

# Mathematical Modelling of the Root-Mycorrhiza-Soil System



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## Introduction & Motivation

- Functional-structural plant models (FSPM) are now standard tools for designing **resource-efficient agronomic practices** and for **screening root phenotypes** under target environments. [2,7,8]
- **Arbuscular mycorrhizal fungi (AMF)**, obligate symbiotes of potentially **up to 90 % of terrestrial plants**. [9]
- **Boost host phosphorus and nitrogen uptake**. Bidirectional Trade: C for P/N [5,6]
- **Enhance drought tolerance** through increased soil root contact [5,6,10]
- Strong coupling of hydraulic and nutrient fluxes in the root–mycorrhiza–soil system requires inclusion of AMF architecture in FSPMs.

## Methods

Extension of **CPlantBox** with an AMF module. The module represents colonization of the root system implicitly as a **Poisson** process and hyphae as 3D tubes.

Hyphal growth patterns depends on:

- hyphal **tip extension** rate
- branching rate and branching distance
- **lateral vs dichotomous** branching probability
- **anastomosis** distance & probability

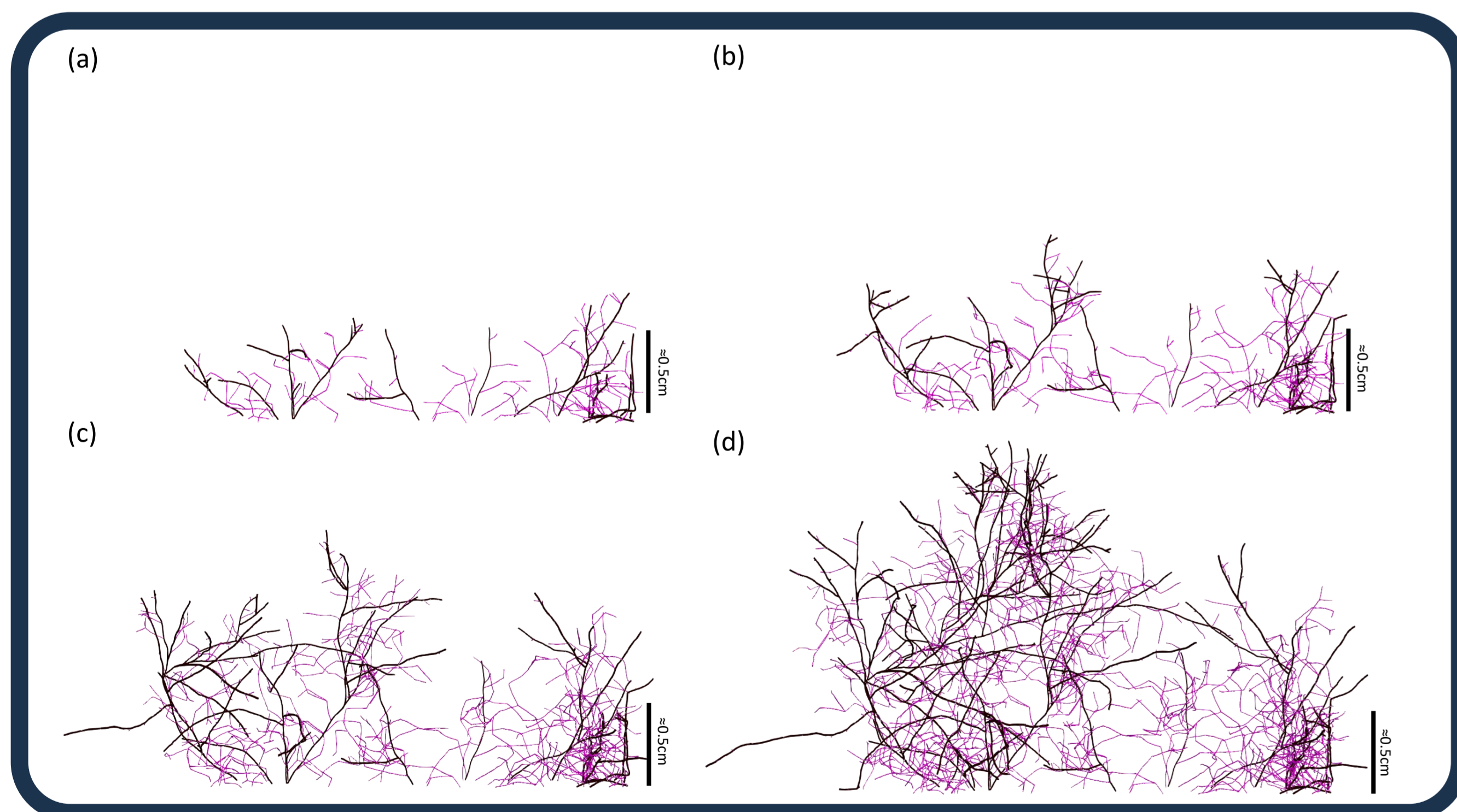


Fig.1.: Visualization of a simulated hyphal network for 9 (a), 19 (b), 39 (c), 59(d) hours in a split petri dish (setup replicated from [1]) (black: lateral branching, fast elongating, pink: dichotomous branching, moderate elongation). All simulated in setup of Fig.4.

