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What Shape is a Landslide? Statistical Patterns in Landslide Length to Width Ratio

Faith E. Taylor (1), Bruce D. Malamud (1), and Annette Witt (2)

(1) Earth and Environmental Dynamics Research Group, Department of Geography, King's College London, Strand, London, WC2R 2LS United Kingdom (faith.taylor@kcl.ac.uk), (2) (2) Department of Nonlinear Dynamics, Max-Planck Institute for Dynamics and Self-Organisation, Postfach 2853, 37018 Göttingen, Germany

We present a variety of methods to approximate landslide shapes by ellipses, to test the goodness of fit of an elliptical approximation to each landslide shape and to examine the probability distribution of the length-to-width ratio (L/W) of the corresponding ellipses in two substantially complete landslide inventories. The planimetric shape of an individual landslide area is controlled by factors such as terrain morphology, material involved and speed, with landslide shapes varying in total area (A_L), type of shape, and their length-to-width ratios. Here, we use mapped polygons from two substantially complete inventories: (i) 11,111 landslides triggered by the 1994 (M = 6.7) Northridge Earthquake, USA (ii) 9,594 landslides triggered by heavy rain during the 1998 Hurricane Mitch in Guatemala. For each landslide polygon, various methods of approximating an elliptical shape were tested. The best method found was fitting a convex hull (CH) to each landslide polygon, approximating an ellipse with equivalent area (A_{CH}) and Perimeter (P_{CH}) of the convex hull and then scaling this ellipse to match the area of the original landslide (A_L). The goodness-of-fit (e) of elliptical approximations was tested using a measure of the area of intersection (A_I) between the original landslide polygon area (A_L) and the elliptical approximation: e = 1 – (2(A_L – A_I)/A_L) =-1+2 A_I/A_L. The goodness-of-fit e ranges from -1 for an imperfect fit and +1 for a perfect fit. We found that the percentage of landslides having a 'good fit' ($e \geq 0.5$) of the ellipse to the inventory landslide polygons were 99% of landslides from the Northridge inventory and 84% of landslides from the Guatemala inventory. For these landslides, the non-dimensional value of the ratio of the ellipse length-to-width (L/W) was calculated. For the Guatemala landslides, 50 % of landslide ellipse L/W values are $\leq$ 2.17, and 90 % of values are $\leq$ 3.6. For the Northridge landslides, 50 % of landslide ellipse L/W values are $\leq$ 2.5, and 90 % of values are $\leq$ 4.4. We find that the probability of the length-to width ratio (L/W) follows a three-parameter inverse gamma distribution, which has an inverse power-law decay for medium and large L/W values (values of $L/W > \sim 2$) and exponential rollover for small L/W values. The 'rollover' value where p(L/W) is at its maximum occurs at L/W = 2.1 and L/W = 1.8 for Northridge and Guatemala respectively. There is generally good agreement between the two inventories' statistical distributions in spite of differences in location, triggering mechanism and geology. This work will aid in stochastic modelling of triggered landslide event inventories where it may not be feasible to deterministically define each landside shape. Using these trends, landslide shape can be approximated as an ellipse, and the length to width ratio of that ellipse selected from a general statistical distribution.