RootS23

1st International Workshop on **Root**ed **S**oils

Soil-Plant-Atmosphere Interaction: Mechanisms, Processes and Geotechnical Engineering Implications

20th – 21st April 2023 PERUGIA, Italy
Department of Engineering, University of Perugia

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Politecnico di Bari

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Preface

This thin volume brings together the synopses of the contributions to the 1st International Workshop on Rooted Soils "SOIL-PLANT-ATMOSPHERE INTERACTION: MECHANISMS, PROCESSES AND GEOTECHNICAL ENGINEERING IMPLICATIONS - RootS23" promoted by the Department of Engineering of Università degli Studi Perugia (Italy) and the Department of Civil, Environmental, Land, Construction and Chemistry, Politecnico di Bari (Italy).

RootS 23 focuses on the current state of knowledge and research concerning the topic of soil-vegetation-atmosphere interaction. This is a very broad and multidisciplinary research theme, spanning several scientific fields, each contributing to the investigation and modeling of specific aspects of the soil and plant behavior, under variable climatic conditions. The considerable current scientific interest for this subject is testified by the numerous scientific studies published in the specialized literature over the last decade.

RootS23 is mainly addressed to researchers in geotechnical engineering, but the participation of researchers working in other fields (e.g., foresters, agronomists, soil physicians, ecologists, ….) is very welcome and considered fruitful for a constructive contamination of knowledge.

RootS23 is intended to be a forum for sharing ideas, recalling basic concepts and discussing recent advances in the thermo-hydro-mechanical behavior of rooted soils, promoting new scientific collaborations. This is the main spirit of the workshop.
The presentations given by the invited Speakers address two main aspects:
- the mechanisms through which vegetation favours ground mechanical reinforcement;
- the phenomena and processes underlying soil-plant-atmosphere interaction, which typically require thermo-hydro-mechanical (THM) coupled analyses.

20 invited presentations will focus in more detail on: plant's physical and hydrological properties, root architecture and properties; experimental evidence of the effects of vegetation evolution on soil hydrological and mechanical conditions; THM numerical analyses of the soil-vegetation-atmosphere interaction; ground bio-engineering techniques for shallow slope stability. The presentations will make reference to case studies and physical modeling.
2 open discussions from the floor will be specifically dedicated to researchers working in the field who shall contribute with very short presentations (2-3 minutes) and/or by posing questions to the Speakers and the floor for a stimulating and informal discussion.
3 half days: the Workshop is held at the Department of Engineering of University of Perugia (Perugia, Italy) on Thursday 20th and Friday 21st April 2023.

We would like to thank the Speakers and all the participants for the interest shown. We hope that RootS23 will stimulate other researchers working in the field and may represent the first of a series of international scientific meetings on the complex interaction among soil-vegetation-atmosphere and its related geotechnical engineering implications.

You are very welcome in Perugia
Enjoy the Workshop!!!

Manuela Cecconi
Federica Cotecchia
Vincenzo Pane
Vito Tagarelli

Programme

Thursday 20th April 2023 - afternoon			
	15:00	Opening session	University of Perugia & Polytechnic of Bari
Topic 1 – ground reinforcement			
1	15:20	**Gerrit Meijer** University of Bath (UK)	Mechanical root reinforcement - Mechanisms, experiments and modelling perspectives
2	15:40	**Vittoria Capobianco** Norwegian Geotechnical Institute (Norway)	Root-soil feedback loops in bio-engineered slopes: examples from experimental studies at laboratory scale
3	16:00	**Pantaleone DeVita** University of Napoli Federico II (Italy)	Control of the coupling between vegetation and soil hydrological regime on the stability of pyroclastic soil mantled slopes in Campania (southern Italy)
4	16:20	**Massimiliano Schwarz** Bern University of Applied Sciences (Switzerland)	Upscaling of root reinforcement for practical applications
16:40 – 16:50 ---------------------------------- **Discussion (10 min)** -------------------------------------			
16:50 – 17:20 -------------------------------------- **Coffee Break** --			
5	17:20	**Giovanni Biondi** University of Messina (Italy)	Seismic performance of root-reinforced slopes
6	17:40	**Zhun Mao** French National Inst. for Agriculture, Food and Environment, INRAE – UMR AMAP (France)	Root mechanical traits: mechanism, variation and impact on root reinforcement
7	18:00	**Francesca Todisco** University of Perugia (Italy)	The role of roots in SPAC and ecohydrological model
18:20 – 18:30 ---------------------------------- **Discussion (10 min)** -------------------------------------			
18:30 – 19:00 **Discussion from the floor – short presentations**			

Friday 21st April 2023 – all day			
Topic 1 - ground reinforcement			
8	9:00	**Giuseppe Cardile** Univ. Mediterranea di Reggio Calabria (Italy)	Assessing the Reliability of Root Reinforcement Techniques for Sustainable Shallow-Landslide Prevention
9	9:20	**Alessandro Fraccica** ISPRA - Italian Institute for Environmental Protection and Research (Italy)	Roots reinforcement mechanisms at different soil hydro-mechanical states: laboratory results and interpretation

10	9:40	**Floriana Anselmucci** University of Twente (Netherlands)	The role of plant roots in the vadose zone: experimental quantification of the hydro-mechanical properties of vegetated sandy soil
10:00 – 10:10 ---------------------------------- **Discussion (10 min)** -------------------------------------			
10:10 – 10:30 --------------------------------------- **Coffee Break** ---			
Topic 2 – THM coupling			
11	10:30	**Alessandro Tarantino** University of Strathclyde (UK)	Physically-based modelling of evapotranspiration to underpin the design of plant-based remedial measures for slope stability
12	10:50	**Ilaria Bertolini** University of Bologna (Italy)	From the calibration of the plant root water uptake spatial distribution to the quantification of its influence on slope stability
13	11:10	**Vito Tagarelli** Polytechnic of Bari (Italy)	The effects of selected vegetation within the soil-vegetation-atmosphere interaction: results from an in-situ test
11:30 – 11:40 ---------------------------------- **Discussion (10 min)** -------------------------------------			
14	11:40	**Anil Yildiz** RWTH Aachen University (Germany)	Volume change behaviour of root-permeated soils
15	12:00	**Sabatino Cuomo**, A. Di Perna, M. Martinelli, M. Moscariello University of Salerno (Italy)	The inception of debris avalanches: possible remediation via long-rooted grass
16	12:20	**David Boldrin** James Hutton Institute; University of Dundee (UK)	Hydro-mechanical reinforcement of slopes by plants: Species and traits matter!
12:40 – 12:50 ---------------------------------- **Discussion (10 min)** -------------------------------------			
13:00 – 14:30 --------------------------------------- **Light Lunch** --			
17	14:30	**Cristina Jommi** University of Delft (Netherlands); Polytechnic of Milano (Italy)	Increasing concern for climate impact on Dutch (organic) dykes
18	14:50	**Jean Vaunat** Universitat Politècnica de Catalunya (Spain)	Soil-Atmosphere-Vegetation interaction: a lesson from a field experiment
19	15:10	**Marianna Pirone**, A.S. Dias University of Napoli Federico II (Italy)	Effects of vegetation on hydro-mechanical behaviour of unsaturated pyroclastic slopes: a case study in Campania region
20	15:30	**Luca Pagano** University of Napoli Federico II (Italy)	Hydrological behaviour of a silty volcanic layer under vegetated conditions
15:50 – 16:00 ---------------------------------- **Discussion (10 min)** -------------------------------------			
16:00 – 16:45 **Discussion from the floor – short presentations**			

Invited Speakers

(in alphabetic order)

