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The impact of systematically incomplete and positionally inaccurate landslide inventories on statistical landslide susceptibility models

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Several publications emphasize that the quality of statistical landslide susceptibility maps is highly dependent on the completeness and positional accuracy of the landslide inventory used as a response variable to produce the underlying models.
We assume that erroneous landslide inventories distort relationships between a landslide inventory and its predictors while we hypothesize that the predictive performance of the underlying models is not necessarily worse in comparison to models generated with an accurate and unbiased landslide inventory. The objective of this study was to investigate the effect of incomplete and positionally inaccurate landslide inventories on the results of statistical landslide susceptibility models. An additional aim was to explore the potential of applying multilevel models to tackle the problem of confounded model coefficients as a results of inventory-based biases.
The study was conducted for a landslide-prone study area (100 km^2) located in the western part of Lower Austria. An accurate earth-slide point inventory (n = 591) was available for that region.
The methodological approach consisted of an artificial introduction of biases and positional inaccuracies into the present landslide inventory and a subsequent quantitative (odds ratios, variable importance, non-spatial and spatial cross validation) and qualitative (geomorphic plausibility) evaluation of the modelling results. Two mapping biases were introduced separately by gradually thinning landslide data (0%, 20%, 80%) within (i) forested areas and (ii) selected municipalities. Positional inaccuracies were simulated by gradually changing the original landslide position (0, 5, 10, 20, 50 and 120 m). The resulting inventories were introduced into a logistic regression model while we considered the effects of including or excluding predictors directly related to the respective incompleteness. All incomplete inventories were additionally introduced into a two-level generalized linear mixed model (GLMM) with random intercepts. These multilevel models allowed us to account for variations that were due to a landslide bias that depends on a categorical variable (e.g. land cover classes, municipalities) when estimating the coefficients of the fixed-effects predictor variables (e.g. slope, lithology). Finally, only the estimated fixed effects were used to predict landslide susceptibility.
The results showed that distorted relationships, but relatively high validation results can be obtained for models produced with biased and positionally inaccurate landslide inventories. Thus, we conclude that a process-based interpretation of models exhibiting high predictive performances should always consider possible biases in landslide inventories. Most strikingly, we observed that AUROCs generally increased with an increasing degree of incompleteness of the underlying inventory in the case where a predictor was able to describe such biases. In this context, only spatial cross-validation technique was able to expose spatially inconsistent modelling results. Furthermore, we showed that the exclusion of bias-describing predictors (e.g. land cover for a forest-related bias) led to confounded relationships between the landslide inventories and those predictors (e.g. slope angle) spatially interrelated with these bias-describing variables. In this context, GLMMs proved useful to reduce the influence of confounders.