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

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CENTRE D'ÉCOLOGIE
FONCTIONNELLE
& ÉVOLUTIVE



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*)

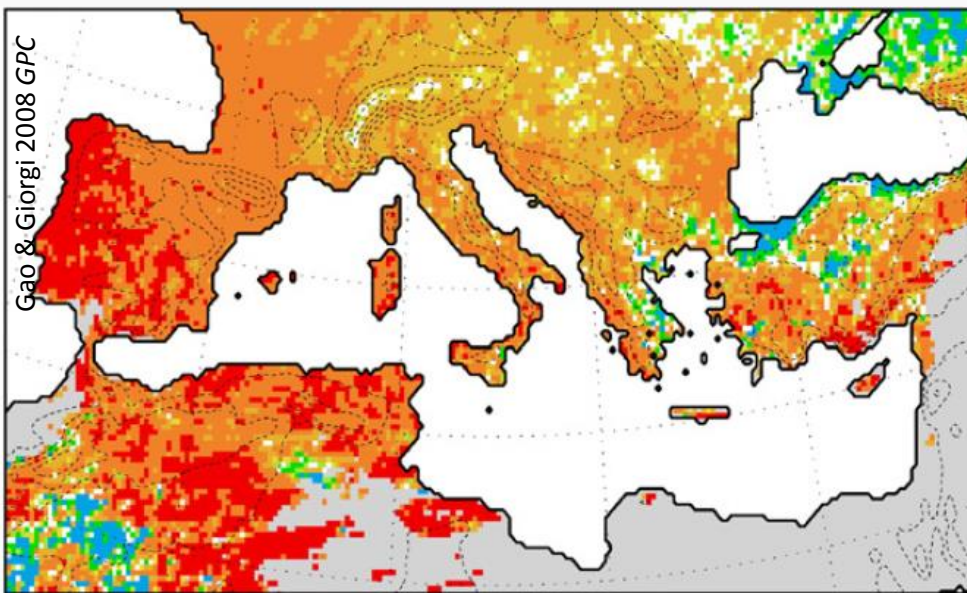
- ✓ **Decrease productivity**

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

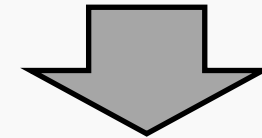
- ✓ **Increase mortality**

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

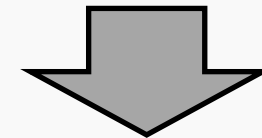
Dryer climate in the future!



Anticipating the future of forests:



Improving process based models

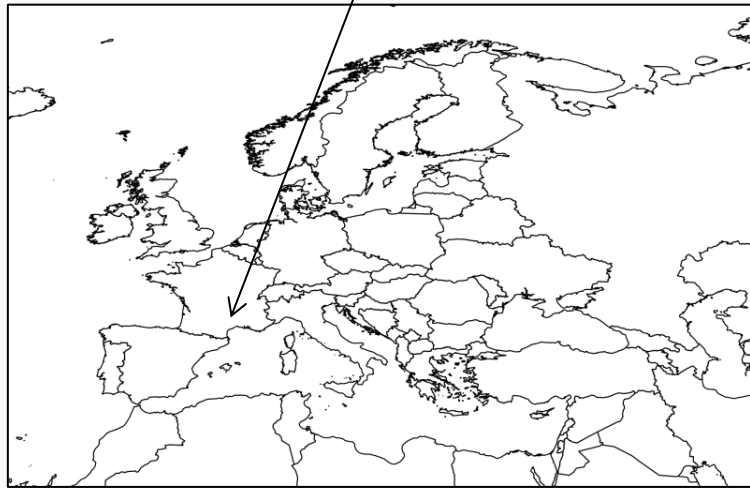


**Finding out
the most influential
processes that drives
growth & C allocation**

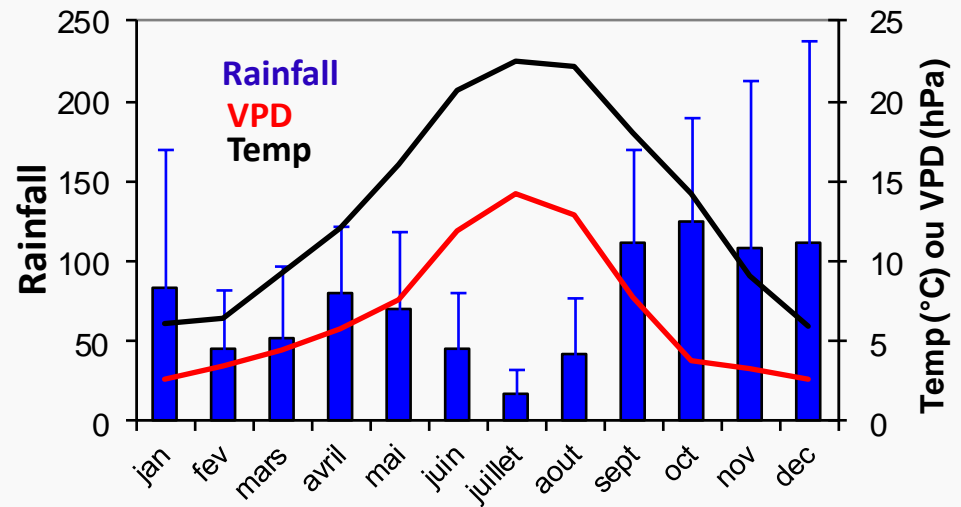
MOTIVATIONS: THE EXPERIMENTAL SITE OF PUECHABON

Puechabon experimental site

<http://puechabon.cefe.cnrs.fr/>



✓ Mediterranean climate



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

✓ Long term records (1998→)

