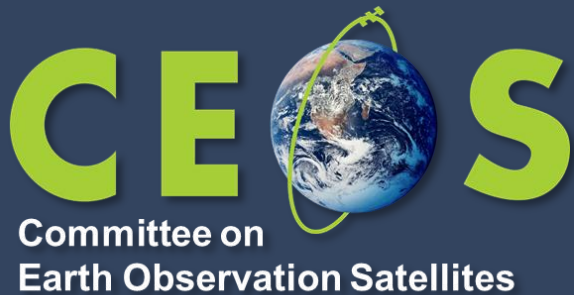


Working Group on Disasters 26 (WGD-26)

Remote sensing solutions for heavy
rainfall induced landslides detection and
identification of slow landslides
impacting on infrastructure

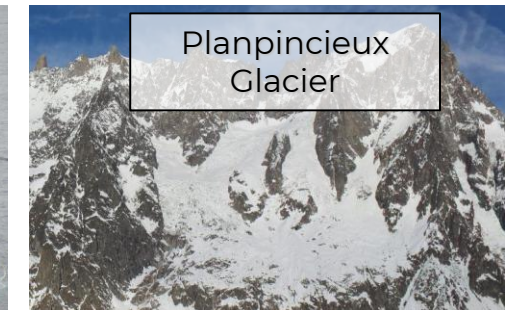
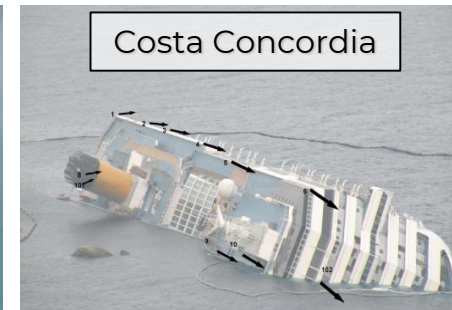
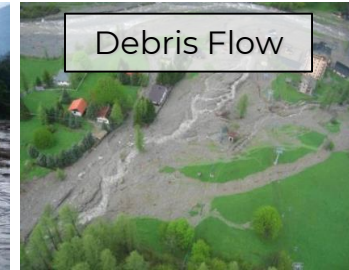


Daniele Giordan,
CNR-GEO – National Research
Council of Italy, Institute of
Geosciences
Session #3 Landslides
WGDisasters 2026
ASI, Rome, Italy
14-18 September 2026

Scientific Research, Risk management and assessment, Monitoring:

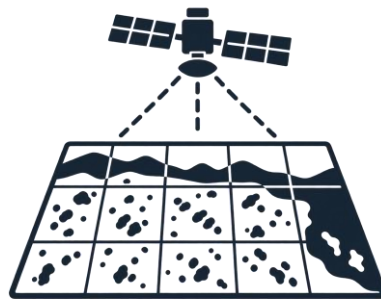
CNR-GEO is a recent research institute. The Research Institute for Geo-Hydrological Protection (IRPI) institute converged in CNR-GEO in July 2026.

The main aim of this institute of the Department of Earth System Sciences and Technology for the Environment (DSSTTA), is to design and execute **scientific research** and **technological development** in the fields of **natural hazards**, environmental protection, and the sustainable use of geo-resources, by operating at **different geographical and temporal scales**, and in **different climatic, physiographic and geological zones**.



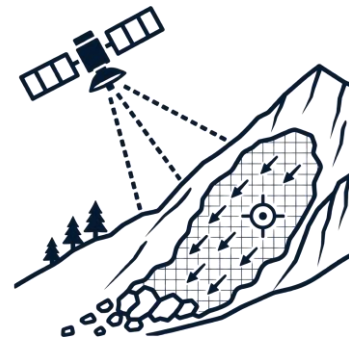
Remote Sensing Approaches Across Different Scales and Applications

Shallow landslides rapid mapping



Sensor	Optical
Approach	Change detection (PANDA)
Scale	Regional
Scope	Critical area identification during emergency

Landslide kinematic characterization



Sensor	Optical
Approach	Pixel offset
Scale	Slope
Scope	Kinematic domains characterization and displacement rates estimation

Slow landslide deformation and impact assessment



Sensor	SAR
Approach	PSInSAR-based infrastructure impact analysis
Scale	Regional
Scope	Geospatial Tool for Infrastructure Intervention Prioritization

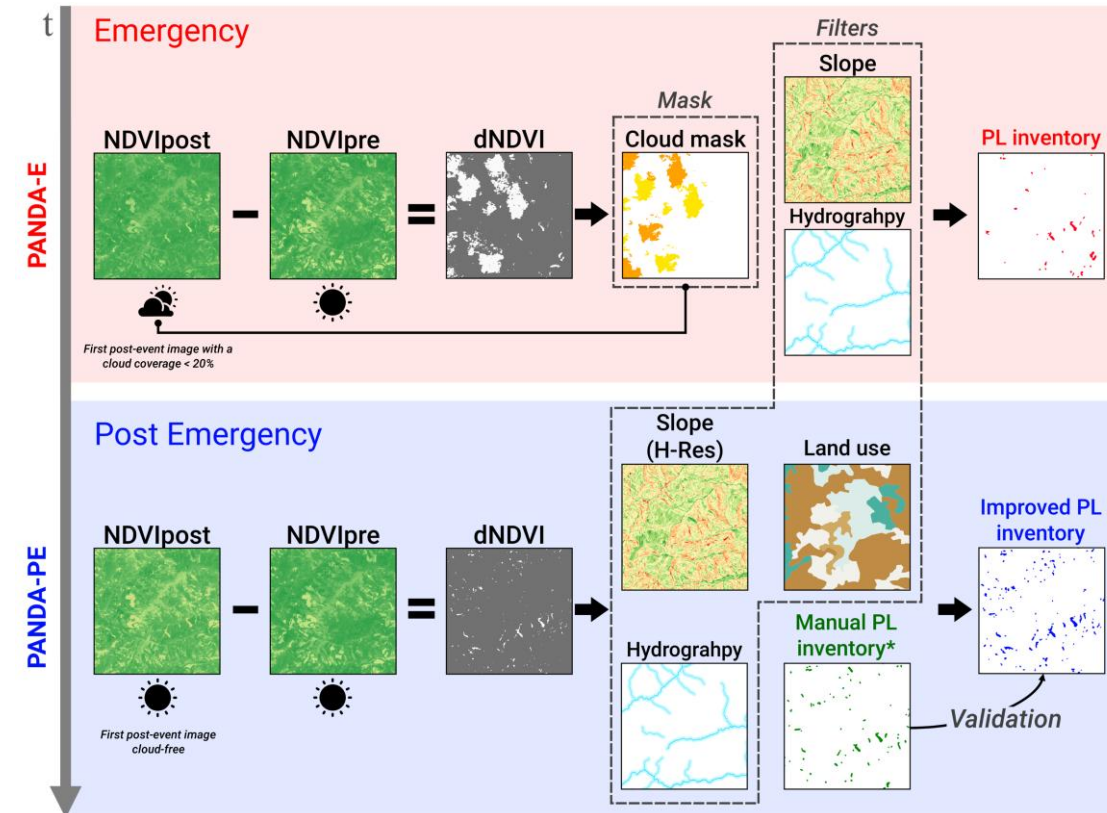
Unsupervised shallow landslide rapid mapping - the PANDA tool

Methodology

PANDA exploits NDVI changes combined with geomorphological filters (e.g., slope, river network) to detect bare-soil disturbances caused by **potential shallow landslides (PL)**

In its **emergency-response phase (PANDA-E)**, the method prioritizes speed, delivering a first reconnaissance map to support field teams within days of image acquisition.

