Detecting recent dynamics in large landslides via airborne photomonitoring tools: the Corvara landslide example (South Tyrol, Italy)

Tondo M. (1 *), Mulas M. (1), Corsini A. (1), Ciccarese G. (1), Marcato G. (2), Bossi G. (2), Tonidandel D. (3), Mair V. (3)

(1) Università di Modena e Reggio Emilia – Dipartimento di Scienze Chimiche e Geologiche (2) CNR – IRPI Padova
(3) Provincia Autonoma di Bolzano – Ufficio Geologia e Prove Materiali

* Autore corrispondente: melissa.tondo@unimore.it

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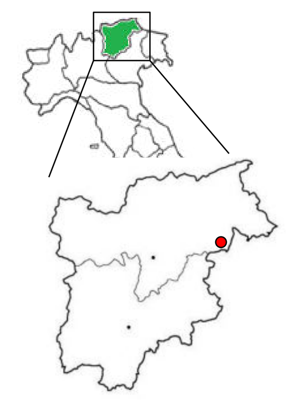
1. INTRODUCTION

The Corvara landslide is a complex slow-moving rotational earth slide-earth flow (with a total volume of more than 30 million m^3, a length of 3.5 km and a depth up to 100 m) that has been studied with various monitoring techniques since 1997.
From 2019 to date, in the framework of the *SoLoMon* project, repeated airborne LIDAR and orthophotos surveys have been acquired in order to test offset tracking and Dem of Difference (DoD) techniques for long-term monitoring of the active movements at the slope scale, thus unrevealing the most recent evolution of the Corvara landslide (Fig. 1 and Fig. 2).



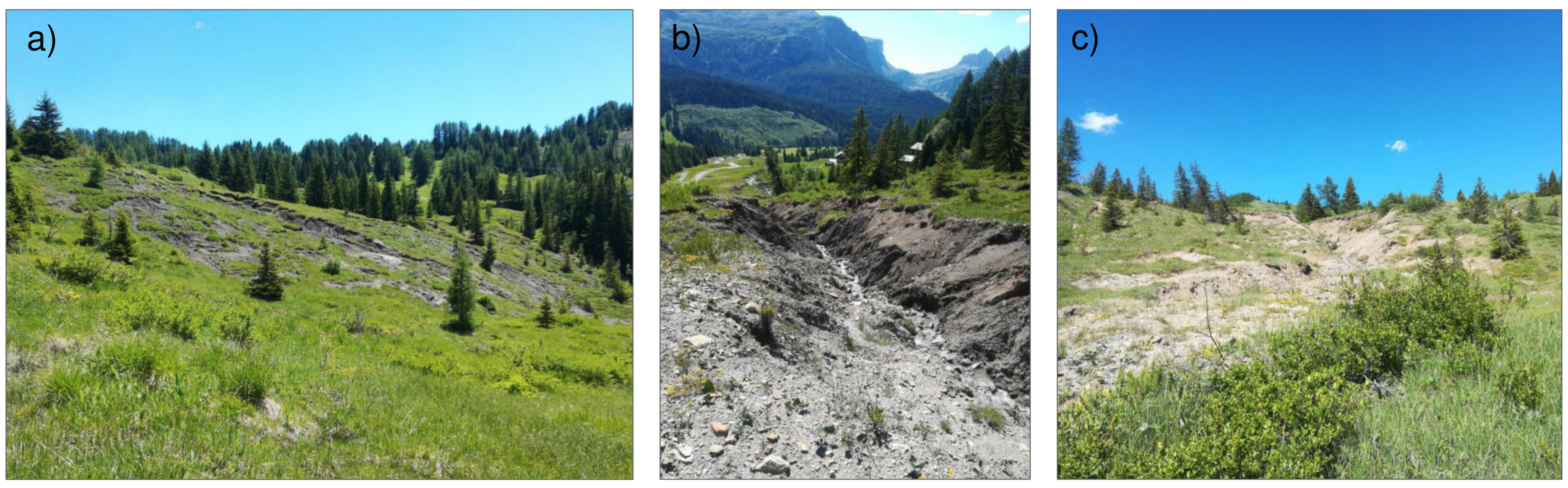


Figure 1: Photos representing a) an active part of the landslide within S2 Source zone, b) and c) two different points of view of the Rio Chiesa passing through the upper part of the Track zone.

