*Proc. of the 9th International Symposium on Geotechnical Safety and Risk (ISGSR)*
*Edited by* Zhongqiang Liu, Jian Dai and Kate Robinson
*Published by* Research Publishing, Singapore.
doi: 10.3850/GRF-25280825_isgsr-238-P170-cd

# SOME REMARKS ON THE POSSIBLE EFFECTS OF VEGETATION CUTTING ON THE TRIGGERING OF DEBRIS FLOWS IN CENTRAL ITALY

Andrea Lepri

*CIRIAF-Department of Engineering, University of Perugia*
*Via G. Duranti 93, Perugia (Italy). E-mail: andrea.lepri@dottorandi@unipg.it*

Alessandro Fraccica

*Department for the Geological Survey of Italy, ISPRA*
*Via Vitaliano Brancati 48, Rome (Italy).alessandro.fraccica@isprambiente.it*

Vito Tagarelli

*Department of Civil, Environmental, Land, Building Engineering and Chemistry, Polytechnic University of Bari*
*Via E. Orabona, 4, Bari (Italy). E-mail: vito.tagarelli@poliba.it*

Jean Vaunat

*Department of Civil and Environmental Engineering, Technical University of Catalonia (UPC),*
*Campus Nord UPC, 08034, Barcelona (Spain). E-mail:jean.vaunat@upc.edu*

Manuela Cecconi

*Department of Engineering, University of Perugia*
*Via G. Duranti 93, Perugia (Italy). Corresponding Author, E-mail: manuela.cecconi@unipg.it*

The paper focuses on a preliminary study of the effects of vegetation cutting on the activation of debris flows in Nottoria village (Perugia, Central Italy), in2012 and 2015. The main causes of the events have been attributed to intense rainfalls involving valleys location at the outcrop of intensely fractured limestones. In situ surveys and satellite images also revealed vegetation cutting,occurred in the area between 2005 and 2011.

An experimental in situ and laboratory investigation is ongoing to assessthe role of vegetation cutting on the triggeringof the debris flows. The debris material consists of calcareous pebbles of varying sizes diffused in a marly-clayey matrix.

In the paper, the results of conventional direct shear tests on dry and fully saturated samples and in-situ corkscrew measurements are presented and discussed. Starting from dry condition, wetting paths were performed upon shearing, showing an abrupt reduction of volume (*collapse upon wetting*) together with a sharp shear stress reduction, moving towards fully saturated conditions. The hydro-mechanical properties of the material were also investigated when in partially saturation condition.

*Keywords*: vegetation cutting, debris flow, root properties, unsaturated soil conditions

## 1. Introduction

It is well known in the scientific literature that vegetation plays a fundamental role in erosion control and protection of slopes. However, given the complexity of the soil (S)-vegetation (V)-atmosphere (A) interaction mechanisms, the analysis of the effects of vegetation on the mechanisms and processes that define the SVA interaction involves several scientific fields, each of which contributes to the study and modelling of specific aspects of the behaviour of the soil/vegetation system upon different climatic conditions. The topic covers two essential aspects: on one hand the mechanisms by which vegetation promotes mechanical reinforcement of the soil; on the other hand, the phenomena and processes underlying the SVA interaction, which typically require advanced thermo-hydro-mechanical analyses. In this context, anexperimental study is ongoing in order to quantify the contribution of vegetation or, on the contrary, the role of vegetation cutting on the activation of the debris flow phenomena that recently occurred in Nottoria, at the south of Norcia (Perugia, Italy). Indeed, the beech forest that dominates both sides of the investigated debris flow propagation channel had been subjected to cutting of trees, prior to the occurring of the landslide events. This evidence motivates the present study aimed at assessing the effect of tree cutting as a predisposing factor ofthe debris-flow triggering, in addition to the main triggering factor imputable to intense rainfalls. Undoubtedly, the cutting of tree's trunks, even worse, the death and decomposition of trees and roots driven into the subsoil altered the hydraulic conditions and the mechanical properties of the topsoil (Lepri et al., 2024).

