Water geven op het ritme van de boom
inzichten uit sapstroom- en stamdiametermetingen

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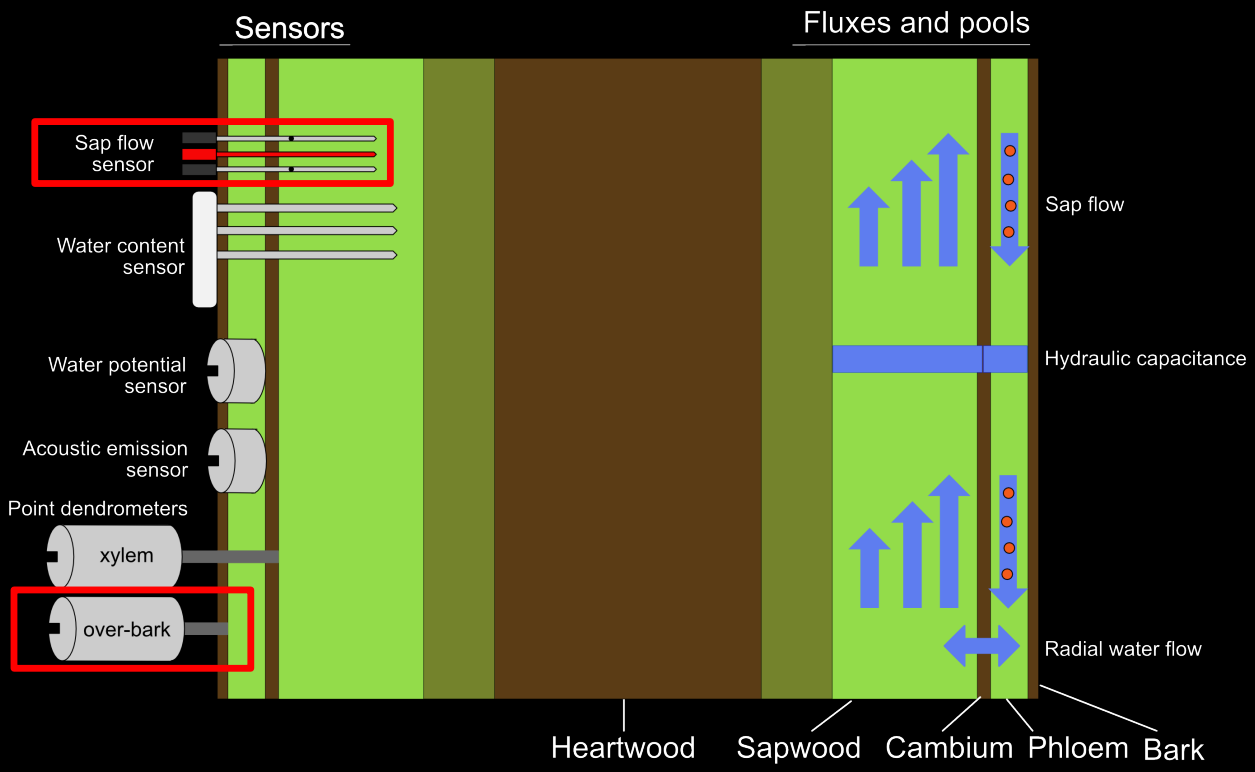
28 oktober 2025

GHENT UNIVERSITY

FACULTY OF BIOSCIENCE ENGINEERING

Ghent University Laboratory of Plant Ecology

Tree monitoring: dynamic water transport and growth



Steppe et al. (2015)
Trends in Plant Science 20: 335-343

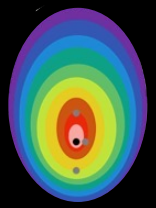
A recap on sap flow methods

Vandegehuchte & Steppe (2013) Functional Plant Biology 40: 213–223

✧ Continuous heating

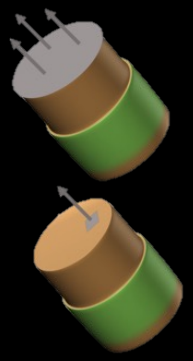
- TDP: Thermal Dissipation Probe | Granier sensor
- HFD: Heat Field Deformation method
- SHB: Stem Heat Balance

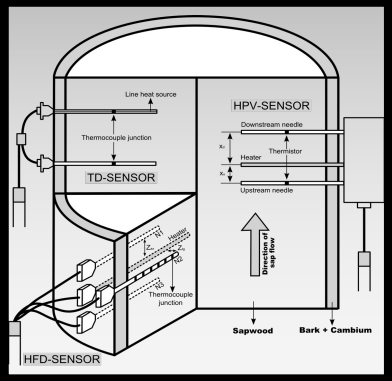
Heat as a tracer

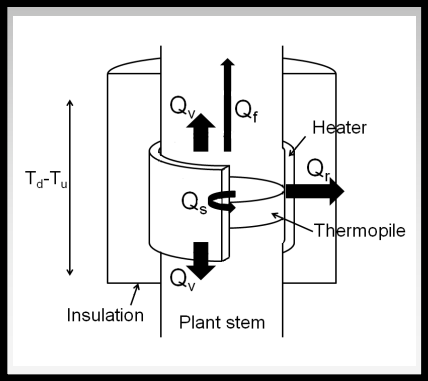


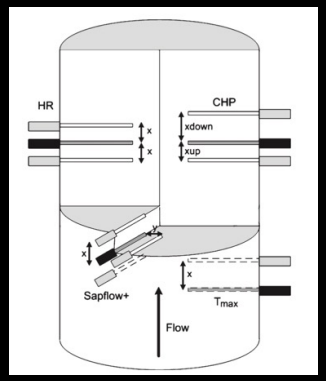
Sap flow rate
[g h^{-1}]

Sap flux density
[cm^3 cm^{-2} h^{-1}]



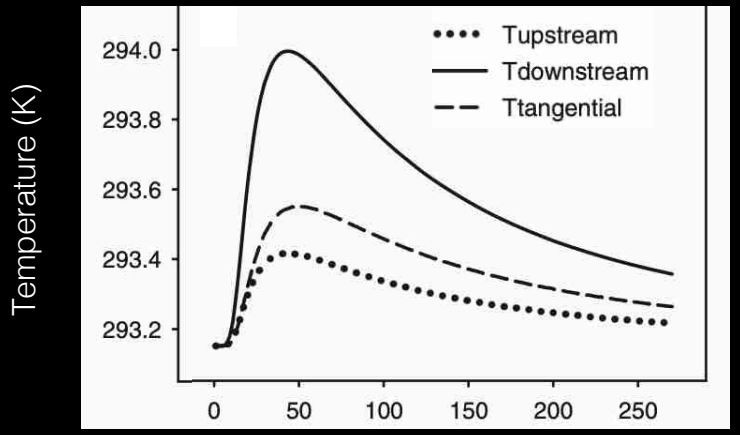






✧ Pulse heating

- CHPM: Compensation Heat Pulse Method
- Tmax method
- HRM: Heat Ratio Method
- Sapflow+ (UGent development)

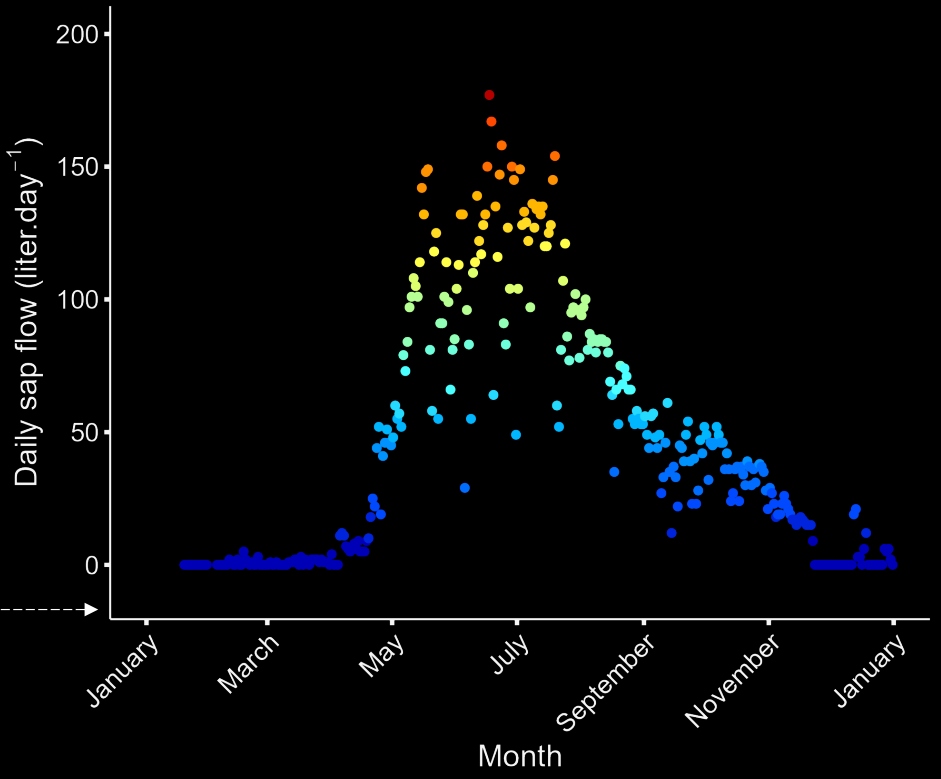


Vandegehuchte and Steppe (2012) New Phytologist 196: 306-317

Vandegehuchte and Steppe (2012) New Phytologist 196: 306-317

Whole-tree water use

Proxy for transpiration



Sap flux density

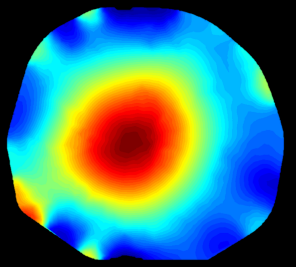
[$cm^3\ cm^{-2}\ s^{-1}$]

×

Sapwood area

[cm^2]

ERT
electrical
resistivity
tomography



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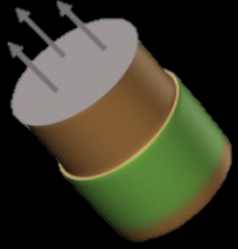
Sap flow rate

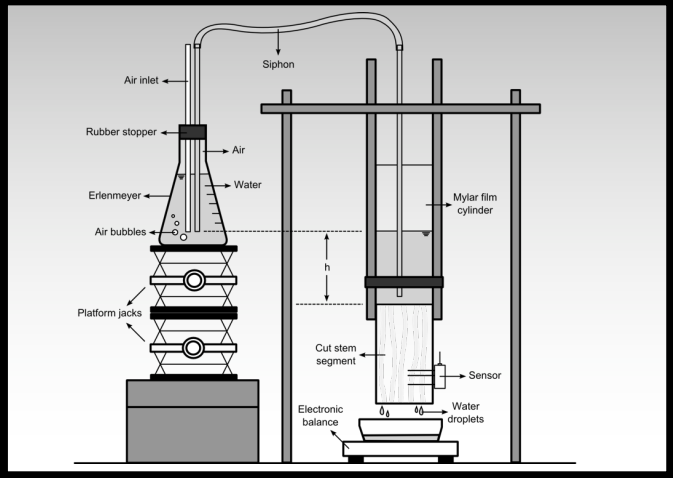
[$g\ h^{-1}$]



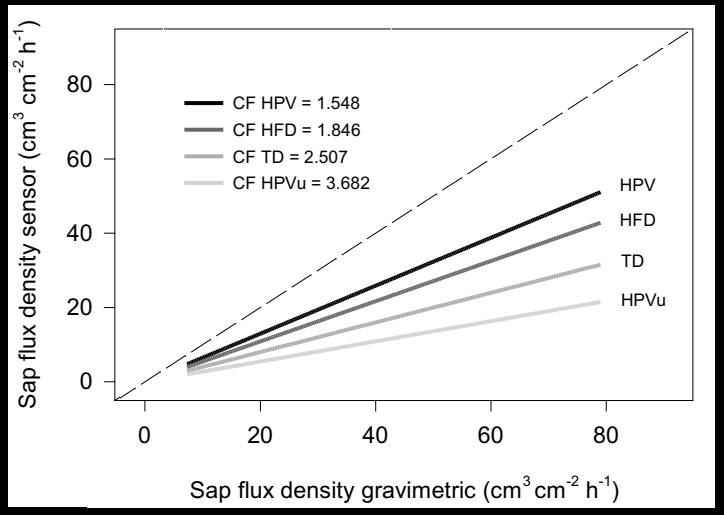
Yearly tree water use: 15 539 liter

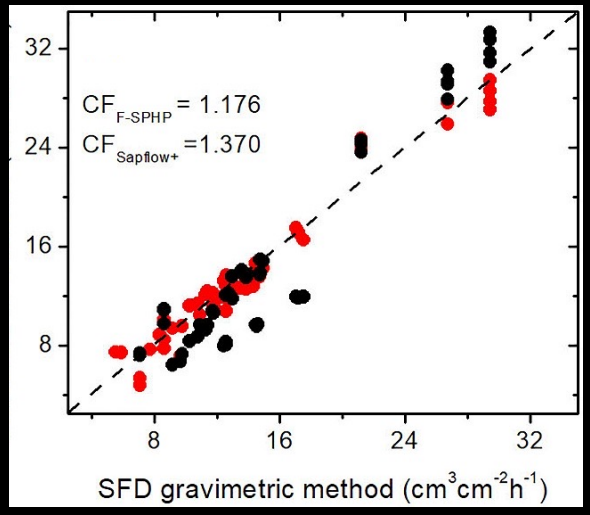
Mariotte-based verification system

Steppe et al. (2010) Agricultural and Forest Meteorology 150:1046-1056
Ren et al. (2020) Agricultural and Forest Meteorology 280: 107788