Floriana Anselmucci, *University of Twente, Netherlands*
Ilaria Bertolini, *University of Bologna, Italy*
Giovanni Biondi*, University of Messina, Italy*
David Boldrin*, The James Hutton Institute, UK; University of Dundee, UK*
Vittoria Capobianco*, Norwegian Geotechnical Institute, Norway*
Giuseppe Cardile*, Mediterranea University of Reggio Calabria, Italy*
Sabatino Cuomo*, University of Salerno, Italy*
Pantaleone De Vita*, University of Naples Federico II, Italy*
Alessandro Fraccica*, ISPRA, Italian Institute for Environmental Protection and Research, Italy*
Cristina Jommi*, Polytechnic of Milano, Italy; Delft University of Technology, the Netherlands*
Zhun Mao*, French National Institute for Agriculture food and Environment (INRAE – UMR AMAP)*
Gerrit Meijer*, University of Bath, United Kingdom*
Luca Pagano*, University of Naples Federico II, Italy*
Marianna Pirone*, University of Naples Federico II, Italy*
Massimiliano Schwarz*, Bern University of Applied Sciences, HAFL, Switzerland*
Vito Tagarelli*, Polytechnic University of Bari, Italy*
Alessandro Tarantino*, University of Strathclyde (UK)*
Francesca Todisco*, University of Perugia, Italy*
Jean Vaunat*, Universitat Politècnica de Catalunya, Spain*
Anil Yildiz*, RWTH Aachen University, Germany*

Floriana Anselmucci
University of Twente, Netherlands

Short Bio

My name is Floriana Anselmucci, and I am currently working as a Postdoctoral Researcher in the Chair of Soil Micromechanics at the University of Twente (Netherlands). After completing my studies in Civil Engineering at the University of Calabria (Italy), I pursued a Master and PhD in Geomechanics at the University of Grenoble Alpes (France). During my time there, I focused my research on vegetated soil and bio-inspired technologies.
Since then, I have been passionate about understanding how living plants develop in soil and the impact they have on the soil microstructure. In addition to my research on vegetated soil, I have also begun to investigate and understand how we can draw inspiration from living organisms to create new and innovative biotechnologies.
I am excited to continue my work in this field and look forward to collaborating with fellow researchers to develop solutions for the challenges facing our environment.

Lecture Abstract

The role of plant roots in the vadose zone: experimental quantification of the hydro-mechanical properties of vegetated sandy soil

The ways in which climate change impacts the hydro-mechanical properties of soil, particularly within the vadose zone needs to be address by researchers nowadays. Droughts and heavy rains can cause significant stress on the soil, which ultimately affects its microstructure. The presence of vegetation, and the bio-hydrological process associated with it, play a crucial role in determining the hydro-mechanical properties of vegetated soil.
The study presented employs an experimental approach, using drying-wetting cycles to induce hydro-mechanical loads in soil samples, with and without the presence of maize plants. Advanced imaging techniques, such as 4D (3D+time) in-vivo x-ray computed tomography and 3D image analysis, are used to study the water content, pore distribution, root architecture, and microstructure of the soil. The proposed research shows how the elongation of alive plant roots induce a shear strain in the soil microstructure, which is translated into a dilatant volumetric behavior in the soil located nearby the root.

3D analysis of the rooted soil microstructure is coupled with global measurements of the retention properties of vegetated soil. The matric suction and the related soil water retention curves are compared between vegetated and unvegetated soil with same initial properties.

The research findings will offer insights into how climate change affects the vadose zone and how the presence of vegetation can mitigate its negative impacts.

Overall, the conducted investigation emphasizes the importance of understanding unsaturated soil mechanics and bio-hydrological processes. It is illustrated how the root-induced shear dilates the soil, the important role played by root architecture in altering and facilitating the process of evapotranspiration from deeper soil layers, and how the soil water retention properties are strongly affected by the presence of vegetation.

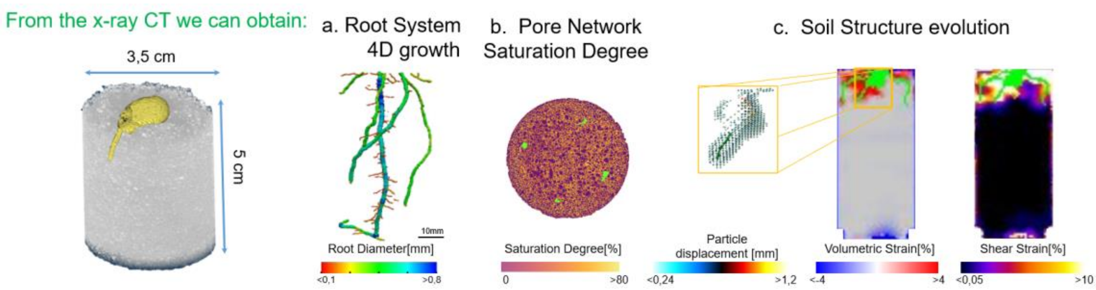

Figure 1 - The x-ray computed tomography allows the observation of the microstructure of vegetated soil. Through image processing, the entire root system architecture is extracted (a.); the saturation degree at pixel level is quantified (b.); the evolution and deformation of the soil structure is measured using digital image correlation (c.).

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Ilaria Bertolini
University of Bologna, Italy

Short Bio

Ilaria Bertolini is a researcher in the field of Geotechnical Engineering and currently Junior Assistant Professor (ICAR/07) at the DICAM Department of the Bologna University (Italy). She earned a Ph.D title from the same Department in 2021 with a thesis on the use of Inverse Analysis for the performance optimization of transient seepage models in river embankments. Her research activity is specific in the fields of the investigation of the response of river embankments subjected to transient seepage conditions and assessment of their vulnerability, of the analysis of the risk connected to backward erosion piping phenomena in river embankments, of the hydraulic benefit given by long-stem plants on the stability of earthen slopes, of soil profiling in fine-grained deposits characterized by a relevant post-depositional history (cementation and aging) by laboratory and field tests and of the effects of soil-structure interaction with specific reference to historic buildings conservation.

Lecture Abstract

From the calibration of the plant root water uptake spatial distribution to the quantification of its influence on slope stability

Soil Bioengineering solutions (SBS) are becoming increasingly popular measures for slopes management. Despite their success, the intrinsic difficulties in the quantification of their effects in soil make hard their conscious use. Vegetation increases slope stability through two main mechanisms: a) mechanical reinforcement of soil given by roots; b) increment in soil matric suction through root water uptake (RWU). A precise assessment of slope stability requires the use of a realistic model which considers both the mechanisms. For a sake of simplification, the problem is often split in two: initially the transient seepage is modelled using a computer code which has implemented Richards' equation and a macroscopic or microscopic model to simulate RWU influence on pore water pressure (pwp) distribution in soil. The simulated pwp distribution in time is then imported as initial condition for slope stability analyses. The numerical modelling of the effects of plant transpiration in soil requires, as input information, the spatial and temporal pattern of RWU in soil, by means of a node-by-node

definition or using root length density distribution models. RWU in soil depends on root architecture and root length density, both difficult to quantify in practical applications. Moreover, RWU is highly dependent on plant species, age and stress factors (influencing root bulb growth) thus its determination is case specific and time dependent. A novel use of a large-scale laboratory experiment (Fig. 1A) is presented for an accurate calibration of the RWU spatial distribution under different imposed boundary conditions, with reference to a native Australian plant, a Melaleuca Styphelioides. Hydrus 2D by Pc-Progress has been used to simulate the different phases of the experiment and to perform the calibration of the model parameters. In 2017 a back-filled slope close to a traffic artery in Newcastle (Australia) experienced shallow landslides due to heavy rains (Fig 1B and C). To stabilise the slope, the use of planting of Melaleuca Stypheliodes has been proposed. The pwp evolution in soil has been investigated in Hydrus 2D for that slope, adopting different configurations and maturities of the plants. Then, slope stability analyses were performed by means of LEM on the different plants conditions and compared to the non-vegetated slope, to highlight the influence of RWU on slope stability assessment. The obtained results in terms of FOS increment, with respect to the bare soil, evidence strong potentials in the use of this plant as SBS for slope stability improvement.

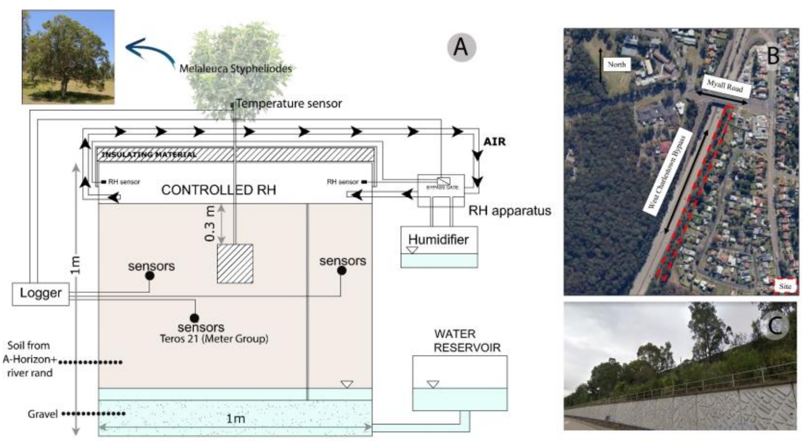

Figure 1: A) Scheme of the large-scale laboratory apparatus, B) aerial photo of the unstable back-filled slope in proximity of the Inner-City Bypass traffic artery in Newcastle (Australia) and C) view of the same slope from the highway.

