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Laboratoire d'Excellence

# ARBRE

*Advanced Research on the Biology of TRees and Forest Ecosystems*



## QLSPiMS: Quantum Leap for Soil-Plant interaction Models

L. Saint-André, D. Bonal & J-D. Bontemps

### Co-Applicants :

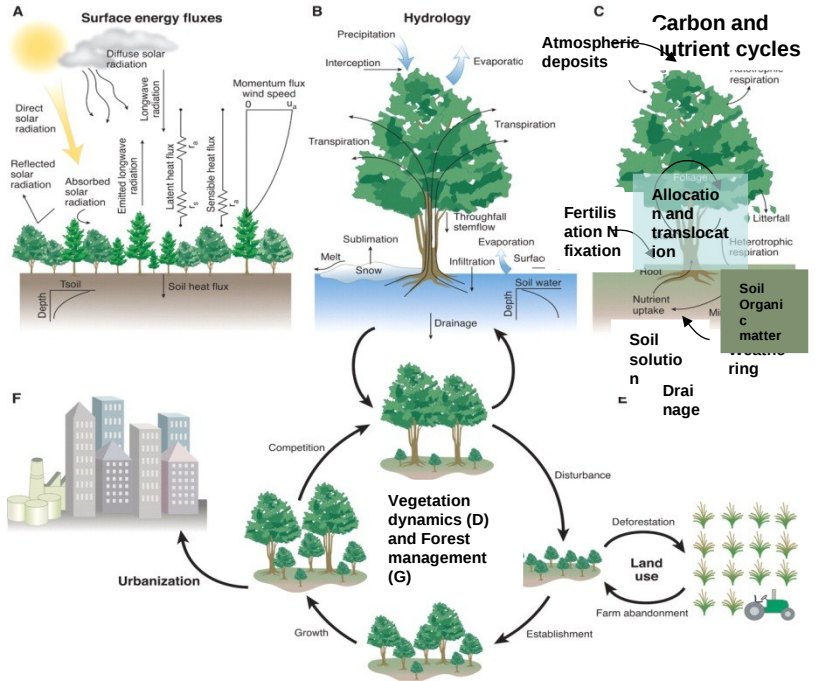
Ecophysiology: M-B Bogeat-Triboulot, D. Bonal, N. Bréda, O. Brendel, D. Epron, D. Gérant, A. Granier, I. Hummel, Y. Jolivet, D. Le Thiec, P. Maillard, N. Marron, C. Massonnet, S. Ponton;

Biometry and dendrometry: J-D Bontemps, J-M. Leban, C. Collet, M. Fortin, F. Longuetaud, F. Mothe, A. Piboule, C. Deleuze, H. Wernsdörfer, I. Seynave;

Biogeochemical cycles: A. Legout, J. Ranger, MP Turpault, D. Derrien, B. Zeller;

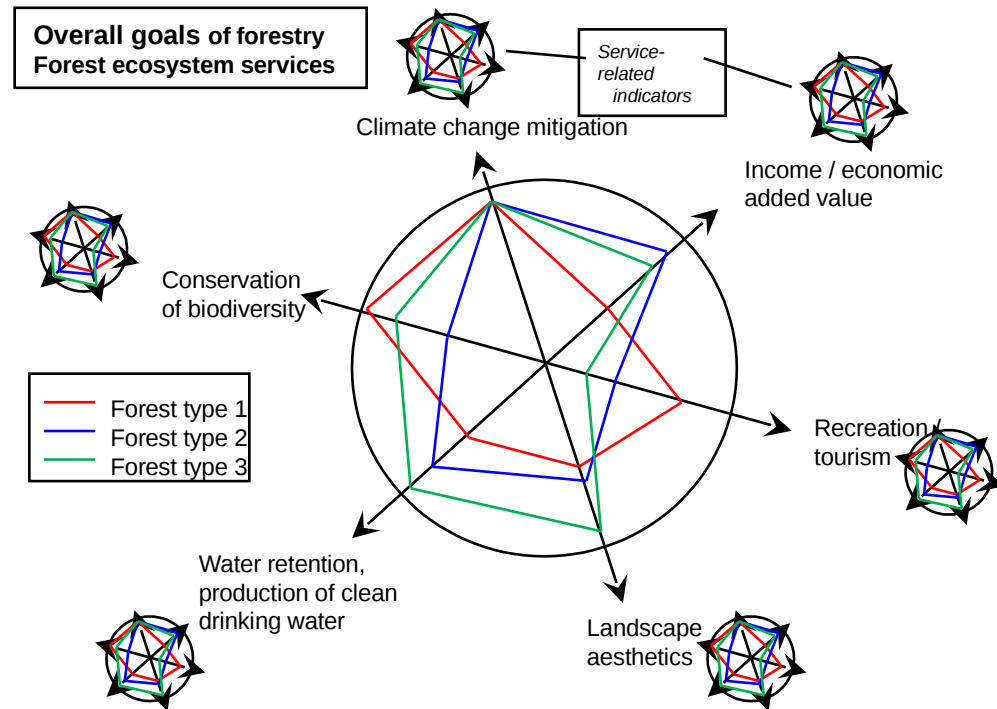
Microbiology: M. Buée, A. Deveau, S. Uroz