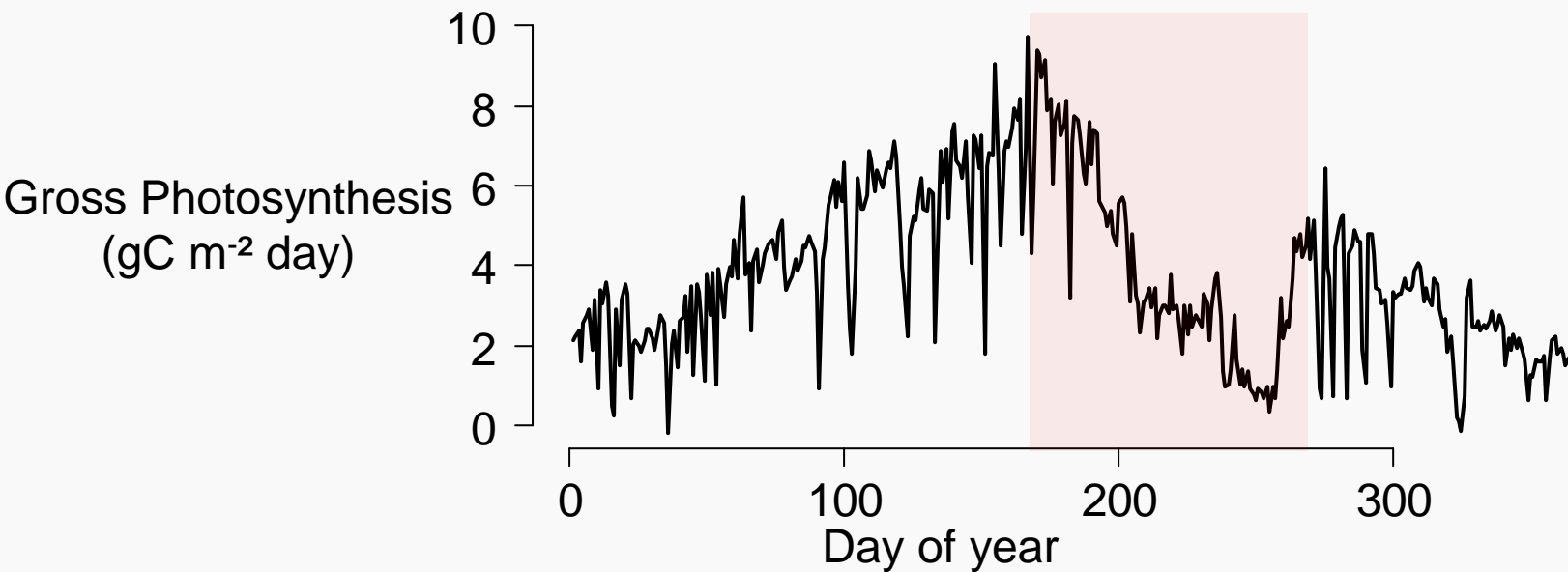
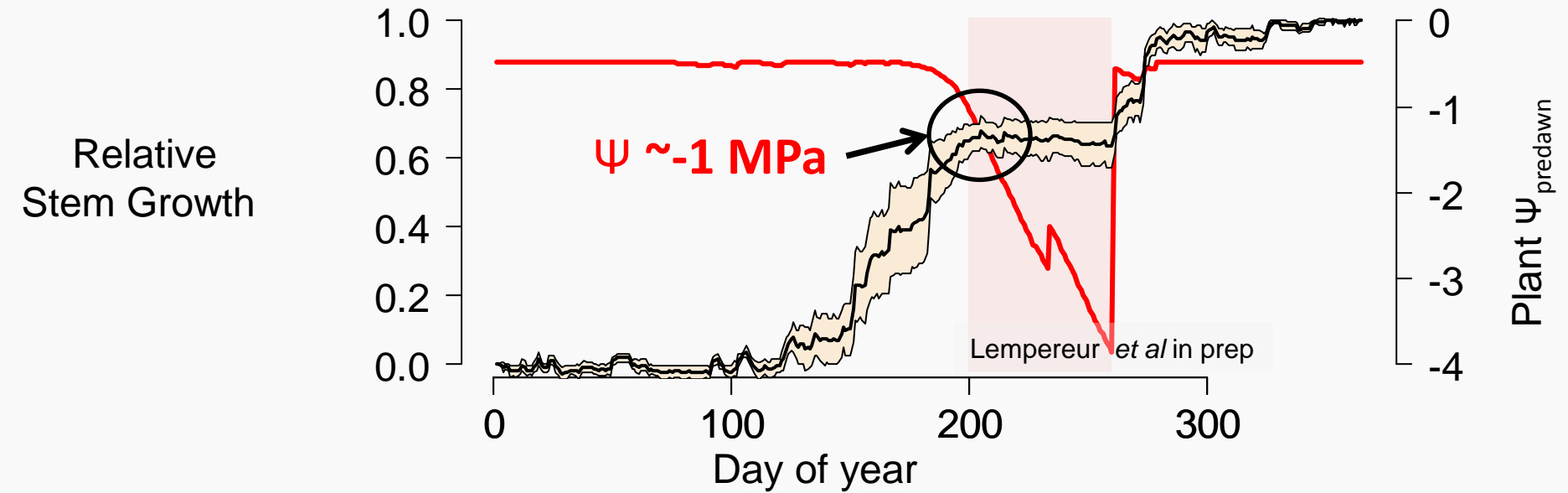
➤ Fluxes: ecosystem (*Eddy Covariance*, *litterfall*); tree (*sap flow*); organ (*Chamber*)

➤ C stocks: forest inventory, litter fall

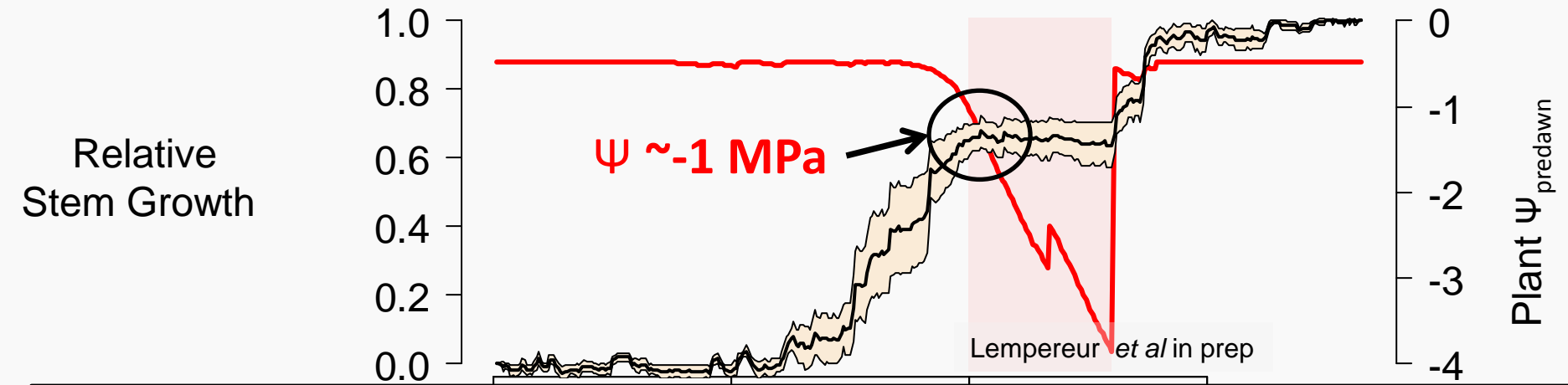
➤ Phenology, growth, cavitation curves, storage



MOTIVATIONS: SEASONAL PATTERN OF GROWTH & C FLUXES



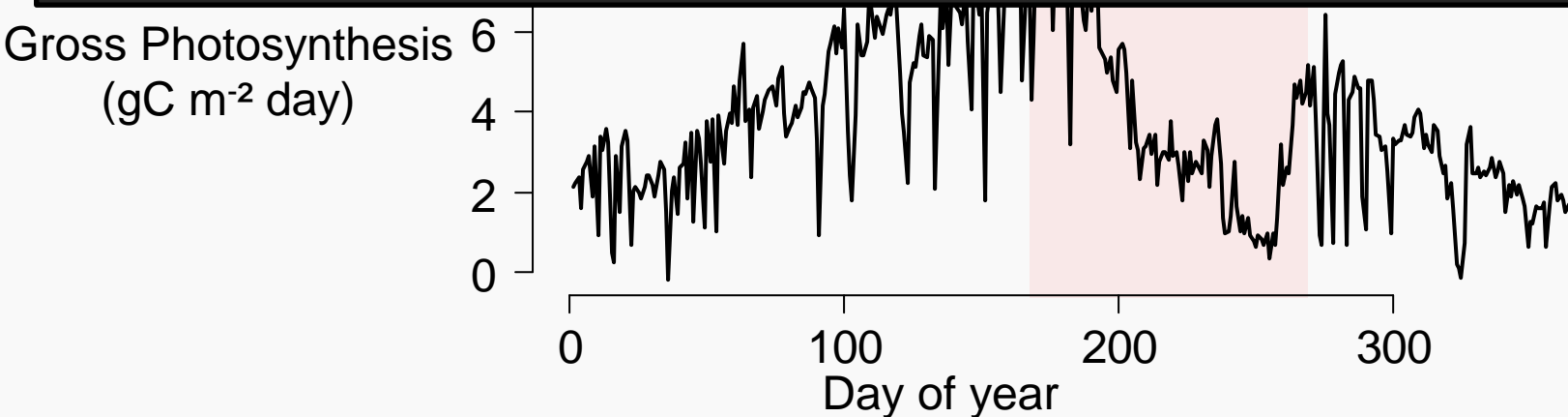
MOTIVATIONS: SEASONAL PATTERN OF GROWTH & C FLUXES



