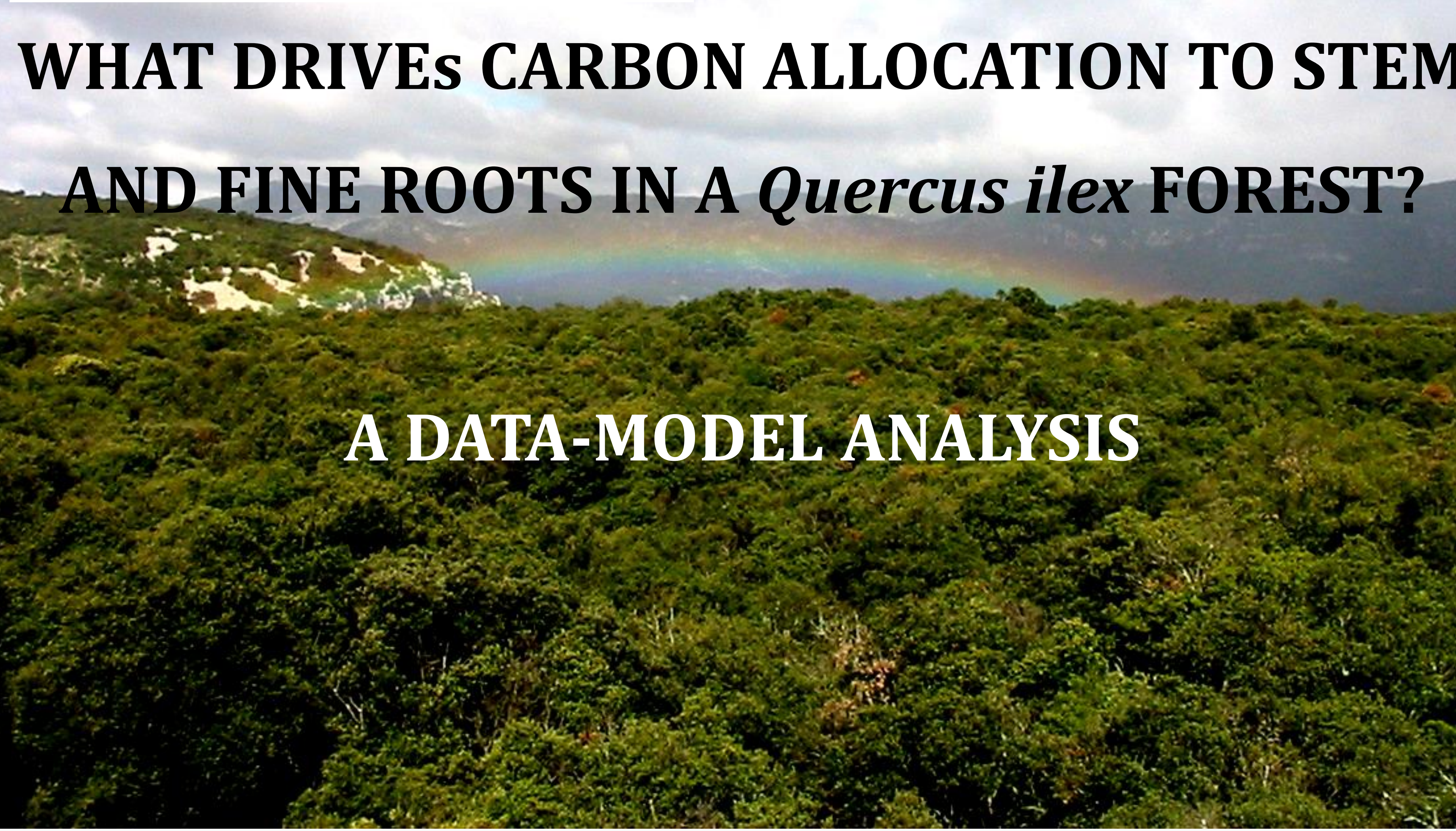
What drives carbon allocation to stem and fine roots in a mature coppice of Quercus ilex in the Mediterranean? A data model analysis

Nicolas Martin-StPaul, Morine Lempereur, Nicolas Delpierre, Jean-Marc Ourcival, Hendrik Davi, Christophe François, Paul Leadley, Eric Dufrene, Serge Rambal

FSPM 2013 7th International Conference on FUNCTIONAL–STRUCTURAL PLANT MODELS 9–14th June 2013, Saariselkä, Finland

Ecologie Systématique Evolution
cnrs advancing the frontiers
Centre d'Ecologie Fonctionnelle & Evolutive
Université Paris Sud



WHAT DRIVEs CARBON ALLOCATION TO STEM AND FINE ROOTS IN A *Quercus ilex* FOREST?

A DATA-MODEL ANALYSIS

MARTIN-STPAUL NK.; LEMPEREUR M., DELPIERRE N., OURCIVAL JM, DAVI H., FRANCOIS C., LEADLEY P., DUFRENE E. & RAMBAL S.

CONTEXT

Recent climate change:

- ✓ **Increase drought prone area world wide**

  (Dai 2012 *Nature Climate Change*)

Increase vulnerability of forests:

(Choat *et al.* 2012 *Nature*)

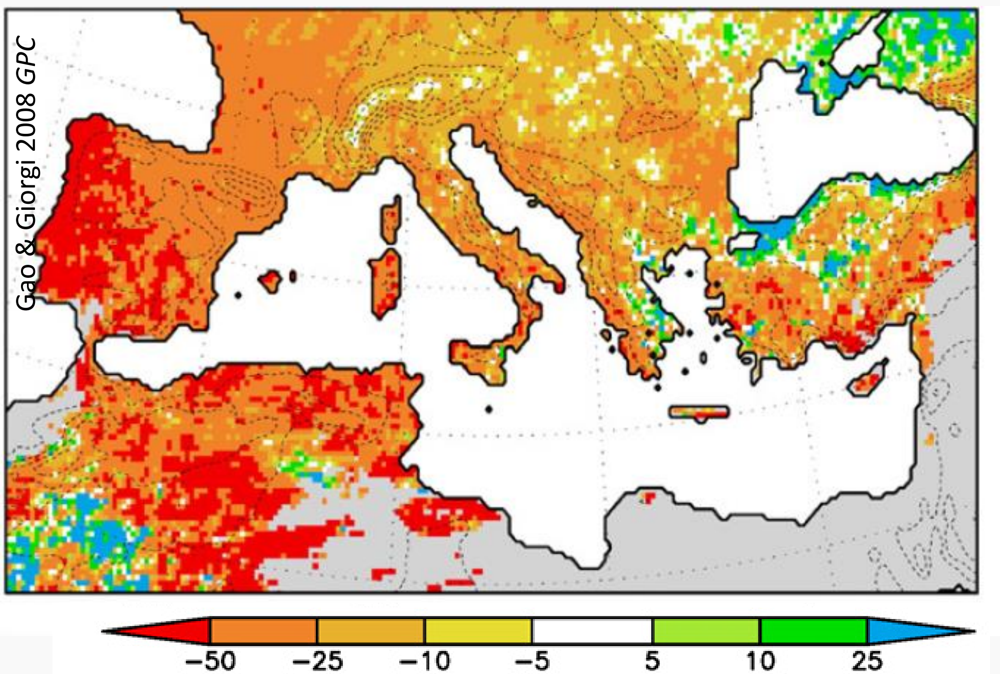
- ✓ **Decrease productivity**

  (Ciais *et al.* 2005 *Nature*)

- ✓ **Increase mortality**

  (Allen *et al.* 2010 *FEM*; Carnicer *et al.* 2012 *PNAS*)

Dryer climate in the future!



Summer rainfall anomaly (%)
[1961 2000] – [2070 2100]

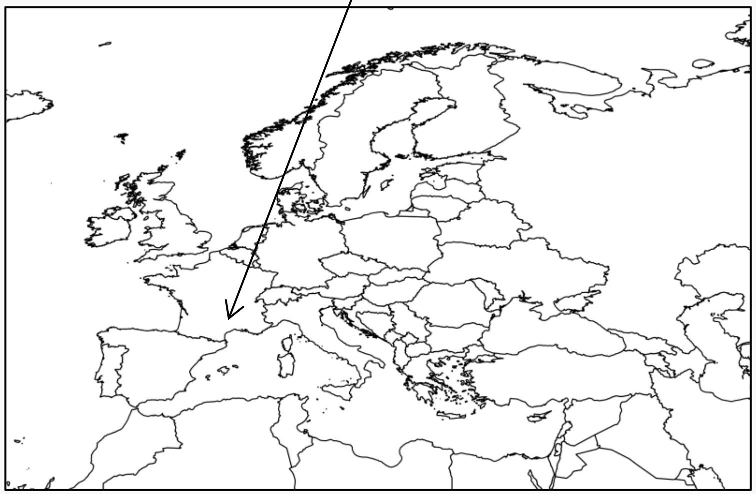
Anticipating the future of forests:

