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A data-driven approach to establish prediction surfaces for rainfall-induced shallow landslides in South Tyrol, Italy

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The occurrence of rainfall-induced shallow landslides is frequently caused by an interplay of predisposing environmental factors and dynamic preparatory and triggering conditions. For large-area assessments and for regional early warning, event-based landslide inventories are often employed to establish critical rainfall thresholds using statistical procedures (e.g., non-exceedance probability curves). These approaches typically put the spotlight on rainfall conditions associated with known landslide occurrences. Not accounting for rainfall conditions that did not induce slope instability comes along with a variety of criticalities, such as the impossibility to discriminate landslide from non-landslide rainfall conditions or the difficulty to validate the results.

This contribution proposes a data-driven approach based on Generalized Additive Mixed Models (GAMM) to identify season-dependent shallow landslide rainfall conditions for the province of South Tyrol, Italy. The work builds upon high resolution gridded daily rainfall data and landslide observations for the period from 2000 to 2020. The workflow comprised an initial filtering of rainfall-induced landslides (presence data) and a rule-based stratified random sampling procedure to select non-landslide rainy days at the same locations (absence data). The time periods (time windows in days) to describe preparatory and triggering cumulative rainfall conditions were determined using an optimization procedure based on cross validation. In addition to modelling a yearly effect, a circular day-of-the-year variable was included in the model to consider additional seasonal influences. The underlying nested data structure (i.e., repeated measurements at each landslide location) was accounted for via a location-dependent random intercept. The resulting probability scores for the analysed variables were validated using space-time cross validation, visualized in the form of probability surface plots and complemented with quantitative thresholds (e.g., curves that optimally separate landslide presences and absences).

Validation of the model showed a high capability to distinguish the two groups (presence vs. absence observations). The results further indicate that the temporal prediction of shallow

landslides in South Tyrol can be improved by accounting for systematic seasonal effects other than triggering and preparatory rainfall variables. This novel approach is flexible and will further be extended to derive space-time predictions. Strengths and limitations for regional landslide early warning will be discussed.

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