Snow preparation in landslide scenarios under multi-hazard perspective: experiences from Lake Campotosto (Italy)

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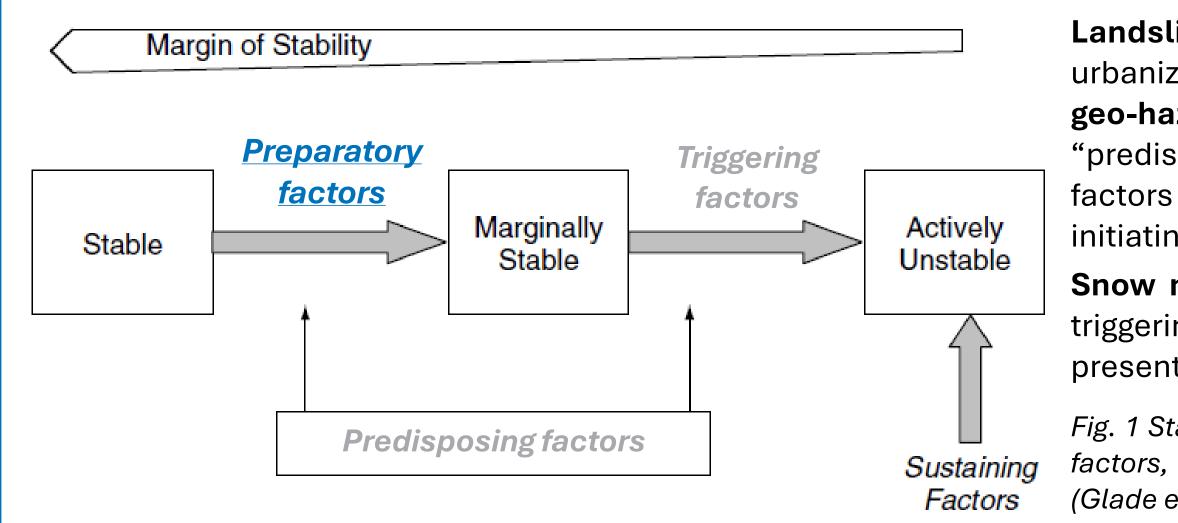
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1. Introduction and case study

Landslides are a natural land-forming process and their interaction with urbanized areas and infrastructures makes them one of the most common **geo-hazards**. Landslides are controlled by three macro-categories of factors: "predisposing", "preparatory", and "triggering". In particular, **preparatory** factors change over time and can gradually reduce the slope stability without initiating the movement.

Snow melting and accumulation are generally mentioned in literature as triggering factors of landslides, particularly shallow ones; however, the here presented approach focuses on their contribution as preparatory factors.

Fig. 1 Stability states on a slope and identification of the different kinds of destabilizing factors, among which the preparatory ones are the object of this work (Glade et Al. (2005), modified)

In mountainous areas, snow loading and, especially, snow melting can increase the soil pore water pressure, leading to a reduction in the available strength. Their influence on soil stability is **time-dependent**, in fact it changes cyclically throughout the year. Snow usually begins to fall in late autumn and accumulates especially in winter, whereas in spring it melts, resulting in water infiltration into the soil and resistance loss.

