# Landslide mapping: evolution, current challenges, and perspectives

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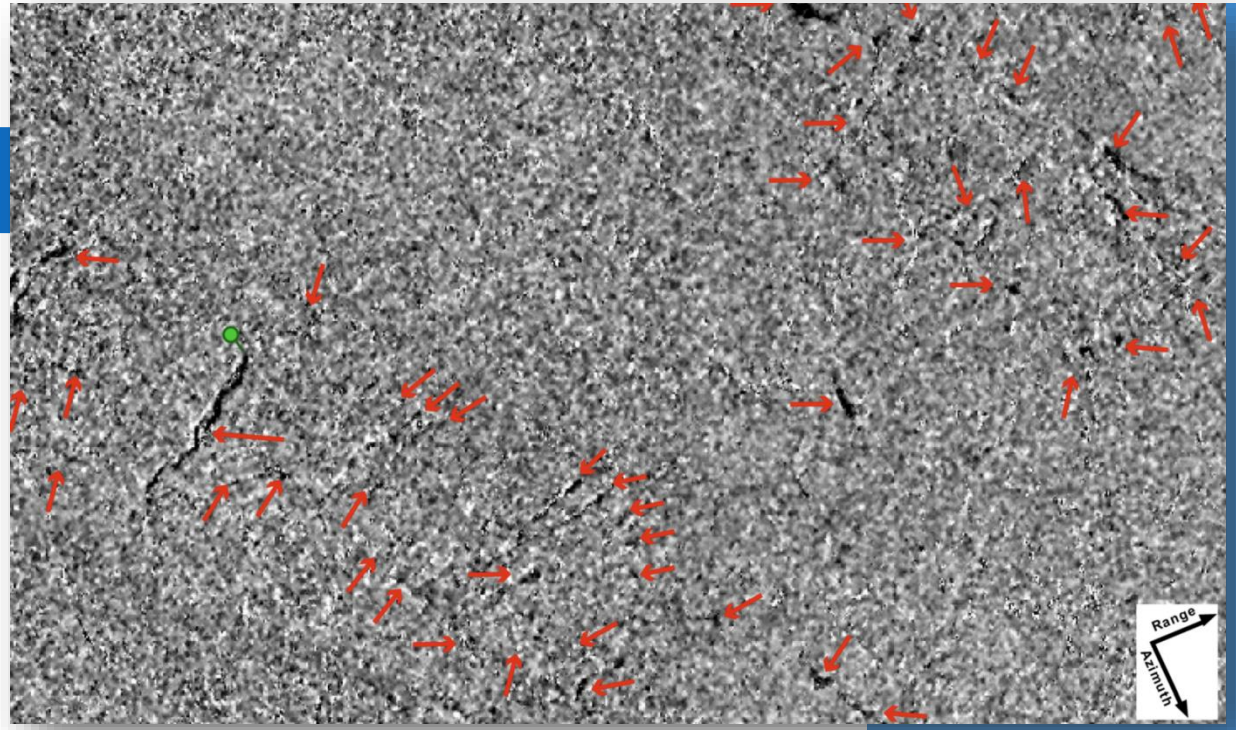
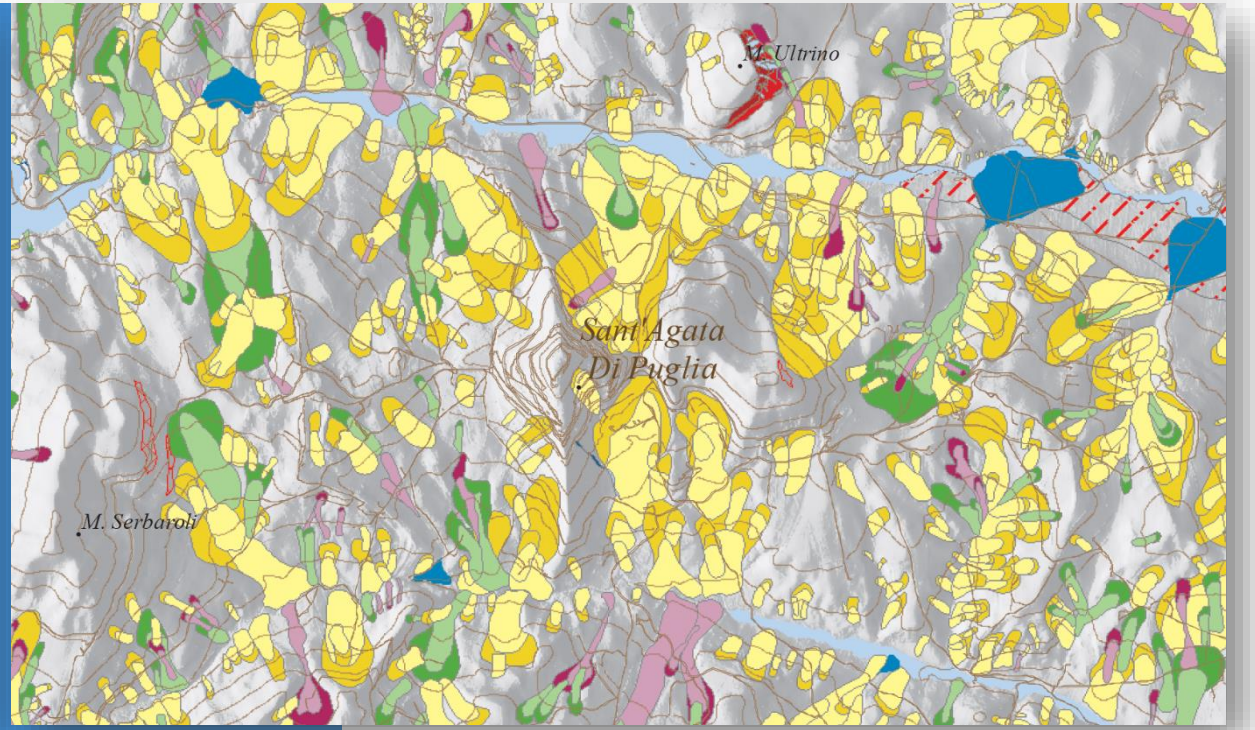
# Summary

- Introduction
- Interpretation criteria and types of inventory
- Evolution of photo-interpretation:
  - Multispectral images
  - LiDAR data
  - SAR backscatter products
- Final remarks and discussion questions




Source: Mondini et al., 2019 - https://doi.org/10.3390/rs11070760




## Landslide **detection**

**Identification** of an element (usually an anomaly that interrupts the continuity of other elements) that can be named as a landslide. No delineation of landslide border. Little information is available. Often only a **point location**, and a tentative classification. Sometimes mistaken with mapping.