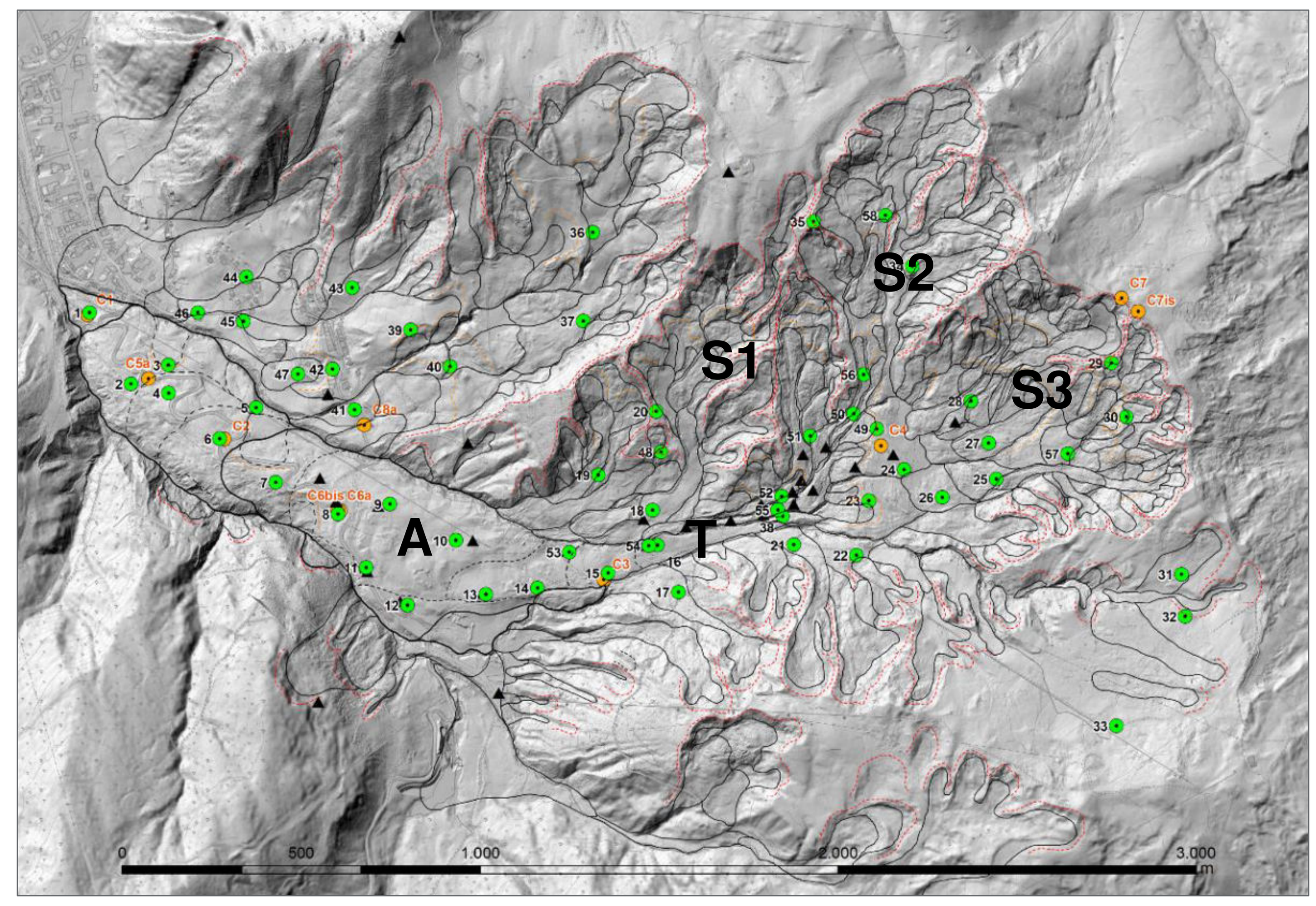


Figure 2: Hillshade showing the extension of the Corvara landslide with the identification of the main Source zones (S1 and S3), Track zone (T) and Accumulation zone (A). Green points are GNSS benchmarks, orange points inclinometers and black triangles are robotic total station targets (recently implemented).

