Tracking tree growth and tree water status to reveal their intra-annual response to climatic events and to foresee future forest dynamics

Gauthier Ligot, Anaïs Gorel, Tom De Mil

fnrs
LA LIBERTÉ DE CHERCHER
LIÈGE université
Gembloux
Agro-Bio Tech

Comprendre, quantifier et modéliser l’impact de perturbations (stress hydrique) sur la croissance et la mortalité des arbres

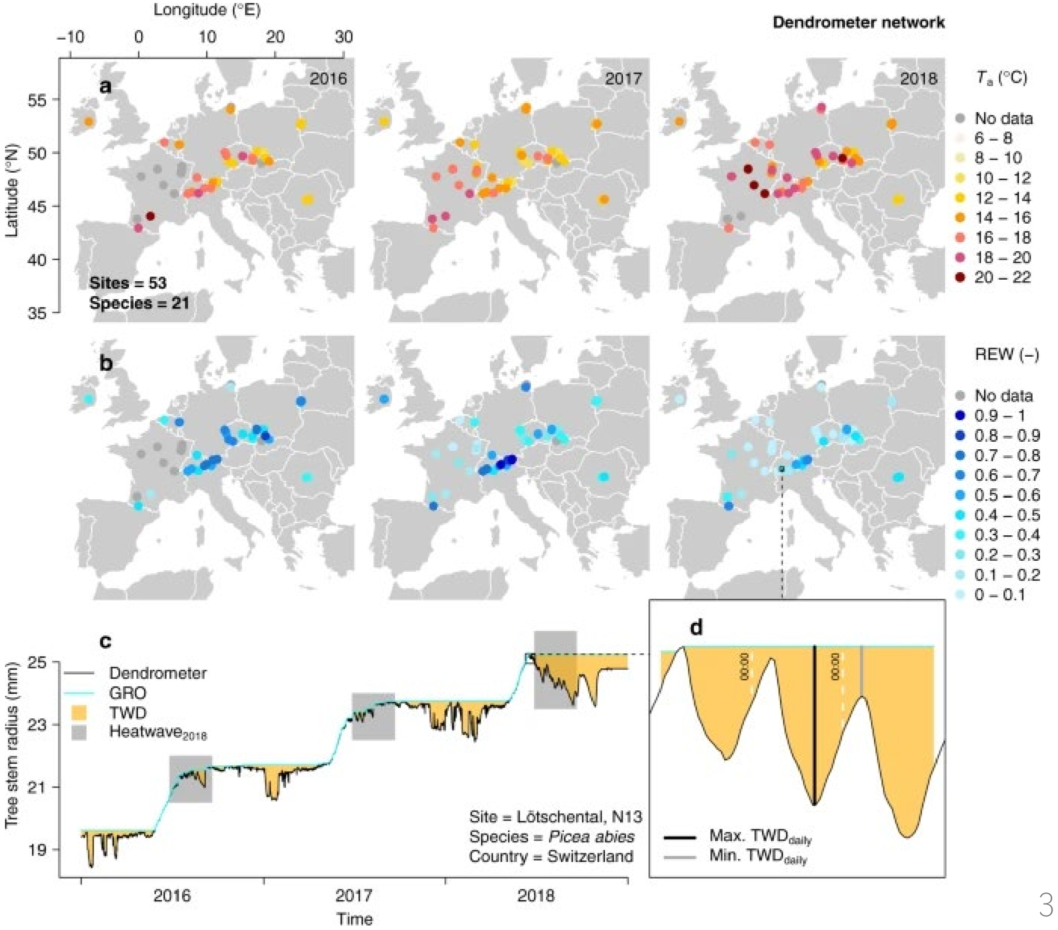
Point dendrometer

Band dendrometer

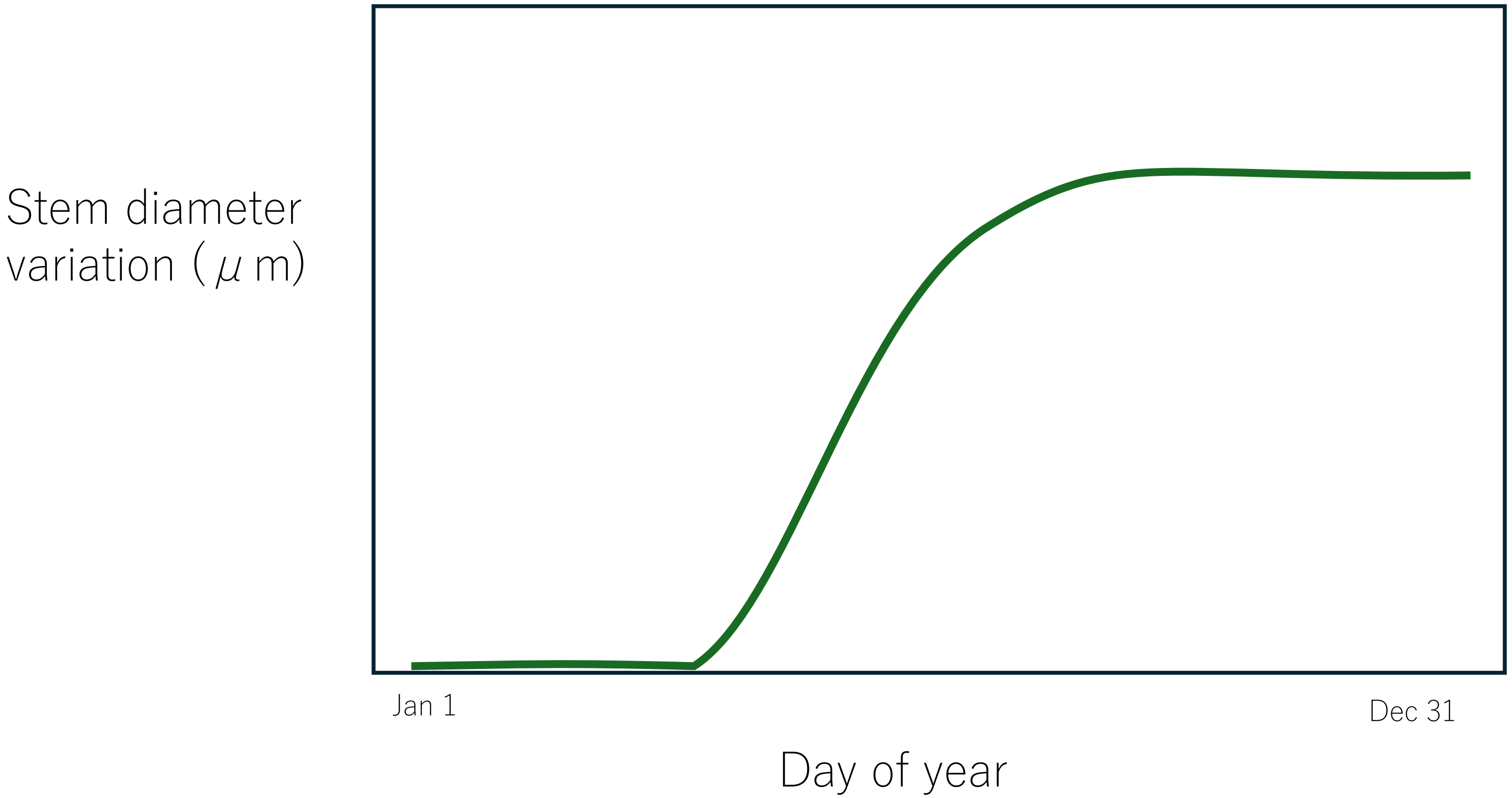
https://doi.org/10.1038/s41467-021-27579-9 OPEN

The 2018 European heatwave led to stem dehydration but not to consistent growth reductions in forests