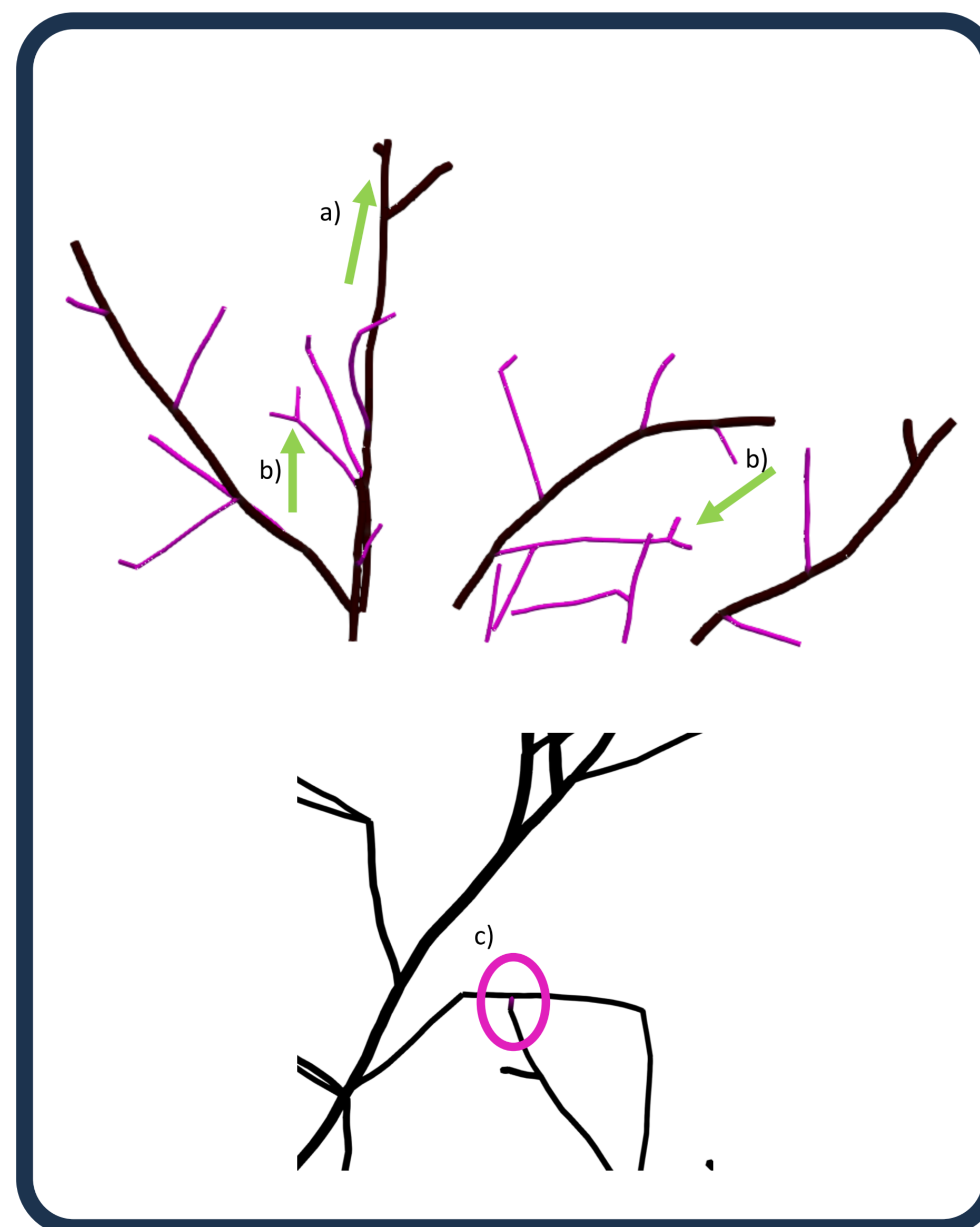


Fig.2.: Annotated simulation output showing key steps of the model hyphal growth. a) lateral branching b) Apical branching c) anastomosis



Fig.3.: Visualization of a model root system colonized by AMF. Simulated for 15 days with completely dispersed inoculum in the soil. Roots in black, hypha in green. Parameters for the AMF taken from [1][4]

## Result:

Proof-of-Concept for AMF Modelling on Roots

- Temporal dynamics: the hyphal network grows continuously over simulated days.
- Spatial expansion: 3-D visualization shows colonization radiating from root tips.
- Ready for coupling: hyphal output can be fed directly into soil-water and nutrient uptake models.

