Modelling and simulating tree growth dynamics including both shootand root compartments. The RoCoCau+TOY model

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Introduction

Tree structural and biomass growth studies are mainly carried out on shoot compartment. Root compartment is usually taken apart due to the difficulties on measuring and observing it, especially when considering root growth. AMAP team is already leading experimental studies including both compartments through field experiments and observations. AMAP also provides shoot or root models and simulators of tree architecture and biomass production applied to many agronomic and forest species. It now becomes very critical to study tree structural plasticity according to global climate change. For this purpose, both shoot and root systems have to be considered at the same time since they play collaborative roles dedicated to climate traits (water availability for roots and light or carbon availability for shoots). We propose a whole-plant model and its simulator (RoCoCau) with a linkable external module (TOY) to represent shoot and root compartments dependencies and thus tree structural plasticity when facing various aerial and edaphic environments.

Literature shows this plasticity but generally at one moment of the tree life cycle. One of the main issue of such a tool is to understand how this balance is managed according to tree development (structure maintenance *vs* space exploration).

Materials and Methods

RoCoCau is made of the association of AmapSim (Barczi et al 2008) and DigR (Barczi et al 2018) to represent shoots and roots. The software simulation environment makes it possible to plug an external functional module to the core structure simulator. We propose the module (TOY) that roughly models the dependency between the two compartments. This dependency remains in (i) biomass production that needs water uptake through roots, carbon and light uptake through leaves and in (ii) biomass partitioning to control development and growth of both compartments in order to preserve a balanced uptake capacity on water, carbon and light.

Results and Discussion

We have been applying RoCoCau to *eucalyptus* root/shoot systems that were previously modeled to check its accuracy to mimic realistic whole tree growth dynamics (figure 1). We then plugged the TOY model to RoCoCau and tried some environmental stresses (water, carbon and light) applied on the same simple tree architecture with different responses capabilities (light-demanding, shade-tolerant, drought tolerant or not). Figure 2 shows optimal environment, water and light stresses applied on the same theoretical species. This situations result in different global plant sizes but also in different shoot/root balances. For each situation, we extracted data along simulations to show how much water, light and carbon were collected and what was the consequence on growth rate change for both root and shoot compartments. It is then possible to monitor tree plasticity according to environmental change.

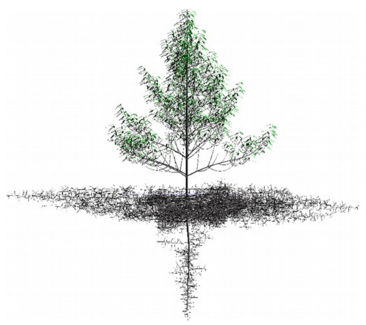

figure 1. « realistic» simulation(RoCoCau)

figure 2. same default plant species growing in optimal environment, with water stress and with light stress (RoCoCau+TOY)

The model has a good quantitative response in accordance to knowledge about tree plasticity. The proportion of root biomass is favored under drought conditions or more generally when trees grow on bad soil (Leuschner et al, 2001). In such stressed environment, stems show frequently a reduced leafy area (Kozlowsky & Pallardy 2002). In shade environment, trees invest more in leaf surface in order to increase light foraging capacity (Poorter & Nagel 2000). Simulations show a permanent balance of both root and shoot system with regulation of architecture and resource capture (leaves, fine roots) according to the species capabilities facing different environmental stresses.

For now, only an *in silico* study was carried out. It is now necessary to get field data to try TOY calibration. For this purpose some measurements are carried out into the FTC2 experimental device where 4 tropical species are grown in french Guyana. Tree individuals are regularly extracted and measured to feed a database used to train a neural network at TOY parameters calibration.

Conclusion

The simulation of the RoCoCau structural model linked with the TOY functional model allows to test hypothesis on tree plasticity facing environmental change. RoCoCau offers a good botanical accuracy at representing both shoot and root architectural dynamics. TOY includes main physiological processes to get water, light and carbon and to produce biomass that will be shared between the two compartments in a way that permanently controls the balance of their shoot and root foraging capabilities.

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