Accuracy of tested heat-based sap flow sensors

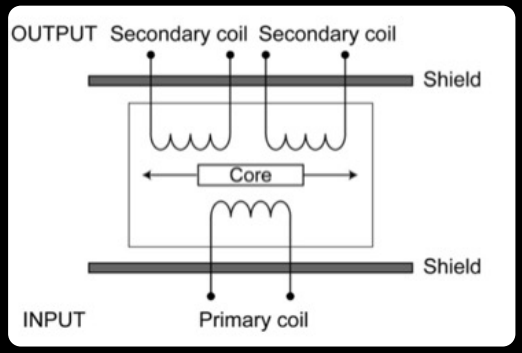




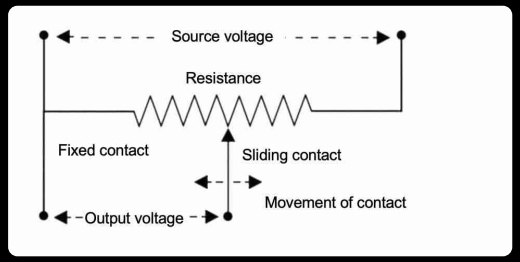
A recap on point dendrometers

De Swaef et al. (2015) Tree Physiology 35: 1047-1061
Steppe et al. (2015) Trends in Plant Science 20: 335-343