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Giovanni Biondi
University of Messina, Italy

Short Bio

Giovanni Biondi is associate professor at the University of Messina where he is also head of the laboratory of soil mechanics and referent for the shaking table with laminar box equipment.
His scientific interests concern with the seismic performance of natural slopes, earth dams, retaining structures and shallow foundations. The research activity led to more than 140 publications on peer reviewed journals and in the proceedings of Italian and international conferences.
He is currently member of the editorial board of three international journals, member of the Council of the Italian Geotechnical Group (GNIG), of the Italian Chapter of the International Geosynthetics Society (IGS) and Italian Corresponding Member of the TC218 "Reinforced Fill Structures" of the ISSMGE.
He is/was also member of the organizing or scientific committee of several conferences among which 12 ICG (Rome, 2023), CPT22 (Bologna, 2022), 7ICEGE (Rome, 2019), IIPDB (Taormina, 2012), VI (Bologna, 2016) and VIII (Palermo, 2023) CNRIG, IARG 2008 (Catania).

Lecture Abstract

Seismic performance of root-reinforced slopes

It is largely recognized that vegetation provides a relevant contribute to the stability condition of the shallowest portion of natural slopes. Accordingly, many theoretical and experimental studies have been carried out in the last decades to fully understand the complex root-soil interaction mechanism and its mechanical contribute to the stability of the shallowest soil masses. Conversely, the seismic stability condition of vegetated-slopes have been seldom examined and the need of further insight on their performance during strong ground motions is apparent. In this vein the presentation focuses on the most recent findings on this topic and, starting from a critical review of existing studies, presents some original solutions developed to account for the mechanical effect of roots on the seismic performance of the shallowest portion of vegetated slopes. Specifically, using the pseudo-static approach some solutions for the yield acceleration coefficient have been derived with reference to some simplified

schemes of vegetated slopes. Then, using a modified Newmark sliding--block approach, the mechanical effect of root on the seismic performance of vegetated slopes is investigated.

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David Boldrin

The James Hutton Institute, United Kingdom

University of Dundee, United Kingdom

Short Bio

Dr. David Boldrin (BSc in Biology; MSc in Environmental biology; PhD in Civil Engineering) is a researcher in soil biophysics at The James Hutton Institute and a research fellow in the EPSRC-funded project "Climate Adaptation Control Technologies for Urban Spaces" at the University of Dundee. His expertise lies in soil bioengineering, soil-plant interactions, and root biomechanics. He has established a track-record of published studies on nature-based solutions, from green roofs in the Mediterranean region to soil bioengineering solutions for the North European climate. His work on slope stabilisation by contrasting plants has been recently awarded with the Geotechnical Research Medal 2022. Dr Boldrin is collaborating with leading UK and international universities, such as Durham University and the Hong Kong University of Science and Technology. Dr Boldrin is currently a member of the early-career board of the UK AgriFood4NetZero Network, working on food-system transition to sustainability.

Lecture Abstract

Hydro-mechanical reinforcement of slopes by plants: Species and traits matter!

The use of vegetation to stabilise natural and man-made slopes has gained increasing interest as an environmentally friendly alternative to traditional engineering solutions, which have generally high embodied energy and carbon emission. Plants stabilise slopes by way of mechanical reinforcement (through root anchorage) and hydrological reinforcement (through transpiration-induced matric suction). However, little is known about the effects of plant traits, species and functional groups on slope hydrology and stabilisation. This makes it difficult for engineers to select appropriate species for soil bioengineering. Moreover, soil bioengineering studies often lack the spatial and temporal scale of interest of engineering applications (e.g., reinforcement of man-made slopes), being commonly based on laboratory experiments (controlled environment) or on the monitoring of mature natural vegetation (e.g., woodlands). The talk will present a series of experiments, recently awarded with the Geotechnical Research Medal, on the hydro-mechanical reinforcement of contrasting species, moving

from initial experiments in controlled environments (e.g., soil columns) to the final application and validation of controlled-environment results on a field slope prone to failure, under climate seasonal-variability. Results suggest that a careful choice of species, based on quantitative plant functional-traits, could greatly enhance the available tools for green engineering and the success of nature-based solutions for slope stabilisation. Novel findings on the effects of root growth and decay (e.g., after vegetation clearance) on water infiltration and root mechanical reinforcement will also be presented.

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Vittoria Capobianco

Norwegian Geotechnical Institute, Norway

Short Bio

Vittoria Capobianco received her PhD in Geotechnical Engineering at University of Salerno (Italy) in 2018 on "The effects of roots on the hydro-mechanical behaviour of unsaturated pyroclastic soils", where she carried out an experimental study at laboratory scale. Part of her PhD research was conducted at Hong Kong University of Science and Technology, where she investigated the effect of nutrients in soil on plant growth and the induced soil hydraulic response.

Her main research topics are root-soil interaction in unsaturated slopes, soil-bioengineering to mitigate rainfall-induced shallow landslides, and revegetation of industrial waste materials. The results of her research are published in several international journals and international conferences. Since 2020 she is project engineer at the Norwegian Geotechnical Institute, where her main activities are related to applied research on EU, national and international research projects related to nature-based solutions for natural hazards mitigation, as well as geotechnical consulting projects.

Lecture Abstract

Root-soil feedback loops in bio-engineered slopes: examples from experimental studies at laboratory scale

The soil hydro-mechanical reinforcement provided by roots has been widely acknowledged by the scientific community. However, roots and soils affect each other continuously, by creating feedback loops that are important to understand when adopting vegetation for geotechnical applications (e.g. slope stabilization). This presentation shows a collection of results from physical modelling conducted at laboratory scale to investigate how the hosting soil can influence/improve roots growth and consequently generate positive feedback loops on soil hydro-mechanical behaviour. Three different feedback loops are discussed.

Nutrient feedback loop: By changing nutrient availability in soil (e.g. via fertilizer), the plants may respond by changing their root and shoot growth, which can further impact the soil properties. A column experiment was conducted on the

growth of a tree in NPK nutrient-supplied compacted soil typical of bioengineered slopes and embankments. The effects of nutrient supply on tree-induced soil suction and water-retention ability during evapotranspiration is discussed. This feedback loop is important for supporting plant growth and induced-soil suction, which can in turn help stabilize slopes.

Soil amendments feedback loop: Soil amendments can impact soil porosity by improving soil structure and increasing pore space. Plant roots thrive in soil with greater porosity, and absorb nutrients, contributing to the build-up of soil organic matter. As roots grow further, they may impact the soil structure by changing soil porosity, in turn affecting the roots growth. This feedback loop has been investigated in column tests where bauxite residue soil (BR) has been ameliorated with different combinations of gypsum and organic matter; the effect of soil amendments on roots growth and how this influences soil porosity is discussed.

Mechanical feedback loop: The mechanical properties of the soil, including its shear strength and its deformation, can be impacted by the penetration of plant roots. This feedback loop has been investigated by triaxial tests on pyroclastic soils containing root biomass in different percentages. The results show that in drained conditions, the presence of roots led to a reduction in the volumetric deformation, while in undrained triaxial tests a general reduction of the excess pore-water pressures was observed, with a possible inhibition of the static liquefaction occurrence.

These studies highlight that root hydro-mechanical reinforcement on soil is influenced by the hosting soil itself, thus knowing the root-soil feedback loops is key for a proper design of bio-engineered slopes.