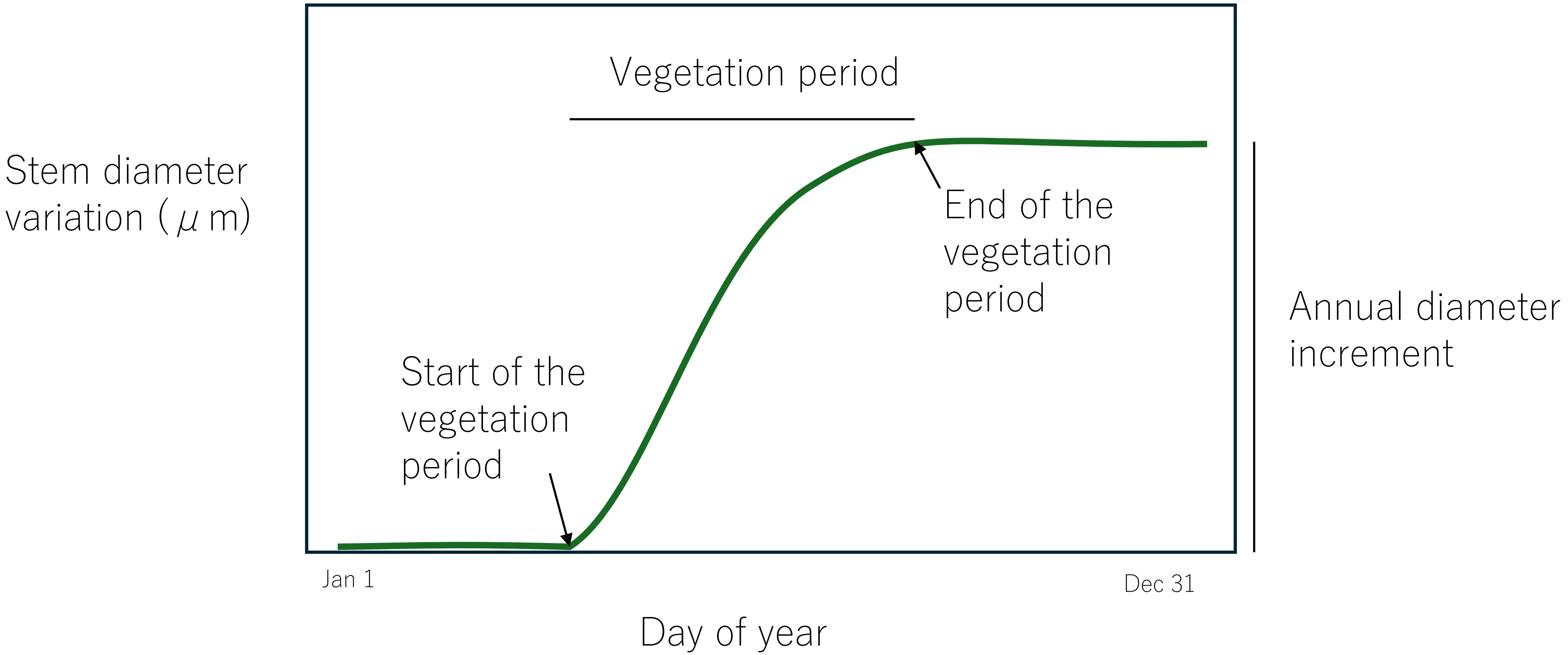
Salomón et al. 2022 Nature communications



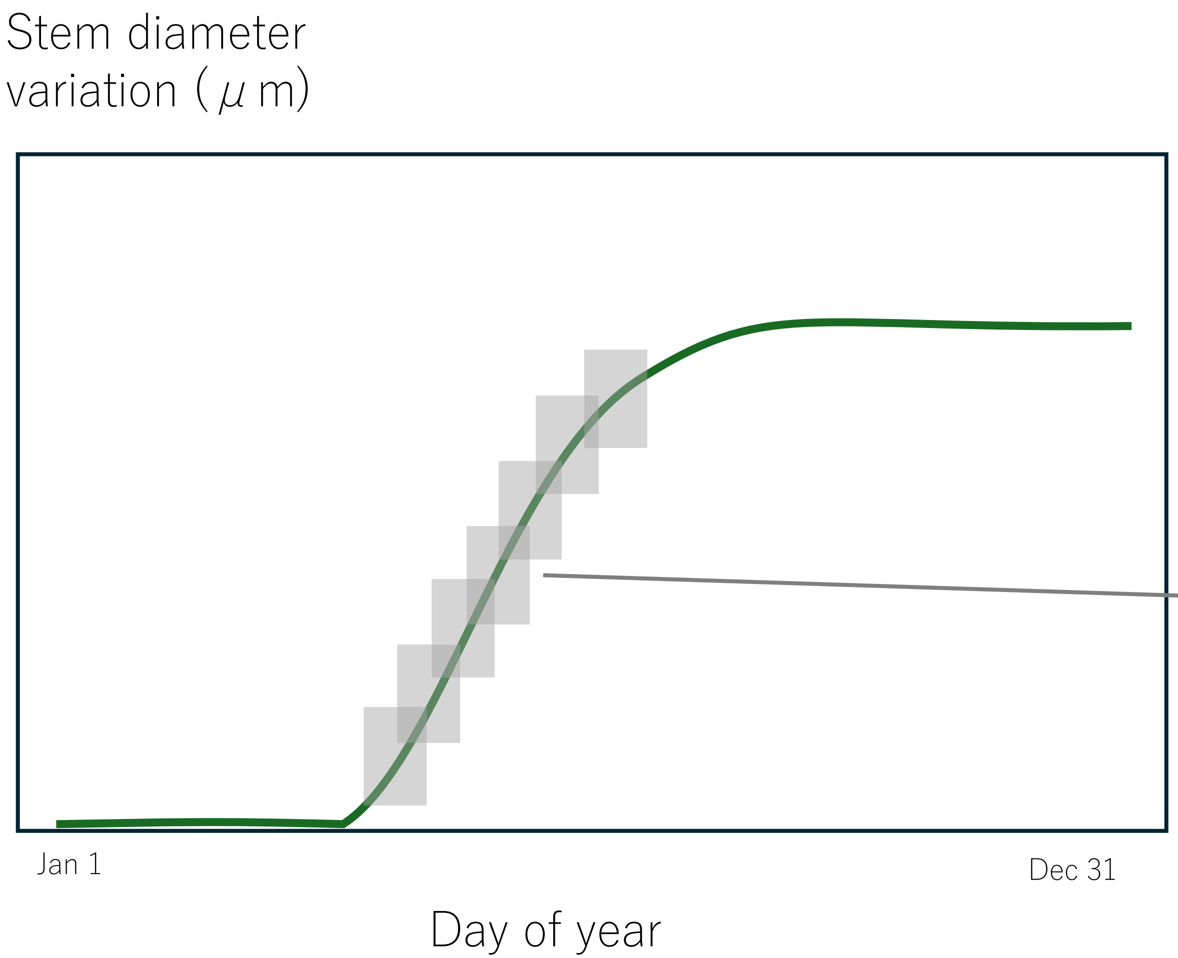
Annual increment variability and phenology