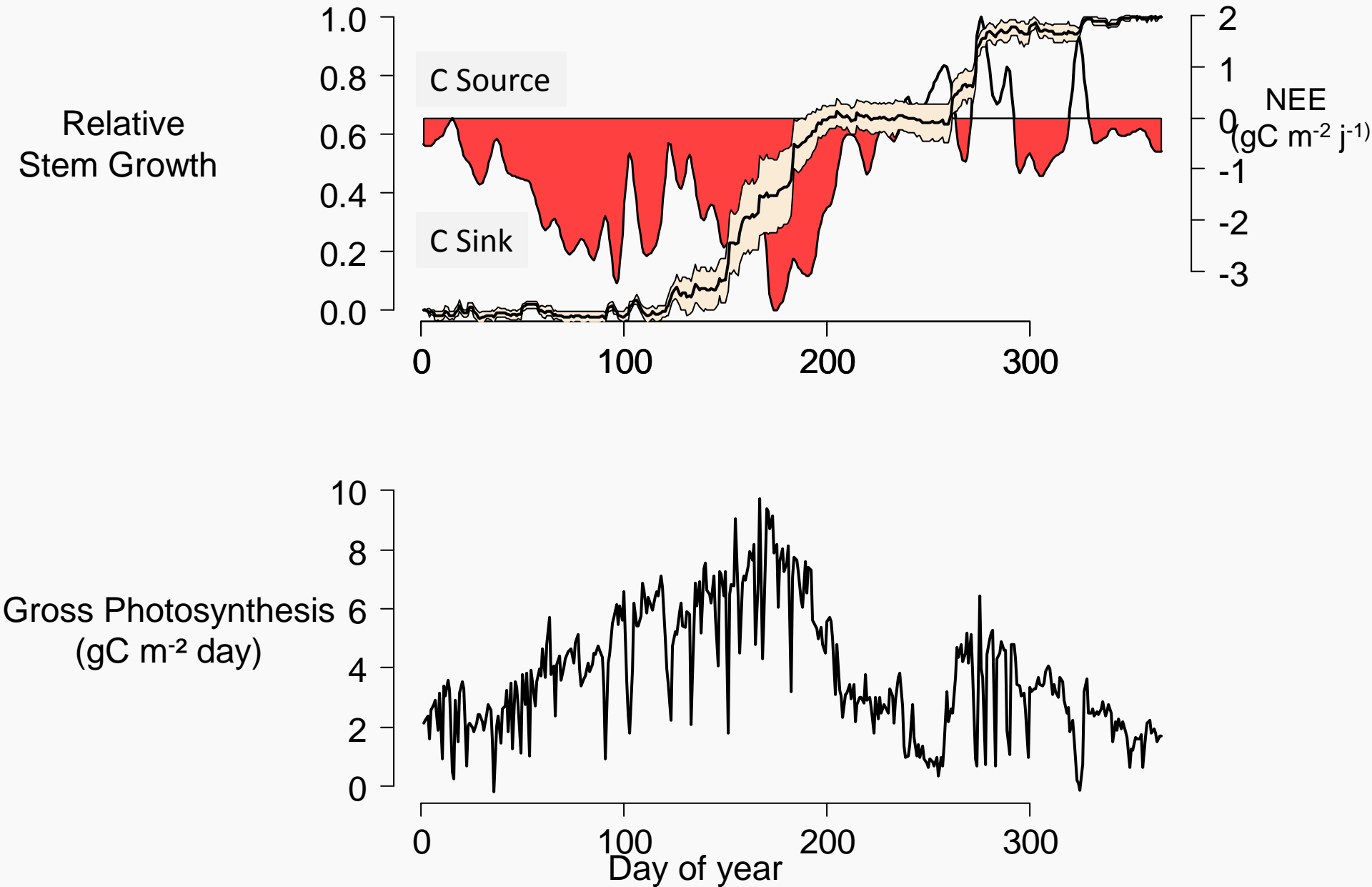
IS GROWTH LIMITED

BY THE SOURCE? due to the decrease in carbon availability

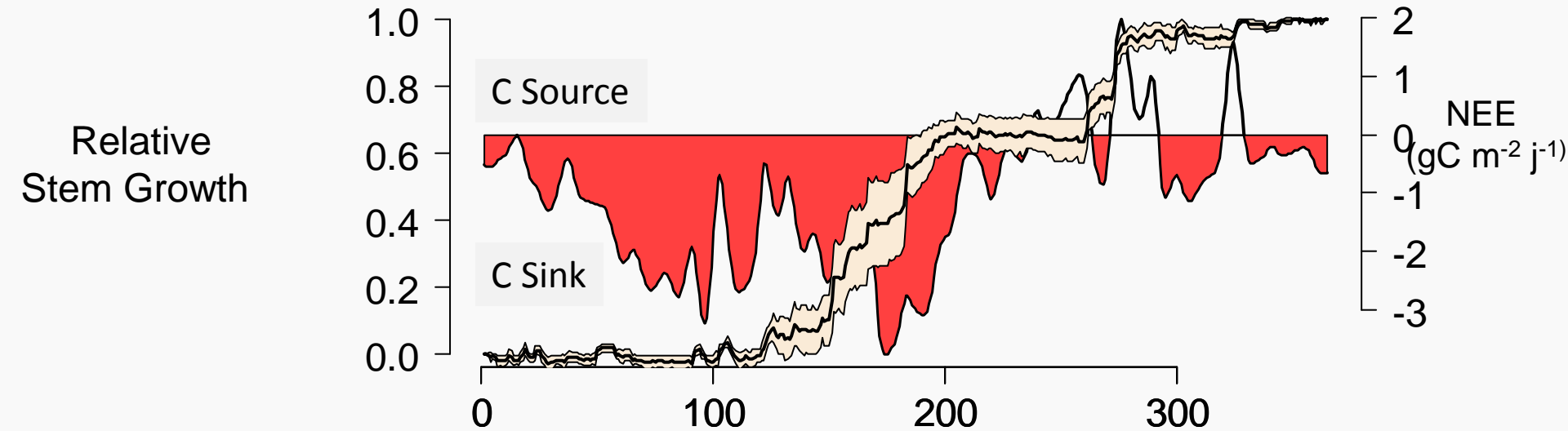
BY THE SINK? Due to the decrease in the water potential



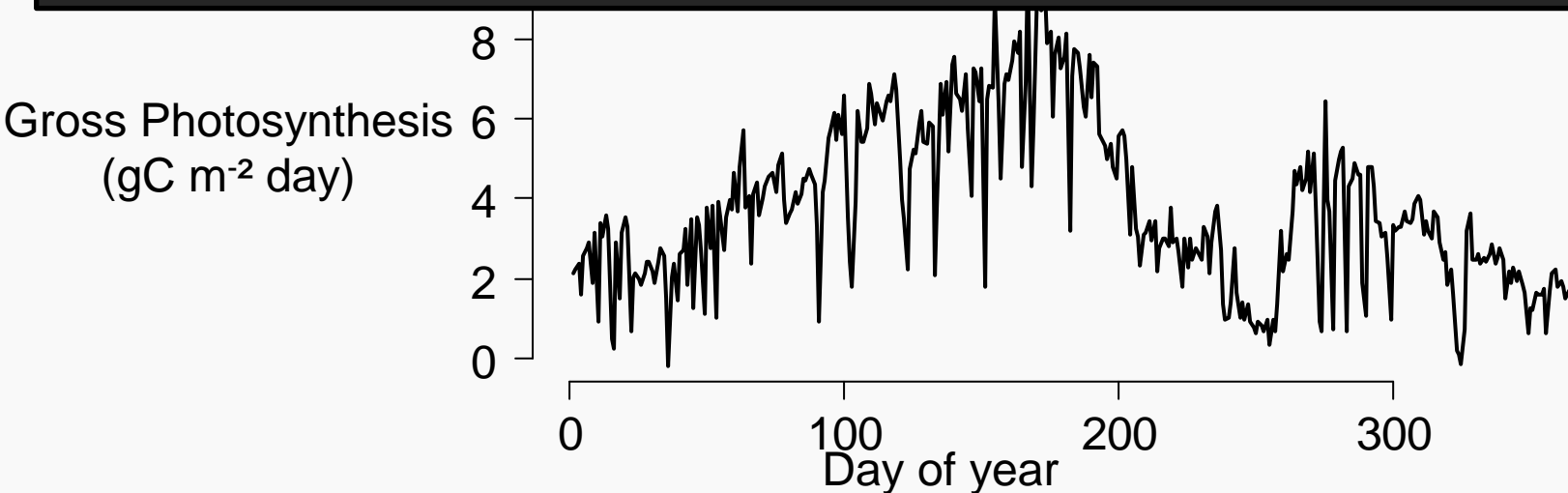
MOTIVATIONS: SEASONAL PATTERN OF GROWTH & C FLUXES