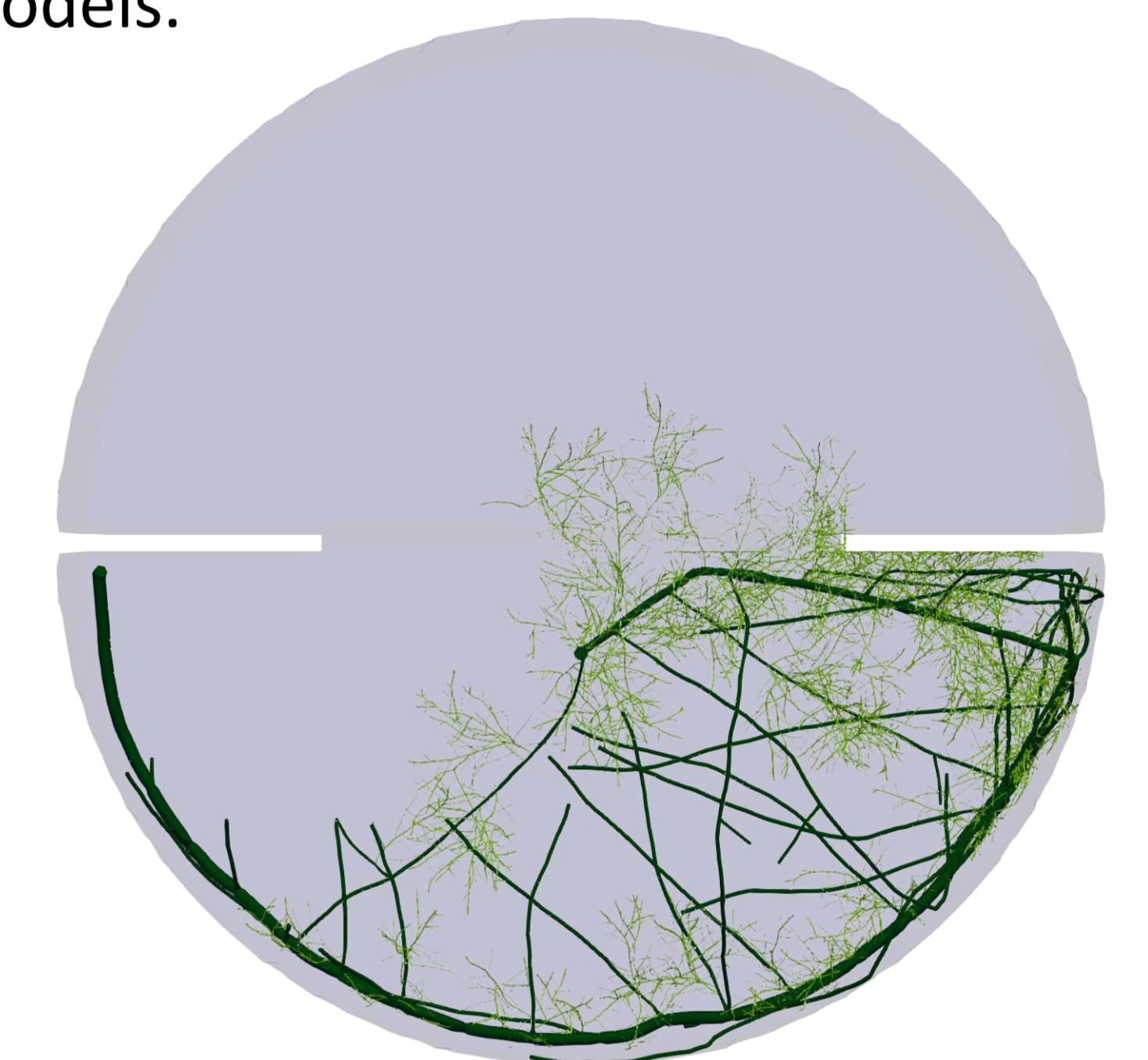


Fig.4: Petri dish was split, roots simulated for 15 days, colonized and followed by hyphal growth simulation for 60 hours. Only hyphae entering the upper compartment grown, everything below inactive.

## Outlook:

- Calibration on quantitative data such as  $\mu$ CT imaging of AMF hyphae
- Quantitative evaluation on hyphal length, colonization frequency, anastomosis frequency, water uptake, nutrient uptake vs carbon investment