Hydrology and Earth System Sciences Discussions

Interactive comment on "A new method for determination of Most Likely Initiation Points and the evaluation of Digital Terrain Model scale in terrain stability mapping" *by* P. Tarolli and D. G. Tarboton

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A new method for determination of Most Likely Initiation Points and the evaluation of Digital Terrain Model scale in terrain stability mapping

Identification of sites subject to landslide initiation is a key component for landslide hazard mapping and for quantification and modeling of sediment fluxes over a landscape. A variety of methods have been developed for delineating probable landslide initiation locations; there are fewer methods, however, for evaluating the results. This paper presents a new empirical approach for assessing slope stability maps. The least stable point along every flow line determined from the digital topography is flagged,

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and the density of these most likely initiation points; within mapped landslide scars is compared to the density over the entire area mapped. The ratio of these densities provides a measure of the success of the stability map at highlighting potential landslide initiation zones based on observed landslide locations. This approach is particularly appropriate when mapped landslides do not or can not differentiate between initiation, runout, and depositional areas. Use of mapped landslide scars to evaluate a slope stability map intended to quantify the potential for landslide initiation is hindered by inclusion of runout and depositional zones. By focusing on the most likely initiation point along every flow path, the authors exclude runout and depositional zones from the analysis. The most likely initiation points (MLIP) method can be used to compare different slope stability maps. The best map (or model that produced the map) is that giving the highest ratio for the density of MLIP points within mapped landslide polygons relative to the area as a whole. The authors illustrate the MLIP method to evaluate the influence that the horizontal resolution of gridded digital elevation data have for results of a slope stability model.

Methods to evaluate slope stability models lag development of the models themselves, so efforts that further our ability to quantitatively assess the results of these models, as represented with this paper, are particularly valuable. The authors present a new method that addresses an important limitation imposed by the constraints of landslide mapping from aerial photographs: the inability to accurately discriminate initiating zones within the mapped landslide area. I think this is a worthwhile contribution; however, I think presentation of this method could benefit from several additions to the paper.

Because this paper is presenting a new method for evaluating stability models, it would be worthwhile for the authors to describe methods currently employed. They provide some hints with equation 1; they could also include a description of how models to identify potentially unstable sites are evaluated using mapped landslide locations, with citations, in the introduction. I admit that I am not aware of much along this line in the

literature, but they might include examples by Chung and Fabbri [2003; 2005], Dietrich et al. [2001], and Borga et al. [2002]. By including information on current methods of assessment, the authors would better differentiate what is new with their approach.

Likewise, because they are presenting a method to, as they say, assess the discriminating ability of an SI (stability index) map, referring to the ability to discriminate landslide initiation points, it would be informative to show examples of the SI maps being compared. The statistics presented in Tables 2 and 3 are useful to evaluate the discriminating ability of the maps, but do not provide a sense of how the spatial distribution of SI values varies between the different options. I suspect that I might gain additional insight as to the discriminating ability of different maps if I could examine examples of the SI and corresponding MLIP maps for two of the DTM resolutions used.

The SINMAP model is used to calculate a spatially distributed stability index. In part, the model used is somewhat irrelevant, since the author's point is to compare effects of different resolution DTMs. Nevertheless, the fact that the method they present can be used to compare models piques one's interest in comparing models. The steady-state groundwater flow condition used in the SINMAP approach implies several physically unlikely assumptions [Iverson, 2000] and renders the calculated stability index dependent on contributing area. How might this model compare to one with more a realistic representation of the groundwater flow field? Or, perhaps more appropriately, how might SINMAP compare to an even simpler model, say one with no contributing area dependence? The SINMAP model is used here with no data on the spatial distribution of soil properties, so that variations in the calculated stability index, and locations of the resulting most likely initiating points, are (I think) driven solely by the gradient and contributing area inferred from the DTM. Could slope gradient alone provide similar discriminating ability? The MLIP algorithm could be readily applied to any spatially distributed index; illustration of the discriminating ability of a model would be substantially increased by including comparison not only between different resolution DTMs, but also between two different forms of a stability index, for which slope gradient could

provide a simple alternative to SINMAP.

In the end, the authors conclude that SINMAP is both applicable to the study area and "has generality beyond our specific study area" based on a ratio greater than 3 in the density of MLIP points within landslide scars relative to the entire study area. A ratio of three is certainly better than a ratio of one, but we do not know how it compares to other stability index options, or how it compares to the ratio found in other areas. I think the authors have presented a useful method for evaluating a stability index, but I do not think they have provided a sufficient range of examples to demonstrate the general applicability of SINMAP, particularly since it has not been compared to any other options. This was not really the point of the paper; I think the MLIP method could be used to evaluate the general applicability of a model when mapped landslides include undifferentiated depositional areas and could be used to compare the effectiveness of different models and of different data, as the authors did for DTMs of different horizontal resolution.

Additional comments follow.

The title would benefit from inclusion of the word landslide;, as in most likely landslide initiation points.

The introduction discusses the development of process-based models. Why limit this discussion to process-based models? The MLIP algorithm ultimately relies on an empirical comparison between predicted and observed zones of landsliding and can be applied to any type of spatially distributed stability index.

Note that grid-based versions of the Montgomery and Dietrich model, which include soil cohesion, have been published [Dietrich, et al., 1995; Montgomery, et al., 1998].

What sort of weather events is landsliding in the study basin typically associated with? Do landslides tend to occur during summer rainstorms, or during periods of intense snow melt, or in association with some other type of event? The nature of landslide-

triggering events might tell us something about the antecedent moisture conditions and the shallow groundwater flow fields associated with landsliding, from which to evaluate the degree to which the steady-state groundwater-flow assumptions in the SINMAP model apply to this case.

The authors mention that the spacing of LIDAR ground returns is variable, with larger spacing occurring in regions of dense vegetation. This implies that the degree to which these data resolve topographic features is variable, with better resolution in unvegetated areas (e.g., landslide scars). In the discussion, they might mention the potential effect of such variable topographic resolution on the relative density of SI and MLIP points within and without mapped landslide polygons.

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