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Which method should we use to draw empirical rainfall thresholds for landslide early warning?

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Landslide thresholds determined empirically through the combined analysis of rainfall and landslide data are at the core of early warning systems. Given a set of rainfall and landslide data, several methods do exist to determine the threshold: methods based on triggering events only, methods based on the non-triggering events only, and methods based on both type of rainfall events. The first are the most commonly encountered in literature. Early work determined the threshold by drawing the lower envelope curve of the triggering events "by eye". More recent work used more sophisticated statistical approaches in order to reduce the subjectivity. Among these methods, the so-called frequentist method has become prominent in the literature. These methods have been criticized because they do not account uncertainty, i.e. the fact that there is not a clear separation between rainfall characteristics of triggering and non-triggering events. Hence, methods based on the optimization of Receiver operating characteristic indices – count of true and false positives/negatives – have been proposed. One of the first methods proposed in this sense referred to the use of Bayesian a-posteriori probability, which is the same of using the so-called ROC Precision index. Others have used the True Skill Statistic. On the other hand, use of non-triggering events only has been discussed just by a few researchers, and the potentialities of this way to proceed have been scarcely explored.

The choice of the method is usually dictated by external factors, such as the availability of data and their reliability, but it should also take into account of the theoretical statistical properties of each method.

Given this context, in the present work we compare, through Monte Carlo simulations, the statistical properties of each of the above-mentioned methods. In particular, we attempt to provide the answer to the following questions: What is the minimum number of landslides that is needed to perform a reliable determination of thresholds? How robust is the method for drawing the threshold – i.e. their sensitivity to artifacts in the data, such as exchanges of triggering events with non-triggering events due to incompleteness of landslide archives? What are the performances of the methods in terms of the whole ROC confusion matrix?

The analysis is performed for various levels of uncertainty in the data, i.e. noise in the separation by triggering and non-triggering events. Results show that methods based on non-triggering events only may be convenient when few landslide data are available. Also, in the case of high uncertainty in the data, the performances of methods based on triggering events may be poor

compared to those based on non-triggering events. Finally, the methods based on both triggering and non-triggering events are the most robust.

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