- **LVDT**
  Linear Variable
  Displacement Transducer

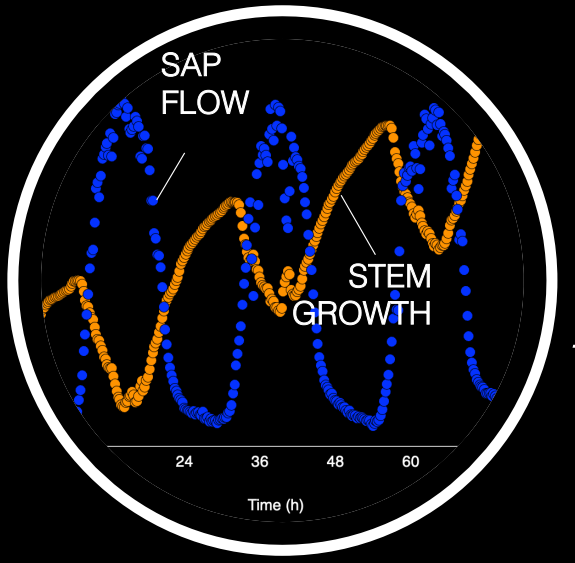


- **LMP**
  Linear motion potentiometer
- **LPS**
  Linear position sensor



Only those
who can
see
the invisible,
can do
the impossible

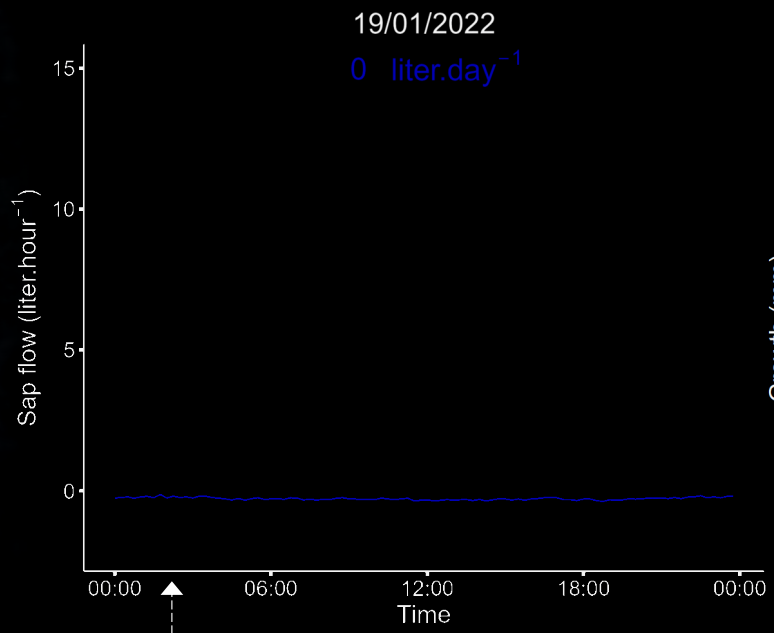
TreeWatch.net



The tree as a biological indicator

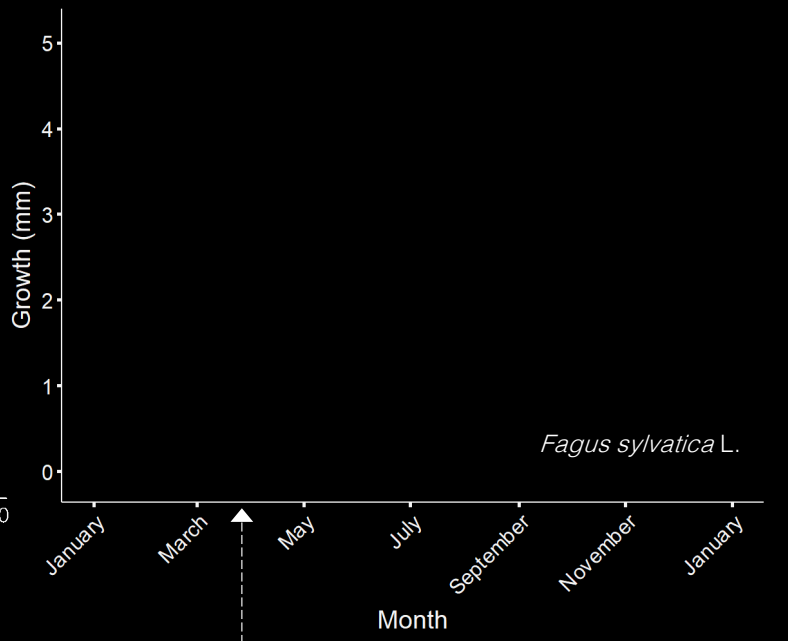
Sap flow

Tree water use



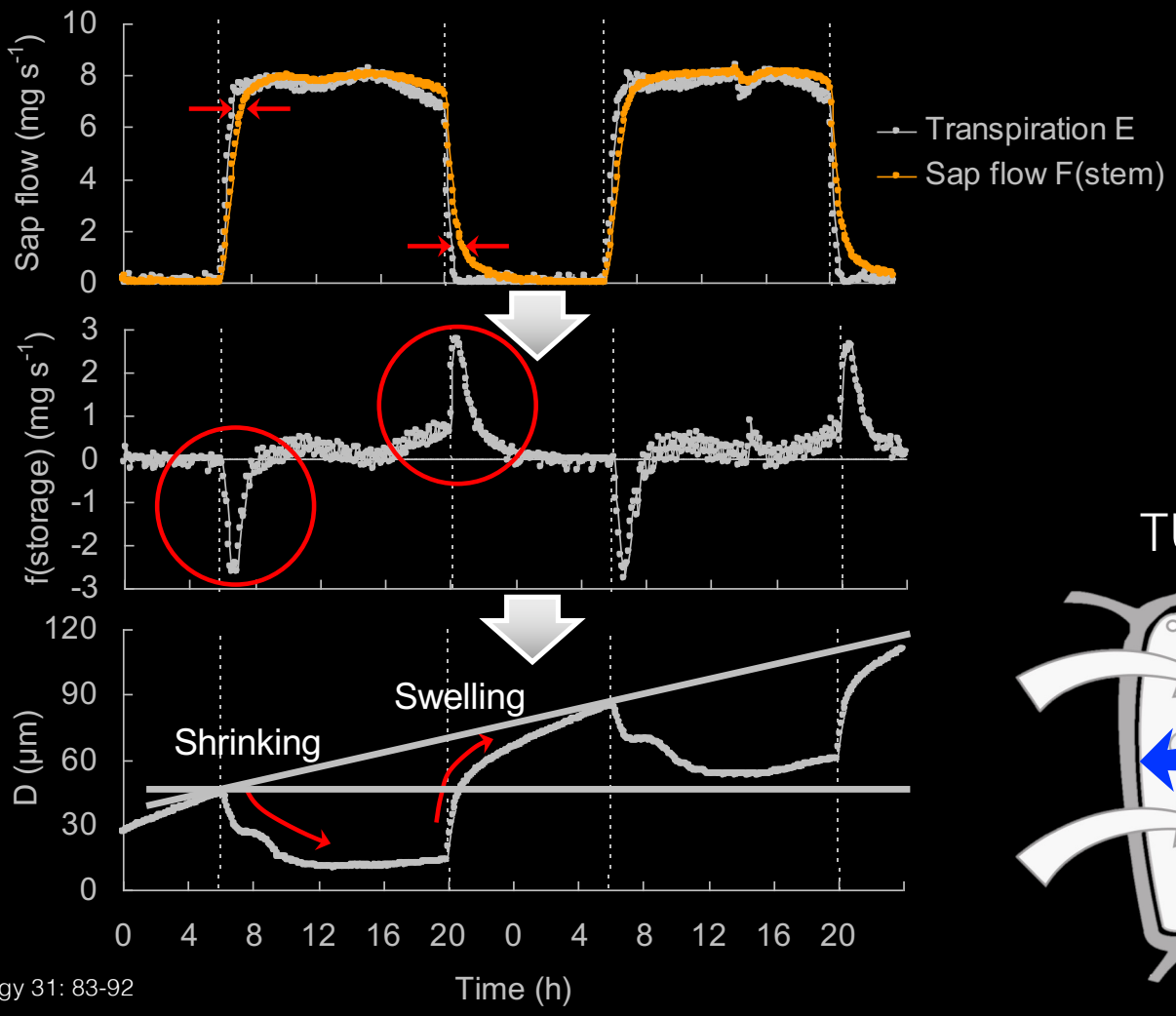
Stem diameter variation

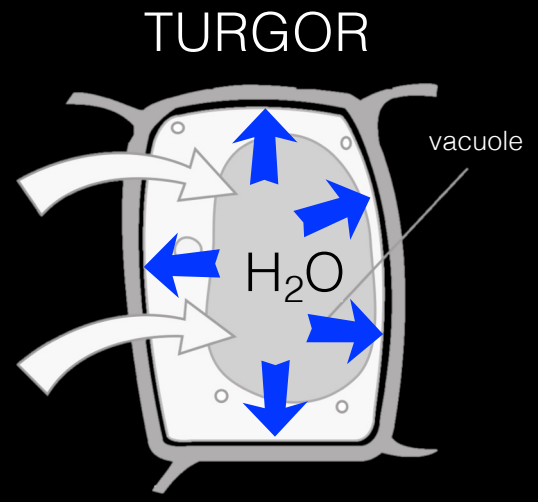
Stem growth and fluctuations



Tight link between sap flow and diameter variation explains turgor-driven growth

- Sap flow rates
- Depletion rates
- Diameter variation

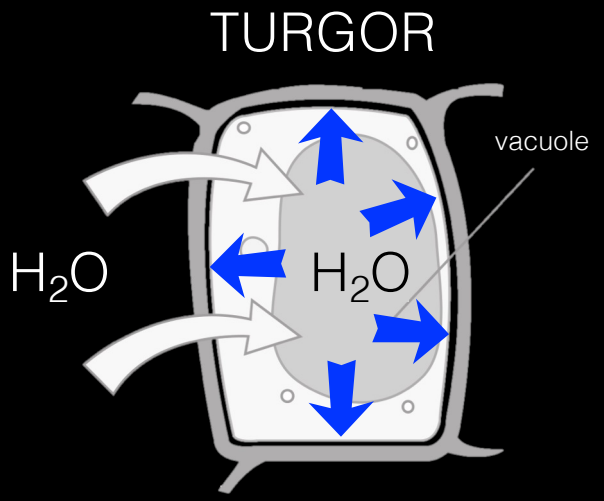




Steppe & Lemeur (2004) Functional Plant Biology 31: 83-92

PLANTS…

UNDER PRESSURE



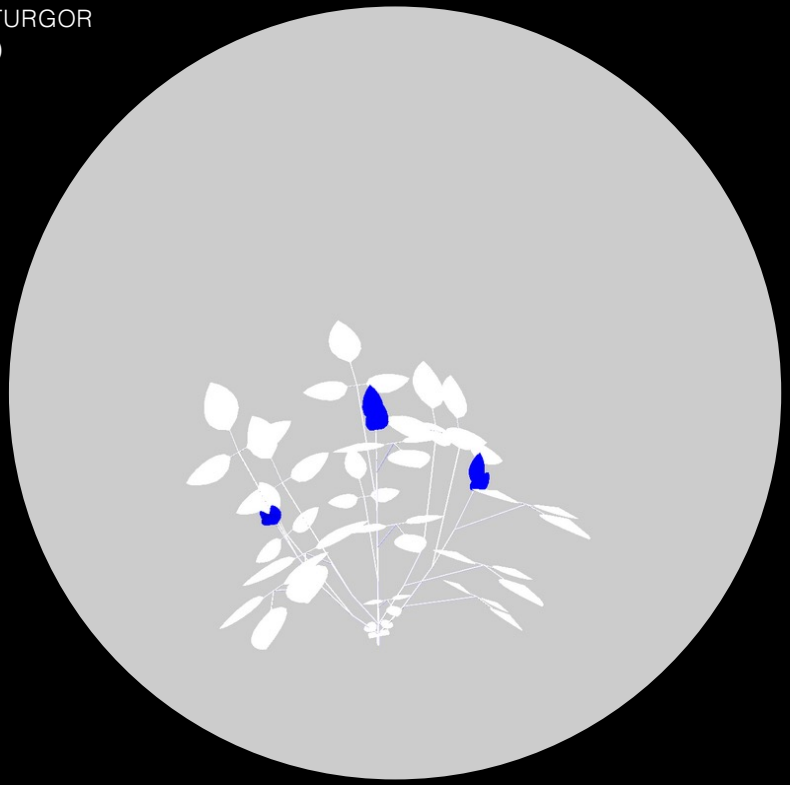
1 day = 1 second

PLANT GROWTH

TURGOR

TURGOR
(night)

NO TURGOR
(day)



PHOTOSYNTHESIS
RESPIRATION

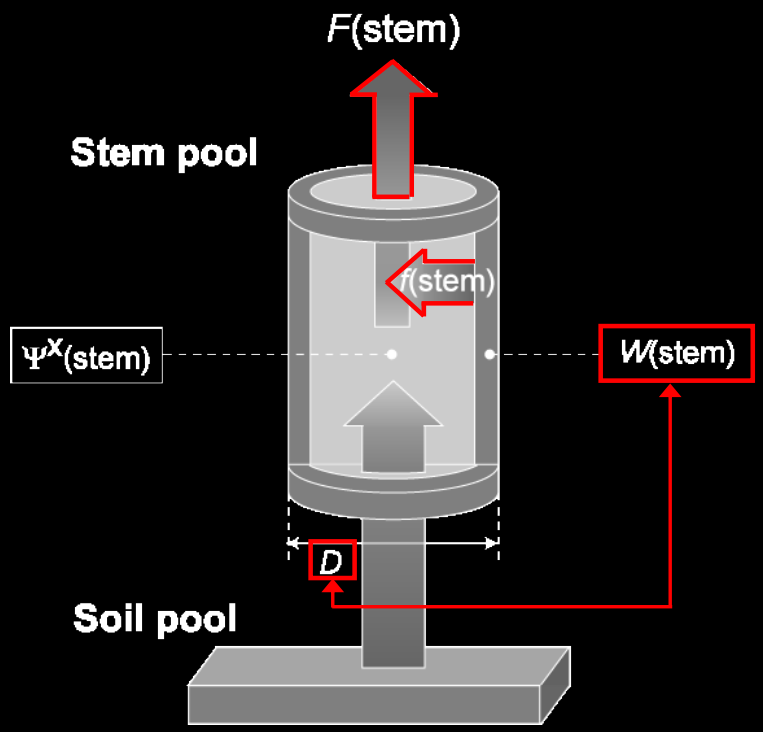
RESPIRATION
(night)

PHOTOSYNTHESIS
(day)

1 hour = 0.5 seconds

Modelling tree responses

Mechanistic or process-based modelling



Steppe et al. (2006) Tree Physiology 26:257–273

Model concept

- direct flow paths
- water flow in and out of storage pool

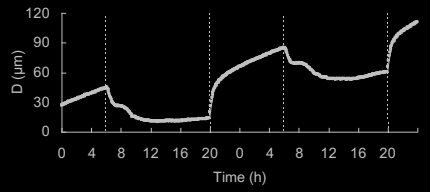
→ change in water content W(stem)

→ change in stem diameter D

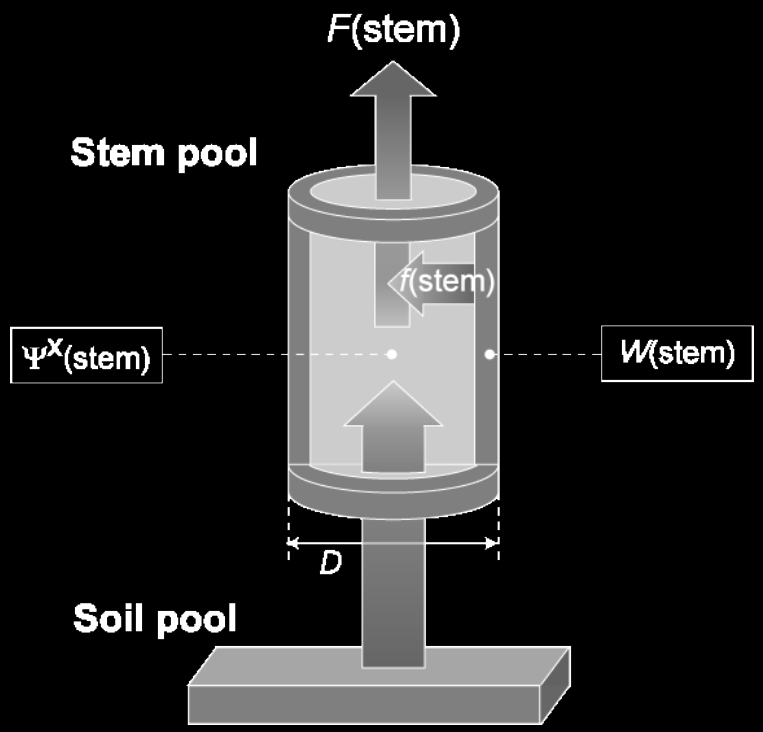
1/ daily stem diameter fluctuations

2/ turgor-driven growth (Lockhart equation)

