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Session NH6.4 - Using satellite soil moisture and rainfall data for the monitoring and the prediction of natural hazards - 29 April 2021

Using satellite soil moisture and rainfall data for the monitoring and the prediction of natural hazards

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1. THE PROBLEM

- **Rainfall-induced shalllow landslides**: triggered by short-period but very intense rainfall events

- Triggering linked with the hydrological and mechanical response of a usually unsaturated soil to rainfall events

- **Causing widespread damages to the terrain, infrastructure, as well as urban and rural developments**

- High density of phenomena in little catchments

- **Increase in their occurrence related to the increase of extreme rainfall events due to climate change**

2. BACKGROUND

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

Rainfall thresholds

+ Rainfall features 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 amount of the rainfall data

Physically-based methods

+ Quantitative analysis of the rainfall triggering conditions leading to the triggering

+ Consideration of the soil hydrological and 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

2. BACKGROUND

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

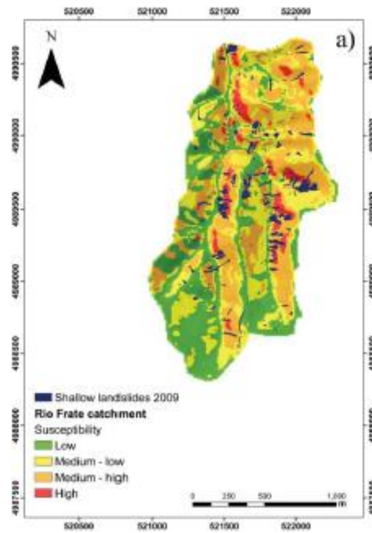
Knowledge-driven or data-driven methods

+ Consideration of the soil and geomorphological features leading to shallow landslides triggering

+ Easily to be implemented at regional scale

+ Modeling of different triggering events, characterized by peculiar inventories

- Dynamic triggering factors (rainfall, soil hydrological features) are generally not taken into account (susceptibility)



Persichillo et al., 2017

It is necessary to develop an **innovative methodology** which integrates all the advantages of the previous methods and fills their gaps

- **Considering both soil and geomorphological predisposing factors and dynamic triggering factors** (rainfall, soil hydrological features)
- **Dynamic analysis of change in time of stable/unstable areas**
- **Easily to be implemented at large scale** (catchment, regional)
- **Able to model different typologies of triggering events for the same area**

3. OBJECTIVES

Development and test of a dynamic data-driven method for the assessment of spatial and temporal probability of occurrence and hazard of rainfall-induced shallow landslides at large scale (catchement, regional), with the integration of satellite measures of rainfall and soil moisture

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

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

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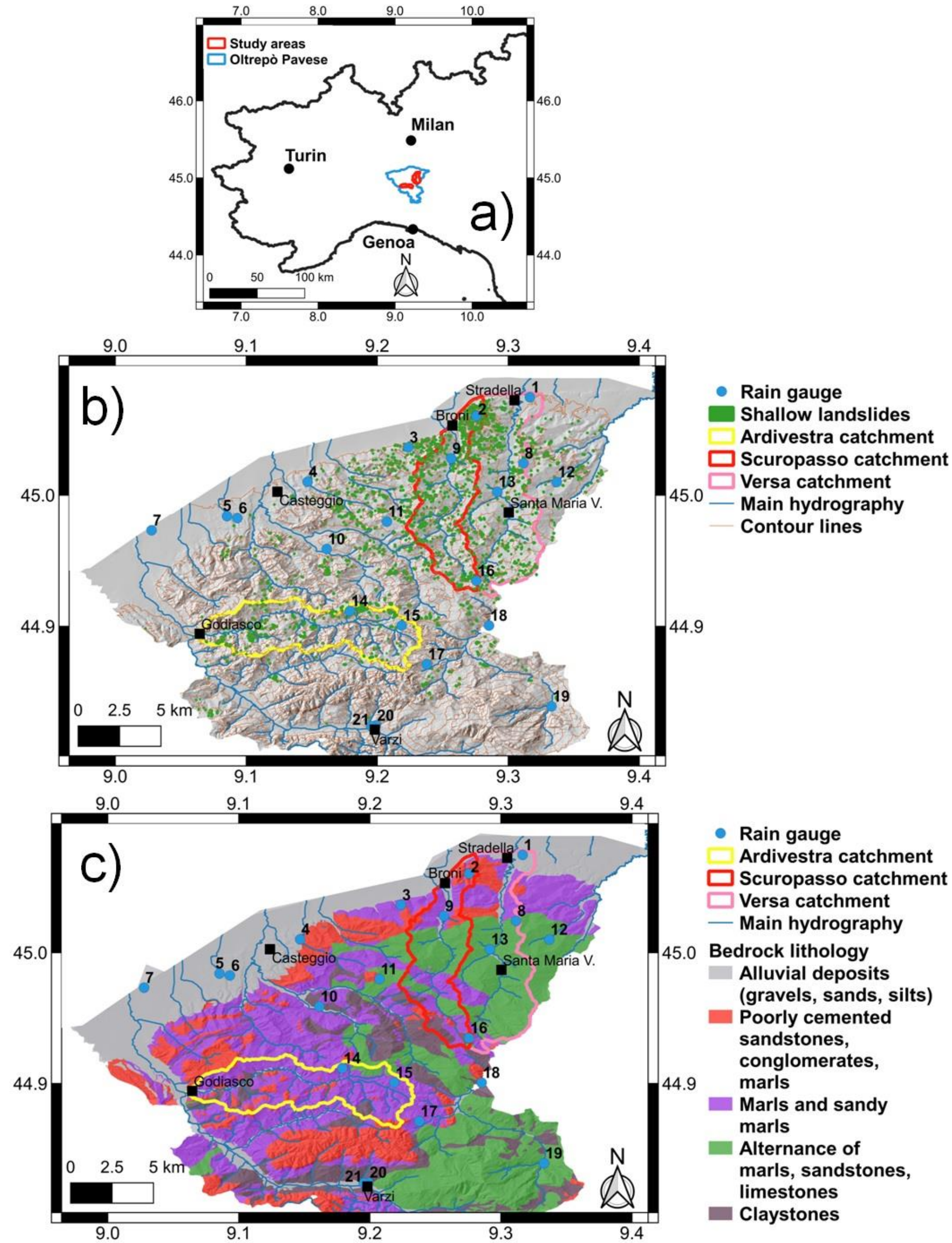
4. STUDY AREAS