2. MATERIAL AND METHODS

Orthophotos of 2019, 2020 and 2021, characterized by a spatial resolution of 5 cm, have been analysed with advanced digital image correlation algorithms in order to perform airborne photomonitoring at slope scale.
Each orthophoto covers an overall area of 7 km^2, and for processing purposes has been subdivided in 8 tiles. Pairwise analysis of orthophotos has been carried out using IRIS© software package, that implements advanced digital image correlation algorithms in a Graphic User Interface. Digital Image Correlation has comprised the following work steps:
(1) Downscaling of orthophotos to 10 cm resolution and compression to JPEG format.
(2) Pre – processing, i.e. Mean Normalization with a window size of 10 pixels and a step size of 2 pixels.
(3) Displacement analysis, i.e. application of "phase correlation", based on fast Fourier transforms to estimate translative offset between two similar images, with a window size of 32 pixels, a subpixel resolution of 0.05 and building of 3 pyramid levels.
(4) Post – processing, i.e application of a "Correlation Coefficient filter" in order to filter off pixels with a correlation value lower than 0.05, and replacing them with no-value ones.

3. RESULTS

Displacement maps related to the 2019 to 2020 and 2020 to 2021 evolution of the landslide are shown in Fig. 3 and 4. With respect to the identification and quantification of active movements, the following results are worthwhile being pointed out:

- 2019 – 2020 (Fig. 3). Results show widespread stable areas (in green colour) and active movements localized in specific sectors of the source area S2 and the Track zone, with maximum displacements in the order of 1.5 – 2 m, locally 2.5 m. In correspondence of wooded ridges, results show, erroneously, movements (i.e. by blu colour) that are most likely related to errors associated to significant changes in vegetation during the analysed period.
- 2020 – 2021 (Fig. 4) Active sectors appear more clearly in Source 2, Source 3 as well as in the upper part of the Track Zone and are in the range of 2 to 2.5 m, locally up to 3.5 – 4.5 m..

Combining the results of the two displacement maps, the Source zones (S2 and S3) showed a total maximum movement of 6 – 7 m in the 2019 – 2021 period, while for the upper part of the Track zone was up to 5 – 6 m.
A validation of these results has been carried on 4 control points in the Track zone (Fig. 5A – 5D). Control points are homologous points, such as valleys or ridges, recognizable in hillshades of different years (2019 and 2021). The offset of such points has been measured by supervised analysis and the results are compared to displacement rates retrieved using digital image correlation in IRIS. A general consistency between the two independent assessment methods has been obtained (see table below).

Control points (cfr. Fig. 5A-5D)	Total Displacement (2019-2021)	
	Hillshade	IRIS
1a - 1b	2.7 m	2.6 m
2a - 2b	8.2 m	7.1 m
3a - 3b	4.9 m	4.5 m
4a - 4b	2.6 m	2.7 m