# Context and objectives



(A) Surface energy fluxes, (B) the hydrologic cycle, (C) the carbon and nutrient cycles and (D) vegetation dynamics so that plant ecosystems respond to climate change. (E) land use (F) urbanization and (G) forest management to represent human action on the biosphere. (adapted from Gordon B Bonan et al 2008, Science 320, 1444, DOI:10.1126/science.1155121)

Forest ecosystems are **complex** and consequently they provide a large range of **ecosystemic services**



Each of these services requires an assessment of **robust** service-related **indicators**

# Context and objectives

State of Europe's Forests 2011 Report of the Ministerial Conference on the Protection of Forests in Europe:

-Identification of the future challenges and opportunities for forest policies and management in Europe (Forest Europe/UNECE/FAO 2011 )

-Among them, **mitigation and adaptation measures rise as priorities to cope with climate change** and to provide a sustained and renewable source of energy for Europe.

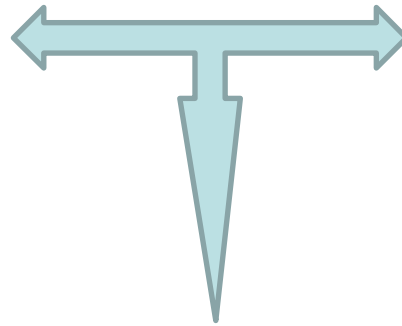
-**A robust metrics system** to compare the impacts of each forest management on different ecosystem services **is still missing**.

-The overlapping challenge is **to deal with the interactions between C sequestration and other forest ecosystem services** (wood and non-wood products; wood for bioenergy; water quality and quantity, soil fertility and protection, recreation).

# Context and objectives

The goal of QL-SPIMS is to deliver a **new generation of soil-plant models** focusing on the **interactions between water, carbon and nutrient cycles** in forest ecosystems while helping the forestry sector to 1) assess the **long-term impacts of local and global environmental changes**, and 2) to **face economic challenges imposed by the adaptation to climate change**

an innovative modeling methodology which combines concepts and takes advantage of the large diversity of modelling approaches



an interdisciplinary approach to deepen the knowledge about the impact of soil nutritional status and soil water availability on tree functioning

a close articulation between theory, process-based modelling, and statistically-assisted observation to explore the patterns of dose-response curves to water, nutrient and energy resources of integrated traits of tree communities

# Rationale

Evidence that interactions between water, carbon and nutrient cycles may drive a large part of the ecosystem functioning

On one hand,  
Current nitrogen deposition loads seem to increase above-ground forest growth in Europe (de Vries et al. 2009, 2010, Solberg et al. 2009, Laubhann et al. 2009) and decreases CO<sub>2</sub> efflux from soil (Janssens et al. 2010)

On the other hand,  
Fertilisation may result in more N<sub>2</sub>O and offset the forest C sequestration (e.g. Schulze et al. 2009)

Enhanced ground level O<sub>3</sub> can substantially mitigate the C sequestration of late-successional tree species forests in view of climate change (Wipfler et al. 2009, Matyssek et al. 2010, Pretzsch et al. 2010, Ren et al. 2011)

Interactions between winter climate (shorter soil frost periods) and snowmelt in the spring may enhance total cumulative flux of C (i.e. dissolved organic C, CO<sub>2</sub>, CH<sub>4</sub>) and N (i.e. dissolved organic N, NH<sub>4</sub>, NO<sub>3</sub>, N<sub>2</sub>O) of forest ecosystems (Reinmann et al. 2011)

