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A Tool for Modelling the Probability of Landslides Impacting Road Networks

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Triggers such as earthquakes or heavy rainfall can result in hundreds to thousands of landslides occurring across a region within a short space of time. These landslides can in turn result in blockages across the road network, impacting how people move about a region. Here, we show the development and application of a semi-stochastic model to simulate how landslides intersect with road networks during a triggered landslide event. This was performed by creating "synthetic" triggered landslide inventory maps and overlaying these with a road network map to identify where road blockages occur.

Our landslide-road model has been applied to two regions: (i) the Collazzone basin (79 km^2) in Central Italy where 422 landslides were triggered by rapid snowmelt in January 1997, (ii) the Oat Mountain quadrangle (155 km^2) in California, USA, where 1,350 landslides were triggered by the Northridge Earthquake (M = 6.7) in January 1994. For both regions, detailed landslide inventory maps for the triggered events were available, in addition to maps of landslide susceptibility and road networks of primary, secondary and tertiary roads.

To create "synthetic" landslide inventory maps, landslide areas (A_L) were randomly selected from a three-parameter inverse gamma probability density function, consisting of a power law decay of about -2.4 for medium and large values of A_L and an exponential rollover for small values of A_L. The number of landslide areas selected was based on the observed density of landslides (number of landslides km^{-2}) in the triggered event inventories. Landslide shapes were approximated as ellipses, where the ratio of the major and minor axes varies with A_L. Landslides were then dropped over the region semi-stochastically, conditioned by a landslide susceptibility map, resulting in a synthetic landslide inventory map. The originally available landslide susceptibility maps did not take into account susceptibility changes in the immediate vicinity of roads, therefore our landslide susceptibility map was adjusted to further reduce the susceptibility near each road based on the road level (primary, secondary, tertiary). For each model run, we superimposed the spatial location of landslide drops with the road network, and recorded the number, size and location of road blockages recorded, along with landslides within 50 and 100 m of the different road levels. Network analysis tools available in GRASS GIS were also applied to measure the impact upon the road network in terms of connectivity. The model was performed 100 times in a Monte-Carlo simulation for each region.

Initial results show reasonable agreement between model output and the observed landslide inventories in terms of the number of road blockages. In Collazzone (length of road network = 153 km, landslide density = 5.2 landslides km^{-2}), the median number of modelled road blockages over 100 model runs was 5 ($\pm$2.5 standard deviation) compared to the mapped inventory observed number of 5 road blockages. In Northridge (length of road network = 780 km, landslide density = 8.7 landslides km^{-2}), the median number of modelled road blockages over 100 model runs was 108 ($\pm$17.2 standard deviation) compared to the mapped inventory observed number of 48 road blockages. As we progress with model development, we believe this semi-stochastic modelling approach will potentially aid civil protection agencies to explore different scenarios of road network potential damage as the result of different magnitude landslide triggering event scenarios.