Progetto *CoupEvent*: Hillslope - Channel coupling during extreme events in South Tyrol

INTRODUCTION

The coupling of hillslope processes with the channel network is of great relevance for the hydromorphological quality of mountain rivers but it may also bring about augmented flood hazards during extreme events(Fig. 1). To date, only few researches have focused on the interconnections among hillslope processes, hillslope toe erosions and channel dynamics during extreme events. In order to fill this gap, the project "CoupEvent - Hillslope - Channel coupling during extreme events in South Tyrol" was proposed (Fig. 2).

Figure 1. Examples of sediments connectivity and disconnectivity in South Tyrol.

CoupEvent OBJECTIVES

The project CoupEvent has developed and tested a novel multidisciplinary scientific framework for the understanding of the sediment transport efficiency from landslides/debris flow to the channel network during extreme events:

1) to provide a basin-scale, evidence-based understanding of hillslopes-channels coupling during extreme events.

2) To develop a new methodology addressing sediment transport efficiency from landslides /debris flows to the channel network.

Duration: February 2020 to February 2022
Lead Partner: Eurac Research, Institute for Earth Observation, Bolzano
Project Partners: Free University of Bozen-Bolzano, CNR-IRPI Padova, Autonomous Province of Bolzano, South Tyrol

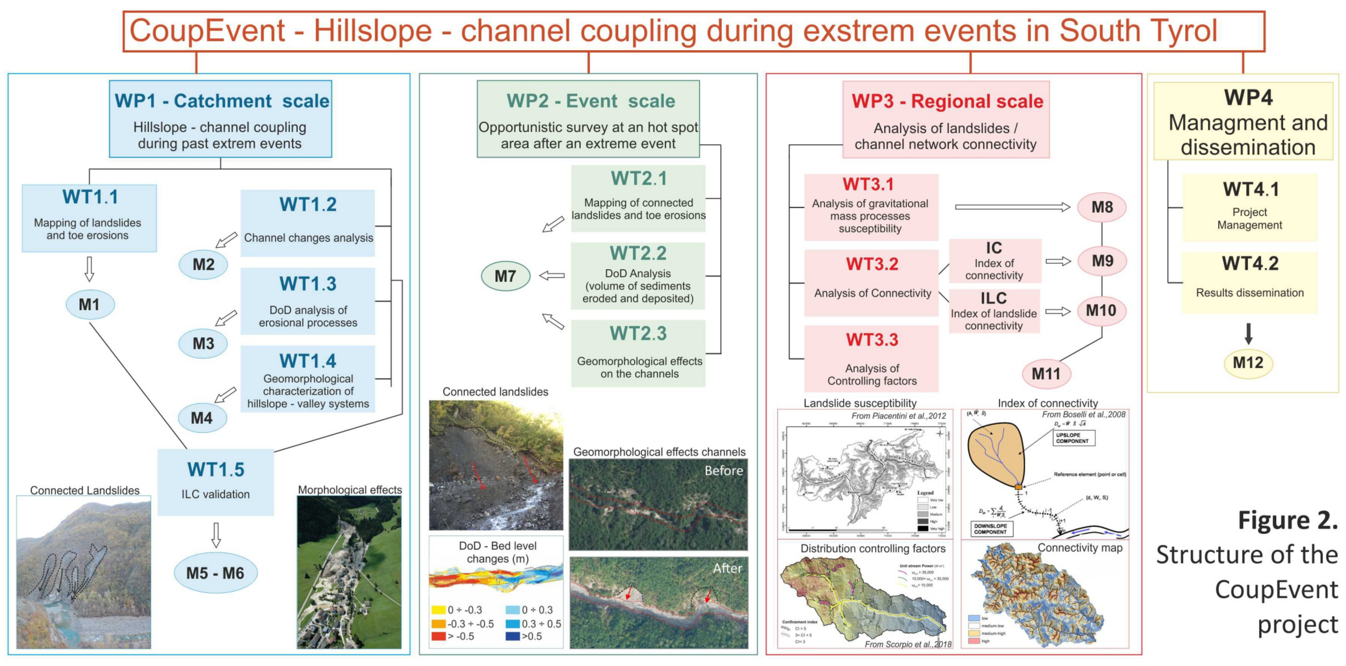

Figure 2. Structure of the CoupEvent project

Monitoring storm-induced morphological effects in a dolomitic catchment of the Italian Alps: insights for the understanding of the hillslope-channel sediment coupling