Large advances in modeling tree and stand growth have been made

in the fields of **ecophysiology** (process-based models, structure-function models, dynamic global vegetation models e.g. Dufrêne et al. 2005; Corbeels et al. 2005; Kirschbaum and Watt 2011, Morales et al. 2005; Hickler et al. 2009; Belassen et al. 2010, 2011),

**forestry and biometry** (growth and yield models e.g. Saint-André et al. 2008, Skovsgaard and Vanclay 2008, Pretzsch et al. 2008, Vallet and Pérot 2011, Garcia 2011, large-scale forest resource models Nabuurs et al. 2002, Wernsdörfer et al. 2011)

**and biogeochemical cycles** (soil chemistry models - Tuomi et al. 2008, D'Annunzio et al. 2008, Sverdrup et al. 2007, Belyazid 2011, Rastetter 2011)

# Rationale

*Evidence that interactions between water, carbon and nutrient cycles may drive a large part of the ecosystem functioning*

*Large advances in modeling tree and stand growth have been made*

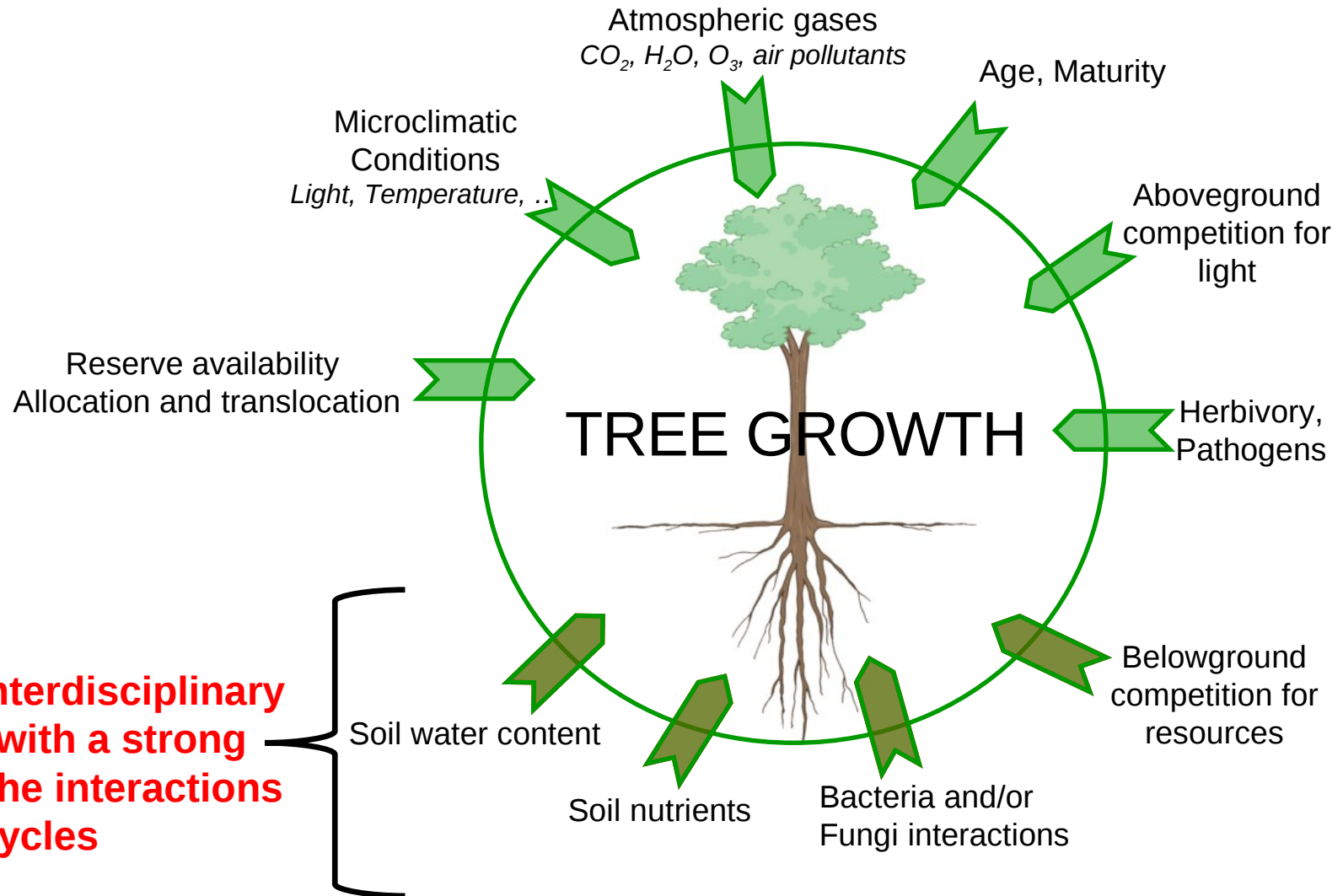
*BUT*

Nutrient cycles and interactions with C and Water cycles still poorly described in tree and stand growth models (even process-based ones)

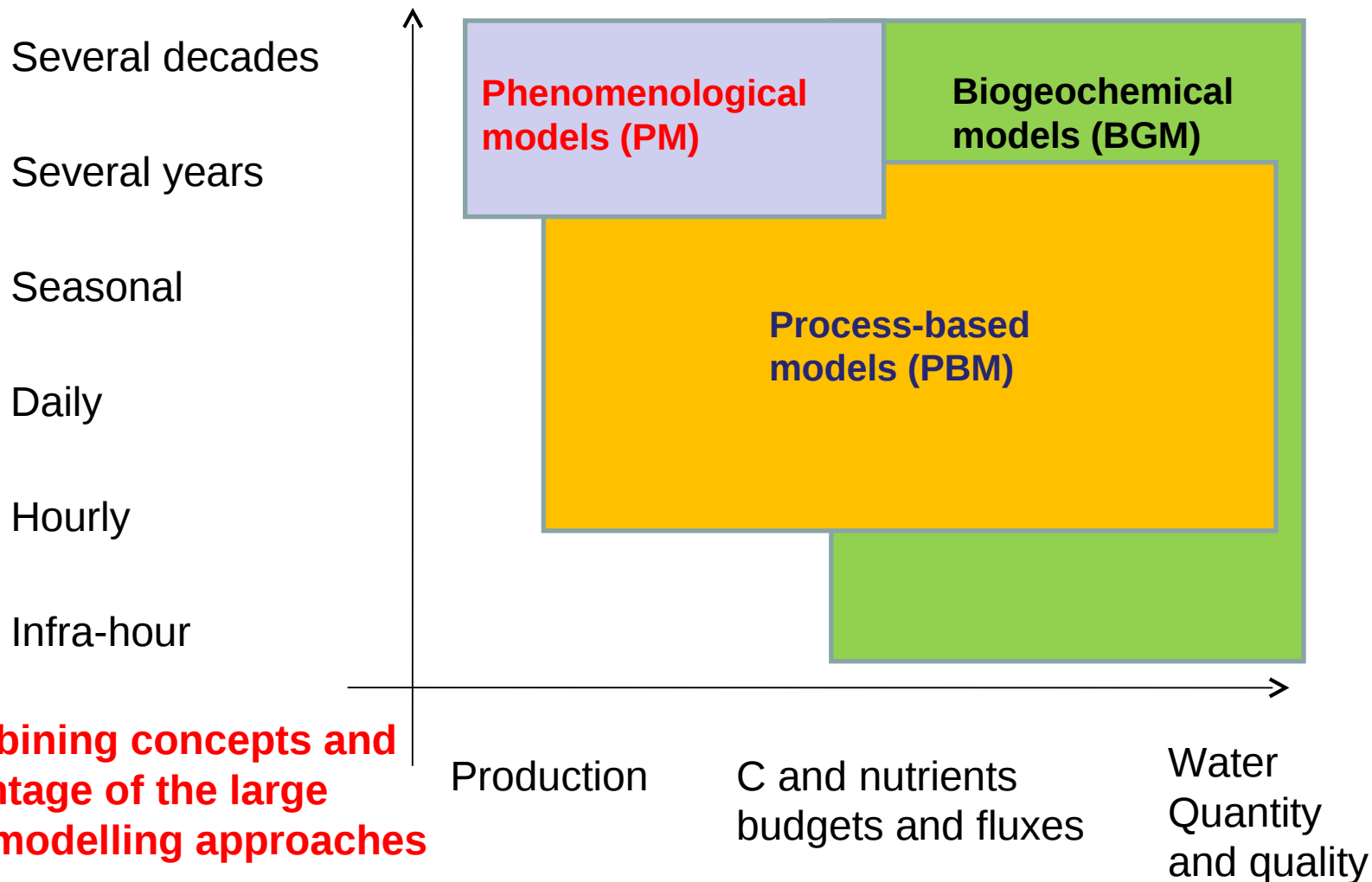
Root growth and function still a “black box” despite its importance in resource (water and nutrient) acquisition

