Debris-flow channel evolution at the triggering and transport zone: learning from a very active case study in the Dolomites

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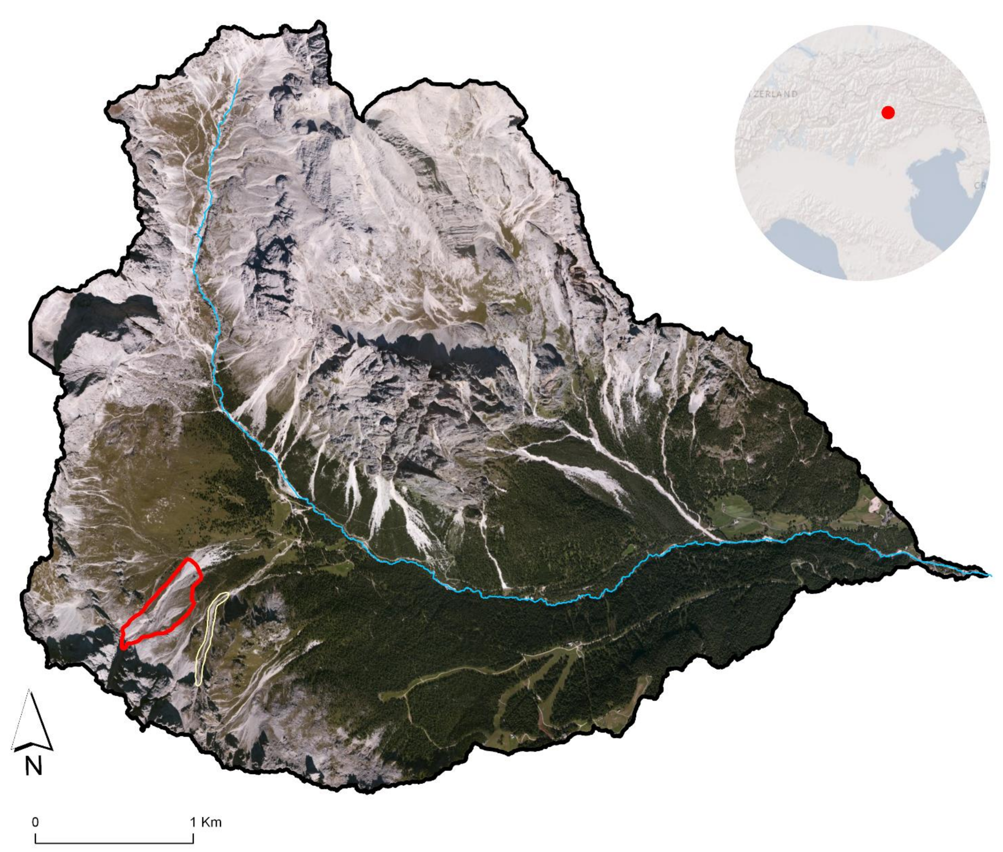
ABSTRACT

Understanding morphology changes and sediment spreading along a debris-flow channel is a key step in hazard mitigation planning. This research analyses a 10 years evolution of erosion/deposition patterns in an active debris-flow upper channel located on the Dolomites (rio Soial, Val di Fassa, Trento, Italy). The morphologic evolution of the channel has been analysed performing a Difference of DEM (DoD) (Cavalli et al., 2015; Wheaton et al., 2010). DEM differencing enables quantitative and spatially-distributed representation of erosion and deposition within the analysed time window, at both channel reach and the catchment scale. In this study, the analysis were performed using two high-resolution Digital Terrain Models (DTMs). The 2008 LiDAR-derived DTM of the Autonomous Province of Trento with a DTM created from a UAV-based point cloud from July 2018 were compared. This data set was also used to determine the changes in the sediment Connectivity Index (CI), which explains the existing degree of linkage between sediment sources and channel network (Cavalli et al., 2013). During the period 2008-2018 five debris flow events have occurred. Each associated rainstorm was analysed in order to assess the evolution of the threshold rain intensities in relation to the evolution of the channel-valley morphology.