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Wp1: Catchment scale; Wp2: Event scale

STUDY AREA and ANALYZED FLOODS

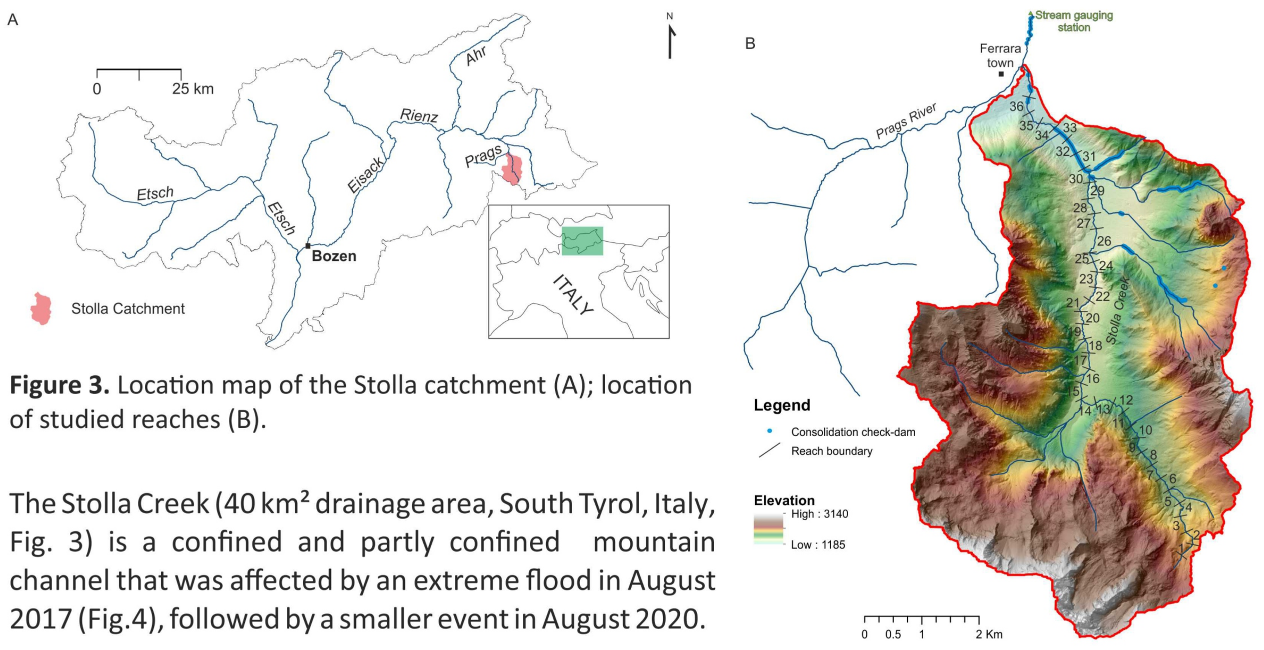


Figure 3. Location map of the Stolla catchment (A); location of studied reaches (B).

The Stolla Creek (40 km² drainage area, South Tyrol, Italy, Fig. 3) is a confined and partly confined mountain channel that was affected by an extreme flood in August 2017 (Fig.4), followed by a smaller event in August 2020.

Figure 4. Debris flow and alluvial channel processes in the Stolla catchment (A); active debris fans connected to the Stolla channel (B); disconnected debris flow (C); toe erosion processes (D); bank erosion (E); overbank deposition on the former floodplain (F); details of the overbank deposits (G);

