The dynamic of annual carbon allocation to wood in european forests is consistent with a combined source-sink limitation of growth: Implications on growth simulations in a terrestrial biosphere model

Joannès Guillemot, Nicolas Martin-StPaul, Eric Dufrene, Christophe François, Kamel Soudani, Jean-Marc Ourcival, Paul Leadley, Nicolas Delpierre

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Joannès Guillemot, Nicolas K. Martin-StPaul, Eric Dufrêne , Christophe François, Kamel Soudani, Jean-Marc Ourcival, Paul Leadley and Nicolas Delpierre

ESE Laboratory
University of Paris-Sud, France
joannes.guillemot@gmail.com

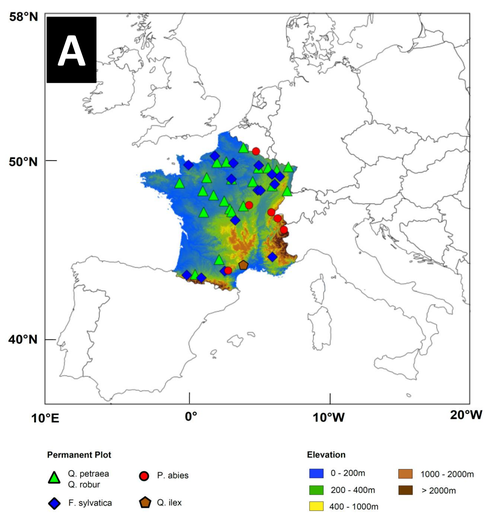
Introduction

- The physiological processes underlying the limitation of forest growth are still under debate. A number of recent local investigations challenge the historical view of a strict carbon (C) limitation of growth that is the basis of the C allocation rules of most terrestrial biosphere models (TBMs).
- The extent to which forest growth is under a C source- or a sink- control is of paramount importance to predict how trees will respond to global changes, especially with regards to the potential fertility effect of rising atmospheric CO_2.

Objectives

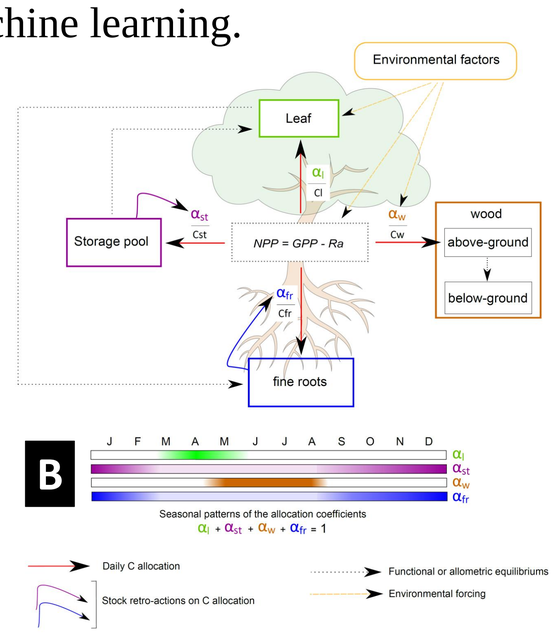
- **To evaluate the dynamics of annual C allocation to wood along regional gradients in 5 major European tree species (in relation to environment and C budget)**
- **To implement the revealed C allocation rules within the CASTANEA TBM and evaluate the simulated wood productivity at regional scale**
- **To evaluate the implications of our new allocation scheme for the productivity of French forests along the 21st century**

Material and Methods



- 4 species from sites representative of the main European biomes.
- C allocation to wood inferred from growth measurements (RENECOFOR permanent plots [**A**]) and simulated GPP and NPP.
- Assessment of inter-site and inter-year drivers using a Random Forest machine learning.

- C allocation scheme in CASTANEA: 4 compartments in semi-competition for C supply (**[B, 1]**).
- Simulated growth results from both source- and sink-limitations (direct effects of water and temp. stresses on growth).



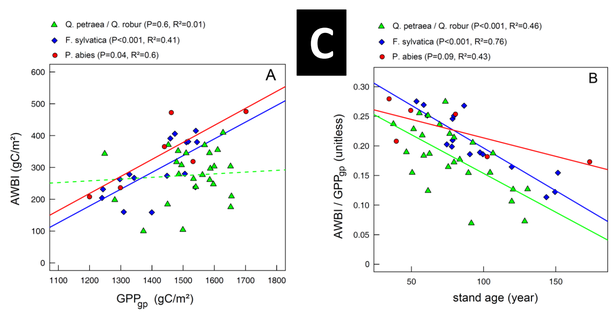
- Performance evaluation was based on the French forest national inventory (5 years of stand biomass increments on >10000 sites).
- Parameters of the allocation scheme were adjusted using a Bayesian optimization (6 param.) and validated on an independent subsample.
- Projections were based on the IPCC AIB scenario **[2]**.