$$\text{Growth} = \phi \left(\Psi_p^s - \Gamma \right)$$

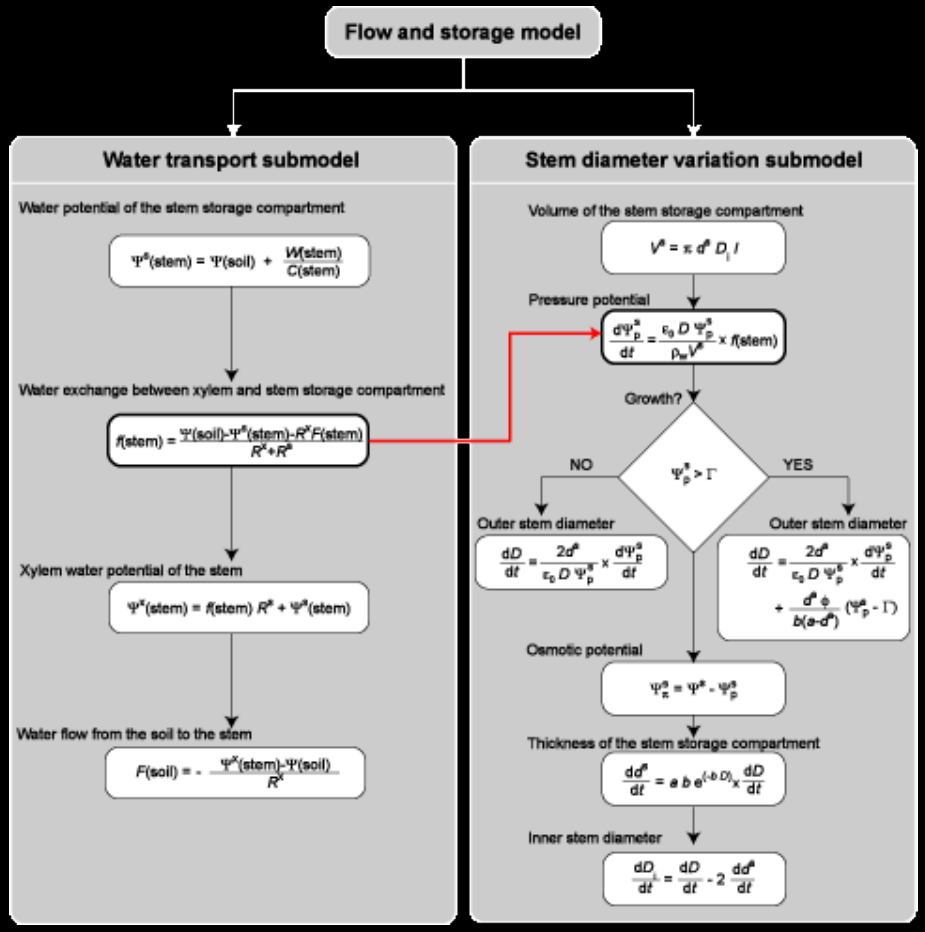


‘Water flow and storage’ model

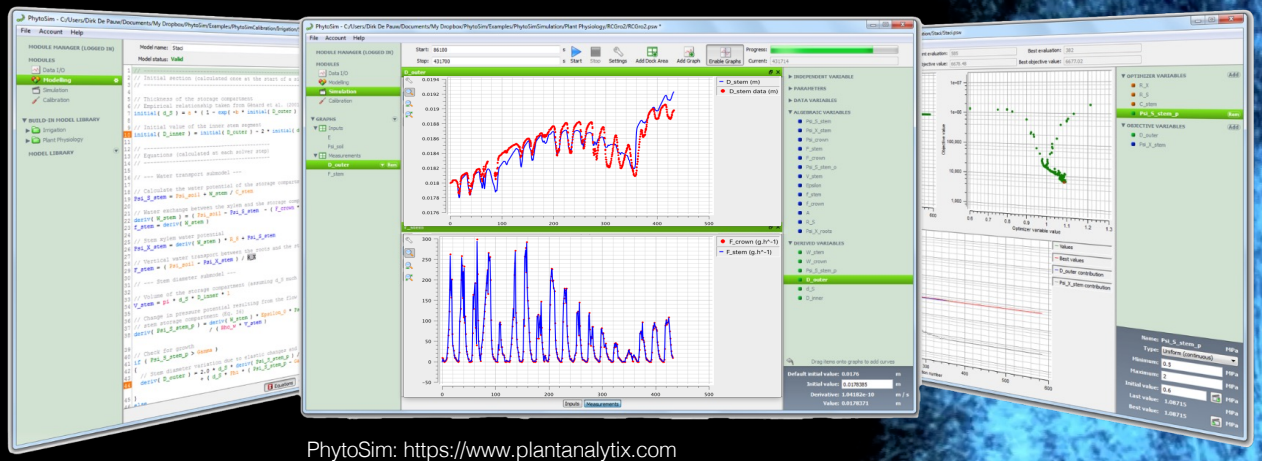


Steppe et al. (2006) Tree Physiology 26:257–273

Mathematical translation



Mechanistic plant modelling



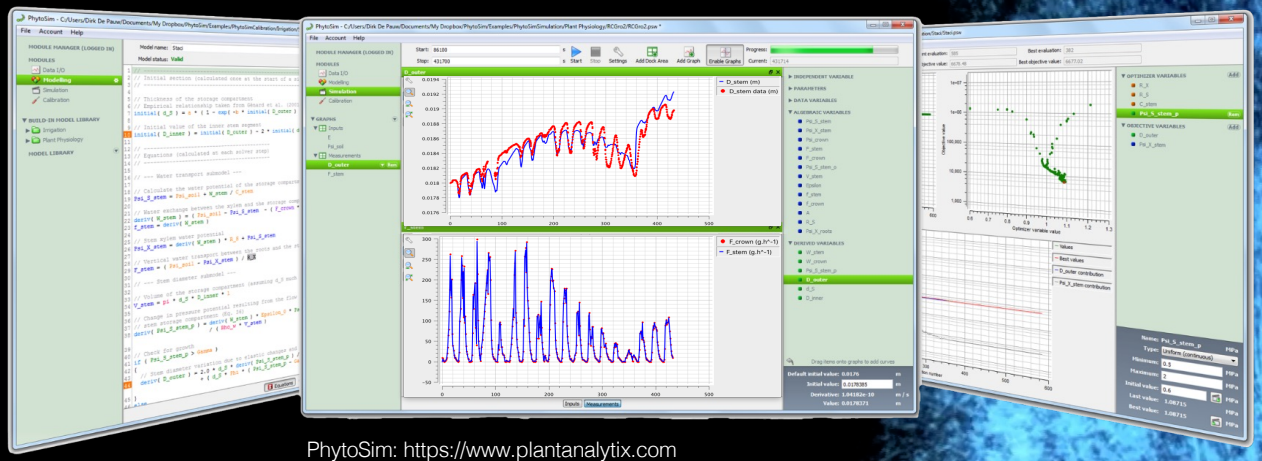
PhytoSim: https://www.plantanalytix.com

Transpiration

H_2O

Water uptake

Mechanistic plant modelling



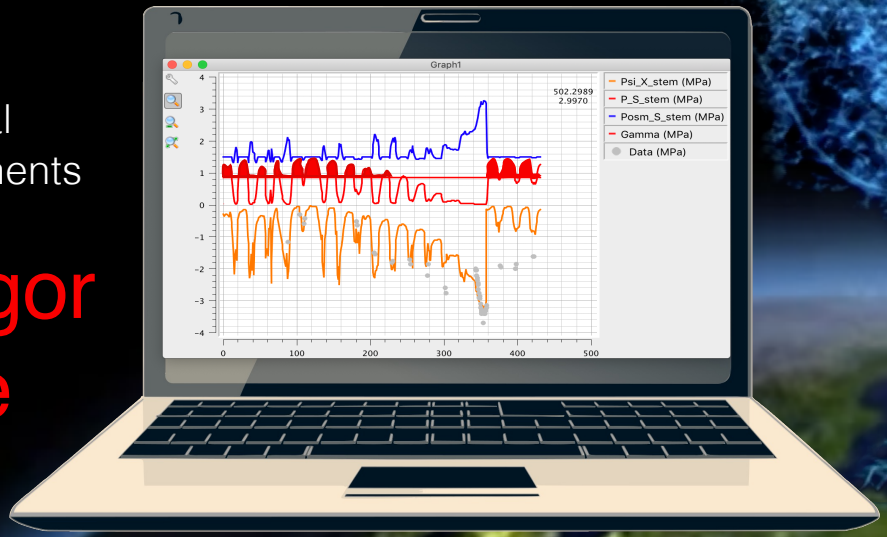
PhytoSim: https://www.plantanalytix.com

Transpiration

H_2O

Water potential components

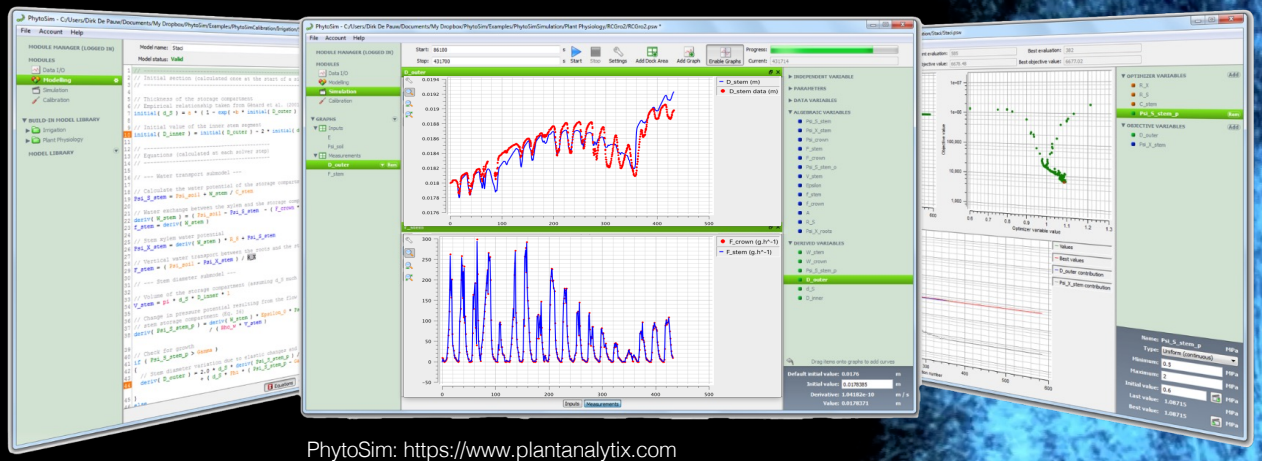
Turgor time



Water uptake

Coussement et al. (2021) Plant, Cell and Environment 44: 1361-1378

Mechanistic plant modelling

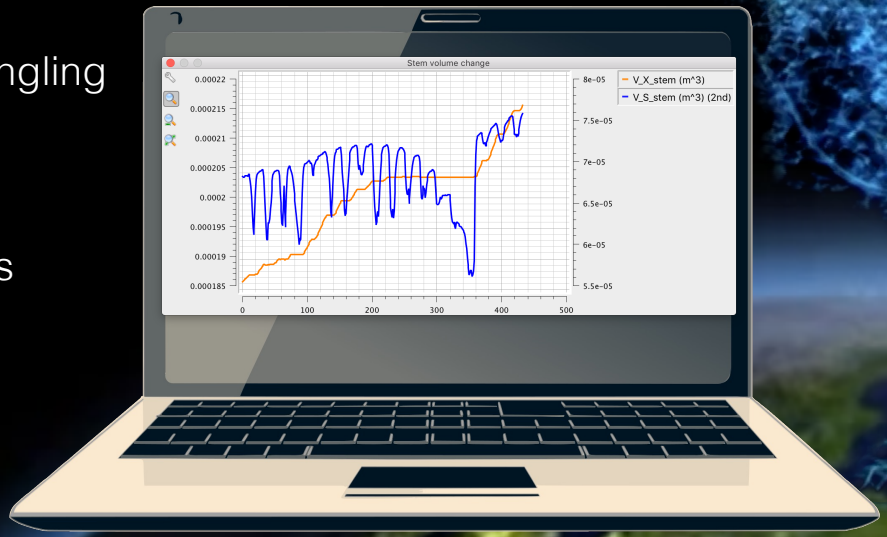


PhytoSim: https://www.plantanalytix.com

Transpiration