In seismic areas, where earthquakes can act as triggers for shallow landslides, seismic action can encounter varying amounts of soil weakness depending on the season, resulting in different landslide scenarios. The same applies to heavy rainfall.
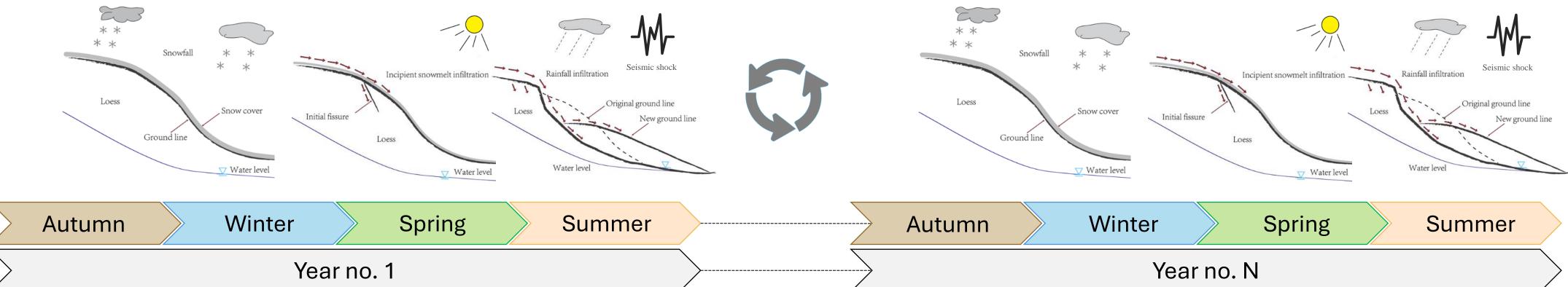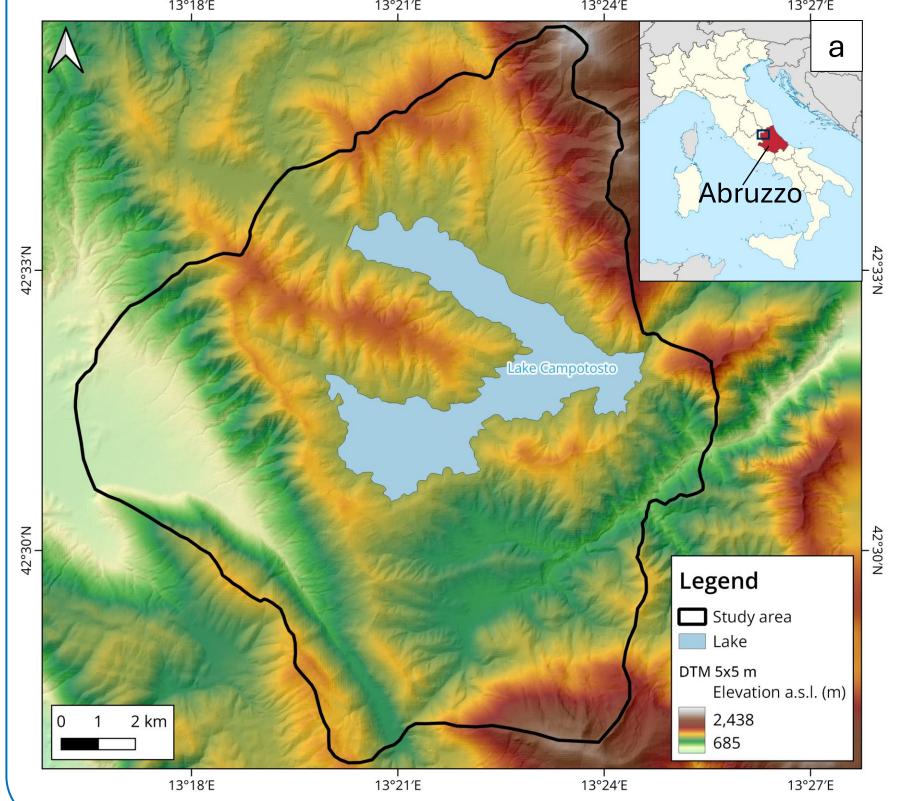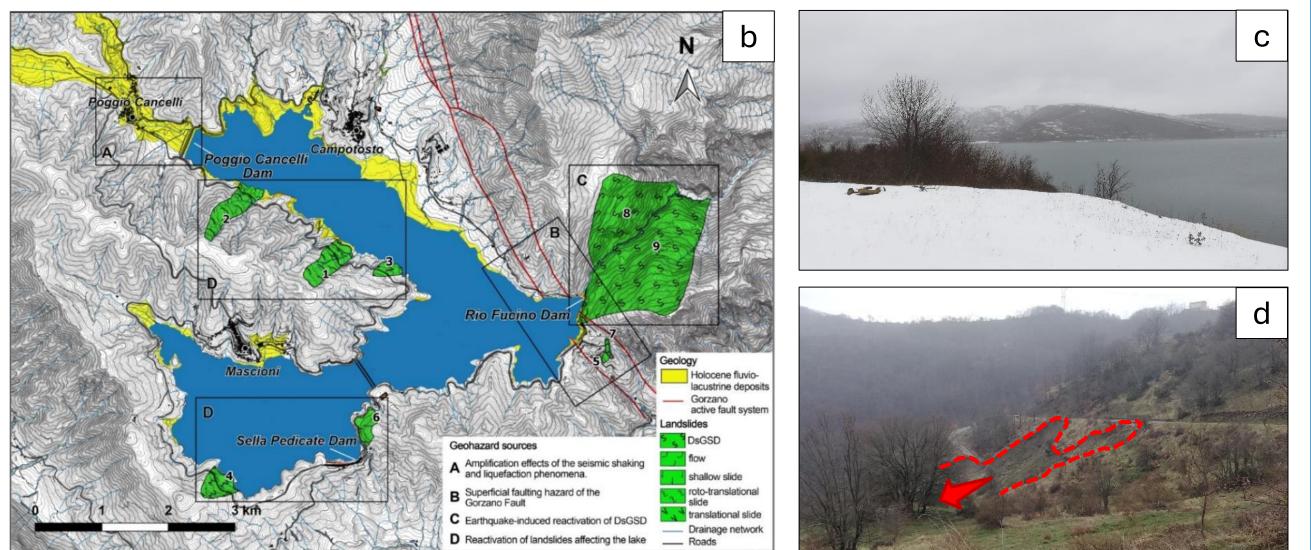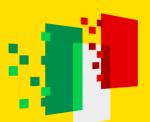

