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Rainfall thresholds for shallow landslides occurrence in a prone area of Northern Italy

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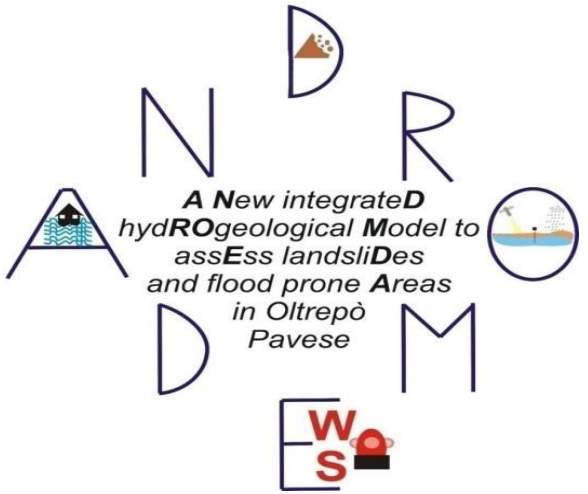
A New integrateD hydROgeological Model to assEss landsliDes and flood prone Areas in Oltrepò Pavese

1. OBJECTIVES

Development and test rainfall thresholds for the assessment of rainfall-induced shallow landslides spatial and temporal probability of occurrence

The work was realized in the frame of ANDROMEDA project, funded by Fondazione Cariplo and realized by University of Pavia and CNR-IRPI Perugia, which aims to develop a prototypal early-warning system for the assessment of shallow landslides and flood occurrence in Oltrepò Pavese area



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2. THE PROBLEM

Rainfall-induced shalllow landslides:

- **triggered** by **short-period** but very **intense** rainfall events;
- causing **significant damages** to cultivations, roads and building
- Increase in their occurrence related to the increase of extreme rainfall events due to **climate change**

27th-28th April 2009 event in Oltrepò Pavese (1639 shallow landslides in about 250 km^2)

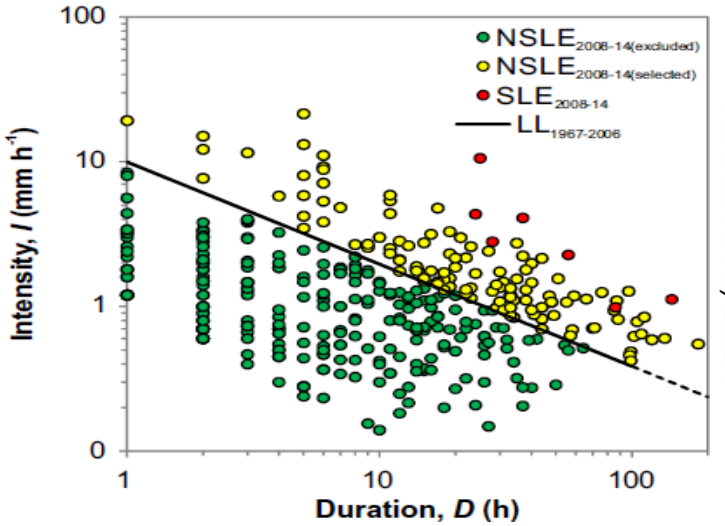
3. BACKGROUND

Methodologies for the assessment of shallow landslides **spatial** and **temporal** probability occurrence

Rainfall thresholds

+ Rainfall features are representative of the triggering conditions
+ Easily to be implemented at regional scale

- Soil features and geomophological predisposing factors are not considered
- Uncertainties related to the quality and the availability of the rainfall data