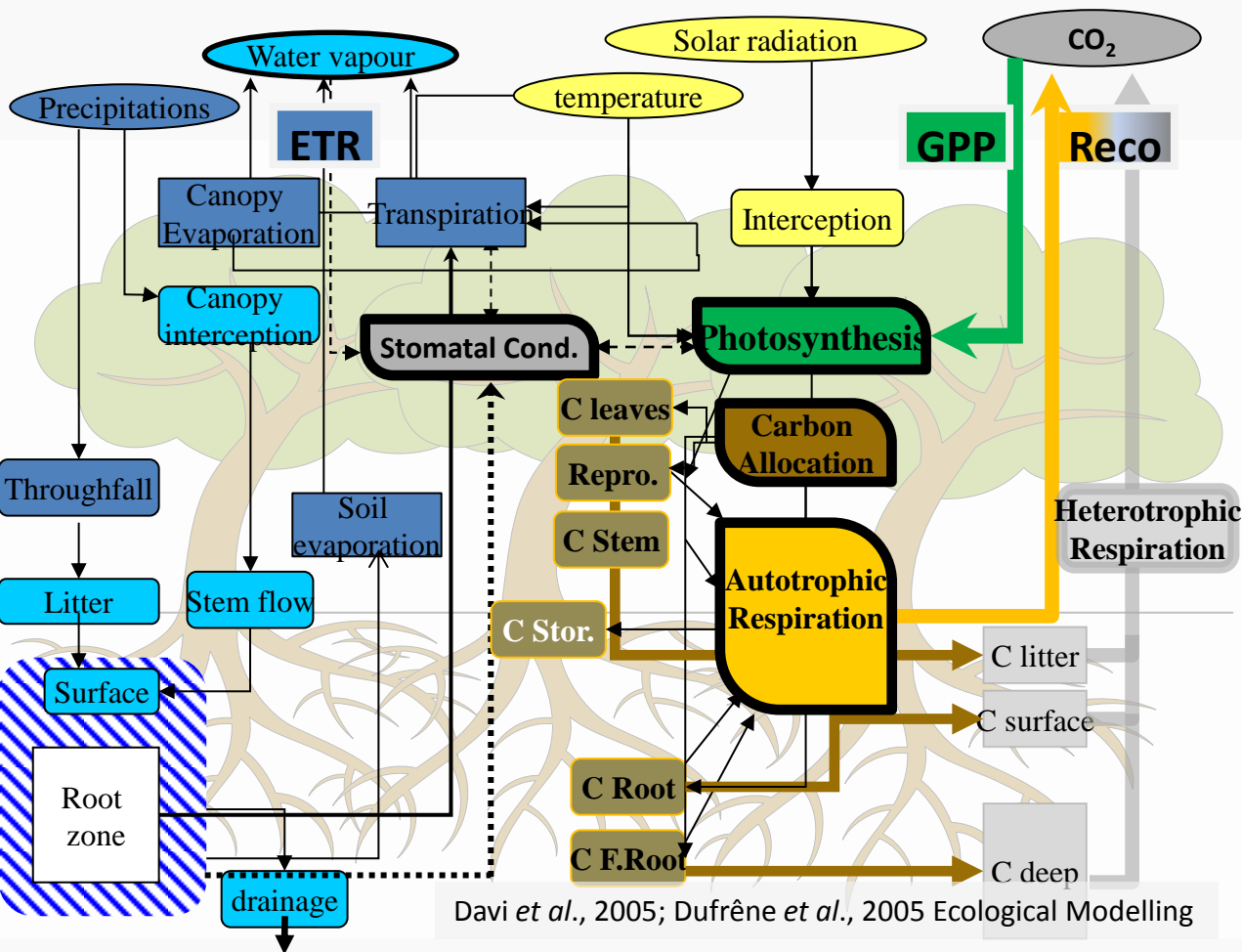
MOTIVATIONS: SEASONAL PATTERN OF GROWTH & C FLUXES



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



THE MODEL CASTANEA



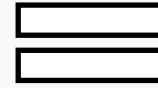
2D Stand-scale model
Half Hourly time step
Average Tree (Monospecific)
Water budget
Carbon Budget
Carbon allocation

