value of the negative exponential of the threshold (-0.66). As a consequence, for short duration (< 10 h) this threshold is only exceeded in the NW Mountains, while for long durations (>1,000 h) it is below the remaining thresholds.

The normalization of the ID threshold by the mean annual precipitation (MAP) has showed that, in relative terms: (i) the ID threshold is highest in Lisbon Region for duration less than 50 h; (ii) in the north of the country, the ID threshold is more exigent in the Douro Valley than in the NW Mountains and (iii) the ID threshold in Povoação Municipality is lower when compared with the other areas, independently on the considered duration. It is apparent the tendency for the normalized rainfall ID thresholds to be as lower as higher is the MAP.

The combined threshold integrating the rainfall event (from 24 to 72 h) and the antecedent rainfall (from 3 to 30 days) has been tested in the the Douro Valley and NW Mountains. The return period of such rainfall combinations were addressed integrating the probability of the rainfall event with the probability of the antecedent rainfall assuming these probabilities as conditional independent. This combined threshold constrains better those rainfall events for which the critical combination of rainfall amount-duration in the context of the ID threshold is not evident.

The upper limit and lower limit rainfall thresholds have been tested in the Lisbon Area. This approach allows constraining false negatives and false positives in the distribution of rainfall events that generated (and not generated) landslide events. Future research should concentrate in the zone between upper and lower thresholds in order to establish the probability of occurrence of a landslide event in any moment within a discrete rainfall episode.

References: Zêzere, J.L.; Vaz, T.; Pereira, S.; Oliveira, S.C.; Marques, R.; Garcia, R.A.C. (2014) – Rainfall thresholds for landslide activity in Portugal: a state of the art. *Environmental Earth Sciences*, DOI: 10.1007/s12665-014-3672-0.

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