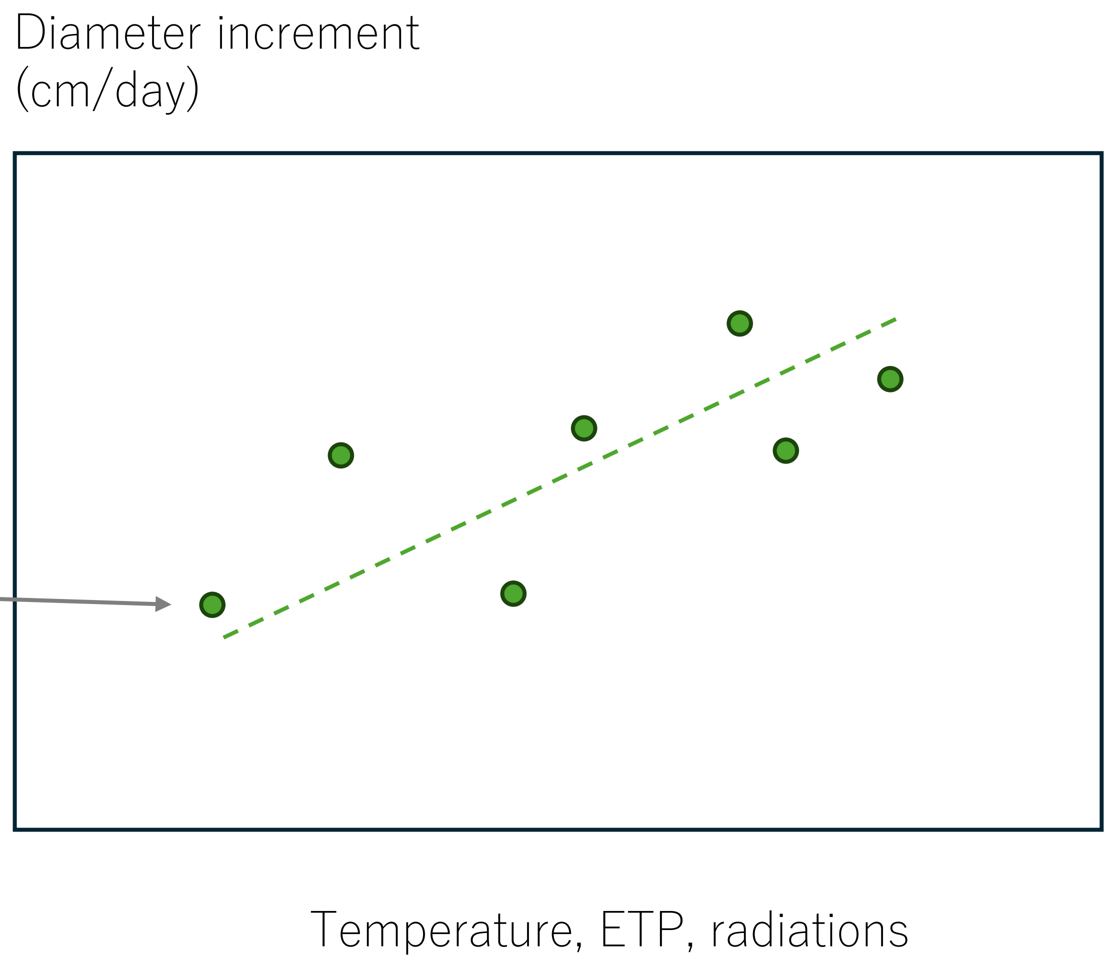


Annual increment variability and phenology

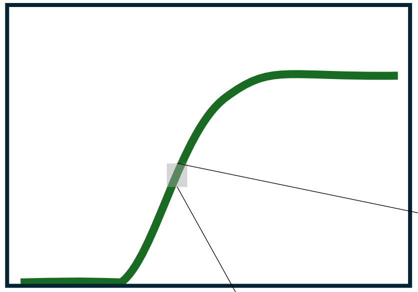


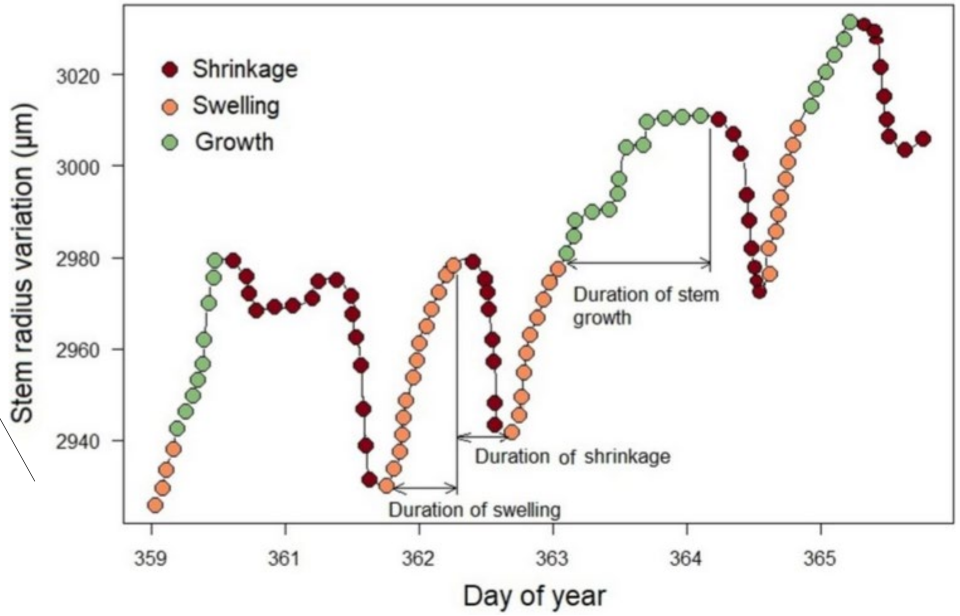
Intra-annual increment variability



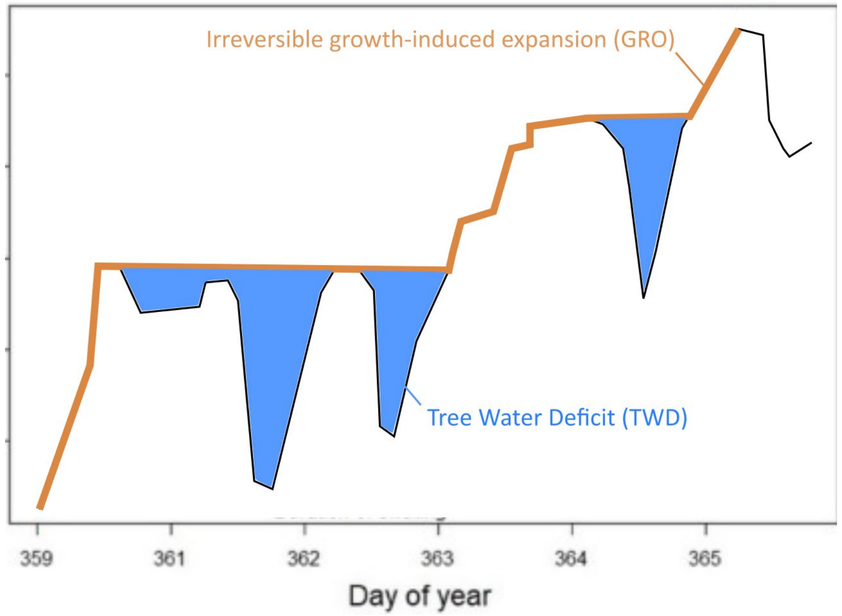


Intra-day increment variability





Zero growth framework



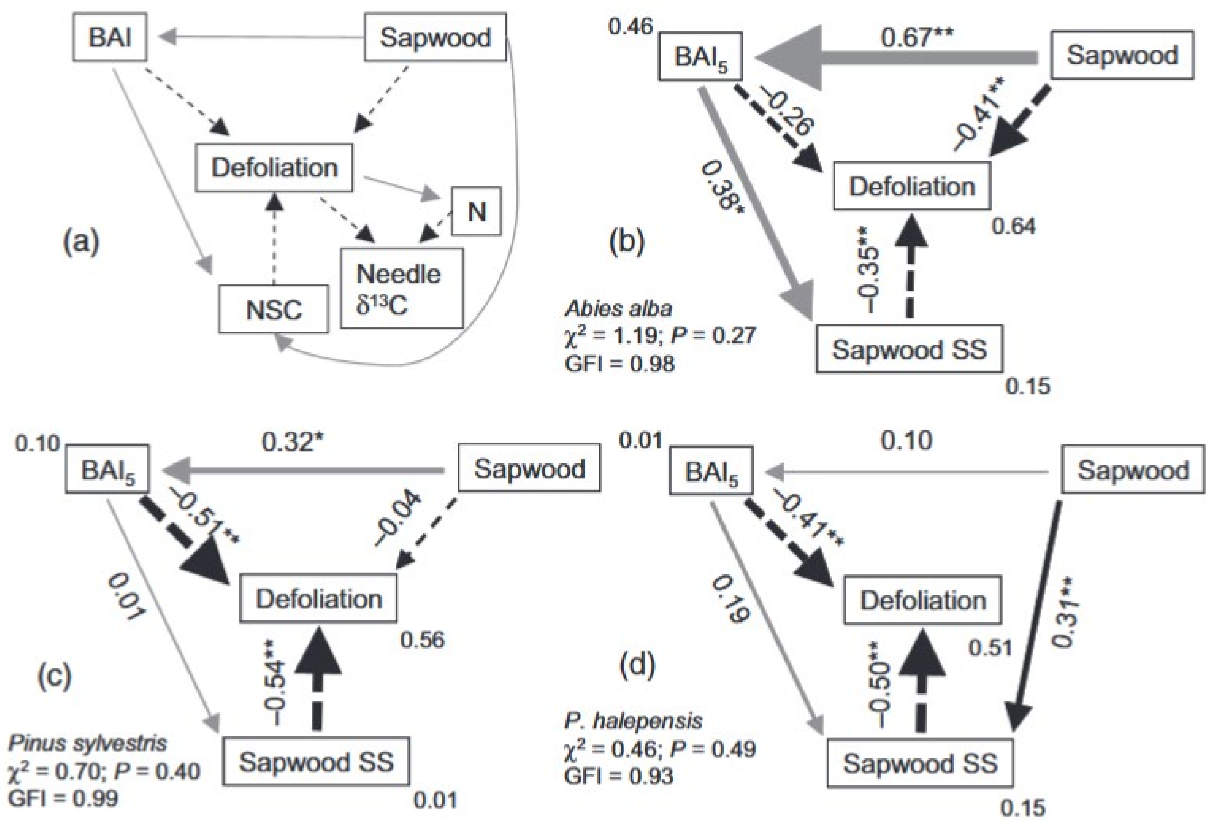
100 YEARS Journal of Ecology
British Ecological Society
Journal of Ecology 2015, **103**, 44–57 doi: 10.1111/1365-2745.12295

