Comparison of the performance of spatial landslides prediction with TRIGRS1D and SCOOPS3D models and parameters optimization

Application to the Oltrepò Pavese

N. Palazzolo[1], D.J. Peres[2], M. Bordoni[3], C. Meisina[3], E. Creaco[1] and A. Cancelliere[2]

[1] Department of Civil Engineering and Architecture, University of Pavia, Italy

[2] Department of Civil Engineering and Architecture, University of Catania, Italy

[3] Department of Earth and Environmental Science, University of Pavia, Italy

Introduction

Physically based models, coupling hydrological and slope stability models are important tools in landslides prediction. Usually, even complex hydrological models are combined with geotechnical models based on the infinite slope assumption to avoid the higher computational demanding of a multi-dimensional analysis. Only few studies have explored the use of 3D approaches at catchment scale, disclosing the need for more investigation on this issue.

Aim of the research

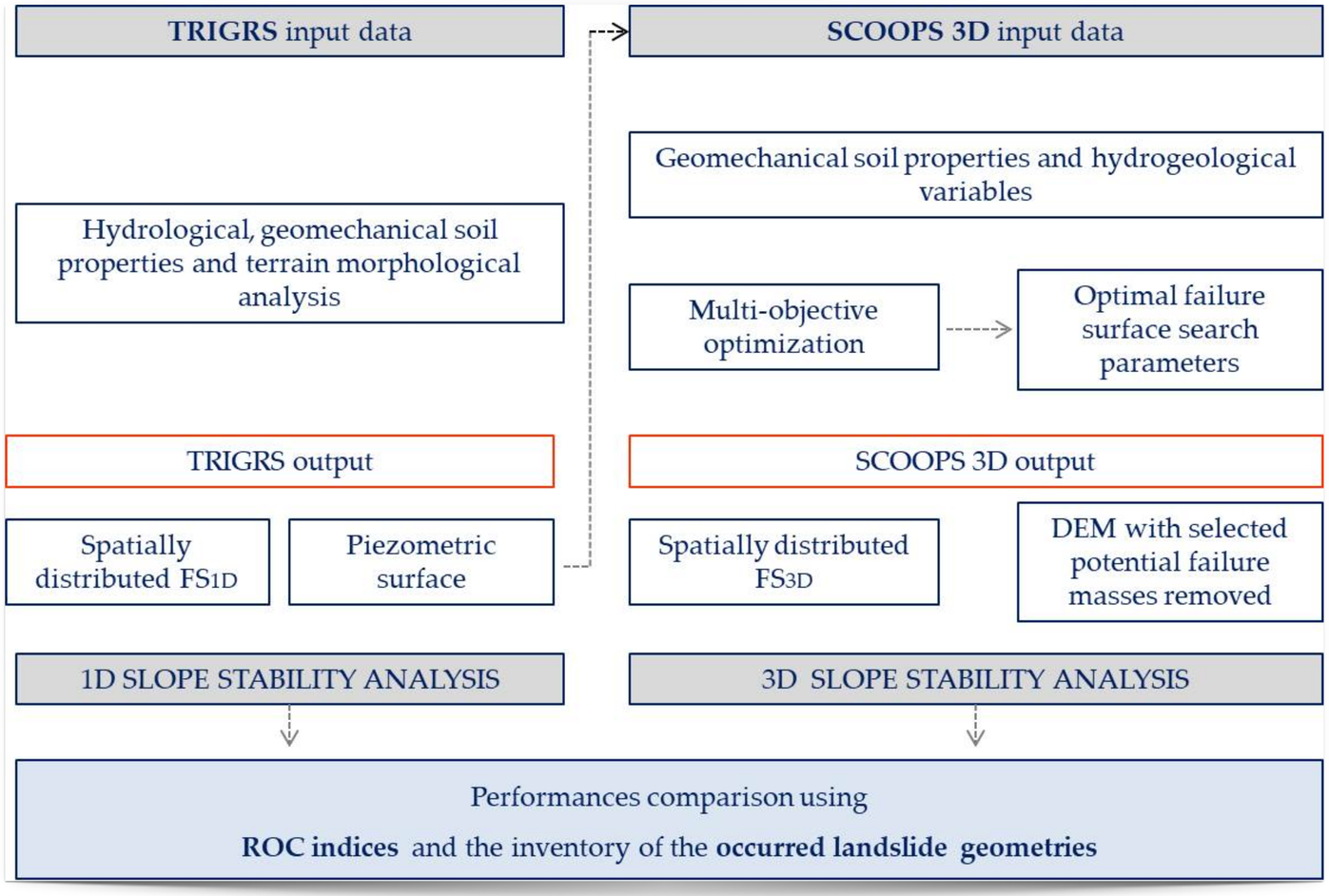
This work aims to investigate the performance of a computational chain adopting two different models:

- TRIGRS v.2.1 (Transient Rainfall Infiltration and Grid-Based Regional Slope-Stability) (Alvioli and Baum 2016) based on the 1D infinite slope assumption
- SCOOPS 3D (Software to Analyze 3D Slope Stability Throughout a Digital Landscape) (Reid ed al. 2015) belonging to the 3D models category

in order to investigate the real advantages and disadvantages of 1D vs. 3D slope stability at the catchment scale

Methodology

- TRIGRS is used for hydrological analysis
- The resulting pressure head field is used first as input to the infinite slope stability model embedded into TRIGRS program itself and then as input to SCOOPS3D, both proposed by USGS
- A multi-objective optimization is proposed to calibrate the SCOOPS3D search parameters to optimize ROC performance statistics, i.e. to maximize the true positive rate while simoultaneously minimizing the false positive rate



Study area

- The approach was applied to a real case study, a catchment in the Oltrepò Pavese region, northern Italy (Figure 1)
- In this region the shapes of triggered landslides were accurately detected after the extreme rainfall event on April 27-28, 2009, feauturing 160 mm in 48 hours (Figure 2)
- Compared to other applications of SCOOPS3D in the scientific literature, in which only a generic point of location of landslides was known, the present work benefits from the availability of a detailed landslides inventory containing observed landslide shapes

γ_s [kN·m^{-3}]	φ' [°]	c' [kPa]	θ_s [-]	θ_R [-]	α_G [kPa^{-1}]	K_S [m·s^{-1}]	D_0 [m·s^{-1}]
18	26	3.8	0.46	0.08	0.014	$1.4 \cdot 10^{-5}$	$2.8 \cdot 10^{-4}$

Figure 1

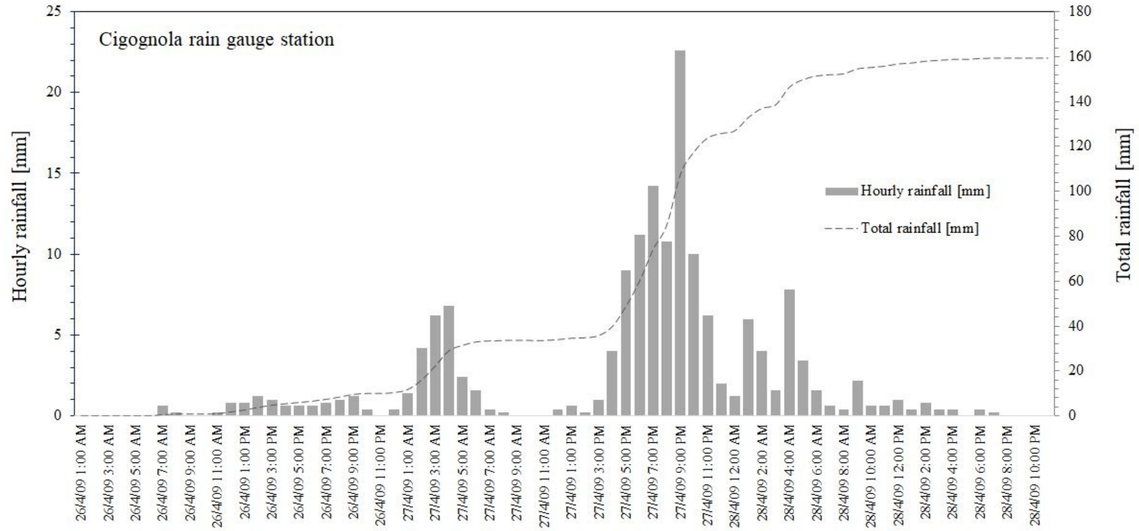


Figure 2

Results

- Figure 3 illustrates the spatial distribution of the unstable areas (red polygons) as a result of each simulation compared with the triggering shapes of the observed landslides (blue polygons)

- Simulation I (slope stability analysis using TRIGRS alone) leads to a rather different spatial distribution of the predicted landslides, neglecting some connectivity of the real failure

- Simulation II (sequence TRIGRS+SCOOPS3D) is more likely to predict observed landslides and incorporates smaller unstable areas into a single larger area

- In terms of True Skill Statistic index, although the 3D model feautures a TSS value equal to 0.4, it is a real improvment if compared with TSS of the 1D model equal to 0.1