Improving process based models

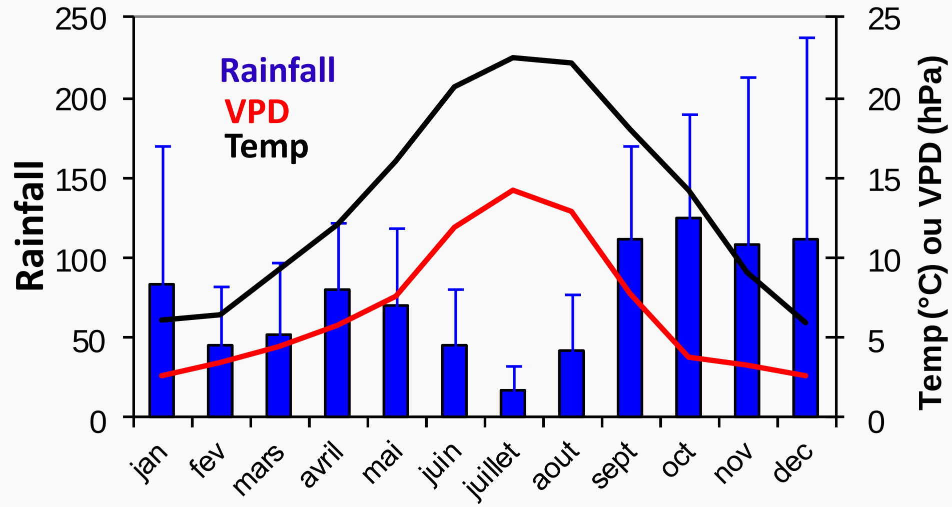
Finding out the most influencial processes that drives growth & C allocation

MOTIVATIONS: THE EXPERIMENTAL SITE OF PUECHABON

Puechabon experimental site
http://puechabon.cefe.cnrs.fr/



✓ Mediterranean climate

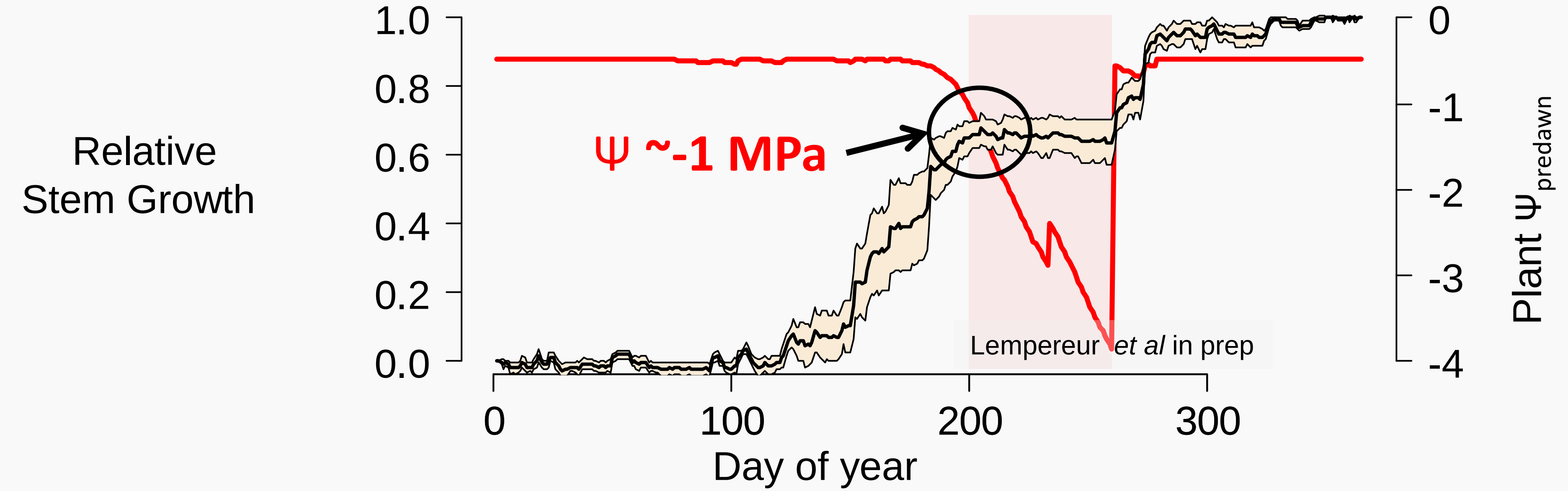


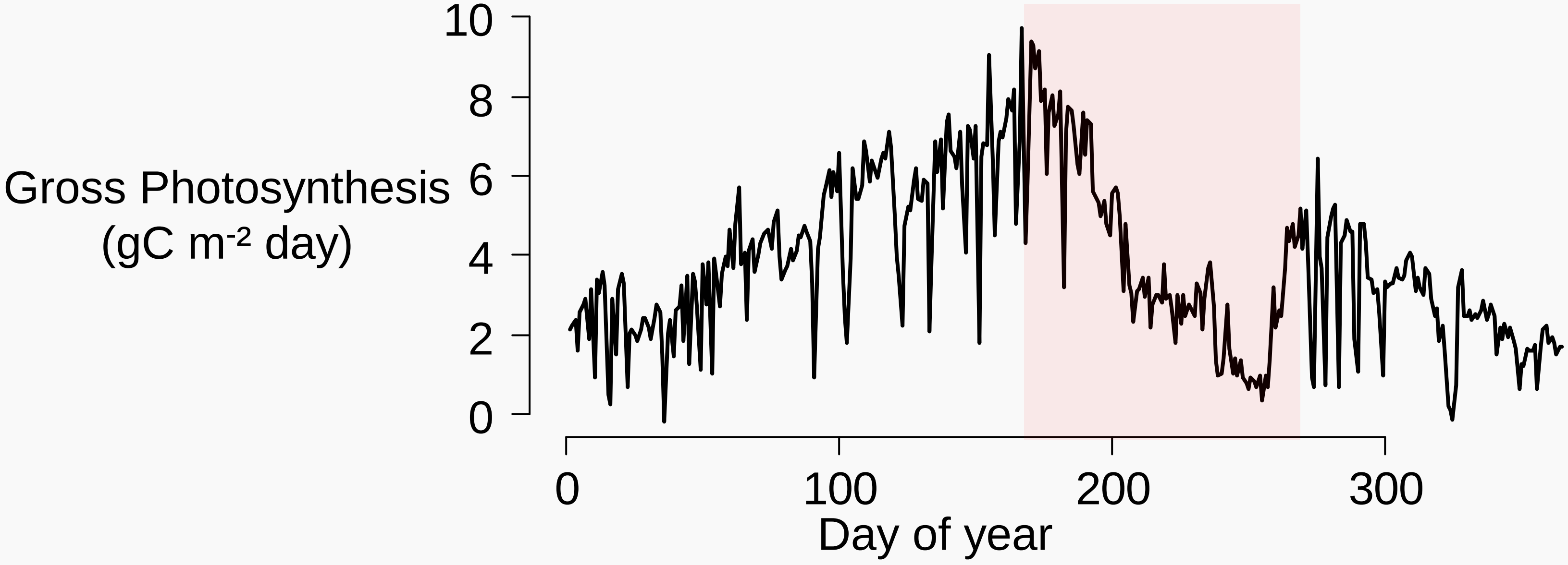
✓ Evergreen *Quercus ilex* (~65 years old)

✓ Long term records (1998→)

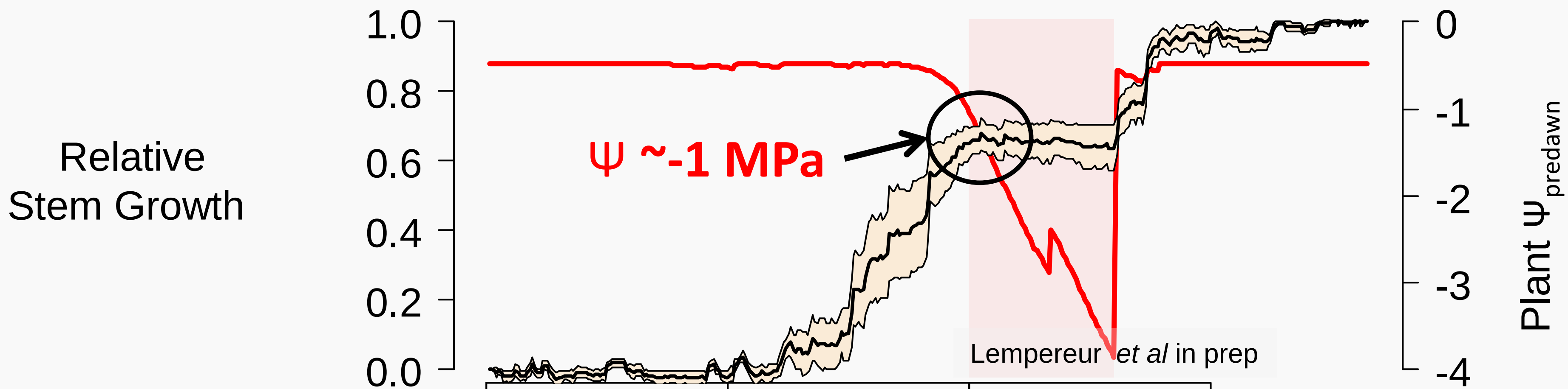
- ➢ Fluxes: ecosystem (*Eddy Covariance, litterfall*) ; tree (*sap flow*); organ (*Chamber*)
- ➢ C stocks: forest inventory, litter fall
- ➢ Phenology, growth, cavitation curves, storage