Two floods in the Stolla catchment

Metereological event in 2017 — Metereological event in 2020

RESULTS: Rainfall and flood response analysis

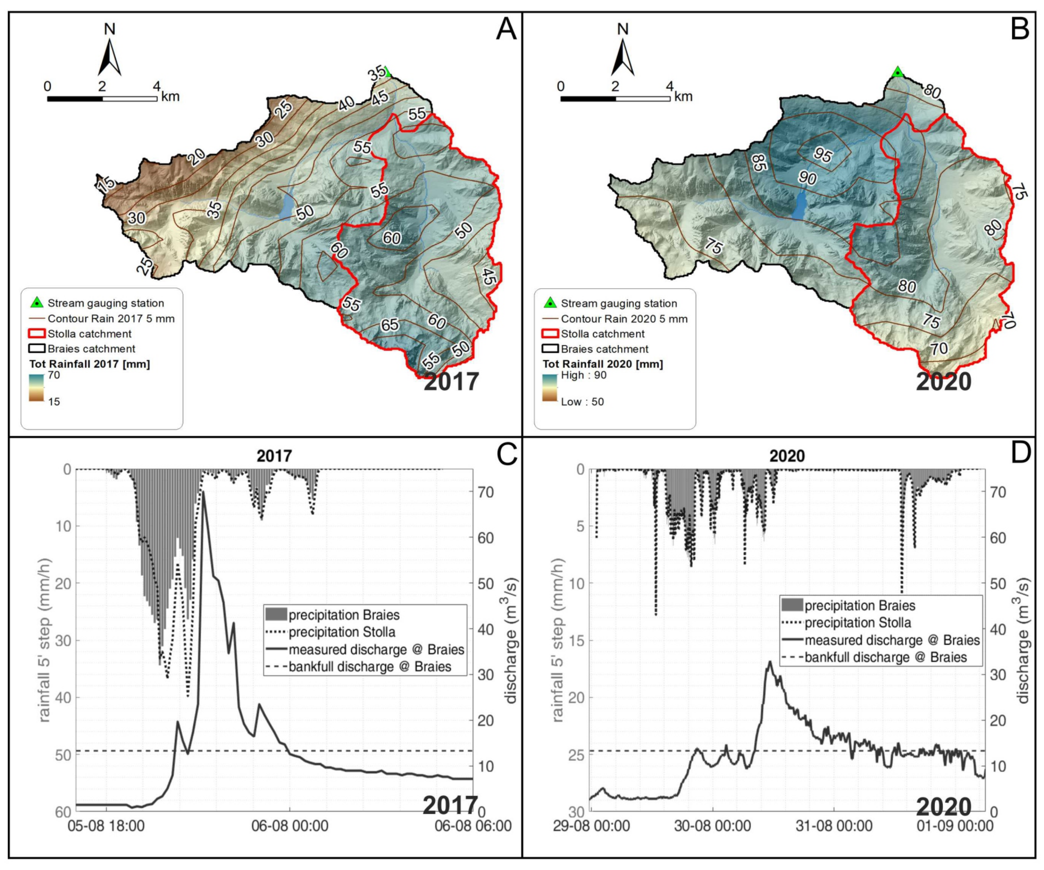


Figure 5. Cumulative rainfall for 2017 (A); and 2020 events (B); recorded flood hydrograph at the Braies station for 2017 (C); and 2020 events (D). Recorded hydrographs are reported in solid black line together with average catchment rainfall for the whole basin (grey bar) and for the Stolla sub-catchment (dotted line) for 2017 (C) and 2020 (D) events. Severe intensities for 2017 event emerge considering rainfall and discharge magnitude (C) while total rainfall and much longer duration for the 2020 event can be inferred at a glance comparing isohyets and patterns in panels A and B along with C and D plot timescale difference. As a reference, bakful discharge calculated for the Braies station is reported with a dashed line.