# Landslide detection and mapping: definitions

## Landslide **mapping**

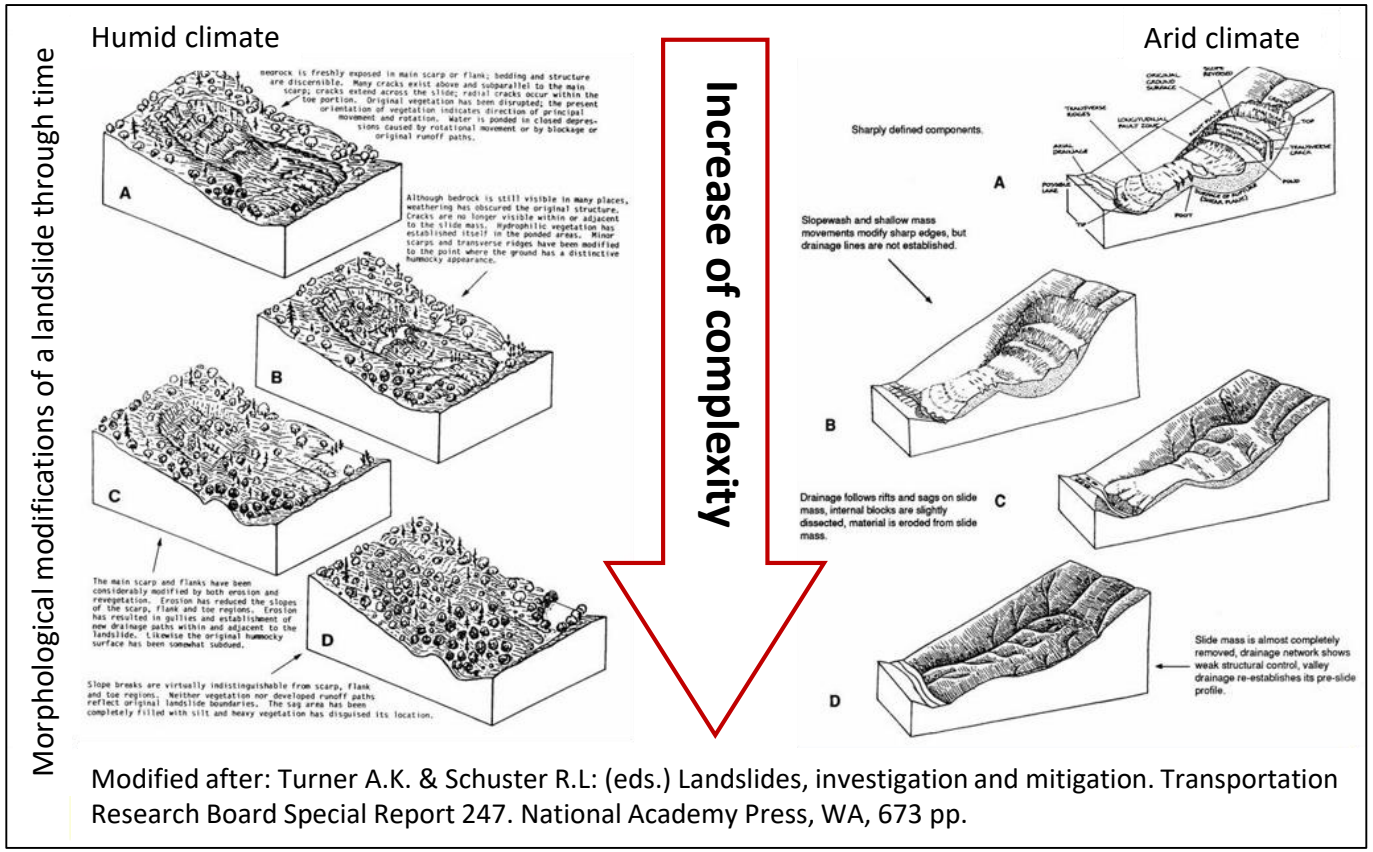
**Delineation** of landslide borders. Maximize external inhomogeneity and internal homogeneity. It is done after a rigorous effort of a **multivariate heuristic model** that puts together photographic and morphologic information based on experience and background knowledge of geology and other environmental processes.

# The need for defining reproducible criteria

*Image interpretation is an **empirical** and **subjective** process*

- ***Experience of the photo-interpreter.*** *Cultural knowledge on a specific field. Knowledge of the objects to investigate.*
- ***Procedures** and **defined criteria of interpretation.** Interpretation is not a simple view and reading of a stereo model, but a systematic scanning assisted by logical and scientific set of formulations and fieldwork evidences.*

**Interpretation of images**
***Potentialities*** – provides complimentary data
***Limitations***– subjectivity (depends on experience)




Modified after: Turner A.K. & Schuster R.L: (eds.) Landslides, investigation and mitigation. Transportation Research Board Special Report 247. National Academy Press, WA, 673 pp.

# Photo-interpretation criteria

**Increasing complexity and weight of experience**

## STEP 1

**READING**

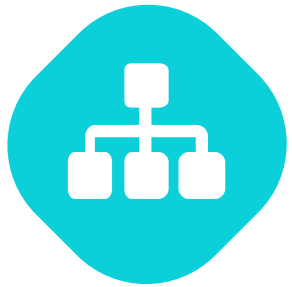
Basic image characteristics: pattern, grain, tone, mottling and texture are read.

## STEP 2

**ANALYSIS**

Identification of objects based on image charactheristics.

## STEP 3



**CLASSIFICATION**

Objects are classified applying a legend, which can be updated during the process.