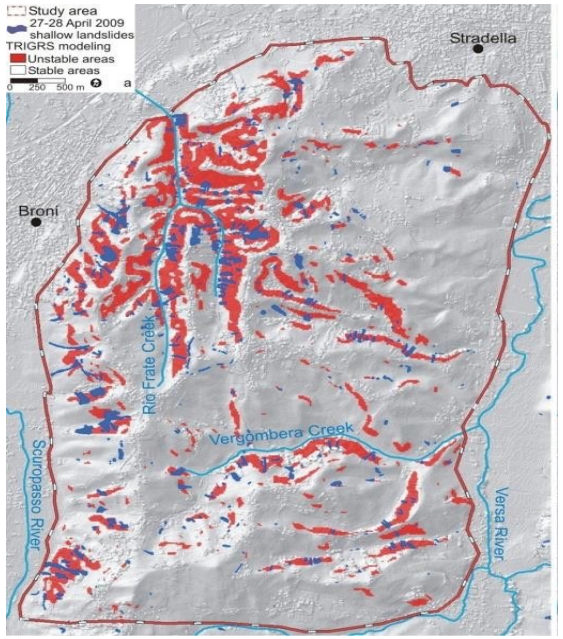


Galanti et al., 2018

Physically-based methods

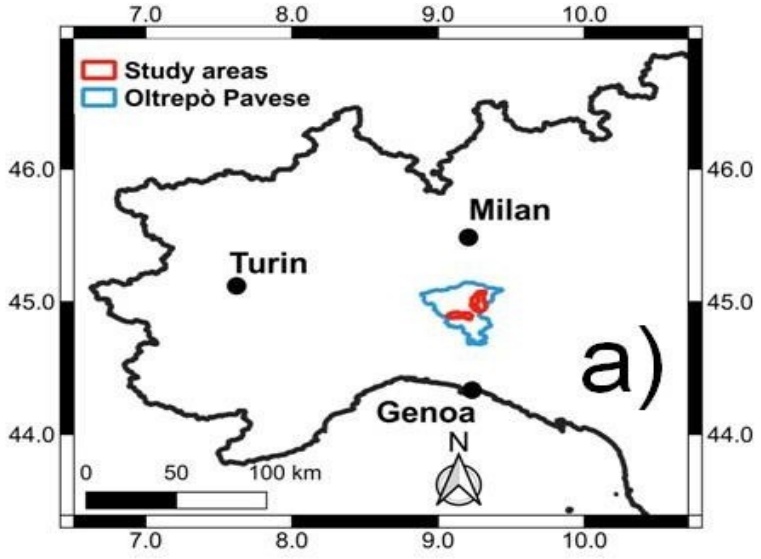
+ Quantitative analysis of the rainfall triggering conditions
+ Consideration of the pre-event soil hydrological/geotechnical parameters and of the geomorphological attributes
+ Analysis of change in time of stable/unstable areas

- Significant amount of input data, difficult to be implemented at large scale
- Uncertainties on the boundary conditions of the model