SPECIAL FEATURE

FOREST RESILIENCE, TIPPING POINTS AND GLOBAL CHANGE PROCESSES

To die or not to die: early warnings of tree dieback in response to a severe drought

J. Julio Camarero[1,2]*, Antonio Gazol[3], Gabriel Sangüesa-Barreda[3], Jonàs Oliva[4] and Sergio M. Vicente-Serrano[3]



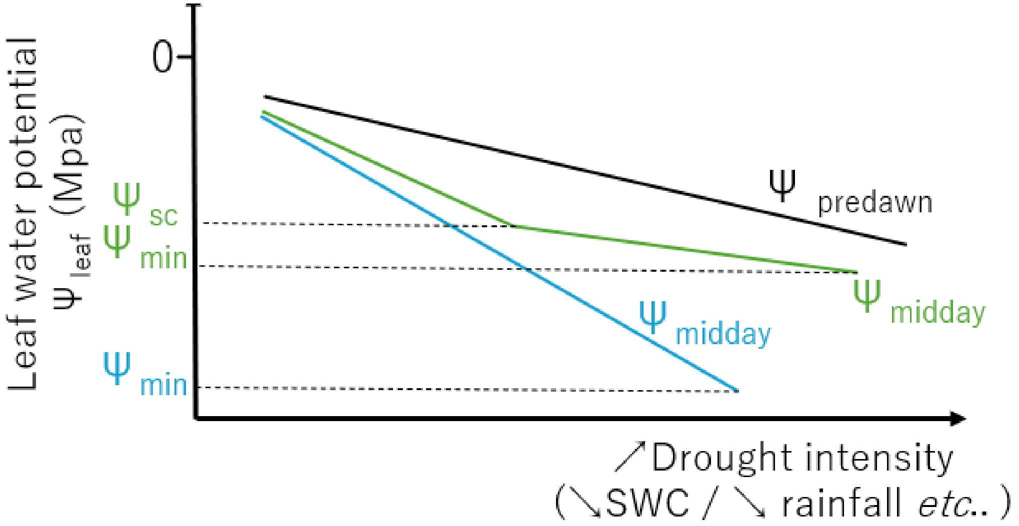
But many different growth patterns can be observed prior to mortality and many different mechanisms are at play

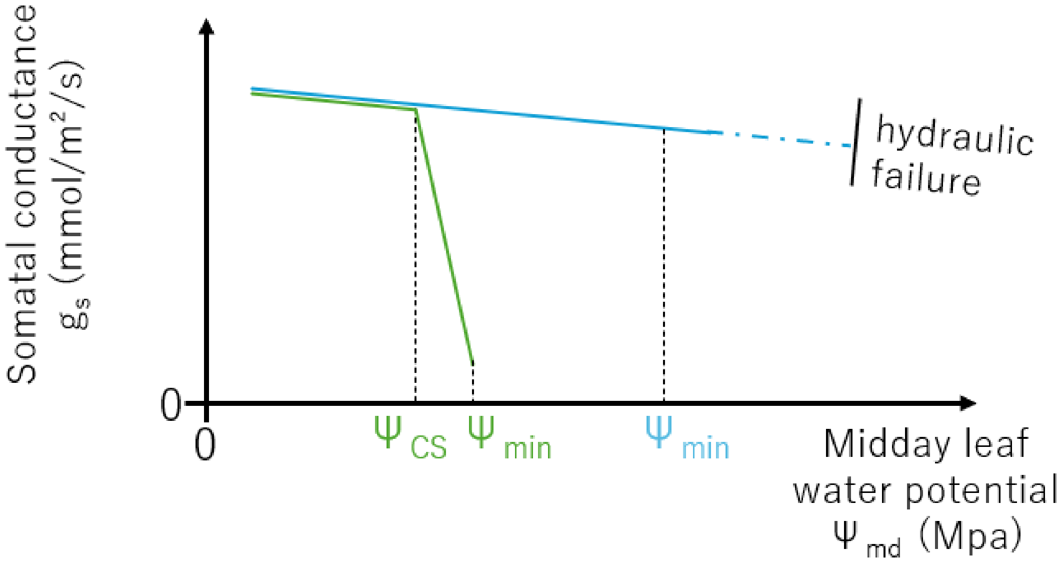
Progressive decline in hydraulic performance and depletion of carbon reserves

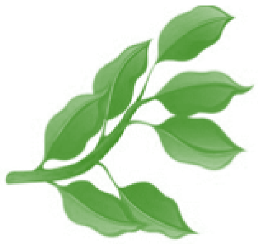
vs

Abrupt reduction in growth due to widespread hydraulic failure

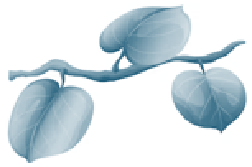
Tree hydraulic strategies







Isohydric species
Xylem sensitive to embolism



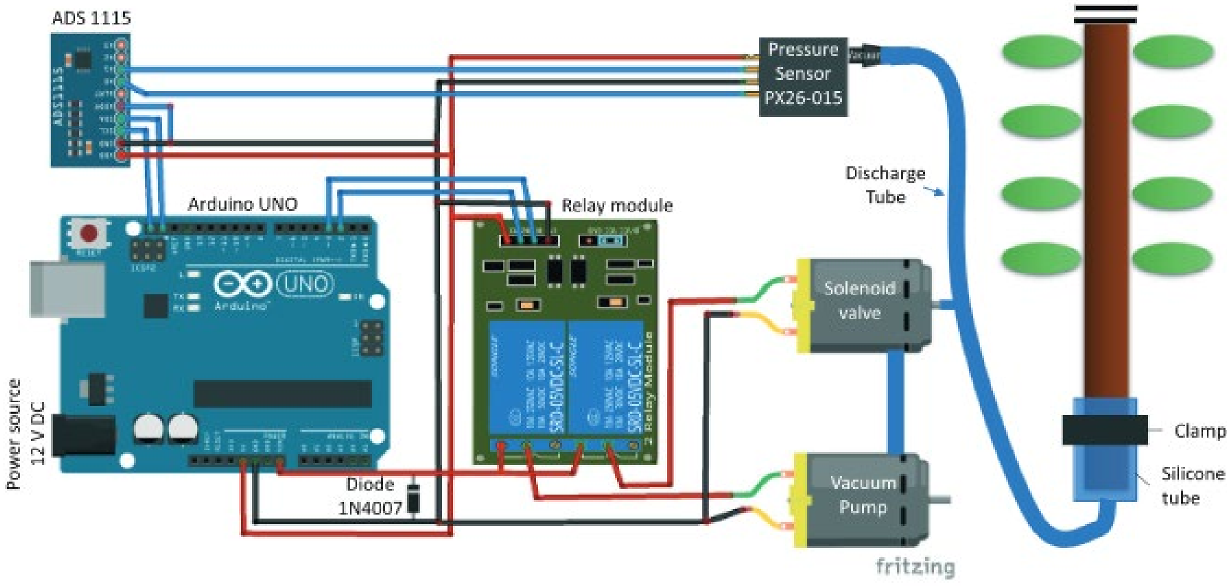
Anisohydric species
Xylem resistant to embolism