In the **post-emergency phase (PANDA-PE)**, the PL inventory is enhanced using cloud-free imagery, iterative NDVI/slope thresholding, and, if available, new images to filter false positives related to land use change and improved ancillary data (e.g., high-resolution DTM)



Notti, D., Cignetti M., et al. The unsuPervised shAllow laNdslide rapiD mApping: PANDA method applied to severe rainfalls in northeastern Appenine (Italy). *International Journal of Applied Earth Observation and Geoinformation* **129**, 103806 (2024). 10.1016/j.jag.2024.103806

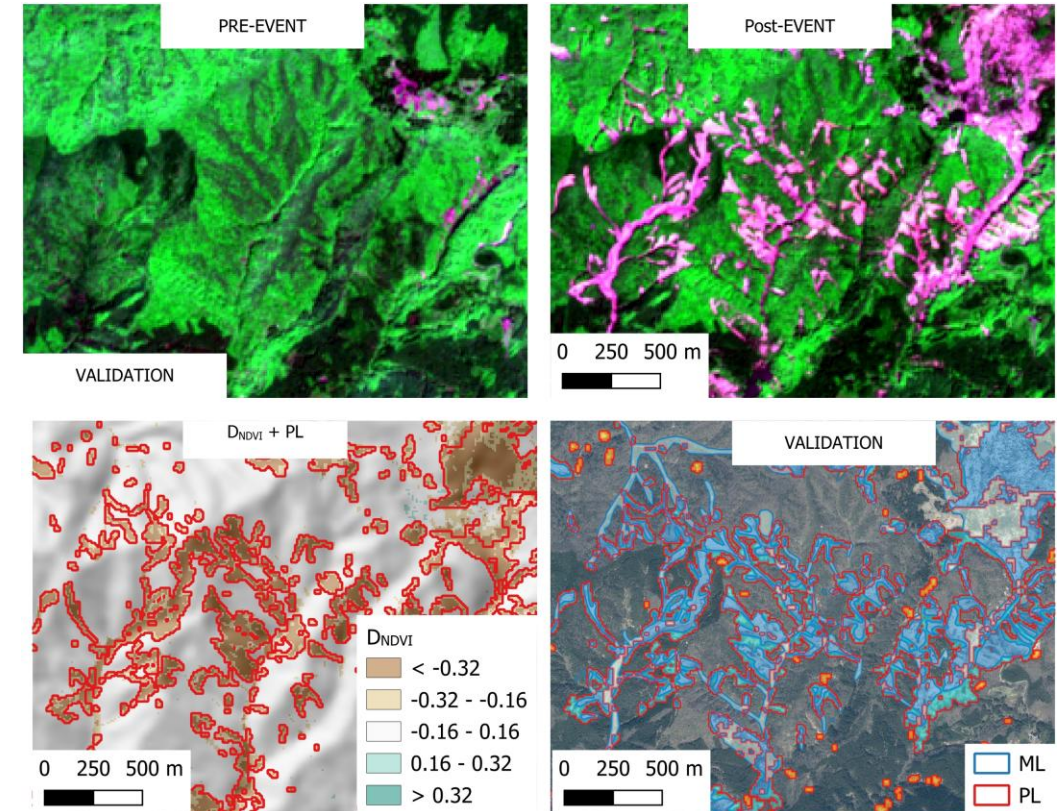
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Unsupervised shallow landslide rapid mapping - the PANDA tool

Case study – Emilia Romagna May 2023 extreme rainfall event

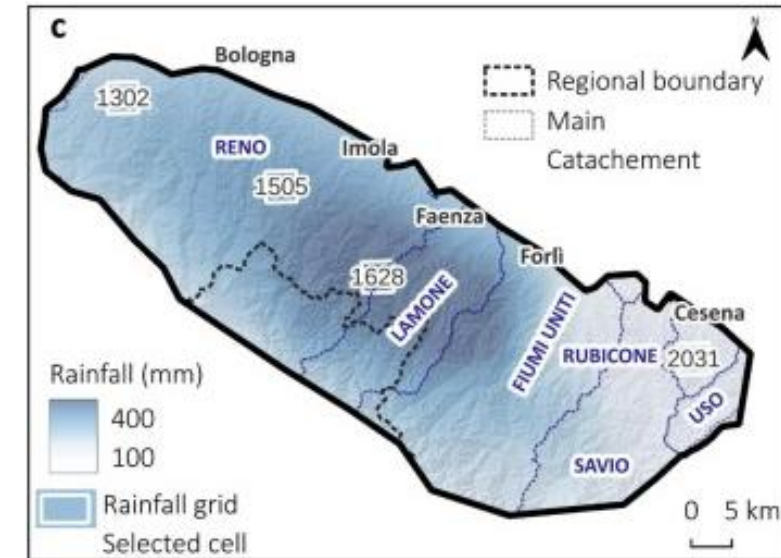
The AOI affected by two consecutive rainstorms that occurred in less than twenty days:
i) 1-3th May 2023 weather event, and ii) 16–17 May 2023 weather event up to 400 mm of cumulated rainfall.



- Wide floods and thousand of shallow landside triggered
- CNR-GEO was involved by Civil Protection Department in emergency surveys
- Need to have first map of most effected areas



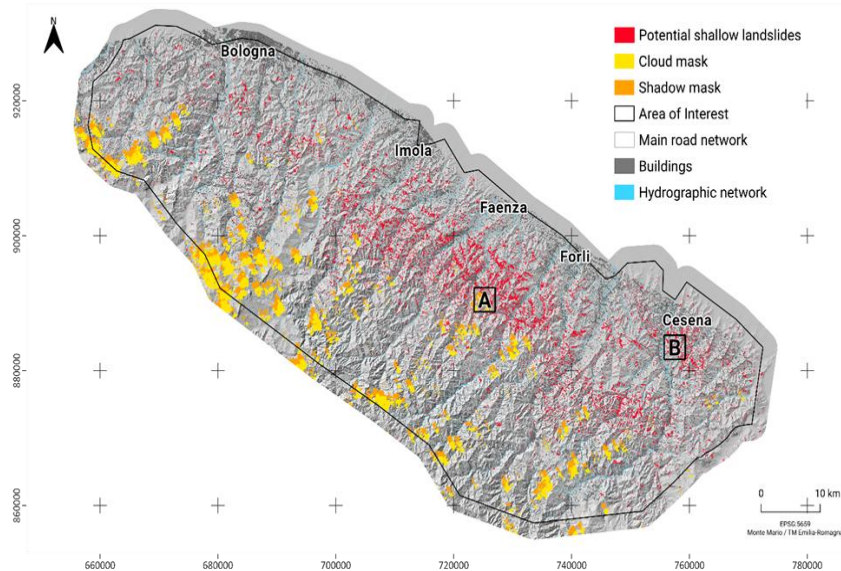
- We developed PANDA in order to have a support on the field
- First assessment map was made on may 26 2023 **just 3 days after** the first Sentinel-2 images (Panda-E) version
- In September 2023 we completed the PANDA-PE



