Investigation of a local tree size gradient in a mixed oak-maple forest

Aim of the study is to have a more global assessment of species performance, the role of niches and potential refugia. For this purpose, we will work towards a mechanistic understanding of the environmental factors driving a gradient of tree size and productivity in a mixed Pubescent Oak-Maple forest ecosystem (north of the experimental field site O3-HP).

Background

Vulnerability to climate change and particularly water stress is likely to increase in the near future (Allen et al. 2010; McDowell et al. 2011). Climatic change induce variability of forest productivity, and has negative impacts through increased vulnerability related to carbon starvation and/or hydraulic failure (Breshears et al. 2008).

However, at small spatial scales, we may find considerable differences in size and growth of plants. Data on such local gradients are rather scarce. We want to study changes in microtopography (niche, refugia) that are likely to mitigate global change effects, and become important for species conservation. Such productivity gradients may have carbon starvation and cavitation as a cause. Using physiological measurements described below we’re able to study both. With the spatial scale being small, we have the specificity of a relative ‘internal control’ by natural conditions, as local climate and soil type are bound to be similar.

Further we can hypothesise that along with reduced water availability, nutrient uptake is constrained. Plants that have less water and nutrients are less efficient in photosynthetic carbon fixation. Such decrease in productivity is postulated to be linked to an increase in secondary (defence) metabolism, see growth differentiation balance hypothesis ((Hermes & Mattson 1992), which will be addressed in this study.

Approach: First objective: We observe a tree size gradient (between 4 m and around 10 m canopy height, and an associated stand density gradient) that we relate to productivity or site index differences, in a 100 m long west-east transect. These trees have the same age and management history. Due to the geological ground structure, changes in run-off or litter accumulation or rooting space availability, the larger trees are likely to be experiencing either a better resource water or nutrient supply or both.

- We will analyse 6 points along the transect and a reference point at the central plot of the O3-HP.
- Tree height, crown extension, and tree density (number and basal area) will be recorded. Leaf area index below and above the shrub-layer will be estimated optically along the transect to document stand structure, associated with measurements of relative irradiance.
Dendrochronological growth analyses of cores and cross sections from this transect will be put in relation to the 60-year local climatic record (Meteofrance, St Michel l’Observatoire, Delphin & O3HP stations, daily records).

We will sample soil organic matter (leaf litter and humus) as a proxy of the isotopic $^{13}$C composition of leaves, that integrates time over several decades and space over a few surrounding meters.

These data will be supported by instantaneous measurements of relevant gas exchange and fluorescence parameters (stomatal and mesophyll conductance) on live foliage (partially performed by a master student, salary already financed in the framework of the ANR SecPriMe²).

N and P will be analysed in litter and humus samples.

The plant community under the tree canopy along the gradient will be recorded and observed with the intention to identify changes in indices of soil nutrients and soil water availability, as well as differences in phenology.

The transects will be analysed by geoelectric tomography to identify geology, and to discuss soil water relations.

A **second objective** is to know more about the competitive behaviour of plants in the stand.

The relative belowground space availability will be qualitatively assessed via geoelectric tomography (see above) as to have a proxy of plant resource availability. It is planned to assess resistivity profiles in periods of contrasting dryness, before summer and end of summer, as to semi-quantitatively identify differences in (the use of) soil water content.

We will investigate differences in ring-porous (Pubescent Oak) and diffuse-porous trees (Montpellier and Opalus Maple) growing in the stand by sap staining and destructive analyses to better understand water redistribution in stems and branches. This requires destructive sampling, which will allow us to analyse tree biometry and allometry.

Further, the relation between shrubs and their neighbouring dominant tree species will be investigated in terms of growth, and leaf gas exchange.

We will investigate defence investments by analyses of secondary metabolites (phenolic and/or terpenoid compounds) content in green leaves of trees and understory species. These measurements will allow understanding plants’ competitiveness in responses to drought.