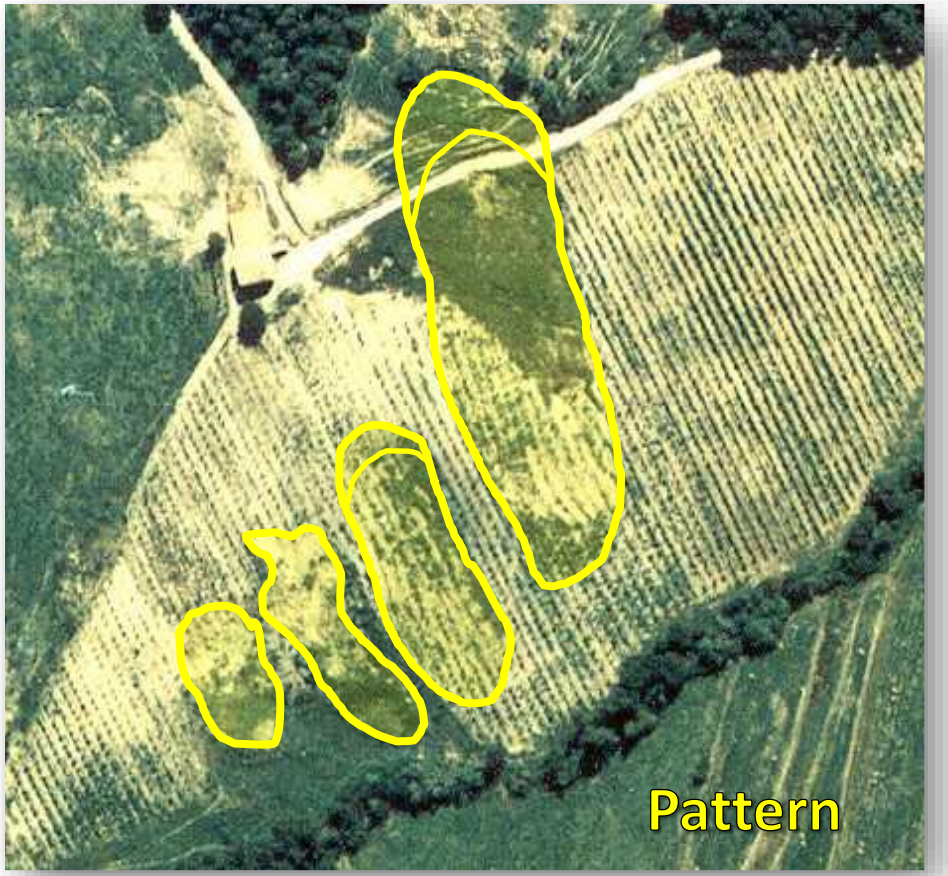
## STEP 4

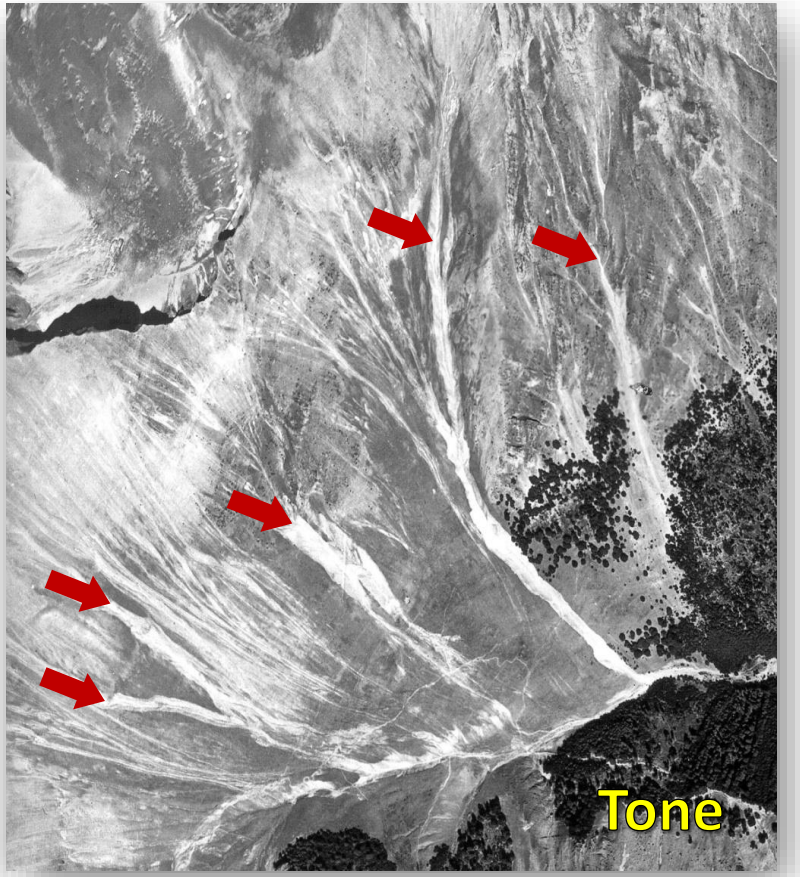
**DEDUCTION**

Making inferences on the processes underlying the classified objects.

# Photographic Elements

***Photographic elements*** (tone, texture, pattern, color) characterize the **landslide photographic signature**



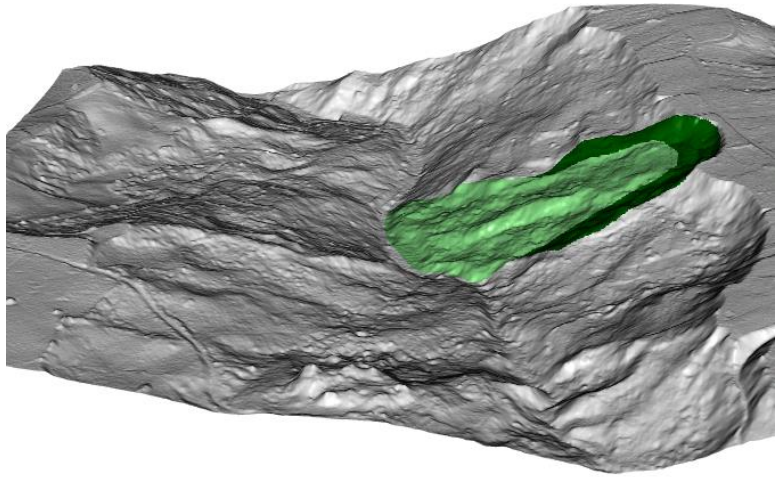



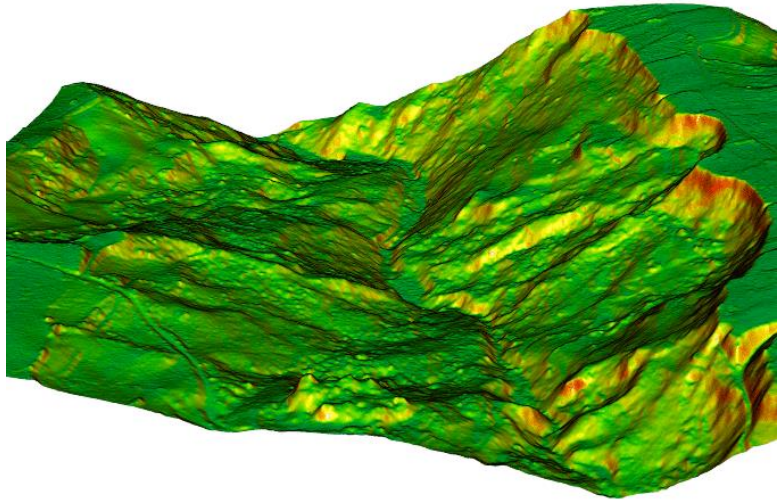
# Morphologic Elements

***Morphologic elements*** **(morphometric variables) characterize the landslide morphologic signature**

- shape
- size
- curvature
- convexity, concavity

- hummocky topography
- Escarpment, trench
- back slope
- morphological context





**DTM + LANDSLIDE**

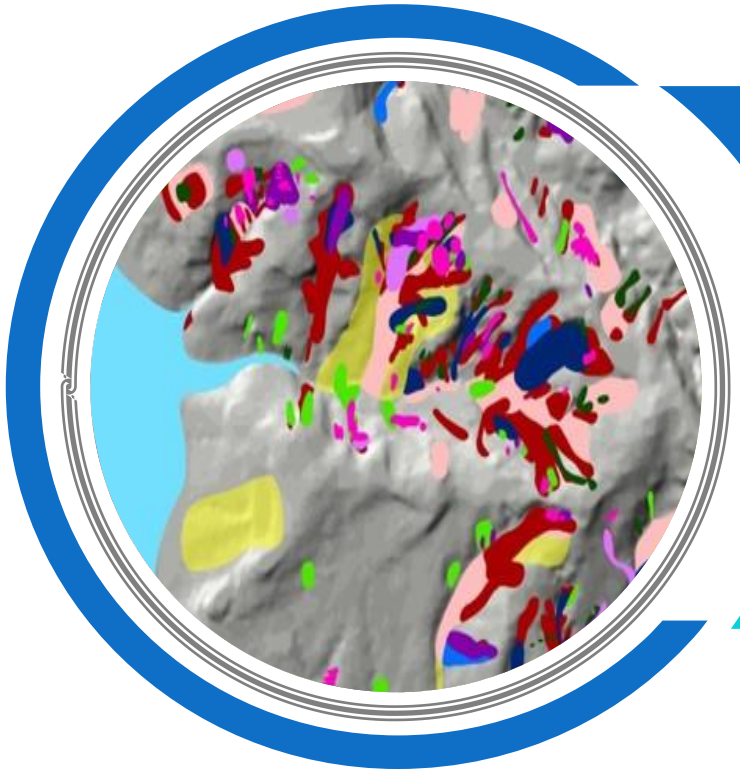
**DTM + SLOPE**

# Type of inventories and their applications

Area

Detail

**Using a landslide map** for whatever application **requires awareness of its limitations**.



**Event inventories**
Report landslides after specific triggering events (rainfall, snowmelt, earthquakes, volcanic eruptions)

**Event impact assessment**
**Emergency support**
**Susceptibility validation**

**Geomorphological inventories**
Report landslides that can be recognized from expert geomorphologists. Can be considered as the sum of events over a territory

**Geomorphological studies**
**Susceptibility modeling**
**Planning**

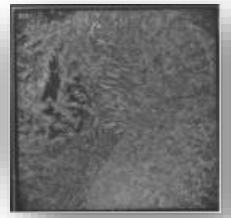
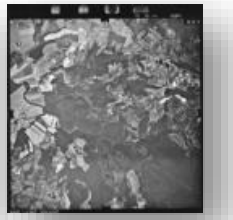
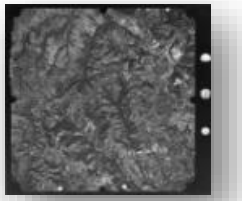
**Multi-temporal inventories**
Add to the geomorphological inventory, landslides that occurred in the last tens of years as visible in the available archive aerial photographs/images.