RESULTS: Planimetric channel changes indiced by the floods

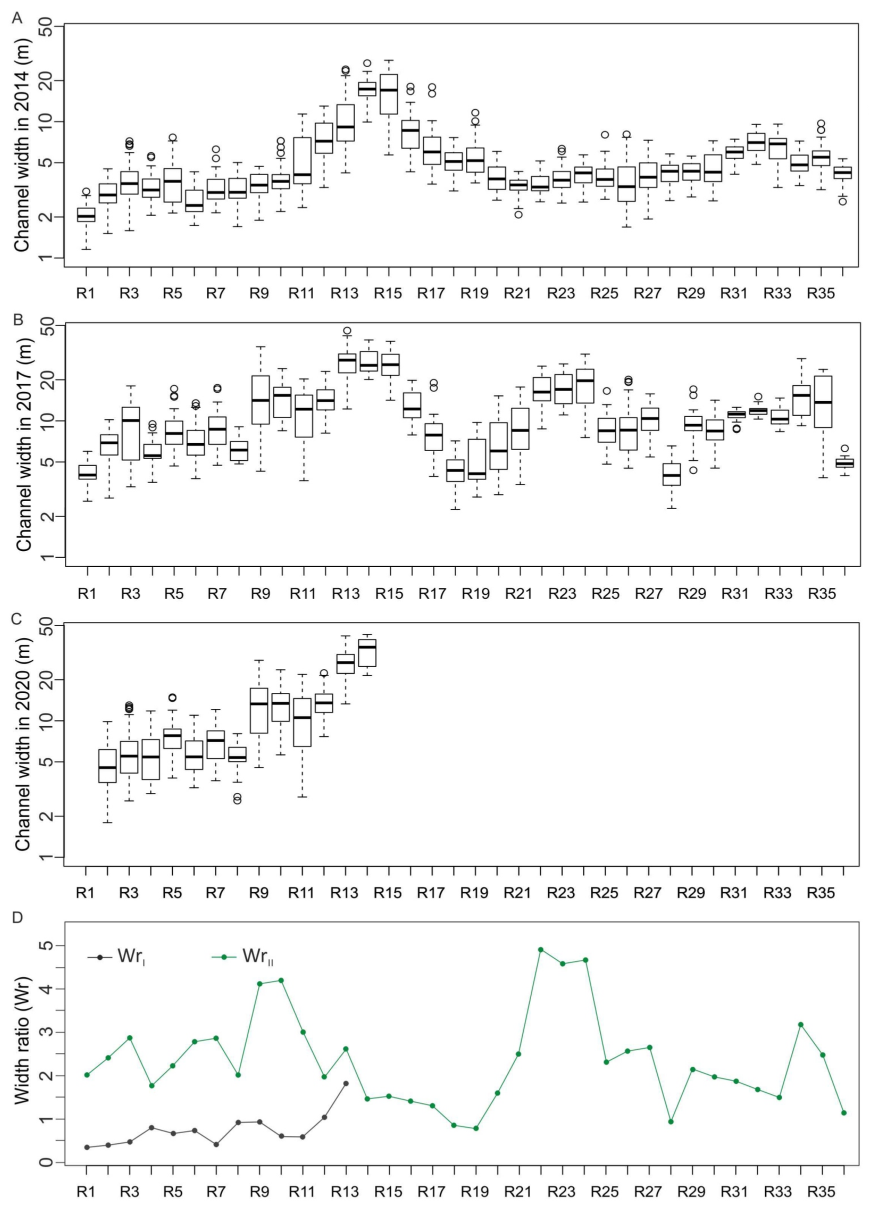
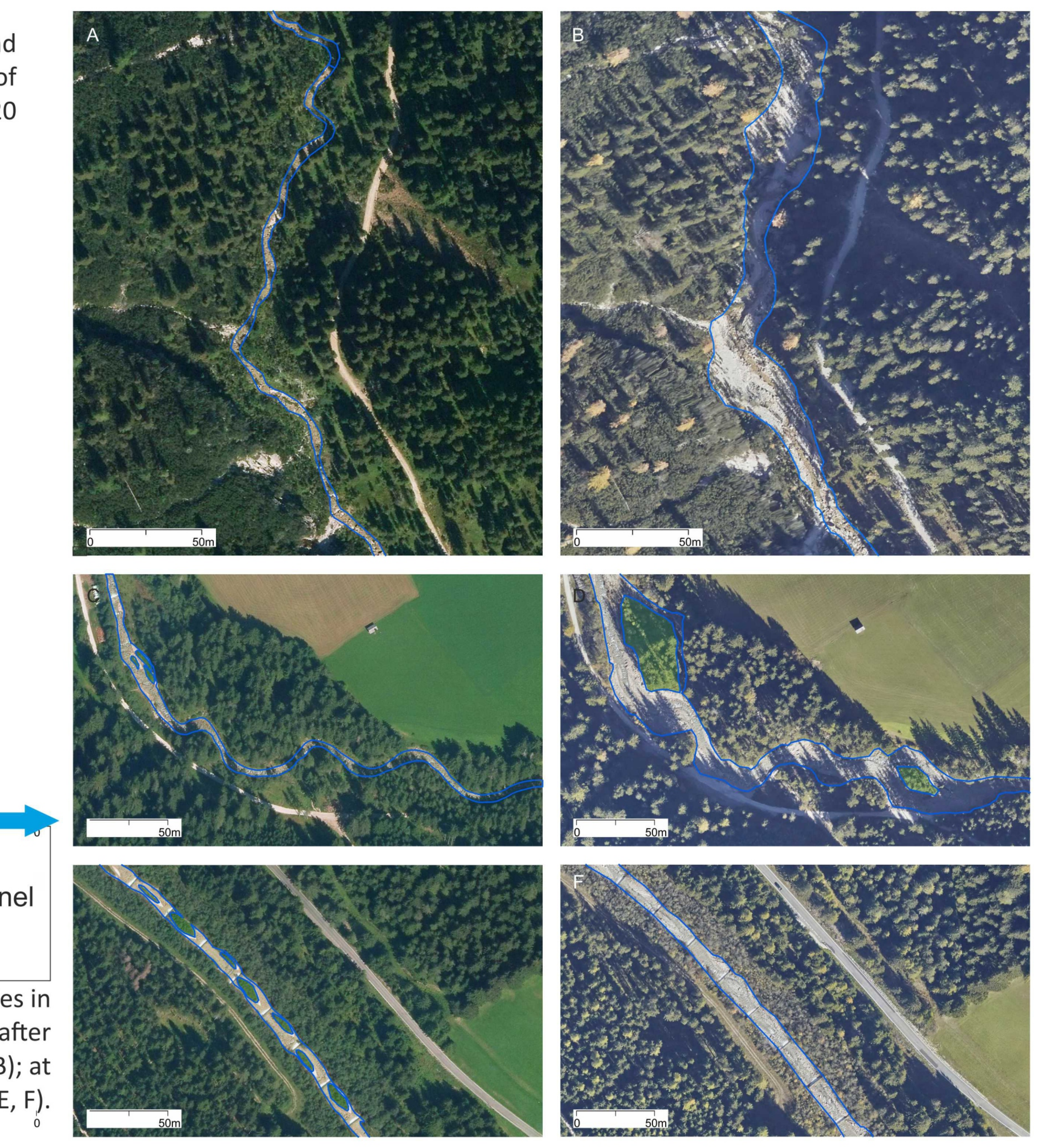