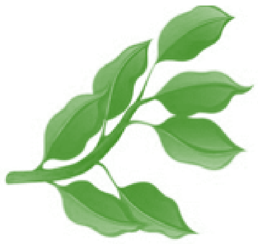
ORIGINAL ARTICLE

WILEY

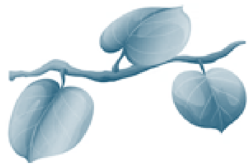
The Pneumatron: An automated pneumatic apparatus for estimating xylem vulnerability to embolism at high temporal resolution

Luciano Pereira[1,2†] | Paulo R.L. Bittencourt[3,4] | Vinícius S. Pacheco[4] | Marcela T. Miranda[1] | Ya Zhang[5] | Rafael S. Oliveira[4] | Peter Groenendijk[4] | Eduardo C. Machado[1] | Melvin T. Tyree[6] | Steven Jansen[5] | Lucy Rowland[3] | Rafael V. Ribeiro[2]

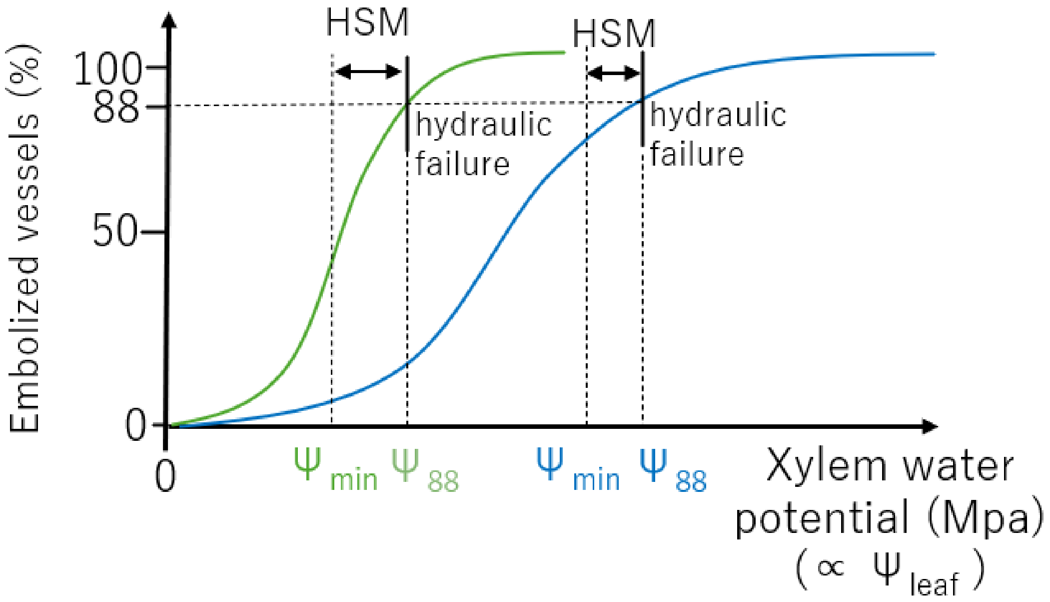




Isohydric species
Xylem sensitive to embolism



Anisohydric species
Xylem resistant to embolism



Pereira et al. 2020. Plant Cell Environ.

Study objectives

For a set of species and across multiple sites

- Model annual and intra-annual growth patterns in response to climatic conditions
- Identify the physiological processes driving tree growth response (to drought)

Sites

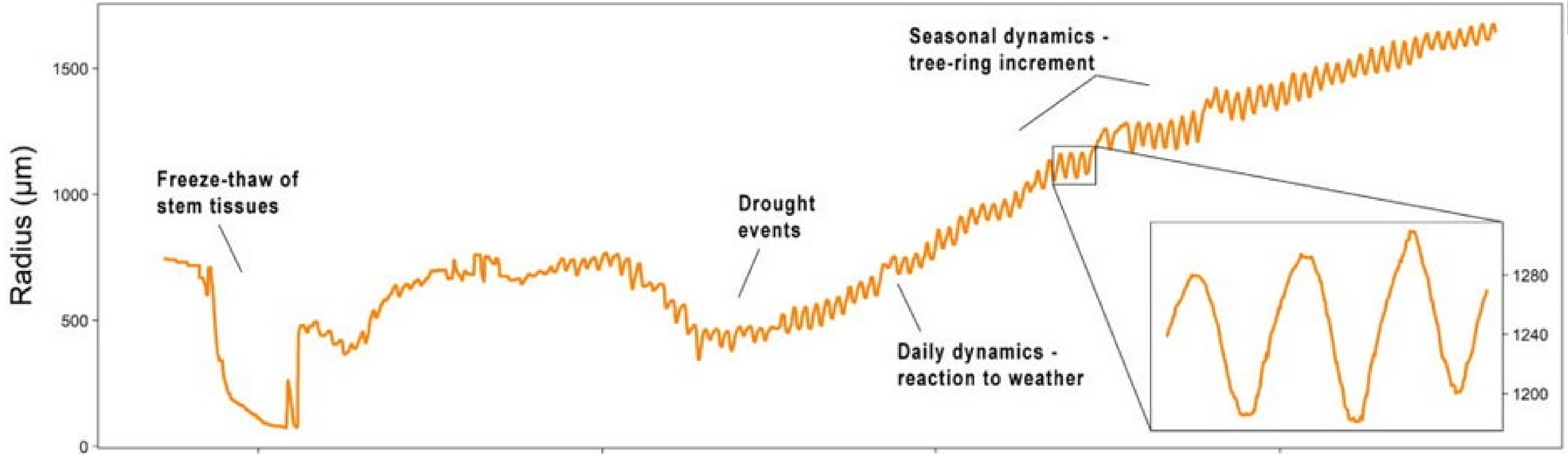
- 34 sites
- Southern Belgium
- One ecological region (Condroz)
- 9.6 ° ; 937 mm/year
- Mostly pure evenaged stands
- Dg : 22 – 40 cm
- Stony loamy soils with no signs of temporary waterlogging