**Landslide temporal pattern**
**Landslide risk assessment**
**Planning**

Increasing detail and effort

# Aerial Photographs and Stereoscopes

**Aerial photographs**

| August 1941 1:18.000 | August 1954 1:33.000 | June 1977 1:13.000 | June 1985 1:15.000 | April 1997 1:20.000 | August 2000 1:34.000 |
|---|---|---|---|---|---|
|  |  |  |  |  |  |

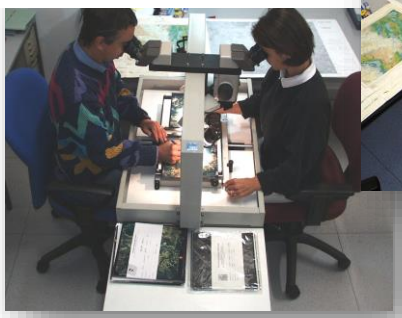
***A stereoscope is used to interpret the aerial photographs.***

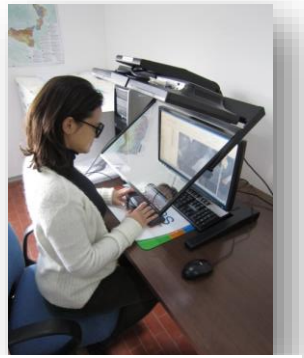
*POCKET STEREOSCOPE*

*MIRROR STEREOSCOPE*

*MIRROR STEREOSCOPE*
*DISCUSSION STEREOSCOPE*
*TWO ZOOM SETTINGS*

*OPTICAL STEREOSCOPE*
*DISCUSSION STEREOSCOPE*
*CONTINUOUS ZOOM*



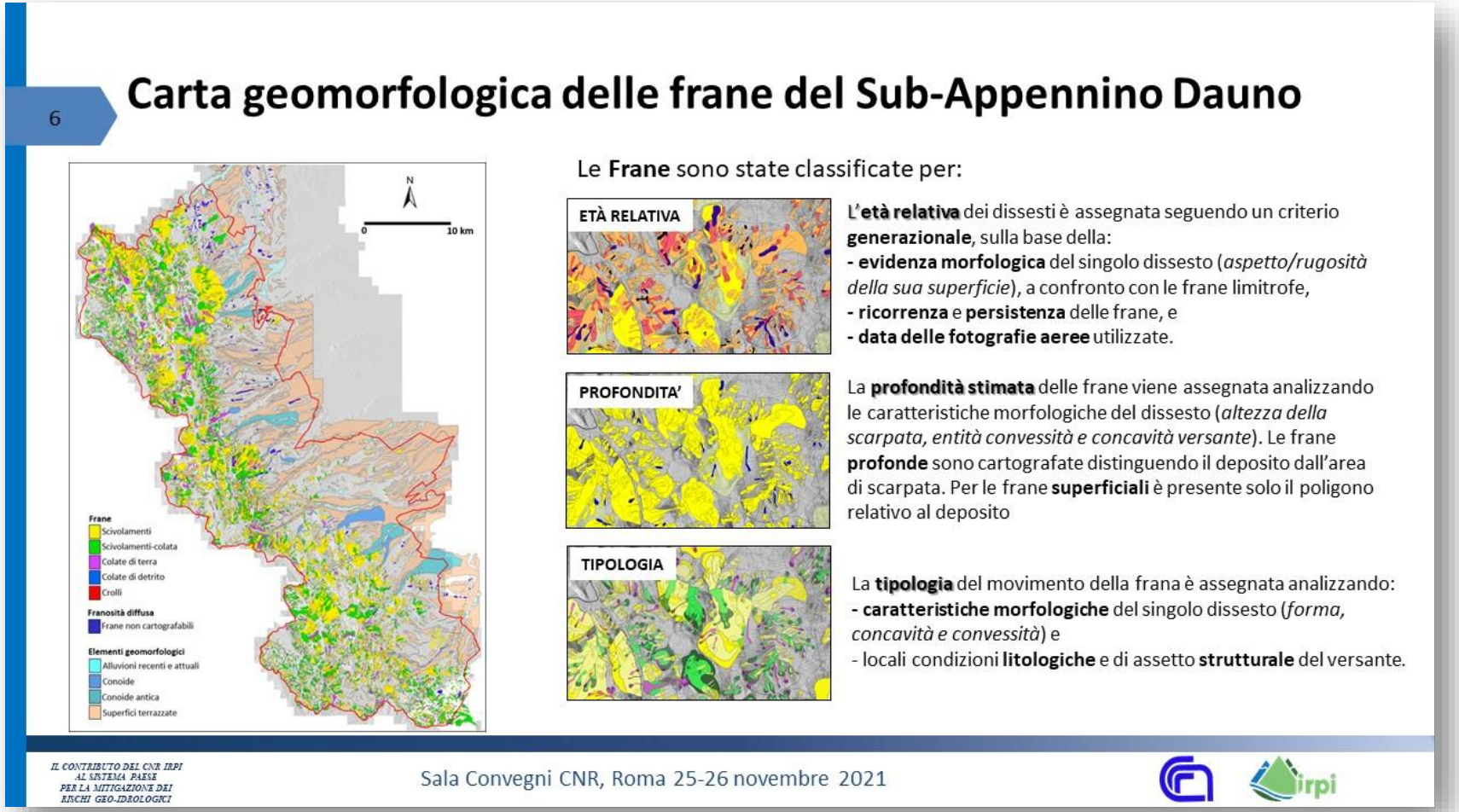


*DIGITAL STEREOSCOPE*

# Our latest application of Aerial photointerpretation

An example of application: the **Daunia Apennine** inventory.

It will be presented by *Federica Fiorucci*

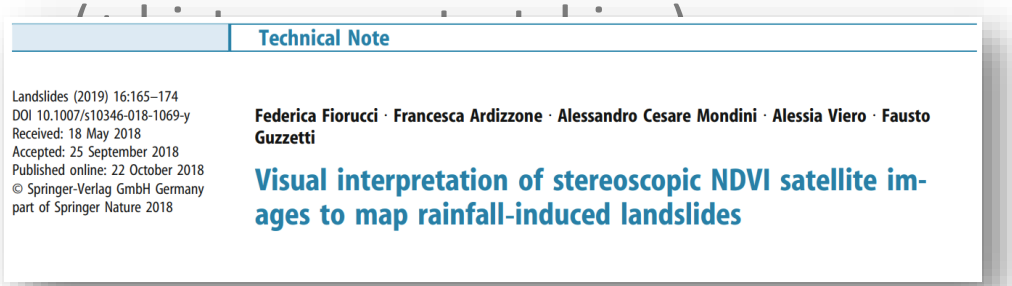


# Evolution of mapping: Visible + IR images

Criteria adapted to images with wider spectral content: the case of the Pogliaschina event in 2011.