Figure 6. Channel width in 2014 (A), in 2017 (B), and in 2020 in the study reaches(C); median values of width ratio for the floods of 2017 (Wr_1) and 2020 (Wr_2) (D).

Wr (Width ratio)
Krapesch et al., 2005

$$Wr = \frac{\text{Post event width}}{\text{Pre event width}}$$

Figure 7. Bank erosion in the Stola channel



Legend Figure 8
Active channel
Island

Figure 8. Comparison of fluvial morphologies in the Solla valley bottom before (A, C, E) and after the flood in 2017 (B, D, F), at reach 9 (A, B); at reach 34 (C, D) and at reach 32 (E, F).

RESULTS: Channel bed level changes

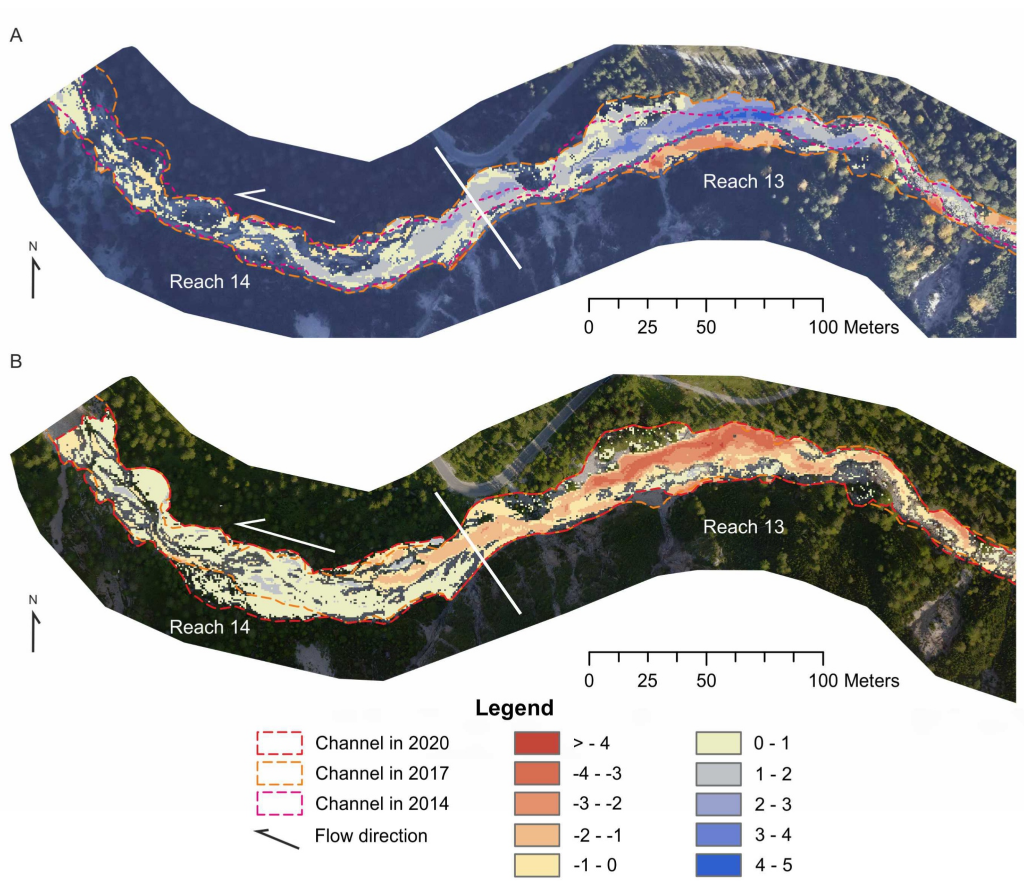


Figura 9. Bed level changes distribution at reaches 13 and 14 between 2010 and 2017 (A) and between 2017 and 2020 (B).

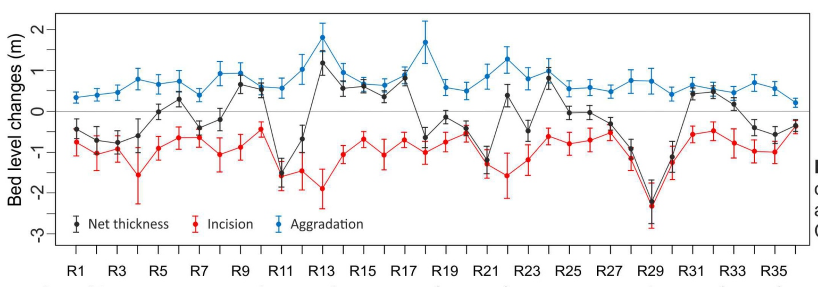


Figure 10. Bed level changes between 2014 and 2017 in the Stolla Channel.

Flood in 2017: max channel incision (2.2 m); max aggradation (+4m)

Flood 2020: max channel incision (-1.5m); max aggardation (+0.8m)