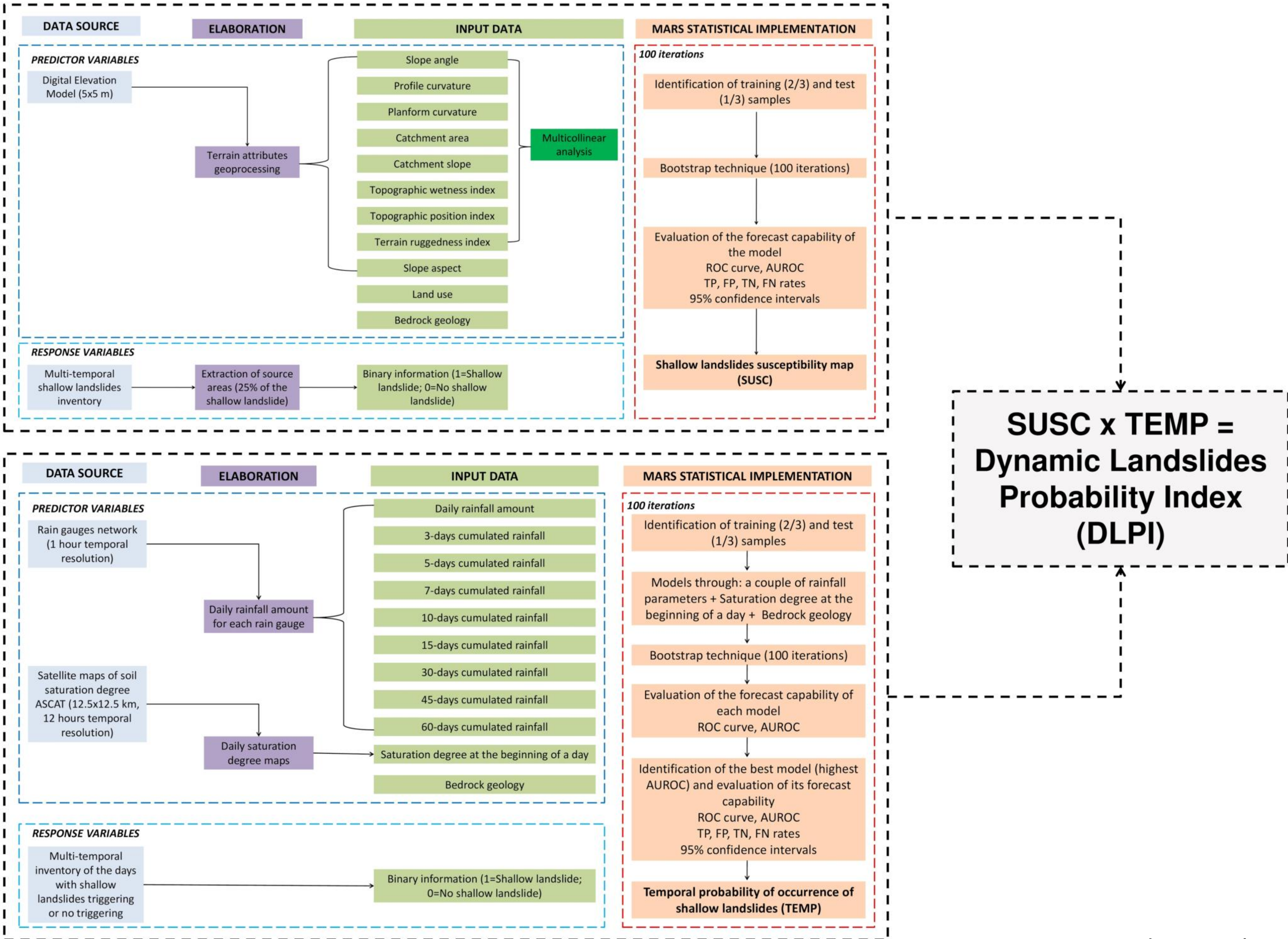
Oltrepò Pavese area (720 km^2)

