Assessing debris-flow activity and geomorphic changes caused by an extreme rainstorm: the case study of the Liera catchment (Dolomites, northeastern Italy)

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The extreme meteorological event “Vaia storm”, which occurred between the 27th and 30th October 2018 over Northeastern Italy, caused widespread windthrows, generated slope instabilities and floods, and damaged several anthropic structures. The Liera catchment (37.7 km²), in the Dolomites, was severely affected by the Vaia storm: an intense flash flood occurred in the valley floor, shallow landslides affected soil-mantled slopes, and 34 sub-basins featured debris flows. These severe impacts, together with the availability of high-resolution multi-temporal topographic data, make the Liera catchment an excellent case-study for the analysis of the geomorphic processes caused by the Vaia storm. To this end, several activities were carried out in the frame of the Interreg SedInOut project (2019-2022) encompassing: (i) the creation and comparison of pre- (2015) and post-event (2019) sediment sources inventories, (ii) the analysis of landforms evolution and (iii) the quantification of debris-flow mobilized volumes. The study methods include field surveys, orthophotos interpretation, rainfall analysis, and the processing of high-resolution (1 m) multi-temporal LiDAR-derived DEMs. The main outcomes of this study include: (i) the identification of new sediment sources generated by the Vaia storm, (ii) the quantitative estimation of mobilized material from each sub-basin through DEM of Difference (DoD), and (iii) the assessment of the debris yield rate (i.e. the volume eroded for unit channel length) for homogeneous channel reaches. The structural setting and lithological variety of the valley led to different debris-flow triggering mechanisms. Event rainfall characterization shows that the Liera catchment is located near the edge of one of the convective precipitation belts of the final phase of the Vaia storm; important rainfall gradients occurred between the two valley flanks, which affected more severely the right side. The 2015 pre-event mapped sediment sources cover a total area of about 1.88 km² while the 2019 inventory covers an area of 2.40 km², pointing out an increase of 22%. The amount of sediment mobilized from the sub-basins was 307,000±63,500 m³, and the total net volume balance exiting the basins was -64,000±14,500 m³. The latter value encompasses the volume that entered the Liera stream and the material that has been removed during and after the emergency operations. Despite the great impact of the event, only a limited amount of the total mobilized material reached the Liera thalweg. A key to explaining this behavior is sediment connectivity: the presence of large buffering areas as large alluvial fans plays a fundamental role in decoupling the subcatchments featuring the greatest debris-flow magnitudes. The proposed approach, devised and tested in the Liera catchment, enabled to recognize sediment sources and to assess debris-flow mobilized...
volumes at the event and catchment scales, leveraging the availability of multitemporal high-resolution topographic datasets and detailed field surveys for event characterization.

**KEY WORDS:** Geomorphic changes, debris flows, sediment delivery, extreme event