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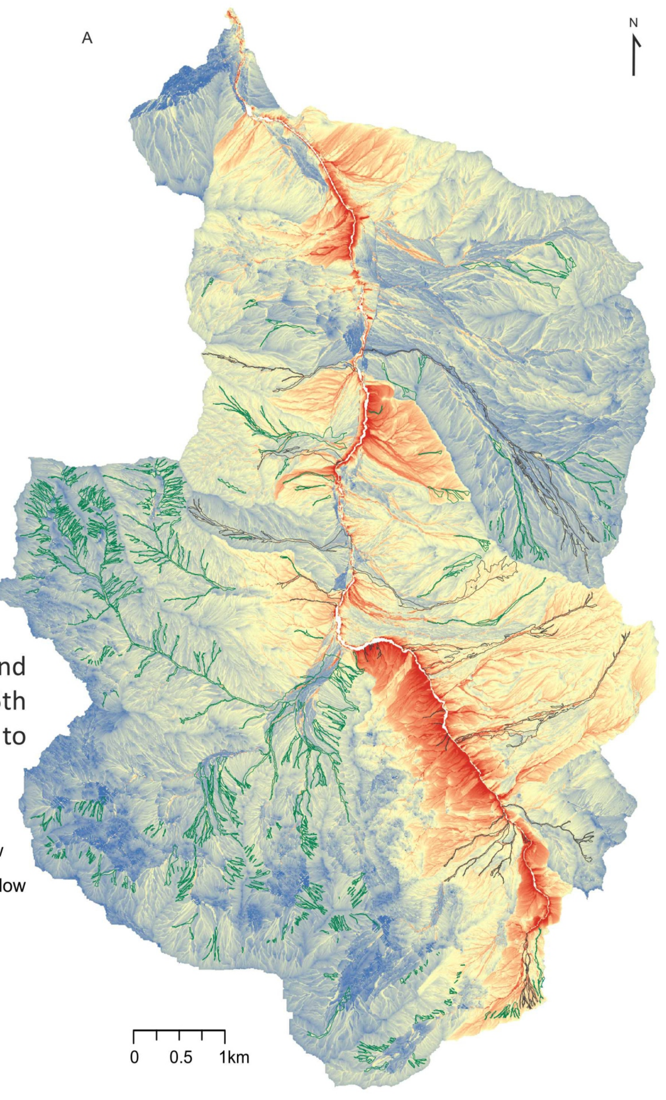
Scorpio, V., Cavalli, M., Steger, S., Crema, S., Marra, F., Zaramella, M. et al. (2022). Storm characteristics dictates sediment dynamic and geomorphic changes in mountain channels: A case study in the Italian Alps. Geomorphology, 403, 108173. Available from: https://doi.org/10.1016/j.geomorph.2022.108173
Steger S., Scorpio V., Comiti F., Cavalli M. (2022). Data-driven modelling of joint debris flow release susceptibility and connectivity. Earth Surf. Process. Landforms, 1-25. Available from: https://doi.org/10.1002/esp.5421

RESULTS: Hillslope processes in 2017

Figure 11. Examples of activated debris flows.



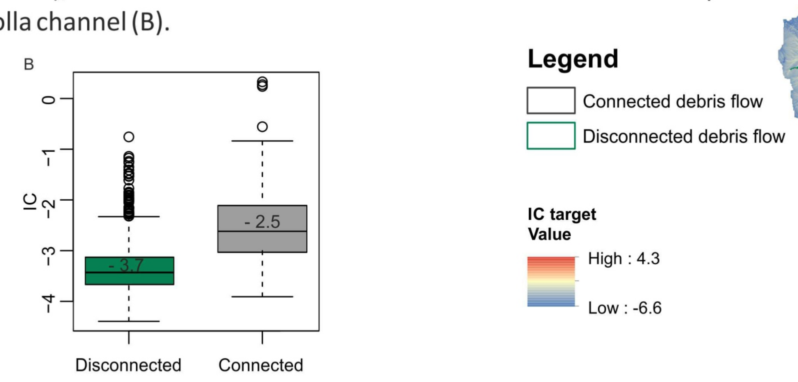


Figure 12. Map of index of Connectivity using the Stolla as target (A). Box and whiskers plots presenting median and interquartile range (25th and 75th percentiles), of the connected and disconnected debris flow with respect to the Stolla channel (B).

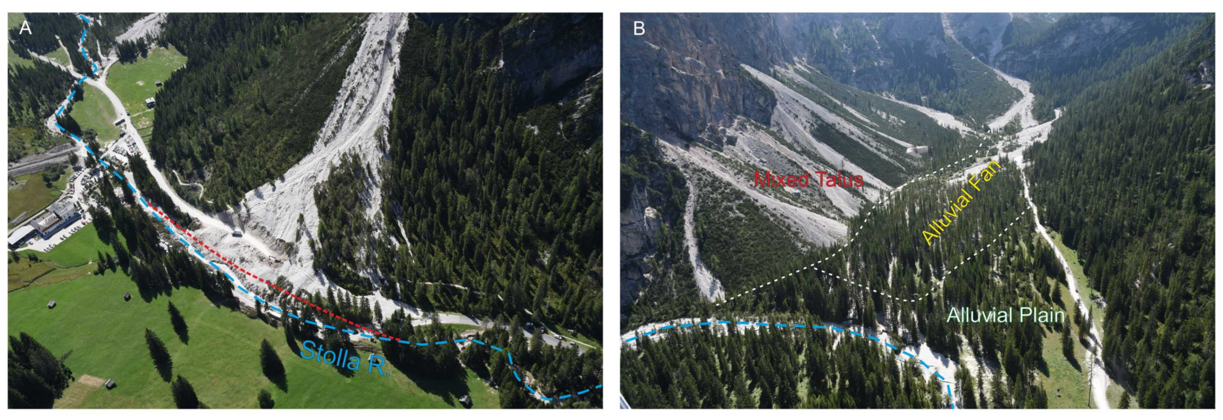


Figure 13. Examples of connected (A) and disconnected (B) debris flows in the Stolla catchment.

