# Young scientist contract (PhD) offered by INRA within the doctoral school RP2E (Université de Lorraine)

## Call for applications - April 2016

Inra and the Doctoral School RP2E offer during 2016 one "Contrat Jeune Scientifique" (Young Scientist Contract) for 3 years (duration for completion of a PhD). Research will take place at Nancy (France). Candidates may choose among the five topics offered this year:

Topic 1
Understanding the molecular dialogues within forest soil microbial communities and investigating their impact on plant health and growth.

Topic 2
Microrefugia facing climate change: bioclimatic modeling of steep-sided valleys in northeastern France.

Topic 3
Modelling the effects of interspecific competition on resource availability and tree growth, to evaluate impact of site preparation in young forest plantation.

The topics and contact persons for specific information are provided below.

### Applications

Applicants to this contract should send the application files including:

1. A detailed CV with all details about obtained degrees, fulfilled training and results;
2. A motivation letter indicating the selected topic, an short description of skills of the candidate with respect to the topic and the plans of the candidate for his/her future career,
3. A recommendation letter provided by a professor or a researcher who supervised the candidate during his/her training.
4. Whenever possible, a copy of the degrees obtained up to now.

You should hold a Master's degree in life sciences or environmental sciences with an excellent grade list. You should demonstrate an interest in transdisciplinary research. You are expected to be creative and open-minded and to have the ability to establish and maintain good interpersonal relationships. Knowledge of French language is not a prerequisite. You should demosntrate a good level of spoken and written English, and the thesis may be written in English.

The research will mostly take place at the Inra campus, Champenoux (30 min by bus) or at the Faculté des Sciences et Techniques, Université de Lorraine, Nancy. The research groups are all members of the "Laboratoire d'Excellence" ARBRE (http://mycor.nancy.inra.fr/ARBRE/). In these groups, you will benefit from the support of advanced technical platforms devoted to genomics, stable isotopes, electronic and confocal microscopy, wood science, etc… You will be member of a large-scale research community of about 350 persons working in forest and wood sciences (see http://www.nancy.inra.fr/).

Nancy is a medium-sized city (350000 inhabitants including suburbs) located in North-Eastern France. The city is very attractive in terms of gastronomy, cultural activities, architectural (ranging from the UNESCO classified Place Stanislas (18th century) to the so-called 'Ecole de Nancy' style),....The countryside is very peaceful with lakes and many forests, close proximity to the Vosges mountains (for skiing, trekking, mountain biking...), to Belgium, Luxembourg and Germany. There is very easy access to Paris (1h30 to Paris with the high speed TGV train) and to other destinations in France and the continent (30 min from National Airport Nancy-Metz, 1h15 from Luxembourg International Airport).

Applications files should be sent to the administration of the Doctoral School (christine.fivet@univ-lorraine.fr) with a copy to the president of INRA Centre de Nancy-Lorraine (presid@nancy.inra.fr) not later than Friday May 27th, 2016.

A selection committee will examine all applications and will select the candidates for an audition, based on skills and adequation to the selected topic. The final selection will follow the audition of the candidates (Mid June 2015). Each audition will be based on a 15 min presentation followed by 20 min questions. The audition may be organised with a video conferencing system.

For more information, please contact: presid@nancy.inra.fr or the scientist responsible for each topic.

RP2E website : http://www.rp2e.univ-lorraine.fr
INRA website: http://www.nancy.inra.fr

# Research topic 1

## Understanding the molecular dialogues within forest soil microbial communities and investigating their impact on plant health and growth.

### Research Units

UMR Inra-UL 1136, Interactions Arbres Microorganismes (IAM)

UMR UL-Inra, 1128, Dynamique des génomes et adaptation microbienne (DynAMic)

### Supervisors of the PhD thesis

Aurélie DEVEAU, Chargée de Recherches Inra UMR 1136 IAM ; aurelie.deveau@nancy.inra.fr

Bertrand AIGLE, Professeur des Universités, Université de Lorraine, UMR 1128 DynAMic ; bertrand.aigle@univ-lorraine.fr.

