

PhD position

Multiscale Hydromechanics of root growth in soils

Context and work environment

Scientific context: Growing roots of plants constitute typical cases of living organisms able to forage the soil by adapting to the environment, avoiding obstacles, and following some attractors as gravity, water or nutrient gradients. Beyond the scientific challenge to understand, characterize, and reproduce strategies of living organisms to penetrate and move into the soil, growing roots and their interactions with soils constitute a model for developing technologies in civil engineering, agriculture and space exploration. This project focuses on the characterization and the description of the abiotic interactions between plant roots and soils. Roots are largely described by biologists and biophysicists, whereas the hydro-mechanical behaviour of soils is a major concern in soil mechanics science. However, the interface between both has been much less investigated so far. Therefore, this PhD project aims to develop a description of the hydro-mechanical behaviour of the root-soil system, at both microscale, considering the soil-root interfaces and close vicinity, and macroscale, considering the system as a whole.

Structure description: the PhD will be carried out jointly with two research laboratories located on the Grenoble campus:

- [3SR laboratory](#), and more particularly the Geomechanics research group, which presents an expertise in the hydro-mechanics and micro-mechanics of soil, granular media and porous media from numerical, experimental and theoretical approaches. The group also has experience in 3D imaging of soil/growing-root systems via X-ray tomography.
- [LIPhy laboratory](#), in the MC2 research group focusing in the biophysics of living biological systems, with an expertise in the numerical and analytical description of the dynamics and growth of cells and living tissues.

The PhD student will work daily in direct collaboration with 5 researchers (3 from 3SR and 2 from LIPhy) involved in this project and will benefit from the technical support provided by these two laboratories.

This recruitment takes place within the PhD@Tec21 Programme, which is co-funded as part of the Marie Skłodowska-Curie COFUND actions under the grant agreement #101217261. The recruitment process follows a specific selection and evaluation procedure with particular eligibility criteria, all of which are detailed in the applicant guide available on [PhD@Tec21 Website](#).

Mission and main activities

Multiscale Hydromechanics of growing roots and soils

Project objectives:

This project addresses the interactions between growing plant roots and the surrounding soil, focusing on (i) the dynamics of the water phase and (ii) on the mechanical response of the soil and the root respectively. Building on prior experimental and numerical efforts conducted at 3SR and LIPhy, the project proposes to develop a multiscale and multiphysics modelling framework that bridges root biophysics, soil mechanics, and water transfer.

The PhD work will contribute to the development of a unified multiscale and multiphysics model linking: cell-scale biophysical processes in the root, grain-scale mechanics in the soil and macroscopic continuum behaviors observable experimentally. This model will be validated using 4D X-ray and neutron tomography to capture soil deformation, water flow, and root growth dynamics.

Possible PhD Research Axes:

Two main research axes are identified. **The candidate will select and specialize in one of the two main research directions**, depending on background and interests:

Axis 1 – Dynamics of the water phase from soil to root

- Study coupled water transport between soil pore space and root tissues, including the effects of mucilage secretion on water retention and hydraulic conductivity.
- Extend poromechanical models (multi-phase soil mechanics) to include water uptake by the root.
- Employ homogenization techniques and numerical simulations (e.g., FEniCSx, FEMxFEM) to link pore-scale phenomena to continuum models, with the ultimate goal of comparing them to tomography data from real root-soil systems.

Axis 2 – Multiscale mechanical interactions between roots and soil

- Model how cell-level growth rules (cell division, cell wall softening) influence the macroscopic mechanics of root elongation.
- Develop vertex and morphoelastic rod models for root tissues and couple them with discrete element models (DEM) or finite element models (FEM) for soil.
- Simulate root penetration and deformation in granular soils and compare with tomography data from real root-soil systems.

Potential Applications:

- **Sustainable agriculture:** understanding root water uptake and soil compaction.
- **Civil engineering:** bio-inspired soil stabilization and root-like foundations.
- **Robotics:** design of self-growing or soil-penetrating robots for environmental monitoring.

Supervisors: Luc Sibille (UGA, 3SR), Pierre Recho (CNRS, LIPhy), Quentin Rousseau (UGA, 3SR), Alexander Erlich (CNRS, LIPhy), Gioacchino Viggiani (UGA, 3SR)

Research fields: geomechanics, biophysics, multiphase modelling

Possible secondments: the following secondments have to be confirmed, also this list could be extended – University of Strathclyde (UK), Twente University (NL), NEIKER (Ikerbasque Basque Foundation for Science, Spain), SAPIENZA University of Rome (IT)

Doctoral school: [I-MEP2](#): Engineering - Materials, mechanics, environment, energy, processes, production

Desired profile and expected skills

Education, diplomas

Master's Degree at the time of application

Disciplinary skills, experience: The ideal candidate should have **a strong background in one or more of the following fields:**

- Continuum mechanics, multiphysics coupling, geomechanics/soil mechanics, biophysics, biomechanics.
- Skills in numerical methods: FEM, MPM, DEM ...
- Ability to carry out analytical developments for application in continuum mechanics or physics.
- 3D imaging and quantitative image analysis.

Personal skills

- Curiosity and willingness to cross boundaries between physics, biology, and engineering.
- Autonomy and initiative to define their specific research focus within one of the two axes.
- Communication skills for interacting with different people forming a fairly wide group around this project.

Employment benefits and conditions

Université Grenoble Alpes (UGA) is offering a 36-month full-time work contract. In line with the European Commission rules for Marie Skłodowska-Curie grant holders, the remuneration will consist of a gross monthly salary of 2,669 EUR. The estimated net salary to be perceived by the PhD fellow will be between 2,050 and 2,152 EUR¹.

Benefits include:

- Access to a high-quality work environment, including a personal computer, scientific equipment and access to library and shared lab facilities
- Full social security benefits and participation to health insurance
- Access to high-level scientific and inter-sectoral training through 120 hours of doctoral courses and workshops
- Opportunity for 2-month secondments at an academic institution or industrial partner during the 2nd year of the PhD
- A vast choice of networking events and activities within the PhD@Tec21 Programme and through the international network of MSCA fellows
- Access to the UGA International Student Office, to assist the PhD fellows in searching for accommodation in Grenoble and support with administrative issues including visas, health, bank accounts, etc.
- Visa fees and registration to the UGA Doctoral School are covered by PhD@Tec21
- Sick leave, parental leave, 45 days of paid holidays

General information

Contact for the questions related to the position:

PhD@Tec21 Management Board: guillaume.chambon@univ-grenoble-alpes.fr / amelie.bataille@univ-grenoble-alpes.fr

¹ As an average over the 3 years, depending on French tax regulations. Fellows might benefit from an additional allowance depending on their family situation (74 EUR monthly net allowance)