QL-SPiMS is exactly designed to make significant progresses on these two topics

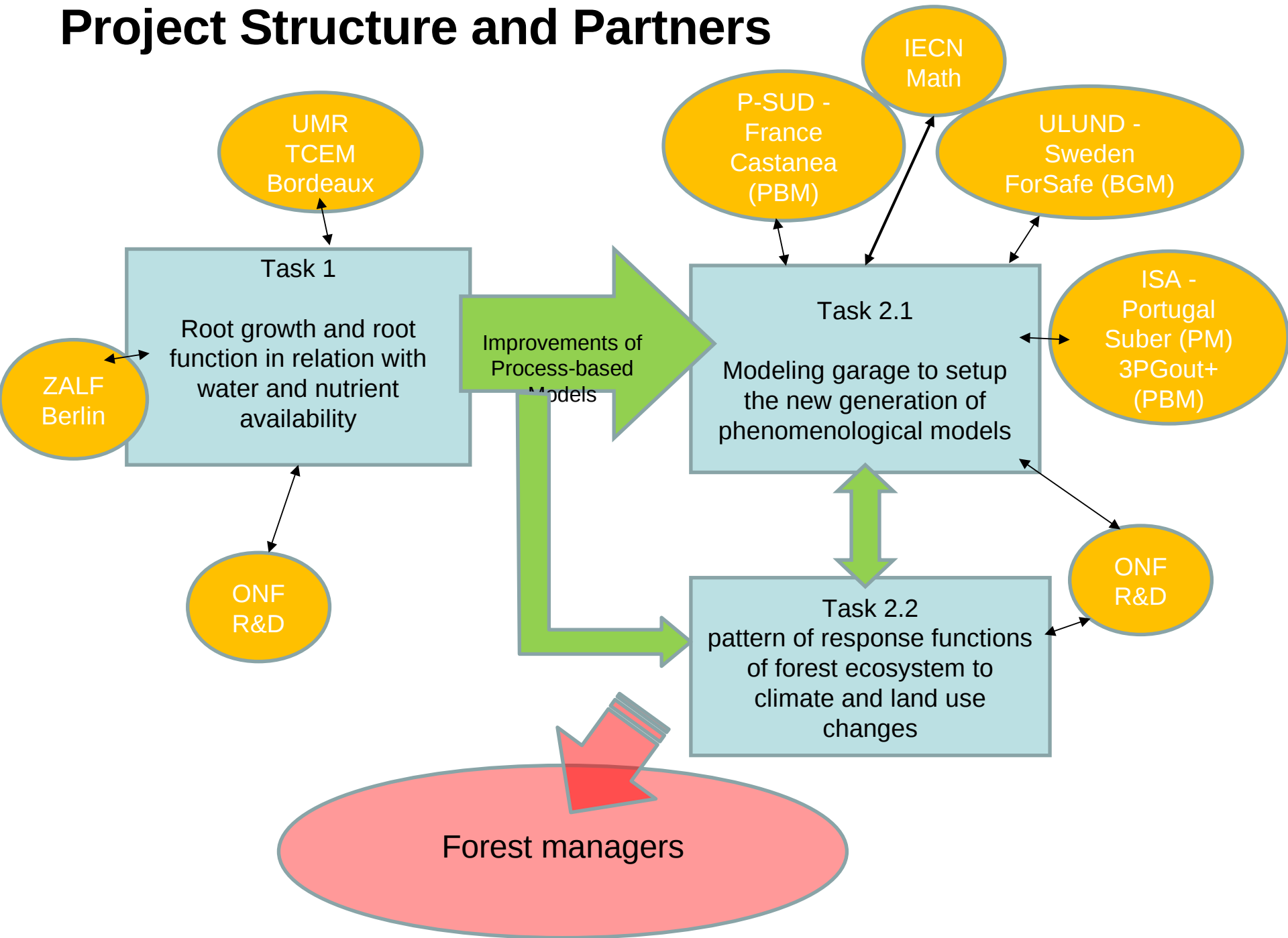
First Challenge : Deepen the knowledge about the impact of soil nutritional status and soil water availability on tree functioning (carbon assimilation and allocation)