- Representative of northern Italian Apennines
- Different geomorphological settings: steep slopes (>15-20°) and narrow valleys with marly, areanaceous, conglomeratic bedrocks - medium steep slopes (10-15°) and large valleys with marly, clayey and chaotic bedrocks
- Soil heterogeneity: clayey-sandy silts/silty sands with thickness around 1 m - silty clays with thickness > 1-1.5 m
- High susceptibility towards shallow landslides (density till > 50 landslides per km^2)
- Three 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)**



Bordoni et al., 2020

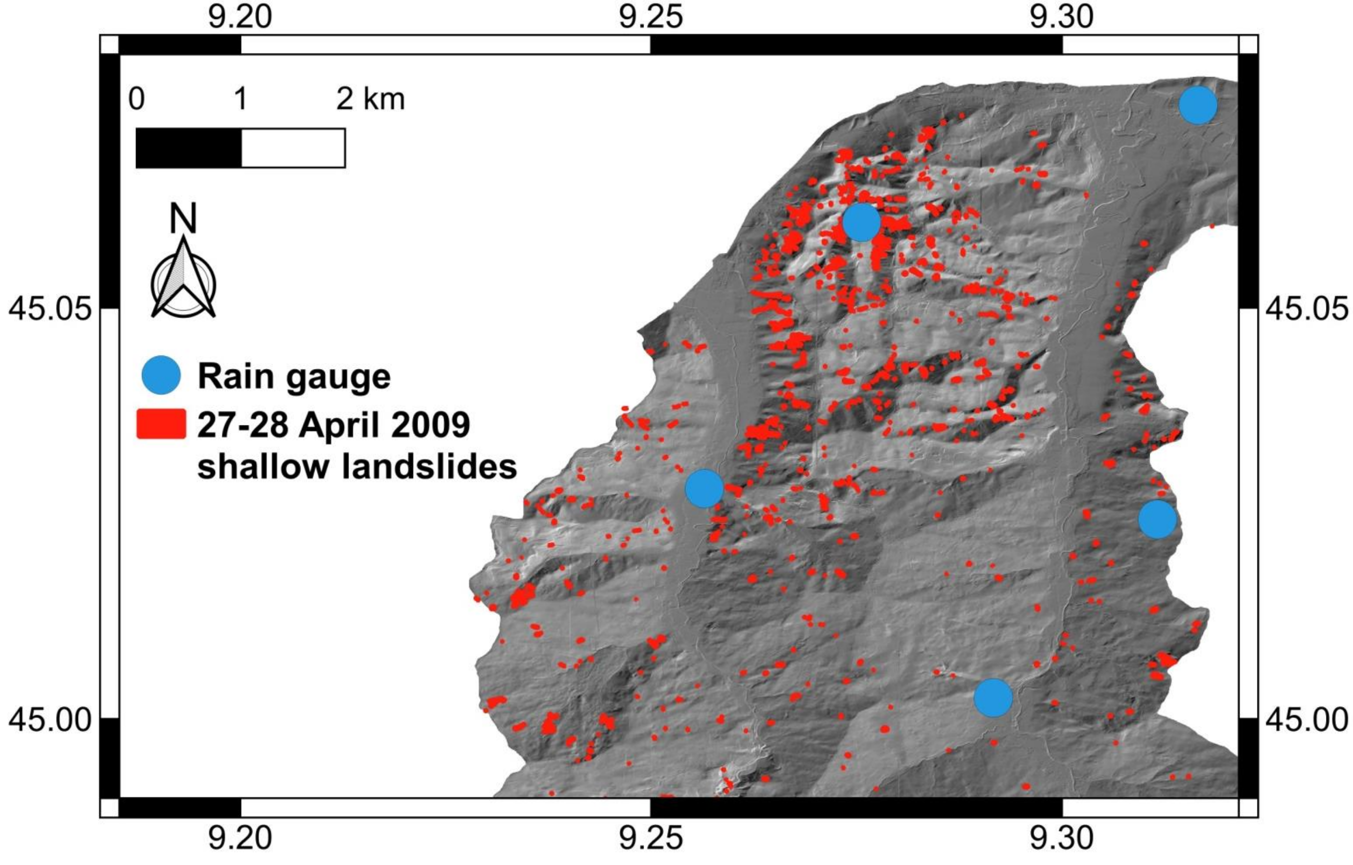
5. METHODS



Bordoni et al., 2020

5. METHODS

For a certain day, rainfall attributes measured by a particular rain gauge are representative of a triggering event if a **shallow landslide occurred in that day in a radius of less than 10 km from the rain gauge**



5. METHODS

Available data

For SUSC:

- Digital Elevation Model 5x5 m, land use map, bedrock geological map, soil lithotechnical map, inventory of deep landslides
- Multi-temporal inventory of shallow landslides occurred since 2008

For TEMP:

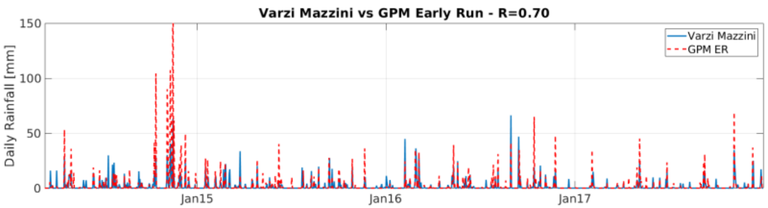
- Rainfall data from rain gauge network, since 2008
- Kriging-interpolated maps of rainfall attributes since data measured in correspondence of the rain gauges of the network
- Satellite maps of soil moisture acquired through ASCAT (since 2008) and Sentinel-1 (since 2015)
- Satellite maps of rainfall acquired through GPM since 2014
- Rainfall derived from satellite maps of soil moisture (SM2RAIN; Brocca et al., 2014) since 2008

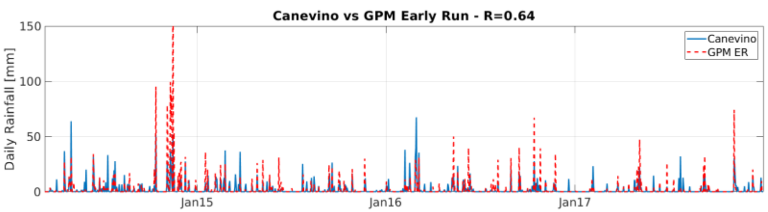
6. RESULTS

Comparison between satellite and field measured rainfall and soil moisture

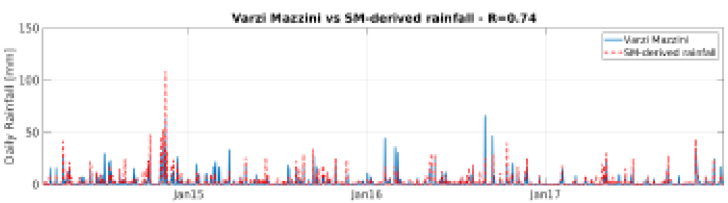
Rainfall

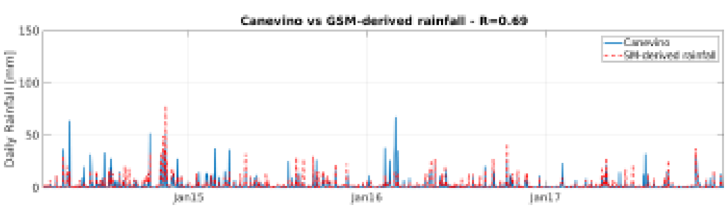
Rain gauge vs GPM: R=0.64-0.70





