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Scenario-based assessment of rockfall risk and cost-efficiency of mitigation works

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Rockfalls are widespread phenomena that cause lots of damages to structures and threaten human beings. Rockfall simulation through computer models can provide useful insight for the analysis of risks related to rockfalls and for the assessment of the cost efficacy of mitigation works. In particular, a sound definition of rockfall risk for mitigation action planning and design require defining: (1) rockfall hazard over the affected area, including onset and propagation components; (2) the spatial probability distribution of impacts on exposed structures; (3) the intensity of the impacts; (4) a vulnerability function for the potentially impacted structures; (5) the expected cost of specific target events or scenarios. We present the case study of Fiumelatte (Lecco, Italy), where a large rockfall occurred on November 13th, 2004, caused 2 casualties, the destruction of several houses and the interruption of roads and railway. This area has been recurrently interested by a series of small rock fall events. Following the disaster, the authorities in charge built a first emergency-stage protection embankment, and started the design of a longer and higher defensive structure to be built in the immediate future. The aim of our analysis is to verify the technical efficiency of both the embankment dams, and to evaluate the cost-efficacy of these works through a cost-benefit analysis. For this, we applied a computer model (HY-STONE) to simulate the propagation of blocks along a 3D topography, including the defensive works and the elements at risk, in order to calculate the energy and the spatial distribution of the impacts. We calibrated the model by studying the rockfall event that hit the village, and we applied the model to the neighbouring areas without the embankments (scenario 0), with the emergency-stage embankment (scenario 1), and with the planned embankment (scenario 2). The distribution of impact energies against each exposed building has been computed and used to attribute a level of expected damage to each structure according to its vulnerability. Then we calculated the costs (evacuation, deployment of defensive works, destruction and repair of buildings, traffic interruption) and the benefits associated to different rockfall probabilities and different time periods for each scenario. We quantitatively demonstrate that the first, emergency-stage embankment is not performing well enough to fully protect the village, both in terms of lateral and vertical extension, and that the planned protective structure will provide the higher benefit-to-cost ratio for the entire community.