Tree fine roots dynamics and carbon sequestration potential in a Mediterranean agroforestry system

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Objectives of the Ecosfix project


- Costa Rica, Laos and France

Source : Catherine Roumet, CEFE
The different sites

- Different sites with gradients of land use, diversity

Source: Catherine Roumet, CEFE

First EURAF conference, Brussels, 9 and 10th October, 2012
## The different sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Crop 1</th>
<th>Crop 2</th>
<th>Crop 3</th>
<th>Crop 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Restinclières</strong></td>
<td>Durum wheat</td>
<td>Durum wheat + Walnut</td>
<td>Walnut + Natural vegetation</td>
<td>Forest (scrubland)</td>
</tr>
<tr>
<td>(France, South)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Laos</strong></td>
<td>Rice</td>
<td>Rice + Teck</td>
<td>Teck + Natural vegetation</td>
<td>Fallow</td>
</tr>
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<td><strong>Costa Rica</strong></td>
<td>Coffee tree</td>
<td>Coffee tree + Erythrine</td>
<td>-</td>
<td>Tropical forest</td>
</tr>
<tr>
<td><strong>Chamrousse</strong></td>
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<td></td>
<td>Forest + Natural vegetation</td>
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Source: Catherine Roumet, CEFE

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- Agroforestry and carbon sequestration

- Carbon sequestration into perennial biomass of trees

- Impact on SOM stocks through leaf litter inputs, root carbon input into deep soil horizons (root turnover, root exudates, mycorrhizae)

- Agroforestry trees have a deep rooting system (Mulia and Dupraz, 2006)

➡ Carbon protection mechanisms into deep soil horizons

(Rasse et al., 2005)
Agroforestry and carbon sequestration

- Agroforestry systems are usually established on former agricultural lands, with a low organic matter content

Some indirect effects: less fuel consumption if branches are used to produce energy, less deforestation if valuable timber wood is produced…
A very simplified pattern…

- The objective is to study tree root carbon input into the soil (root mortality) and its fate

- In this project, we do not take into account mycorrhizae or root exudates
The experimental site – Restinclières, France

- Trees were planted in 1995

LEGEND
- Small pit
- Big pit

© R. Cardinael
The experimental site – Restinclières, France

- A huge pit in the agroforestry system: 5m x 1.5m x 4m

Photos © R. Cardinael

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The experimental site – Restinclières, France

- 4 small pits: 2m x 2m x 1.7m

Small agroforestry pit

Small agricultural pit

Small forestry pit

Small scrubland pit

Photos © R. Cardinael
Estimation of the root carbon input into the soil ➔ Living fine root biomass

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Estimation of the root carbon input into the soil ➔ Living fine root biomass

- **Root mapping**

More than 3800 tree fine root impacts (< 2mm in diameter) were counted in the big pit

We also counted tree fine root impacts in the forestry pit and in the small agroforestry pit
Estimation of the root carbon input into the soil ➔ Living fine root biomass

Tree fine root impacts in the big pit (mean of the East and West profile)
Estimation of the root carbon input into the soil  ➔ Living fine root biomass

- Cubes of soil – 2D to 3D

- 48 cubes of soil (1 dm³) were sampled in the big pit (agroforestry) at different depths (10, 40, 70, 100, 150, 200, 300, 400) and distances
- 30 cubes in the forestry pit, 30 cubes in the small agroforestry pit

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(Maurice et al., 2010)
Estimation of the root carbon input into the soil  ➔ Living fine root biomass

- Cubes of soil

For each face of each cube, we counted tree fine root impacts. Then, roots were sorted out and analysed (total length and dry weight)

\[
\text{Root length density (m dm}^{-3}\) = 0.43 * Tree fine root impacts \\
R^2 = 0.5911
\]

\[
\text{Root density (g DM dm}^{-3}\) = 0.0443 * Tree fine root impacts \\
R^2 = 0.444
\]
Estimation of the root carbon input into the soil ➔ Living fine root biomass

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Living fine root biomass ➔ Root turnover ➔ Root carbon input into the soil ➔ Decomposition ➔ Stabilization

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Estimation of the root carbon input into the soil ➔ Root turnover

Minirhizotrons in the field

20 minirhizotrons were installed at the surface (2 per walnut)
Minirhizotrons in the pit

16 minirhizotrons were implemented in the big pit, at different depths (0, 100, 250 and 400cm) and distances from the trees (1m and 5m)
Estimation of the root carbon input into the soil ➔ Root turnover

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Root decomposition

- Living fine root biomass
- Root turnover
- Root carbon input into the soil
- Decomposition
- Stabilization

CO₂

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Root decomposition

• Root sampling

Fine roots and coarse roots were sampled in two soil horizons for the 4 small pits: 0-20cm (shallow roots) and 100-150cm (deep roots)

For the big pit, we sampled deeper horizons: 200-250cm and 300-350cm
Root decomposition

Part of the roots was used for chemical analysis, the other part was used to make litterbags

Chemical analysis  (Van Soest 1963, Goering and Van Soest 1970)

Lignin, cellulose, hemicellulose
C/N

Litterbags

Photos © R. Cardinael
Root decomposition

- Litterbags

For each of the four small pits, we installed 18 litterbags 10cm deep and 18 litterbags 120cm deep. A temperature sensor was installed at each depth.

Litterbags will be removed in 1 year, roots will be weighted and re-analysed (chemical composition)

Photos © R. Cardinael
Carbon stabilization

Living fine root biomass → Root turnover → Root carbon input into the soil → Decomposition → CO₂ → Stabilization

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Carbon stabilization

- Cylinders were sampled at 5, 20, 40, 70, 100, 150cm in all pits on 3 different profiles (= 90 cylindres per pit) and at 155, 200, 300, 400cm in the big pit

- Soil samples were analysed for bulk densities, penetrometry, root traits, carbon content, soil fractionation…
- Not yet analysed…

Photos © R. Cardinael
A modelling approach

- We used the Hi-sAFe model - a biophysical model of 3D heterogeneous stands including a tree component - , developed by INRA, to:
  - estimate carbon inputs into the soil during the growth of trees (40 years)
  - estimate carbon storage into perennial biomass
  - test the role of external parameters – like groundwater – on carbon input into the soil

- Improvement of the model with field data (root density, root turnover)

Source: C. Dupraz, INRA
A modelling approach

- Modelling of carbon sequestration with the Hi-sAFe model, comparison with field data

Carbon storage into perennial biomass of a walnut grown in an agroforestry system

Root carbon input into the soil (kgC / m³)
Conclusion

- The project is still in progress, only *preliminary* results

- Long term experiment (minirhizotrons, pit)

- PhD starting in November: « Carbon sequestration and soil organic matter dynamics under a Mediterranean agroforestry system »
Thank you for your attention