**Problem**: shadowed areas

**Approach**: interpretation of NDVI stereoscopic images



Technical Note

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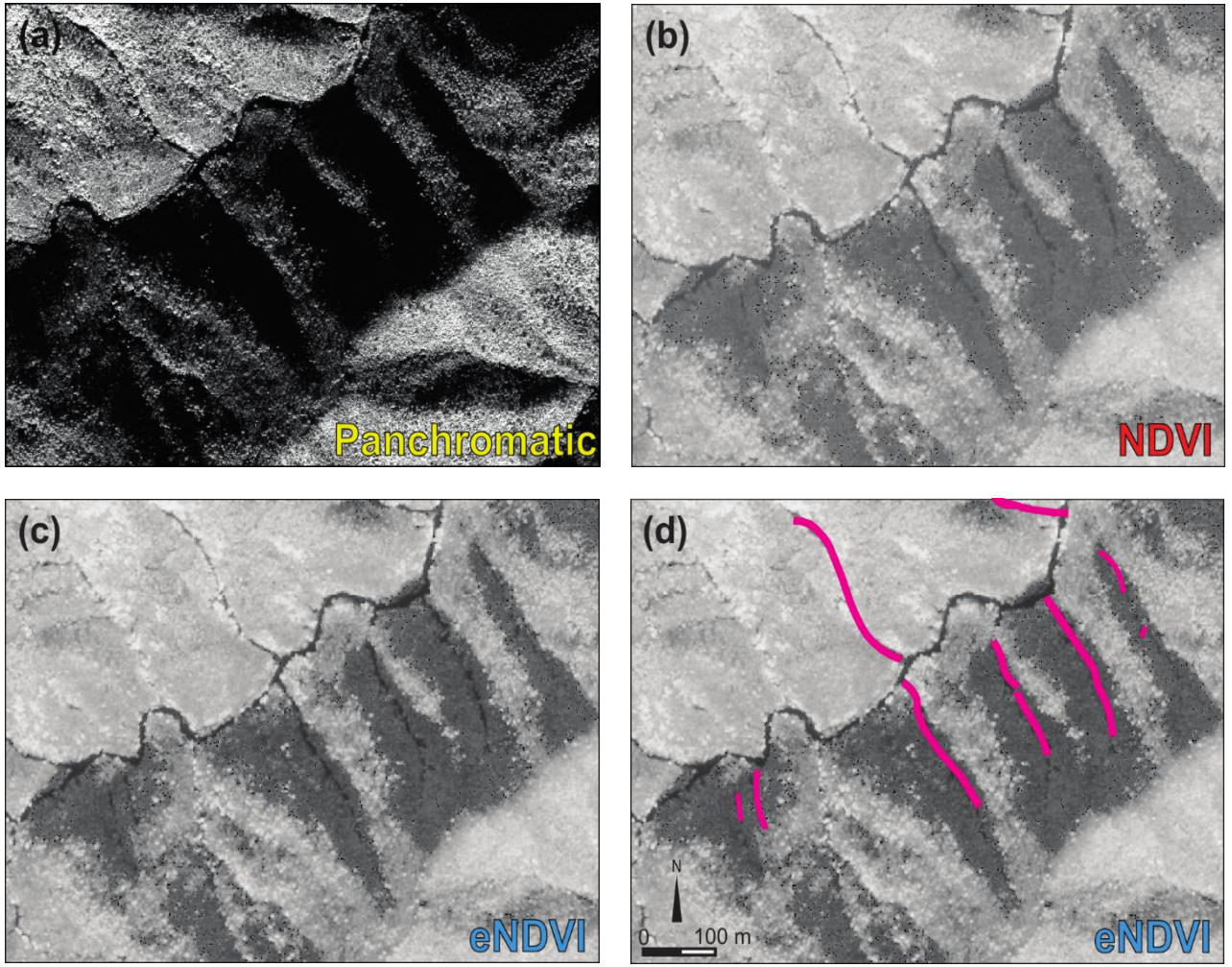
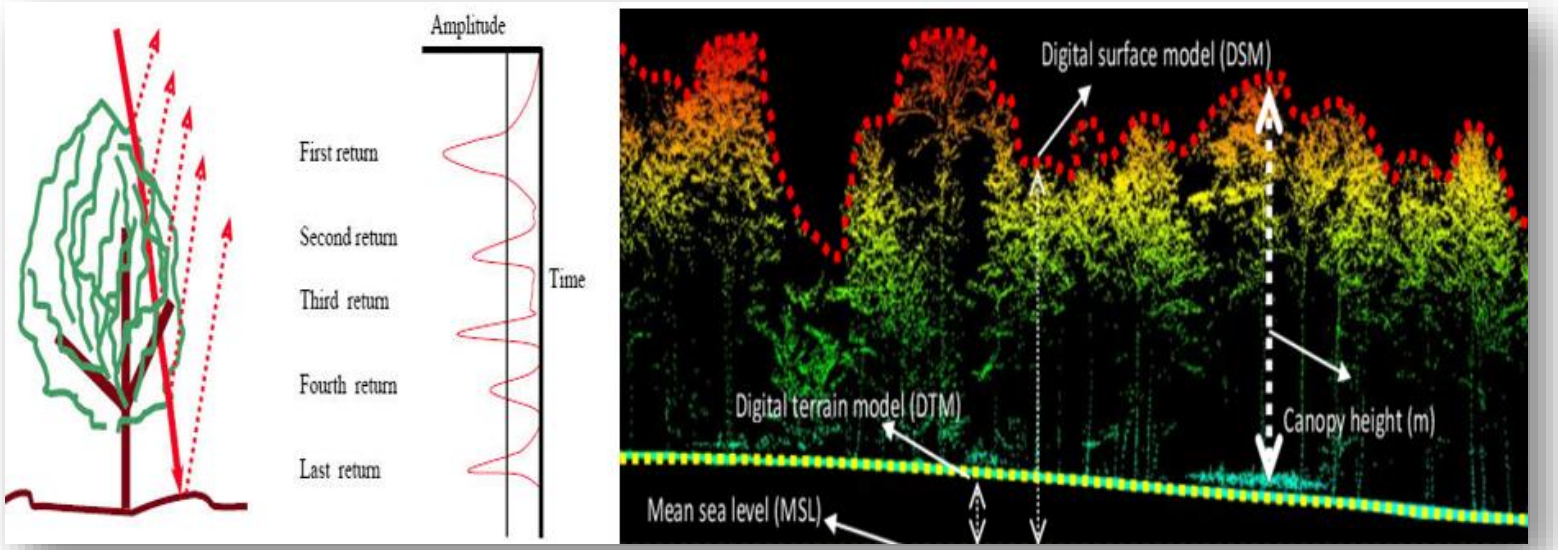
Visual interpretation of stereoscopic NDVI satellite images to map rainfall-induced landslides



# Evolution of mapping: LiDAR

***PROS*** of using LiDAR:

- Penetrate (dense) vegetation
- High resolution digital topography

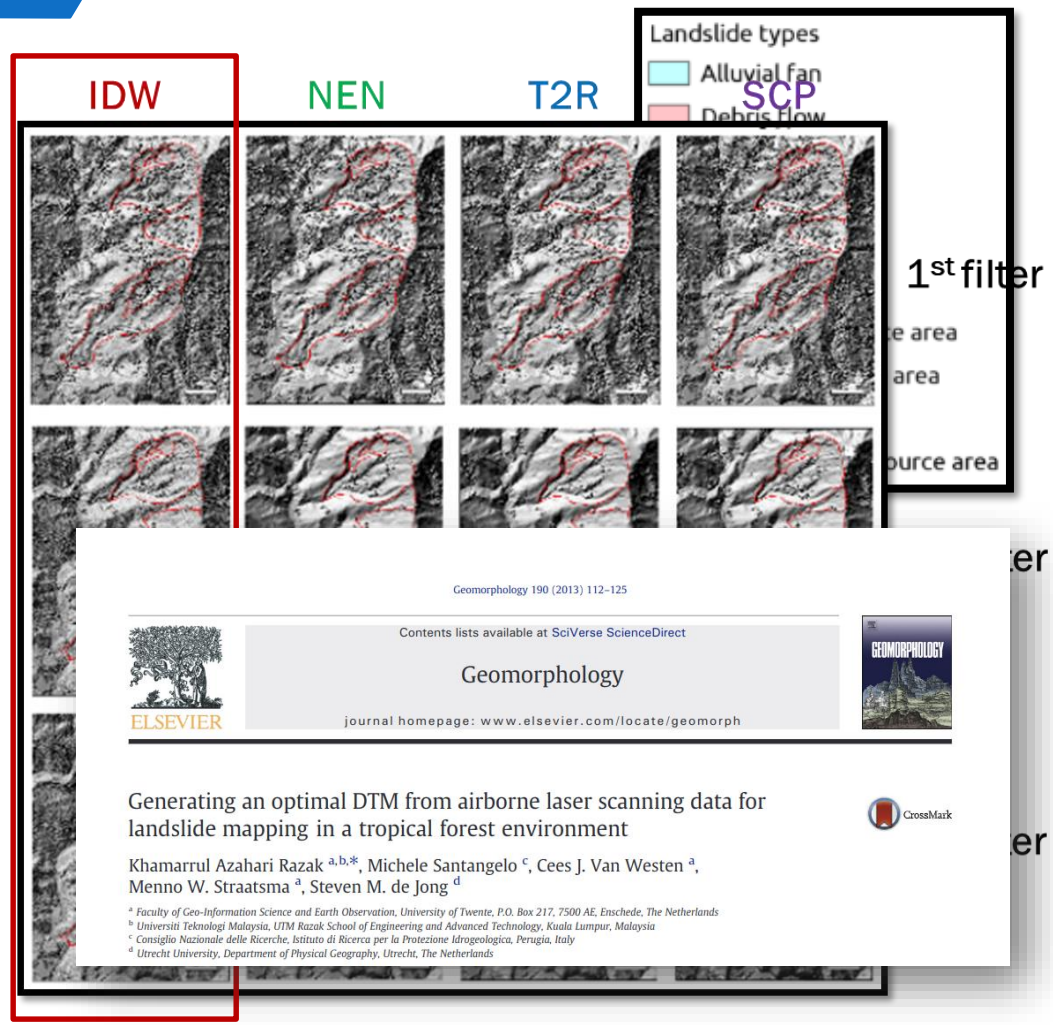



Source: http://www.top-aerial.com/index.php/services/data-acquisition/lidar-topographic-survey