### General aims and state of the art

Underground is a hidden world of soil borne microbes, fungi and bacteria that interact with plant roots and soil resources, and make vital contributions to the ecosystem. The complex network of interactions connecting the plant roots to the soil resources via its associate microbes (fungi and bacteria) assist plants in overcoming problems such as accessing water and nutrients or damage caused by toxic compounds and pathogens. In their ecological niches, microbes do not live as independent individuals but they are constantly interacting. They communicate and manipulate their local environment through the production of signal molecules and metabolite exchanges. Some microorganisms also establish exchanges with plants in a relation that sometimes results in symbiosis. All these metabolic exchanges and molecular dialogues are key processes in the structuration of soil microbial communities, in the resilience of these communities in response to external perturbations and in plant development and health. Yet, little is known about the chemicals and molecular actors involved in these metabolic exchanges.

The aim of the project is to acquire insight into the impact of these dialogues between microorganisms on their behaviour, on their response to environmental changes as well as on the structure of the microbial communities. In a longer term, the goal is to understand how specific dialogues between microbes influence tree development and how plants take part in these metabolic exchanges.

### Specific research topic

The proposed project aims at deciphering the dialogues between microbial partners originating from the rhizosphere of trees by combining *in vitro* and *in situ* approaches. The objectives are to identify the actors involved in these cross-talks and to understand how these interspecies chemical cross-talks impact plant health and growth.

In a first step, an *in vitro* approach will be used to identify pairs of interacting microorganisms and to decipher the molecular mechanisms involved in the interactions. To this end, a library of bacterial strains isolated from the beech rhizosphere will be used. The microorganisms have been isolated at the micro-niche level (soil grain) in which they are likely to have experienced biotic and functional interactions. The library includes different potential plant growth-promoting rhizobacteria such as *Pseudomonas fluorescens* and *Variovorax* strains as well as different *Streptomyces* strains, a bacterial genus known for its ability to produce a wide range of secondary metabolites including antibiotics. Analyses of the interactions between representative members of the different families will first be performed by pairwise (and gradually more) cultures on media of growing complexity (up to a mimic of the natural environment) on well plates and by observation of growth and morphology of the partners and bioactivity tests. For co-cultures showing specific phenotypes (*e.g.* cooperation, stimulation of growth...), the microbial dialogues will be studied at a global and spatio-temporal scale by Imaging Mass Spectrometry (IMS) and high throughput mass spectrometry.

Volatile organic compounds, which are potential dialogue molecules, will be also analysed. The metabolites of the partners whose biosynthesis is influenced by the interaction and could therefore play a role in the dialogue will be characterized further. In parallel, the genome of the partners will be sequenced to identify the secondary metabolite biosynthetic gene clusters and transcriptional analyses by RNAseq will allow identification of clusters whose expression is modulated in co-cultures as well as genes encoding the molecular actors potentially involved in the transduction of the communication signals.

In a second step, microcosms mimicking soil microbial communities (bacteria, fungi) will be performed to assess the impact of the resulting cross-talk on tree parameters such as root development and tree growth and reciprocally the effect of the plant on the microbial interaction. This will be carried out on Petri dishes of transparent soil with tree vitroplants inoculated with the microbial consortium on the roots. The transparent soil allows *in situ* imaging of living plants and root-associated microorganisms. The microbial partners, that can be genetically transformed, will be labelled with different markers (GFP, RFP...). The combination of bacterial detection and localization by 3D imaging confocal laser scanning microscopy and of spectrometric analyses will help to determine the role of each partner in the interactions at the root level.

In parallel, we plan to directly study environmental samples collected from tree rhizosphere by using an approach combining IMS with fluorescence *in situ* hybridization (FISH) to simultaneously obtain metabolite profiling and taxonomic identification of the producers (this approach was proved to be efficient to co-localize compounds and producers from the same sample). We aim to get a real picture of the metabolic dialogues established by plants and microorganisms at the root level.