MOTIVATIONS: SEASONAL PATTERN OF GROWTH & C FLUXES





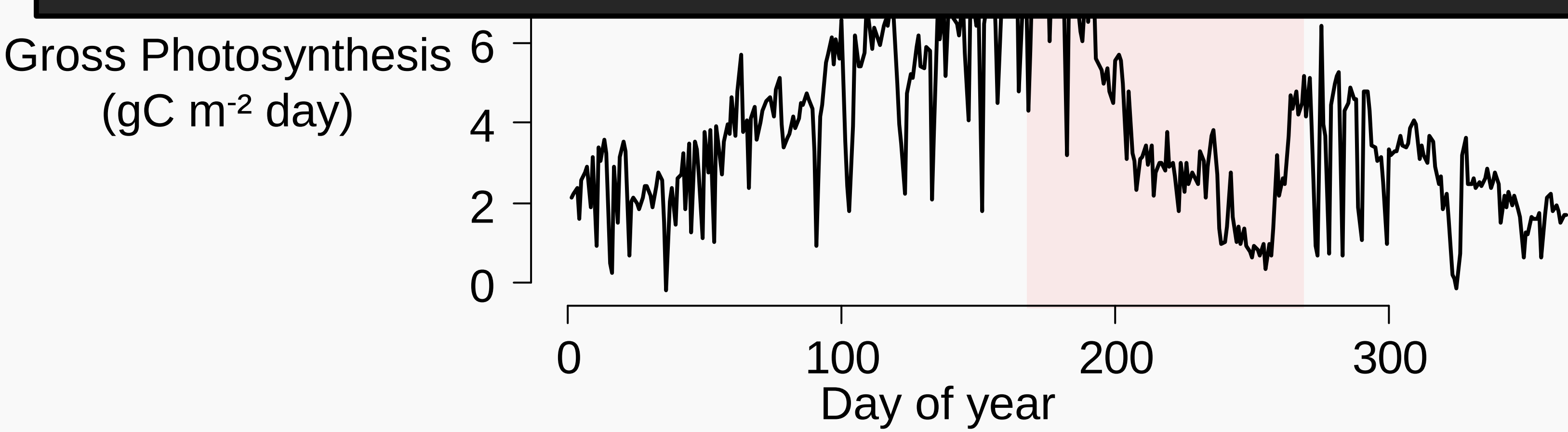
MOTIVATIONS: SEASONAL PATTERN OF GROWTH & C FLUXES



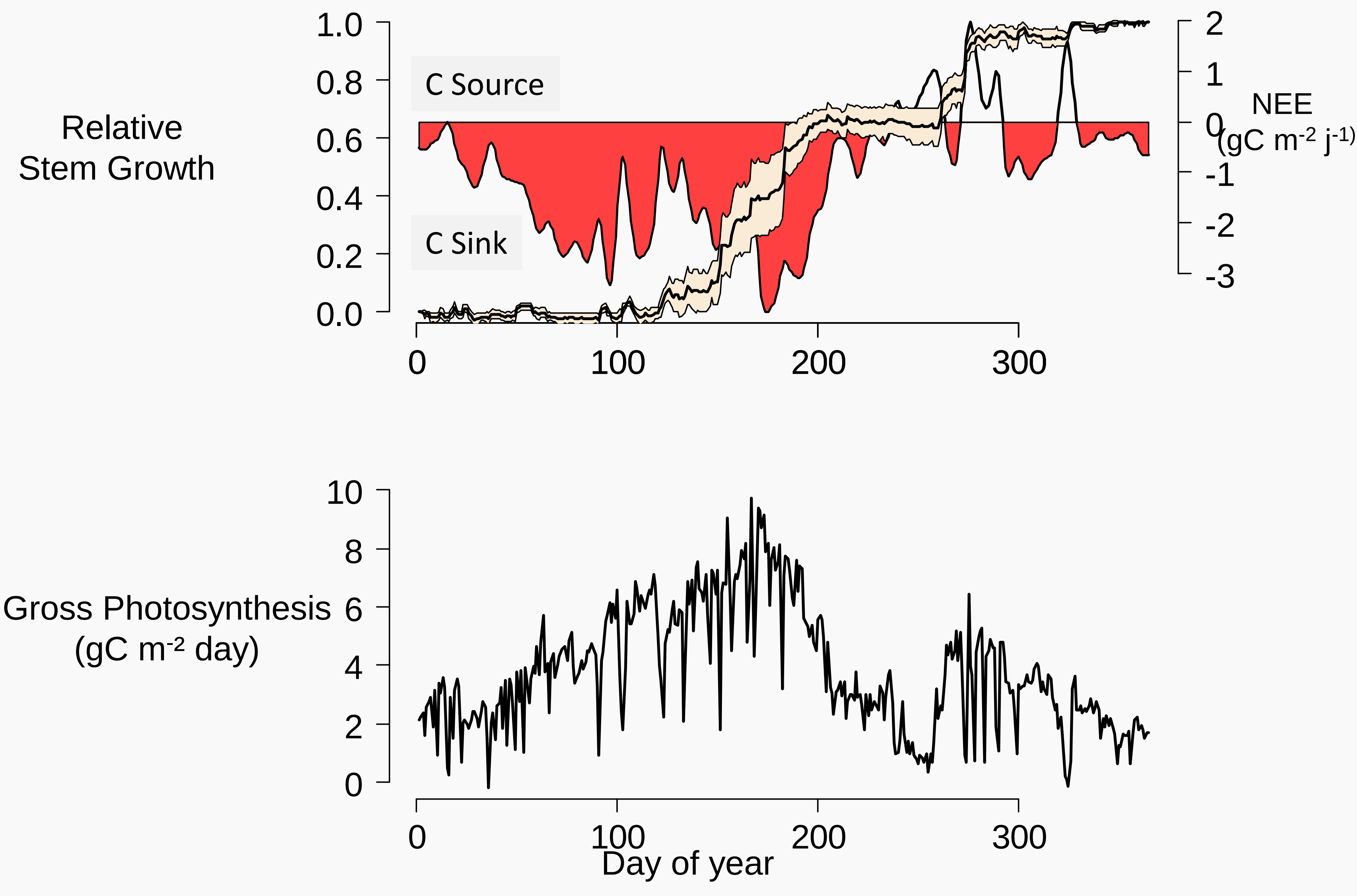
IS GROWTH LIMITED

BY THE SOURCE? due to the decrease in carbon availability

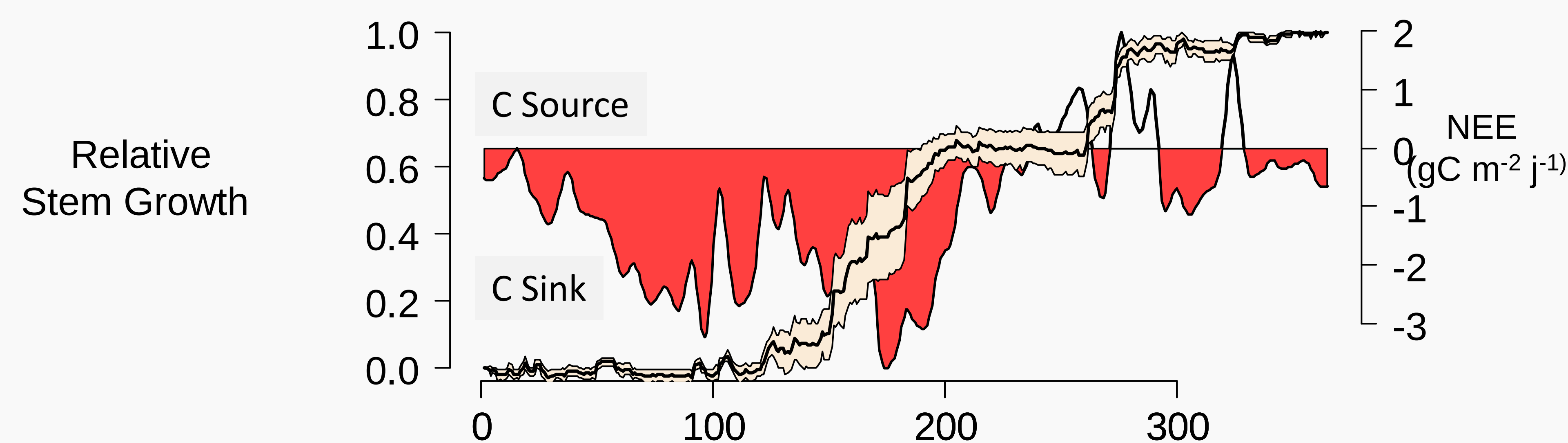
BY THE SINK? Due to the decrease in the water potential