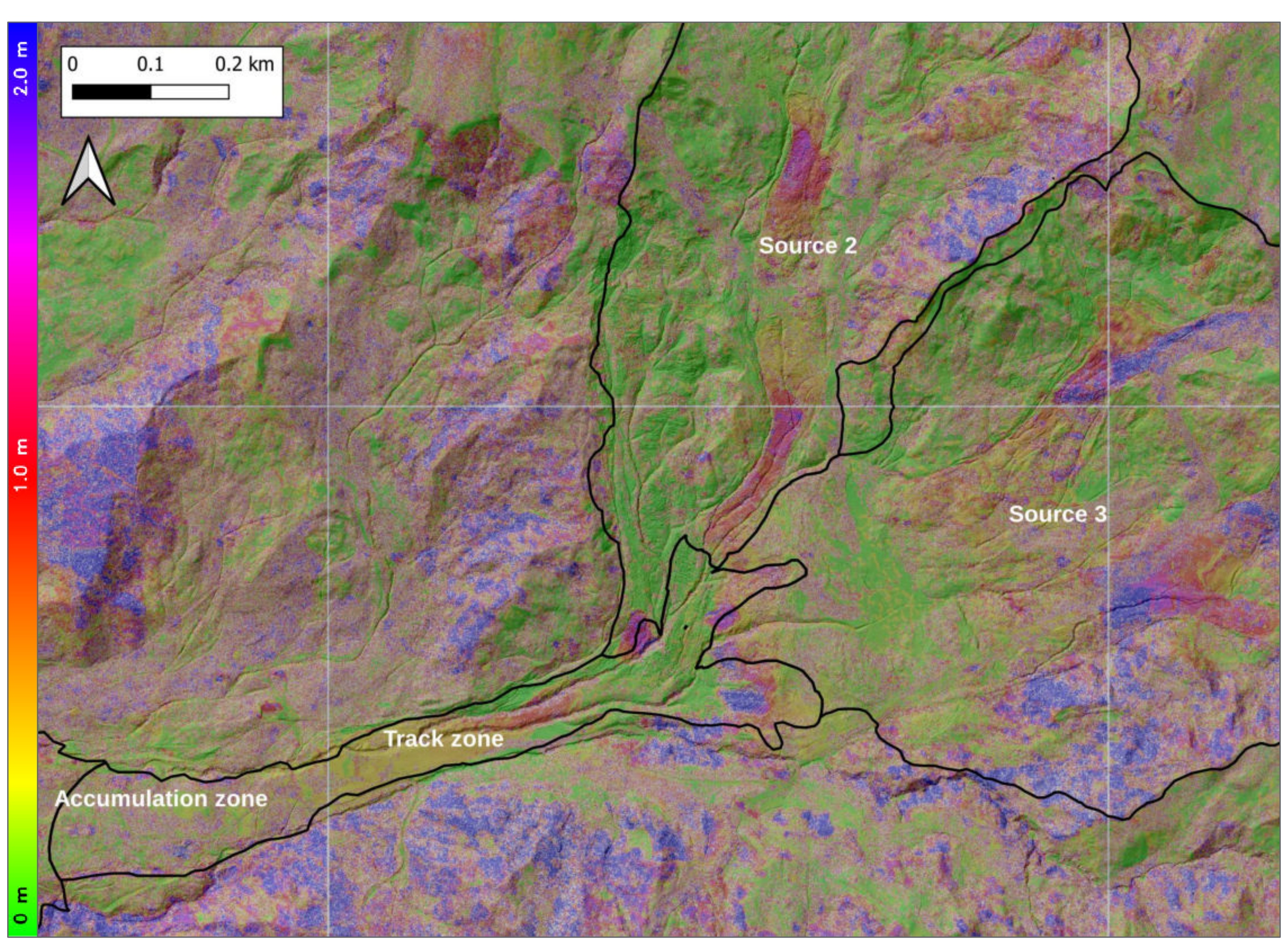


Figure 3: Phase correlation displacement map 2019 – 2020.