## Novelty and relevance of the research project to the team

UMR 1136, in collaboration with UMR 1128, is deeply involved in the analysis of the complex network of interactions connecting the tree roots to the soil resources via its associate microbes. The teams combine microbial ecology, molecular biology and genetics to identify the cornerstone microorganisms, to characterize their functional activities and to decipher the molecular mechanisms involved in their activities. This project will complete this knowledge by providing a new and complementary approach to get insights into the activities of tree associated microorganisms during their interactions. The *in situ* approach will provide for the first time direct insights into the activities of microbes in their original niche and will permit to link metabolite production to taxonomic identity in environmental samples. This will be possible thanks to the development of cutting edge tools such as IMS and MALDI-FISH that can also benefit other research projects within the groups.

## Innovation and impact for the society

Despite recent advances in our knowledge of the composition of forest soil microbial communities, the soil remains a black box. This is because we lack information on how microorganisms behave and interact *in situ*. The project we propose will permit to get insights into the activities and the interactions of microorganisms in the tree rhizosphere and thus to shed light into the forest soil black box. This knowledge is important to further understand and predict how tree associated microorganisms' respond to perturbations such as the global change.

In addition, the project may lead to the discovery of new secondary metabolites since most secondary metabolites are mainly produced during interactions with other microorganisms. While resistance to antibiotics are increasing in the medical field and the demand for sustainable agriculture is rising, the finding of new bioactive natural products is major challenge for science. This project could contribute to this goal.

## Available equipment / experimental support / associated research projects

Equipment for transcriptional analysis (real-time PCR, microplate reader for fluorescent reporter genes...), microbiology and classical molecular microbiology are available in the laboratory. The partners have also access to the microscopic, genomic and metabolomic (including HPLC, LC-MS, last generation confocal microscope...) platforms on site. Collaborations have been established with Pieter Dorrestein (UCSD, USA) for the global analysis of metabolic exchange by spectrometric analysis (IMS) through the visits of Bertrand Aigle (2 weeks) and Aurélie Deveau (3 months) funded by the Labex ARBRE.

## Skills that the doctoral fellow will gain during the contract

The proposed project will allow the doctoral student to gain skills in molecular microbiology, integrative biology (microscopy, genomics, transcriptomics and metabolomics) as well as in microbial ecology. He/she will be trained for chromatographic analyses (HPLC, LC-MS, IMS...) as the project may lead to the identification and chemical characterization of novel secondary metabolites. A learning in microscopy (*e.g.* CLSM) and in the technology of FISH will be also offered to the PhD student. He/she will be involved in the development of MALDI-FISH approach.

The student will be fully involved in the development of the strategy of the project and of new research directions that may occur during the thesis. He/she will be expected to become autonomous relatively quickly.

Finally, the doctoral student will acquire open-mindedness through the collaborations he/she will have to establish during his /her PhD. All these qualities will allow him/her to apply for different positions after the PhD in molecular ecology and forestry research areas or in biotechnology. Five publications of the research group on the topic:

## Publications of the research group on the topic (max. 5)


1. Deveau A., Gross H., Palin B., Mehnaz S., Leblond P., Dorrestein P. .C, Aigle B. Role of secondary metabolites in the interaction between *Pseudomonas fluorescens* and soil microorganisms under iron limited conditions. *FEMS Microbiol Ecol.* Submitted.

2. Deveau A. (2016). How does the tree root microbiome assemble: influence of ectomycorrhizal species on *Pinus sylvestris* root bacterial communities. *Environmental Microbiology*. Feb 4. doi: 10.1111/1462-2920.13214

3. Galet J, Deveau A, Hôtel L, Frey-Klett P, Leblond P, Aigle B (2015) *Pseudomonas fluorescens* pirates both ferrioxamine and ferricoelichelin siderophores from *Streptomyces ambofaciens*. *Appl Environ Microbiol*, 81, 3132-41.