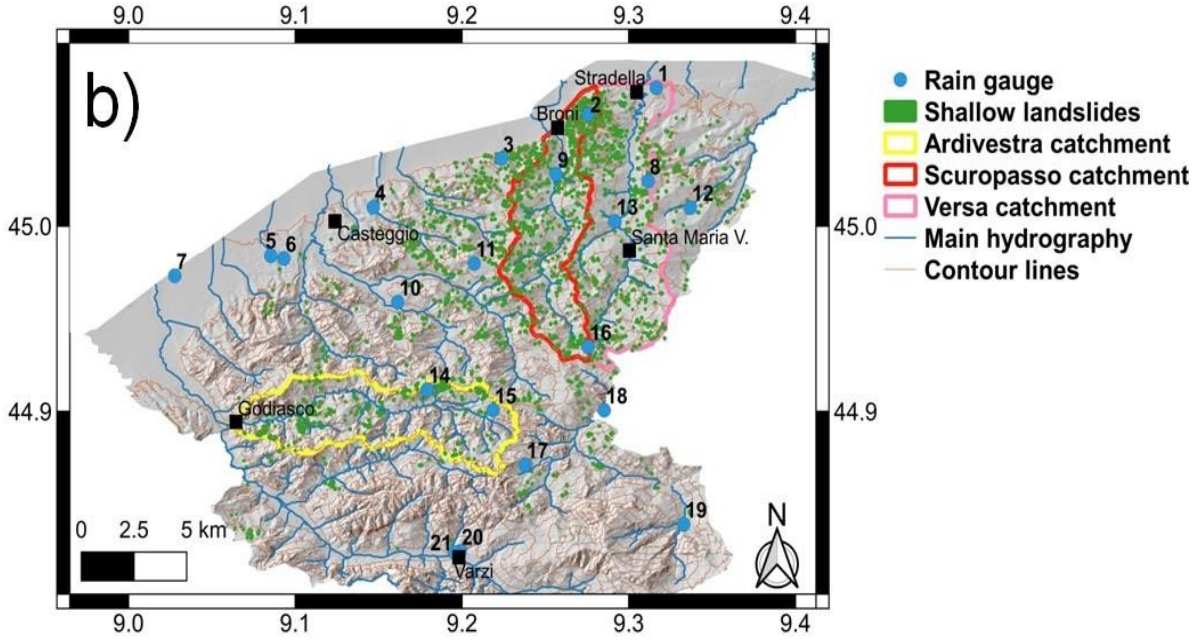
Bordoni et al., 2015

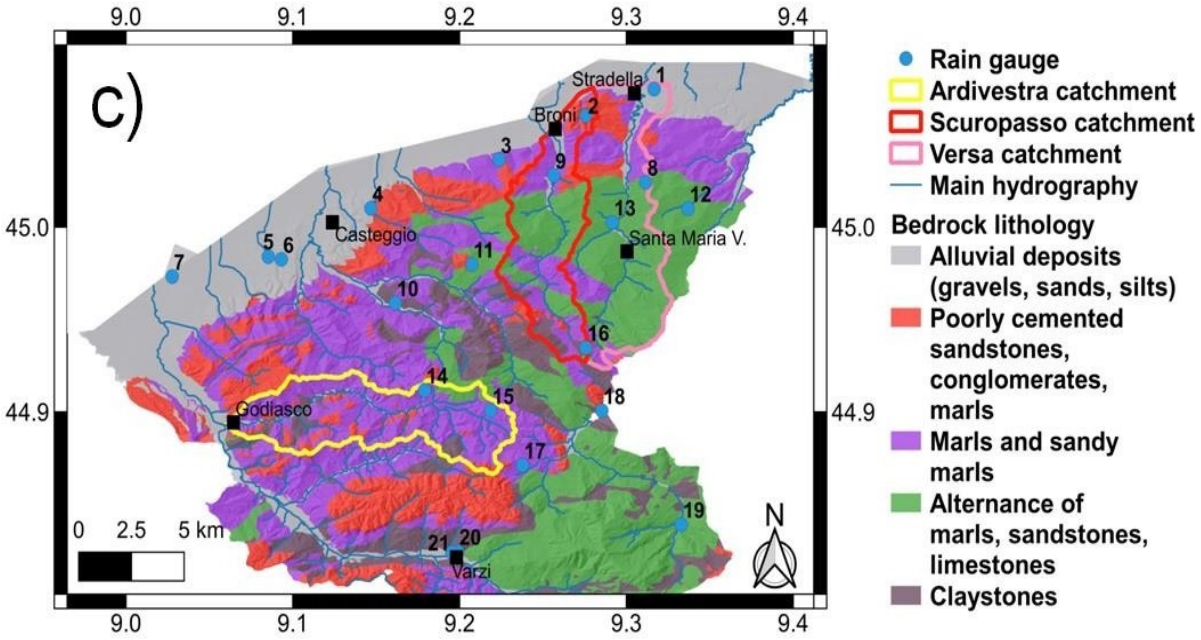
4. STUDY AREAS



Oltrepò Pavese area (720 km²)

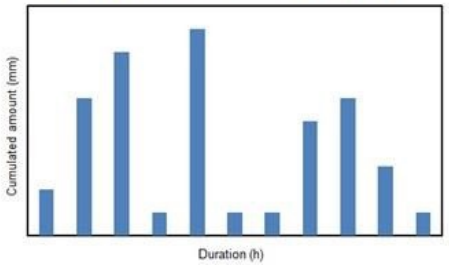
Pilot catchments representative of the typical geological and geomorphological settings: **Ardivestra (medium steep slopes, clayey and chaotic bedrocks) Scuropasso-Versa (very steep slopes, marly, areanaceous, conglomeratic bedrocks)**