Second Challenge : Development of a new generation of phenomenological models and analysis of the pattern of response functions of forest ecosystem to climate and land use changes



# Project Structure and Partners



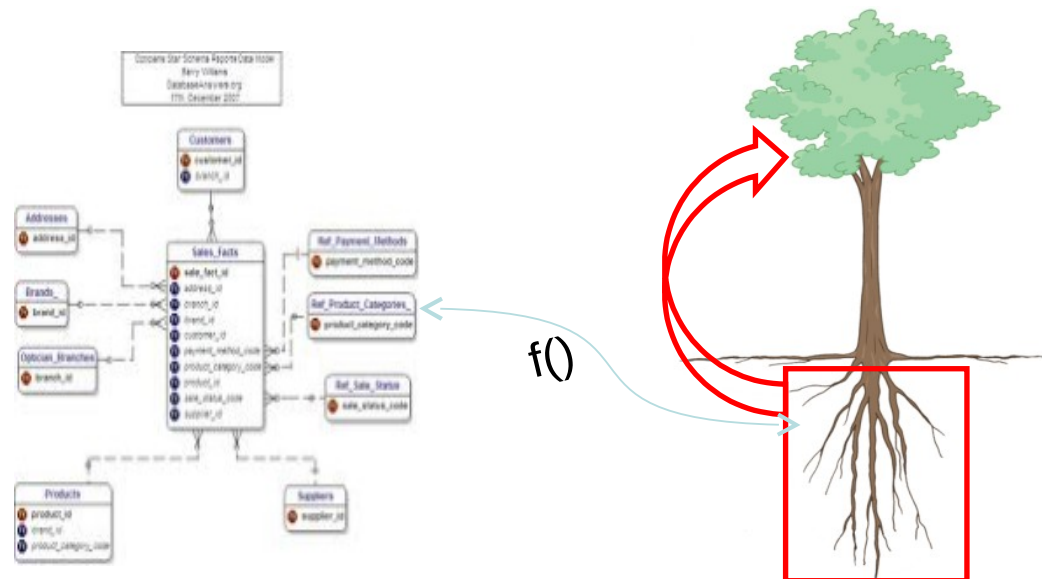
Task 1. Deepen the knowledge about the impact of soil nutritional status and soil water availability on tree functioning (carbon assimilation and allocation)

Objectives:

(i) To analyze the morphological and physiological root processes impacted by changes in soil nutrient availability (N, P...) and soil water

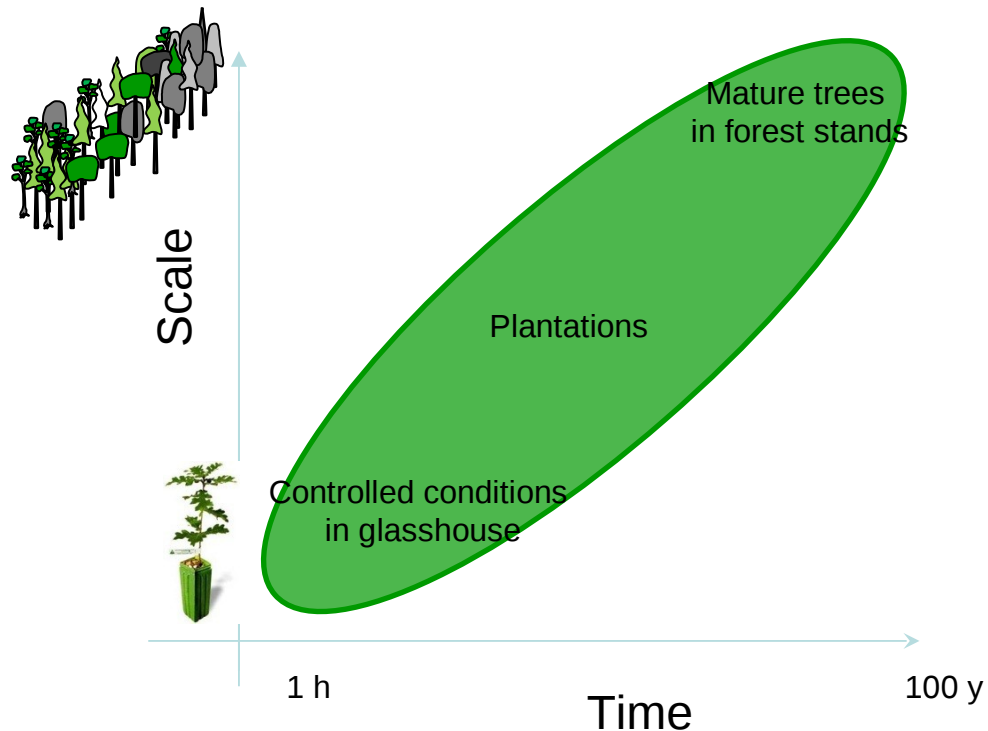
(ii) To study the influence of these modifications on plant functioning and growth