4. Deveau A., Barret M., Diedhiou A.G., Leveau J., de Boer W., Martin F., Sarniguet A., Frey-Klett P. (2015) Pairwise transcriptomic analysis of the interactions between the ectomycorrhizal fungus *Laccaria bicolor* S238N and three beneficial, neutral and antagonistic soil bacteria. *Microbial Ecology*. 69: 146-159.

5. Galet J, Deveau A, Hôtel L, Leblond P, Frey-Klett P, Aigle B (2014) Gluconic acid-producing *Pseudomonas sp*. prevent γ-actinorhodin biosynthesis by *Streptomyces coelicolor* A3(2). *Arch Microbiol*, 196, 619-27.

# Research topic 2

## Microrefugia facing climate change: bioclimatic modeling of steep-sided valleys in northeastern France.

### Research Unit

UMR-1137 Ecologie et Ecophysiologie Forestières (EEF) (Centre Inra de Nancy-Lorraine, Université de Lorraine)

### Supervisors of the PhD thesis

Jean Luc DUPOUEY, Directeur de Recherches, Inra, UMR UMR-1137 Ecologie et Ecophysiologie Forestières ; dupouey@nancy.inra.fr;

Sandrine CHAUCHARD, Maitre de Conférences, Université de Lorraine, UMR UMR-1137 Ecologie et Ecophysiologie Forestières ; sandrine.chauchard@univ-lorraine.fr;

Vincent BADEAU, Ingénieur de recherches Inra, UMR UMR-1137 Ecologie et Ecophysiologie Forestières ; vincent.badeau@nancy.inra.fr.

### General aims and state of the art

The Jurassic limestone plateaus in Northeast France (from Longwy (north) to Dijon (south)) are deeply carved by several wide river valleys (e.g. Moselle, Marne, Meuse, Armençon, Yonne) but also by numerous steep-sided valleys. These peculiar landforms, often parts of wide and homogeneous forest areas, have long been identified as specific and rare habitats, of high environmental value (Le Tacon & Timbal, 1972; Bugnon et al., 1974; Rameau & Timbal, 1979). According to the variability of their orientation, length, width, depth, hydrography and sinuosity these steep-sided valleys are characterised by a diversity of small-scale microclimates (Scherrer and Körner 2011) which differ greatly from the regional climate and the surrounding plateau, with greater thermal and moisture amplitudes (at a daily or annual time step; Le Tacon & Timbal 1972). If the south-facing slopes are much warmer and characterized by a sub-mediterranean climate, north-facing slopes and thalwegs are colder, wetter and characterized by a sub-montane climate. Consequently, each steep-sided valley of the Jurassic limestone plateaus exhibits large variation of climate at fine-scale (below 100m scale) «Cold valleys» constitute thus a microrefugia - e.g. *small areas with local favourable environmental features in which small populations can survive outside their core distribution area (Rull, 2009)* - for both cold-adapted and thermophilous species.

Presence of these restricted microclimate leads to the occurrence of specific plant species (thermophilous species on south-facing slope e.g. *Quercus pubescens*, cold-adapted species in the thalweg and on the north-facing slope, e.g. *Aconitum lycoctonum* or *Cardamine heptaphylla*) and habitats (Bugnon & Rameau 1974, Noirfalise 1960, Timbal 1977). Species and habitats of “cold valleys” are in sharp decline for several reasons: presence of forest tracks in the thalwegs, changing hydrology due to management, substitution of native deciduous forest species by coniferous plantations, strong logging on steep slopes leading to soil erosion or at the other extreme decrease of forest management leading to a canopy closure and the disappearance of the heliophilous species (such as the very rare Cypripedium calceolus, for example). Climate change poses a new threat to these ecosystems but it has never been evaluated. Since the coldadapted plant species located in the north-facing slopes and thalwegs of the “cold valleys” are already located at their lower altitudinal range, a temperature increase could have strong negative impacts on their distribution and then lead to change in species distribution and then communities composition. On the opposite, thermophilous species located in the south-facing slopes should benefit from temperature increase and their range should expand. Then, in a context of anthropogenic warming, “cold valleys”, as microrefugia might i) continue or not to provide suitable habitat for some cold-adapted species, ii) provide suitable habitat for new threatened species (mesic species) and mitigate the extend of the biotic extinction (Rull, 2009) and iii) play a role in subsequent range expansion notably for thermophilous species located in the south-facing slope (Hylander et al, 2015). “Cold valleys” should contribute to mitigate climate change effect as their microclimates are decoupled from