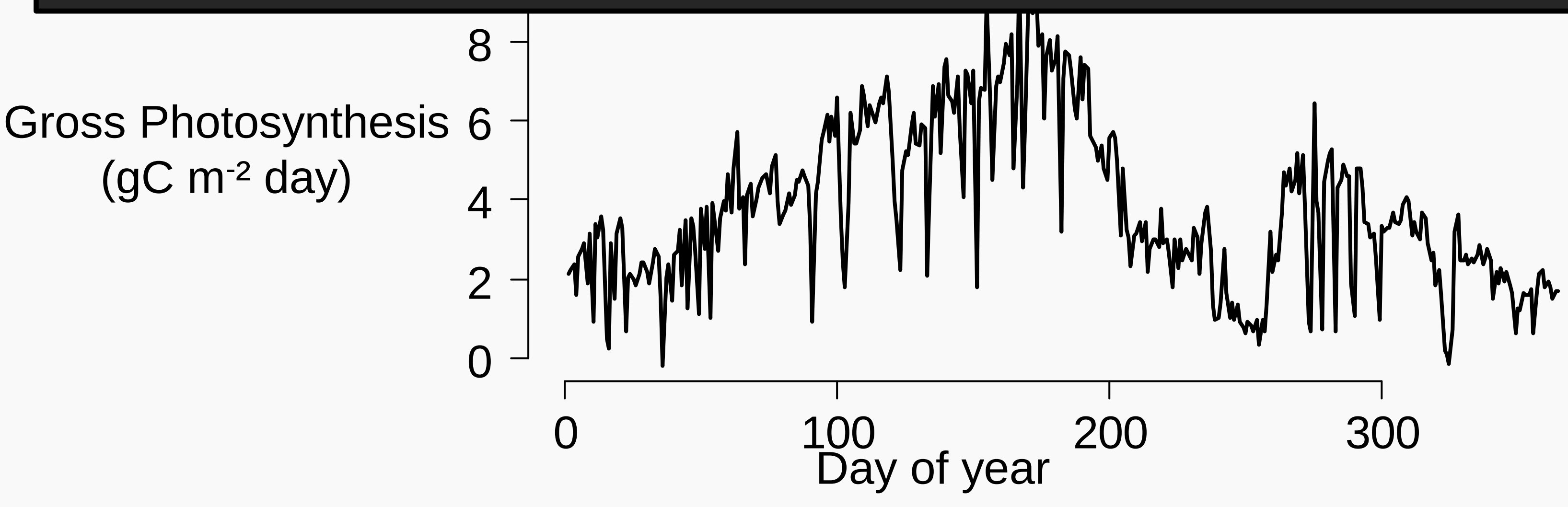
MOTIVATIONS: SEASONAL PATTERN OF GROWTH & C FLUXES



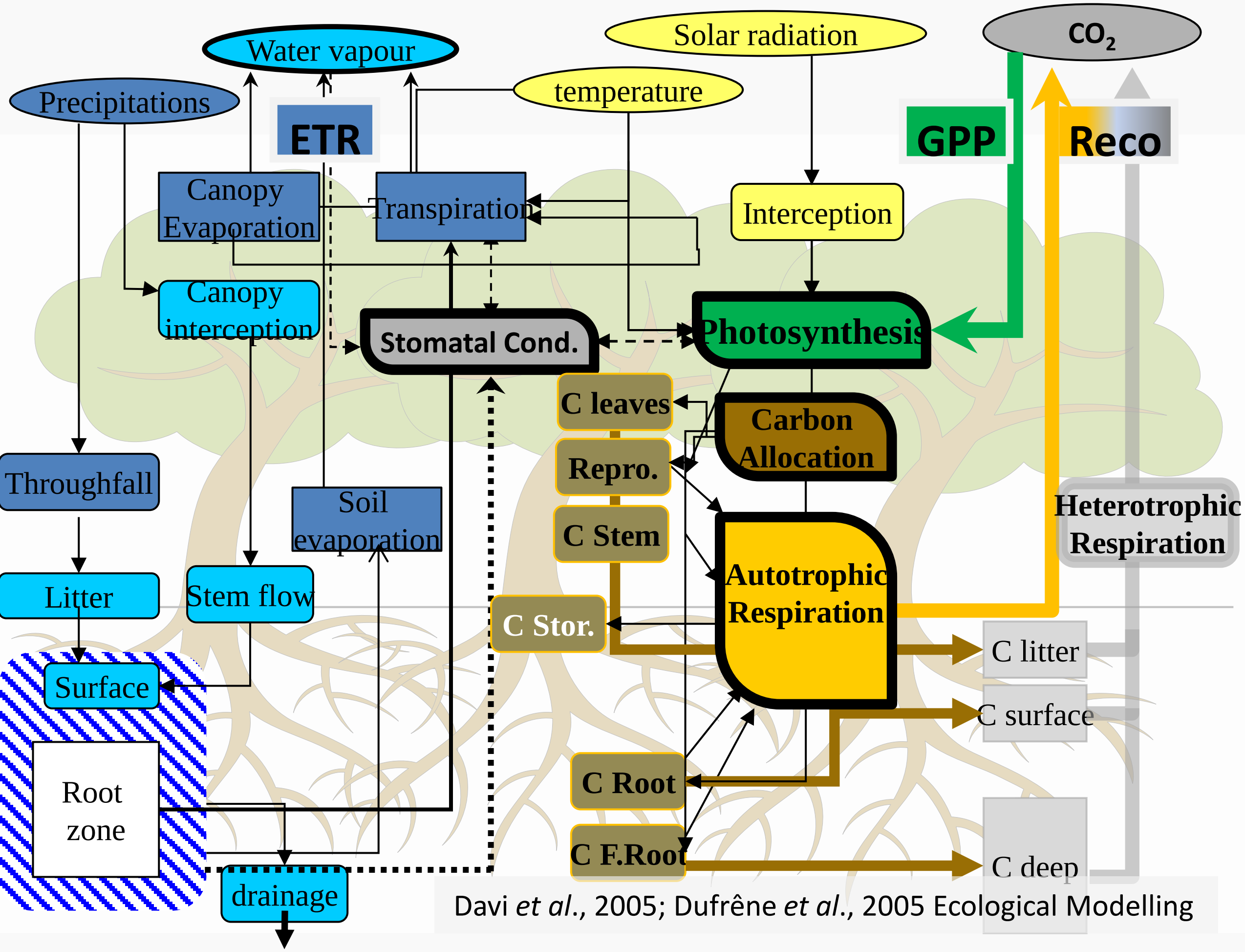
MOTIVATIONS: SEASONAL PATTERN OF GROWTH & C FLUXES



Where the C sequestered during the summer period is allocated to ?



THE MODEL CASTANEA



Davi *et al.*, 2005; Dufrêne *et al.*, 2005 Ecological Modelling

2D Stand-scale model

Half Hourly time step

Average Tree (Monospecific)