***CONS*** of using LIDAR:

- Criteria must be adapted to images portraying **only morphological signature of landslides**: more ambiguities

# The case of Malaysia

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Generating an optimal DTM from airborne laser scanning data for landslide mapping in a tropical forest environment

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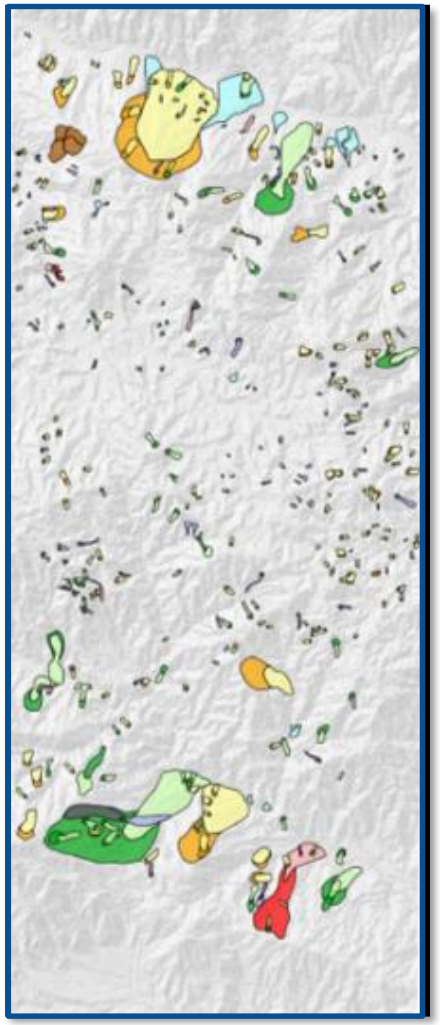
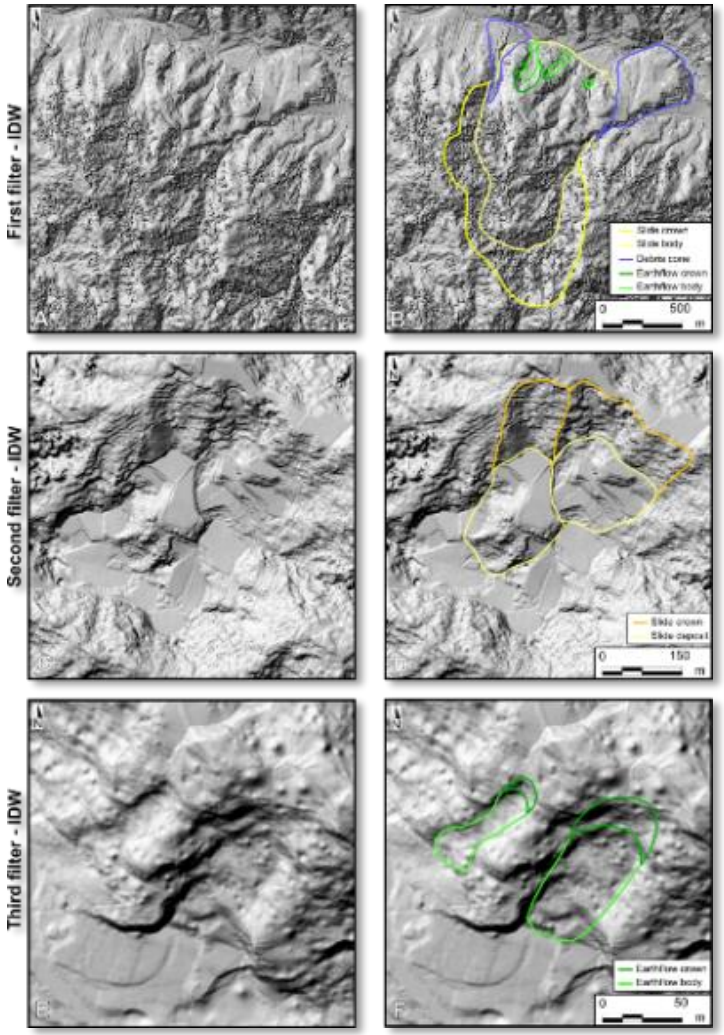
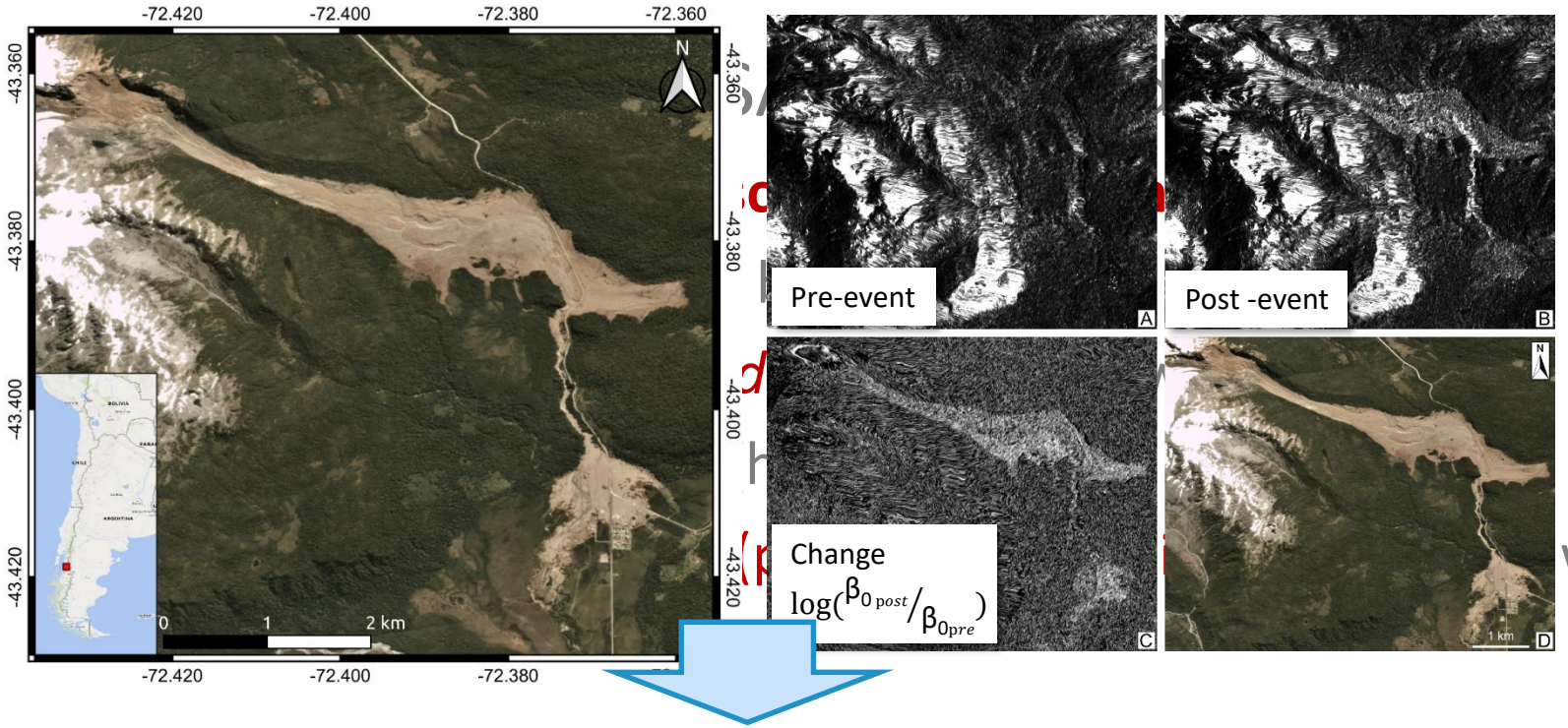
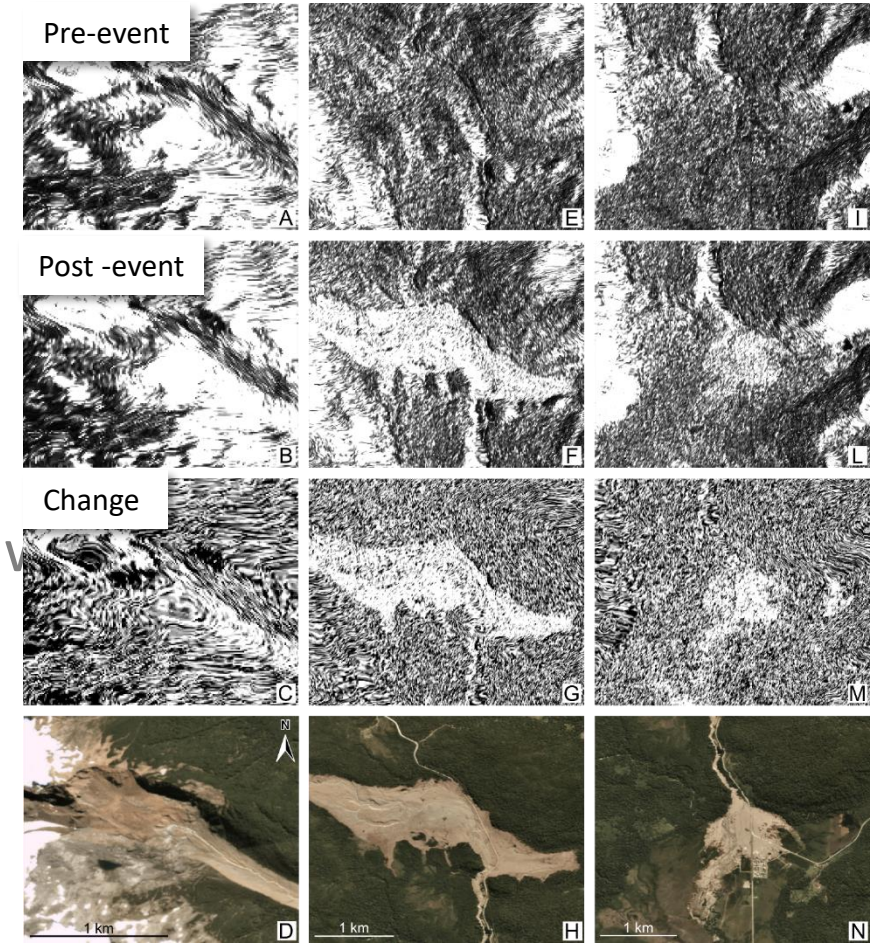