5. DATA AND METHODS

Synthetic rainfall events (duration, cumulated amount)



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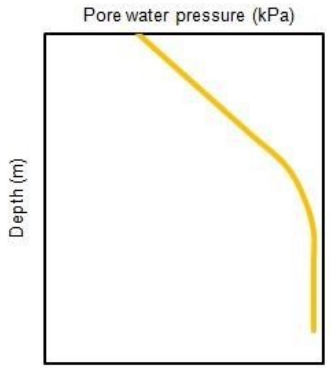
Initial pore water pressure conditions



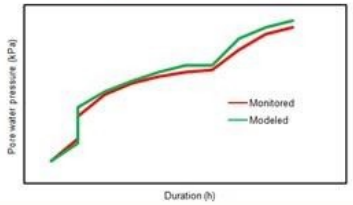
Physically-based modeling at site-specific scale (TRIGRS model)

Boundary conditions:

- Soil hydrological and geotechnical profile
- Impermeable bedrock layer below soil profile
- Uprise of perched water table

Validation of the physically-based model

Comparison between modeled and monitored pore water pressure during past events

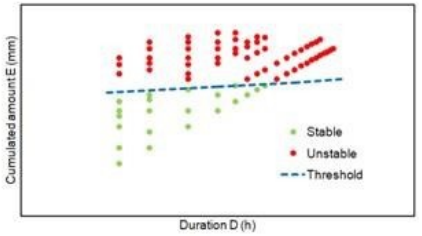


Calculation of slope safety factor (Fs) for each modeled rainfall event (function of duration and cumulated amount)

Fs<1 unstable conditions: rainfall event (duration, cumulated amount) is not enough to trigger shallow landslides

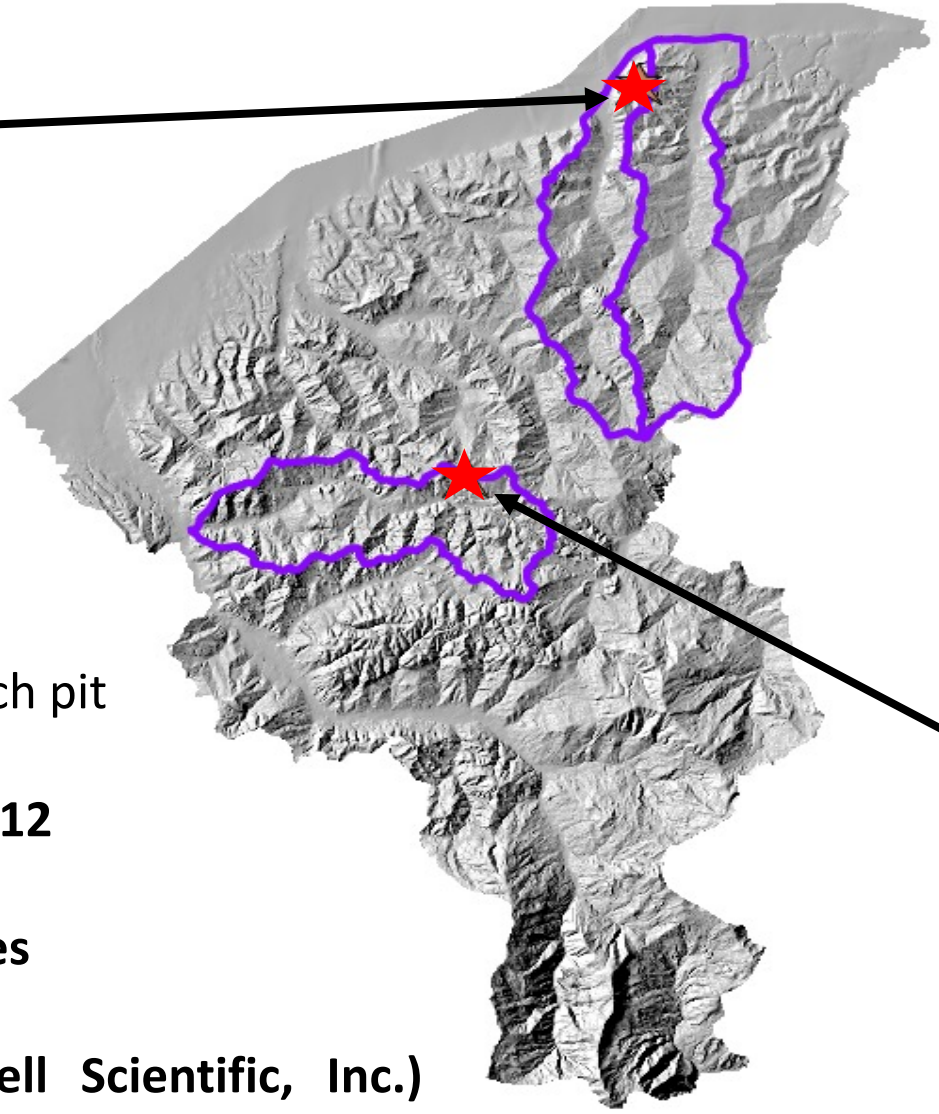
Fs>1 stable conditions: moment during the rainfall event (duration, cumulated amount) when shallow landslides can trigger