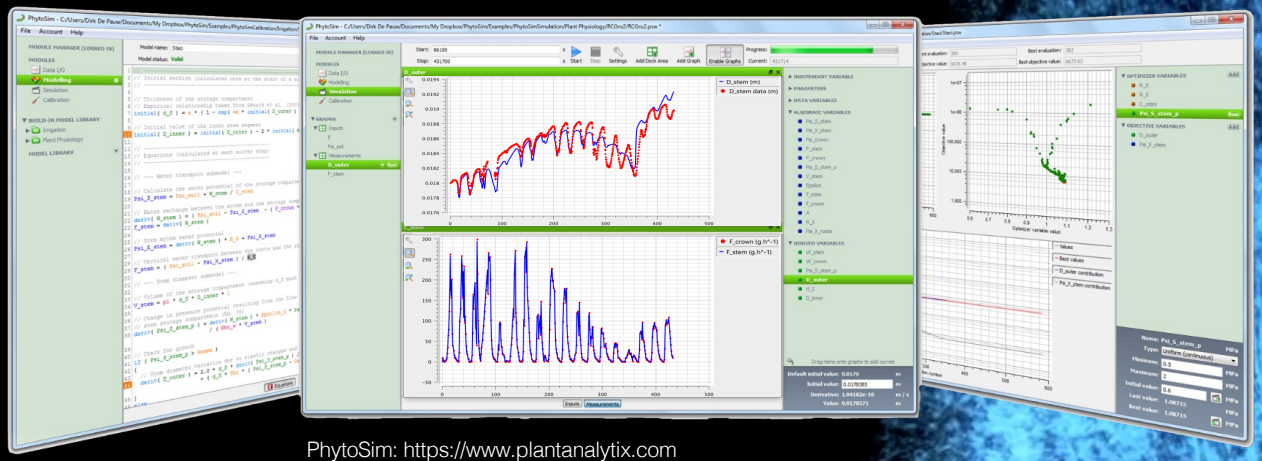
H_2O

Disentangling growth from elastic changes



Water uptake

Mechanistic plant modelling

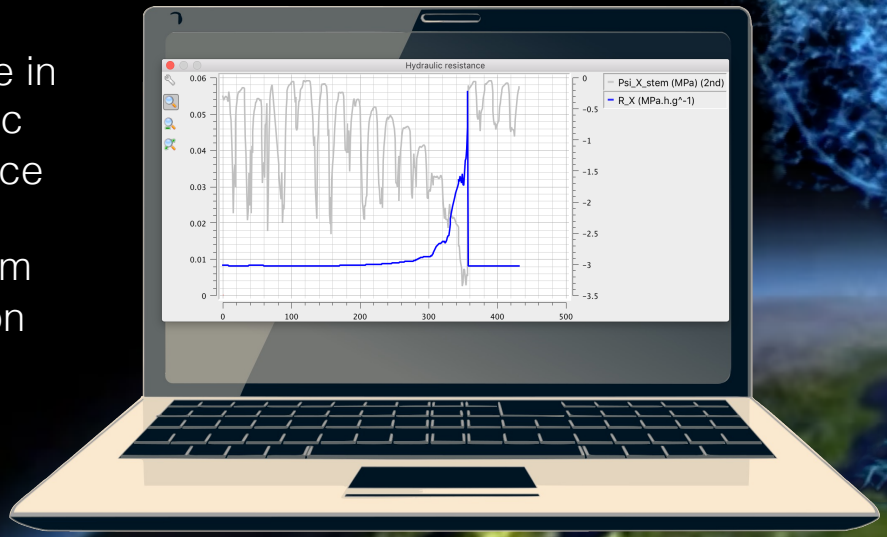


PhytoSim: https://www.plantanalytix.com

Transpiration

H_2O

Increase in hydraulic resistance due to embolism formation

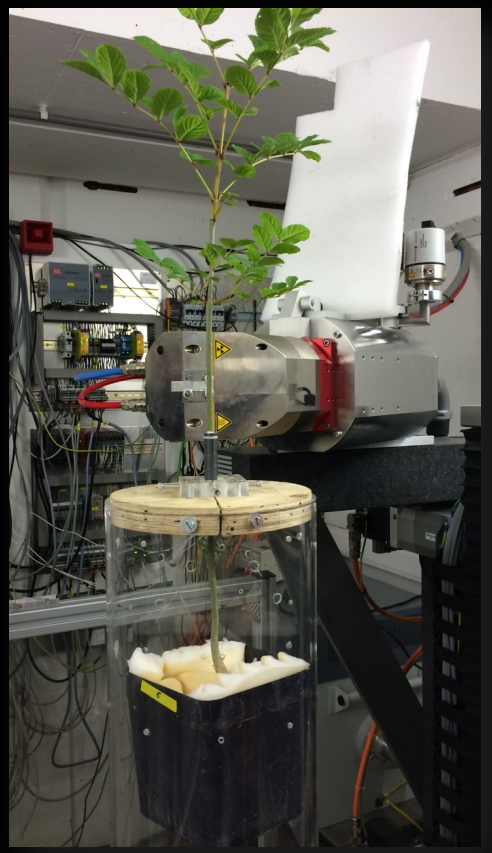


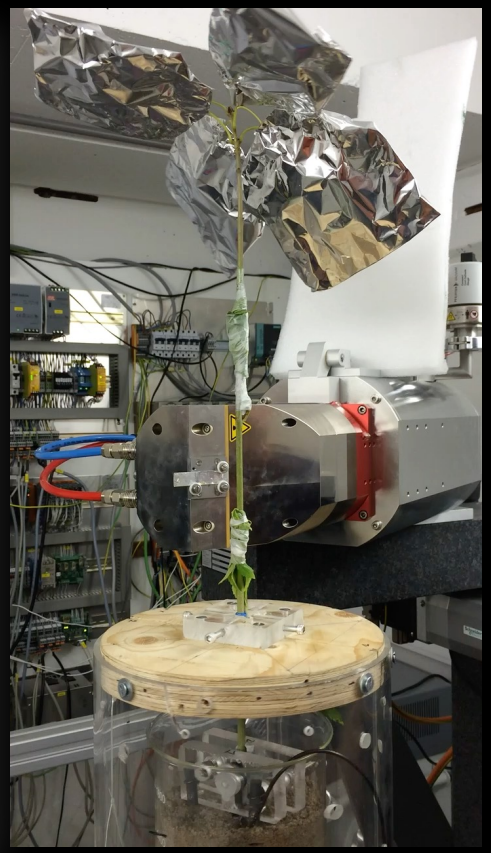
Water uptake

Hydraulic failure of trees

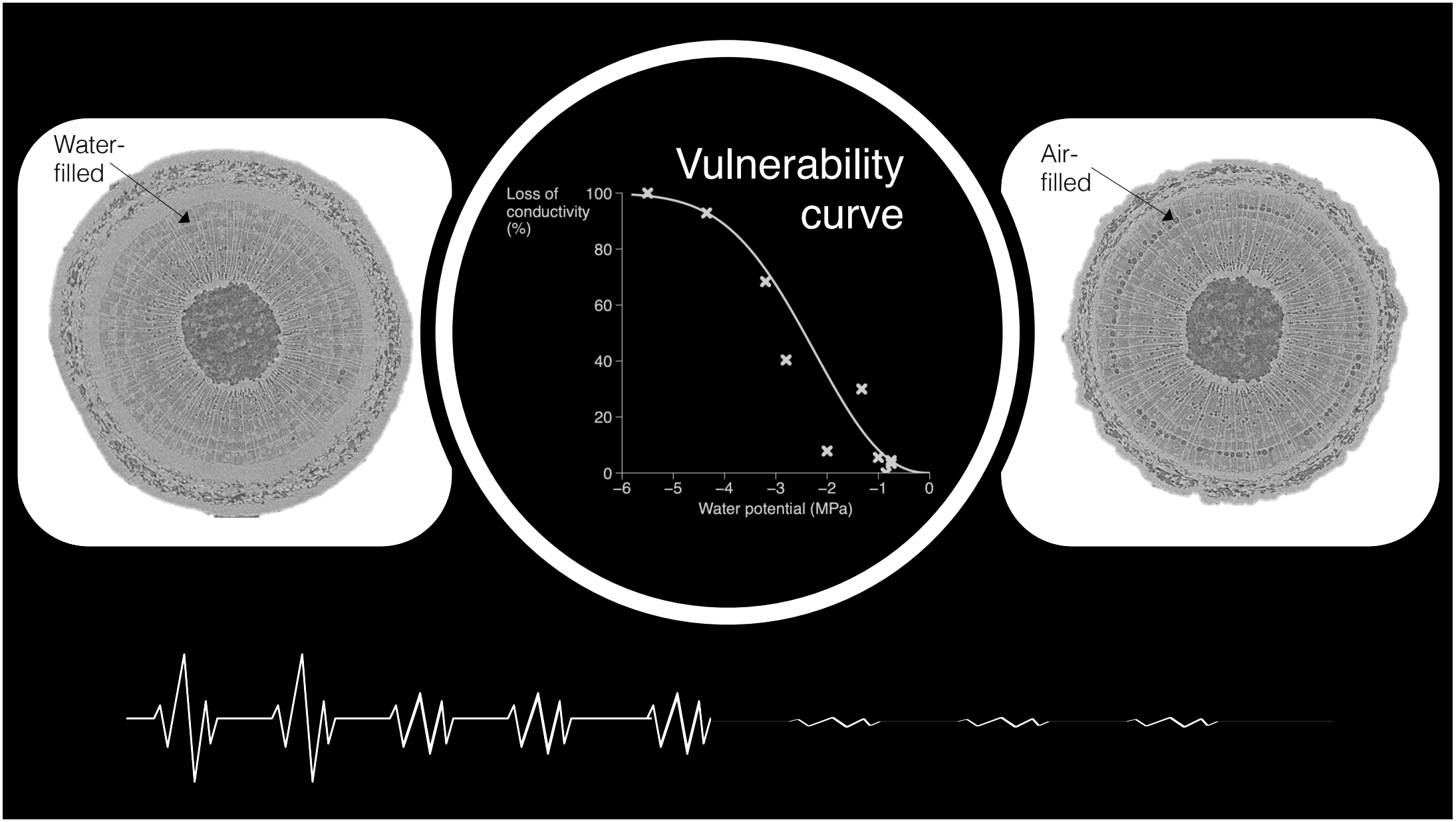
Core facility
UGCT

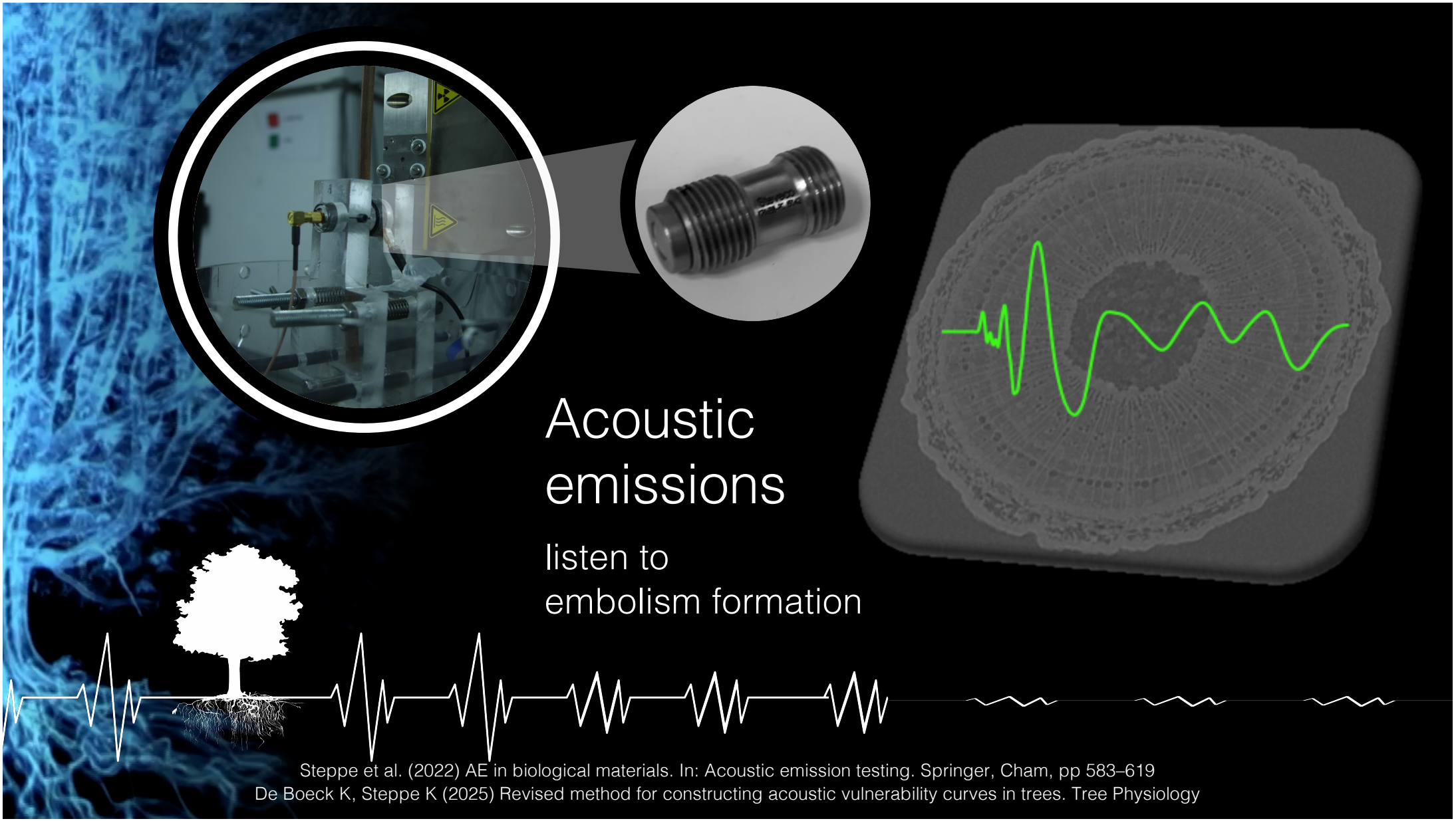
visualise
embolism formation



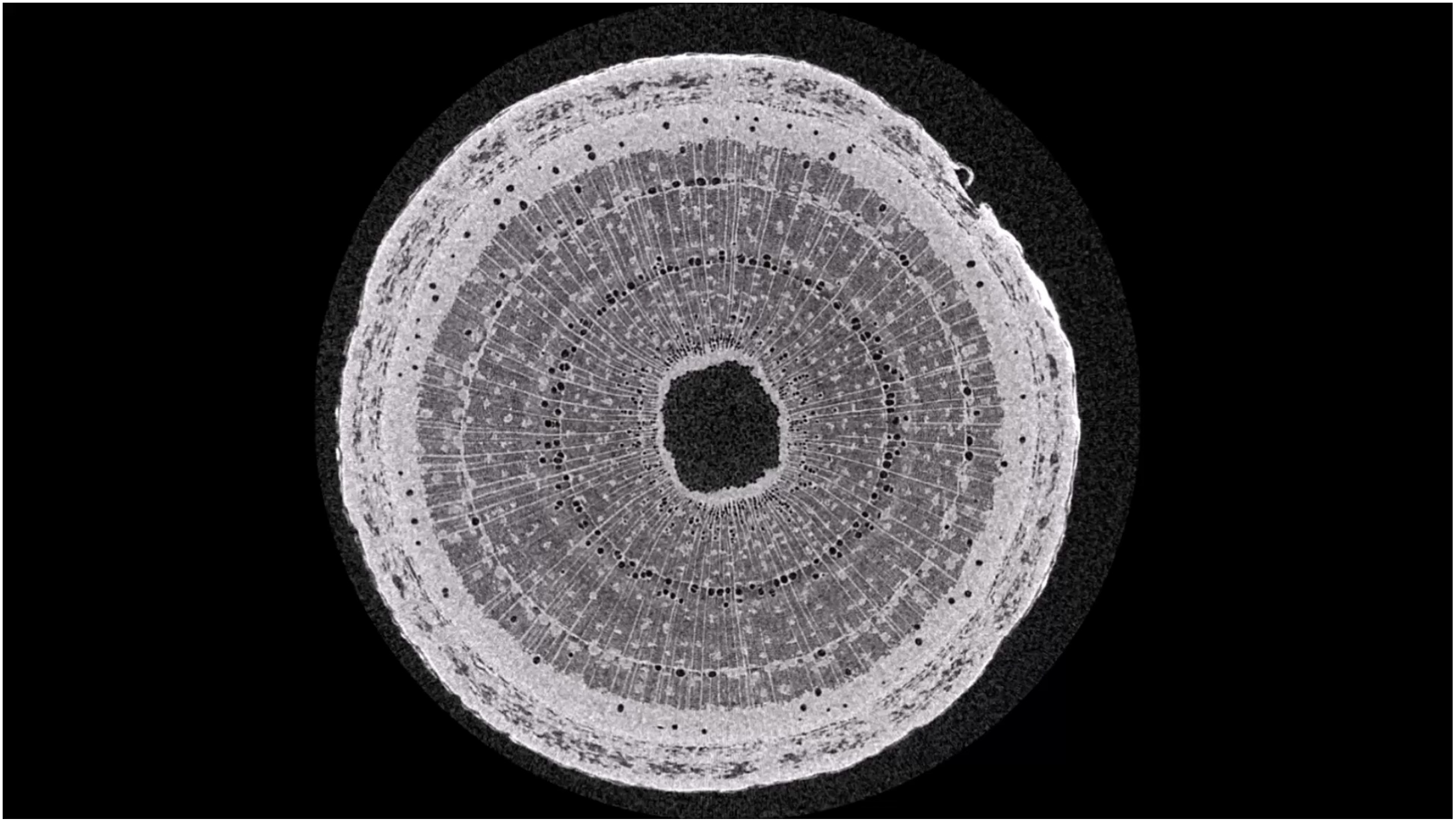


Vergeynst et al. (2015) Tree Physiology 35: 400-4095
De Roo et al. (2016) Applied Sciences – Basel 6: 71
Steppe et al. (2022) AE in Biological Materials. In: Grosse et al. (eds) Acoustic emission testing. Springer, Chambridge, pp 583–619