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Giuseppe Cardile
Mediterranea University of Reggio Calabria, Italy

Short Bio

Giuseppe Cardile, Ph.D., is a Geotechnical Engineering Professor at the Mediterranea University of Reggio Calabria, Italy. He is an active council member of the Italian Geotechnical Society (AGI) and serves as the secretary of the Italian chapter of IGS (International Geosynthetics Society). In 2008, he was awarded the IGS Student Award, and in 2017, he received the Best Paper Award (Honourable Mention) from the Geotextiles and Geomembranes Journal. Prof. Cardile is also an editorial board member of prestigious international journals on geotechnical engineering and is a member of various technical committees in IGS and ISSMGE. With 70 scientific papers in International Journals and Conference Proceedings, he has extensively researched landslides and slope stability, soil reinforcement with geosynthetics and vegetation, innovative technologies and materials, sustainable geotechnical works, and the mechanical behaviour of pre-treated municipal solid waste. He has designed several prototype test apparatuses and served as a member of several Organizing and Technical Committees of Geotechnical conferences.

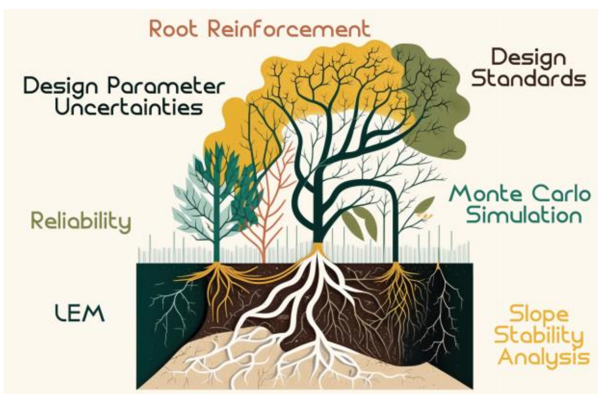
Lecture Abstract

Assessing the Reliability of Root Reinforcement Techniques for Sustainable Shallow-Landslide Prevention

Debris flows have garnered increasing attention from governmental bodies and the international scientific community due to the substantial harm they inflict in fatalities and the cost of repairing structures and infrastructure. These events provide no forewarning, pose significant monitoring challenges, and frequently mobilise vast quantities of material at high velocities, resulting in substantial run-out distances and impact forces exerted by debris flow. Therefore, there is a critical need for a protective policy that employs sustainable landslide risk mitigation measures that consider environmental, social, and economic factors.
Root reinforcement is extensively employed to prevent shallow landslides triggering and for erosion control, contributing substantially to environmental sustainability. Despite the capability of the reliability-based design method to address the limitations of deterministic approaches that do not explicitly consider geotechnical uncertainties, scientific studies have not applied it to

evaluate root-reinforced slope stability so far. Given the inherent uncertainty in root reinforcing provided by plants, it is necessary to investigate the reliability of soil-bioengineering techniques.

This study aims to determine whether using Eurocodes and their partial factors in root-reinforced slope design may result in an unacceptable probability of failure even though they provide satisfactory safety factors. The present research encourages designers to conduct a more informed root-reinforced slope stability analysis. Several probabilistic analyses were conducted using Monte Carlo simulation on the simplified Bishop Method modified to account for pseudo-static forces representing earthquake loading to achieve this. An apparent root cohesion was added to the Mohr-Coulomb failure criterion to account for the mechanical effect provided by roots. The results indicate that not all slope configurations that meet the safety criterion have acceptable levels of reliability, and this is due to the high variability which could characterise the root design parameters. It is crucial to consider the reliability of root-reinforced slopes in the design process to ensure their effectiveness in preventing landslides and controlling erosion while minimising the risk of failure. Moreover, the study sought a tool such as iso-reliability charts to optimise the selection of combinations between average root depth and root strength necessary to achieve the desired reliability level for three distinct slope configurations in a typical seismic scenario.



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Sabatino Cuomo
University of Salerno, Italy

Short Bio

Sabatino Cuomo is Associate Professor of Geotechnical Engineering at the University of Salerno, Italy. He is Coordinator of LARAM School (International School on "LAndslide Risk Assessment and Mitigation) for PhD students, and Board Officer for the Italian Chapter of IGS (International Geosynthetics Society).
Prof. Sabatino Cuomo serves as Associate Editor-i n-Chief of Geoenvironmental Disaster Journal, Springer, and member of the Editorial Board of Computers and Geotechnics, Canadian Geotechnical Journal, Soils and Foundations, Geotechnical Engineering, and Environmental Geotechnics. His research interests include Landslide Mechanisms, Solid-fluid transition, Landslide Dynamics, Regional slope stability, Slope erosion, Geosynthetics reinforcement, Laboratory testing of unsaturated soils, Constitutive Modelling. He has published more than 150 papers in international journals and conference proceedings.

Lecture Abstract

The inception of debris avalanches: possible remediation via long-rooted grass

in collaboration with Angela Di Perna[1], Mario Martinelli[2], Mariagiovanna Moscariello[1]
[1] Geotechnical Engineering Group (GEG), University of Salerno, Italy
[2] Deltares, Delft, Netherlands

Debris avalanches often originate along steep unsaturated slopes and are catastrophic in many cases. Notwithstanding some recent achievements, debris avalanches still pose scientific challenges in relation to their forecast and mitigation. Specifically, in correspondence with high sub-vertical bedrock outcrops, various mechanisms have been observed including the impact loading of soil failed upslope the outcrop, the build-up of pore water pressures in the inception zone, and the bed entrainment along the landslide propagation path. On this complex topic of debris avalanche inception, an experimental and numerical investigation has been started for a few years aimed to explore the feasibility of using long-rooted grass to mitigate or even inhibit the inception of debris avalanches. Based on previous laboratory results achieved through a

careful investigation done in twin 2m-long columns (one bare, one vegetated), where the change in soil retention curve and soil mechanical response have been assessed, an experimental field set-up has been installed in 2020 first, and in an improved configuration in 2021. Here, three different species of long-rooted grass have been grown. In-situ soil suction and water content measurements were periodically collected in the vegetated and original soils. In both cases, soil specimens were also collected, and laboratory geotechnical tests were performed to individuate the changes in both the water retention and strength response. Increased values of soil suction and shear strength were outlined, despite some differences, for all the grown species compared to the original soil. Advanced large-deformation stress-strain hydro-mechanically coupled analyses were recently performed through a Material Point Method (MPM) approach, by using recent laboratory and in-situ experimental data. Original slope conditions were compared to various slope configurations engineered via long-rooted grass. The benefits and the open issues related to this novel green technology for landslide mitigation are discussed. Some promising insights are also outlined related to the possible reduction of the soil volumes mobilized inside the inception zone of debris avalanches.

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Short Bio

Pantaleone De Vita is a geologist carrying out research and didactic activities at the Department of Earth, Environmental and Resource Sciences (University of Naples Federico II, Italy) on topics encompassing fields of engineering geology and hydrogeology. The main research activity has regarded the debris flows involving ash-fall pyroclastic soils that cover the mountain slopes surrounding the volcanic centers of the Campania region, through the reconstruction of engineering-geological models, field soil hydrological monitoring and hydro-mechanical modeling of slope stability. The aim of this research has been focused on the understanding of triggering mechanisms and the estimation of landslide early warning systems, based on rainfall thresholds. Another significant field of research has been related to the estimation of the groundwater recharge processes in karst aquifers of the southern Apennines through the analyses of hydrological processes occurring in the unsaturated zone.

Lecture Abstract

Control of the coupling between vegetation and soil hydrological regime on the stability of pyroclastic soil mantled slopes in Campania (southern Italy)

Ash-fall pyroclastic deposits that mantle steep slopes of the mountainous area surrounding the volcanic centers of the Campania region (southern Italy) are notoriously involved in deadly debris flows under high-intensity and prolonged rainfall, thus representing a principal geohazard for settlements located alongside the footslope areas. In such a geomorphological framework, given the shallowness of the slope instability phenomena, the understanding of the coupling among soil thickness, stratigraphic setting, vegetation cycles and soil hydrological regime is a key factor for assessing and modelling landslide hazard as well as for setting up reliable early warning systems.
Along with this research focus, in the period between January 2011 and June 2020, field monitoring activities were carried out in a test area of the Sarno Mountains to assess hillslope hydrological processes that predispose and trigger slope instability. To such a scope, tensiometers, Watermark and MPS-2 dielectric sensors were installed closely upslope of a landslide source area and distributed

along the vertical according to different soil horizons. Moreover, field surveys aimed at analyzing the contribution of roots on shear strength were carried out by measurements in exploratory excavations of the number, diameter and tensile strength of the root systems.