Water budget

Carbon Budget

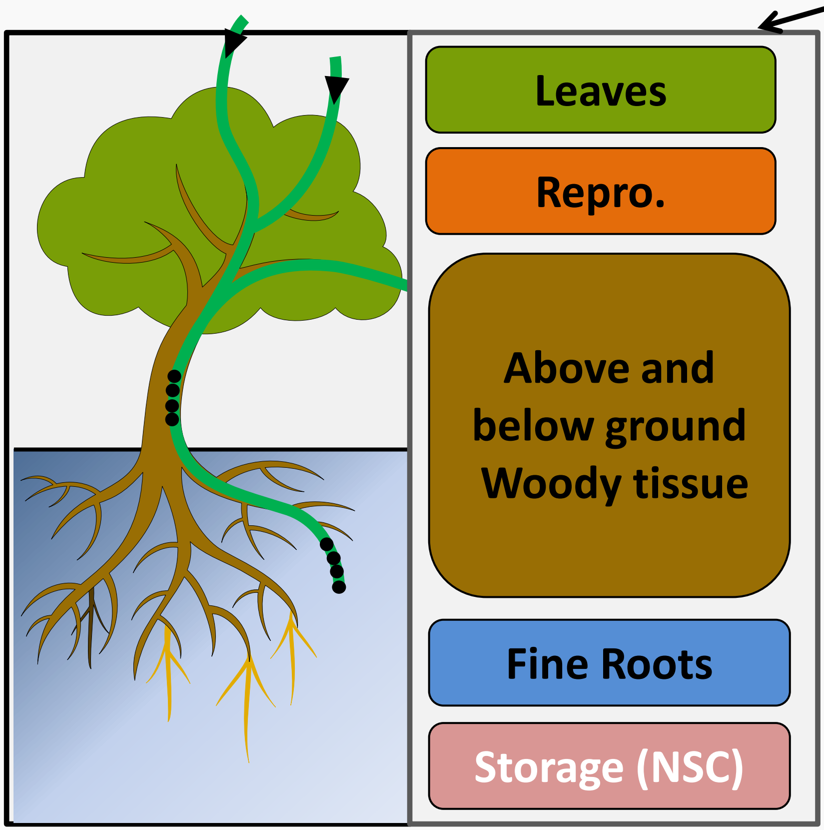
Carbon allocation

ALLOCATION IN CASTANEA & HYPOTHESIS TESTING

Photosynthesis − **Maintenance Respiration** = **Carbon available for growth**

ALLOCATION IN CASTANEA & HYPOTHESIS TESTING

Photosynthesis − **Maintenance Respiration** = **Carbon available for growth**

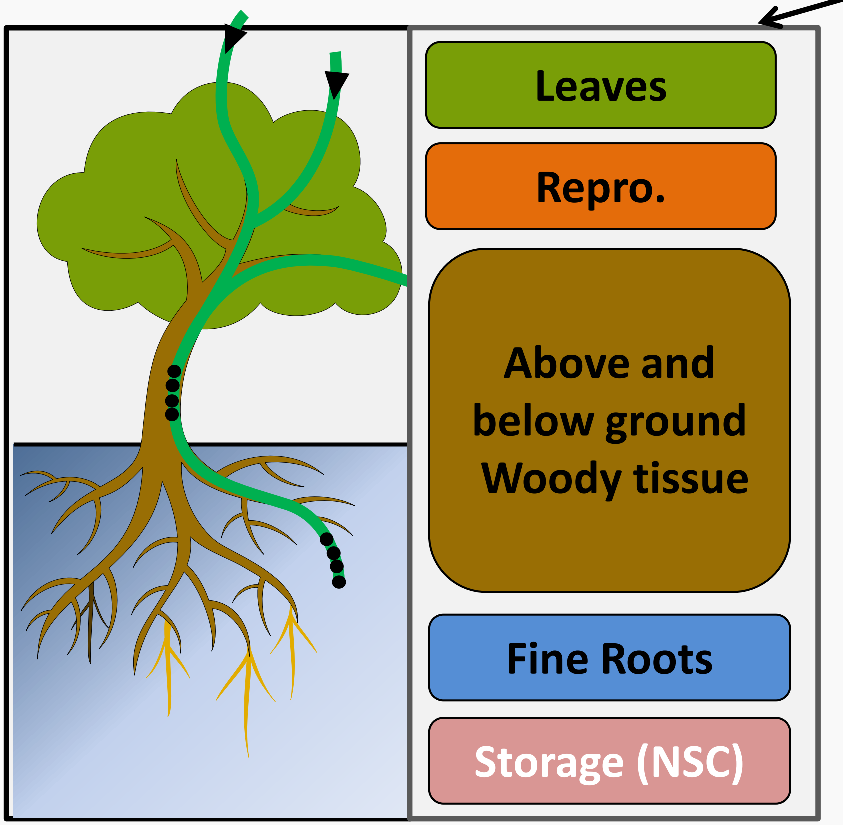


ALLOCATION IN CASTANEA & HYPOTHESIS TESTING

Photosynthesis − **Maintenance Respiration** = **Carbon available for growth**

Data assimilation (MCMC)
Eddy Covariance, sapflow

Extensive calibration
(Rodriguez-Calcerrada *et al* 2012)
(Rodriguez-Calcerrada *et al* sub)

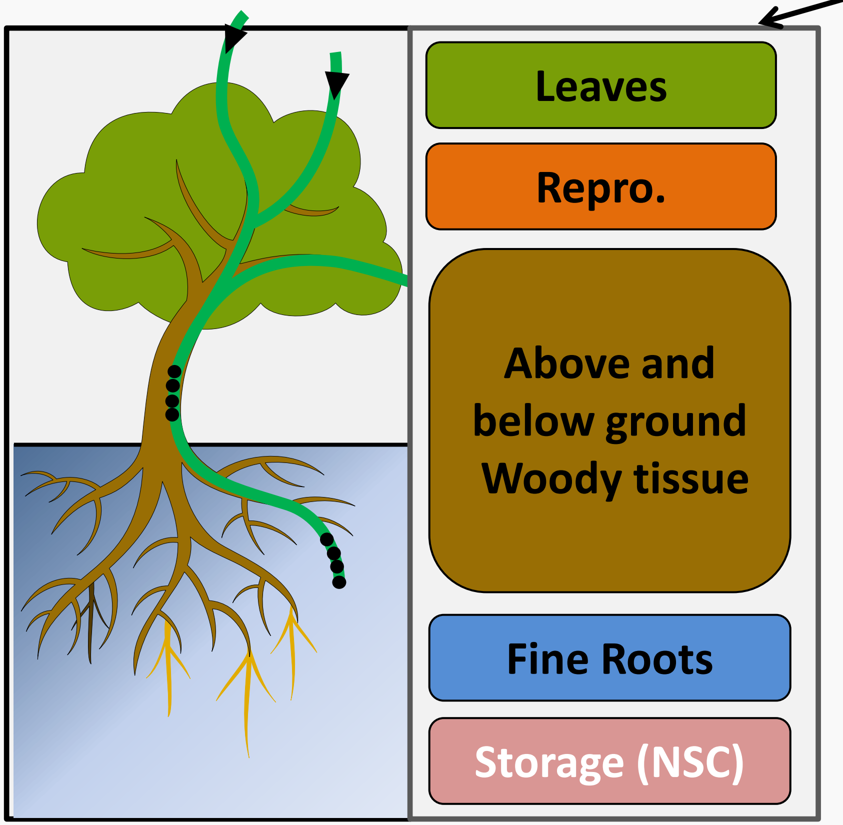


ALLOCATION IN CASTANEA & HYPOTHESIS TESTING

Photosynthesis − **Maintenance Respiration** = **Carbon available for growth**

Data assimilation (MCMC)
Eddy Covariance, sapflow

Extensive calibration
(Rodriguez-Calcerrada *et al* 2012)
(Rodriguez-Calcerrada *et al* sub)

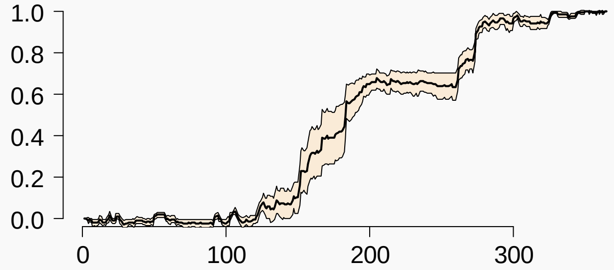


Prescribed
(in situ measurements litterfall & phenology)

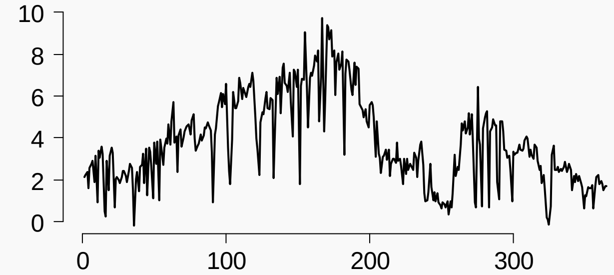
Simulated
by testing 3 different hypothesis

ALLOCATION IN CASTANEA & HYPOTHESIS TESTING

Relative growth



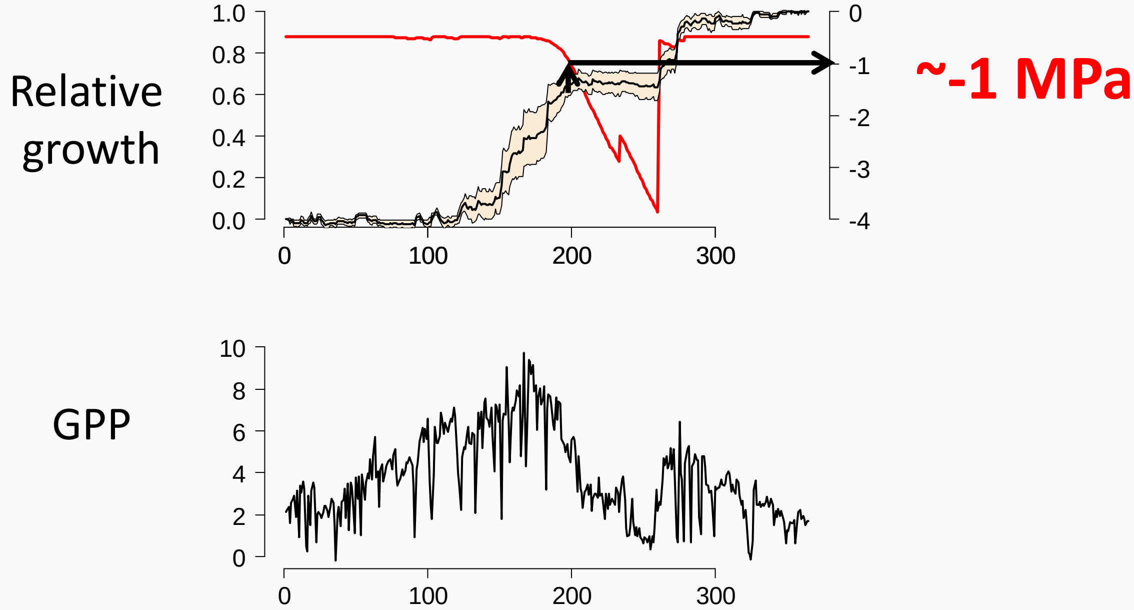
GPP



H1: Source Limitation

Growth depends
on available carbon only

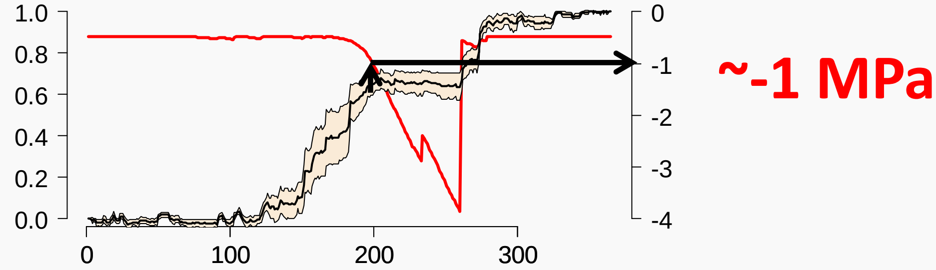
ALLOCATION IN CASTANEA & HYPOTHESIS TESTING