### Statistical analyses

Besides classical statistics (GLM and ANOVA) data will be analysed using Multivariate component analyses (cf. Löw et al. 2012)

### Timeline

A big campaign early in the growing season (June) before summer and some activity in the late summer (September to October).

<table>
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<tr>
<th>Task</th>
<th>Apr</th>
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<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
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<td>litter d13c + nutrients</td>
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<td>plant community</td>
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<td>x</td>
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<td>phenology</td>
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<td>Secondary metabolites</td>
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<td>soil sensor installation</td>
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<td>soil tomography</td>
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Important preliminary results: The analyses of the leaf area index of single trees (4-5 m².m⁻²) and the forest stand (2 m².m⁻²) at the O₃HP have shown that though the forest canopy is typically open - the projected leaf area of single crowns are similar to those of dense oak forest canopy in well water and nutrient supplied floodplain forests. This is supportive of the hypothesis that tree productivity is limited by resource availability. It is, however, not clear in this context how the increase in plant productivity is related to plant size/form. Note: We are aware that the forest ecosystem structure is driven to some extent by human management practice.

First tree ring analyses have shown that the short and tall trees used in the gradient have about the same age.

<table>
<thead>
<tr>
<th>Budget</th>
<th>Cost</th>
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<tbody>
<tr>
<td>13C discrimination analyses of 28 litter &amp; 28 humus samples (15 € per sample)</td>
<td>840 €</td>
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<tr>
<td>Dendrochronological analyses (lab consumables) + spare tree corer (250 €, fragile when used with oaks)</td>
<td>450 €</td>
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<tr>
<td>Gas exchange and fluorescence analyses (Consumables for and maintenance of equipment Licor 6400 XT, and Delta-T AP4)</td>
<td>200 €</td>
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<tr>
<td>Geoelectric tomography analyses (consumables and sensors for vertical soil temperature profile needed for data correction)</td>
<td>450 €</td>
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<td>Soil water relations (6 sensors, 350 € each, for continuous monitoring + cable)</td>
<td>2300 €</td>
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<tr>
<td>Student (e.g. DUT) for field campaigns and laboratory work 2.5 months</td>
<td>1090 €</td>
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<tr>
<td>Missions (from St Paul lez Durance, Avignon &amp; Aix-en-Provence to the O₃HP field site, and for meetings)</td>
<td>1000 €</td>
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<tr>
<td>Consumables for sample containers, transect &amp; tree labelling , tree harvest ...</td>
<td>200 €</td>
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<tr>
<td>Secondary metabolites analyses</td>
<td>500 €</td>
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<tr>
<td>Total</td>
<td>7030 €</td>
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</table>

Perspectives: The scientific community around the O₃HP program is aiming at developing a project (ANR type) to study belowground plant stress and belowground competition, for which this represents an important pilot study.

We aim to publish the results of this investigation in a peer-reviewed journal in plant biology (tree physiology, trees, plant biology or similar).

Consortium: The group is associated to tackle common questions by interdisciplinary approaches, ranging from soil physics (tomography), and chemical approaches (isotopic, nutrient analyses, secondary metabolites) to biological investigation on instantaneous (gas exchange), and long-term (dendrochronology) ecophysiological traits. This is supported by structural analyses of the plant cover and interfaced with biological indicators and phenology. An inversed modelling approach of tree growth using CASTANEA allows analysing hypothesis on plant performance.

<table>
<thead>
<tr>
<th>Contributor</th>
<th>Institute, Lab</th>
<th>Location</th>
<th>Expertise</th>
<th>Time in days</th>
</tr>
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<tbody>
<tr>
<td>I Reiter (IR) codirection with JB</td>
<td>CEA Cadarache, SVBME</td>
<td>St Paul-lez-Durance</td>
<td>leaf gas exchange, stand structure sensing network</td>
<td>20</td>
</tr>
<tr>
<td>G Gea-Izquierda (Post-doc)</td>
<td>IMBE, OT-Med</td>
<td>Aix-en-Provence</td>
<td>dendrochronology, MAIDEN growth model</td>
<td>10</td>
</tr>
<tr>
<td>H Davi (CR)</td>
<td>INRA, URFM</td>
<td>Avignon</td>
<td>CASTANEA growth model</td>
<td>10</td>
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</tbody>
</table>
Interfaces among contributors: Isotopic analyses will be related to leaf gas exchange & water potential, and analyses of soil tomography / dendrochronology related to local climate records, stand structure and growth modelling (with intercomparison of the MAIDEN and CASTANEA model results) / nutrients, secondary metabolites related to growth and isotopic analyses of the litter / plant communities to nutrients and secondary metabolites, and phenology to growth.

