cell size. These models also implicitly assume that deformation is large enough to allow failure at the base of a soil column and subsequent detachment upslope, yet small enough to allow the transfer of the loads by columns leaning on their downslope neighbors. However, because these models assume failure initiates at individual grid cells, and test the stability of groups of cells failing in series rather than failing simultaneously, they do not require a search algorithm.

Here we develop an efficient search algorithm that can be applied at the catchment scale to identify unstable clusters of adjacent cells without constraints on their size or shape, provided that the grid resolution is sufficiently fine (1–2 m) to represent a landslide as a collection of grid cells. Our approach is different from prior work in that it is deterministic rather than involving a random sample of possible shapes and is less dependent on grid spatial resolution in the sense that it does not require instability of individual cells to locate possible search locations. To test the search algorithm, we couple it to the limit-equilibrium multidimensional slope stability model MD-STAB [*Milledge et al*., 2015], which uses a traditional Mohr-Coulomb formulation of strength to calculate the driving and resistive forces on each cell. Other three-dimensional limit-equilibrium models could also be used with the search algorithm that identifies landslide location and size. With this definition of slope stability, we apply the search algorithm to a synthetic landscape and show that it can recover predefined clusters of unstable cells having a variety of regular and irregular shapes; and that it offers better performance and greater flexibility when compared to constrained rectangular or elliptical exhaustive searches using the same slope stability model. We then apply the search algorithm to a field setting and find that it recovers the size and location of a rainfall-triggered shallow landslide at a research site near Coos Bay, Oregon (CB-1), where all the relevant physical parameters such as hydrological conditions, soil depth, and root strength were field measured [*Montgomery et al*., 2009]. We do not perform model calibration to minimize misfits between predictions and observations. Rather, we use field measurements to estimate the landslide-relevant parameters (e.g., soil depth, root strength, and pore water pressure). In contrast to *Milledge et al*. [2015], who test the stability of predefined shapes, we let the search algorithm find the unstable (as defined by the slope stability model) shapes. We also assess the robustness of the procedure by varying each field-measured parameter by ±5% and ±10%, finding that it is not very sensitive to modest changes in the relevant parameters. Finally, in Appendix A we show that our procedure is efficient, with the number of operations growing quadratically with the number of grid cells, a dramatic reduction from the prohibitive exponential number of operations required to test every combination of grid cells. In a companion paper (*D. Bellugi*, *Milledge*, *D*., *Dietrich*, *W.E*., *McKean*, *J*., *Perron*, *J.T*., Predicting shallow landslide size and location across a natural landscape: Application of a spectral clustering search algorithm, submitted to *JGR-Earth Surface*, 2014, hereafter referred to as Bellugi et al., submitted), we use process-based submodels to estimate soil depth, root strength, and pore water pressure, to test the coupled search algorithm and slope stability model across a larger landscape where the parameters have not been directly measured at all locations.

2. A Three-Dimensional Slope Stability Model

In a landscape during times of elevated pore pressure, patches of unstable ground (represented as a collection of neighboring grid cells), where the collective driving forces exceed the resisting forces, may develop. While our search algorithm does not depend on the specific slope stability method adopted to characterize these forces, here we adopt the multidimensional slope stability model MD-STAB [*Milledge et al*., 2015]. This model is fully three-dimensional and incorporates the effects of root strength and soil friction on sloping boundaries and is thus appropriate for application to a natural landscape. *Milledge et al*. [2015] provide an extensive derivation and discussion of this model, and we summarize the approach here. The landscape is discretized into columns defined in the vertical by the soil layer bounded by the ground surface and the bedrock interface (Figure 1). To compute the stability of a group of adjacent columns, a framework similar to *Hovland*'s [1977] method to calculate the limit equilibrium stability is utilized. The Factor of Safety is computed from the ratio of total resisting force to total driving force along the failure surface [*Hovland*, 1977]. Resisting forces (forces that act against the driving force to maintain equilibrium) due to friction and root cohesion exist on the base, cross slope, upslope (head), and downslope (toe) margins of the group of columns (Figure 1). Driving forces are the downslope component of the block's weight and the force exerted from the soil mass upslope. MD-STAB assumes that failure occurs by simultaneous shear on the boundary of the landslide, without internal deformation and with the soil columns constituting the body of the landslide not