Results of the soil hydrological monitoring revealed a composite temporal variability, from the daily to the seasonal time scales, related to rainfall patterns and evapotranspiration regime as well as to unsaturated flow dynamics. Unsaturated conditions were always observed with soil water pressure head values ranging at the annual scale from about -0.6 m to, and beyond, -20 m. Therefore, the hydrological regime was found as characterized by a strong seasonal variability reliant on precipitation and evapotranspiration patterns, due to the vegetation cycle of the local deciduous chestnut forest. Frequency analyses of soil water pressure head for each soil horizon showed a strongly delayed timing determining in winter and summer an opposite hydrological behavior between the shallowest and deepest ones. Results of the root measurements showed a Root Area Ratio (RAR) decreasing with the depth, with a reduction of the soil reinforcement with the depth leading to a negligible anchorage to the local bedrock.

The preliminary results obtained can be conceived as a comprehensive approach aimed at understanding and modeling the complex soil-plant-atmosphere interactions, comprising the coupling of soil thickness, stratigraphic setting and vegetation on mechanical conditions that predispose and cause the landslide triggering in pyroclastic soil mantled slopes of the Campania region.

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ISPRA, Italian Institute for Environmental Protection and Research, Italy

Short Bio

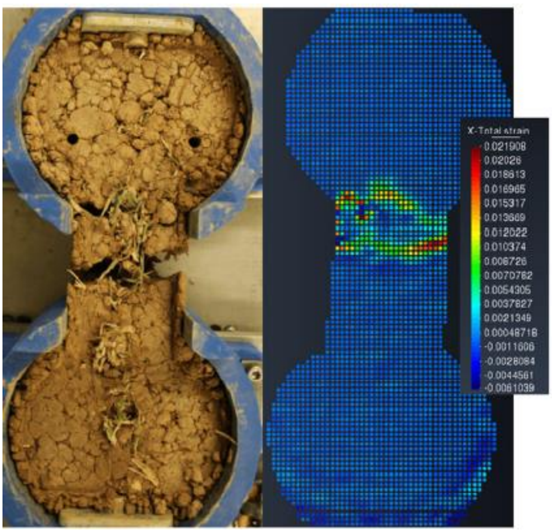
Dr. Fraccica obtained his Bachelor's degree in 'Civil and Environmental Engineering' at the Politecnico di Bari (Italy) and his Master's degree in 'Geomechanics, Civil Engineering and Risks' at the Université Grenoble Alpes (France). He obtained the title of 'PhD in Geotechnical Engineering' at the Universitat Politècnica de Catalunya (Spain), on the effects of vegetation on the hydro-mechanical behaviour of soils. His PhD thesis was awarded as the best thesis presented in Spain, in the years 2019/2020, by the Spanish Society of Soil Mechanics and Geotechnical Engineering (Antonio Soriano Prize). Following a period at the same Spanish university as a post-doc researcher, he was hired as a Technologist at the Department for the Geological Survey of Italy of ISPRA (Italian Institute for Environmental Protection and Research).

Lecture Abstract

Roots reinforcement mechanisms at different soil hydro-mechanical states: laboratory results and interpretation

Nowadays, the use of vegetation to mitigate the risk of landslides and erosion phenomena is having a significant interest from researchers and professionals. Literature agrees that roots improve soil shear strength properties, while counterposed results have been found in terms of soil hydraulic behaviour. Furthermore, there is little information on how roots influence soil microstructure and its consequences at the macroscopic scale. The reinforcement of roots on soils is complex and depends on their morphological and mechanical characteristics and the stresses that develop at the soil–root interface. In this regard, many models have been produced in literature to infer the increase in soil shear/tensile strength due to roots. Among the variables considered, soil hydraulic state was found to have poor relevance, even if some examples on how it affects root’s pull-out are present in literature.

Large cell triaxial tests and tensile tests were carried out to explore the mechanical effects of vegetation on a compacted soil at low confining stresses and at different hydraulic states (monitored in terms of suction and degree of saturation). Root features were thoroughly assessed for each soil specimen and were correlated, jointly with soil hydro-mechanical states, to the two soil reinforcement mechanisms observed (roots breakage and slippage). Strain spatial distributions due to roots presence in soil were also observed by an advanced imaging technique (Particle Image Velocimetry), which helped in the discrimination of the reinforcement mechanisms. A combination of two literature reinforcement models was adopted to interpret the results: one model to consider root tensile strength full exploitation and breakage, and the other to predict friction forces at the soil–root interface during root slippage. The correlation coefficients of these two models were calibrated based on this experimental campaign.



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Cristina Jommi
Politecnico di Milano, Italy
Delft University of Technology, the Netherlands

Short Bio

Cristina Jommi is Professor of Geotechnical Engineering at Politecnico di Milano and Professor of Dykes and Embankments at Delft University of Technology. She got her PhD from Politecnico di Milano in 1992, where she has been working as assistant and associate professor. In 2013, she became Professor at Delft University of Technology and since 2017 she is sharing this position with a professorship at Politecnico di Milano. Her research activity covers the multiphysics behavior of geomaterials from the element scale to the field, with combined theoretical, experimental and numerical approaches. At TU Delft, she has been leading a full-scale test on a historical dyke on soft soils. She is currently working on the monotonic and cyclic response of peats and soft organic soils, and on the consequences of increasing climate stresses on the assessment and maintenance of infrastructures on soft soils. She has co-authored more than 100 scientific publications.

Lecture Abstract

Increasing concern for climate impact on Dutch (organic) dykes

As the Netherlands has been dealing with a water surplus for centuries, the water defence infrastructure has been designed to drain and dispose water and as fast as possible, which is counterproductive in longer periods of drought. In the last years, due to changing weather patterns, the Netherlands is facing more and more relatively long drought periods between April and August also resulting in heavier rainfall events, which recently caused few dyke breaches and flooding of urban areas. Extreme temperatures and prolonged hot summers are increasing the concern about safety of the water defence infrastructure, which is being addressed through many research initiatives promoted by public authorities.
Compared to other countries, the risk for the Netherlands is increased by presence of various kilometres of dykes made of peat or lying on peat layers, which have been providing a natural carbon sink over the past centuries thanks to waterlogged conditions. However, unfavourable environmental conditions due to increasing temperatures and more frequent droughts will reduce their water retention capacity, increase their temperature sensitivity and their

decomposition rate, in turn producing and emitting greenhouse gases, including CO2 and CH4. Evidence of gas production from increasing decomposition rate is coming from pore pressure measurements in saturated layers below the water table, which are being monitored to assess the safety of the water defence infrastructure. Increasing water pressure in closed piezometers compared to vented ones seem to suggest that gas is produced and capped in the ground, until the breakthrough pressure is reached and the gas vents from cracks opened in the soil matrix.
A research effort has been undertaken in the last years at TU Delft to investigate in depth the consequences of drying of peats on their hydromechanical properties, paying special attention to the degradation of fibres, which are responsible of the high strength mobilised by peats in the ground and of most of the water holding capacity of the organic soil. The role of biogenic gas on the hydromechanical response of peats is also investigated, in an attempt to provide comprehensive experimental information for the development of advanced theoretical and numerical models to be used in the practice. The contribution provides a comprehensive overview of experimental results, constitutive and numerical modelling recently developed to address current concerns and possible mitigation measures.

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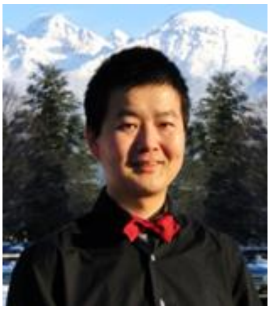

Zhun Mao
French National Institute for Agriculture food and Environment (INRAE – UMR AMAP)

Short Bio

Dr. Zhun Mao obtained his PhD in ecology in the University of Montpellier (France) in 2011. Since 2015, he has been a research scientist at the French National Institute for Agriculture food and Environment (INRAE) and a member of the Joint Research Unit of botAny and Modelling of Plant Architecture and vegetation (UMR AMAP), i.e., an interdisciplinary lab specialised in ecology, plant sciences and applied mathematics. Zhun is interested in applied ecology and his research has focused on belowground ecosystem services provided by vegetation, including soil fixation by roots and carbon sequestration.

