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Multi-Dimensional Shallow Landslide Stability Analysis Suitable for Application at the Watershed Scale

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Current practice in regional-scale shallow landslide hazard assessment is to adopt a one-dimensional slope stability representation. Such a representation cannot produce discrete landslides and thus cannot make predictions on landslide size. Furthermore, one-dimensional approaches cannot include lateral effects, which are known to be important in defining instability. Here we derive an alternative model that accounts for lateral resistance by representing the forces acting on each margin of an unstable block of soil. We model boundary frictional resistances using ‘at rest’ earth pressure on the lateral sides, and ‘active’ and ‘passive’ pressure, using the log-spiral method, on the upslope and downslope margins. We represent root reinforcement on each margin assuming that root cohesion declines exponentially with soil depth. We test our model’s ability to predict failure of an observed landslide where the relevant parameters are relatively well constrained and find that our model predicts failure at the observed location and predicts that larger or smaller failures conformal to the observed shape are indeed more stable. We use a sensitivity analysis of the model to show that lateral reinforcement sets a minimum landslide size, and that the additional strength at the downslope boundary results in optimal shapes that are longer in the downslope direction. However, reinforcement effects alone cannot fully explain the size or shape distributions of observed landslides, highlighting the importance of the spatial pattern of key parameters (e.g. pore water pressure and soil depth) at the watershed scale. The application of the model at this scale requires an efficient method to find unstable shapes among an exponential number of candidates. In this context, the model allows a more extensive examination of the controls on landslide size, shape and location.