Rain gauge vs SM2RAIN: R=0.69-0.74

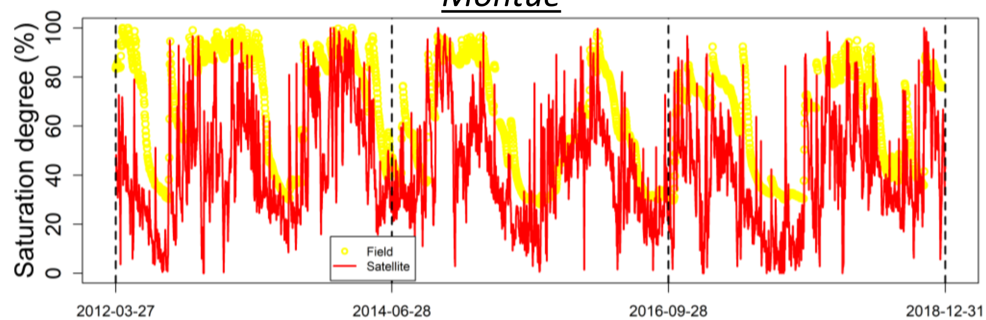




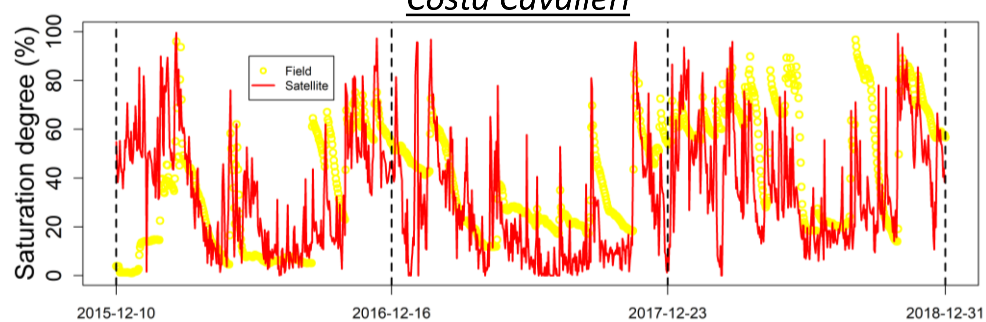
Soil moisture

Field vs ASCAT: R=0.64-0.71

Montuè

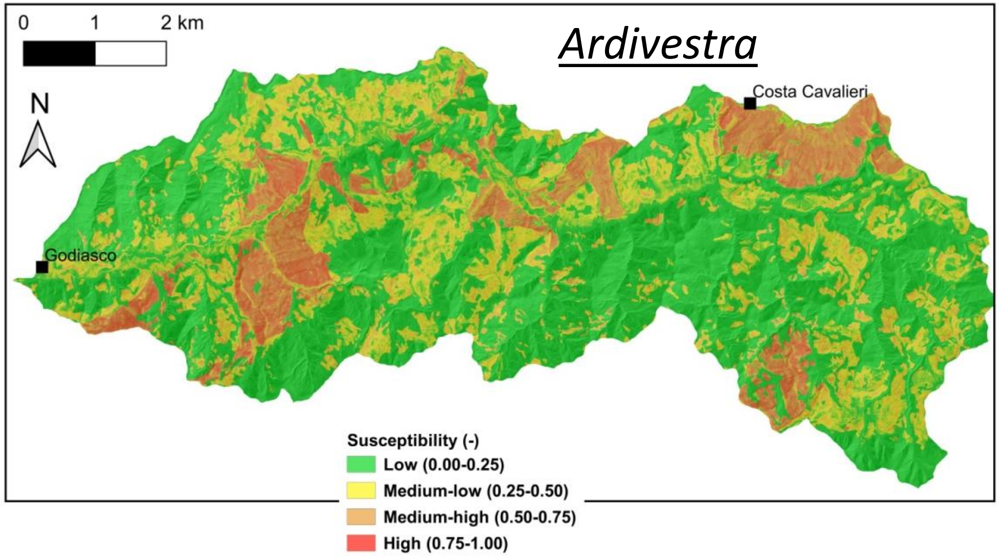


Costa Cavalieri



6. RESULTS

Susceptibility maps



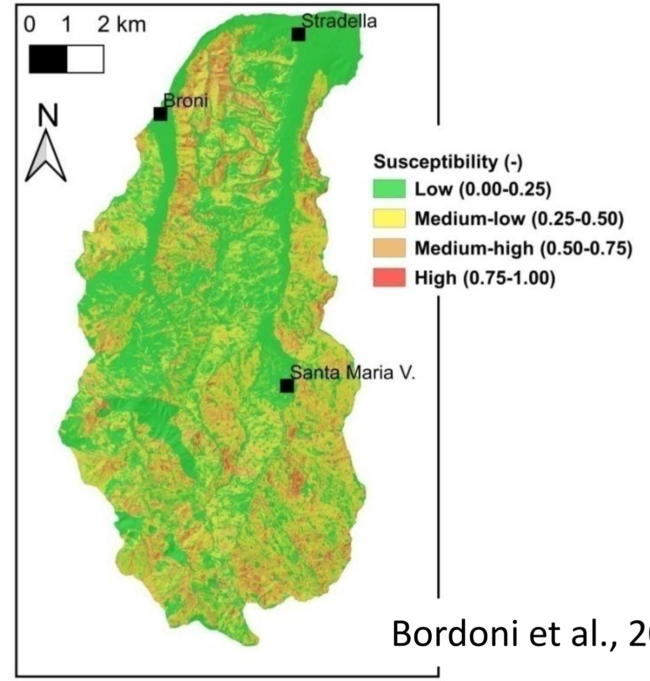
Significant parameters: slope angle (non-linear), tpi (non-linear), catchment area, land use, lithotechnical units

AUROC=0.90

TP=85%, TN=75%, FP=25%, FN=15%

Ef=86%, HK=70%

Scuropasso-Versa



Bordoni et al., 2020

Significant parameters: slope angle (non-linear), tpi (non-linear), twi (non-linear), planform curvature (non-linear), catchment slope (non-linear), slope aspect, land use, lithotechnical units