## 2. Geological context

The study area falls within the perimeter of ahigh landslide hazard mapped by the official landslide hazard map(P.A.I.). For both the debris flow events (2012, 2015), the main causes of the phenomenon were attributed to the intense rainstorms that affected the valleys, characterised by highly fractured limestoneoutcrops withmarly-clay interlayers, and deposits of altered limestones. These events rapidly transported downward large quantities of solid material reaching accumulation thickness of about 1 m for year 2012 and 0.2 m for year 2015 m. The debris still lying on the propagation channel, generally presents erosion furrows between 1 and 2 m deep, due to water run-off and landslide events occurred.Although it is rather well known that vegetation has been proved to be significantly effective in reducing soil erosion (e.g.: Apollonio et al., 2021), and may prevent runoff-generated debris-flow deposits, this issue is not discussed in this paper.

## 3. Laboratory experimental tests and results

The laboratory investigation on the physical and hydro-mechanical properties of the material involved in the debris flow is currently in progress. In this paper we present and discuss the results of conventional direct shear tests carried out on bare and rooted samples ($D_{\max}$of soil grains= 2 mm), prepared at initial voids ratio $e_0 = 1.0$ in: *i)* fully saturated conditions and in *ii)* dry conditions following wetting paths after the attainment of peak shear strength. The material constituting the debris flow deposit consists of calcareous pebbles of various sizes distributed in a marly-clayey matrix. It is classified as a well graded- to coarse gravel (GW), with uniformity coefficient $C_U = 8$ and curvature coefficient $C_C = 2.4$. The material is composed of very angular grains, with roundness index of 0.15 (Krumbein and Sloss, 1963). Woody roots, with diameters varying between 0.5 and 2 mm (see Figure 1), belonging to beeches and oaks, were found in the soil samples retrieved in situ.The maximum voids ratio was measured, $e_{\max}$= 1.64 (ASTM D4254-16 method A).

### 3.1. *Shear strength properties*

Direct shear tests were performed on remoulded samples of bare and rooted soil. The adopted shear box apparatus is a standard one, the shear force being developed by an electric motor driving, providing a variable speed control. All direct shear tests (ASTM 3080-94) were performed in consolidated drained conditionsat a displacement rate of 0.1 mm/min. The dry material was gently compacted, without dynamic action, inside circular shear boxes (dia. = 50 mm) and then submerged in water to get full saturation conditions or left in dry conditions. No suction measurementswereperformedbeforeandduringthetests.Micrometer dial gauges with a resolution of 0.01 mm were used to measure vertical and horizontal displacements. Increasing stress levels were applied, namely 50,100, 200and 400 kPa. Table 1 reports the initial physical properties of both bare and rooted samples, and roots used in this study.

Table 1. Initial physical properties of bare and rooted soil, and roots($w$: water content; $G_s$: specific gravity; $S_r$: saturation degree; $\gamma_d$: dry unit weight; $\gamma$: bulk unit weight; $e$: voids ratio; $n$: porosity; $D_r$: relative density)

| | $w$ (%) | $G_s$ (-) | $S_r$ (%) | $\gamma_d$ (kN/m$^3$) | $\gamma$ (kN/m$^3$) | $e$ (-) | $n$ (%) | $D_r$* (%) |
|---|---|---|---|---|---|---|---|---|
| SOIL (bare/rooted) | 37.7 | 2.65 | 100 | 13.25 | 18.22 | 1.0 | 50 | 66.7 |
| ROOTS | - | - | - | 8.02 | 14.18 | - | - | - |

*estimated, by assuming $e_{\min} = 0.68$ (average values from Chang et al. (2018), Cubrinovski and Ishihara (2002), Riquelme and Dorado (2017), Santamarina and Cho (2004)).