ALLOCATION IN CASTANEA & HYPOTHESIS TESTING

Photosynthesis



**Maintenance
Respiration**



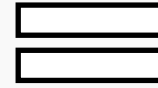
**Carbon available
for growth**

ALLOCATION IN CASTANEA & HYPOTHESIS TESTING

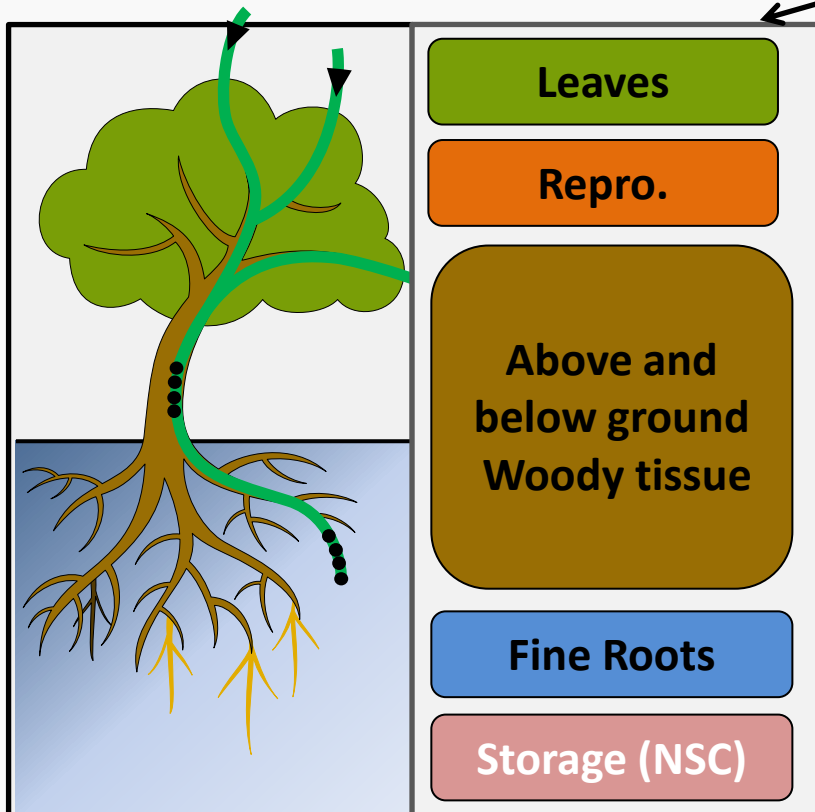
Photosynthesis



**Maintenance
Respiration**



**Carbon available
for growth**

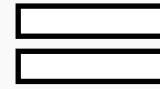


ALLOCATION IN CASTANEA & HYPOTHESIS TESTING

Photosynthesis



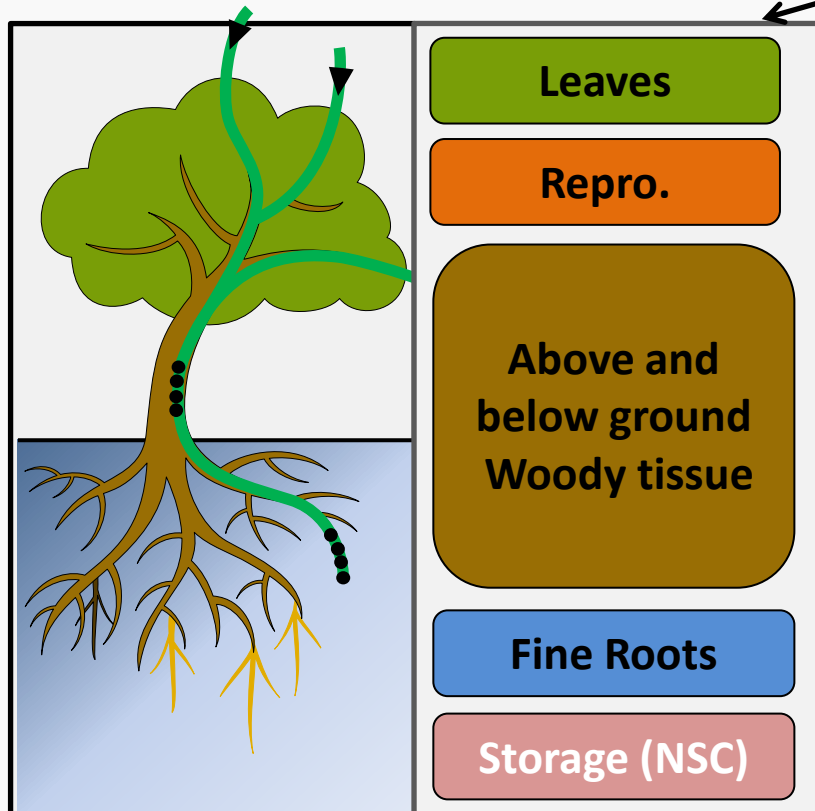
**Maintenance
Respiration**



**Carbon available
for growth**

Data assimilation (MCMC)
Eddy Covariance, sapflow

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

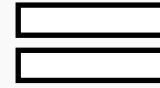


ALLOCATION IN CASTANEA & HYPOTHESIS TESTING

Photosynthesis



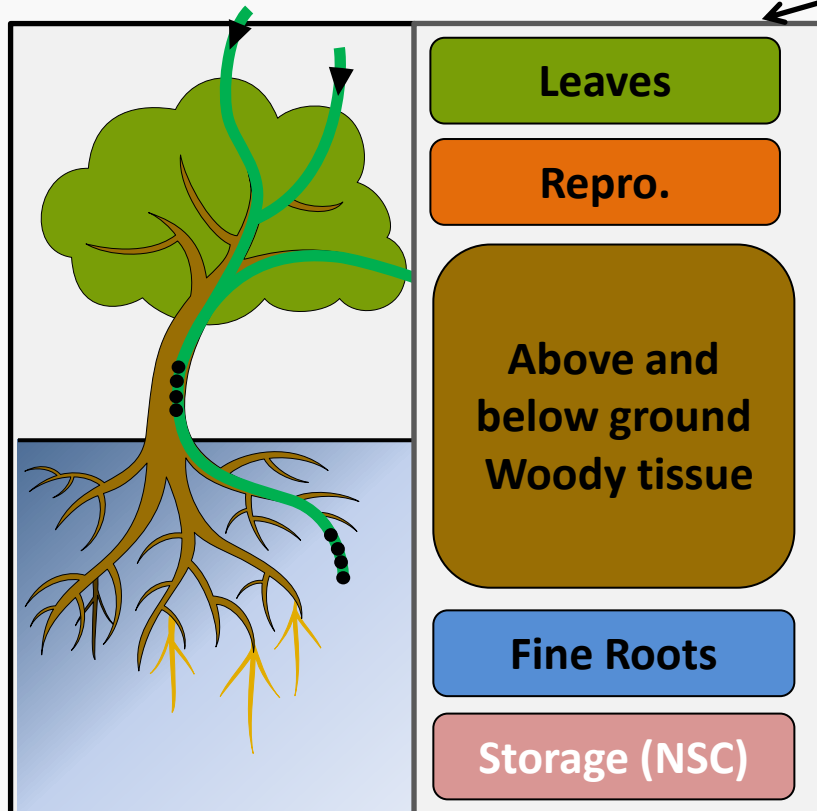
**Maintenance
Respiration**



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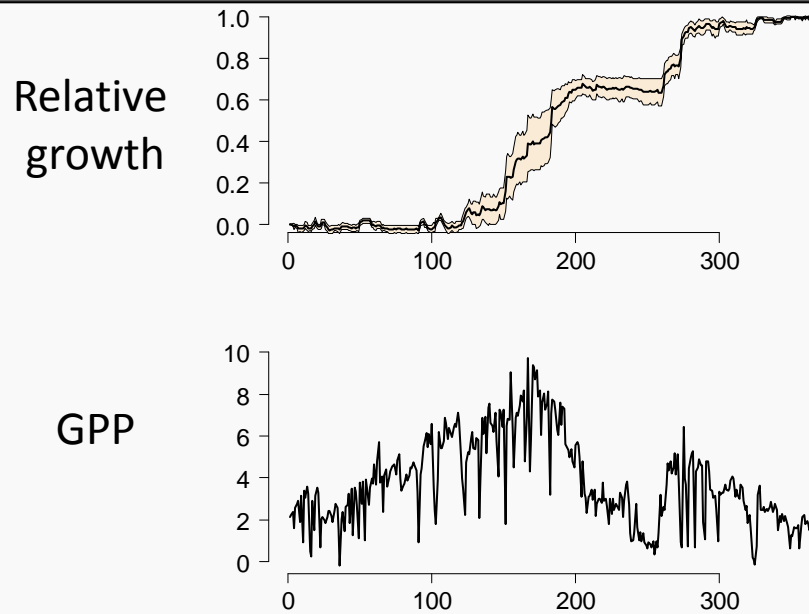
Extensive calibration
(Rodriguez-Calcerrada *et al* 2012)
(Rodriguez-Calcerrada *et al* sub)



Prescribed
(in situ measurements
litterfall & phenology)

Simulated
by testing 3 different
hypothesis

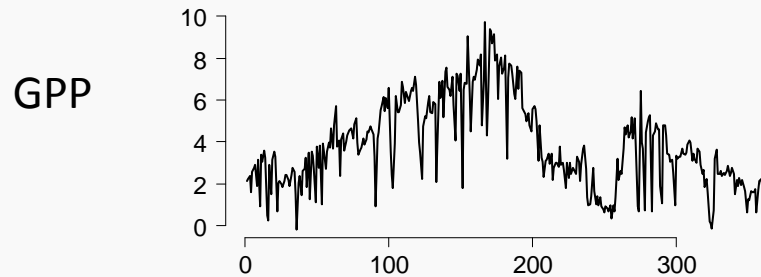
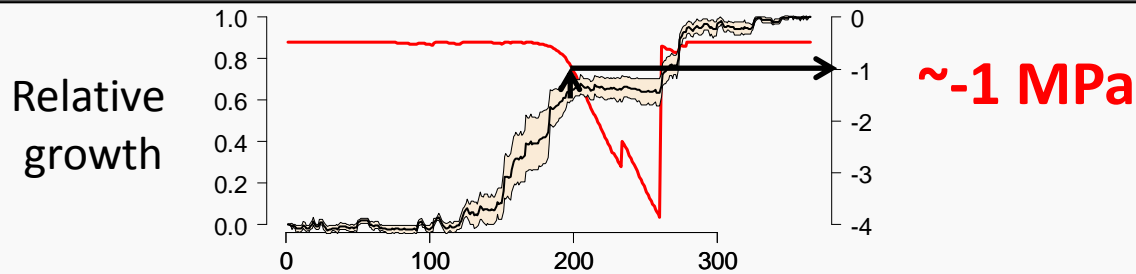
ALLOCATION IN CASTANEA & HYPOTHESIS TESTING



