PhD thesis 2022-2025

Biophysical relationships between 3D networks of galleries and water flows in porous media: study by X-ray tomography and modeling

Institut de Mécanique des Fluides de Toulouse (IMFT) et Laboratoire d'Ecologie Fonctionnelle et Environnement (UMR 5245)

Context and motivation:

Earthworms are engineering organisms for the environment: the network of galleries they create influences the flow of water in the soil and the biophysical processes that take place there. These processes allow the purification of water, when the soil is used as a filtering medium, as in some "green" biotechnologies for the treatment of wastewater. This project is based on the X-ray tomography technique, which allows to study the 3D morphology and the evolution with time of the network dug in a model soil, coupled with a characterization of the hydraulic properties of the substrate. It combines the skills of IMFT (X-ray tomography, flows in porous media) and those of UMR 5245 LEFE (functional ecology, interactions between worms and soils). The acquisition of new experimental data to identify the parameters of the galleries influencing the flow will lead to a modelling of water transport coupling ecology and hydrodynamics processes.

Objective of the thesis work:

The first objective of the thesis is to experimentally access the fine knowledge of the worms' influence on the 3D structure of the substrate, and more particularly of the effect of the network of galleries. Thanks to the X-ray tomography technique (Cf. Figure 1), we will thus be able to image the evolution of the 3D network of galleries of course, but also the other components of the porosity of the substrate such as the interstitial biofilm. This information is essential to be able to explain the modifications of the water flow in the substrate through galleries and interstitial space, compared to a reference case without galleries. The novelty of the approach lies in the implementation of gallery-digging organisms at the origin of an evolutionary macroporosity, while measuring their effect on hydraulic conductivity. The use of networks of artificial galleries, obtained by 3D printing, is another original feature of this project. The gallery walls will be porous, mimicking the natural exchange between the ground and the galleries.
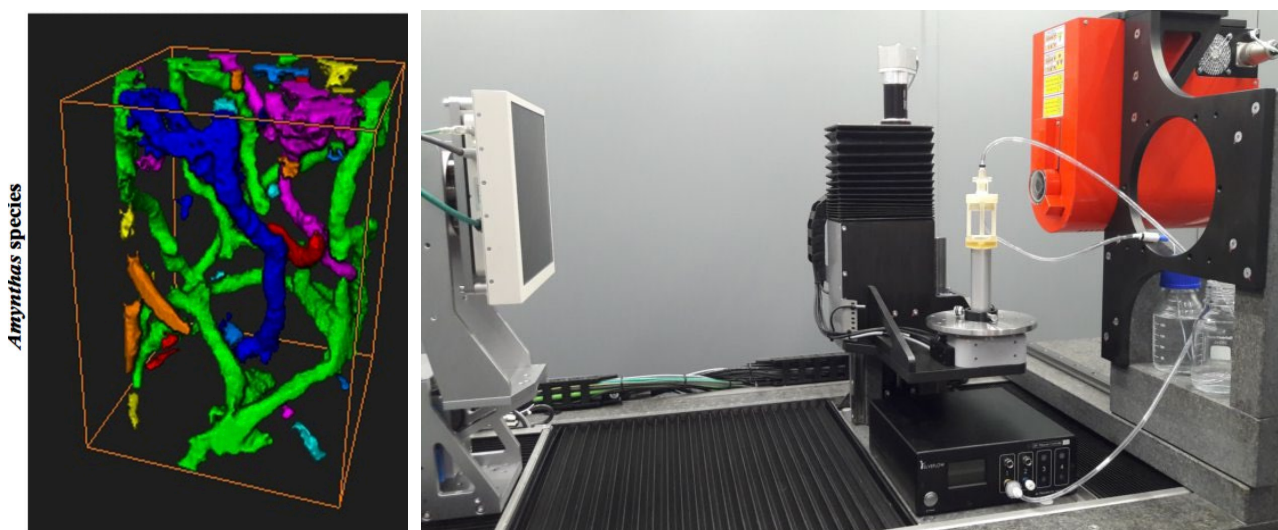

Figure 1: Left: 3D visualization of the gallery network of a population of Lumbriculidae Amynthas type worms, obtained after 30 days in a substrate core (Bottinelli et al. 2017). Right: X-ray tomography facility set at IMFT. The large workspace allows in situ instrumentation (flow control, sensors, etc.) of tomographed samples or columns.

The second objective of the thesis work is to develop a deterministic modeling tool (heuristically modeling phenomena using a system of partial differential equations). The goal is to reach a large-scale description of the porous medium where the biological component (network of galleries and biofilm) controls the physical transport parameters (of biological and physical origins).

Skills needed for the present PhD work:

The candidate must have a Master's degree or an engineering degree with skills in fluid mechanics (particularly porous media). A Master in Water Science or Aquatic Ecology will be admissible if it includes lessons in fluid mechanics. An advanced level of scientific and technical English and good written and oral communication skills are required. A particular interest in experimental research activities (X-ray tomography, 3D image processing, breeding of invertebrate organisms) will be appreciated. Knowledge or openness to ecological engineering, environmental management, wetlands, and water resources are welcome but not mandatory. You show autonomy and curiosity. You are sociable, creative and enjoy taking on challenges. Your involvement in associations related to sustainable development and social responsibility is a plus that will be appreciated.

Funding: The financing of the Ph-D student will be provided by a scholarship from the Federal University of Toulouse.

Supervision and contact:

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Send a resume, cover letter, and your most recent grades/ranking to the addresses listed above. Please indicate "ADI Thesis" in the subject of your email.