Thestress–strainbehaviourobservedforboth bare and rooted samples isshowninFigure1intermsof shear stress, τ*vs.* horizontal displacement δx (Figures 1a) , c) ) and measuredvertical displacement δy *vs.*δx (Figure1b), d)).The results clearly highlight the effect of confining stress combined with the beneficial effect of vegetation on the stress–strain behaviour. Forboth moderately and larger applied stress level the bare material in saturated conditions exhibit a ductile and contractive behaviour. Wetting paths upon shearing were also explored in order to simulate a quick rainfall-induced soil saturation. The effect of wetting at peak is very clear in causing a sharp volumetric collapse until a stable condition is observed. Contextually, after a sudden reduction of shear stress due to wetting, the mobilised shear stress further increases towards the same final value attained by the saturated samples. The stress-strain behaviour of rooted samples is slightly different, i.e. it is noted that:

- for both stress levels, the shear strength of rooted soil is approximately 30-50 % larger than the bare one.
- the observed trend is again ductile and contractive, with vertical displacement slightly larger than the bare soil.

- at vertical stress of 400kPa, after wetting at maximum strength, the amount of shear stress reduction and associated volumetric displacement for rooted soil is definitely larger than the bare one. In the range of investigated horizontal displacements, the recovery/retrieval of mobilised shear stress is only partial.

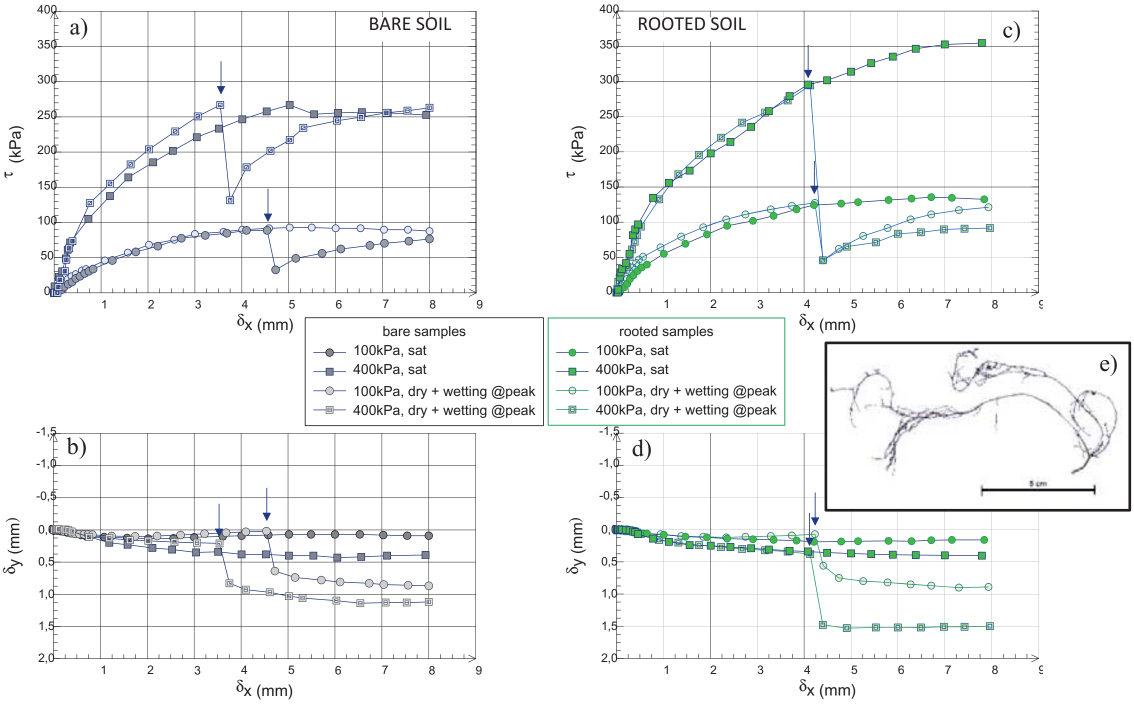

Figure1. Results of direct shear tests on saturated bare samples (Figs. a), b)) and rooted samples (Figs. c), d)). An example of roots retrieved from soil samples is presented in Fig. 1-e).