the regional climate. Their present and future roles depend on the degree and the persistence of decoupling. Indeed, portion of the sites with strong decoupling to regional conditions have a greater potential to persist through time (Dobrowski, 2010). Microrefugia, notably warm-stage microrefugia, have been the subject of recent studies and syntheses in mountain environment, notably in the Alps (Patsiou et al. 2014, Gentili et al 2015) but none was conducted in lowlands whereas climate change velocity should be much higher in flat landscapes (Loarie et al. 2009). Moreover, sites that support microrefugia most often differed for cold and warm stage (Dobrowski 2010). "Cold valleys" offer both kinds of microrefugia in close vicinity: warm-stage microrefugia for cold-adapted species in the thalweg and the north-facing slopes, and cold-stage microrefugia for thermophilous species on the south-facing slopes. Thus, "cold valleys" offer the opportunity to study the different roles of microrefugia in a lowland landscape: i.e. conservation of cold-adapted species and source for range expansion of thermophilous species.

## Specific research questions

Although the flora of "cold valleys" has been surveyed in the past, a synthesis of this documentation, often published in grey literature, is needed to consolidate our knowledge on the vegetation, soil and climate of these peculiar environments. This will help, on one hand, building a relevant knowledge basis to model the present (and then through times) distribution of these habitats and their specialized species and, on the other hand, identifying and protecting the most typical sites. This synthesis could help managers of protected areas, as Natura 2000 sites, to identify conservation values of site and prioritize conservation actions in an anthropogenic warming context.

Due to the high level of decoupling of the local and micro-climates of such "cold valleys" compared to the regional climate, they represent ideal and appropriate case studies for challenging and refining species and community distribution models that use climate and high-resolution topoclimatic predictors. Commonly used species or community distribution models that use only general climate parameters as predictors often show poor accuracy. Several studies have shown the relevance of using high-resolution topographic predictors to refine species distribution models (Lassueur et al. 2006, Pradervand et al. 2013, Leempoel et al. 2015). In particular, cold valleys could help in addressing the following questions: (1) are high-resolution topo-climatic predictors sufficient to detect the presence of such topographic features and to adequately predict the distribution of specialized species or vegetation units? (2) can new-developed predictors (slope, aspect, solar radiation, particular topographic features), selected to be proxies for processes occurring in cold valleys, improve the predictions of distribution models?

The main objectives of the project are:

i) Improving our knowledge on location of "cold valleys" in order to help protect the most typical plant species and communities;

ii) Characterising the vegetation and the local and micro climate of "cold valleys" as a function of their topographic attributes;

iii) Understanding mechanistically the climatic basis of "cold valleys" with climate sensors to ultimately refine topo-climate predictors used in species and community distribution models;

iv) Evaluating the temporal dynamics of climate and vegetation of cold valleys with the combination of databases, empirical models and *in situ* measurements by sensors. Novelty and relevance to the research project of the team:

## Novelty and relevance of the research project to the team

UMR-EEF, notably Vincent Badeau, has been involved for many years in research projects related to the distribution of forest species at the national and European scales (e.g. GICC-Carbofor, ANRClimator, ANR-QDiv, FP7-Trees4Future) and has a strong expertise in the field of climate databases (baseline and future scenarios) and the processing of these data. UMR-EEF has involved in research project centered on habitat and species conservation. This thesis represents a unique opportunity to refining species and community distribution models, notably to integrate new topoclimatic predictors (as predictors of temperature inversion and cold air pooling). The novelty lies in using both high-resolution topographic predictors and high-temporal resolution and modeled temperature/moisture from sensor to refine species distribution models. In this thesis, Christophe Randin (Lausanne University) will be

solicited notably for its competence in fine scale modeling of bioclimatic constraints in complex topogra for its species niche and climate modeling competences (model including soil water holding capacity).

## Innovation and impact for the society

This thesis will enhance our knowledge on “cold valleys” (notably their spatial distribution, enhance knowledge of vegetation microclimate relationship), and therefore the adequacy of our decisions, concerning the identification and the protection of the specific habitats of steep-valleys, which have a high environmental value. Several public agencies in France are directly interested in the results of this project: DREALs, Conservatory of natural sites, General council, Forest National Office.

## Available equipment / experimental support / associated research projects

Floristic informations on species occurrences (Lorraine's and Burgundy's limestone plateaus) have been previously collected: 416 floristic inventories (mainly collected in the 1970s, 1980s) were compiled from ancient literature and SOPHY database and classified to offer habitat/communities characterization. The knowledge of such a list of species should allow a more efficient search for relevant ancient vegetation surveys in other, complementary databases (e.g. National Forest Institute database, regional databases). The teams have access to and expertise on the main environmental and forest vegetation databases at the French and European levels.

The availability and intensity of sunlight (solar radiation) can be calculated with computational routines developed by the team for ArcMap or R, using the digital terrain model of the IGN at a 25m resolution. Topographical features can estimate the cold air pooling, e.g. topographic amplification factor and local concavities/convexities of the terrain, as used by the Lausanne University team. The team owns about 30 temperatures/humidity sensors that will be used for field measures.

## Skills that the doctoral fellow will gain during the contract

The doctoral fellow will gain field botanic, Geographical information systems, and modeling skill. Different modeling approach (generalised linear or additive models for example) should be developed during the thesis. The doctoral fellow will develop methodology for identification of biodiversity’s hotspots in forest and acquire general abilities in forest conservation.

## Five publications of the research group on the topic


Badeau, V., Dupouey, J.-L., Cluzeau, C., Drappier, J. (2007). . Aires potentielles de répartition des essences forestières d'ici 2100. *Rendez-vous Techniques de l'ONF* (3), 62-66.

Cheaib, A., Badeau, V., Boe, J., Chuine, I., Delire, C., Dufrêne, E., ... & Thuiller, W. (2012). Climate change impacts on tree ranges: model intercomparison facilitates understanding and quantification of uncertainty. *Ecology letters*, *15*(6), 533-544.

Engler, R., Randin, C. F., Vittoz, P., Czáka, T., Beniston, M., Zimmermann, N. E., & Guisan, A. (2009). Predicting future distributions of mountain plants under climate change: does dispersal capacity matter? *Ecography*, *32*(1), 34-45.

Patsiou, T.S., Conti, E., Theodoridis, S., Randin, C.F. (In revision) Quantifying the discrepancy between regional climate and climate in the micro-habitats of an arcto-tertiary relictual alpine species. *Progress in Physical Geography*.

Randin, C. F., Jaccard, H., Vittoz, P., Yoccoz, N. G., & Guisan, A. (2009). Land use improves spatial predictions of mountain plant abundance but not presence-absence. *Journal of Vegetation Science*, *20*(6), 996-1008.

# Research topic 3

## Modelling the effects of interspecific competition on resource availability and tree growth, to evaluate impact of site preparation in young forest plantation.

