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A data-driven approach to derive spatially explicit dynamic "thresholds" for shallow landslide occurrence in South Tyrol (Italy)

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When and where shallow landslides occur depends on an interplay of predisposing, preparatory, and triggering factors. At a regional scale, data-driven analyses are extensively used to assess landslide susceptibility based on “static” maps of predisposing conditions. In contrast, data-driven analyses focusing on landslide triggering factors often rely on non-spatially explicit approaches to derive empirical rainfall thresholds. So far, few attempts have been made to integrate the spatial and temporal analysis domains beyond a posterior combination of separately derived susceptibility models and rainfall thresholds.

This work focuses on the mountainous Italian province of South Tyrol (7400 km²) and proposes a novel data-driven landslide prediction model that jointly considers landslide predisposition and dynamic preparatory and triggering factors. The approach builds on a hierarchical generalized additive model, multi-temporal shallow landslide data from 2000 to 2020 and a range of environmental variables (e.g., daily rainfall, topography, lithology, forest cover). The model produces maps that portray the relative probability of landslide occurrence. These spatially explicit predictions change dynamically as a function of local predisposition, seasonality, and observed (or hypothesized) dynamic preparatory and triggering rainfall (i.e. cumulative rainfall amounts based on varying day-windows). Linking the model output to known measures of model performance, such as hit rate and false alarm rate, enables the creation of dynamic classified maps that can be interpreted in analogy to commonly used empirical rainfall thresholds. The approach also accounts for potential spatial and temporal biases in the landslide inventory by restricting the underlying data sampling to effectively surveyed areas and time periods and by including (and averaging out) bias-describing random effect variables. Our validation confirms the model's high

generalizability and predictive power while providing insights into the interplay of predisposing, preparatory and triggering factors for shallow landslide occurrence in South Tyrol. Application possibilities of this novel approach are discussed.

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