Tree sample

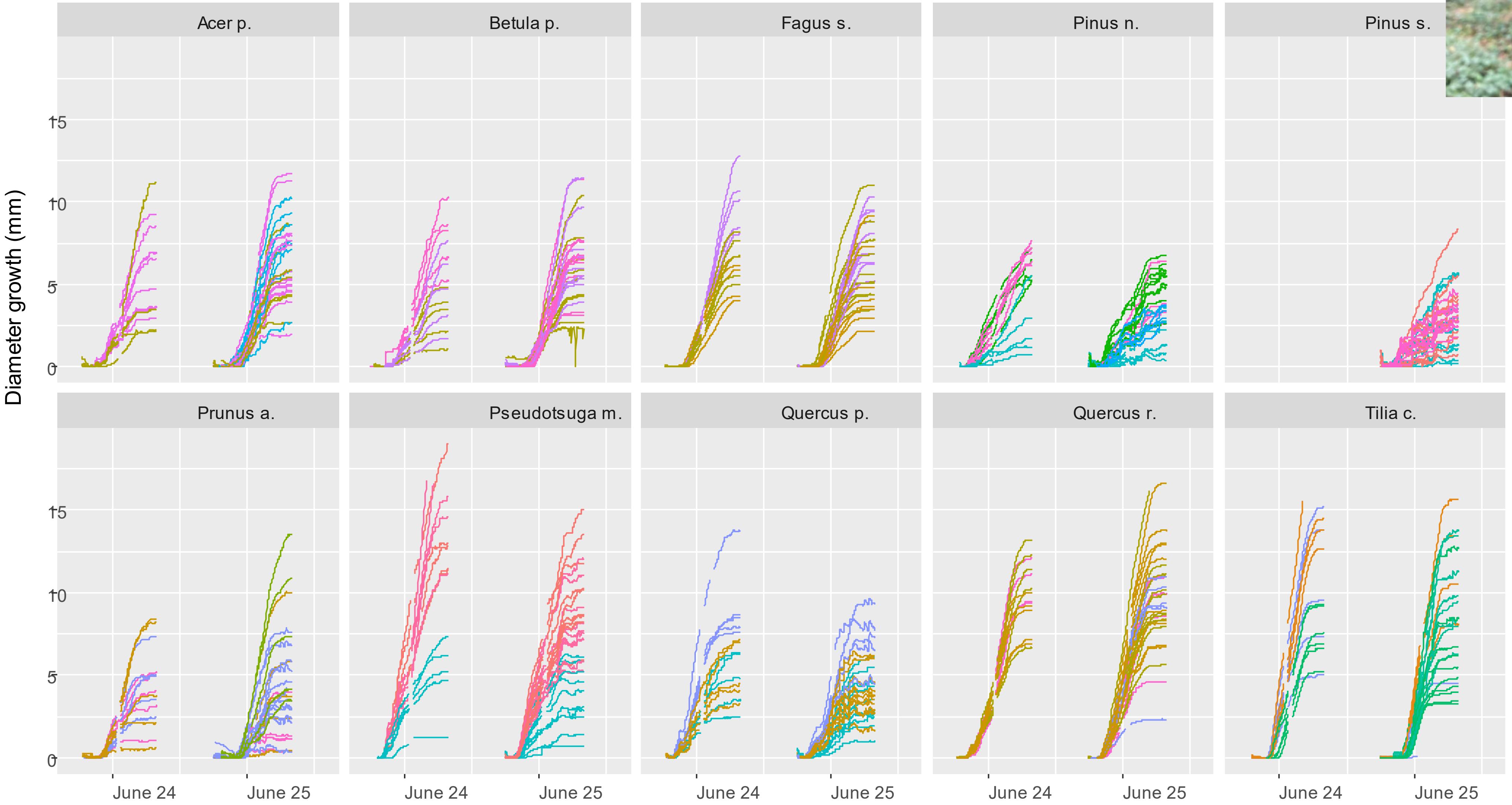
Common name	Scientific name	Number of sites	Number of trees	Diameter (cm)
Northern red oak	*Quercus rubra*	3	30	34 (25 – 40)
Sessile oak	*Quercus petraea*	3	30	34 (24 – 46)
European beech	*Fagus sylvatica*	3	30	34 (27 - 44)
Norway maple	*Acer platanoides*	3	30	40 (26 - 54)
Wild cherry	*Prunus avium*	4	30	29 (23 - 36)
Silver birch	*Betula pendula*	3	30	34 (25 - 40)
Littleleaf linden	*Tilia cordata*	3	30	31 (22 - 46)
Douglas-fir	*Pseudotsuga menziesii*	3	30	30 (22 - 41)
Scots pine	*Pinus sylvestris*	3	30	38 (32 – 41)
Black pine	*Pinus nigra corsicana*	3	30	39 (33 - 44)

Point dendrometers

- TOMST dendrometer
- Maintenance : 1-3 times/year
- 300 trees



Point dendrometers



Competition

Circular plot :

- centered on each monitored trees
- Radius : 15 – 18 m
- ≥ 15 surrounding trees
- Minimum DBH : 22 cm

- Diameter, species, distance, azimuth

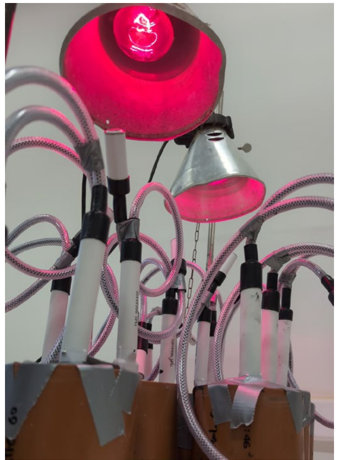
Meteorological data

- Air sensors of temperature and humidity
- Ventilated shelter
- 1 in each site in the understory

Will be combined with meteorological observations in open field conditions (IRM, Copernicus)

Soil sensors

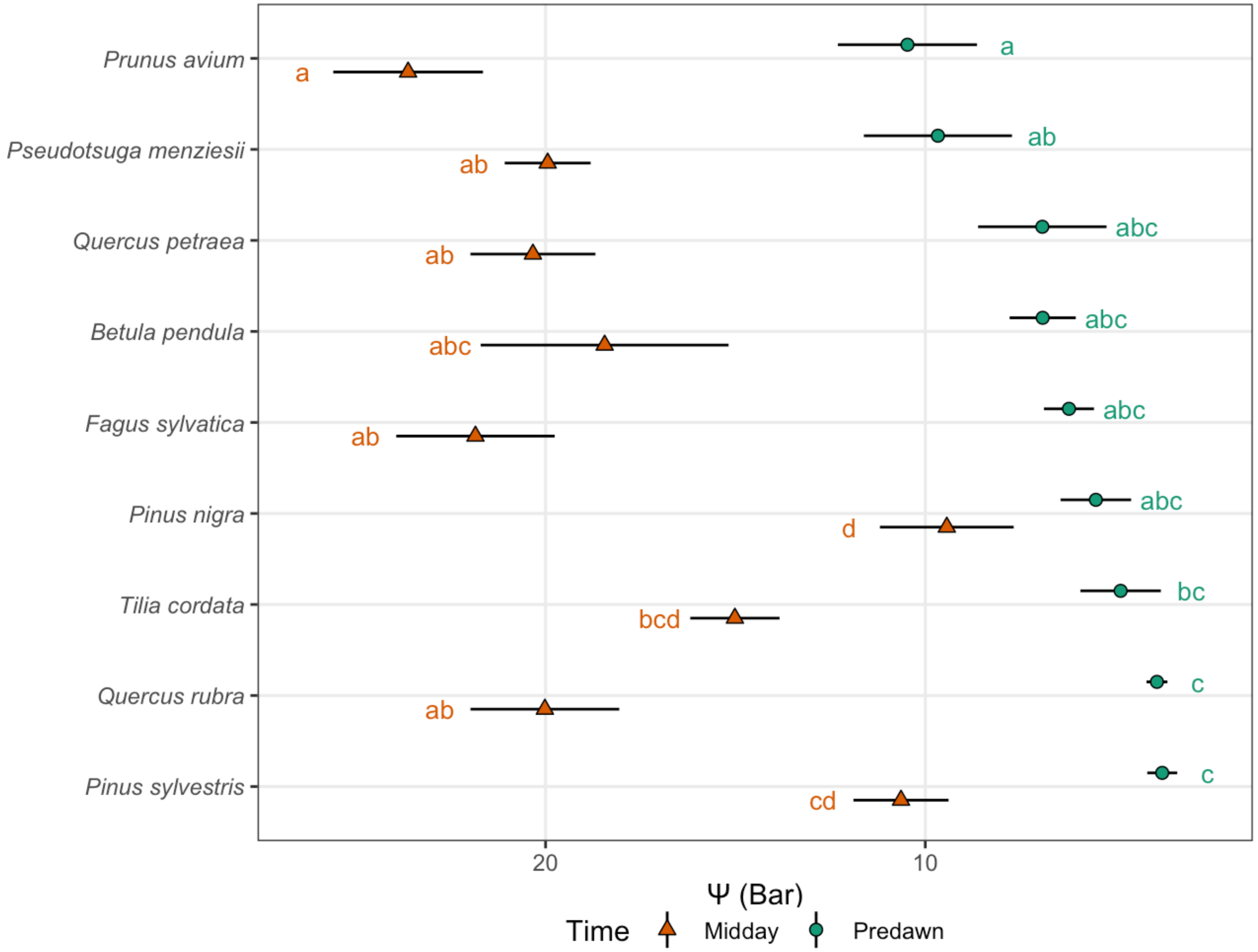
- 2 soil sensors / site (20 – 60 cm)
- Tomst TMS
- Lab calibration (humidity ~ permittivity, sensor bias)
- Lab measurement (bulk density, Humidity ~soil water potential)