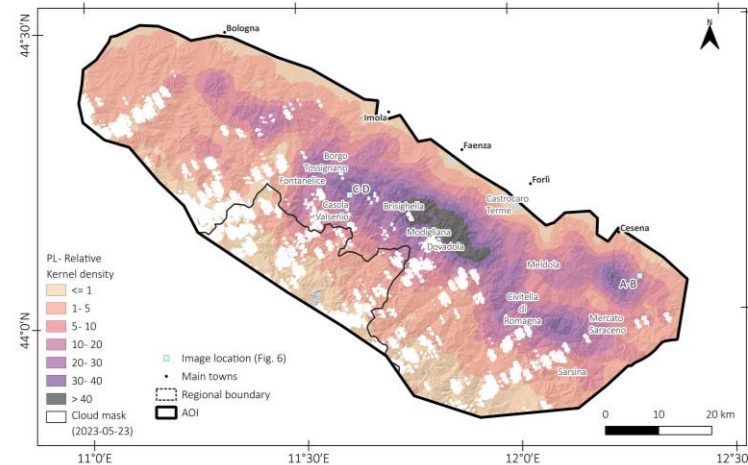
Unsupervised shallow landslide rapid mapping - the PANDA tool

Case study – Emilia May 2023 extreme rainfall event

PANDA-E



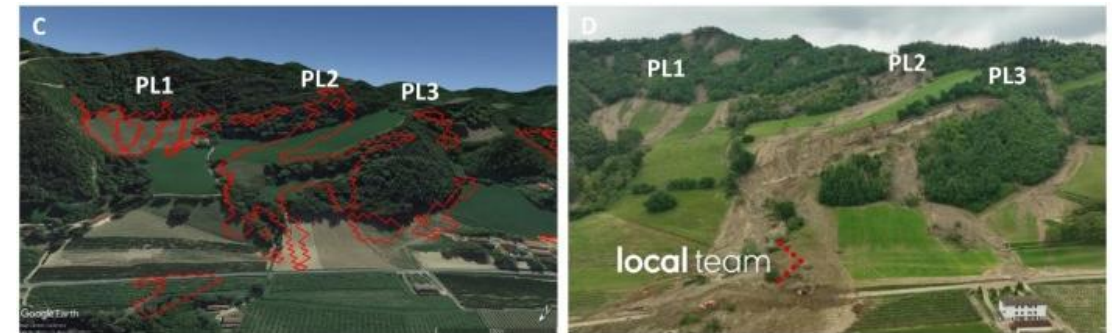
Density MAP



Field survey



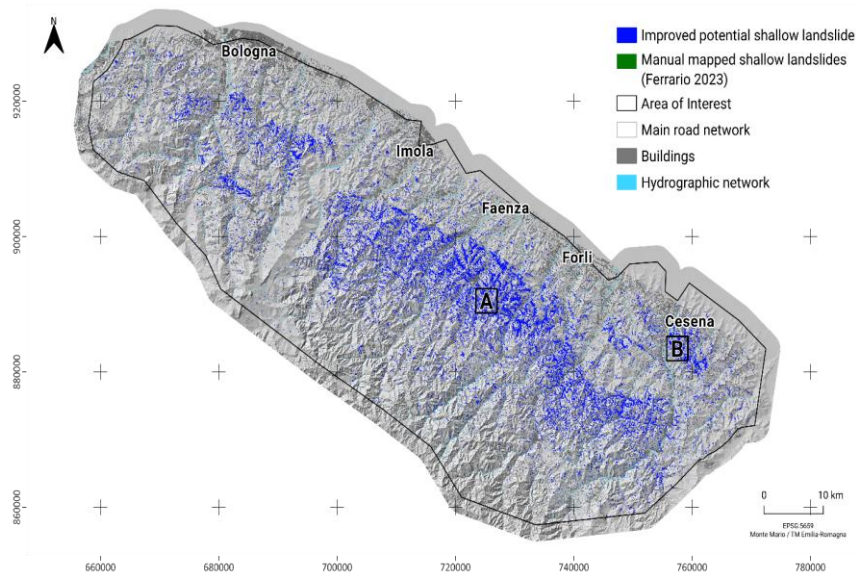
Local validation from web source



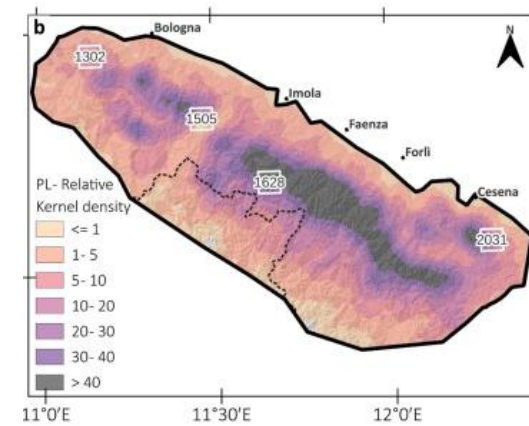
Unsupervised shallow landslide rapid mapping - the PANDA tool

