ROOTMIX

Are positive diversity- production relationships mediated by root interactions ? A study with different forest mixtures.

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Context — Biodiversity has been shown to enhance ecosystem functioning and ecosystem services. In particular, much attention has been drawn on the diversity-production relationship in plant communities, showing that mixtures produce on average more biomass than monocultures. Identifying the underlying processes and determining the necessary conditions for the positive diversity-production relationship to occur is a prerequisite to assess whether the relationship will be maintained under changed environmental conditions and to estimate how mixed stands may be used to adapt forests to future climatic conditions.

Objectives — The general objective of the project is to analyse belowground and aboveground competition processes in mixed-species stands and to assess whether complementarity for belowground resources occur between species that may explain the higher productivity observed in mixed-species stands. The specific objectives are to:

1. Characterise the spatial distribution (vertical and horizontal) of root systems of trees growing in pure or in mixed stands and analyse how intra and interspecific competition affects the root distribution of individual trees.
2. Estimate the depth of water uptake by root systems of trees growing in pure or in mixed stands.
3. Estimate the combined effects of mixture and tree density on branch mortality and crown morphology.
4. Estimate the importance of competition for belowground resources (water and nutrients) in the overall interaction among trees growing in pure or in mixed stands.

Approach — The project is based on an experimental approach. Experimental work is performed in two complementary research setups, involving a total of four target tree species: *Fagus sylvatica*, *Acer*

pseudoplatanus, *Quercus petraea* and *Carpinus betulus*. The setups are established in France (Forêt de Haye) and in Belgium (Ardenne).

In each setup, complementarity for belowground resource was assessed by characterising belowground resource distribution, root system spatial arrangement, and spatial variation in water acquisition. The main novelty was to combine a set of innovative experimental and analytical methods to characterise root competition, that allowed to overcome many of difficulties that usually limit the study of root systems: (1) Implement infrared reflectance spectroscopy (NIRS-MIRS) method to estimate the specific composition of root samples; (2) Use inverse modelling to estimate root expansion around individual trees and root distribution in tree mixtures; (3) Use stable isotope tracers to estimate resource uptake by individual trees; (4) Use neighbourhood models and structural equation models (SEM) to predict tree growth from resource availability and resource partitioning among competing trees and to predict branch mortality and growth.

Key results —

Experiment in Nancy:

- Mixture has only a slight effect on depth of soil water extraction and vertical root distribution of both species (*Fagus* et *Acer*), suggesting a lack of vertical spatial segregation between the root systems of the two species, either morphologically or functionally (regarding water acquisition).
- Mixture slightly enhances nutrition of *Acer* and slightly reduces nutrition of *Fagus*.
- A higher richness of fungal community was observed in the mixture, which could contribute to enhanced belowground resource acquisition.
- Annual branch mortality was influenced by local tree density, relative neighbouring tree height and several branch and tree level variables. Mixture did not affect branch mortality, for both species.
- *The analysis of root distribution at the individual tree level using inverse modelling has not yet been performed.*

Experiment in Belgium:

- *The analysis of 4-species root mixtures is on going.*

Main conclusions including key points of discussion — No mechanism of aboveground or belowground complementarity between *Acer* and *Fagus* was observed, that could explain the higher productivity of the mixture, except a slight effect on the nutrition of *Acer*. All response variables representing tree growth and functioning responded primarily to tree density, vertical stand structure, and tree size and secondarily to mixture.

These results underline the need to control properly all primary factors affecting tree growth and functioning to analyse tree mixture effects, by designing experimental approaches that decorrelate explanatory variables and by using modelling approaches that account for potentially confounding factors. The sampling procedure established to analyse Fagus and Acer nutrition allowed to decorrelate tree density and tree size and the SEM approach allowed to account for tree size effects in the analysis. The combination of both approaches allowed identifying and quantifying slight effects of mixture on tree nutrition.

Future perspectives — The double clinal experiment is a distinctive approach compared to existing networks of experimentation analysing tree diversity effects. Most networks focus on the combined effects of mixture and environmental gradients (fertility, drought, …), whereas the double clinal experiment focus on the combined effects of mixture, tree density and tree size. A nice perspective would be to cross the two approaches and establish double-clinal experiments in contrasted environmental conditions.

Valorization —

Publications

Nickmans H, Collet C, Bonal D, Verheyen K, Ponette Q 2017 Tree size and local neighbourhood affect foliar nutrient content in a mixed plantation of beech (Fagus sylvatica) and maple (Acer pseudoplatanus). Forest Ecology and Management 400 : 159-172.

Thesis and reports

Fruleux A. 2017 Développement racinaire du hêtre (Fagus sylvatica) en interaction avec d'autres espèces forestières et en fonction de la disponibilité en eau. Conséquences sur la croissance et le fonctionnement hydrique et carboné. Thèse Univ. de Lorraine.

Frauenfelder A. 2017 Branch growth and mortality in response to neighbour density and species identity in a young forest plantation with two competing species. Master FAGE, Univ. de Lorraine.

Presentations

Fruleux A. et al., 2015 Is there complementarity between European beech and sycamore maple in their soil resource acquisition? Conférence internationale "Root Down Under", Canberra, Australie, Oct 2015.

Nickmans H. et al., 2016, Tree size and local neighbourhood affect foliar nutrition in a young forest plantation of beech (Fagus sylvatica) and sycamore maple (Acer pseudoplatanus). International Conference on Mixed Forests, Prague, Oct 2016.