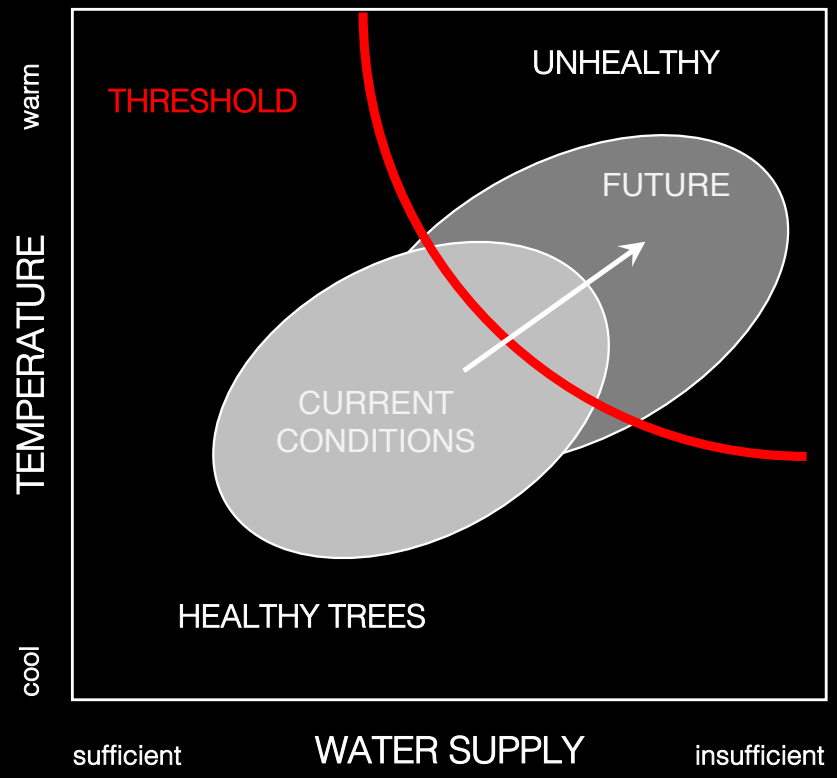

Water-filled
Vulnerability curve
Loss of conductivity (%)
100
80
60
40
20
0
−6
−5
−4
−3
−2
−1
0
Water potential (MPa)
Air-filled



Steppe et al. (2022) AE in biological materials. In: Acoustic emission testing. Springer, Cham, pp 583–619
De Boeck K, Steppe K (2025) Revised method for constructing acoustic vulnerability curves in trees. Tree Physiology



TreeWatch applications



1

The tree as a biological indicator

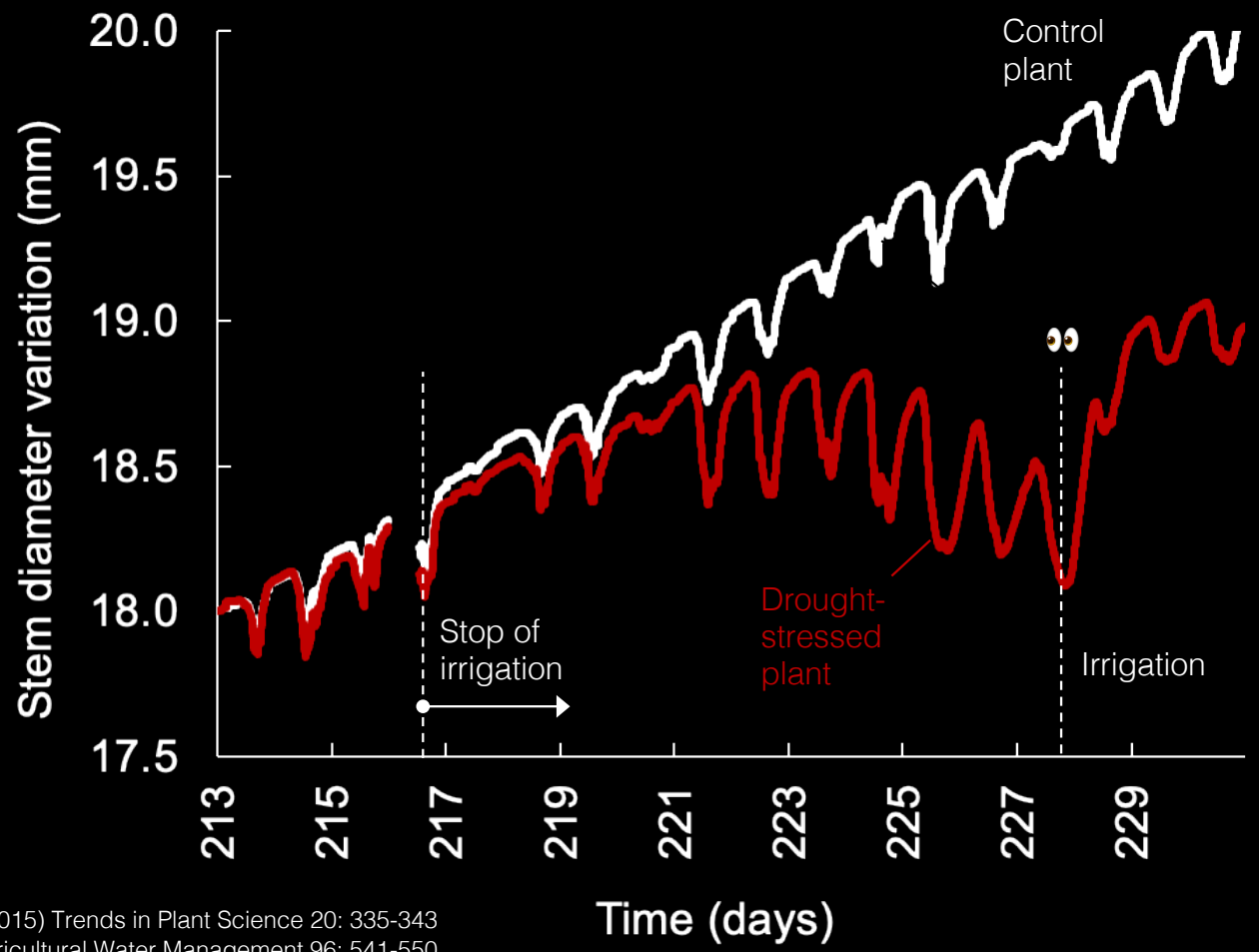
Early-warning systems

Talking trees

cost EUROPEAN COOPERATION

FruitCREWS

https://cost-fruitcrews.eu



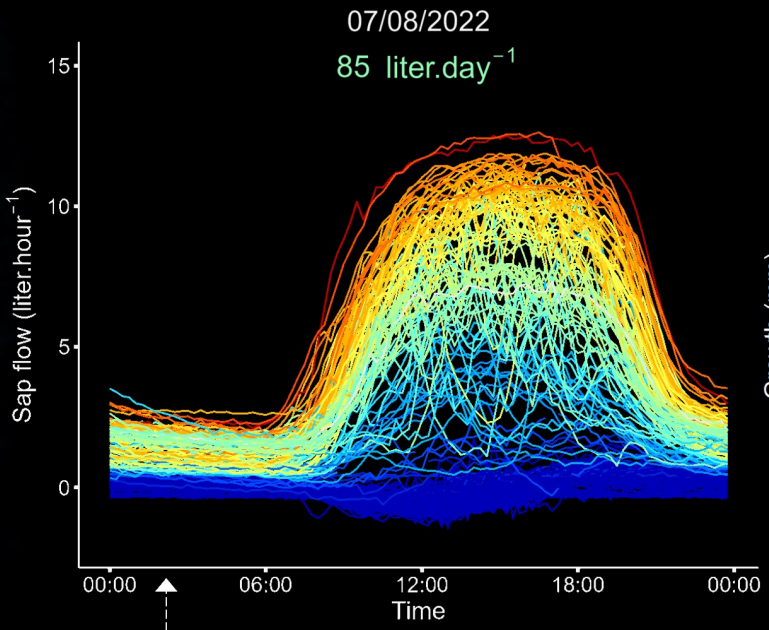
Steppe et al. (2015) Trends in Plant Science 20: 335-343
De Swaef et al. (2009) Agricultural Water Management 96: 541-550