Leaf water potential and stomatal conductance

- 3 species : *Quercus petraea, Betula pendula, Quercus rubra*
- 3 trees / site / species (n = 27)
- Monthly + during drought periods
- Predawn + midday leaf water potential

Preliminary results and tests (2025, n=81)



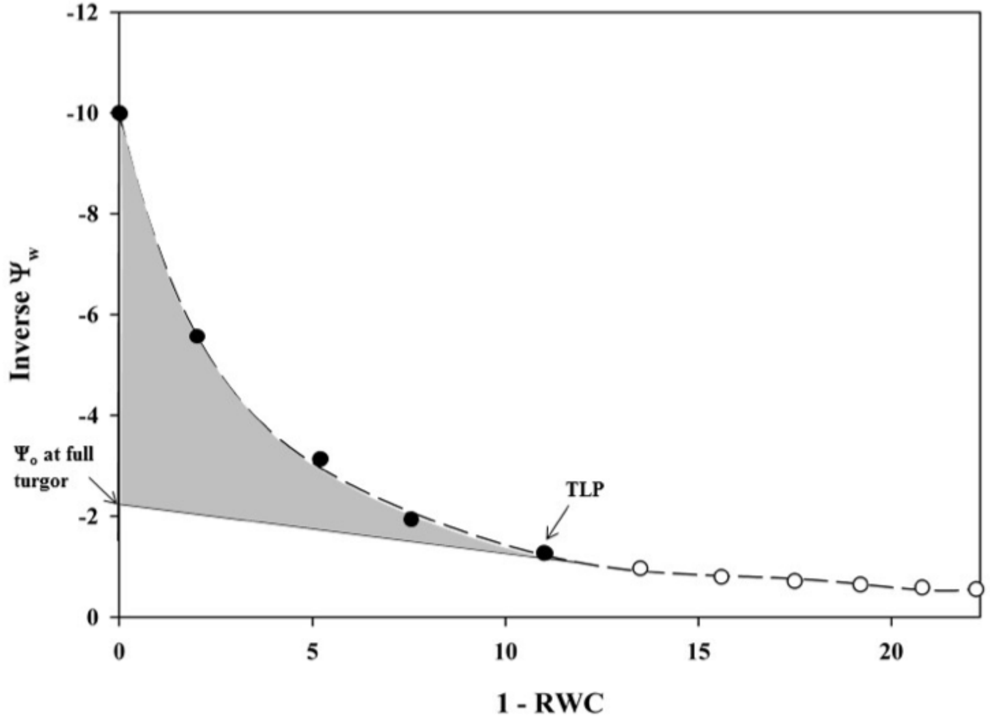
→ Most isohydric behavior

Stomata traits

- 10 species
- 3 trees / site / species (n = 90)
- 2025
- 3 sun-exposed leaves
- Stomata size
- Stomata density

Pressure – Volume curves

- 6 species : *Quercus petraea, Fagus sylvatica, Tilia cordata, Betula pendula, Prunus avium, Quercus rubra*
- 3 trees / site / species (n = 54)
- 2 times during the growing season
- 2 sun-exposed leaves
- Plotting xylem pressure against relative water content
- → leaf traits : Turgor loss point (TLP)

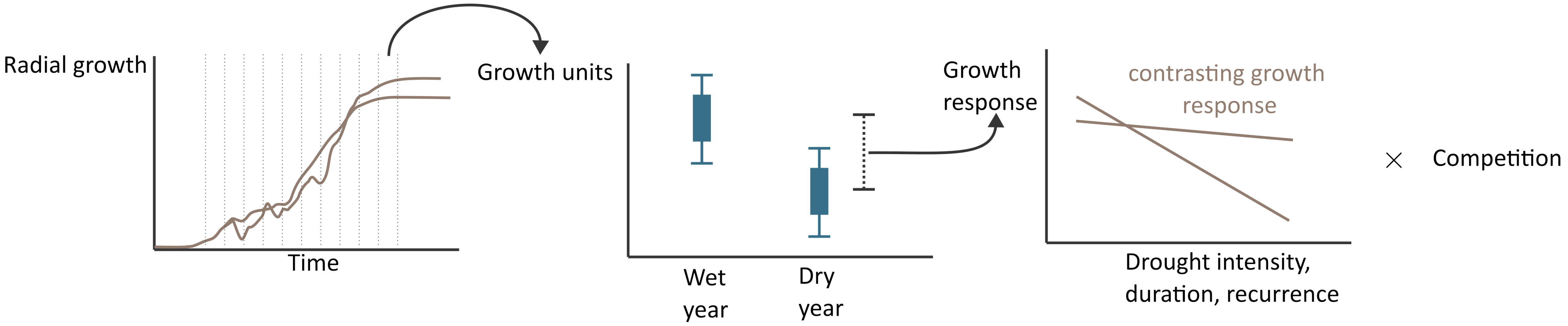


Vulnerability curve and hydraulic safety margins

- 6 species : *Quercus petraea, Fagus sylvatica, Tilia cordata, Betula pendula, Prunus avium, Quercus rubra*
- 3 trees / site / species (n = 54)
- Pneumatron
- Resistance to embolism
- → P50, P88

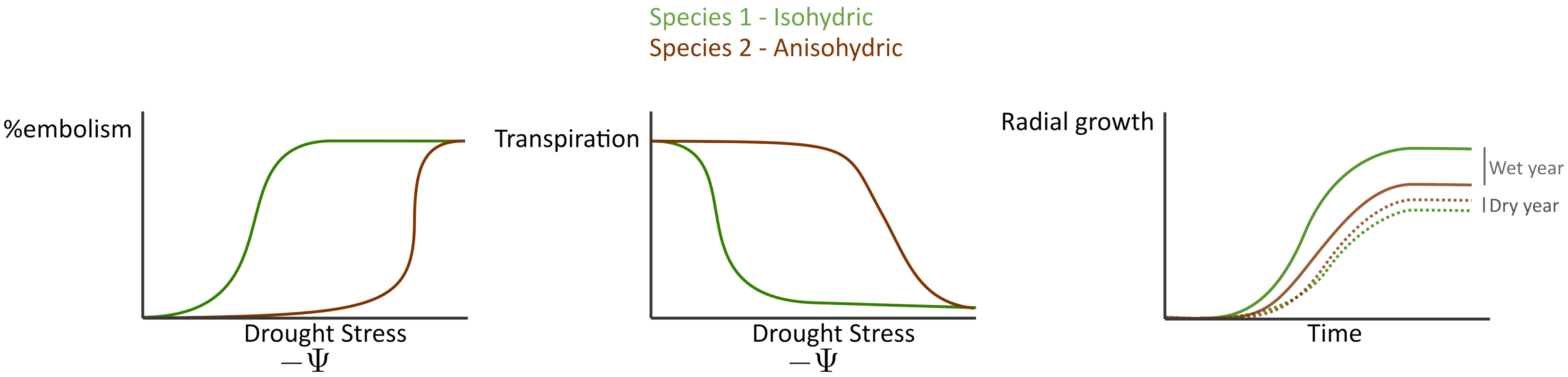
Hypotheses

- Contrasting tree growth response — deviations from "normal" growth rates — when exposed to droughts and heatwaves. Some species (or individuals) experience a strong reduction in growth, while others are less affected.
- Growth response depends on the intensity, duration, and recurrence of drought and heat events.