RESULTS: Sediment flux during the floods

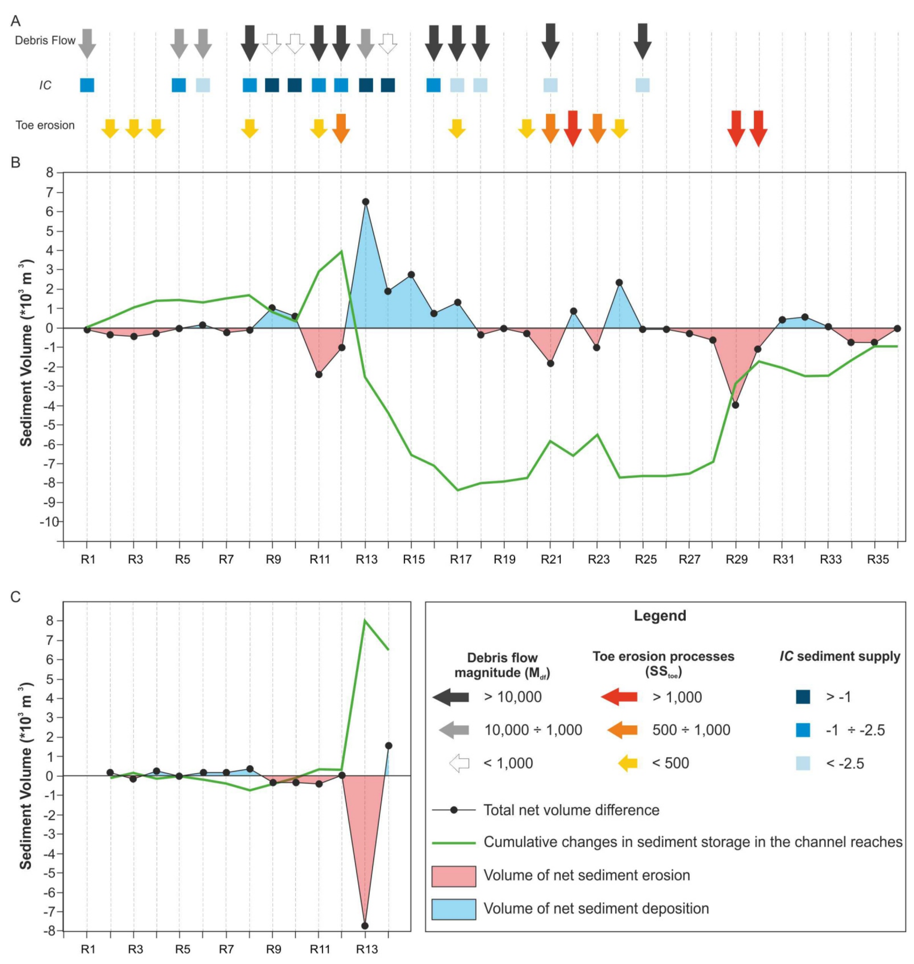


Figure 14. Spatial distribution and magnitude of sediment supply for debris flows and toe erosions and of sediment supply for debris flows connectivity during the event in 2017 (A); sediment storage and cumulative changes in the sediment storage in the Stolla channel after the flood event in 2017 (B); and 2020 (C).

Conclusion

- Basin structural connectivity describes potential sediment delivery to the main channel.
- Functional connectivity determined by rainfall characteristics controlled actual sediment supply and transport.
- Same channel reaches subject to both aggradation and incision depending on event type.
- Sediment export from the study basin during an extreme flood event was very limited.
- Channel widening through bank erosion and overbank deposition was driven by valley confinement and stream power.