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Export of earthquake-triggered landslides in active mountain ranges: insights from 2D morphodynamic modelling.

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In active mountain ranges, large earthquakes (Mw > 5-6) trigger numerous landslides that impact river dynamics. These landslides bring local and sudden sediment piles that will be eroded and transported along the river network causing downstream changes in river geometry, transport capacity and erosion efficiency. The progressive removal of landslide materials has implications for downstream hazards management and also for understanding landscape dynamics at the timescale of the seismic cycle. The export time of landslide-derived sediments after large-magnitude earthquakes has been studied from suspended load measurements but a full understanding of the total process, including the coupling between sediment transfer and channel geometry change, still remains an issue. Note that the transport of small sediment pulses has been studied in the context of river restoration, but the magnitude of sediment pulses generated by landslides may make the problem different. Here, we study the export of large volumes (>10^6 m^3) of sediments with the 2D hydro-morphodynamic model, Eros. This model uses a new hydrodynamic module that resolves a reduced form of the Saint-Venant equations with a particle method. It is coupled with a sediment transport and lateral and vertical erosion model. Eros accounts for the complex retroactions between sediment transport and fluvial geometry, with a stochastic description of the floods experienced by the river. Moreover, it is able to reproduce several features deemed necessary to study the evacuation of large sediment pulses, such as river regime modification (single-thread to multi-thread), river avulsion and aggradation, floods and bank erosion. Using a synthetic and simple topography we first present how granulometry, landslide volume and geometry, channel slope and flood frequency influence 1) the dominance of pulse advection vs. diffusion during its evacuation, 2) the pulse export time and 3) the remaining volume of sediment in the catchment. The model is then applied to a high resolution (5-10 m) digital elevation model of the Poerua catchment in New Zealand which has been impacted by the effect of a large landslide during the last 15 years. We investigate several plausible Alpine Faults earthquake scenarios to study the propagation of the sediment along a complex river network. We characterize and quantify the sediment pulse export time and mechanism for this river configuration and show its impact on the alluvial plain evolution. Our findings have strong implications for the understanding of aggradation rates and the temporal persistence of induced hazards in the alluvial plain as well as of sediment transfers in active mountain belts.