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Natural Hazards and Earth System Sciences
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Discussions

Interactive comment on "Origin of the power-law exponent in the landslide frequency-size distribution" *by* Ahoura Jafarimanesh et al.

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Dear reviewer,

Thank you for your comments on the discussion paper by Jafarimanesh et al. (2018) and for providing a list of recent publications on the same topic. Please find below our answers to your comments:

1) Literature on landslide power-law distribution

We will add the following references: Liucci et al. (2017); Stark and Guzzetti (2009); Frattini and Crosta (2013). We will mention these studies in the Introduction with other landslide models, as well as in the new Discussion section. We note that Liucci et al.'s results agree with ours, i.e., that the topography is key in the origin of the power-law

behaviour, which provides a validation of the two models, and verifies the hypothesis postulated by Frattini and Crosta. Our study remains the first to explore the changes of α per modelling step (topography slope, initiation phase, propagation phase), and to investigate the direct role of the fractal dimension of the topography. Moreover, using the factor of safety as main controlling slope failure metric avoids the use of ad-hoc parameters, as done in some previous CA studies.

2) The importance of the power-law exponent in hazard assessment

We will develop more on the importance of the power-law exponent in the introduction: After "This is of importance in the probabilistic hazard assessment of landslides to be able to extrapolate the size of larger potentially damaging events", we will now add: "Indeed, as already mentioned by Liucci et al. (2017), α provides the mean to estimate the probability of occurrence of landslides of different magnitudes, including landslide sizes greater than experienced in the past. An increase in α means a decrease in the ratio of larger event sizes. This is analogue to the Gutenberg-Richter law in earthquake risk where the power exponent (or b-value in exponential scale) is the most critical parameter with the earthquake rate."

3) On the (non-)universality of the power-law

First, in "the frequency-size distribution (FSD), which, despite the variety of triggers, appears to systematically follow a power law probability density function", we will change "systematically" by "reasonably".

Second, we will clarify that the power-law behaviour is only an approximation of the landslide FSD behaviour and that other functions have been proposed, such as the double Pareto and inverse Gamma. Those functions consider the roll-over at small sizes but can also explain a potential curvature in log-log space at the tail of the FSD - this will be better illustrated in the new version of Figure 1. More generally, while using the power-law provides a proxy to the true distribution, it should be emphasised that the universality of the power-law is now contested in various domains (Broido and Clauset, 'Scale-free networks are rare', 2018), including landslides. Tanyas et al. (2018) showed on a large landslide inventory that the FSD is much more variable than previously assumed. Only part of this variability can be explained by the α range. We here use the 'α proxy' to be consistent with previous studies spanning from 1969 to 2013.

4) Update of the landslide meta-analysis

We will update our reference database with Brink et al. (2006) and Tanyas et al. (2018) and update our results accordingly. The recent result of $1.8 < \alpha < 3.7$ is in agreement with our review of $1.7 < \alpha < 2.8$ (1-sigma range).

5) Limitations of the LSgCA model

The limitations are the following: âĂć Landslides are considered instantaneous since the successive increments in the cascading process are not related to specific time intervals. âĂć In contrast to some other CAs, no time-dependent weakening is used. Instead the decrease in the slope angle stability threshold is quantified by increasing the water saturation parameter in the factor of safety. This parameter is kept constant for any given CA run. âĂć Water saturation is assumed homogeneous in space, illustrative of loading per rainfall but unrealistic locally, ignoring water flow. âĂć Tectonic uplift is neglected, but negligible at the temporal scale of individual landslides. âĂć The soil characteristics are homogeneous along z.

They will now be listed in the new Discussion section.

6) Background information development

More background information will be given for the following terms:

Df is the fractal dimension of the topography, here assumed constant in the studied area. It can be understood as the degree of roughness of the topographic surface, via Df = 3-H where H is the Hurst exponent. Therefore the 2 parameters are anti-correlated with an increase of roughness representing a decreasing H and increasing

Df. The Hurst exponent is a measure of the randomness of the stochastic process with H = 1/2 representing the standard Brownian motion.

More details about the power exponent α are given in answer #3.

The landslide propagation phase corresponds to the cellular automaton process of mass transfer between the grid cells. The initiation phase therefore does not include any SOC behaviour. In this case, the power-law can emerge from the spatial distribution of the factor of safety that is function of the fractal topography.

7) Structure of the article

We will rearrange the paper using the common Method/Results/Discussion structure, considering the detailed remarks of the reviewer.

8) Real topography validation

Real topography validation is the subject of another manuscript currently in preparation. We tested the model on the Illhorn slope located in the Illgraben catchment, in Swiss Valais, and obtained results in agreement with observations. Interestingly the lower α observed there is retrieved by the LSgCA by refining the site-specific soil characteristics. The preliminary result is shown in Figure B.1.

Fig. B.1. Simulated landslides with LSgCA on the Illgraben catchment topography. For the quartzite site conditions, we obtained α = 1.7-1.9 in agreement with observations of real landslide inventories (Bennett et al. 2012).

Minor comments: we will update the manuscript accordingly.

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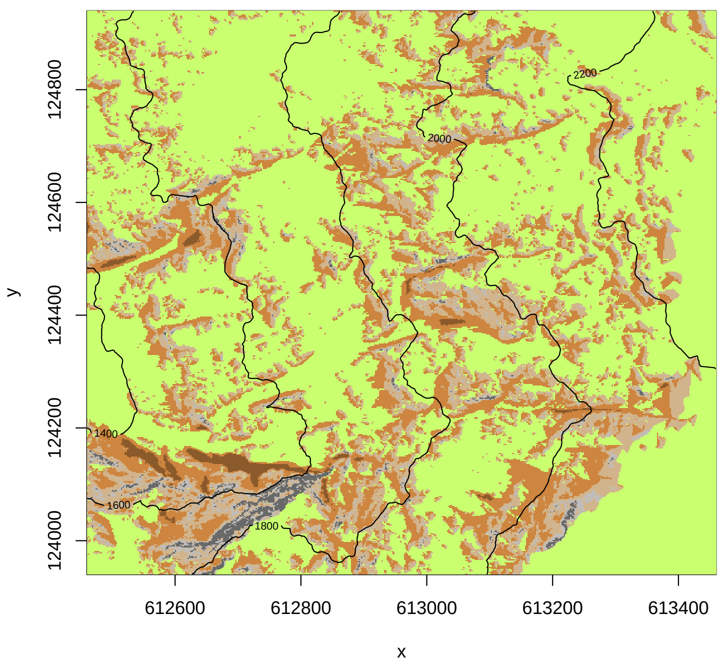
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Fig. 1.