Lecture Abstract / Lecture Highlights / Lecture Summary

Root mechanical traits: mechanism, variation and impact on root reinforcement

Root tensile strength, strain, stiffness and toughness are commonly used traits to describe a root's mechanical robustness. They are widely incorporated as key inputs in root reinforcement and slope stability models that assess the contribution of vegetation for protecting against shallow landslides. Today, despite the increasing studies measuring root mechanical traits, our understanding on them is still limited: why are their values so various at intra- and interspecific levels? How are they important in moderating root-soil interaction and affecting root reinforcement? Here, I try to provide some preliminary answers to these questions using several recently published results at individual root and root bundle scales.

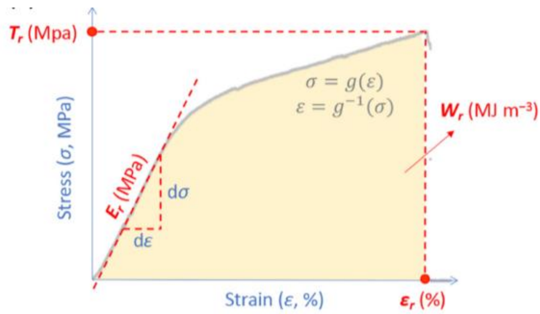

Fig. 1 – Different root mechanical traits illustrated over a stress versus strain curve of a root.

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Gerrit Meijer
University of Bath, United Kingdom

Short Bio

Dr Gerrit Meijer is a lecturer in geotechnical engineering at the University of Bath. For the last ten year he has worked on various aspects of root-reinforced soils, including in situ testing as well as physical, analytical and constitutive modelling. He enjoys experimental investigation into soils that appear to defy traditional soil mechanics and likes to develop models that had a thorough shave with Occam's razor.

Lecture Abstract

Mechanical root reinforcement - Mechanisms, experiments and modelling perspectives

Vegetation can be used as a green and sustainable way to reinforce slopes, embankments or cuttings against instability. Plant roots add additional strength to the soil, analogous to the function of steel rebar in reinforced concrete. Incorporating this mechanical reinforcement in engineering design however comes with unique challenges – affecting both experimentation ("how to measure reinforcements?") and modelling ("how to predict reinforcements?").
Root reinforcement varies both in space and time, making it challenging to accurately quantify. The fibrous nature of the root system and low soil stress levels make it difficult to collect undisturbed soil samples and conduct conventional geotechnical laboratory tests. We will look at innovative in situ testing devices that can be used to obtain rapid quantification of rooted soil strength and will cover physical modelling of vegetated slopes using a geotechnical centrifuge.
Modelling efforts traditionally focussed on quantifying the root reinforcement as an increase in soil cohesion. While this "root cohesion" approach may be practical for ultimate limit state design, it provides little information about how soil and roots interact during strength mobilisation. We will look at various new modelling approaches with an increasing level of complexity, starting at (revised)

fibre bundle models, then on to analytical modelling roots as cables or beams, and ending with constitutive models for rooted soil based on composite theory.

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Luca Pagano
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Short Bio

Civil Engineer degree in 1991. Ph.D degree in Geotechnical Engineering at the University of Rome La Sapienza in 1996. Researcher in Geotechnical Engineering at University of Naples "Federico II" (2000-2011). Associate professor in Geotechnical Engineering at University of Naples "Federico II" since 2011. National qualification as a Full Professor of Geotechnical Engineering in 2014 and 2019. Research themes pursued in his scientific studies: static and seismic behaviour of earth dams, river embankments, road embankments; full-scale physical modelling of floods on river embankments; seismic behaviour of natural and artificial slopes; retaining wall; rainfall-induced landslides in shallow volcanic covers; experiments by physical modelling of rainfall-induced landslides; experiments by physical modelling of soil-atmosphere interaction of silty volcanic soils by lisimeter; monitoring of natural slopes; development of early warning systems for geotechnical systems.

Lecture Abstract

Hydrological behaviour of a silty volcanic layer under vegetated conditions

This work examines the hydrological behaviour of a silty volcanic layer (SIL) of one cube meter (thickness=75 cm) exposed to the atmosphere over 12 years. Monitoring is designed for estimating energy fluxes, incoming or outgoing water fluxes and how these fluxes relate to internal hydrological and thermal variables. Instrumentation records internal hydrological variables (soil suction, soil water content, layer water storage), thermal variables (soil temperature, soil heat flux) and atmospheric variables (air temperature, air relative humidity, wind speed, net radiation, solar radiation). Five years of the experiment have been conducted under vegetated conditions, sowing a grass whose root apparatus expanded throughout the layer. Four years are tested with the layer surface under bare conditions and three years placing a wooden embers cover (WEC) 5 cm thick on the SIL (it simulates the residual material of a wildfire). Measurements allow building representations of the layer’s behaviour patterns depending on its surface covering, comparing the behaviour in vegetated conditions with those observed under bare and WEC conditions.

Results show that differences in fluxes and hydrological variables among the three tested conditions reduce to negligible levels during cold-wet periods but increase significantly during hot–dry and transition periods. Suction trends recorded under vegetated and bare conditions arise similarly over wet periods while differing over dry periods. Under substantial meteorological forcing, vegetation induces higher suction levels in depth due to water uptake action exerted by roots and lower suction levels at shallowest positions due to shade from vegetation cover. Under WEC conditions, suction levels recorded during wet periods are comparable with those observed under bare and vegetated conditions. Suction increments observed during the dry periods result instead much more limited. Suction levels never overtake tensiometer full scale (80 kPa) during summer without requiring maintenance due to desaturation as it occurs under bare and vegetated conditions.

Wetting patterns delivered by TDRs at different depths and continuously weighing the layer result consistent with suction patterns. Under all cover conditions, water content approaches saturation during the wet periods, while it reduces to different "dry levels" for the three cover conditions. Minimum values at all depths are observed under vegetated conditions, while maximum under WEC conditions due to the thermal and capillary barrier exerted by WEC on SIL that significantly inhibits outgoing fluxes during dry periods.

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Marianna Pirone
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Short Bio

Marianna Pirone is an Associate Professor in Geotechnical Engineering at University of Naples 'Federico II'. She teaches Geotechnics in the M.Sc. course in Building Engineering. Her research themes concern: unsaturated soil mechanics; field monitoring of slopes; numerical modelling of unsaturated and saturated soil slopes and earth embankments; analysis and design of slope stabilising piles and drainage for slope stabilization. In particular, for many years she has been interested in field monitoring of pyroclastic slopes in Campania region for on time prediction of flow like-slides. Recently, she is on the development of a prototype for the measurement of the volumetric water content in unsaturated pyroclastic soils.

Lecture Abstract

Effects of vegetation on hydro-mechanical behaviour of unsaturated pyroclastic slopes: a case study in Campania region

Marianna Pirone, Ana Sofia Dias

In Campania, shallow pyroclastic soil covers are susceptible to flow-like landslides triggered by intense rainfall. The antecedent hydraulic state of the slope combined with unfavourable local geomorphological factors represent the predisposing conditions of these phenomena. In this context, the effect of the local vegetation on the stability of a natural pyroclastic slope was investigated by setting up a Test Site in Mount Faito (Campania, Southern Italy) on March 2017. The vegetation is mainly composed of cultivated Castanea sativa.

In the laboratory, the influence of the roots on the soil hydraulic properties was investigated: saturated hydraulic conductivity, soil-water retention properties and root dry biomass were concurrently determined on undisturbed soil samples containing roots of C. sativa. The soil specimens with more roots presented higher hydraulic saturated conductivity and lower air-entry value. These observations could be explained by the preferential water flow enabled

by the roots and a change in the pore-size distribution resultant from the microbial and plant activity in the soil (Dias et al., 2022a, b).
Field monitoring was performed to understand how the roots' distribution of C. sativa affects the groundwater regime. An attempt of correlation between field measurements with the root density determined at the boreholes close to the instrumented vertical is still in progress.
Then, the mechanical soil reinforcement due to tree roots was determined using the Fibre Bundle Model as function of the Root Area Ratio (RAR). It was estimated that roots increase the soil shear strength by providing additional cohesion to the soil of up to 25.8 kPa. By modelling the monitored slope section as infinite preliminary, the root reinforcement was able to guarantee the stability of the cover close to fully saturation (2-3 kPa of matric suction) until an inclination of 42°(Dias, 2019). Such conclusions may be extended to the other areas of Campania where C. sativa plantations are present.