### Research Unit

UMR Inra/AgroParisTech 1128 Laboratoire d'Etude de la Ressources Forêt-Bois (LERFoB) F54280 Champenoux

### Supervisors of the PhD thesis

Catherine COLLET, Chargée de Recherches Inra, F 54280 Champenoux (catherine.collet@nancy.inra.fr )

### General context

Plantation is major tool to implement forest management strategies for climate change adaptation and mitigation. It may be used to increase carbon storage in forest stands, to install more resilient species, and to regenerate damaged stands (storm, drought, pathogens).

Plantation is also a critical step of the forest management cycle, from a financial and from a technical perspective. It concentrates both the main financial costs and the main risks of technical failure.

Site preparation is very often required to ensure plantation success. It is used to alleviate the main constraints to seedling establishment: competition from neighbouring vegetation for light, water and nutrients, soil compaction, waterlogging. A large range of site preparation methods is presently available to forest managers. The choice of site preparation method and its implementation (intensity, frequency, pattern…) must be adapted to site characteristics (soil, vegetation, climate…) and to management objectives (tree species, planting pattern, environmental constraints…). Decision support tools that describe the effects of site preparation methods on seedling survival and growth, and characterise their overall technical, economical and environmental performance would be very helpful for forest managers to select appropriate site preparation methods.

Tree growth models are effective tools to simulate the impacts of silvicultural operations. In France, there is presently no tree growth model to evaluate or compare silvicultural operations performed during young stages, even for well-known species such as pine, oak or douglas-fir. Existing growth models are not calibrated properly for the young stages, and they do not incorporate appropriate tree variables and tree growth processes to describe the impacts of silvicultural operations performed during the early stages.

The general objective of the project is to build a growth model to evaluate the impact of silvicultural operations performed during the first years after planting.

### State of the art and novelty

Growth models have been used widely for many years (Mason and Dzierzon, 2006). Most of them are mensurational models (i.e. phenomenological models) describing the requested dendrometric variables (h, d, G) according to technical characteristics of the silvicultural operations performed (Knowe et al., 1992, Westfall et al., 2004). These models generally produce robust predictions. However, their results can hardly be extrapolated to different conditions (soil, climate, tree species…) or used to identify the main factors limiting seedling growth (Richardson et al., 2006).

More recently, functional models (Arneth et al., 1999) that describe plant carbon gain as a function of resource availability and environmental conditions in order to estimate seedling growth, have been used to overcome the limits of mensurational models (Sands et al., 2000). These models may be used to incroporate the impacts on seedling growth of soil fertility or competition with neighbouring plants. However, such models focussed on

physiological processes require a high number of parameters that may be difficult to obtain and, additionnally, produce predictions of tree growth that are not always robust.

Hybrid models that incorporate into mensurational model some functional relatinships describing the impacts of resource availability (light, water, nutrients) and environmental conditions (air temperature, soil characteristics…) on tree growth, have been developped (Landsberg et Waring 1997). The models follow the classic representation where actual growth is described as the product of a growth potential and a series of growth reductors. The growth potential represents growth in optimal conditions and is described using empirical relationships established on tree growth data. The reductors represent the impacts of limiting environmental factors and neighbouring plant competition. They are based on functional relationships representing resource acquisition and partitioning among plant individuals.

Hybrid models that blend mensurational methods with ecophysiology are a promising approach that allows to use functional relationships expressing tree growth while obtaining a robust predition of growth. Such models have already been used to evaluate the impacts of cultivation practices or environmental factors (soil, climate) on tree growth (Watt et al. 2007, Mason et al. 2011) : e.g., the model 3-PG was used to describe the impacts of silvicultural operations (fertilisation, vegetation control, site prep) during the young stages (Mason 2004).

## Specific research question

The general objective is to build a hybrid growth model that may be used to evaluate the impact of silvicultural operations in the first years after planting, in a two-step-approach:

1. Analyse the functional form of height and diameter growth curves and build reference curves for the studied species, in the young stages (up to 10 years). The models will then be used to quantify the impacts of some silvicultural operations on seedling growth.