Fig. 2 Example of a time-dependent cascading hazard in which snow accumulation and melting play a preparatory role for shallow landslides that is repeated every year (Xian et Al. (2022), modified)

The case study is the area around **Lake Campotosto (Italy)**, located in one of the Apennines areas with the highest amount of snowfall per year, is in the near fault sector of one of the most important seismogenic sources of the Apennines (Mt. Gorzano Fault System), and is characterized by landslides of various sizes and mechanisms.

Fig. 3 a) Location of the study area; b) Geohazards acting on the case study (Antonielli et Al., 2021); c) Snow cover in the study area; d) Example of active landslide in the area of interest
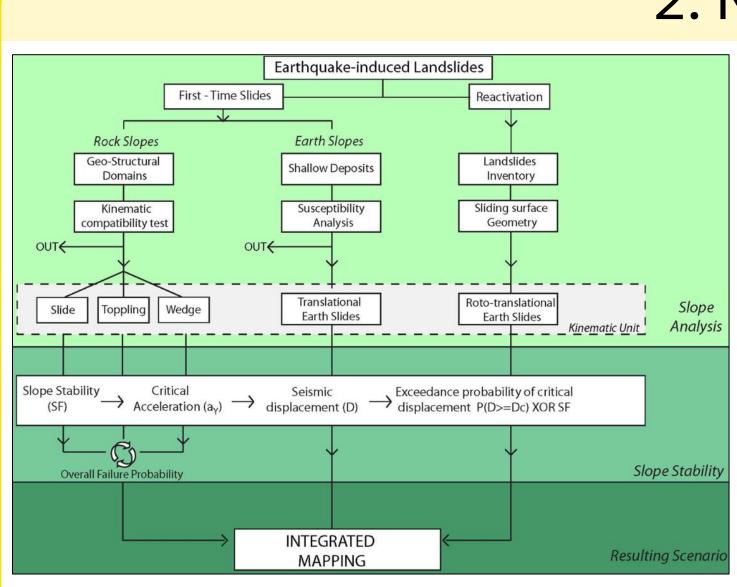
2. Methods and preliminary results

