What are the functional mechanisms underlying forest decline? A case study on a European beech (Fagus sylvatica L.) stand

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Context

Climate change
➔ increase in drought frequencies and intensities
➔changes in tree species' geographical range
➔ forest declines

Material and methods

One mature beech stand, with healthy and severely declining trees, temperate climatic conditions (Fontainebleau, France)

5 healthy trees

5 declining trees

C and N reserves
↳ Enzymatic method
↳ Bradford's method

Hydraulic properties
↳ Cavitron

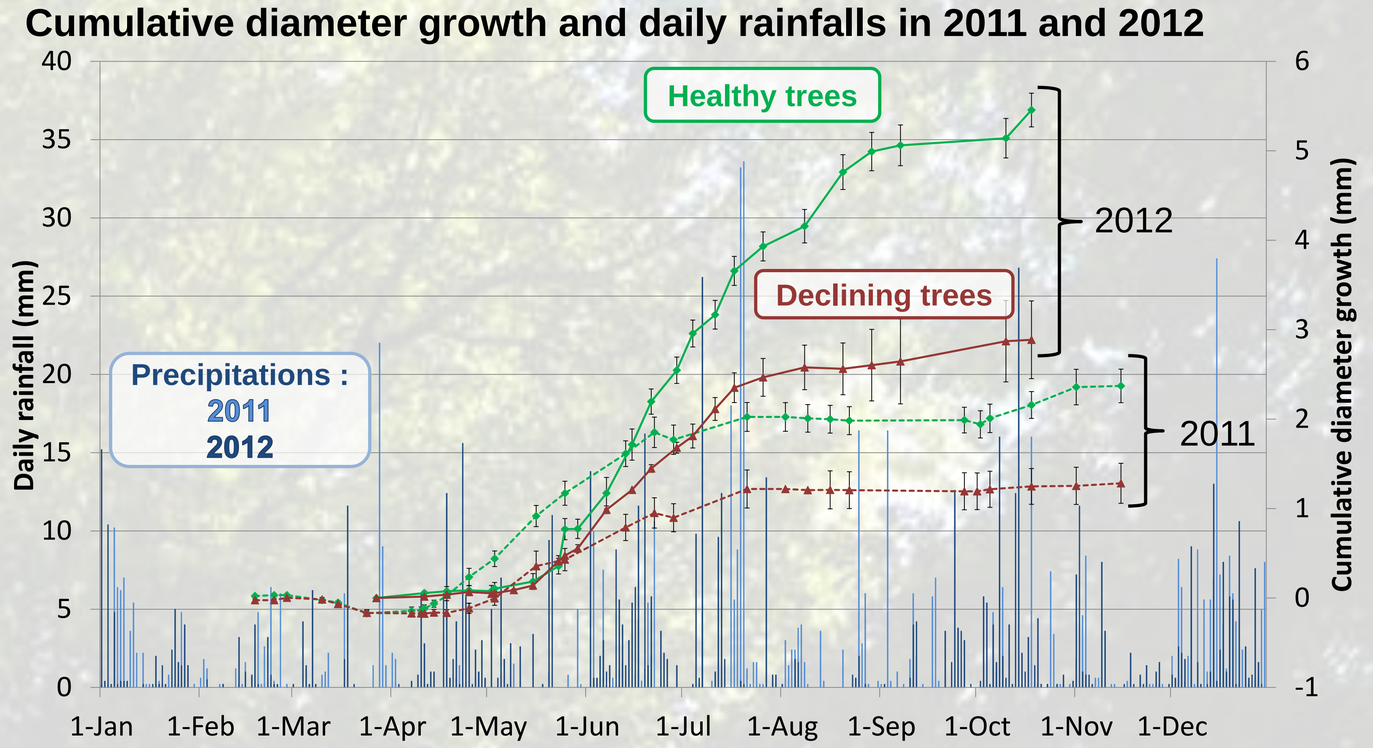
+ weekly growth measurements + phenological monitoring (budburst and yellowing)

Question :

Can the observed forest decline be related to carbon or nitrogen metabolism malfunction, or to hydraulic failure ?