### 3.2. *Water retention properties*

It is very well known that several mathematical equations have been proposed in the literature to describe the soil-water retention curve (SWRC), provided that the grain size distribution is known. Kamiya and Uno (2000) proposed a method apparently very effective in predicting the SWRC for different soils, as well as being very advantageous for its simplicity. The fundamental assumption is that the entry pore diameter is derived from the grain diameter, through the shape factor of particles $K_s$, and linked to suction through the Young-Laplace equation, while the degree of saturation is linked to passing fractions of the grain-size distribution. Suction measurements were performed through a small tip tensiometer (Soil Moisture Equip. Corp., USA), while gravimetric water content was evaluated through soil mass check. The SWRC obtained from the grain-size distribution of the material retrieved from the study area and a$K_s$ = 10, corresponding to a soil with angular shape grains, fairly predicts the retention measurements carried out (Figure 2).

## 4. In situ tests and monitoring

The need to set up specific in situ instrumentation to detect roots geometry, typology and depth is also recognized, with the goal of quantifying the hydro-mechanical effects of roots on the material shear strength through in situ tests. For this purpose, in-situ investigation has been planned, consisting of corkscrew tests, water content and suction in-situ monitoring, lidar drone and geo-electric surveys.A "corkscrew" test (Meijer et al., 2018) allows to measure the strength of the rooted soil, by means of a corkscrew weeder screwed into the soil at different depths (namely 3 steps, 0 – 125mm, 125–250mm, 250–375mm). At each step, the screw is pulled out and the strength at the interface screw-soil is measured through a load cell. Corkscrews were installed vertically (Figure 3a), rather than perpendicular tothe slope, as this was thought to yield more consistent results as the slope gradient varied across thesite. Results generally indicates a greater accumulation of low soil shear strength values into areas with vegetation cutting (Figure 3b). More measurements will be carried out in the closest areas without cutting.

## 5. Concluding remarks

In this paper, the geological context and preliminary geotechnical experimentalstudies have been presented on a study area affected by debris flow events and on which vegetation cutting has been observed close to the debris flow source area. The mobilized material consists of calcareous pebbles distributed in a marly-clayey matrix. Its shear strength has been investigated through standard direct shear tests and in-situ corkscrew tests, both in vegetated and bare conditions. Vegetation roots were proven to provide a shear strength increase to the tested soil as well as larger volumetric displacements. Both vegetated and bare samples showed volumetric collapse and shear stress loss upon wetting during shearing. In-situ shear strength measurements, topographic surveys and geophysical tests are foreseen in the area to assess the potential role of vegetation cutting on the triggering of debris flows occurred in the previous years.

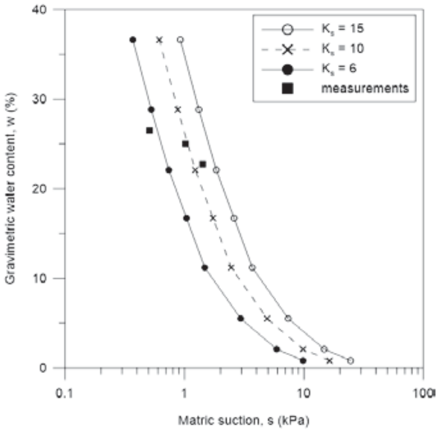

Figure 2.SWRCs estimated through the Kamiya and Uno (2000) model in comparison with measurements.

Figure 3. a)corkscrew equipment and b) investigated area of debris flow (marked by the orange polygon): the symbols refer to the cork-measurements (in kPa) inside and outside vegetation cutting areas (marked by the green polygons). The yellow line is the trace of a bridle built as a risk mitigation work.

**Acknowledgements**
This study has been funded through a project under the Italian National Recovery and Resilience Plan (NRRP).

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