Case study – Emilia May 2023 extreme rainfall event

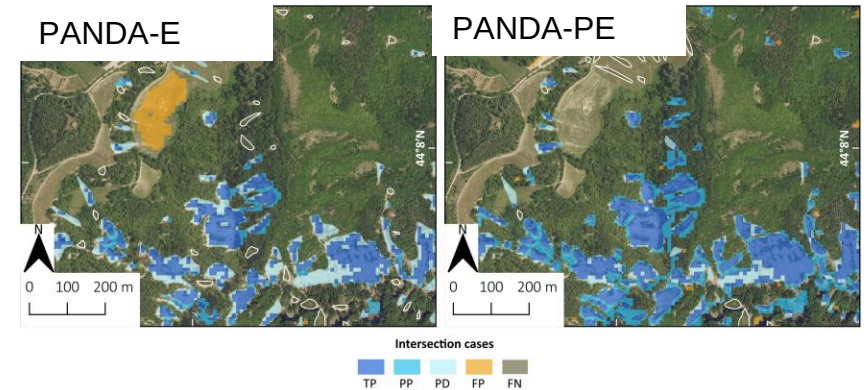
PANDA-PE



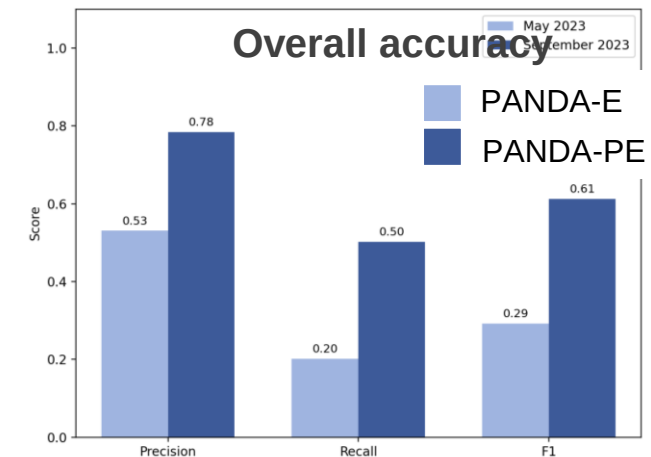
PE- Density MAP



Validation

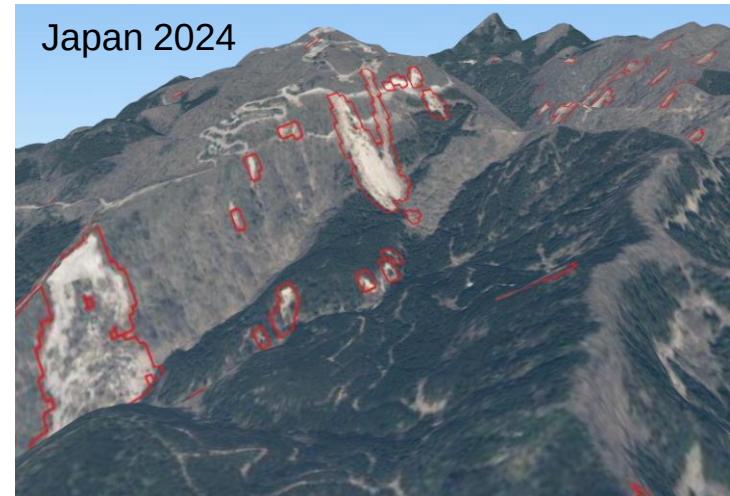
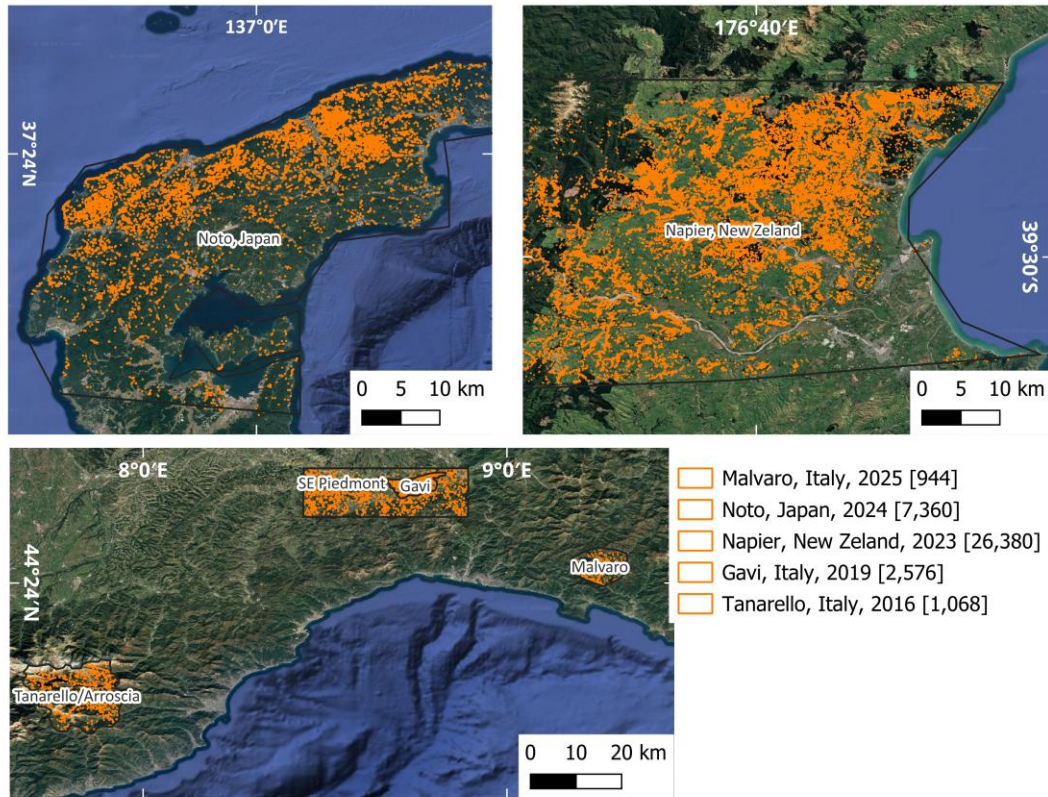