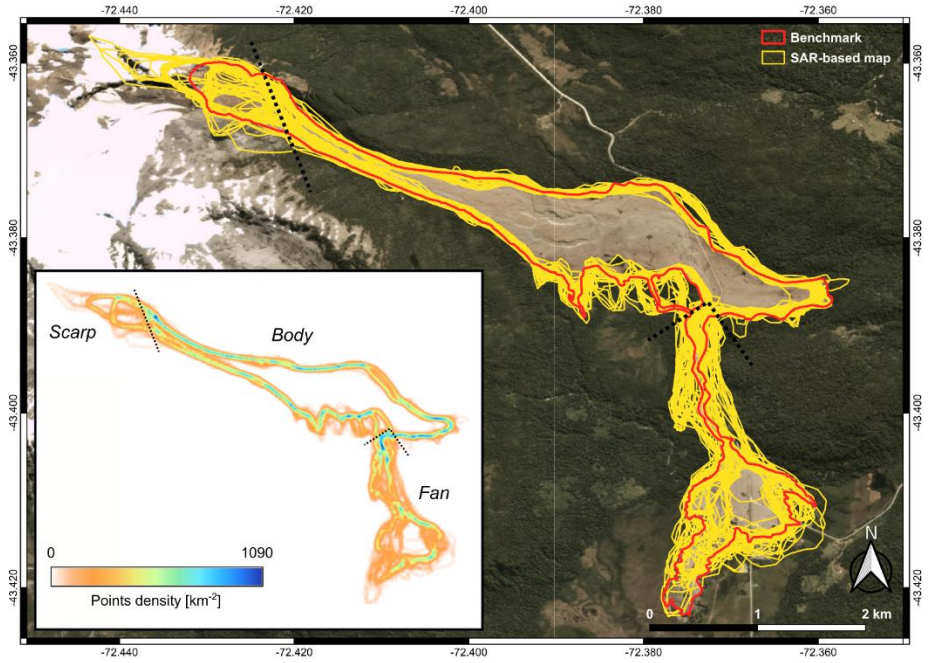
# Evolution of mapping: radar backscatter products




**Radar backscatter signature** of event landslides

# Evolution of mapping: radar backscatter products




**Acquisition geometry and multilook**

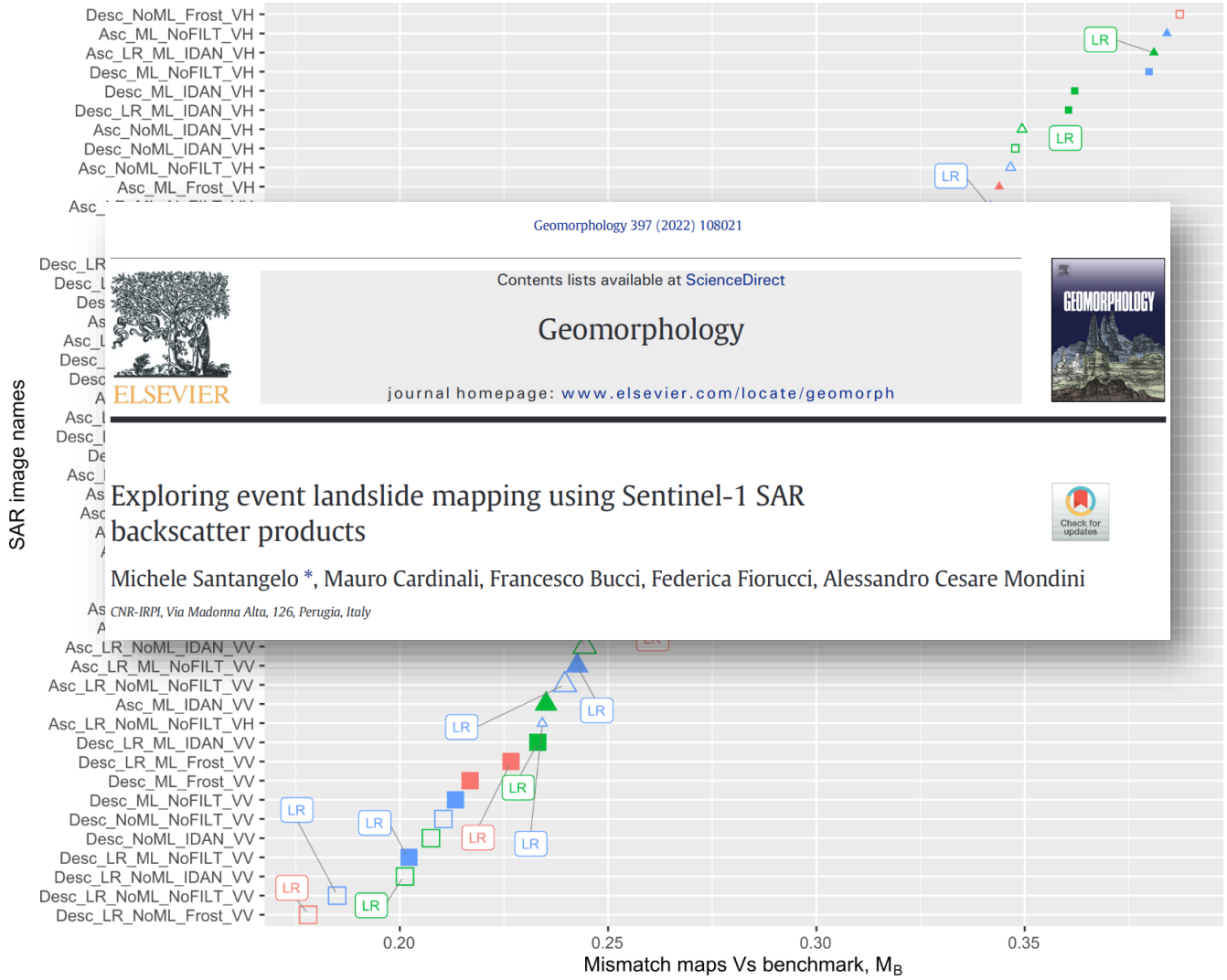
- ▲ Ascending with multilook
- △ Ascending without multilook
- ■ Descending with multilook
- □ Descending without multilook