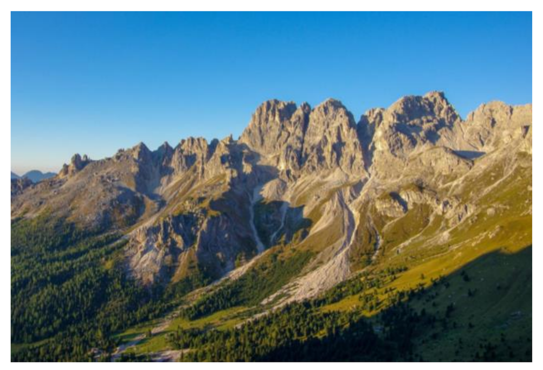
The results on the CI analysis show a general decrease in CI values, meaning an increased disconnection between the head basin areas and the outlet at the end of the transport reach. Also, the rain thresholds show a slight increase after the lasts event, indicating a gradual stabilization of the basin and a possible reduction of the expected frequency of debris flow events.

Area of Study



Location: Sèn Jan di Fassa – Autonomous Province of Trento (Italy)

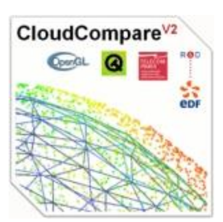
	Rio Soial	Sub-catchment
Area (km^2)	17.2	0.14
Min. elevation (m.a.s.l.)	1324	2028
Max. elevation (m.a.s.l.)	3002	2638
Mean elevation (m.a.s.l.)	2204	2226
Check Dam	30	0



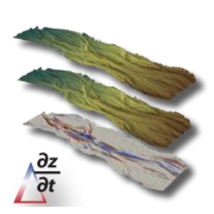
Methods

HIGH-RES TOPOGRAPHY

PhotoScan



Copernicus
Europe's eyes on Earth

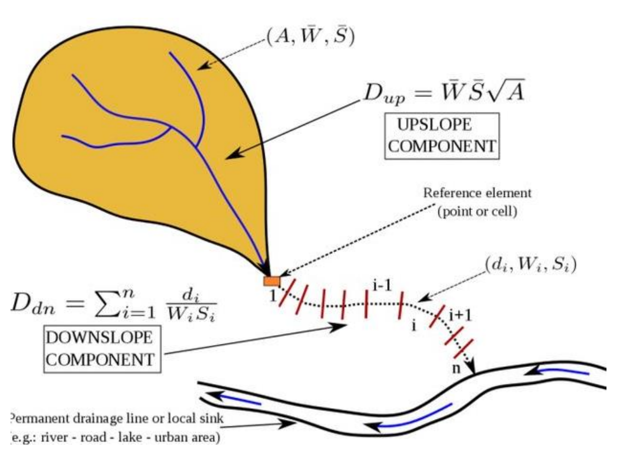


Geomorphic Change Detection 7

CONNECTIVITY INDEX

It is a topographic index intended to represent the potential connectivity between different parts of the catchment.

$$CI_k = \log_{10}\left(\frac{\overline{W_k}\,\overline{S_k}\,\sqrt{A_k}}{\sum_{i=k,\dots,n_k} \frac{d_i}{W_i S_i}}\right)$$



RAINFALL ANALYSIS

Understand triggering rainfall of DF events

Intensity/duration analysis – max mean intensities (mm/h) for 5,10,15,30,60,120 minutes

Research questions

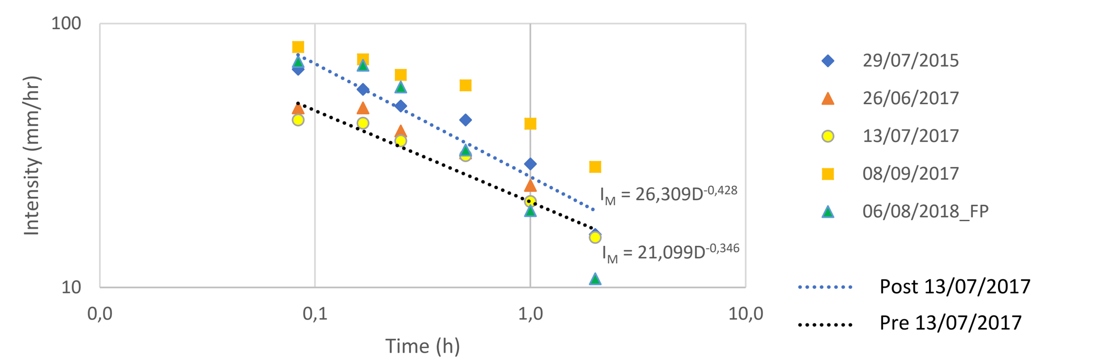
- How a Debris-flow triggering area is evolving over time? And what about the subsequent transport and deposition areas?
- Is the triggering rainfall threshold stable? Or is it evolving in the analysed period (2015-2019)?
- Has the morphology of the channel changed? If yes, How at the triggering, equilibrium and deposition area?
- How is the area connected at the closest sink (Rio Soial)? How the Connectivity Index evolved over time?
- How we can protect the exposed pastureland and mountain hut? Does it have the same impact on connectivity in 2018 as 2009?