Overall accuracy

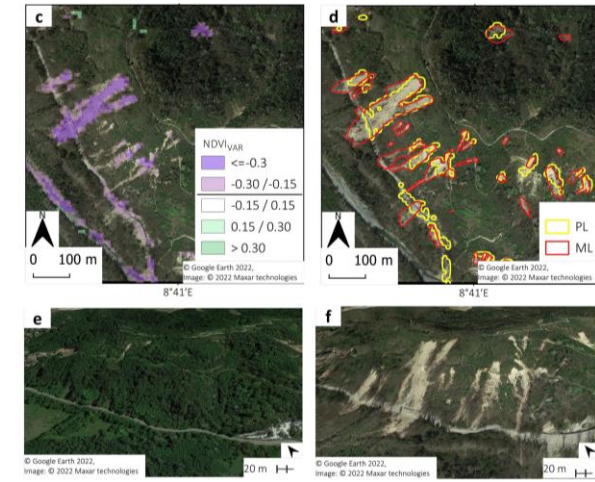


Unsupervised shallow landslide rapid mapping - the PANDA tool

PANDA Application



Piemonte 2016



Download the Paper and test the dataset

Japan and NZ



Piemonte



Emilia



PANDA Paper



Optical Image Correlation

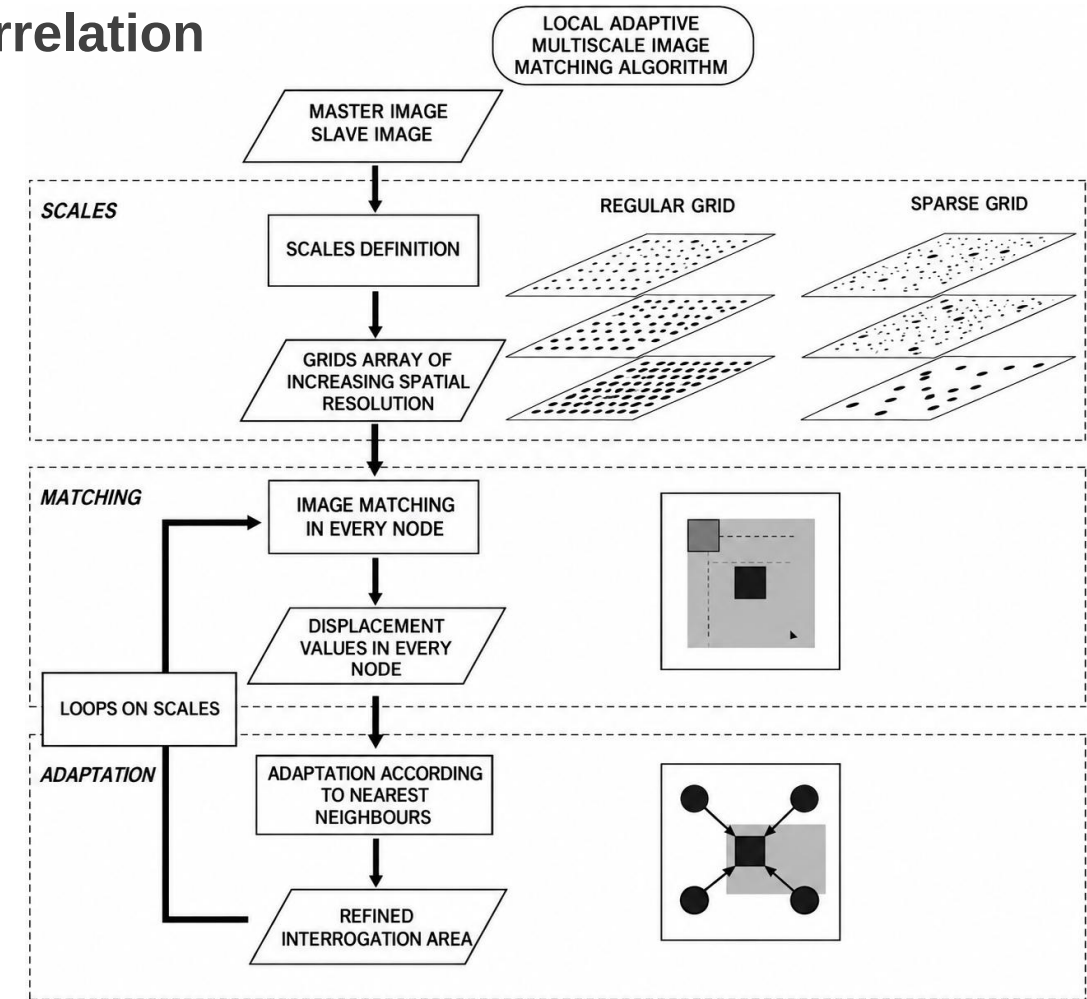
Optical Image Correlation (OIC) estimates the magnitude and direction of surface displacement by identifying the offset of corresponding image patches between two multitemporal optical images.

Applications

Image correlation is widely used in **Earth observation** to quantify surface motion and deformation from multitemporal optical imagery. Main applications include:

- **Glaciology** → glacier and ice-flow velocity
- **Landslides** → displacement and velocity monitoring
- **Rock glaciers** → surface deformation and creep
- **Volcanic processes** → ground deformation and lava flow velocity
- **Other geomorphological processes** characterized by detectable surface motion

It can be applied to **satellite, aerial/UAV, and terrestrial/oblique optical imagery**.



Workflow of **LAMMA** (Local Adaptive Multiscale Image Matching Algorithm)

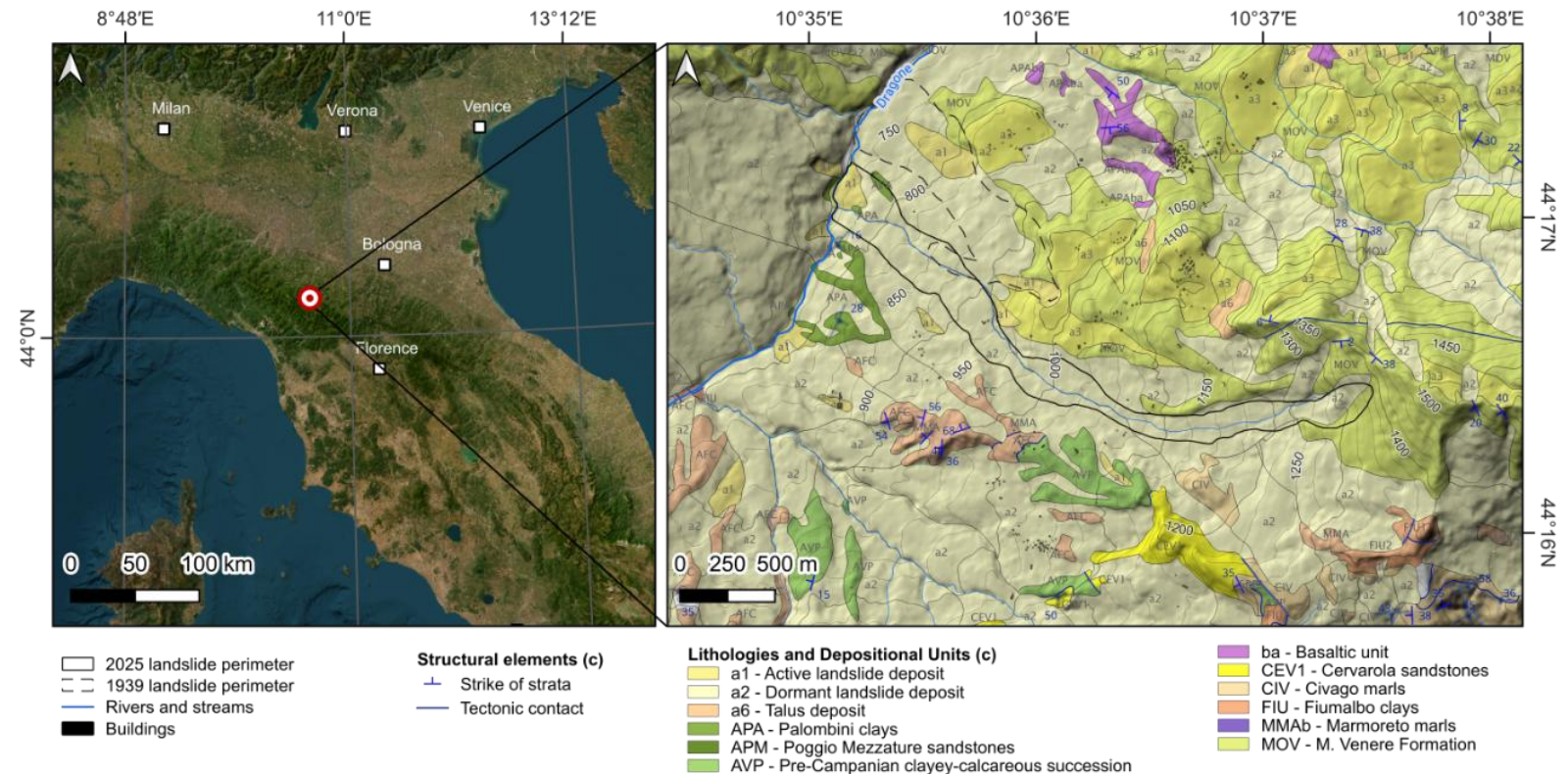
Dematteis et al., 2022

Case study – Boccassuolo Landslide

The Boccassuolo landslide occurred in the Northern Apennines, within the municipality of Palagano (Modena Province, northern Italy), approximately 1.5 km south of Boccassuolo village.