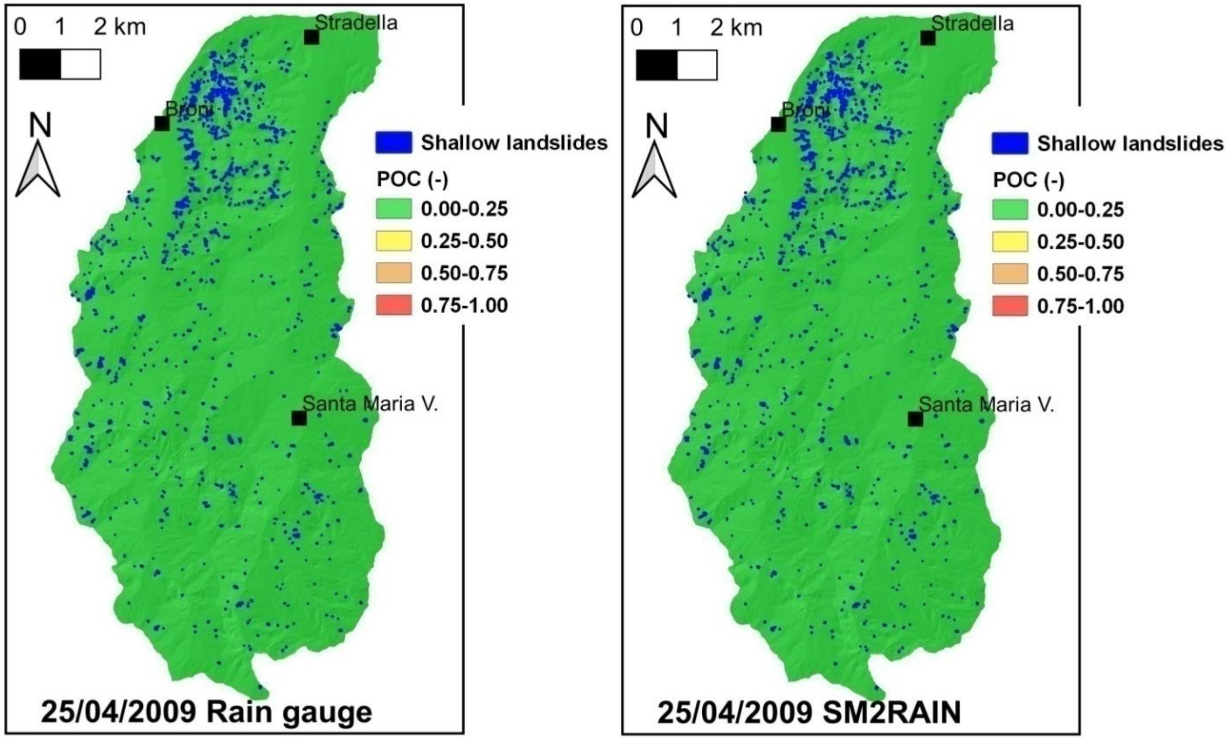
AUROC=0.89

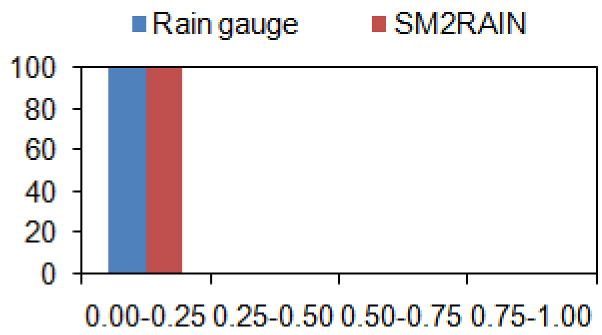
TP=88%, TN=76%, FP=24%, FN=12%

Ef=82%, HK=76%

6. RESULTS

Scuropasso and Versa catchments - 25/04/2009





3d-rain=0.4-0.6 mm
30d-rain=141.6-149.8 mm
Sat.=56%

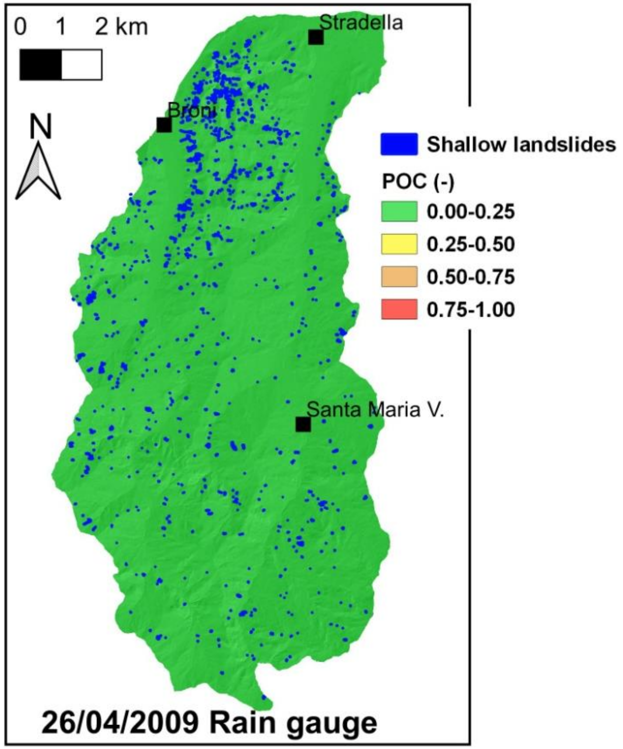
3d-rain=0.0-5.0 mm
30d-rain=141.0-193.0 mm
Sat.=56%