PRELIMINARY RESULTS

Rainfall Analysis

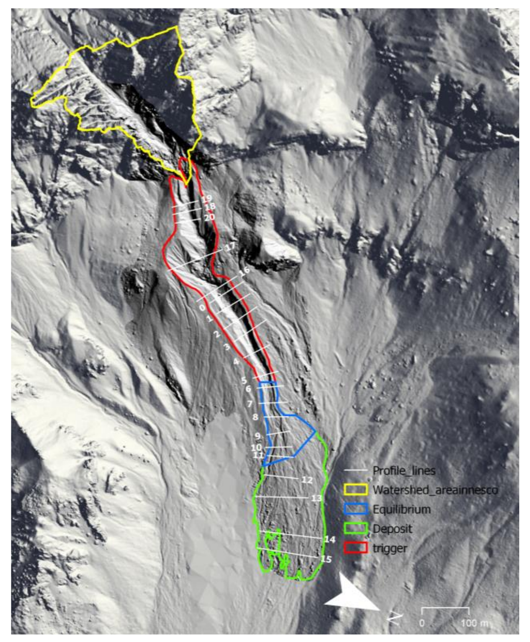
D.F. Event	h (mm)	Im (mm/h)	D (min)
29/07/2015	32	20.21	95
26/06/2017	24.4	24.4	60
13/07/2017	44.6	11.12	170
09/08/2017	61.4	21.67	165
06/08/2018 FP	39.2	9.60	150

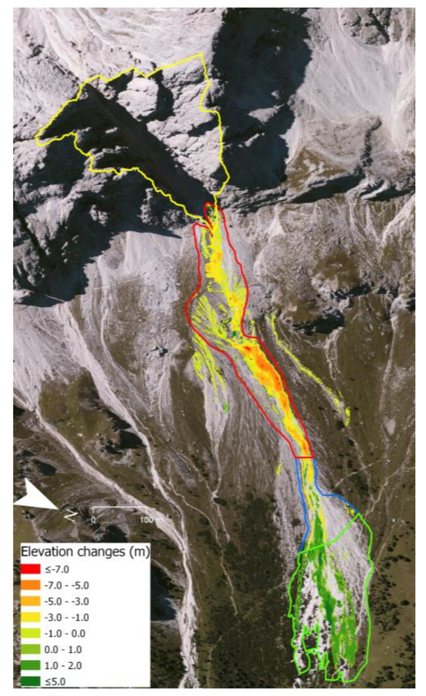
*FP= False Positive



Increased triggering rainfall threshold: related to a stabilisation of the channel

Geomorphic evolution





Trigger

	Thresholded DoD Estimate:			
VOLUMETRIC:			± Error Volume	% Error
Total Volume of Surface Lowering (m^3)	**31805**	±	5621	18%
Total Volume of Surface Raising (m^3)	**345**	±	125	36%
Total Volume of Difference (m^3)	32150	±	5746	18%
Total Net Volume Difference (m^3)	**-31461**	±	**5622**	-18%

Equilibrium

	Thresholded DoD Estimate:			
VOLUMETRIC:			± Error Volume	% Error
Total Volume of Surface Lowering (m^3)	**2061**	±	691	34%
Total Volume of Surface Raising (m^3)	**1165**	±	413	36%
Total Volume of Difference (m^3)	3225	±	1104	34%
Total Net Volume Difference (m^3)	**-896**	±	**805**	-90%