Conclusion

- **European forest growth is under a complex panel of source and sink limitations, related to ontogeny, direct effect of water shortage and lagged response to past condition.**
- **C supply – growth homeostasis and sink controls should both be involved in growth modeling. This will strongly change our predictions regarding the future of forest growth.**

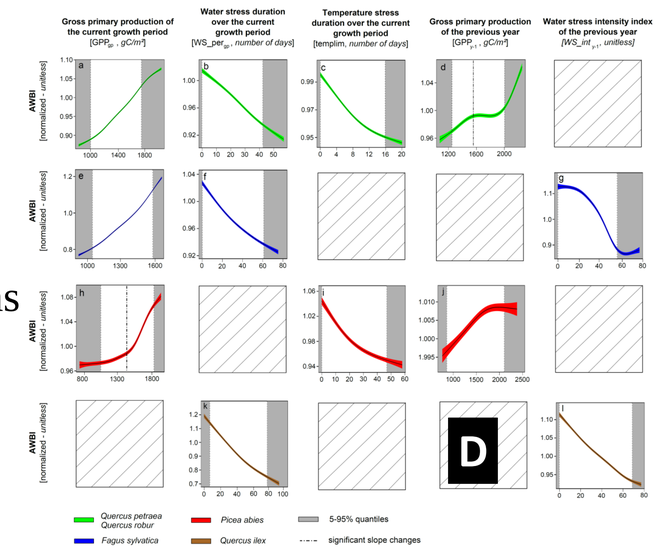
[1] **Guillemot et al., 2014.** Assessing the effects of management of forest growth across France, *Annals of Botany* 114:779,793.
[2] **Cheaib et al., 2014.** Climate change impacts on tree ranges, *Ecology Letters* 15:533,544.

Results and Discussion

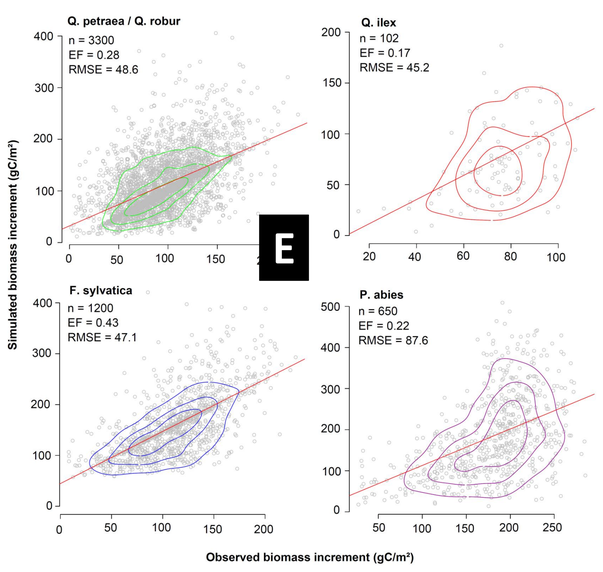


- GPP – growth relationship is not consistent in temperate oak across France (**[C]**).
- Inter-site variability of C allocation to wood was mainly driven by an age-related decline.

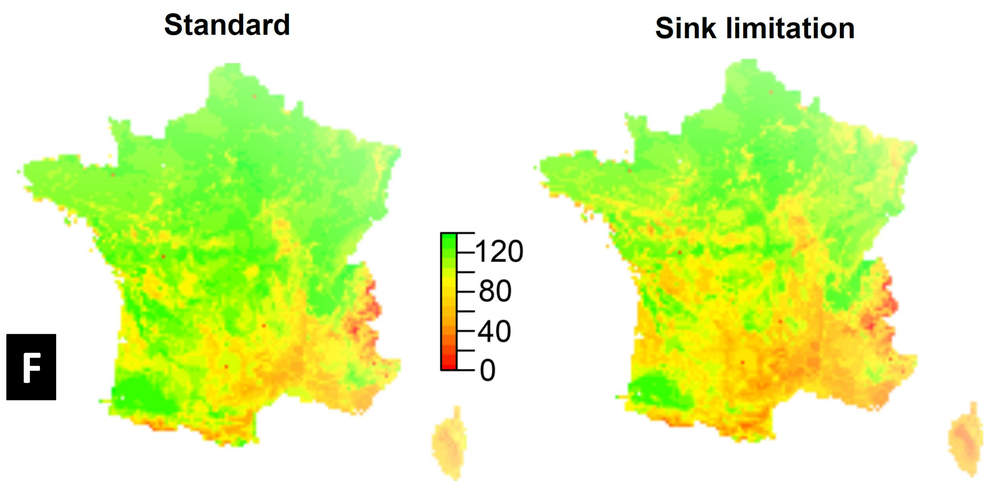
- The direct control of temperature or water stress on sink activity exerted a strong influence on the annual wood growth (**[D]**).
- The lagged effect of the past environment conditions was a significant driver of the annual C allocation to wood (**[D]**).
- C supply strongly limited growth only in deciduous temperate species.



- The source- sink- C allocation scheme performed satisfactorily against observed forest productivity (**[E]**), unlike the CASTANEA standard version (*data not shown*).
- It is crucial to evaluate TBMs against productivity (flux) rather than against stand biomass (stock) to gain insight into the underlying processes of forest growth.



- The CASTANEA projections for the French forest productivity are strongly affected by the implementation of the sink-limitation of growth **([F])**.



Predicted productivity over the 2065-2095 period (Q. petraea, gC/m²)