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Point process-based modeling of multiple debris flow landslides using INLA: an application to the 2009 Messina disaster

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We develop a stochastic modeling approach based on spatial point processes of log-Gaussian Cox type for a collection of around 5000 landslide events provoked by a precipitation trigger in Sicily, Italy. Through the embedding into a hierarchical Bayesian estimation framework, we can use the Integrated Nested Laplace Approximation methodology to make inference and obtain the posterior estimates. Several mapping units are useful to partition a given study area in landslide prediction studies. These units hierarchically subdivide the geographic space from the highest grid-based resolution to the stronger morphodynamic-oriented slope units. Here we integrate both mapping units into a single hierarchical model, by treating the landslide triggering locations as a random point pattern. This approach diverges fundamentally from the unanimously used presence-absence structure for areal units since we focus on modeling the expected landslide count jointly within the two mapping units. Predicting this landslide intensity provides more detailed and complete information as compared to the classically used susceptibility mapping approach based on relative probabilities. To illustrate the model's versatility, we compute absolute probability maps of landslide occurrences and check its predictive power over space. While the landslide community typically produces spatial predictive models for landslides only in the sense that covariates are spatially distributed, no actual spatial dependence has been explicitly integrated so far for landslide susceptibility. Our novel approach features a spatial latent effect defined at the slope unit level, allowing us to assess the spatial influence that remains unexplained by the covariates in the model. For rainfall-induced landslides in regions where the raingauge network is not sufficient to capture the spatial distribution of the triggering precipitation event, this latent effect hence provides valuable imaging support on the unobserved rainfall pattern.