The landslide was **triggered in late March 2025**, initially as a rotational slide, and rapidly evolved into an earth flow, remaining active until mid-June 2025. The **affected slope extends downslope to the Dragone Stream**.

Notti, D., Dematteis, N., Cardone, D. *et al.* Satellite-based investigation of the spring 2025 Boccassuolo Landslide, Northern Apennines (Italy). *Landslides* **23**, 2337–2348 (2026).
<https://doi.org/10.1007/s10346-026-02775-0>



Main characteristics:

Length: ~3.5 km

Maximum width: ~500 m

Estimated volume: $\sim 3.5 \times 10^6 \text{ m}^3$

Activity period: late March – mid-June 2025

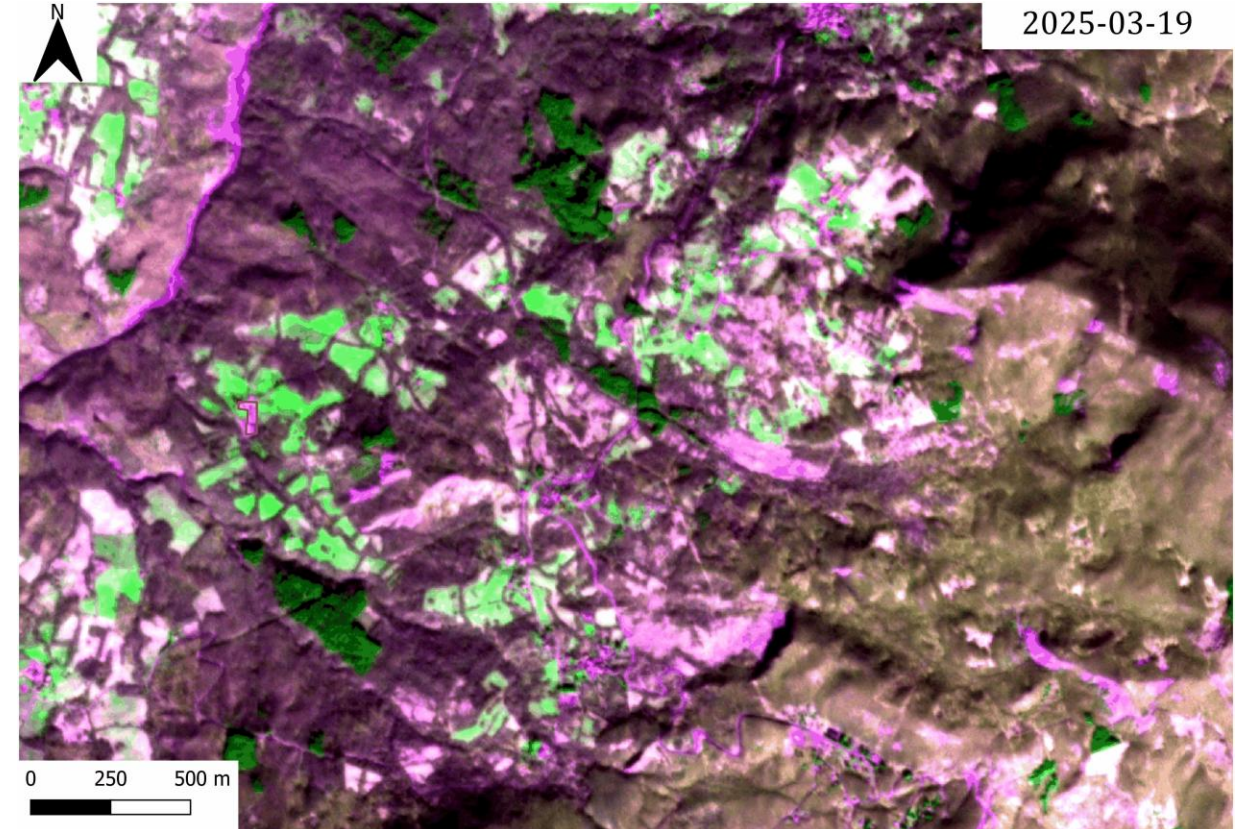
Landslide kinematic characterization



Sentinel-2



Planet scope



Landslide kinematic characterization

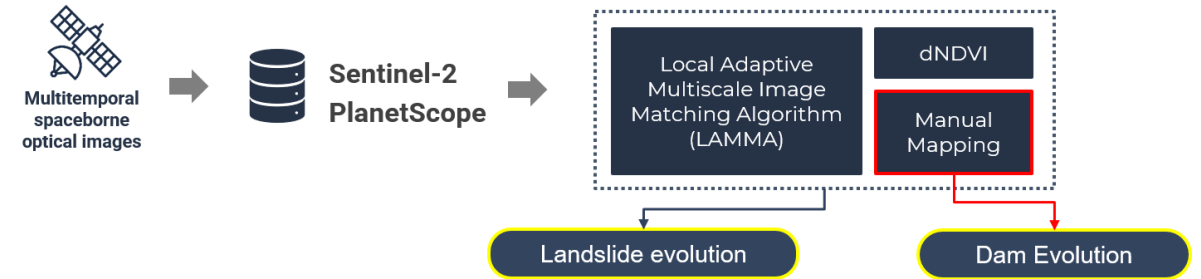


- **Landslide mapping**

The landslide extent was **manually mapped** using multitemporal optical imagery, supported by **dNDVI-based change detection**.