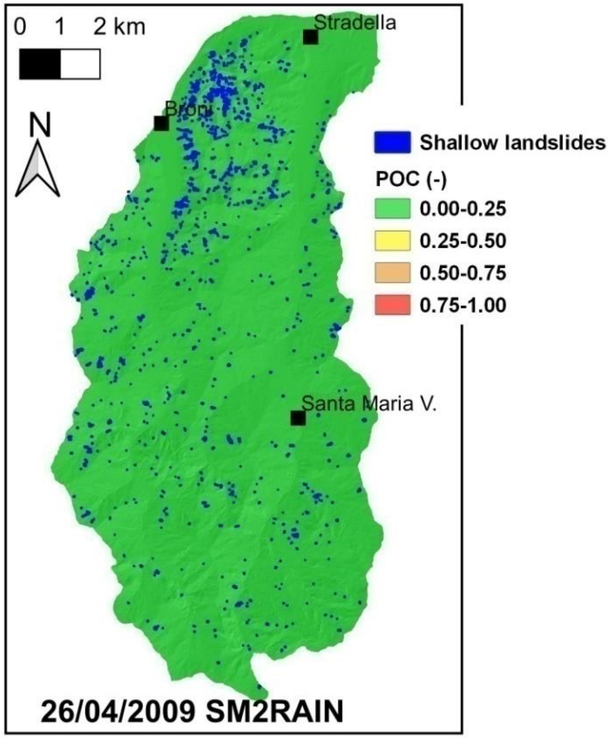
Bordoni et al., 2020

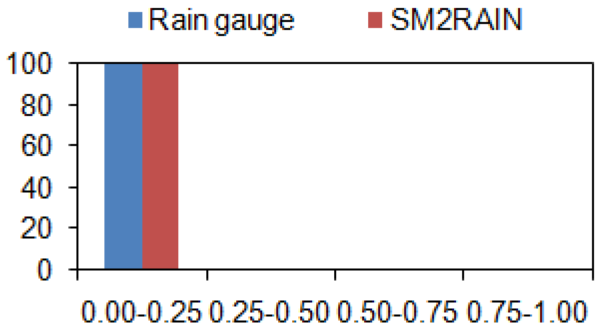
Kappa index=1.00

6. RESULTS

Scuropasso and Versa catchments - 26/04/2009







3d-rain=10.8-11.4 mm
30d-rain=152.0-161.2 mm
Sat.=53-54%

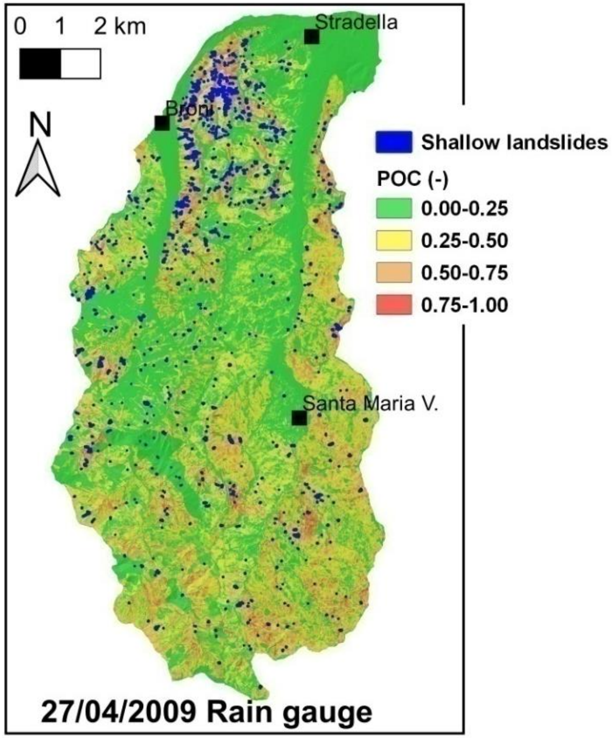
3d-rain=15.0-17.5 mm
30d-rain=158.5-203.0 mm
Sat.=53-54%