Fig. 3 Flow chart illustrating the multi-step PARSIFAL approach (Martino et al., 2020)

The **PARSIFAL** method (_Probabilistic Approach to pRovide Scenarios of earthquake-Induced slope FaiLures_) is a multistep approach designed to recreate probabilistic scenarios for **seismo-induced landslide** activations on areas ranging from municipal to basin size, through susceptibility and stability analyses executed for earth-slides (activation and re-activation), rockslides and topplings.

Its main outputs consist of maps illustrating the probability of exceedance of pre-defined seismic displacement thresholds.

It can consider different combinations of hydraulic conditions and seismic actions.

Preliminary research on the stability of soil covers under seismic conditions emphasizes the importance of hydraulic conditions during earthquakes, which also suggests the relevance of snow loading and snow melting in regulating slope stability.

Fig. 4 Use of the PARSIFAL approach to generate scenarios of earthquake-induced landslides under different hydraulic conditions around Lake Campotosto

Dry — Medium saturation — High saturation

3. Research goals

Further research is being done utilizing satellite and meteorological data, and geomorphological features, and then elaborating them using statistical and geostatistical tools, up to **advanced computing**.
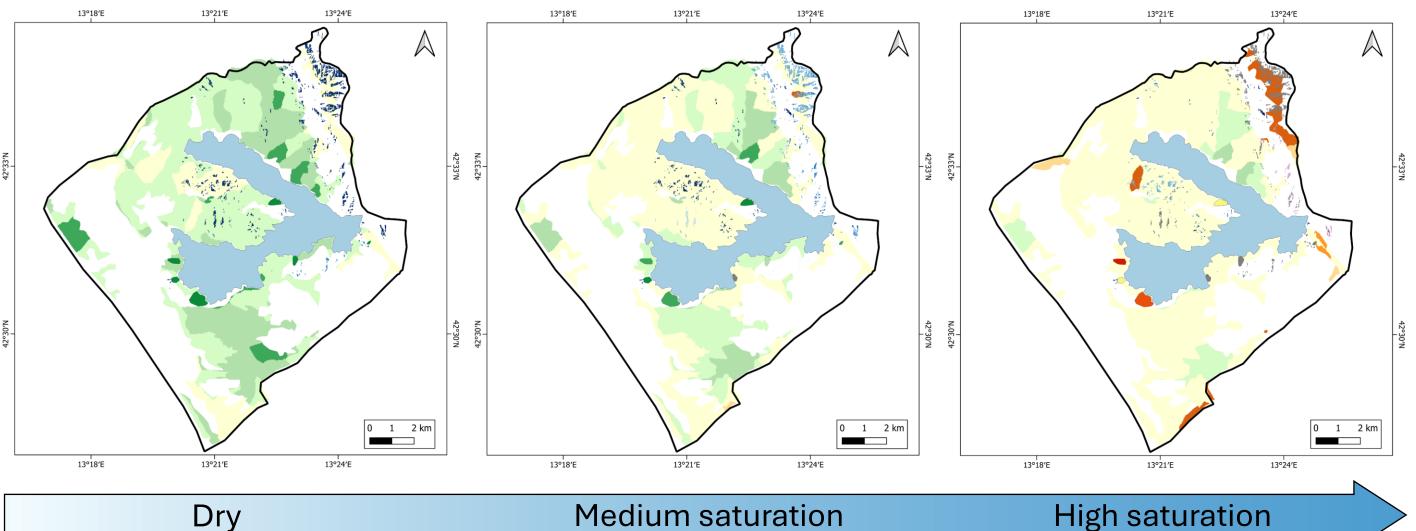
The goal is to generate time-dependent landslide hazard scenarios by **weighting the preparatory effect of snow precipitation** throughout the year and adding a related tool to PARSIFAL.

