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Combined statistical analysis of landslide release and propagation

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Statistical methods – often coupled with stochastic concepts – are commonly employed to relate areas affected by landslides with environmental layers, and to estimate spatial landslide probabilities by applying these relationships. However, such methods only concern the release of landslides, disregarding their motion. Conceptual models for mass flow routing are used for estimating landslide travel distances and possible impact areas. Automated approaches combining release and impact probabilities are rare.

The present work attempts to fill this gap by a fully automated procedure combining statistical and stochastic elements, building on the open source GRASS GIS software: (1) The landslide inventory is subset into release and deposition zones. (2) We employ a traditional statistical approach to estimate the spatial release probability of landslides. (3) We back-calculate the probability distribution of the angle of reach of the observed landslides, employing the software tool r.randomwalk. One set of random walks is routed downslope from each pixel defined as release area. Each random walk stops when leaving the observed impact area of the landslide. (4) The cumulative probability function (cdf) derived in (3) is used as input to route a set of random walks downslope from each pixel in the study area through the DEM, assigning the probability gained from the cdf to each pixel along the path (impact probability). The impact probability of a pixel is defined as the average impact probability of all sets of random walks impacting a pixel. Further, the average release probabilities of the release pixels of all sets of random walks impacting a given pixel are stored along with the area of the possible release zone. (5) We compute the zonal release probability by increasing the release probability according to the size of the release zone – the larger the zone, the larger the probability that a landslide will originate from at least one pixel within this zone. We quantify this relationship by a set of empirical curves. (6) Finally, we multiply the zonal release probability with the impact probability in order to estimate the combined impact probability for each pixel.

We demonstrate the model with a 167 km^2 study area in Taiwan, using an inventory of landslides triggered by the typhoon Morakot. Analyzing the model results leads us to a set of key conclusions: (i) The average composite impact probability over the entire study area corresponds well to the density of observed landside pixels. Therefore we conclude that the method is valid in general, even though the concept of the zonal release probability bears some conceptual issues that have to be kept in mind. (ii) The parameters used as predictors cannot fully explain the observed distribution of landslides. The size of the release zone influences the composite impact probability to a larger degree than the pixel-based release probability. (iii) The prediction rate increases considerably when excluding the largest, deep-seated, landslides from the analysis. We conclude that such landslides are mainly related to geological features hardly reflected in the predictor layers used.