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Prediction of earthquake-triggered landslide event sizes

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Seismically induced landslides are a major environmental effect of earthquakes, which may significantly contribute to related losses. Moreover, in paleoseismology landslide event sizes are an important proxy for the estimation of the intensity and magnitude of past earthquakes and thus allowing us to improve seismic hazard assessment over longer terms. Not only earthquake intensity, but also factors such as the fault characteristics, topography, climatic conditions and the geological environment have a major impact on the intensity and spatial distribution of earthquake induced landslides.

We present here a review of factors contributing to earthquake triggered slope failures based on an "event-by-event" classification approach. The objective of this analysis is to enable the short-term prediction of earthquake triggered landslide event sizes in terms of numbers and size of the affected area right after an earthquake event occurred. Five main factors, 'Intensity', 'Fault', 'Topographic energy', 'Climatic conditions' and 'Surface geology' were used to establish a relationship to the number and spatial extend of landslides triggered by an earthquake. The relative weight of these factors was extracted from published data for numerous past earthquakes; topographic inputs were checked in Google Earth and through geographic information systems. Based on well-documented recent earthquakes (e.g. Haiti 2010, Wenchuan 2008) and on older events for which reliable extensive information was available (e.g. Northridge 1994, Loma Prieta 1989, Guatemala 1976, Peru 1970) the combination and relative weight of the factors was calibrated. The calibrated factor combination was then applied to more than 20 earthquake events for which landslide distribution characteristics could be cross-checked.

One of our main findings is that the 'Fault' factor, which is based on characteristics of the fault, the surface rupture and its location with respect to mountain areas, has the most important contribution for the prediction of the number (and concentration) of induced landslides. This, for instance, partly explains why the Wenchuan 2008 earthquake triggered far more landslides than the Nepal 2015 earthquake. Moreover, according to our prediction the most severe earthquake-triggered landslide event would have been the Assam 1950 earthquake (India), followed by the 2008 Wenchuan earthquake. Regarding the overall performance of our prediction method it can be seen that the number of landslides is overestimated for a series of earthquakes, while the size of the affected area is often underestimated. Especially for older events the incompleteness of the published catalogues can partly explain the overestimation of the landslide numbers. The underestimation of the affected area however is real and must be attributed to particular remote effects of earthquakes.