(iii) To identify, in close collaboration with Task 2 members, those process-based growth modifiers to be injected in a new generation of growth models



Task 1. Deepen the knowledge about the impact of soil nutritional status and soil water availability on tree functioning (carbon assimilation and allocation)

Multidisciplinary (ecophysiology, biogeochemistry, microbiology) approaches covering a large range of time and spatial scales and monospecific as well as plurispecific systems



Species of interest:

Oak, Beech Pine, Douglas

Short-term coppice systems

Mixed-species systems

Interest in the interactions between trees and bacteria and/or fungi

Task 1. Deepen the knowledge about the impact of soil nutritional status and soil water availability on tree functioning (carbon assimilation and allocation)

Three main operations:

O1.1- Impact of soil nutritional status and water availability on root development (growth, architecture, and tree functioning (interactions with microbes and nutrient availability) and consequences on tree growth

O1.2- Impact of soil nutritional status and water availability on carbon acquisition and allocation (photosynthesis, gas exchange, water use efficiency) – Consequences on tree growth

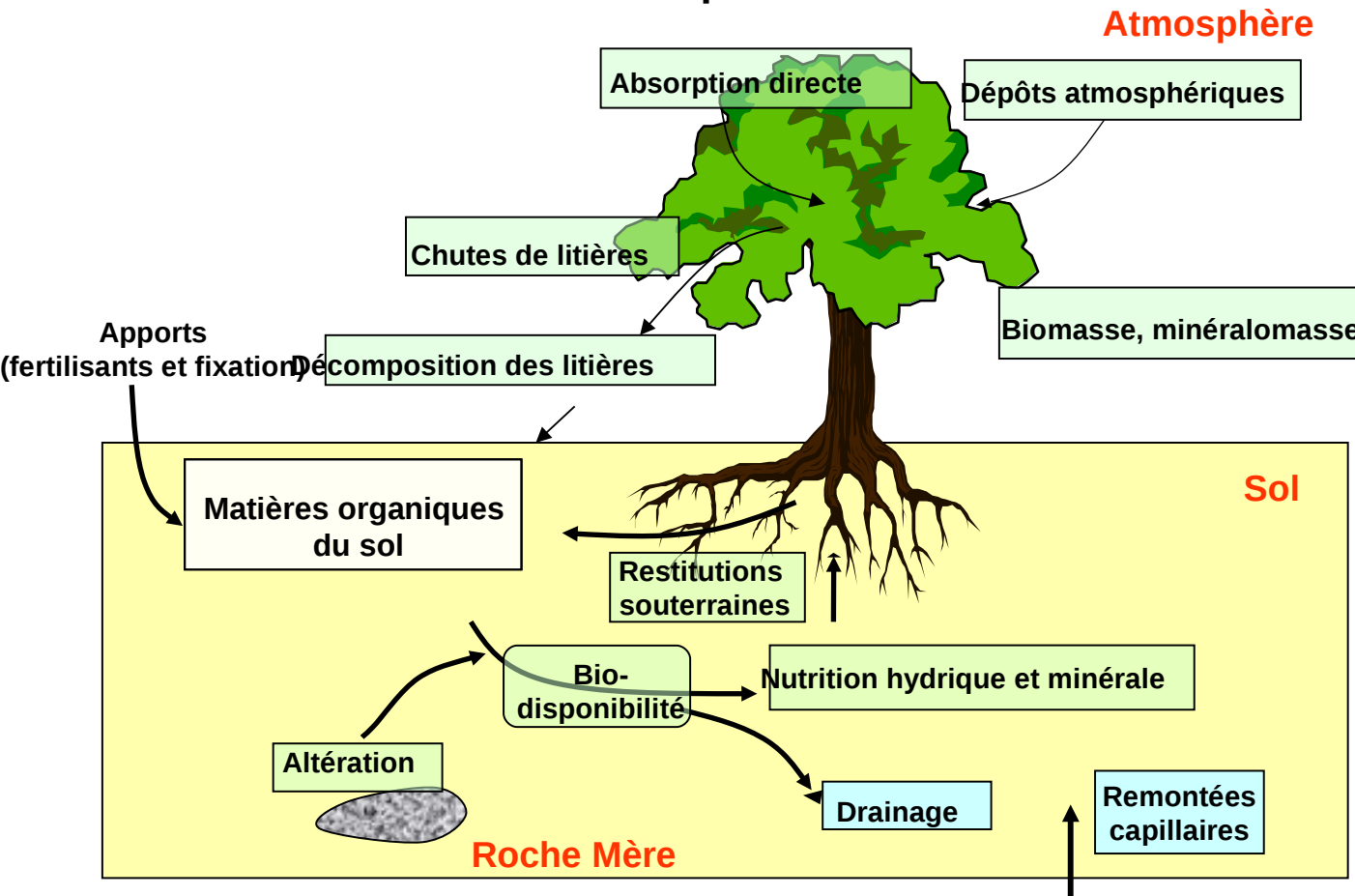
O1.3- Impact of soil nutritional status and water availability on resource allocation, special attention to C and N reserve storage and allocation to above- and below-ground growth