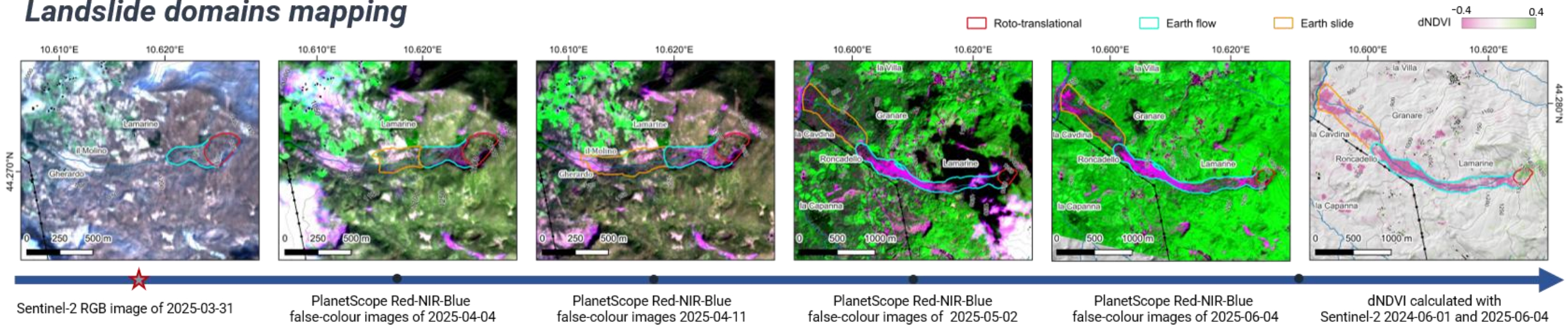
- **Kinematic analysis**

OIC was performed using the **LAMMA algorithm** (Dematteis et al., 2022) to estimate **surface displacement rates** and identify distinct **kinematic domains**. Different template sizes (**16 × 16** and **30 × 30 px**) were adopted according to the temporal baseline between image pairs.

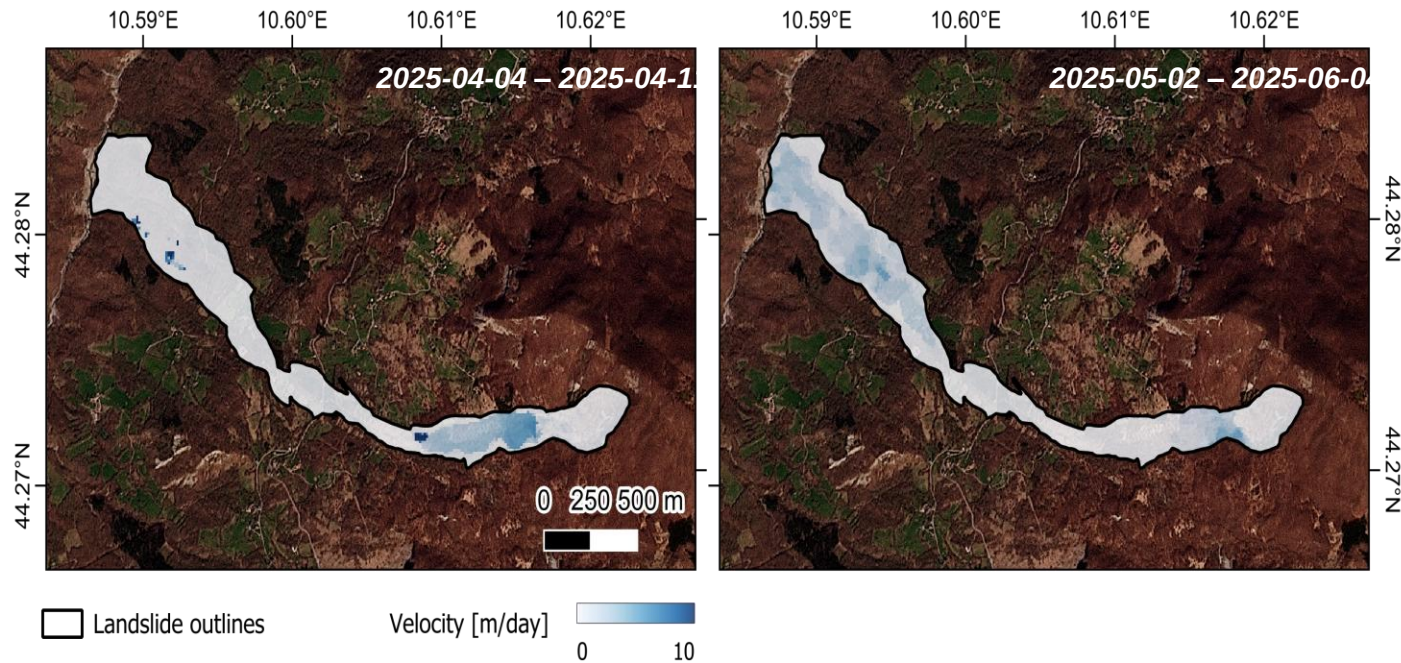


Dematteis, N., Giordan D., Crippa B., Monserrat O. Fast local adaptive multiscale image matching algorithm for remote sensing image correlation. *Computer and Geosciences* 159, 104988 (2022). <https://doi.org/10.1016/j.cageo.2021.104988>

Landslide domains mapping



Optical Image Correlation – Velocity assessment



Identification of 5 phases (March – June 2025)

Phase 1 – Initial rotational landslide evolving into an earth flow (late March)

Phase 2 – Partial reactivation (early April) Earth flow: >5 m/day • Earth slide: ~3 m/day

Phase 3 – Full reactivation (mid-April – early May 2025) Runout: 1,700 m in 21 days (~80 m/day)
Affected area: ~300,000 m² (by May 2)

Phase 4 – Toe advancement and river damming (May – early June 2025) Earth flow stops

Phase 5 – Suspended/inactive state (after June 2025)

Notti, D., Dematteis, N., Cardone, D. *et al.* Satellite-based investigation of the spring 2025 Boccassuolo Landslide, Northern Apennines (Italy). *Landslides* **23**, 2337–2348 (2026). <https://doi.org/10.1007/s10346-026-02775-0>



MEASURES PROJECT PARTNERS: CNR – GEO, CNR IREA, UNIPV, CUGRI, ADAM

MAIN OBJECTIVES

Implementation of a **technical-operational tool to public administrations** for monitoring **infrastructure networks affected by slow-moving landslides**, through the integration of satellite data (SAR and optical) and environmental and territorial information.

This service is structured in:

❖ **Baseline tool (dedicated to quantitative analysis on large scale)**

- ✓ Integration of multi-temporal SAR data, landslide inventories, land use and infrastructures inventories;
- ✓ Synergic and qualitative analysis of the territory.