The majority of these concepts are being studied at Sapienza Department of Earth Sciences in the CN1 (**National Centre for HPC, Big Data, and Quantum Computing**) – Spoke5 PNRR Linea Tematica 1 (Reconstruction of multi-hazard scenarios from seismic source models to the simulation of seismic-induced instabilities), which aims at generating ground effects scenarios in terms of instabilities induced by nonlinear effects produced by the propagation of seismic waves from the seismogenic source to the surface, also considering geomorphological and geotechnical characteristics of the near subsurface.
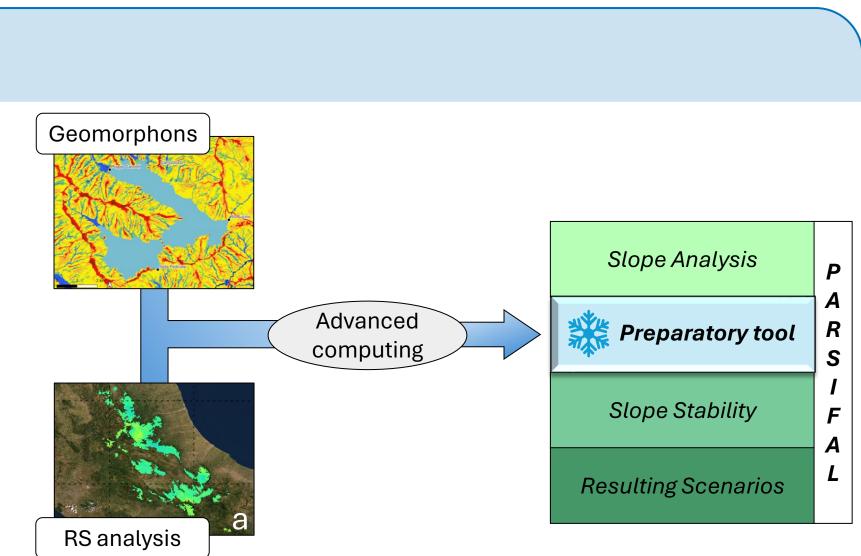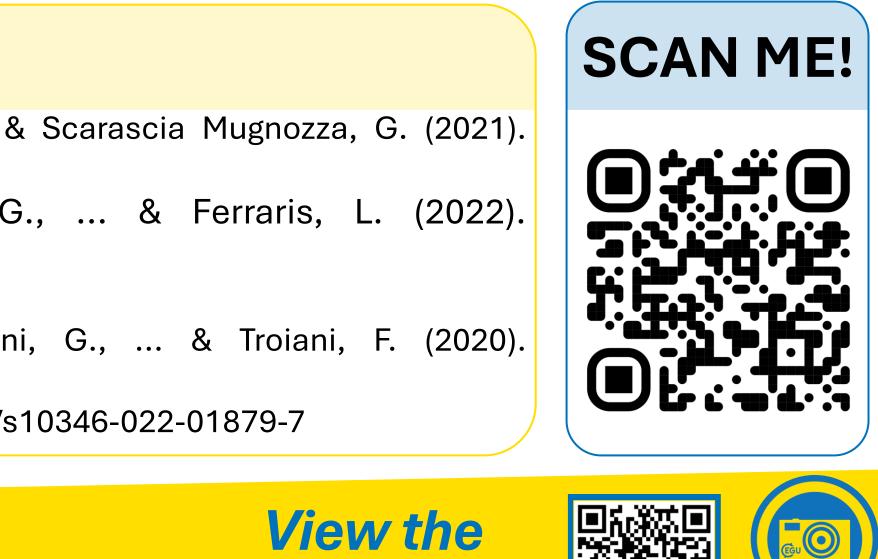

Fig. 5 Ongoing and future activities for the identification of the preparatory effect of snow cover on landslide hazard scenarios and the generation of a specific tool in PARSIFAL. a) From Avanzi et al. (2023)

4. References

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