root strength). These cells extend vertically from the top of the bedrock to the surface, forming columns that represent the soil mantle. Although some of the landscape properties are often underconstrained, such a representation of a landscape is what is typically available as input to physically based models for predicting landslides, such as those shown in Figure 1. A shallow landslide prediction procedure thus needs to identify the collections of cells that together would be unstable considering the assigned properties for each cell. Common models that adopt a one-dimensional representation of slope stability define a landslide as either a single cell or a set of cells that will fail when pore water pressure is above a critical threshold [e.g., *O'Loughlin and Pearce*, 1976; *Wu et al*., 1979; *Montgomery and Dietrich*, 1994; *Wu and Sidle*, 1995; *Pack et al*., 1998; *Dietrich et al*., 1995, 2001; *Borga et al*., 2002; *Casadei et al*., 2003a; *Dhakal and Sidle*, 2003; *Iida*, 2004; *Rosso et al*., 2006; *Baum et al*., 2008; *Tarolli et al*., 2008; *Simoni et al*., 2008; *Lanni et al*., 2012]. In these models, landslides such as those shown in Figure 1 can be identified only if each of the cells that they contain is individually unstable and surrounding cells are not. Furthermore, such one-dimensional approaches cannot include lateral effects (notably root strength and soil friction), which are known to be important in defining instability [e.g., *Arellano and Stark*, 2000; *Schmidt et al*., 2001].

In order to account for lateral effects a multidimensional slope stability analysis is required. Many three-dimensional slope stability models have been proposed [e.g., *Hovland*, 1977; *Chen*, 1981; *Burroughs*, 1985; *Dietrich et al*., 2008]. These models perform a limit-equilibrium analysis for a defined failure surface, assuming that the soil mass behaves as one or more rigid blocks. While they usually require similar input parameters as the infinite-slope methods, their application has been limited as they require the treatment of discrete shapes that are not known a priori. Because the number of possible shapes grows exponentially with the number of grid cells, an exhaustive search that tests all possible shapes is effectively intractable at any relevant scale [*Dietrich et al*., 2008].

Few attempts have been made to apply three-dimensional methods at the watershed scale; all involve the introduction of constraints that effectively reduce the computational complexity of the problem. *Montgomery et al*. [2000] incorporated the effects of lateral root strength by using a predefined single rectangular landslide shape with fixed size, which results in the same limitations of the infinite-slope approaches with respect to landslide size (i.e., size is defined a priori). To examine the controls of lateral root reinforcement on landslide size, *Gabet and Dunne* [2002] and *Casadei et al*. [2003b] assumed landslides are rectangular and have a fixed length to width ratio but did not apply their model to a landscape. *Okimura* [1994] also assumed landslides to be rectangular but relaxed the restriction of a single length to width ratio. In this model landslide size is determined by computing a least stable cell using an infinite-slope stability model then exploring a fixed number of potential rectangular slide masses (constrained to be oriented downslope) that include the least stable cell, resulting in good agreement between predicted locations and shapes and of observed failures but over a very limited area. *Qiu et al*. [2007] instead tested potential ellipsoidal slip surfaces, using Hovland's method [*Hovland*, 1977] to compute their three-dimensional stability. They did not account for additional resistance provided by roots on the margins of the unstable block. To reduce the computational complexity, they took a nondeterministic approach in which 100 random potential failure surfaces centered on each grid cell were tested (thus limiting the number of slope stability tests to at most 100 times the number of grid cells).

Lehmann and Or [2012] proposed an alternative approach that relaxes the assumption of a regular landslide shape but requires landslides to originate at a single cell to reduce its computational complexity. In their model a hillslope is discretized into soil columns interconnected by frictional and tensile mechanical bonds represented as fiber bundles [e.g., *Schwarz et al*., 2010]. If a failure threshold is reached based on the forces acting on the base of a column, its load is redistributed to its neighbors via the fiber bundles which in turn can gradually fail, allowing the failure to progress in both the upslope and downslope directions. This model allows for irregular shapes to develop but is computationally very intensive and as a result has only been applied to small synthetic landscapes. *Ruette et al*. [2013] developed a simplified version of this model that relies on prescribed brittle mechanical bonds between adjacent columns rather than the fiber bundle representation of lateral resistance used by *Lehmann and Or* [2012] and applied it to two catchments in the foothills of the Swiss Alps. While they generally yielded reasonable predictions of landslide events, they overpredicted the number and volume of observed landslides and greatly overpredicted the slopes on which landsides initiated. Both these approaches can capture the progressive nature of failure observed in some shallow landslides but have a dependence on grid resolution, as the likelihood of initial failure will vary with