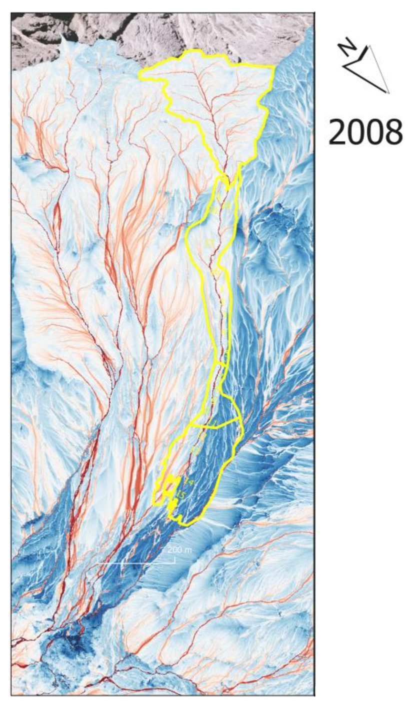
Deposit

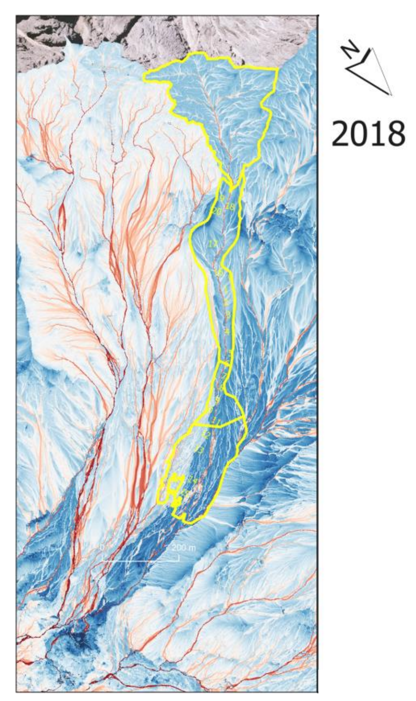
VOLUMETRIC:			± Error Volume	% Error
Total Volume of Surface Lowering (m^3)	**386**	±	260	67%
Total Volume of Surface Raising (m^3)	**20075**	±	5909	29%
Total Volume of Difference (m^3)	20461	±	6169	30%
Total Net Volume Difference (m^3)	**19689**	±	**5914**	30%

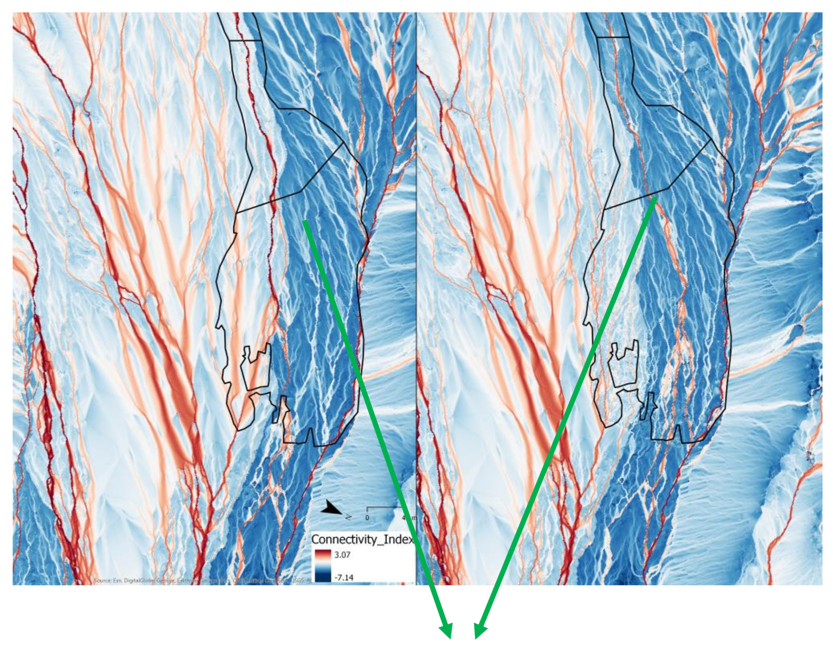
Total

Attribute	Thresholded DoD Estimate:			
VOLUMETRIC:			± Error Volume	% Error
Total Volume of Surface Lowering (m^3)	34252	±	6572	19%
Total Volume of Surface Raising (m^3)	21541	±	6433	30%
Total Volume of Difference (m^3)	55793	±	13005	23%
Total Net Volume Difference (m^3)	**-12711**	±	**9196**	-72%

Connectivity Index evolution







Re-activation of a pre-existing channel

Year	Minimum	Maximum	Mean	St.dev
2008	-6.12	-1.67	-3.73	0.51
2018	-6.40	-1.88	-4.10	0.43

General decrease of CI

Future steps

DoD with the UNESCO 2011 LiDAR-derived DTM.

Estimate antecedent moisture content (AMC) for each event.

Hydrologic simulation with FLO-2D.

Plan and verify protection measures to defense the mountain hut and its pastureland

Scan here for more maps, GIF animation and future developments

References

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