References


Direction by Ilja REITER and Jérôme BALESDENT
CV, publications and implication in former AOI ECCOREV below:

Ilja REITER (FR 3098 ECCOREV, IR2-CNRS BAP-A)

- Since Nov 2009, FR 3098 ECCOREV, Responsible for experimental installations at the O3HP field site, co-animation of the scientific O3HP network
- 2005-2009 CEA Cadarache, Laboratory of Molecular Plant Ecophysiology
- 2004 PhD on plant competition and impact of ozone pollution (Technological University of Munich/ Germany)
1999 Biologist specialized in Ecology (Ulm University/ Germany)

Coordinator for the French side of the ERASMUS intensive program “Soil & Water” held in 2012 in the Czech Republic, and 2013 in Estonia (http://www.uni-ulm.de/nawi/nawi-erasmusip.html)

3 relevant publications:


Former AOI ECCOREV : COOPERATE in 2011 : Common database for field sites dedicated to experimental studies on climate change in of Southern France (as project manager).

Output: O3HP database (https://o3hpbd.obs-hp.fr/db/index.php/fr/), development is ongoing, currently further DBs are being integrated into COOPERATE : CLIMED site & local OHP datasources (in progress), ICOS@OHP (planned once functional). In this context, invited speaker to the FORESTERRA meeting and the CESAB meeting in 2014.

### Jérôme BALESDENT (INRA research lab GSE - Soil and Water Geochemistry)

Current position : INRA (National Research Institute for Agriculture, Food and Environment) UR 1119 Soil and Water Geochemistry, Aix en Provence. Senior Scientist (DR1). 2006-present.

Contribution to the Master "Sciences of the terrestrial environment", Aix-Marseille University.

Publication of ca. 100 articles in scientific journals and book chapters in the following fields : soil organic matter dynamics, carbon cycling, isotopic biogeochemistry, stable carbon isotopes, mitigation of greenhouse gas emissions, functional biodiversity in soils.

3 related publications


Catherine FERNANDEZ (Professor at the Aix-Marseille University)

- Since sept. 2009: Professor at Aix-Marseille University (PR1 since Sept 2013)
- 2001-2009: Associate professor (Univ. Provence)
- 1997-2001: Assistant professor (Univ. de Corse)

- 2005 Habilitation thesis ‘HDR’ in Ecology (Univ. Provence)
- 1996 PhD Ecology and population Biology (Univ. Corsica)

Research topic: Mediterranean terrestrial ecosystems functioning with a chemical ecology approach: plant secondary metabolism as driver of ecosystem functioning and biodiversity evolution: (i) how does the impact of environmental conditions affect the production of secondary metabolites, (ii) how do these metabolites, once released into the environment, affect biodiversity (allelopathic processes), (iii) how does the presence of secondary metabolites act on the cycles of matter.

- Since 2008: Research Manager of the DFCV Team (Functional Ecology) of IMBE,
- Since 2012: joint director of the OSU Institut Pytheas (for Ecology)
- Principal Investigator for 6 research programs (including ANR SecPriME) participation in 20 research programs

**3 relevant publications:**

54 publications included in the Journal of the Citation Reports. h index 16 – (ID Research: http://www.researcherid.com/rid/A-2556-2009)


Output: Results under analysis. Participation to the 7th World Congress on Allelopathy : Complex Interactions in a Changing Climate in Summer 2014.