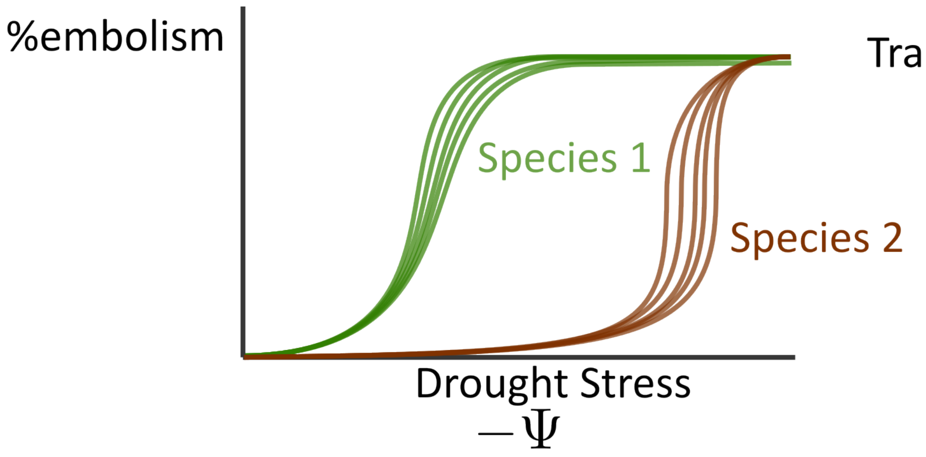
Hypotheses

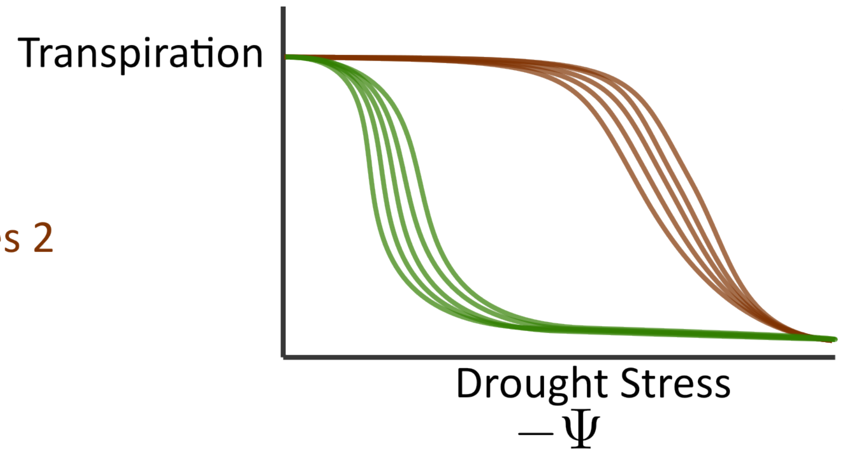
- Growth response is determined by hydraulic strategies.
- The more anisohydric and embolism-resistant a species is, the more likely it is to maintain relatively stable growth under drought and heat stress.

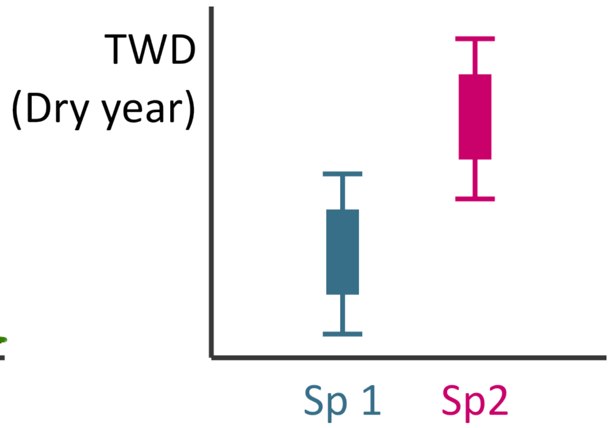


Hypotheses

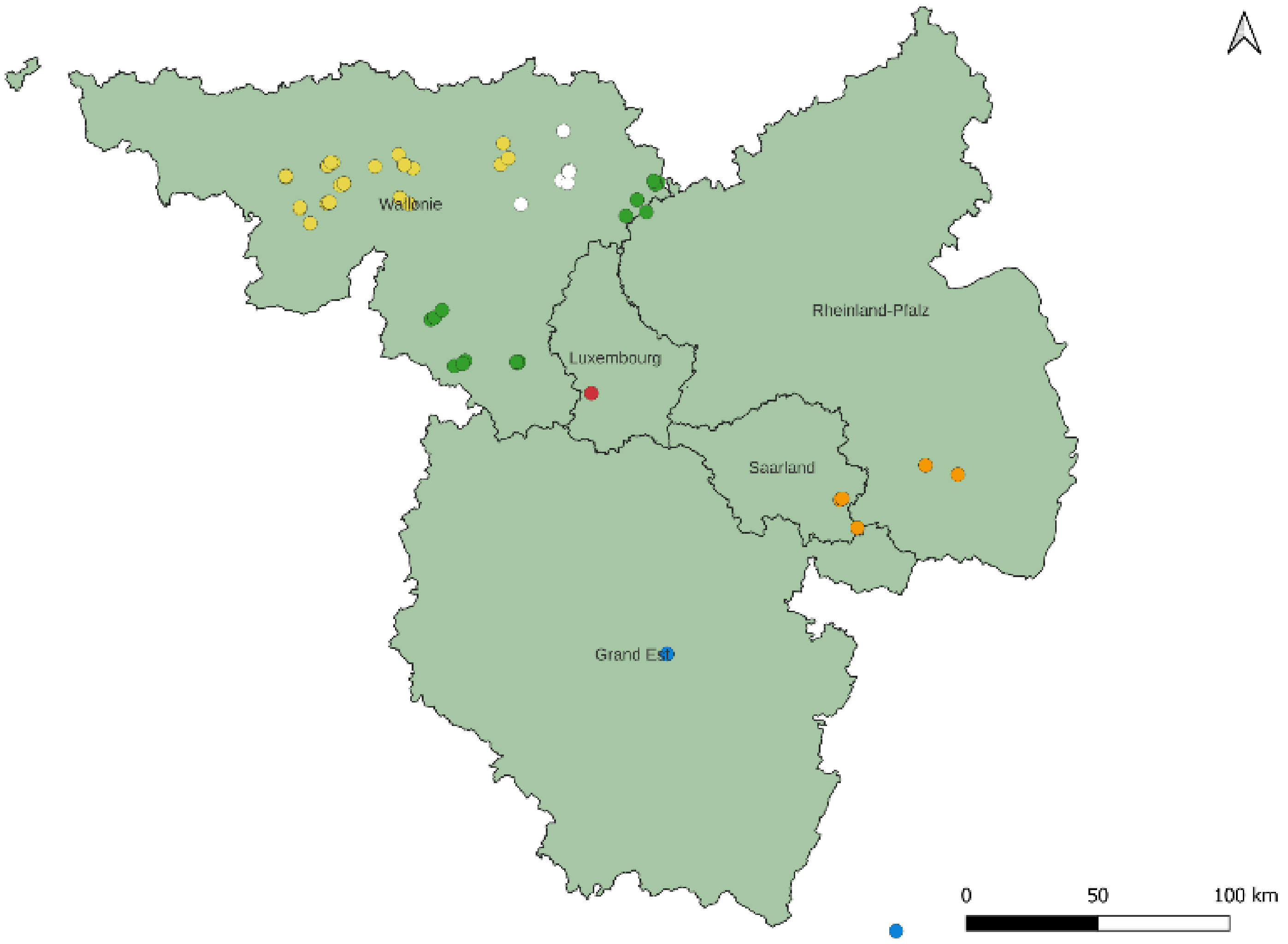
- In a homogeneous site, within-species variability in hydraulic resistance is much less important than between-species variability.







Developing more extensive networks for monitoring tree growth and hydraulic resistance



Interreg

Grande Région | Großregion

Perspectives

- Discuss potential species-specific adaptation to drier and warmer climatic conditions
- Develop monitoring system to quantify how future climatic events will affect forest functioning and guide forest management
- Provide data to calibrate mechanistic forest dynamics models
- Provide data to simulate different drought stress scenarios (sensitivity analysis with empirical models)

Thank you !

Harold Hauzer, Gilles de Leso, Maryem Telmoudi, Alice Latour, Charlier Eline, Alain Monseur, Florentin Reginster, Boris Lemaigre, Cédric Geerts, Dubucq Cyrielle, Adèle Philippot, Marie-Pierre Tasseroul, Lorna Zéoli, Arthur Gilles, Violette Van Keymeulen

LIÈGE université Gembloux Agro-Bio Tech

fnrs LA LIBERTÉ DE CHERCHER