1

The tree as a biological indicator

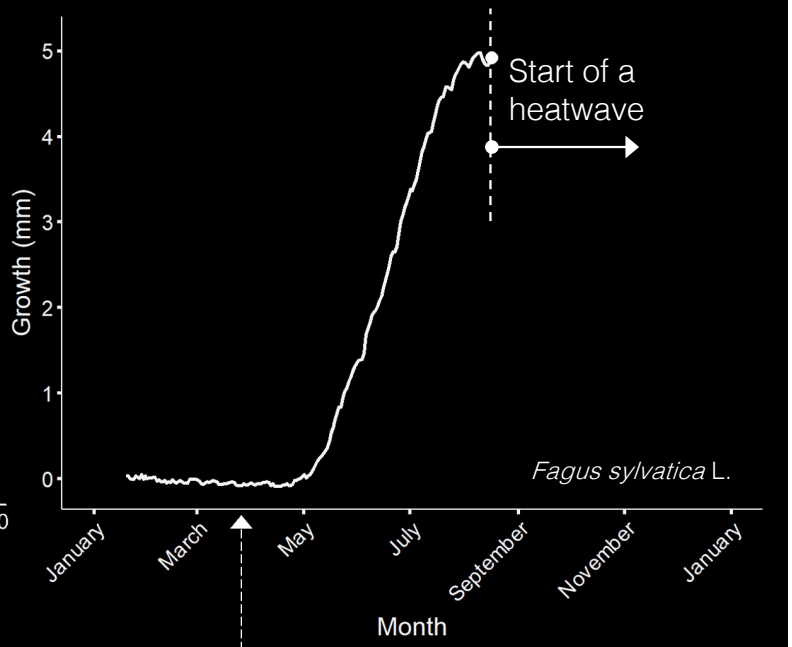
Sap flow

Tree water use



Stem diameter variation

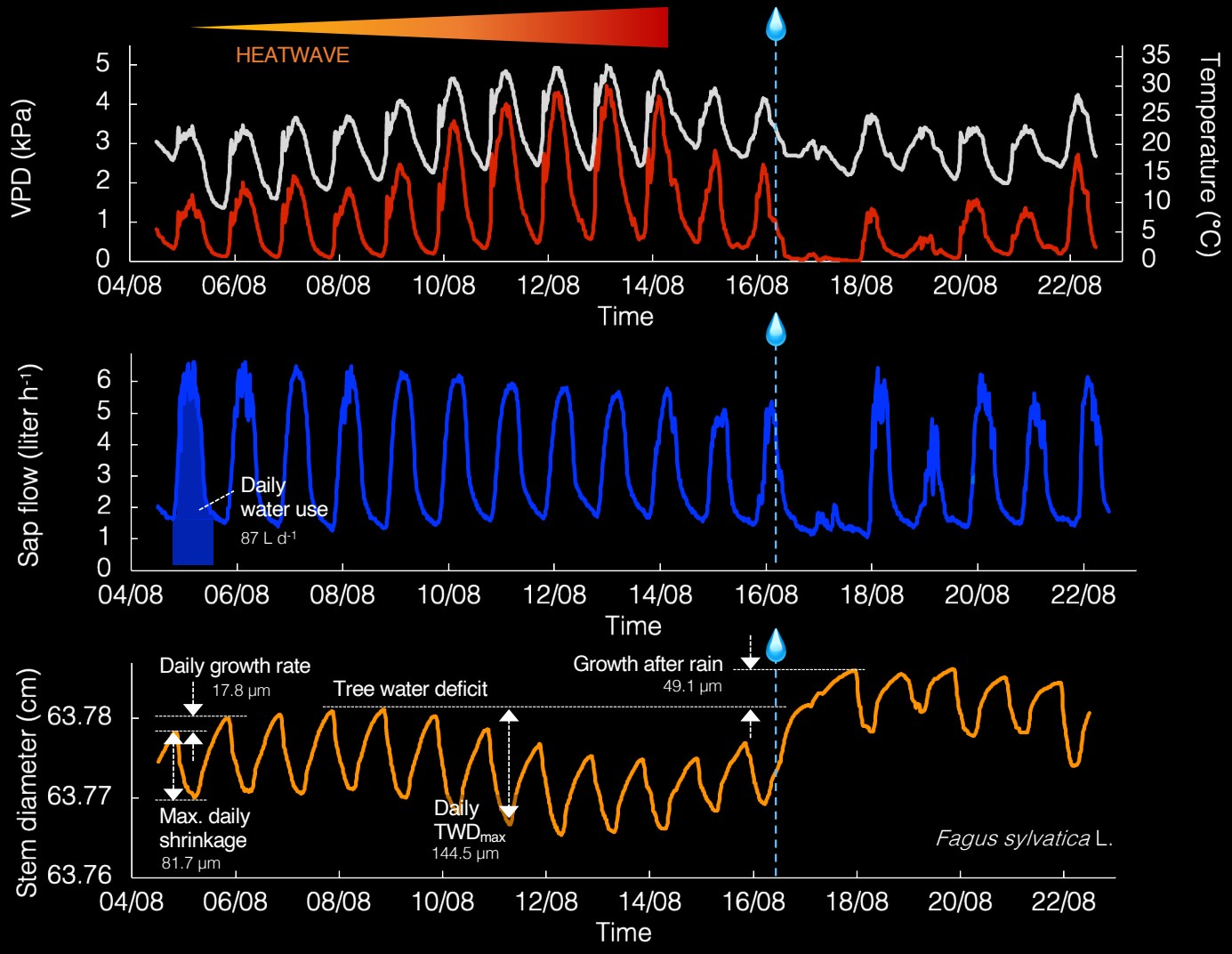
Stem growth and fluctuations



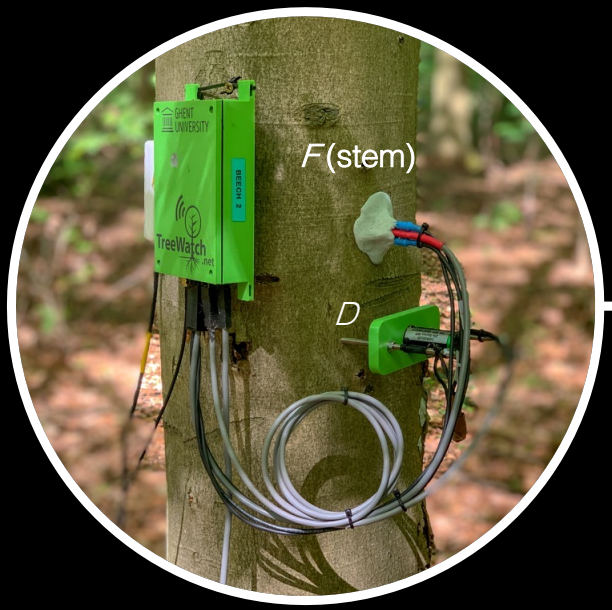
1

The tree as a biological indicator

Tree responses to the 2022 heatwave



② Tree sensors + mechanistic modelling = control algorithms



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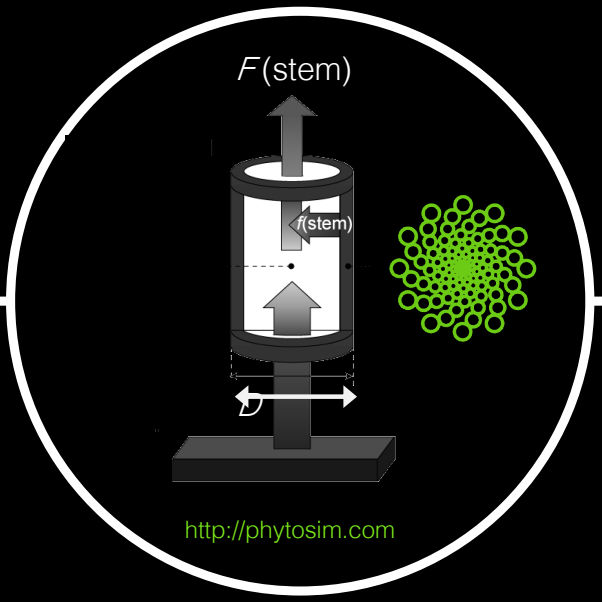