Results

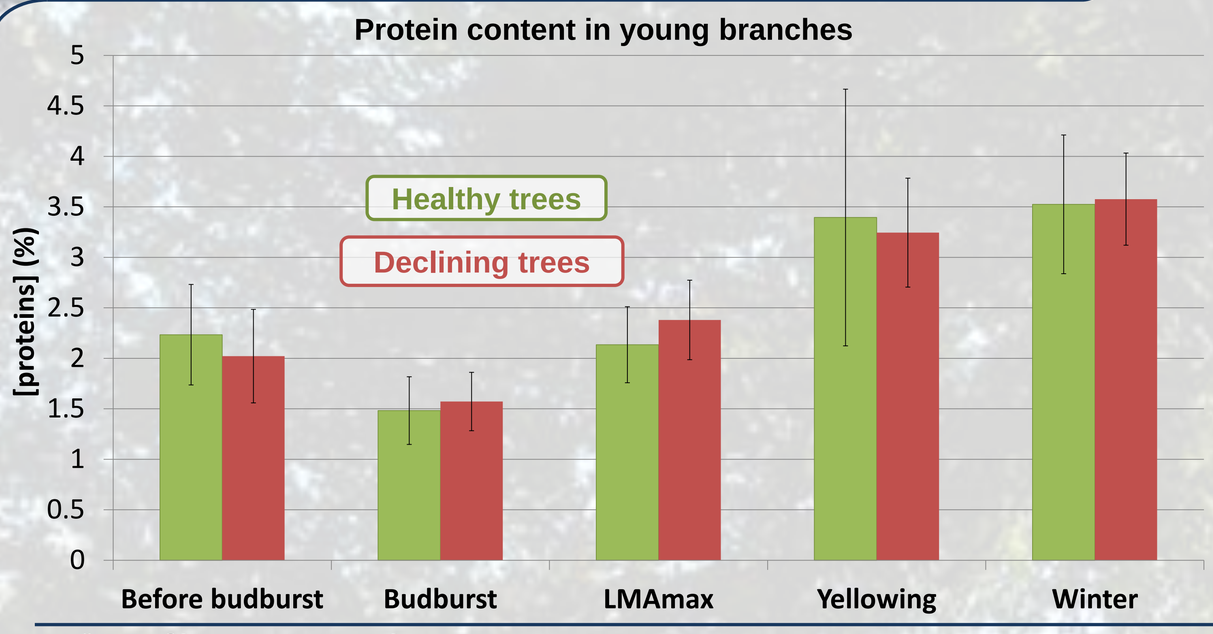
Cumulative diameter growth and daily rainfalls in 2011 and 2012



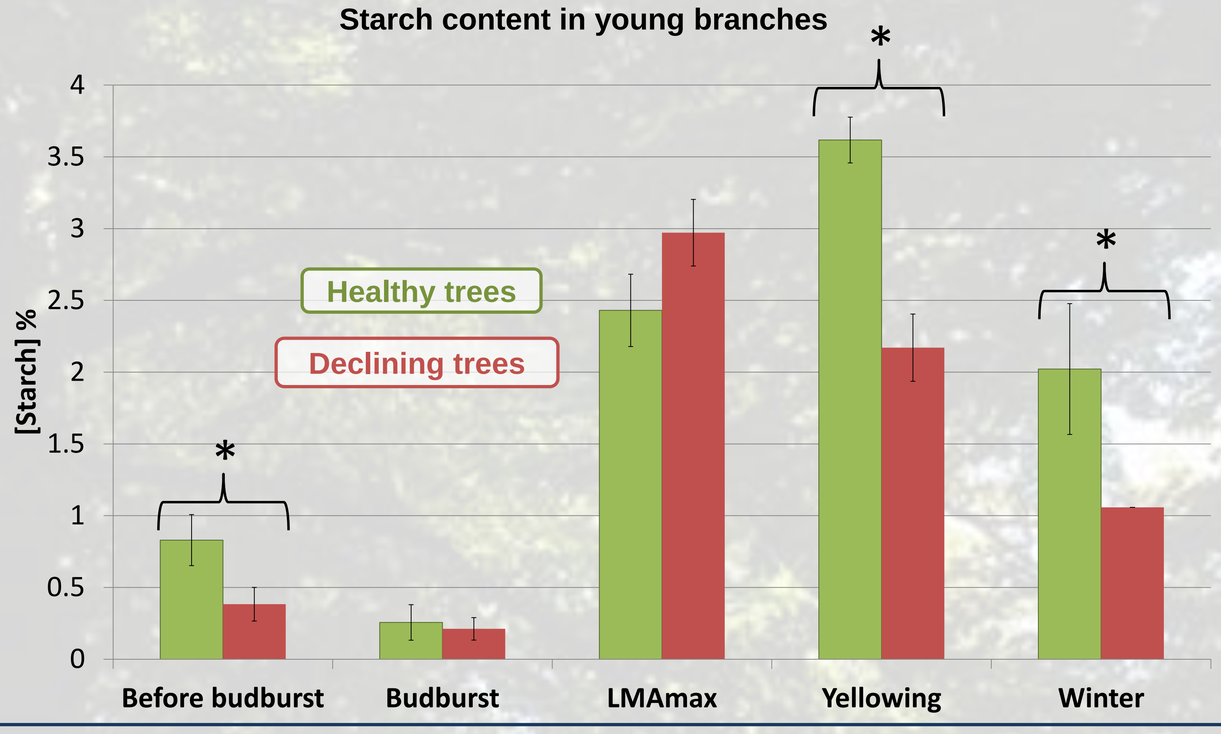
Speed AND duration of **growth** are **reduced** in declining trees