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Massimiliano Schwarz
Bern University of Applied Sciences, HAFL, Switzerland

Short Bio

2010: Doctorate in Natural Sciences, Swiss Federal Institute of Technology (ETH), Zürich, Switzerland, title: „Hydro-mechanical characterization of rooted hillslope failure: from field investigations to fiber bundle modeling“.
Advisor Prof. D. Or (EPFL-ETHZ).
2006: MSc Degree in Forest and Environmental Science, University of Florence, Italy. Thesis: Development of plants and soil within the scope of soil bioengineering measures.
Advisor Prof. F. Preti (UNIFI) and Dr. F. Graf (SLF-WSL).

Since 2022: Bern University of Applied Sciences – HAFL, Zollikofen (CH)
Full Professor of Forest Soil Sciences and Ecological Engineering
2010 – 2022: Bern University of Applied Sciences – HAFL, Zollikofen,(CH)
Lecturer, Scientific collaborator & Project Leader (80%), Group of Mountain Forests, Natural Hazards, and GIS
2016 University of Sydney, Sydney (AU), Visiting researcher
2011 Landcare Research, Christchurch (NZ), Visiting researcher
2010 - 2013 WSL, Birmensdorf (CH), Post-Doc (20-80%)

Lecture Abstract

Upscaling of root reinforcement for practical applications

The quantification of root reinforcement and its realistic implementation in practical tools for integrated risk and protective forest management are of fundamental importance for land-use planning. The challenge faced by researchers and experts is that to find the compromise between quantification of complex processes with models and their pragmatic application in current practice. The more is the need to simplify a model, the greater is the need to understand what of the processes can be legitimately simplified.
In line with this motivation, this contribution discusses the upscaling of root reinforcement for practical applications starting from the single root mechanics up to the quantification of risk reduction at regional scale. The basic steps of the

presented applications are the use of the RBMw model for the calculation of root reinforcement under different types of sollecitations, the characterization of the spatial and temporal distribution of root reinforcement at the individual tree/stand scale, and finally the implementation of the spatio-temporal information of root reinforcement in different types of modelling approaches for the quantification of geo-morphological processes.

The relevance of the practical applications is discussed in the contest of several case studies such as the design of bio-engineering measures (model RBMw, SOSlope and SlideforNET), the definition of guidelines for the management of protection forests (model SlideforNET), the prioritization of natural based solutions for risks mitigation (model SlideforMAP, BankforMAP) and the temporal changes of risks due to climate changes and forest disturbances (model SlideforNETdynamic). These tools are available on the EcorisQ platform.

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Vito Tagarelli
Polytechnic University of Bari, Italy

Short Bio

Vito Tagarelli gained a PhD in 2019 at the Polytechnic University of Bari (PoliBA, Italy), defending the thesis: "Analysis of the slope-vegetation-atmosphere interaction for the design of the mitigation measures of landslide risk in clayey slopes". During the PhD Vito Tagarelli conducted numerical modelling of whether-induced landsliding, as well as in-situ monitoring, and the set up of a vegetated field test at the slope scale, by seeding selected deep-rooted vegetation. Part of his PhD research was conducted at the Universitat Politecnica de Catalunya, where he carried out thermo-hydraulic modelling. From 2019 to 2022 Vito Tagarelli was a post doc researcher at PoliBA, where since the 2023 he holds the position of assistant professor in Geotechnics and Slope Stability. His main research topics are thermo-hydro-mechanical numerical modelling, diagnosis of the landsliding, slope-vegetation-atmosphere interaction, early warning system for weather-induced landslides, root-soil interaction in unsaturated slopes, soil-bioengineering to mitigate weather-induced landslides.

Lecture Abstract

The effects of selected vegetation within the soil-vegetation-atmosphere interaction: results from an in-situ test

The soil-vegetation-atmosphere (SVA) interaction is becoming a subject of intense scientific research within the geotechnical community, motivated by the wish of using selected vegetation as sustainable mitigation measure for erosive phenomena and landslide processes. The use of novel naturalistic interventions adopting vegetation have been already proven to be successful in the reduction of erosion along sloping grounds, or in increasing the stability of the shallow covers of slopes; whereas the efficiency of vegetation as slope stabilization measure still needs to be scientifically proven for slopes location of deep landslides, whose current activity is weather-induced, as frequent in the south-eastern Apennines. Recently, though, peculiar natural perennial grass species, which are able to develop deep root systems, have been found to grow in the semiarid climate characterizing the south-eastern Apennines and to determine a relevant transpirative flow. Their leaf architecture, crop density, combined with

their transpiration capacity, make in principle such grass species suitable for the reduction of the net infiltration rates. Hence, the grass species here of reference have been selected as vegetation measure intended to determine a reduction of the piezometric levels in the slope down to large depths, to increase the stability of deep bodies, eventually. To this aim, a full scale in-situ test site of about 2000m^2 was realized at the toe area of a deep landslide mechanism where selected Gramineae crops were seeded and farmed (Fig. 1). The test site was also equipped with sensors for monitoring the SVA interaction, i.e., the soil state, the forcing atmospheric action and the vegetation features. The impact of the vegetation on the soil state was investigated, both within the vegetated test site and outside it, where only spare and spontaneous wild plants occur, to assess the effects of the seeding of the selected vegetation (Fig. 1). Furthermore, the properties of the rooted clayey soil cover were investigated in laboratory and in-situ in terms of both saturated permeability and retention properties.

All the measurements were coherent in testifying that roots impact on the hydraulic properties of the soil, by both increasing the permeability and reducing the retention properties of the composite material. Overall, despite the vegetation caused an increase in the saturated permeability, the impact of selected vegetation is believed to be positive, since the net rainfall was found to decrease, due to the combined effect of the aerial portion and roots system.

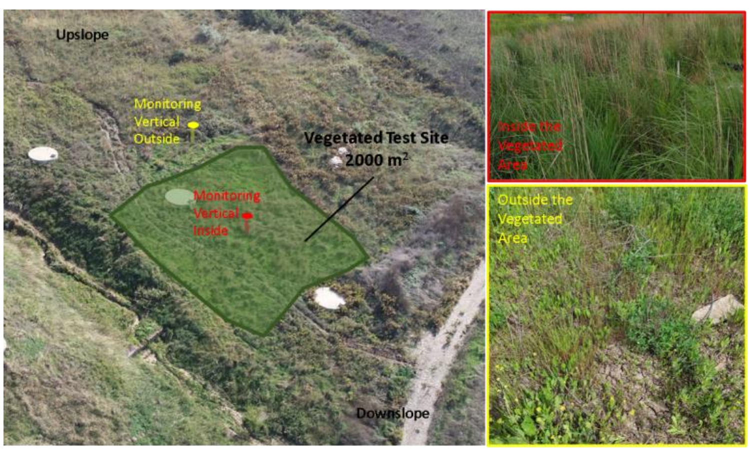

Fig.1 – View of the vegetated test site area and pictures of the plants inside/outside the Test Area.

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Alessandro Tarantino
University of Strathclyde (UK)

Short Bio

Alessandro Tarantino is Professor of Experimental Geomechanics at the University of Strathclyde in Glasgow, Scotland. He is leading researcher in the field of unsaturated soil mechanics and a renowned specialist in the measurement of medium and high suction (water tension). He has been keynote/theme lecturer at the 3rd, 4th, 5th, and 8th International Conferences on Unsaturated Soils (Brasil 2002/ USA 2006 / Spain 2010 / Greece 2023), the 2nd and 3rd European Conferences on Unsaturated Soils (Italy 2012/ France 2016), the 3rd International Conference on 'Soil Bio- and Eco-Engineering (Canada 2012), and 16th IACMAG Conference (Italy 2022). He led major European consortium projects including the European Training Network 'TERRE ('Training Engineers and Researchers to Rethink geotechnical Engineering for a low carbon future) and the Industry-Academia Partnerships and Pathways 'MAGIC' (Monitoring systems to Assess Geotechnical Infrastructure subjected to Climatic hazards'). He has been nominated to give the ICE Géotechnique Lecture 2023.

