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Rapid post-seismic landslide evacuation boosted by dynamic river width and implications for sediment fluxes during the seismic cycle

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Mass wasting caused by large magnitude earthquakes choke mountain rivers with several cubic kilometers of sediment. The timescale and mechanisms by which rivers evacuate the coarse fraction of small to gigantic landslide deposits are poorly known, but are critical to predict post-seismic hydro-sedimentary hazards, interpret the signature of earthquakes in sedimentary archives and decipher the coupling between erosion and tectonics. Here, we use a new 2D hydro-sedimentary evolution model to demonstrate that river self-organization into a narrower alluvial channel overlying the bedrock valley dramatically increases sediment transport capacity of coarse sediments and reduces export time of gigantic landslides by orders of magnitude compared to existing theory. Predicted export times obey a universal non-linear relationship function of landslide volume and pre-landslide valley transport capacity. Dynamic alluvial channel narrowing is therefore a key, previously unrecognized, mechanism by which mountain rivers rapidly digest extreme events and maintain their capacity to incise uplifted rocks. Upscaling these results to realistic populations of landslides show that removing half of the total sediment volume introduced by large earthquakes in the fluvial network would typically last 5 to 25 years in various tectonically active mountain belts, with little impact of topography and climate. If several studies indicate a strong dependency of total landslide volume to earthquake magnitude, our study show that the sediment export time of a landslide population is not strongly impacted by earthquake magnitude or by the total volume of the landslide population. Building on these new findings, we then investigate the dynamics of mountainous landscapes submitted to a series of earthquakes, following either a Gutenberg-Richter distribution or a single large magnitude event. We infer the temporal and spatial evolution of the number of active landslide deposits, of the sediment load along the fluvial network and of the exported sediment flux throughout several seismic cycles. These results highlight how landscapes and sediment fluxes respond on longer time scales to a succession of earthquakes able to trigger landslides.