H1: Source Limitation

Growth depends
on available carbon only

ALLOCATION IN CASTANEA & HYPOTHESIS TESTING



H1: Source Limitation

Growth depends on available carbon only

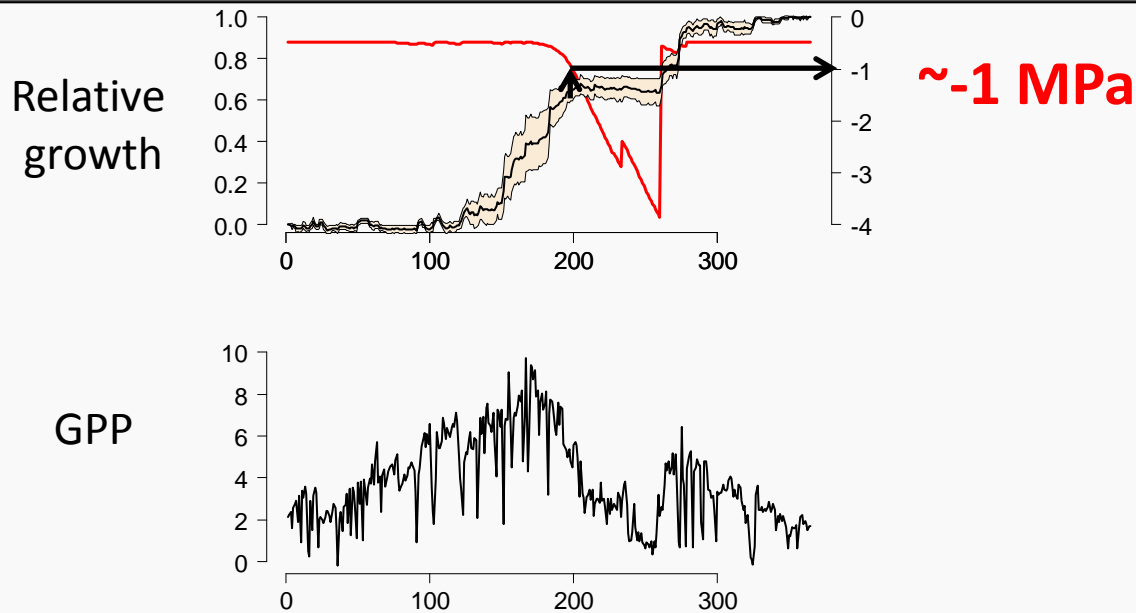
H2: Sink-*FineRoots*

Growth is **Limited by water potential** → Available Carbon is allocated to **Fine Roots**

H1: Sink-*Storage*

Growth is **Limited by water potential** → Available Carbon is allocated to **Storage**

ALLOCATION IN CASTANEA & HYPOTHESIS TESTING



H1: Source Limitation

Growth depends on available carbon only

H2: Sink-*FineRoots*

Growth is **Limited by water potential** → Available Carbon is allocated to **Fine Roots**

H3: Sink-*Storage*

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

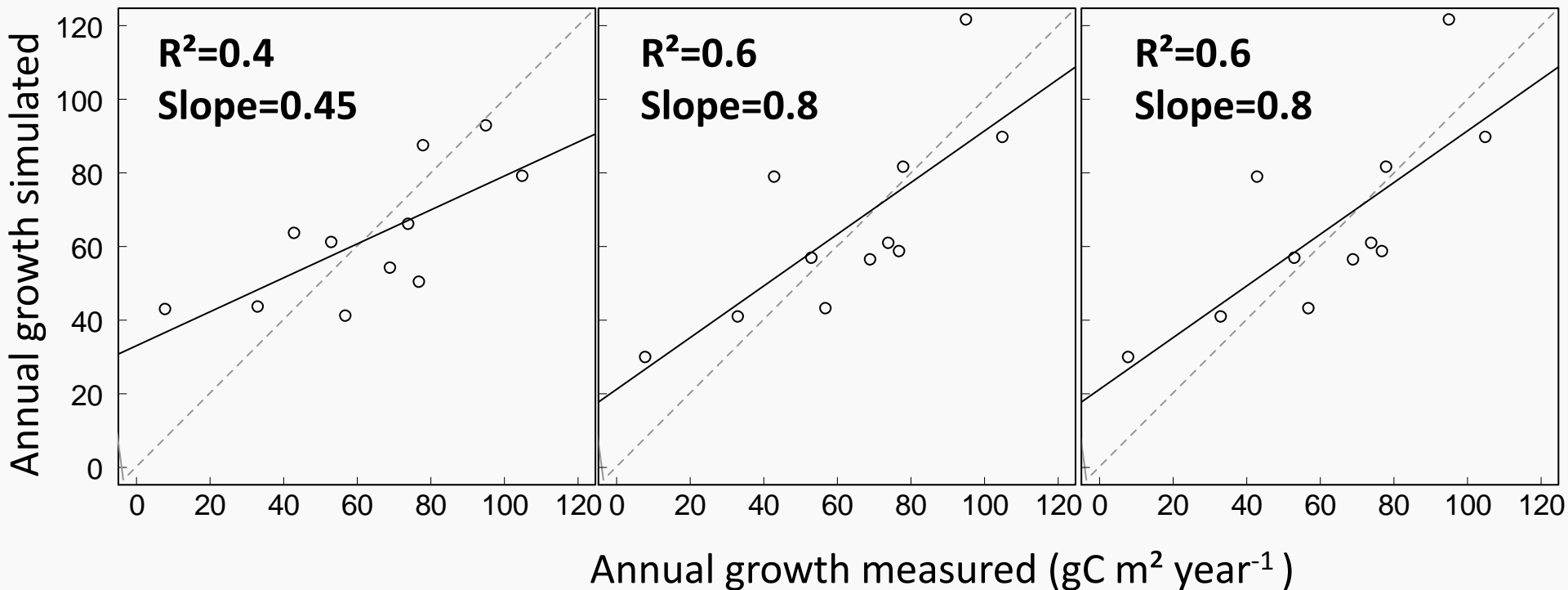
Temporal dynamic & Level of $\frac{\text{FineRoot}}{\text{Leaf}}$ biomass