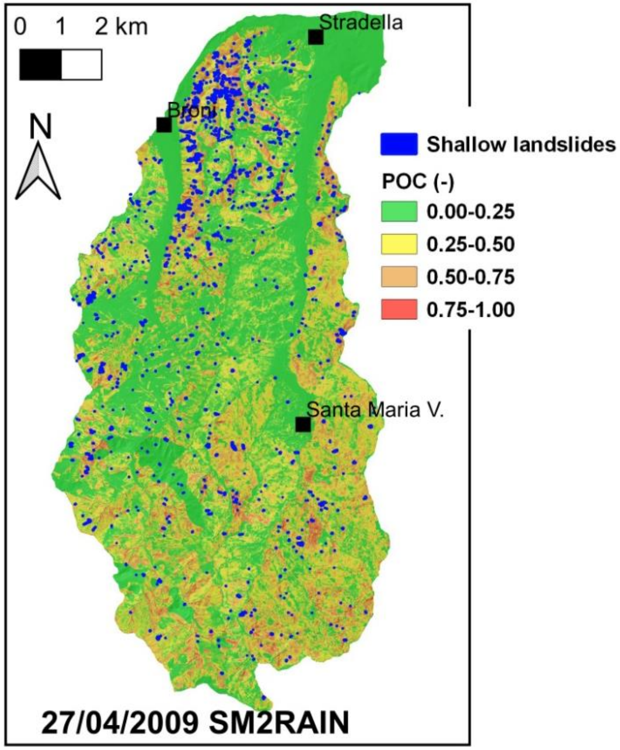
Bordoni et al., 2020

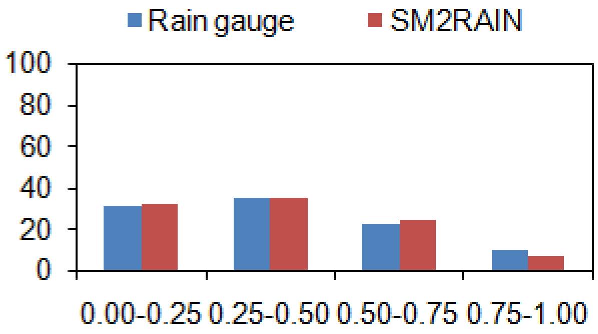
Kappa index=1.00

6. RESULTS

Scuropasso and Versa catchments - 27/04/2009 → Triggering moment







3d-rain=113.6-125.8 mm
30d-rain=260.2-264.4 mm
Sat.=80%

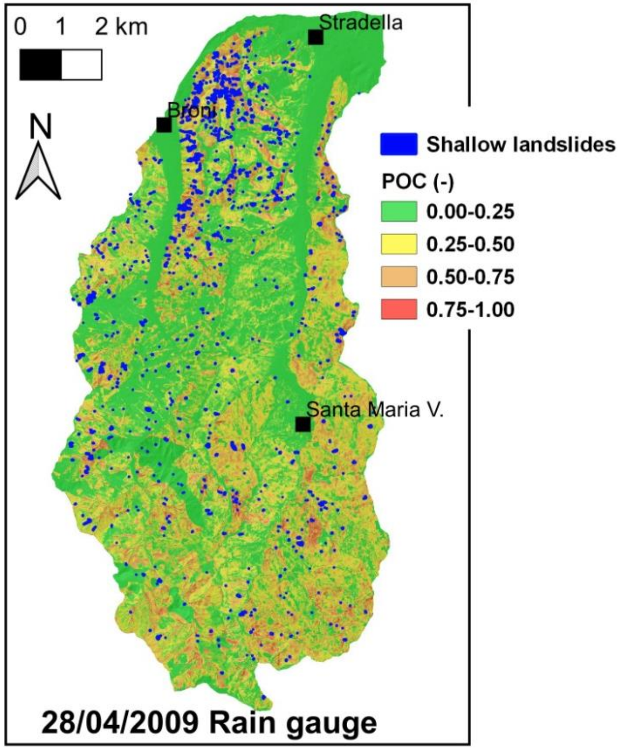
3d-rain=63.0-75.0 mm
30d-rain=176.5-211.0 mm
Sat.=80%

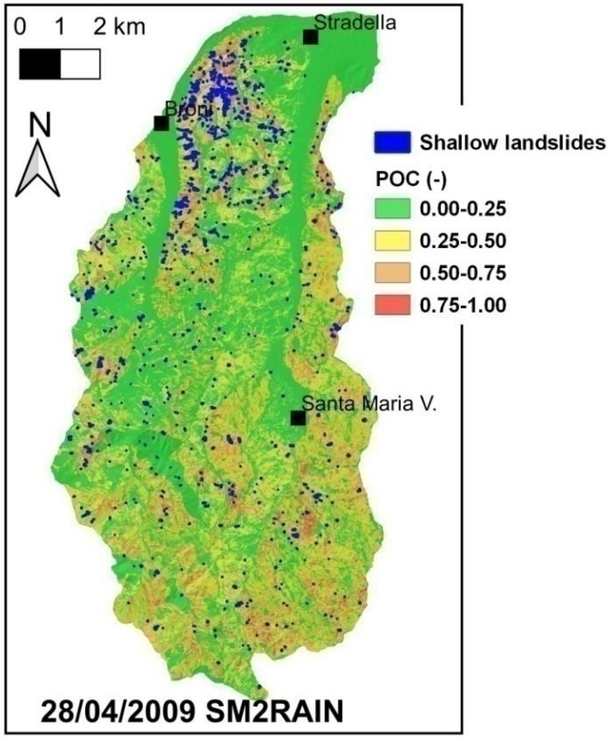
Bordoni et al., 2020

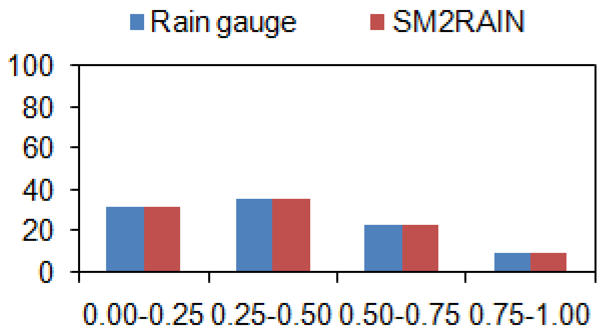
Kappa index=0.97-0.99

6. RESULTS

Scuropasso and Versa catchments - 28/04/2009 → Triggering moment







	Rain gauge	SM2RAIN
AUROC	0.88	0.88
TP	91.8	91.8
TN	84.1	84.1
FP	15.9	15.9
FN	8.2	8.2
Ef	85.3	85.3
Hk	75.9	75.9

3d-rain=113.6-125.8 mm
30d-rain=260.2-264.4 mm
Sat.=80%

3d-rain=63.0-75.0 mm
30d-rain=176.5-211.0 mm
Sat.=80%

Kappa index=1.00

Bordoni et al., 2020

7. CONCLUSIONS AND FUTURE DEVELOPMENTS

Advantages and limits of the proposed methodology

+ Considering the most important soil and geomorphological predisposing factors and dynamic triggering factors
+ Dynamic assessment of spatial and temporal probability of occurrence of rainfall-induced shallow landslides at large scale, with evaluation of its change in time according to different rainfall-soil moisture features
+ Correct modeling of different triggering events, with reliable assessment of the real events and of the correct day of triggering
+ Integration with satellite maps of rainfall and soil moisture

- Significant number of false positives
- Unstable conditions modeled also for 1-2 days following the triggering moment

Future developments

- Integration with more resoluted satellite data (e.g. Sentinel-1, 1x1 km)
- Considering maps of soil moisture modeled at typical depths of sliding surfaces (1 m from the ground)
- Hazard scenarios for different return times

8. REFERENCES

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THANKS FOR THE ATTENTION

For more information on ANDROMEDA project:

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