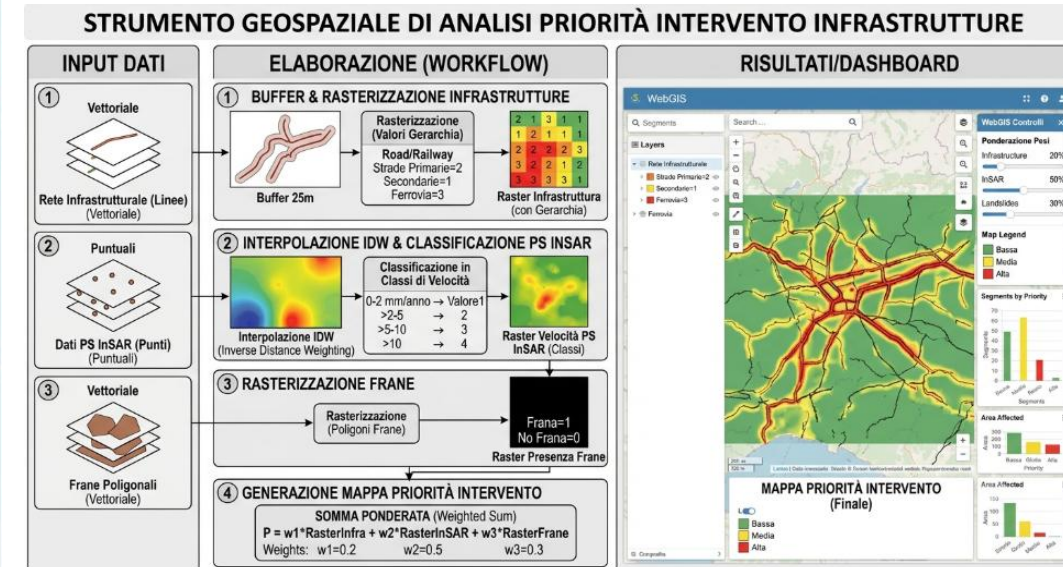
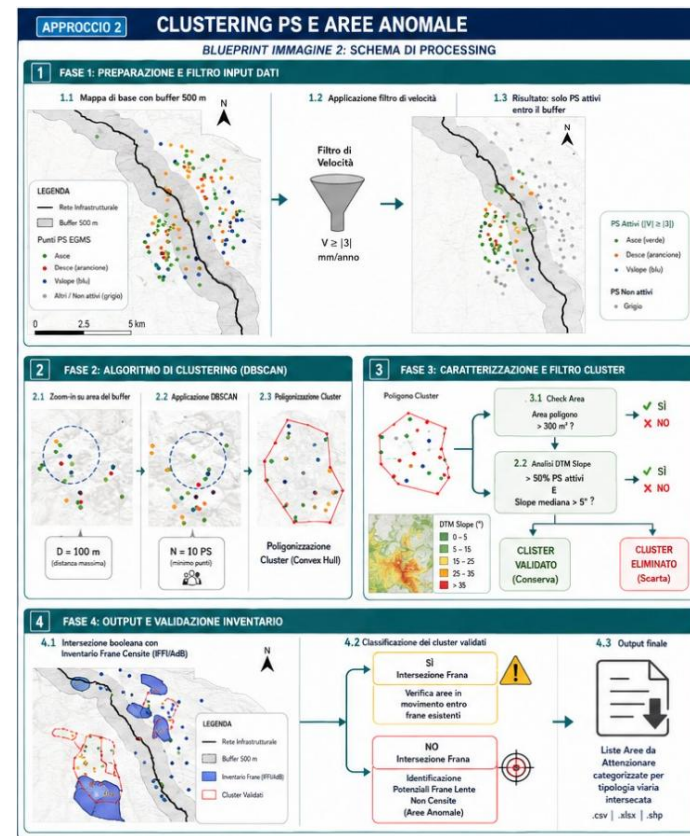
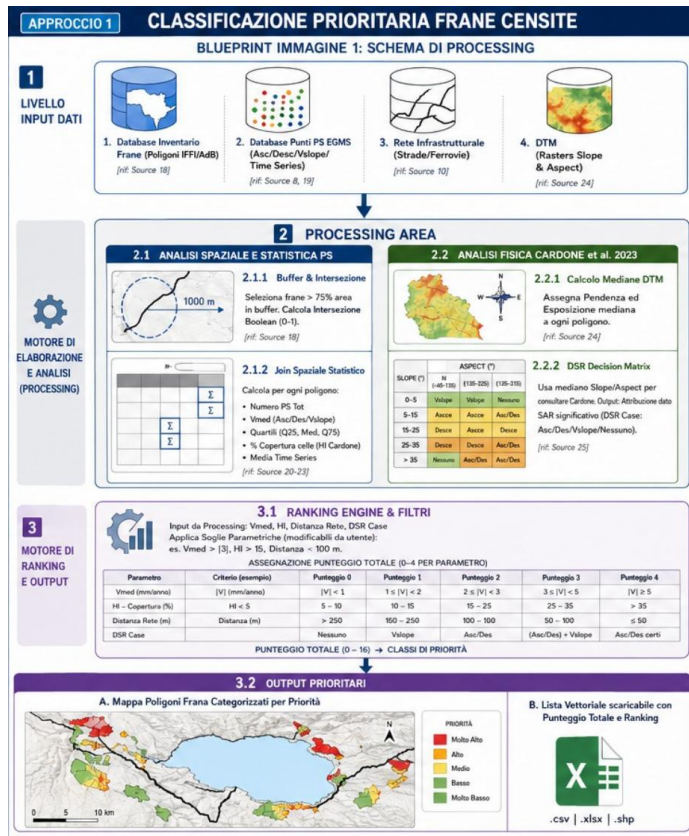
❖ **Advanced tool (dedicated to quantitative analysis for local scale investigations)**

- ✓ Focused on critical sector of road networks;
- ✓ Use of very-high resolution data (SAR and multi-spectral);
- ✓ Evaluation of the expected damage

Slow landslide deformation and impact assessment MEASURES Project



TOOL BASELINE – Development of the tool baseline is currently under way, which provides a number of operational features that the **basic user** can perform to **analyse the interaction between large slow-moving landslides and the road network of the entire Southern Apennine District (ADAM).**





FUTURE DEVELOPMENT

- ❖ The project aims to develop innovative and functional tools for managing landslide-prone infrastructure, to support Public Administrations (PAs).
- ❖ The multidisciplinary team, already the protagonist of fruitful collaborations in previous ASI projects, combines complementary skills to address the project's challenges.
- ❖ The potential of Big Data is expected to be integrated for large-scale analysis with detailed site-specific information in the most critical areas.
- ❖ The direct participation of an PA will allow the instruments to be adapted to real needs and operating conditions.
- ❖ Clear and detailed guidelines will be drawn up to help PAs understand: the operation of data processing processes, the information that can be measured, the limitations and criticalities of the system.
- ❖ The project offers advanced technological development potential for data management, processing, and visualization.

We presented three different applications of remote sensing datasets applied to the study of landslides in different phases and scenarios:

PANDA is a tool developed for the rapid mapping of effects of heavy rainfall events at the regional scale; the goal is a fast identification of shallow landslides of most affected areas. **PANDA-E and -PE** (emergency and post emergency) prioritize the rapid deployment of results or a most detailed and effective mapping, according to the dynamic of emergency activities

At the local scale, the application of **LAMMA algorithm** is a good solution to follow the evolution of large and complex landslides. The application to the **Bocassuolo landslide** shows how the techniques of pixel offset can be very useful to follow large earthflows and characterize their kinematic domains and evolution

The availability of large SAR datasets can be very useful for a screening at a regional scale. The use of this dataset for the identification of active slow moving landslides is a well-known application that we adopted, for example for the characterization of Deep Seated Gravitational Slope Deformation (DSGSDs) of Aosta Valley region.

In **MEASURES**, we are developing tools for public administrations aimed to recognize the intersection between landslides and infrastructures and support a better management of the territory