RESULTS: STEM GROWTH MEASURED vs. SIMULATED

Source Limitation

H2: Sink-FineRoots

H3: Sink-Storage

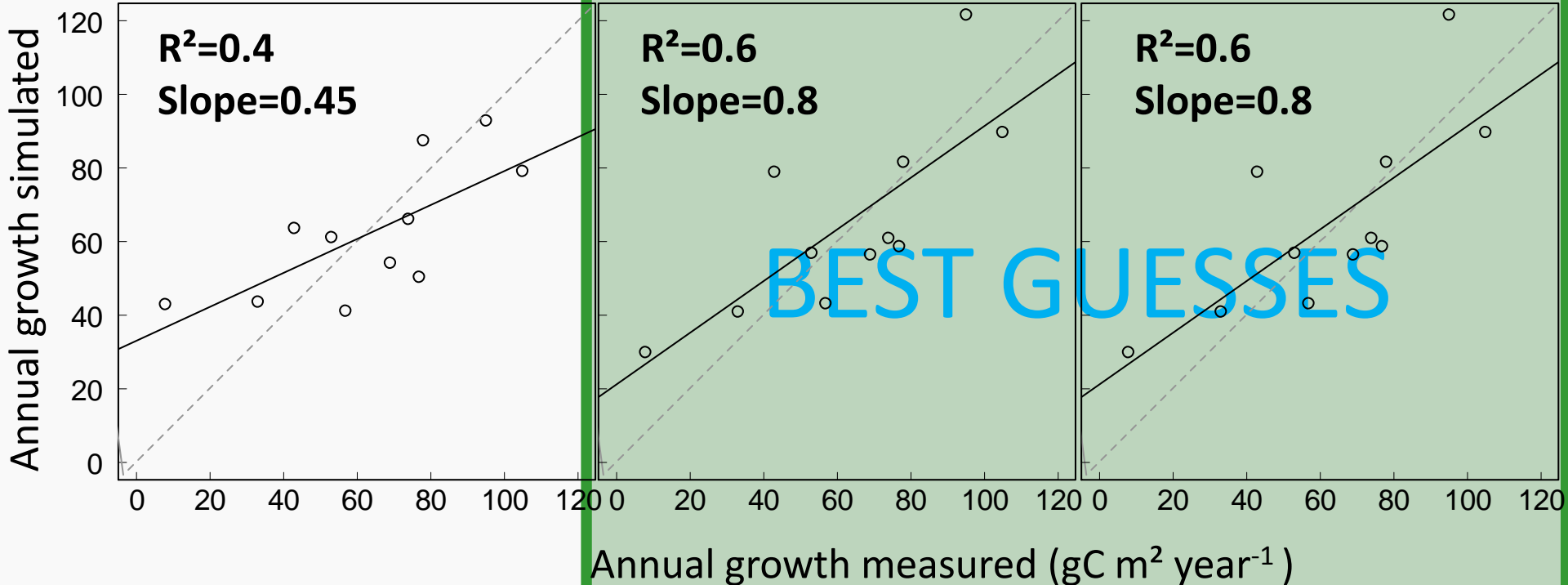


RESULTS: STEM GROWTH MEASURED vs. SIMULATED

Source Limitation

H2: Sink-FineRoots

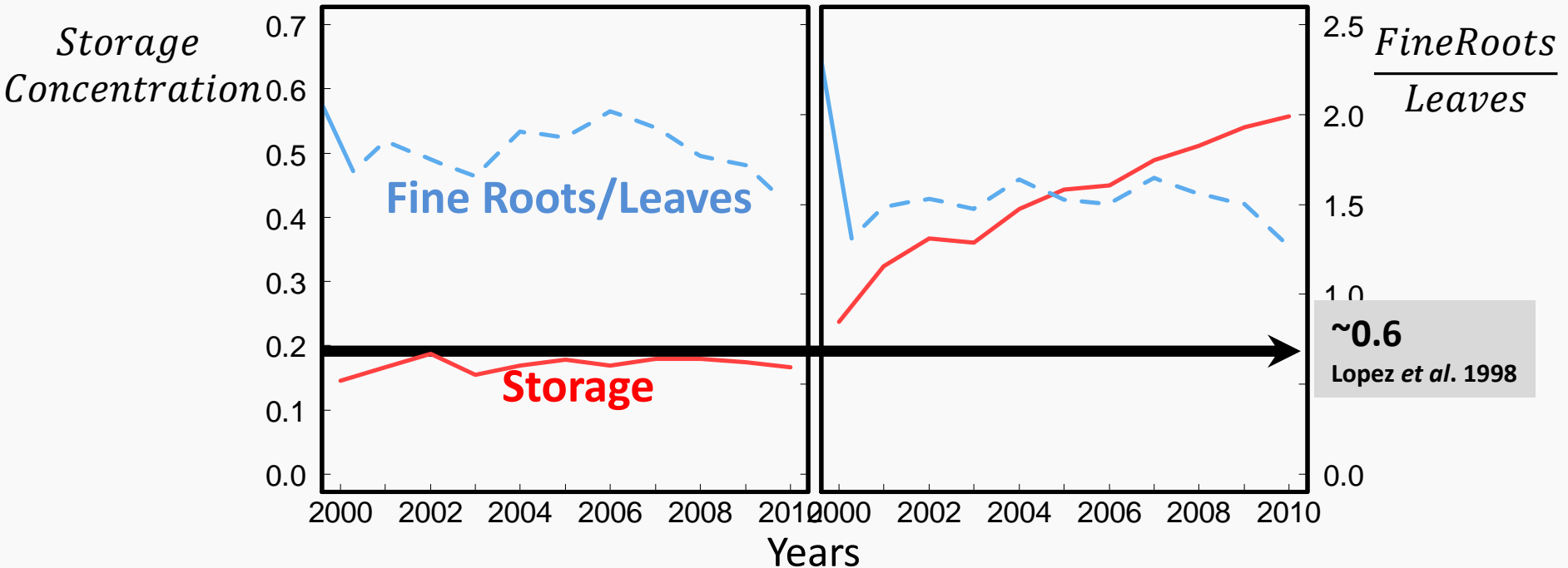
H3: Sink-Storage



RESULTS: STORAGE & FINE ROOT/LEAF BIOMASS

H2: Sink-FineRoots

H3: Sink-Storage

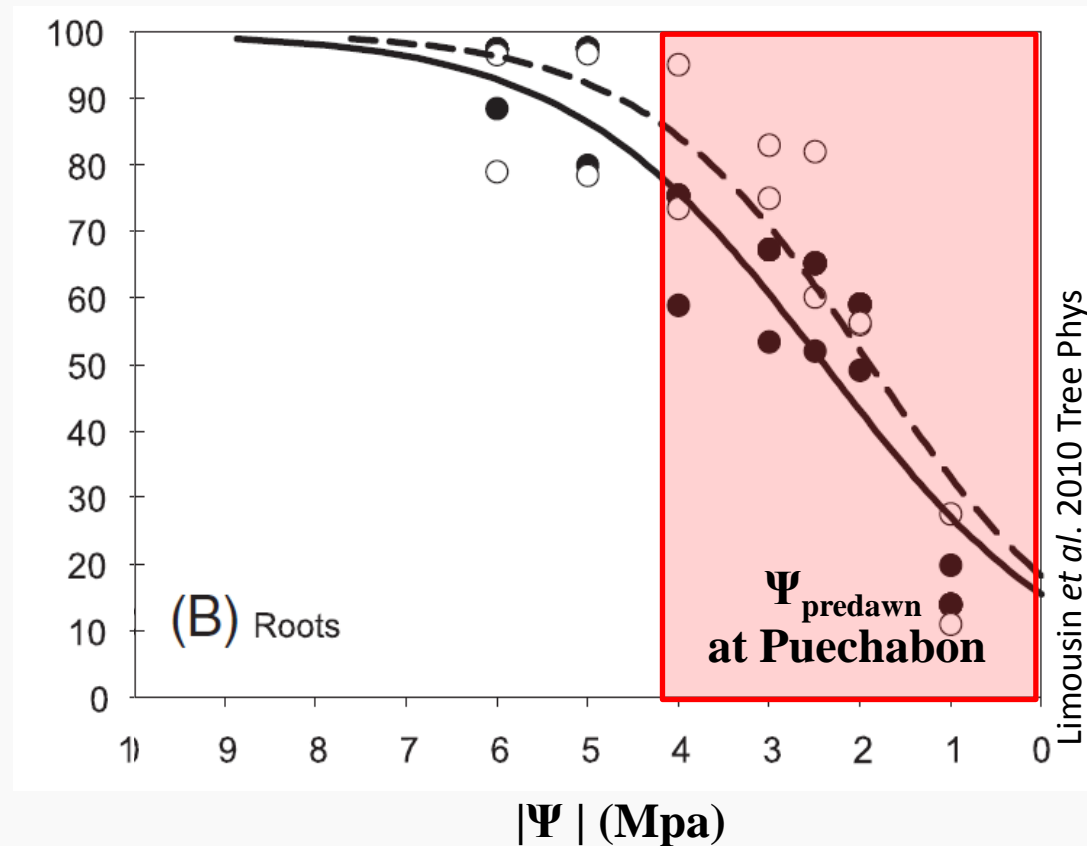


Challenge:

- $\frac{\text{Fine Root}}{\text{Leaf}}$ 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