C and N reserves

Protein content in young branches

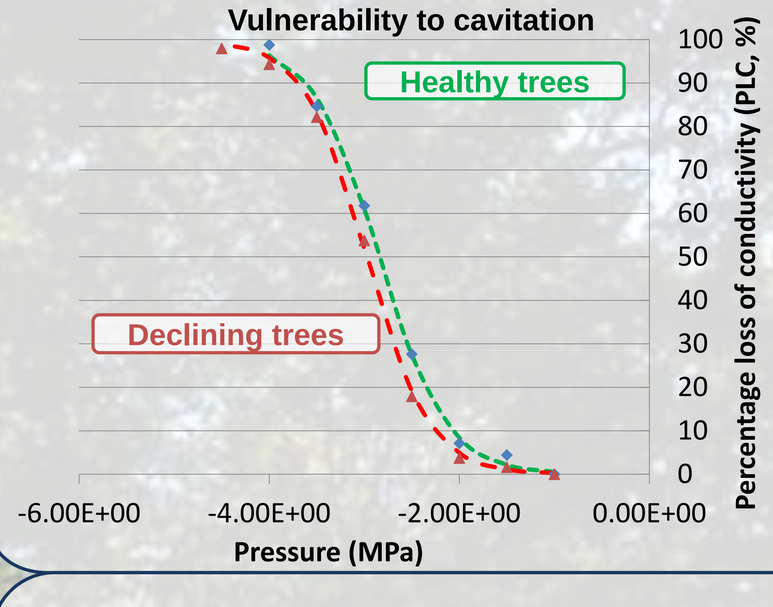


Starch content in young branches



Hydraulic properties

Vulnerability to cavitation



Total non-structural carbohydrate content (starch + sugars)
Total non-structural nitrogen content (soluble proteins + aminoacids)
Vulnerability to cavitation + pre-dawn and midday **water potentials** (data not shown)
⇨ **SAME** for healthy and declining trees

Starch deficit in young branches in **declining trees**
→ enhanced vulnerability to biotic and/or abiotic stresses ?

No carbon starvation, no hydraulic failure

Conclusion

Growth is very **reduced** in declining trees
→ **C allocation to reserves** is maintained, **at the expense of growth**

Isohydric species
e.g. Pine (Mitchell et al, 2013)
↓
Carbon starvation

Drought
Early stomatal closure
Late stomatal closure
Beech
?

Anisohydric species
e.g. Aspen (Anderegg et al, 2012), Eucalyptus (Mitchell et al, 2013)
↓
Hydraulic failure

Same functioning for healthy and declining trees (except for growth) under **non-extreme climatic conditions**…
but is it still the case **during a severe drought ?**

Anderegg, W. R. L., Berry, J. A., Smith, D. D., Sperry, J. S., Anderegg, L. D. L., & Field, C. B. (2012). The roles of hydraulic and carbon stress in a widespread climate-induced forest die-off. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(1), 233–237.
Mitchell, P. J., O'Grady, A. P., Tissue, D. T., White, D. A., Ottenschlaeger, M. L., & Pinkard, E. A. (2013). Drought response strategies define the relative contributions of hydraulic dysfunction and carbohydrate depletion during tree mortality. *New Phytologist*, *197*(3), 862–872.