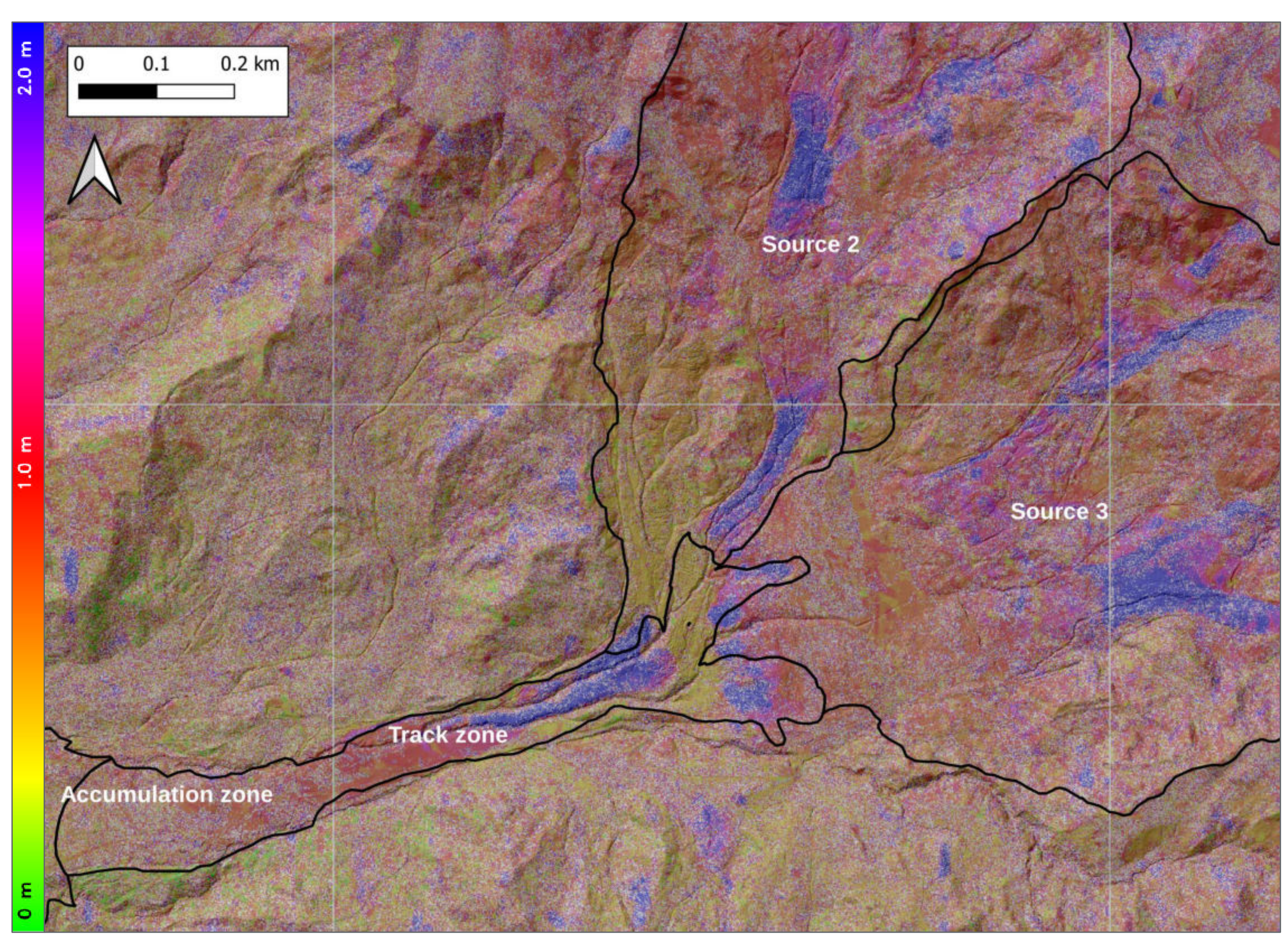


Figure 4: Phase correlation displacement map 2020 – 2021.

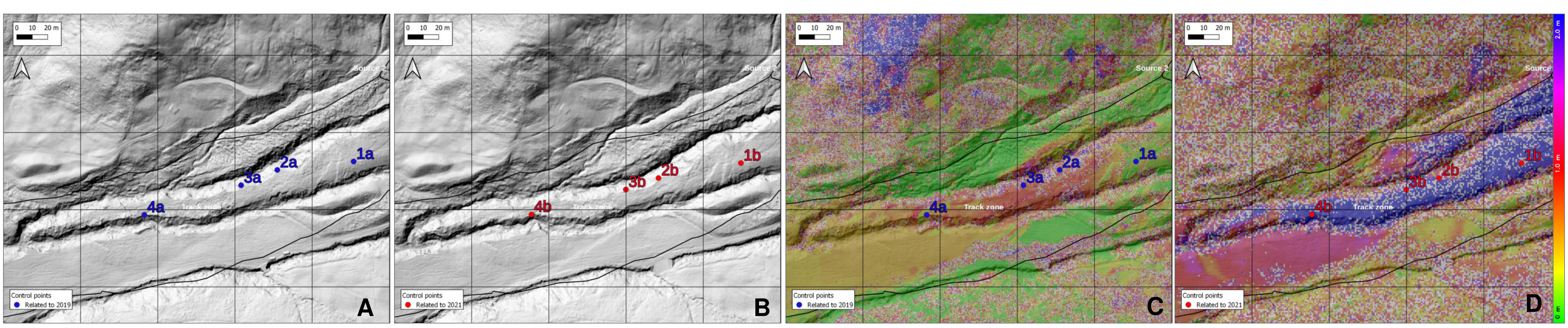


Figure 5: A) Hillshade of the Track zone in 2019 to be compared with B) hillshade of the Track zone in 2021. C) IRIS displacement map of the Track zone in 2019 – 2020. D) IRIS displacement map of the Track zone in 2020 – 2021.
In all the images, the blue and red points are the control points selected for the validation of Phase correlation results (blue for 2019 and red for 2021)

4. CONCLUSIONS

Airborne photomonitoring technique was effectively applied as a tool for area-wide identification and quantification of superficial dynamics in large landslides. Displacement values obtained through the implementation of IRIS software were consistent with values derived from the comparison of homologous points within hillshades of different years. It was therefore possible to efficiently analyze the most recent evolution of the Corvara landslide (2019-2021) by tracking active areas and quantifying their displacements.

ACKNOWLEDGEMENTS
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