**Strong links between these operations**  
**Definition of growth modifiers to be injected**  
**in new growth models**



# Task 2.1 Open a workspace, or modeling garage, for the set-up of the new generation of phenomenological model suites

## Modélisation des interactions sol-plante



Series of **thematic Workshops** (exchanges, planification, and priorities for the 5-days working groups)

Sets of **5 days-working group** (web conference in the morning, work during the afternoon, cycles of 5 consecutive days)

**Position papers** and conceptualisation of forest ecosystem functioning

3 **Progress Workshops**

One international conference

## Task 2.2 On formalizing the response of forest trees and forest ecosystems to environment

# Aim

- ① To interpret past forest ecosystem changes
  - species **distribution**, forest **growth**, **wood** properties...
- ② To provide projections over the next decades and beyond
  - with increased **realism** and **confidence**
- ③ In a challenging modelling context, and a trade-off between:
  - scale-relevant empirical approaches, but **not general/robust enough**...
  - cognitive PB approaches, but **data-consuming and scale restricted**

Task 2.2 On formalizing the response of forest trees and forest ecosystems to environment

# Data-analysis and modelling framework

- Such environmental interpretation requires knowledge/formalization
  - On the dose-response functions of integrated tree/ecosystem traits to the environment, including their non-linearities and thresholds
  - On their interplay and combination, including their interactions
  - On acclimation effects and temporal drifts in dose-response patterns
- A generic phenomenological modelling framework is needed
  - To conduct exploratory or retrospective simulations
  - To explore environmental responses on a quantitative basis
  - To give a process-oriented interpretation of ecosystem changed

Task 2.2 On formalizing the response of forest trees and forest ecosystems to environment

# Implementing a 3-axes strategy

- Build on [theory](#), PB/BGC [modelling](#), and statistical [observation](#)
- ① Theories from schools of agricultural economics and of the ecological niche
  - foreaging strategies, resulting dose-response curves and their interplay
- ② PBM/BGC modelling approaches (Task 2.1)
  - meta-modelling of PBMs
  - = what integrated responses to the environment and their interactions ?
  - what main dominant processes in these responses ?
- ③ Statistical observations of trait-environment relationships
  - based on large databases (IFN, Ecoplant, GIS, permanent networks)
  - dependence of environmental responses on statistical tools ?
  - knowledge built on most recent statistical tools (e. g. BRT, RF)