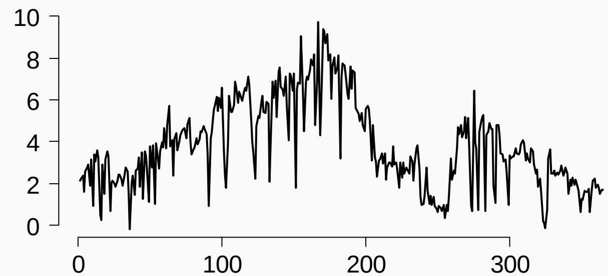
H1: Source Limitation	**H2:** Sink-*FineRoots*	**H1:** Sink-*Storage*
Growth depends on available carbon only	Growth is **Limited by water potential → Available** Carbon is allocated to **Fine Roots**	Growth is **Limited by water potential → Available** Carbon is allocated to **Storage**

ALLOCATION IN CASTANEA & HYPOTHESIS TESTING

Relative growth



GPP



H1: Source Limitation	**H2:** Sink-*FineRoots*	**H3:** Sink-*Storage*
Growth depends on available carbon only	Growth is **Limited by water potential → Available** Carbon is allocated to **Fine Roots**	Growth is **Limited by water potential → Available** Carbon is allocated to **Storage**

VALIDATION:

Yearly wood increment (forest inventory + allometric relationship): 2000 →2010

Temporal dynamic of Storage concentration

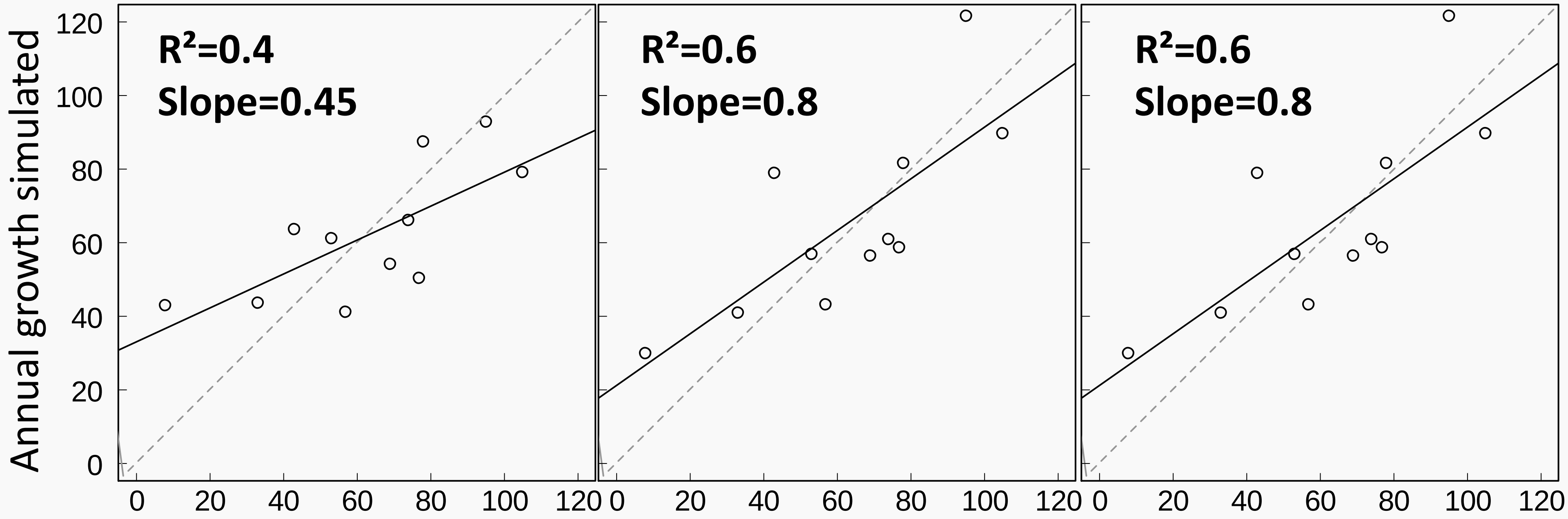
Temporal dynamic & Level of $\frac{FineRoot}{Leaf}$ biomass

RESULTS: STEM GROWTH MEASURED *vs.* SIMULATED

Source Limitation

H2: Sink-*FineRoots*

H3: Sink-*Storage*



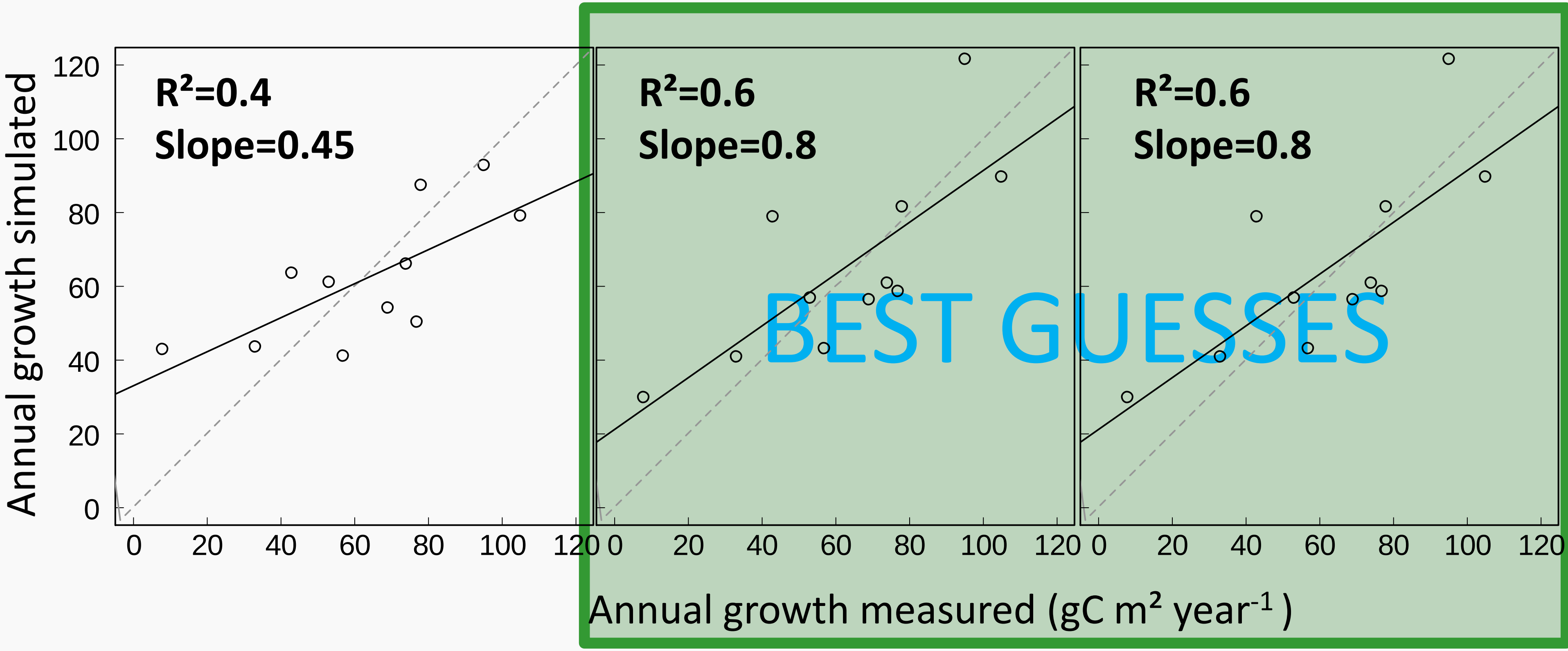
Annual growth measured (gC m² year⁻¹)