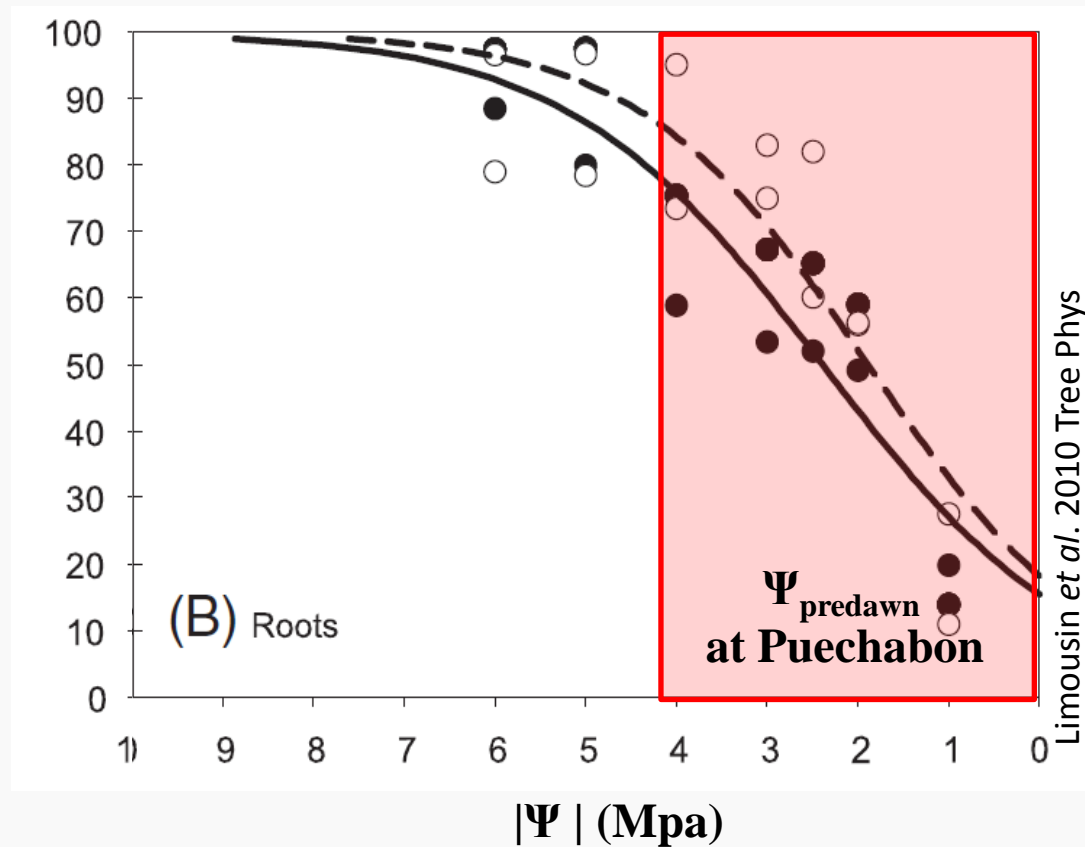


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NEW HYPOTHESIS

**% CAVITATION
OF ROOTS**



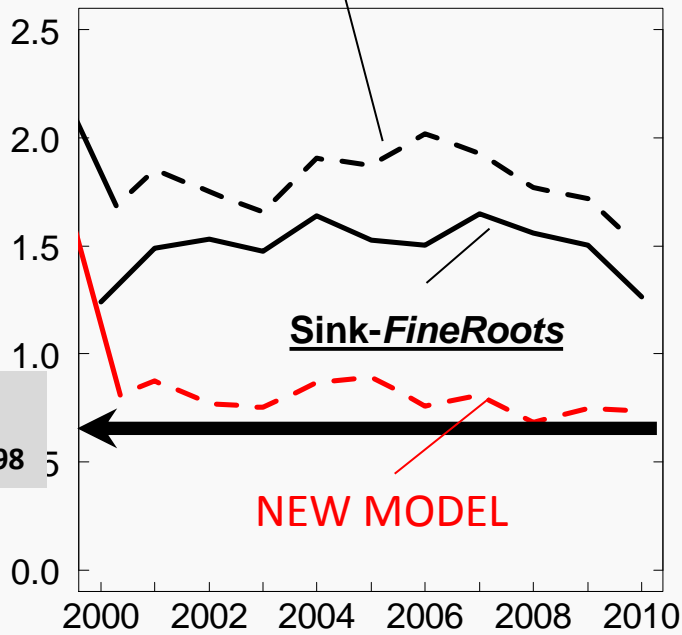
if ($\Psi_{\text{dawn}} < -1\text{MPa}$) {All growth = 0; Storage = 1}

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

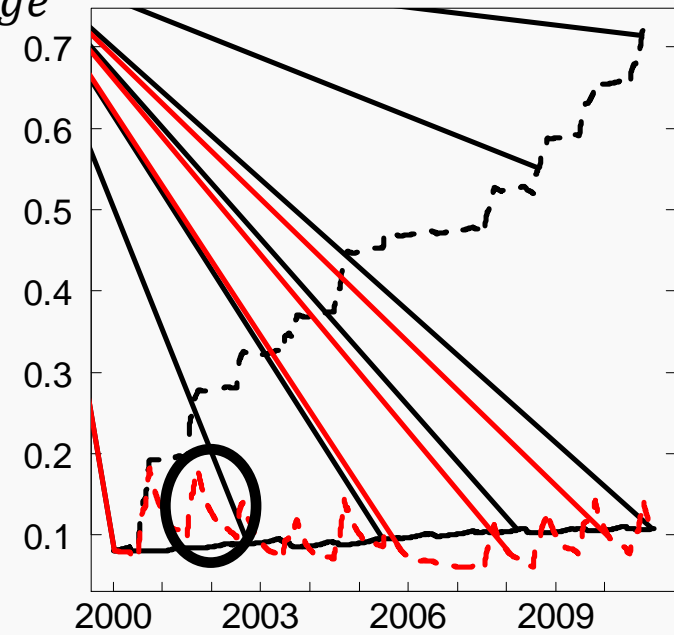
$$\text{Fine root growth} = f(\text{Storage}, \text{FRootTh})$$

NEW HYPOTHESIS

$\frac{\text{FineRoot}}{\text{Leaf}}$

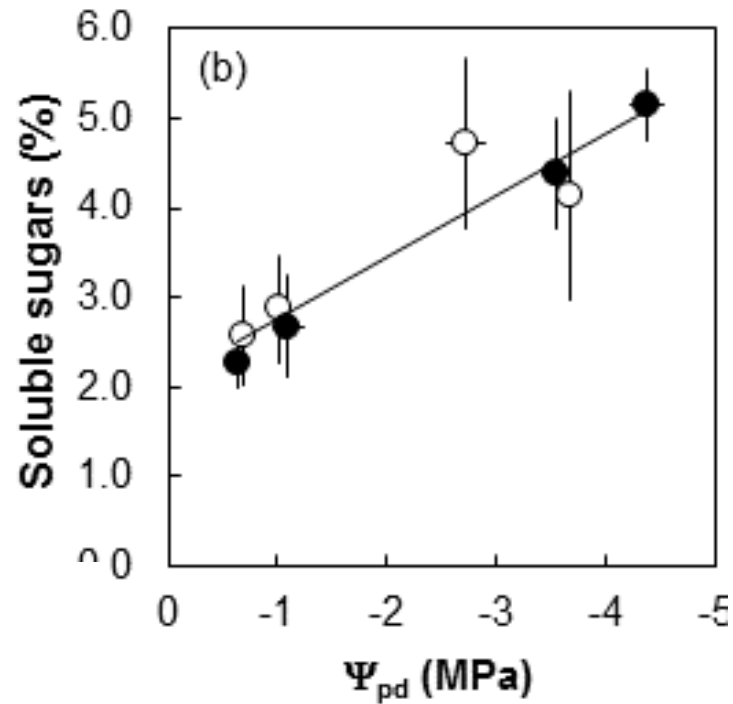


Storage



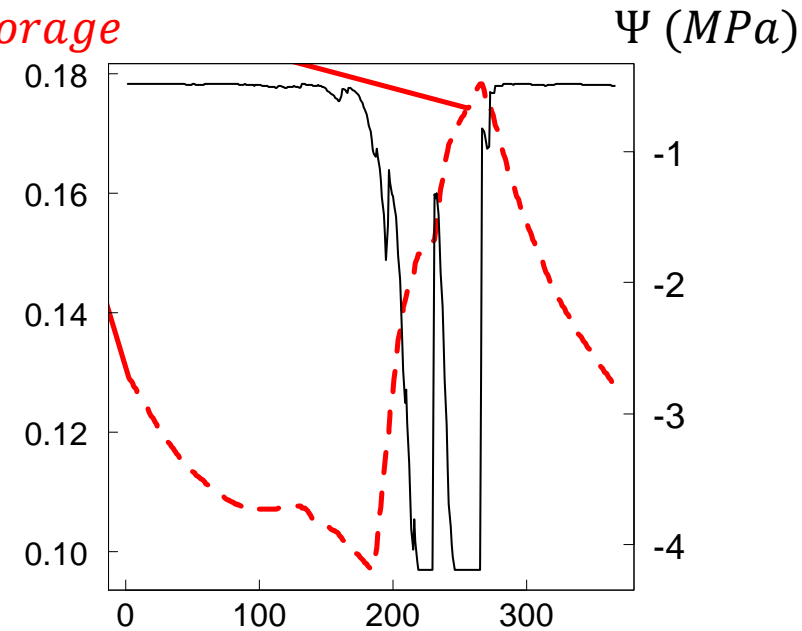
NEW HYPOTHESIS

Storage in the sapwood at the Puechabon site



Rodriguez-Calcerrada *et al.* submitted

Storage



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 accounting 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 accounting 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**

A scenic landscape featuring a dense green forest in the foreground, a rainbow in the distance, and mountains under a cloudy sky. The text "Thank you for your attention" is overlaid in white.

Thank you for
your attention