2. Analyse the factors that determine seedling growth and the difference between the actual and the reference growth curve, and build the growth reductors. In this step, the study will focus more specifically on competition for light and for soil water, occurring between the seedlings and the neighbouring vegetation.

Note: The project focuses on seedling growth. Seedling mortality will not be taken into account. Analysing mortality requires large data sets with much more trees (to describe situations with low mortality rates) and with a larger range of environmental conditions with more repetitions (factors determining tree mortality are numerous, non linear, and interacting). Such data are currently not available.

## Available equipment/ experimental support/ associated research projects

### Available data

- Data describing tree growth, in young plantations with different silvicultural scenarios, to calibrate the reference growth curves to build the mensurational models.

- An inventory of avalaible data in existing databases at INRA, ONF and FCBA is presently ongoing. Approximately 50 experiments that could potentially provide the data, have been identified. In addition we will try to complement the french dataset with data available in neighbouring countries (Spain, Germany).

### Experimental site

Experimental site to analyse the impacts of different site preparation methods on resource availability and tree growth: During 2012, we established an experimental site, where young sessile oaks and scot pines are grown under a different site prep methods that provide a range of competition intensity and soil characteristics. Soil water and light measurement devices will be established at the beginning of the thesis.

### Associated projects

1. Projet Capsol: «Dynamique du carbone et de la croissance après préparation du sol dans les plantations forestières ». Leader : INRA-LERFOB. Participants : INFA-BEF, INRA-LEF, Univ. Rouen, ONF, IRSTEA, FCBA. The project was submitted to ADEME in Sept 2015. Task1 focuses on carbon dynamics in the soil, following site preparation. Task 2 focuses on tree growth. The overall objective is to evaluate the technical and environmental performance of site preparation methods.

2. Projet Pilote « Les travaux préparatoires à la plantation ». Leader : INRA-LERFOB. Participants : ONF, FCBA, IDF-CNPF, Alliance-Forêts-Bois, SF-CDC. The project is funded by France-Forêt-Bois. The objective is to evaluate the technical and economical performance of site prep methods.

3. Projet « Maîtrise de la végétation forestière concurrente : utilisation raisonnée des herbicides et méthodes de gestion alternatives ». Leader : INRA-LERFOB. The project is funded by the MAAF. The objective is to develop and evaluate site prep methods.

## Skills that the doctoral student will gain during the contract:

General knowledge: Tree growth and yield; Competition process; Management of forest plantation

Methodological knowledge: Experimentation in natural conditions; Data analysis; Modelling: model conception and parameterization; Statistical analysis

## Publications of the research group on the topic (max. 5):


Van Couwenberghe, R., Gégout, J.-C., Lacombe, E., Collet, C. (2013). Light and competition gradients fail to explain the coexistence of shade-tolerant *Fagus sylvatica and shade-intermediate Quercus petraea seedlings*. *Annals of Botany, 112* (7), 1421-1430.

Barbeito Sanchez, I., Collet, C., Ningre, F. (2014). Crown responses to neighbor density and species identity in a young mixed deciduous stand. *Trees-Structure and Function, 28* (6), 1751 - 1765.

Collet, C., Ningre, F., Barbeito, I., Arnaud, A., Piboule, A. (2014). Response of tree growth and species coexistence to density and species evenness in a young forest plantation with two competing species. *Annals of Botany, 113* (4), 711-719.

Trouvé R, Bontemps JB, Collet C, Seynave I, Lebourgeois F 2014 Growth partitioning in forest stands is affected by stand density and summer drought in sessile oak and Douglas-fir. *For Ecol Manage*, 334: 358-368.

Annighöfer P, Ameztegui A, Ammer C, Balandier P, Bartsch N, Bolte A, Coll L, Collet C, et al. 2016 Species-specific and generic biomass equations for seedlings and saplings of European tree species *Eur J Forest Res* DOI 10.1007/s10342-016-0937-