Lecture Abstract

Physically-based modelling of evapotranspiration to underpin the design of plant-based remedial measures for slope stability

Plants represent a potential Nature Based Solution to improve stability of natural and engineered slopes. Plants can reinforce slopes hydrologically by removing soil water via transpiration to generate stabilising suction. In turn, the depletion of soil water content reduces the hydraulic conductivity of the shallow layers, and this hinders rainwater infiltration during the wet period possibly preserving suction in the deeper layers susceptible to failure. Hydrological reinforcement is key to reinforce slopes for the very frequent case of failure surfaces developing below the root zone (where root mechanical reinforcement obviously plays no role). Evapotranspiration can occur in two different regimes, 'energy limited' and 'water limited' respectively. Energy limited evapotranspiration, also referred to as potential evapotranspiration, occurs when the soil-plant system can supply the water demanded by the atmosphere. Potential evapotranspiration is driven by solar energy, air relative humidity, and wind speed. When the degree of

saturation and, hence, the hydraulic conductivity of the soil declines, the soil-plant system is not able to accommodate the evaporative demand of the atmosphere and the evapotranspiration reduces. This regime is referred to as 'water limited'. A very convenient and widely used approach to model water uptake by vegetation in these two regimes is to consider actual transpiration AET as the product of the potential (energy-limited) evapotranspiration PET times a reduction factor β (AET= β·PET), assumed to be a function of soil suction in the root zone (Fig. 1). This approach is convenient in geotechnical numerical modelling because only requires information about the suction in the root zone without the need to address the complex interaction between the soil, the plant, and the atmosphere. However, this simplicity is only apparent because the complexity of such an interaction is hidden in the 'empirical' choice of the parameters of the reduction function. To improve upon vegetation-based hydrological stabilising techniques, it is vital to develop physically-based transpiration models that account for the hydraulic characteristics of the soil and plant (below- and above-ground) in turn to guide the choice of suitable plant functional traits.

This presentation introduces and discusses a novel closed-form transpiration reduction function developed around the concept of Soil-Plant-Atmosphere Continuum (SPAC) (Fig. 2).

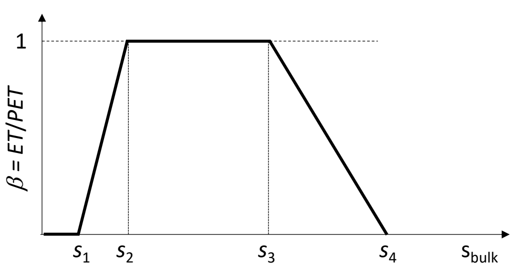

Fig. 1. Feddes reduction function

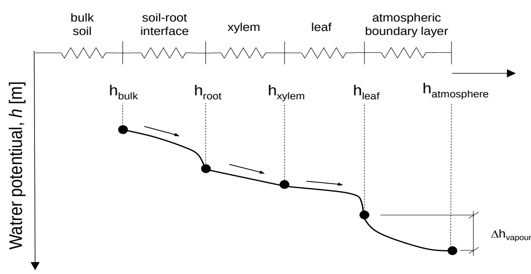

Fig. 2. Hydraulic resistances in the SPAC system

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Short Bio

Francesca Todisco, is a professor of Agriculture and Forestry Hydraulics at the University of Perugia, has a Master degree in Civil Engineering with a focus in Hydrology, and a PhD in Hydronomy. Is Associate editor of Journal of Agricultural Engineering, water in the terrestrial biosystems, and member of the Academic Board of the PhD in Agricultural, Food and Environmental Sciences and Biotechnology. Has a long experience in the research field aimed at correct and sustainable water management. In particular, she has also participated as principal investigator in research projects finalized to the definition, calibration and application of SPAC models for the optimization of agricultural water management and irrigation; to the use of sensor-based monitoring systems for the advanced control of hydraulic water distribution networks integrated into digital platforms and smart control systems; to assess agricultural drought for the quantification and mitigation of current climatic trends and their impacts on water resources and water needs in agriculture. As a chief researcher of the Soil ERrosion experimental LABoratory (SERLAB), she works on physical models reproducing hydrological processes and nature-based solutions in a slope field, for the study and modelling of the hydrological processes involved and for the characterization, testing, and design of soil protection strategies.

Lecture Abstract

The role of roots in SPAC and ecohydrological model

Water is the key factor controlling fluxes in the soil-plant-atmosphere continuum (SPAC) and ecological-hydrological processes in subsurface environments. Roots represent an interface between plants and soil, providing entrance and initially distributed pathways for fluxes of water and nutrients from the external environment to the plant. Water flows into the roots in the process called water uptake, a function of the rhizosphere water potential distribution, axial and radial root conductivities, and the three-dimensional architecture of the root system. Furthermore, soil water is tunnelled along roots, forming preferential flow that triggers rapid lateral subsurface flow and creates nonuniform flow transport.

The process description of plant transpiration and soil water uptake in macroscopic root water uptake models is often based on simplifying assumptions. The most common approach in soil-plant-atmosphere continuum (SPAC) macroscopic models is to consider only root depth or concentration in the soil profile, combined with some empirical or physically based function of water content or water potential limiting water.
Several eco-hydrological and plant-scale models preserve the variability in three-dimensional root architecture. The specific emphasis on root processes is essential for understanding the spatiotemporal dynamics of soil moisture in the rhizosphere, the hydrological processes associated with vegetation, and the appropriate design and calibration of SPAC models.
Vegetation traits and roots traits have decisive effects on the life of plants and their adaptivity to the environment. Hence, given the central role of water-plant interactions in the climate system, representations of vegetation attributes were included in early Earth system models (ESMs).
My presentation will highlight the role of roots in the SPAC, ecohydrological and ESMs models.

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Short Bio

Jean Vaunat is Professor of Modelling in geoengineering, Foundations and earth retaining structures and Soil mechanics at BarcelonaTECH, belonging to the International Centre for Numerical Methods in Engineering, within the Department of Civil and Environmental Engineering, Universitat Politècnica de Catalunya at Barcelona, Spain.
His research activity covers the multiphysics behavior of geomaterials in both saturated and partially saturated conditions from the element scale to the field, with combined theoretical, experimental and numerical approaches. He is co-author of more than 100 scientific publications.

Lecture Abstract

Soil-Atmosphere-Vegetation interaction: a lesson from a field experiment

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Short Bio

Anil Yildiz works as a postdoctoral researcher at the chair of Methods of Model-based Development in Computational Engineering, RWTH Aachen University, Germany. He earned his B. Sc. Degree in Civil Engineering at Bogazici University, Istanbul, Turkey in 2010, and obtained his Dr. sc. In Civil Engineering from ETH Zurich, Switzerland in 2018. He has been awarded the Culmann Prize 2019 for an outstanding thesis on the quantification of biological effects on soil stability. He worked at the National Green Infrastructure Facility and Newcastle University, United Kingdom, and University of Göttingen, Germany as a postdoctoral researcher after completing his PhD. His research focusses mainly on geohazards, covering a wide range of topics, such as shallow landslides, root reinforcement, soil-plant-atmosphere interactions, and methods, such as complex laboratory and field testing as well as computational and surrogate modelling.

Lecture Abstract

Volume change behaviour of root-permeated soils

Shallow landslides, either on bare or vegetated slopes, can be triggered after a rainfall event due to loss of suction. Vegetation, in particular roots, serves different functions in relation to increased shear strength under saturated and partially saturated conditions. Quantification of mechanical contribution of roots due to their tensile strength, and relationships of various vegetation parameters and plant-induced suction, as well as shear strength, have been widely studied. Although shear strength is directly related to the volume change characteristics of soil, dilative or contractive behaviour of root-permeated soils has only been of significant interest very recently. This contribution presents how volume change during shearing is related to the hydrological and mechanical characteristics of vegetated soils relevant to slope stability and shear strength of root-permeated soils under partially saturated conditions. Insights into the relationships of biotic and abiotic parameters were derived from specimens grown under controlled conditions planted with a mixture of species from different plant functional groups, and volume change behaviour has been investigated from an extensive

study of large-scale suction-monitored direct shear tests. Increase in matric suction, which was linked to root biomass and root : shoot ratio, resulted in higher maximum dilatancy angles. It was also found that maximum dilatancy is controlled by net normal stress, but not effective stress. Laboratory results were transferred into field conditions via a statistical model, and a susceptibility criterion was defined. Lastly, a critical experience-based overlook on the testing of root-permeated soils has also been presented.

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