Rainfall thresholds for triggering of shallow landslides



5. DATA AND METHODS

Montuè site

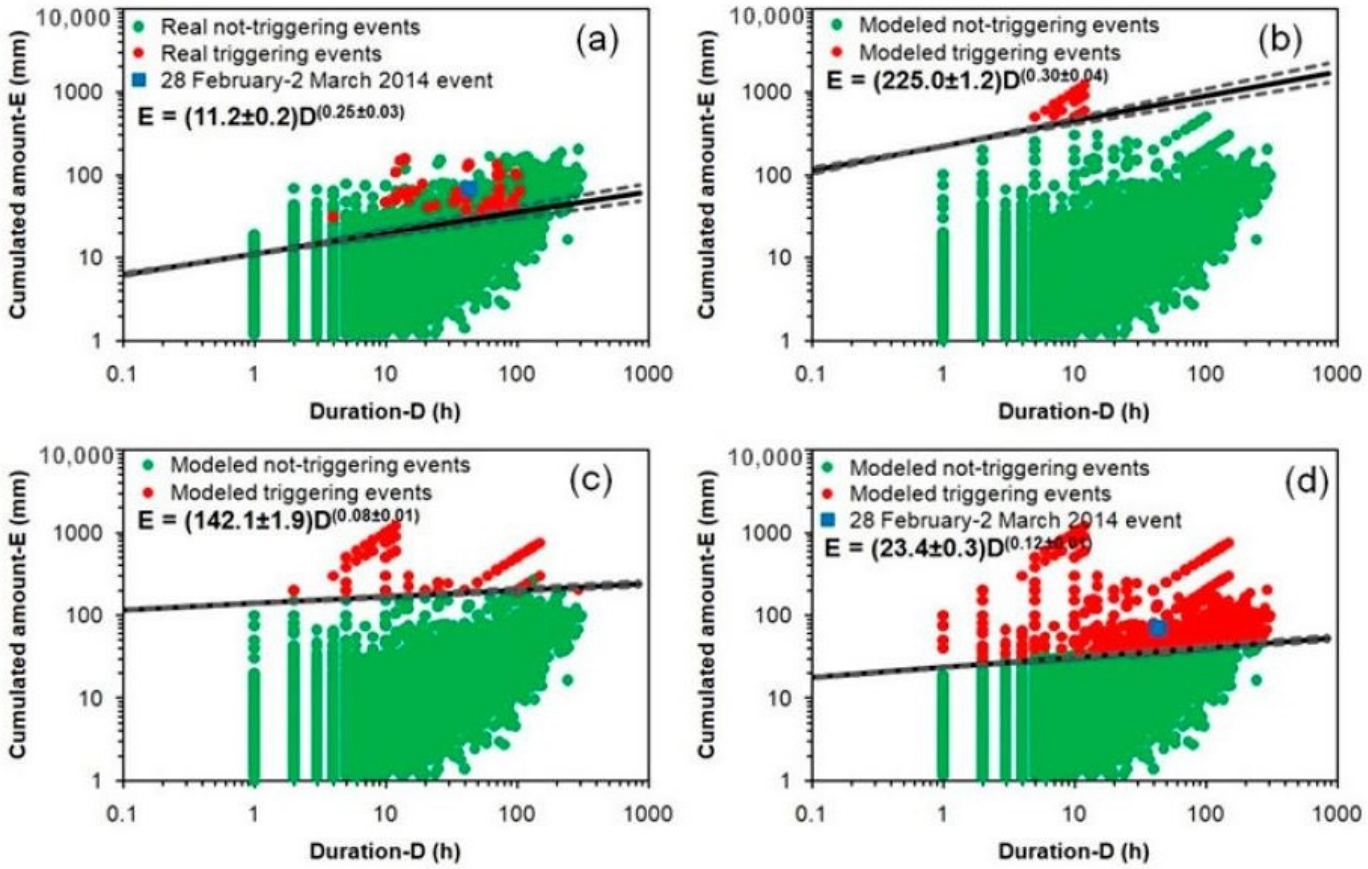


- **Soil devices installed in** a trench pit
- **Data collection since 27/03/2012**
- Temporal resolution: **10 minutes**
- **datalogger (CR1000X, Campbell Scientific, Inc.) powered by a photovoltaic panel (20 W)**

- **Soil devices installed in** a trench pit
- **Data collection since 27/11/2015**
- Temporal resolution: **10 minutes**
- **datalogger (DL-6te, EM-50) powered by batteries**

Costa Cavalieri site

6. RESULTS - RAINFALL THRESHOLDS



Threshold	TP (%)	TN (%)	FP (%)	FN (%)
Empirical thresholds	95 ± 2	76 ± 3	24 ± 3	5 ± 2
Physicallybased thresholds (−20 kPa) (TRIGRS/−20)	-	100 ± 0	0 ± 0	-
Physicallybased thresholds (−10 kPa) (TRIGRS/−10)	-	100 ± 0	0 ± 0	-
Physicallybased thresholds (0 kPa) (TRIGRS/0)	100 ± 0	93 ± 1	7 ± 1	0 ± 0

- Significant differences on the rainfall cumulated amount between different thresholds
- Significant effects of the initial pore water pressure on the cumulated amount required to trigger shallow landslides
- Low values of triggering rainfall for empirical-statistical thresholds
- Better estimation of rainfall triggering conditions since thresholds reconstructed through physically-based methods

7. CONCLUSIONS AND FUTURE DEVELOPMENTS

- ❑ Development of **empirical** and **physically-based** thresholds for the occurrence of shallow landslides
- ❑ Taking into account monitored rainfall observatins and soil moisture data
- ❑ Validation of the model
- ❑ Reconstruction of rainfall thresholds through satellite data (rainfall, soil moisture)
- ❑ Development of Early-Warning System for future events

THANKS FOR THE ATTENTION

References:

Bordoni M., Corradini B., Lucchelli L., Valentino R. Bittelli M., Vivaldi V., Meisina C. (2019). Empirical and physically based thresholds for the occurrence of shallow landslides in a prone area of Northern Italian Apennines. Water 11, 2653. doi:10.3390/w11122653

Bordoni M., Corradini B., Lucchelli L., Meisina C. (2019). Preliminary results on the comparisons between empirical and physically-based rainfall thresholds for shallow landslides occurrence. Italian Journal of Engineering Geology and Environment, 1, 5-10. doi:10.4408/IJEGE.2019-01.S-01

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