**Filter applied**

- Frost (moving window)
- IDAN (adaptive)
- None

**SAR images polarization**

- VH
- VV

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## Exploring event landslide mapping using Sentinel-1 SAR backscatter products

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# Some remarks …

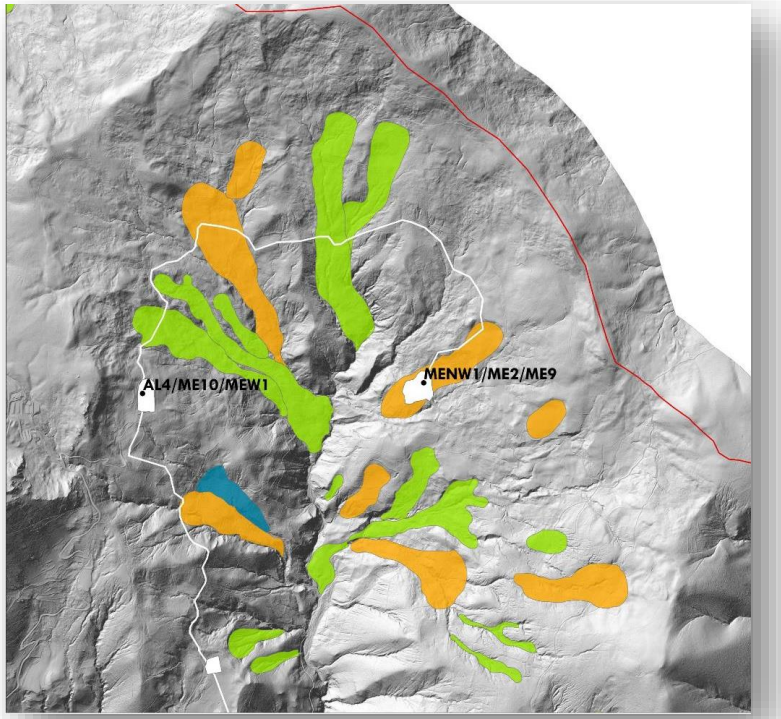
- **Interpretation criteria** proved to be **highly flexible**
- **More experience** and research needed on some images
- Explore **new sysyems** to map landslides (**AR/VR**)
- **New sensors** at higher spatial and spectral resolution may offer new images to test.

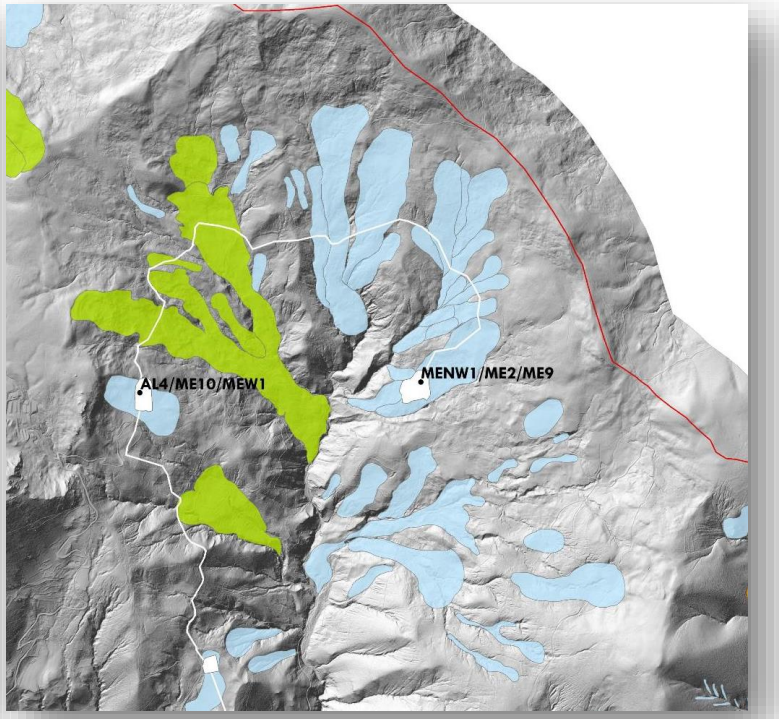
# …and discussion questions

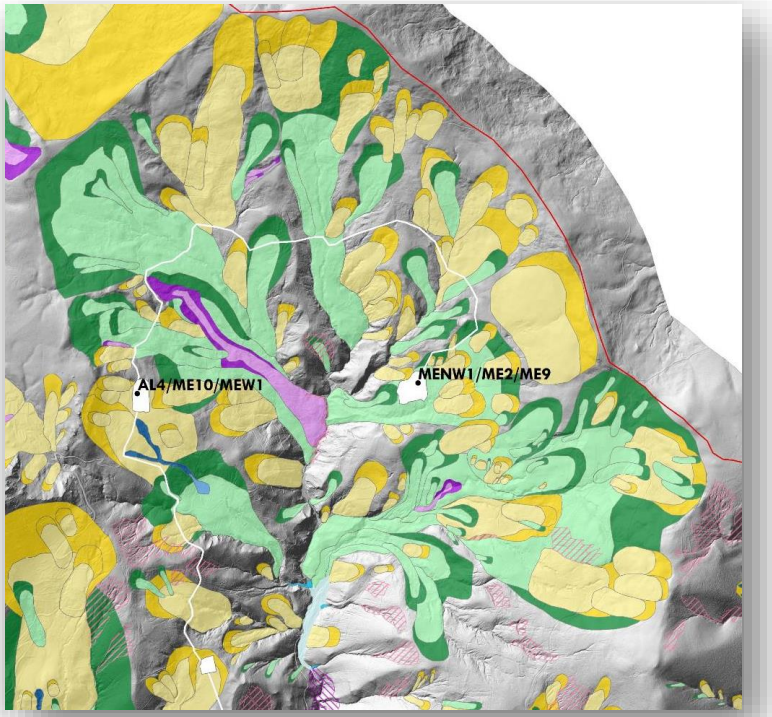
Without **reliable data** no **model**/application can be **reliable**. Nevertheless landslide **mapping** seems to become **less important.**

- Is **landslide mapping** yet considered as a **strategic** activity?
- Are these abilities/**competences worth keeping** and teaching?

# Quality standards: a major challenge




What is the role of **quality evaluation** in this situation? Are we **aware of errors and how they propagate**?