RESULTS: STEM GROWTH MEASURED *vs.* SIMULATED

Source Limitation

H2: Sink-*FineRoots*

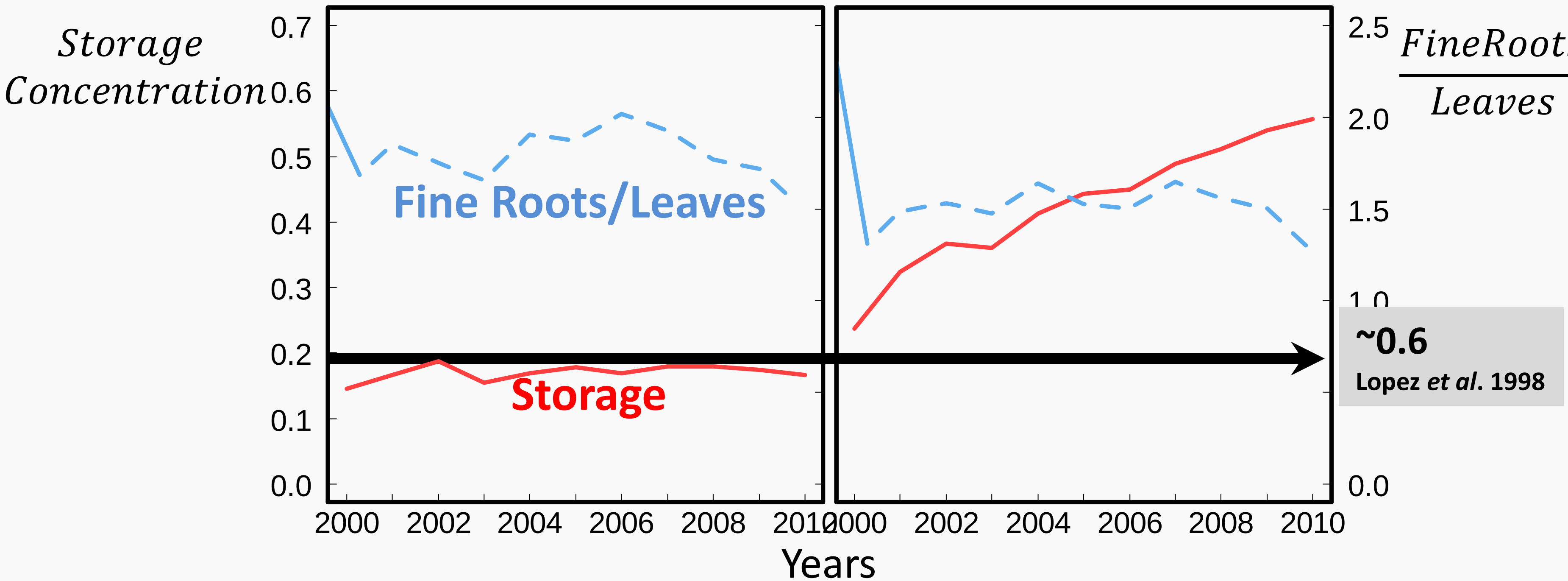
H3: Sink-*Storage*



RESULTS: STORAGE & FINE ROOT/LEAF BIOMASS

H2: Sink-*FineRoots*

H3: Sink-*Storage*

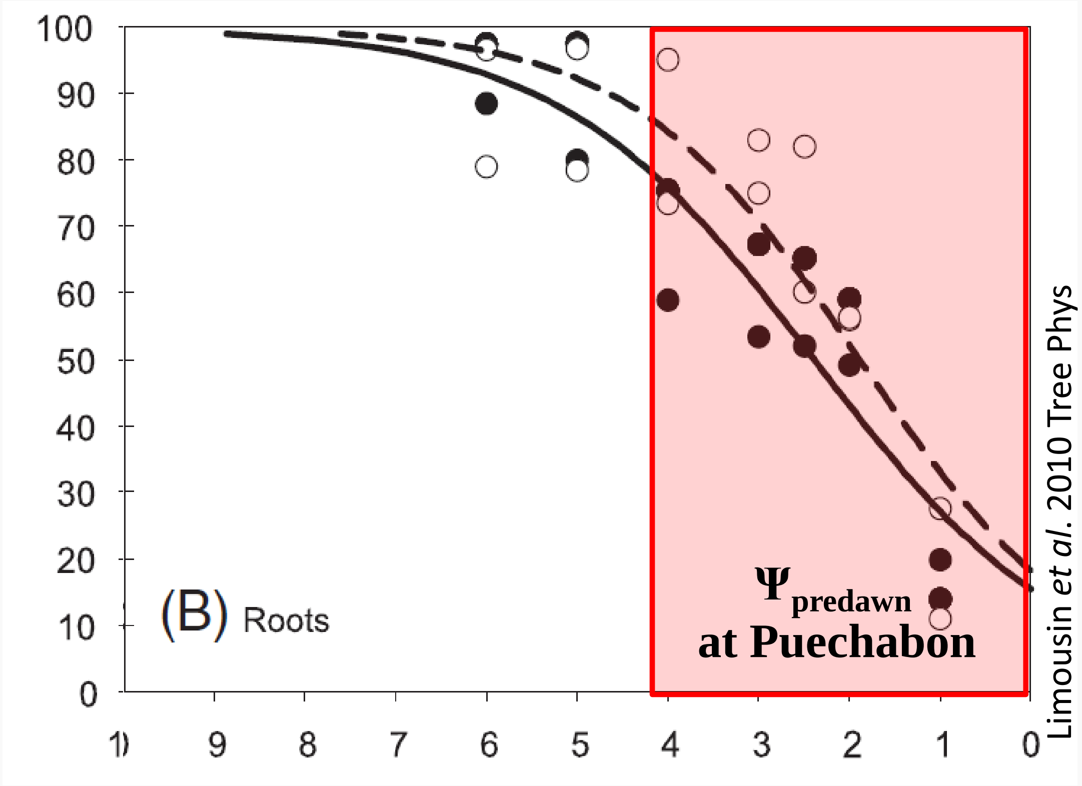


Challenge:

- $\frac{Fine\ Root}{Leaf}$ **is far from published value (~0.6, Lopez *et al.* 1998 Plant & Soil)**
- **Fine roots are sensitive to** Ψ_{plant} (**Growth**: Lockhart 1965 ; **Mortality**: Anderegg *et al.*, 2012)

RESULTS: STORAGE & FINE ROOT/LEAF BIOMASS

% CAVITATION OF ROOTS



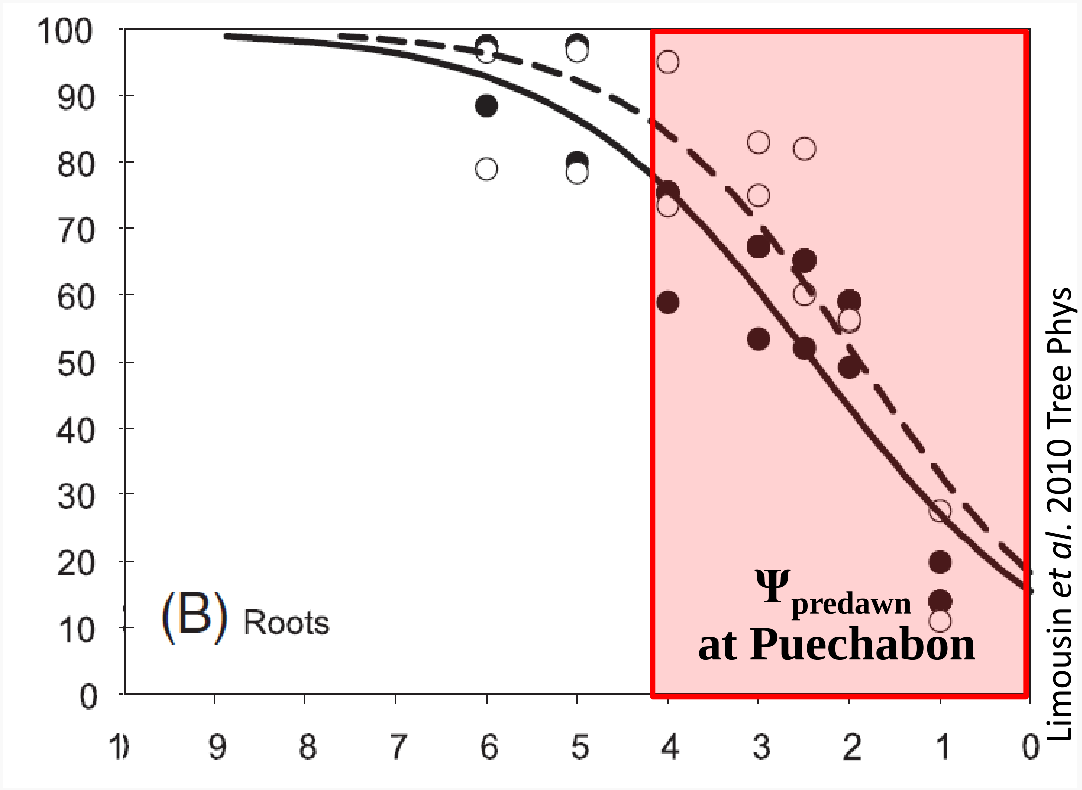
|Ψ | (Mpa)

Challenge:

- ➢ $\frac{Fine\ Root}{Leaf}$ **is far from published value (~0.6, Lopez *et al*. 1998 Plant & Soil)**
- ➢ **Fine roots are sensitive to** Ψ_{plant} (**Growth**: Lockhart 1965 ; **Mortality**: Anderegg *et al*., 2012)

NEW HYPOTHESIS

% CAVITATION OF ROOTS



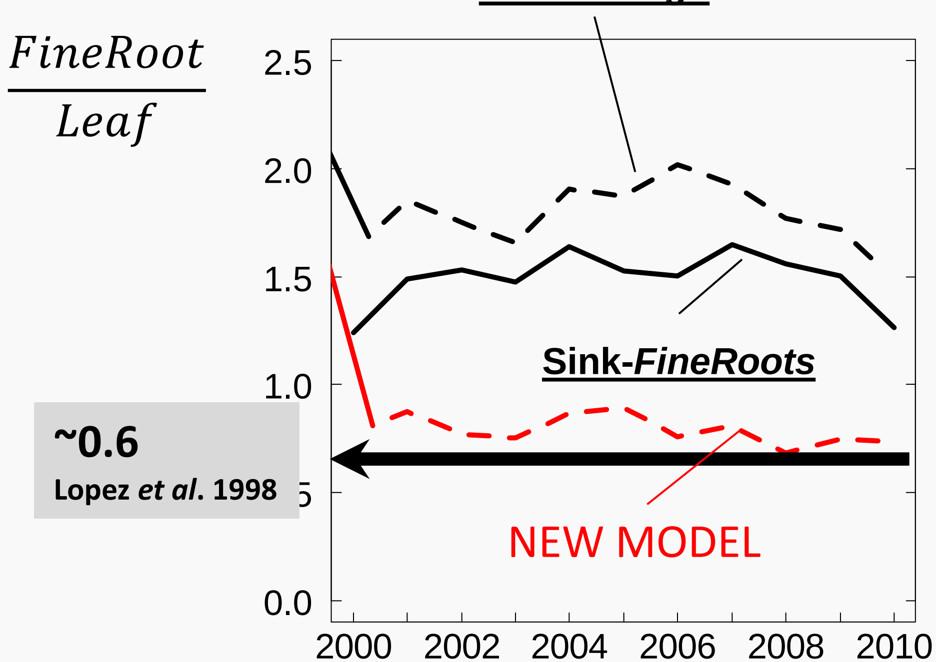
|Ψ | (Mpa)

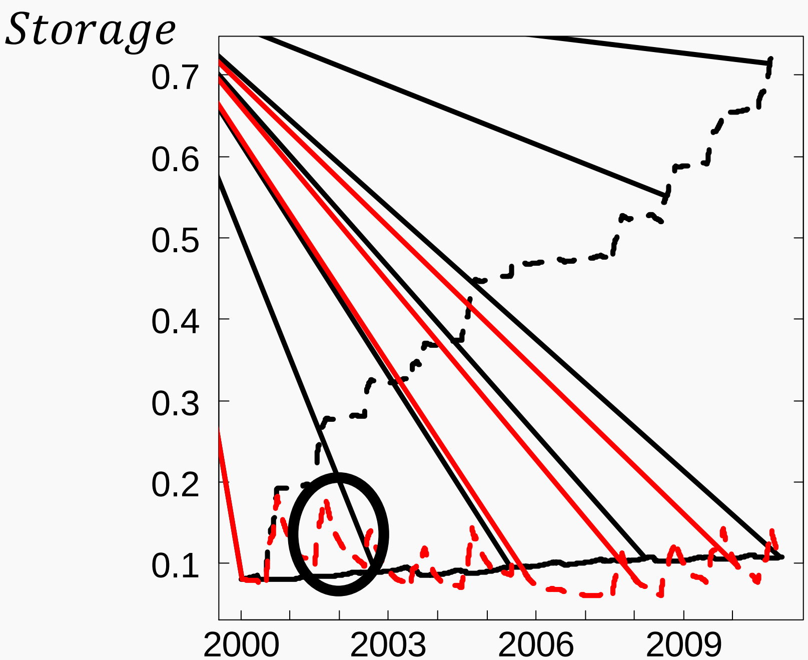
$$if\ (\Psi_{dawn} < -1\text{MPa})\ \{All\ growth = 0\,;\ Storage = 1\}$$

$$Fine\ root\ mortality = \frac{1}{(1 + \exp(0.77 \times \Psi_{Predawn} + 2.4))}$$

$$Fine\ root\ growth = f(Storage, FRootTh)$$

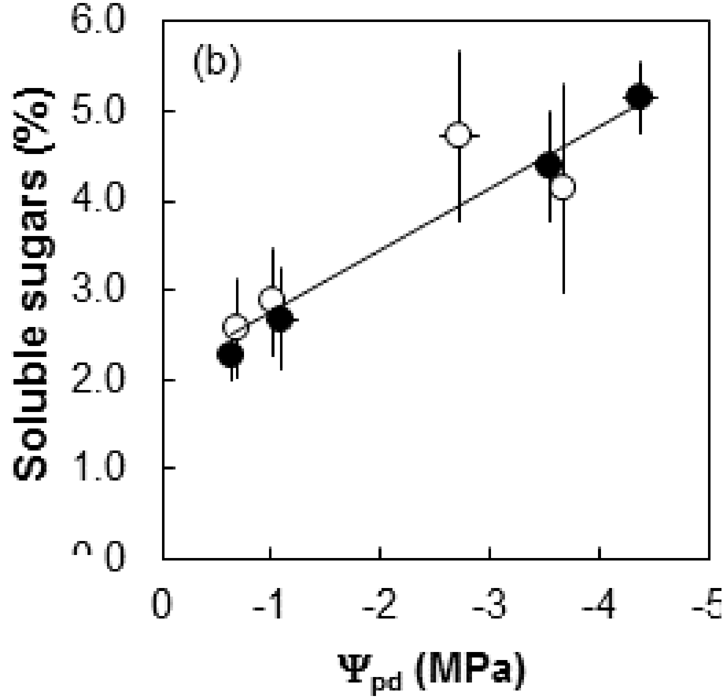
NEW HYPOTHES[redacted]



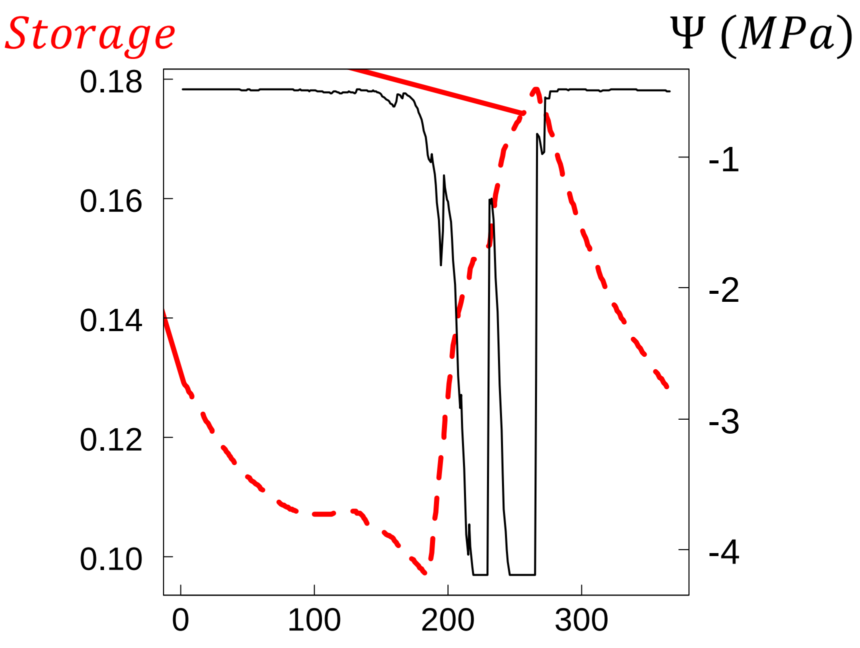


NEW HYPOTHESIS

Storage in the sapwood at the Puechabon site



Rodriguez-Calcerrada *et al*. submitted



SUMMARY

- ✓ **Stem growth is likely not C-limited and can be accurately model assuming a direct effect of water potential**

- ✓ **The carbon sequestered during the drought period might be used for fine root production or reconstruction**

- ✓ **A model accouting for fine roots mortality and reconstruction was consistent with the observations of increasing storage concentration during the seasonal drought**

SUMMARY & CONCLUSION

- ✓ **Stem growth is likely not C-limited and can be accurately model assuming a direct effect of water potential**

- ✓ **The carbon sequestered during the drought period might be used for fine root production or reconstruction**

- ✓ **A model accouting for fine roots mortality and reconstruction was consistent with the observations of increasing storage concentration during the seasonal drought**

- ✓ **The process simulated by the improved model are believed to be involved in tree vulnerability to drought** (McDowell *et al.* 2011 *Trends. Ecol. Evolution*)

- ✓ **This model might be a step in assessing tree' outcomes under climate changes**


Thank you for
your attention