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Recent landslide-rainfall thresholds in Serbia

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Landslides in Serbia gained attention due to the massive landslide occurrences in the central and eastern parts of the country in the last decade. Apart from the usual, expected landslide activity (after snow thaws, heavy rainfalls, and strong earthquakes) there were several unusual, massive episodes that were coupled with floods and flash-floods and caused serious damages and casualties. These episodes took place in the fall of 2006, the early summer of 2010, and the spring of 2014. The public awareness on landslides was raised and problems started revealing themselves. The aftermaths of these extreme events drove governmental and local authorities to resolve acute emergencies, but also to seek consultancy for better understanding the landslide-rainfall interaction patterns for better preparedness in the future. Several projects and legislative campaigns were issued, but data-related obstacles were encountered at their very beginning. Historical repositories were poor, because the national landslide inventory is still underway and far from operative usage, whereas alternative sources, such as technical reports from various infrastructural projects, were lacking in accurate triggering date of related landslide events. The most reliable were journal articles, suitable for building preliminary inventories and establishing a solid background for hazard frequency estimations. However, these turned insufficient for analyzing rainfall thresholds, and relating the (re)occurrence frequency with the local meteorological conditions. Herein, we proposed a technique of enriching the rainfall-landslide record by using various Machine Learning (ML) algorithms. The objective was to use reported landslide events and relate them with their antecedent rainfall sums, acquired from the closest meteorological station in a typical learning protocol. Subsequently, the established relations were extrapolated, so that potential, but unreported landslide events can be used for rainfall threshold analyses. It was necessary to reach a sufficient amount of unreported and reported landslides to build a reliable rainfall threshold model. Such model can be used for an early-warning system and improve resilience to landslides at local level. The approach is demonstrated on the example of western Serbia. The landslide occurrence data were obtained from the journal articles by identifying accurate triggering date (the actual time if possible), approximate location (closest settlement or road section, with 1 km accuracy), and additional information (previous activity, damage, etc.). Rainfall data were acquired from the official meteorological stations (10 stations in total within the area of interest) and included daily measurements. These were densified (where possible) by calibrated TRMM satellite imagery. Daily sums were used to calculate several antecedent rainfall parameters (1, 2, 3, 5, 10, 15, and 30-day sums). Both, landslide and rainfall data covered the 2006-2016 period. Obtained rainfall-landslide model was used to estimate the lower (usual landsliding) and upper (massive landsliding) thresholds. We also proposed an improvised evaluation metrics in order to adjust the penalization of model errors in relation to their temporal reference. In conclusion, the ML-enriched threshold models were more accurate and more realistic then the ones based solely on reported landslides, especially for short term (1-3-day) antecedent rainfall.