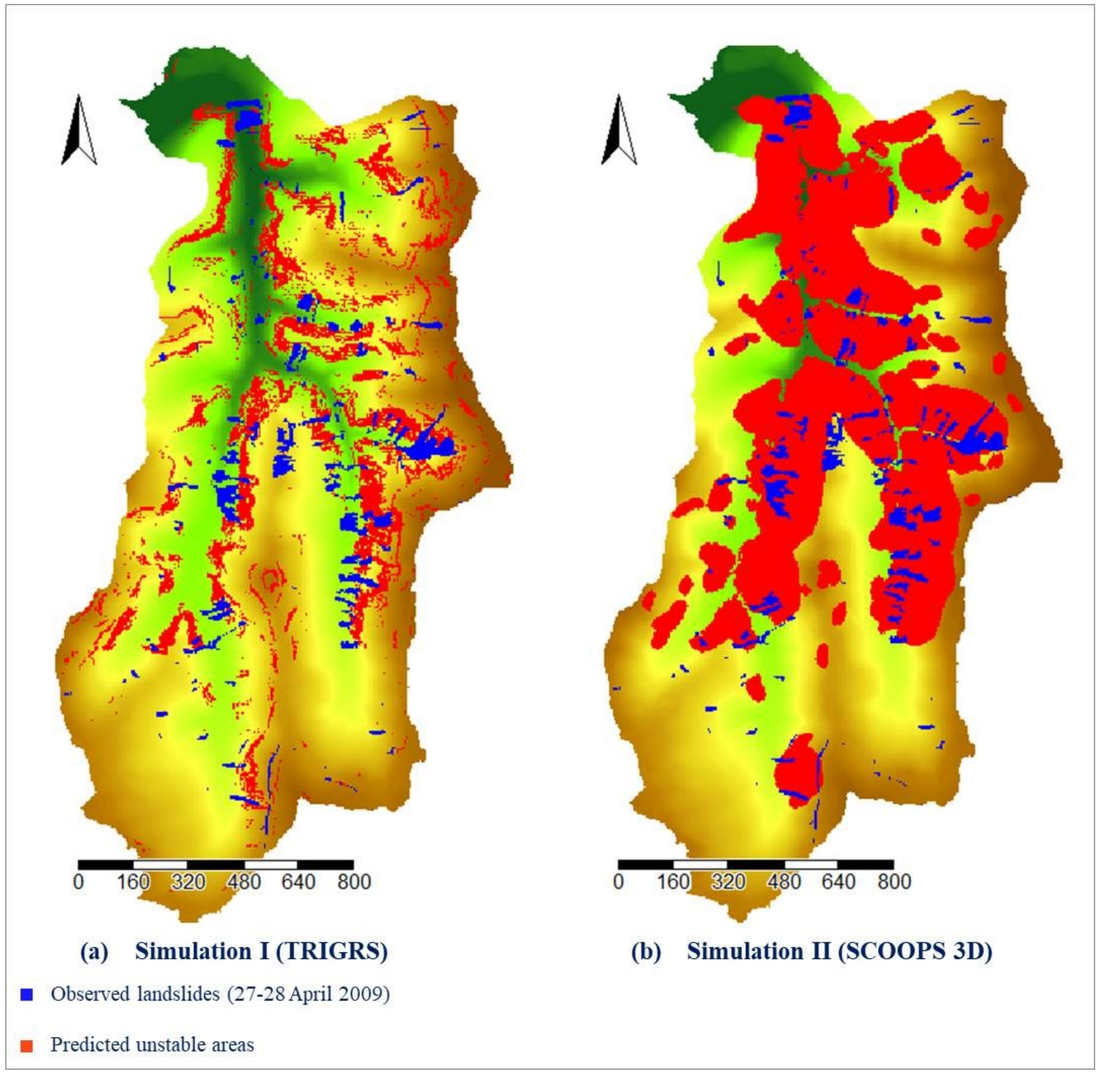


Figure3

Conclusions

- The results suggest that the 3D slope stability analysis can significantly reduce the probability of obtaining false and missing prediction compared to the 1D approach
- The 3D approach overestimates the extension of the unstable area, partially due to the modeling approach inherent in SCOOPS3D, in which soil columns in the slip surface tend to slide simultaneously
- Further efforts must be spent in the comparison between 3D and 1D models and in their sensitivity to the hydrological initial conditions, whose knowledge is commonly subject to a significant level of uncertainty

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Any questions?

nunziarita.palazzolo01@universitadipavia.it

Workgroup

Nunziarita Palazzolo, Department of Civil Engineering and Architecture, University of Pavia, Italy

David J. Peres, Department of Civil Engineering and Architecture, University of Catania, Italy

Massimiliano Bordoni, Department of Earth and Environmental Science, University of Pavia, Italy

Claudia Meisina, Department of Earth and Environmental Science, University of Pavia, Italy

Enrico Creaco, Department of Civil Engineering and Architecture, University of Pavia, Italy

Antonino Cancelliere, Department of Civil Engineering and Architecture, University of Catania, Italy

Thank you!