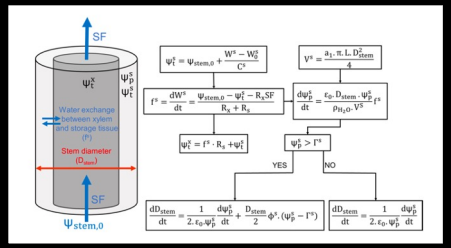
Advanced control algorithms

INPUT

Measured sap flow → Stem diameter model

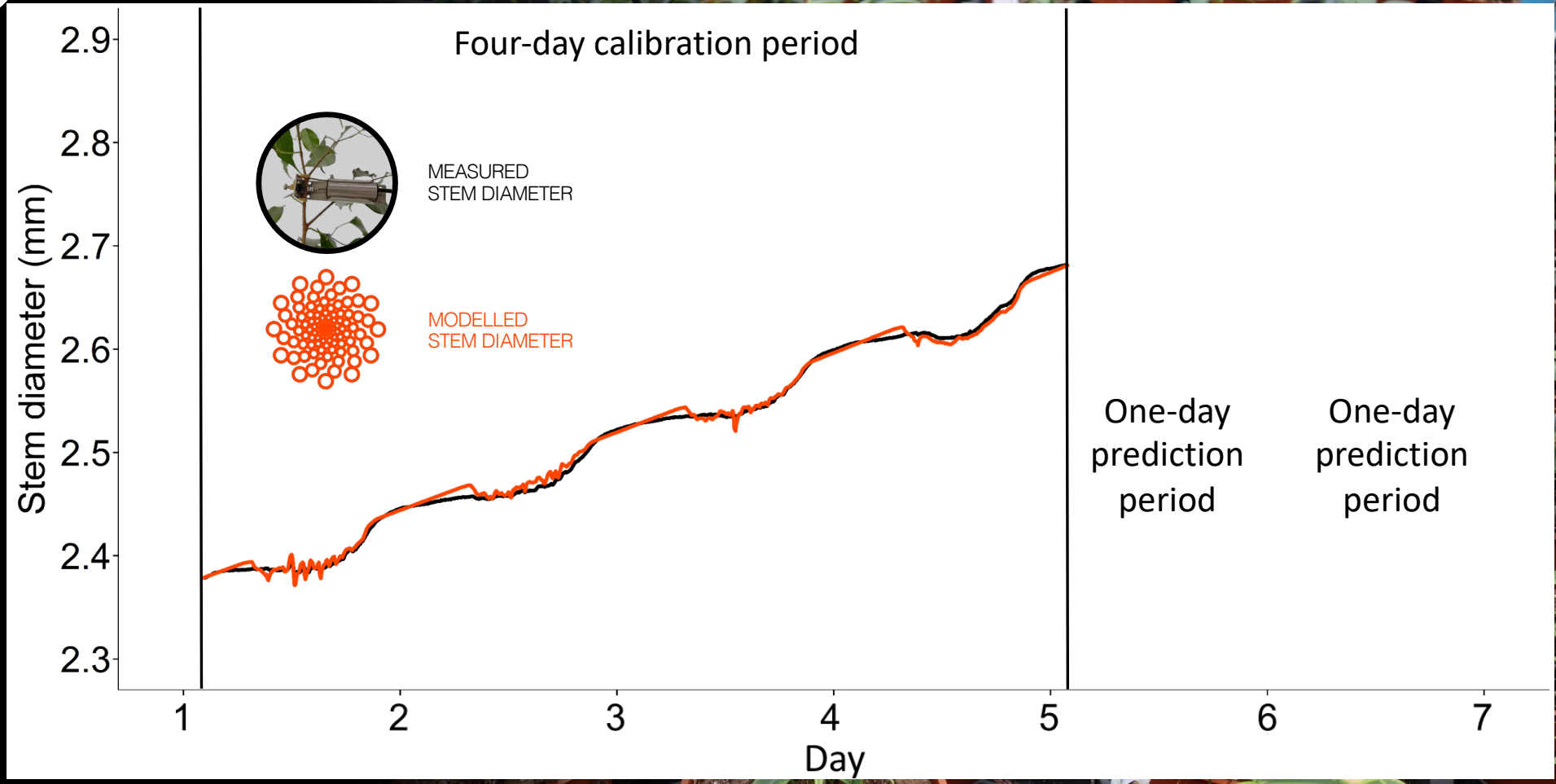
Measured stem diameter

Van de Put and Steppe (2022)
Irrigation Science 40: 29-43

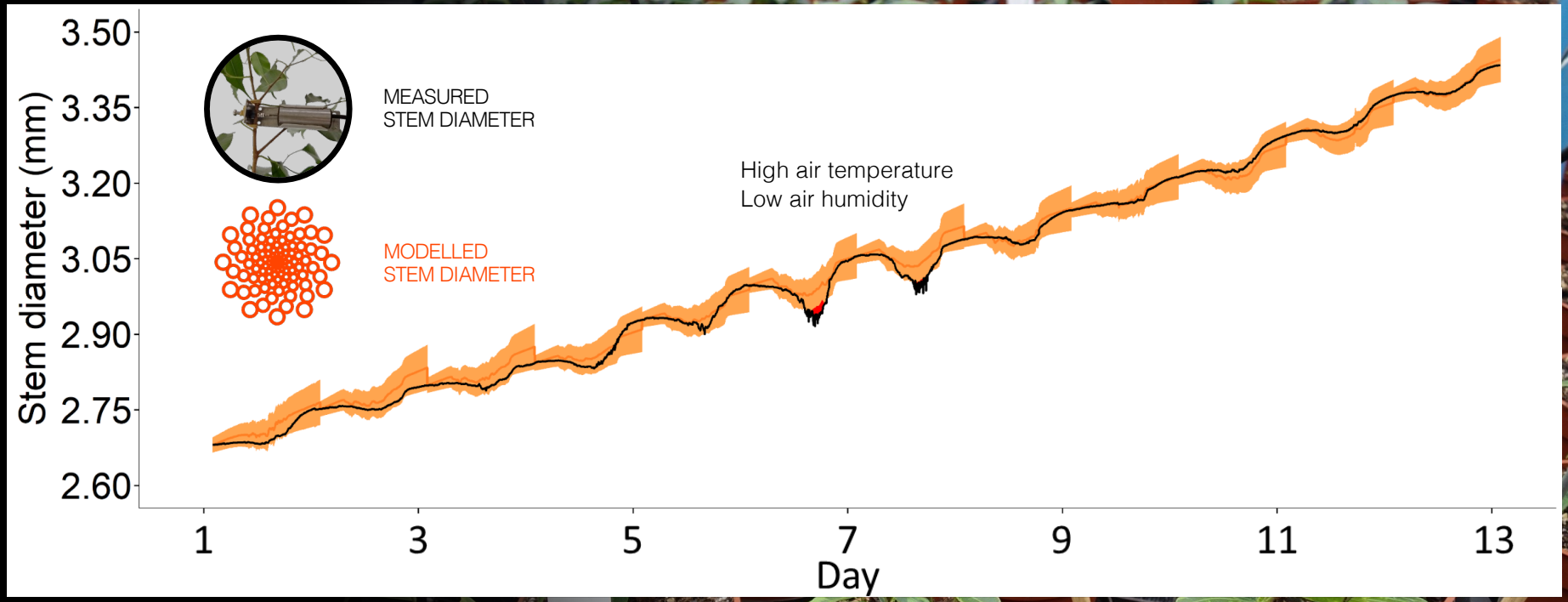


2 Automated drought stress detection

Van de Put and Steppe (2022)
Irrigation Science 40: 29-43

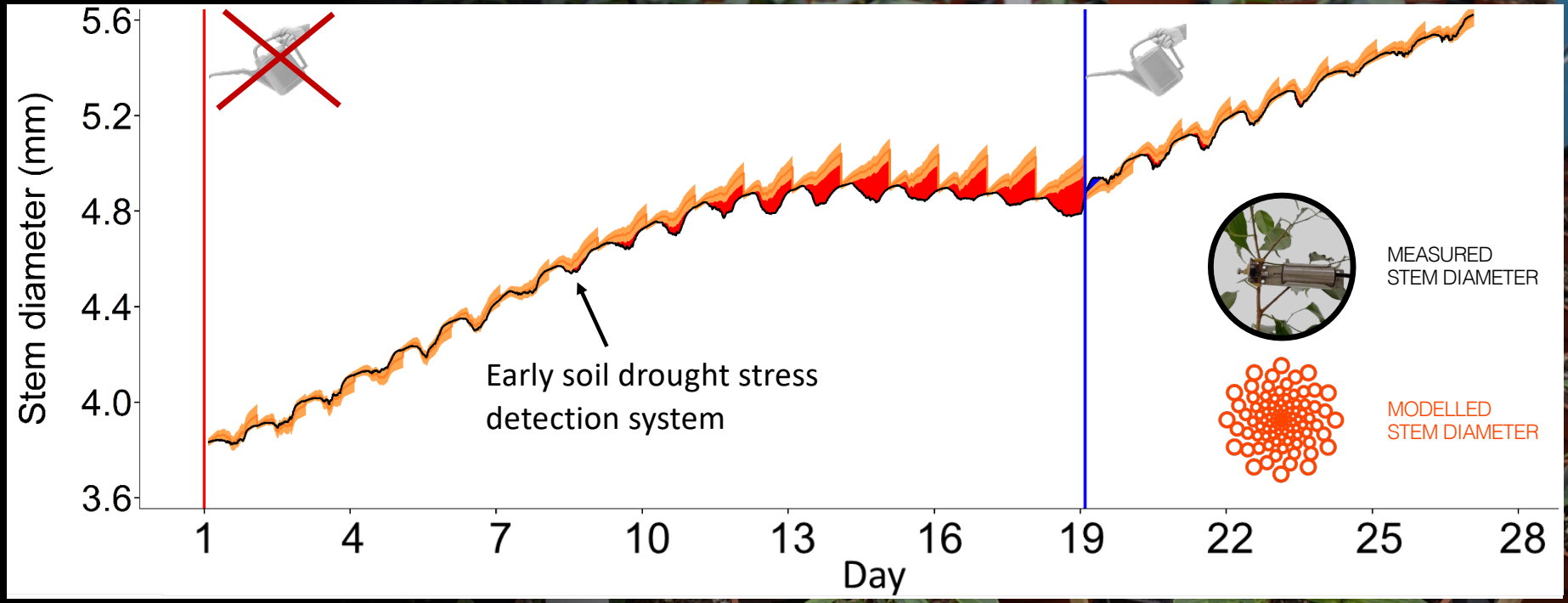


2 Atmospheric drought stress detection



Van de Put and Steppe (2022) Irrigation Science 40: 29-43

2 Soil drought stress detection



Van de Put and Steppe (2022) Irrigation Science 40: 29-43

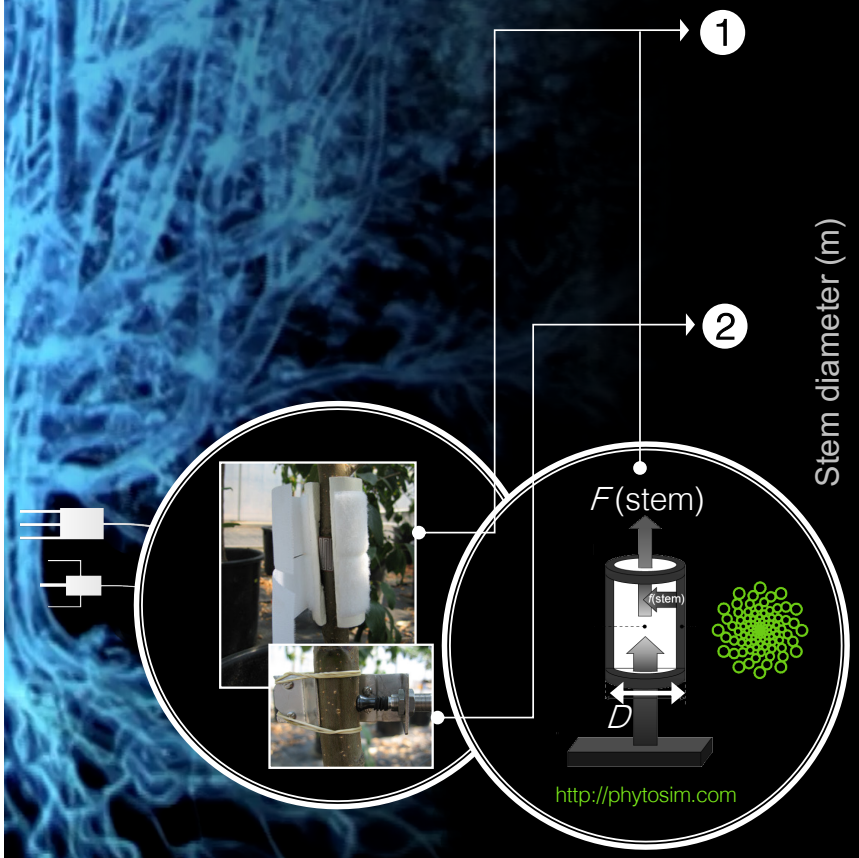
3 STACI

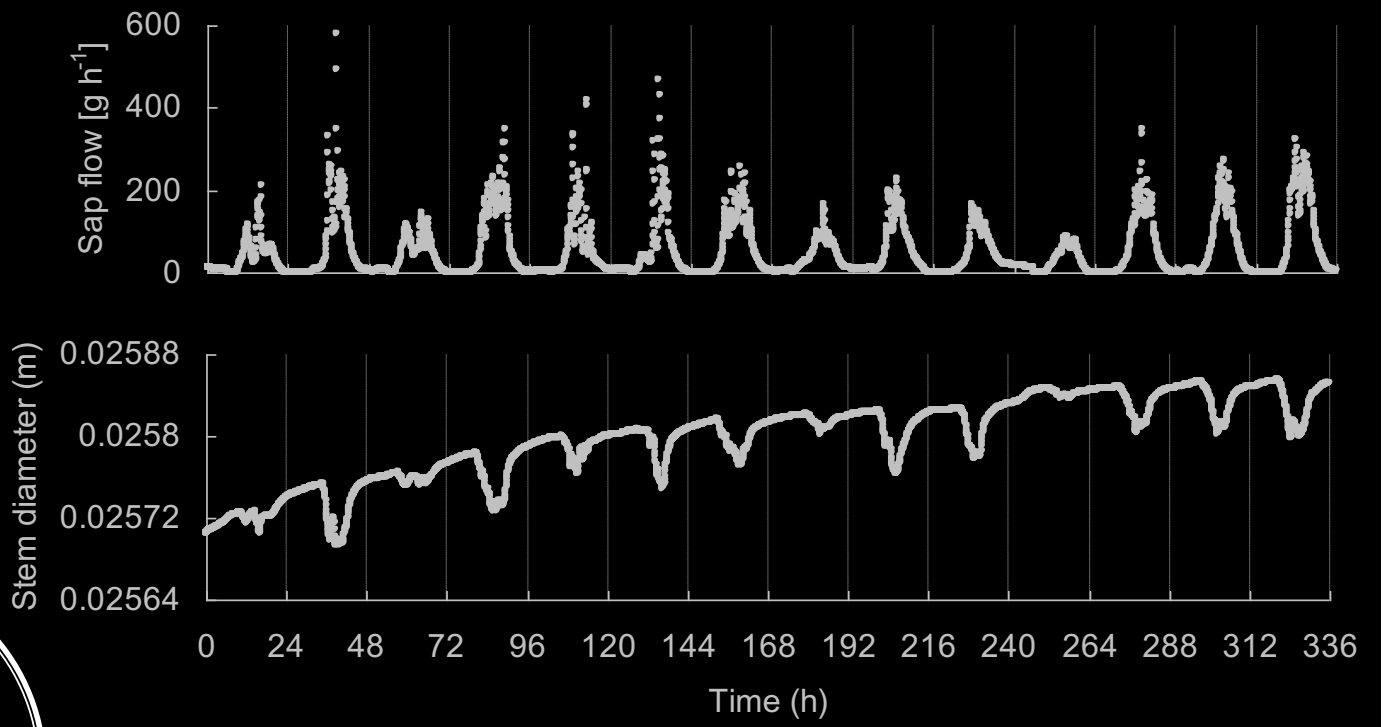
Novel irrigation strategies

STACI: Software Tool for Automatic Control of Irrigation

cost EUROPEAN COOPERATION

FruitCREWS
https://cost-fruitcrews.eu





Steppe et al. (2008)
Irrigation Science 26: 505-517

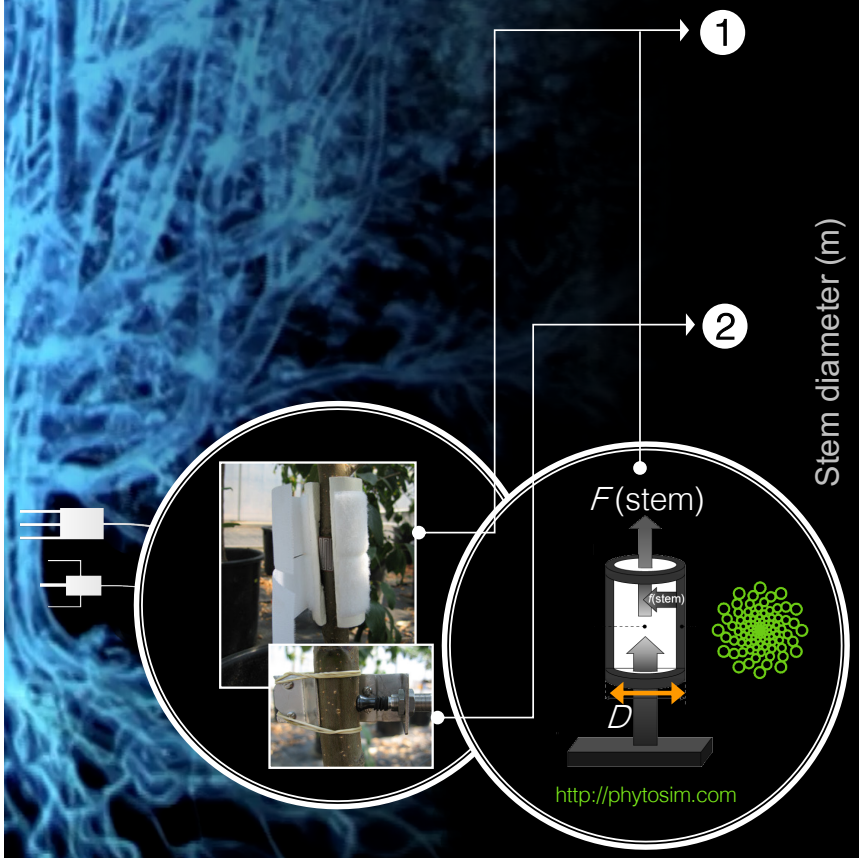
3 STACI

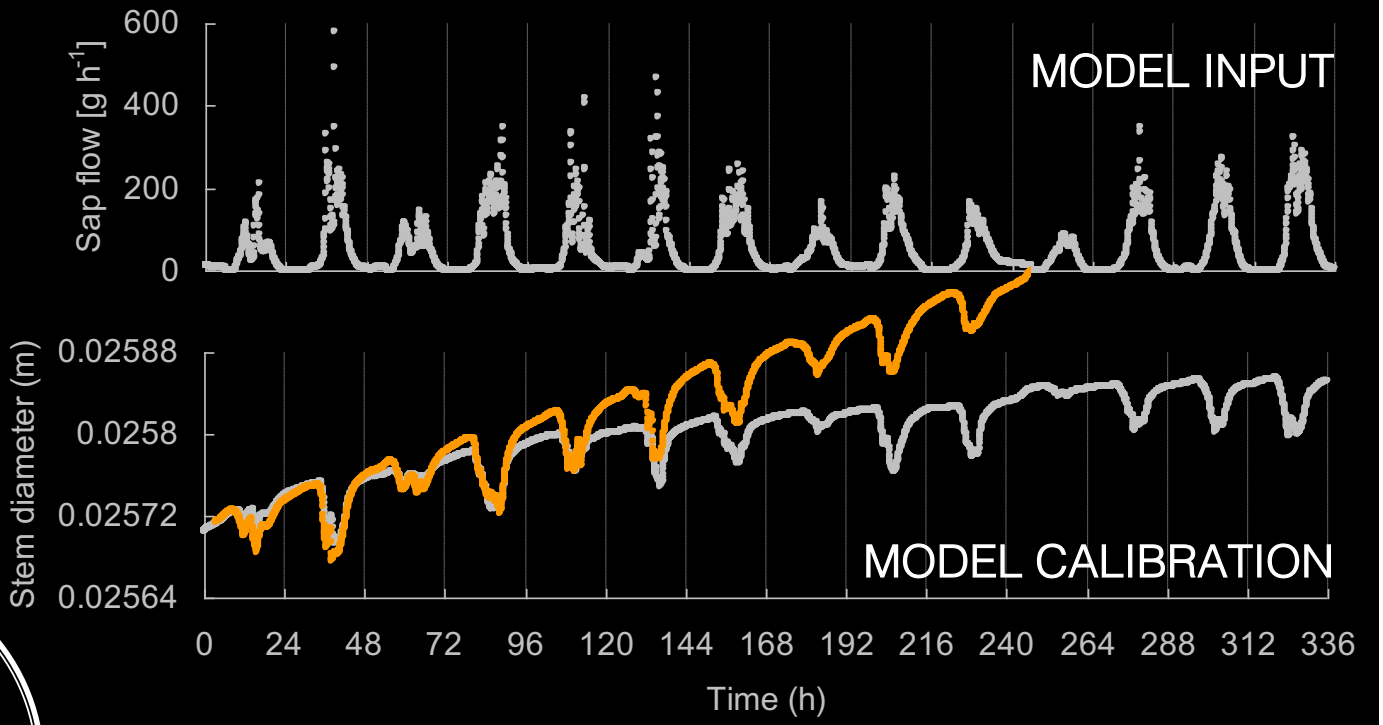
Novel irrigation strategies

STACI: Software Tool for Automatic Control of Irrigation

cost EUROPEAN COOPERATION

FruitCREWS
https://cost-fruitcrews.eu





Steppe et al. (2008)
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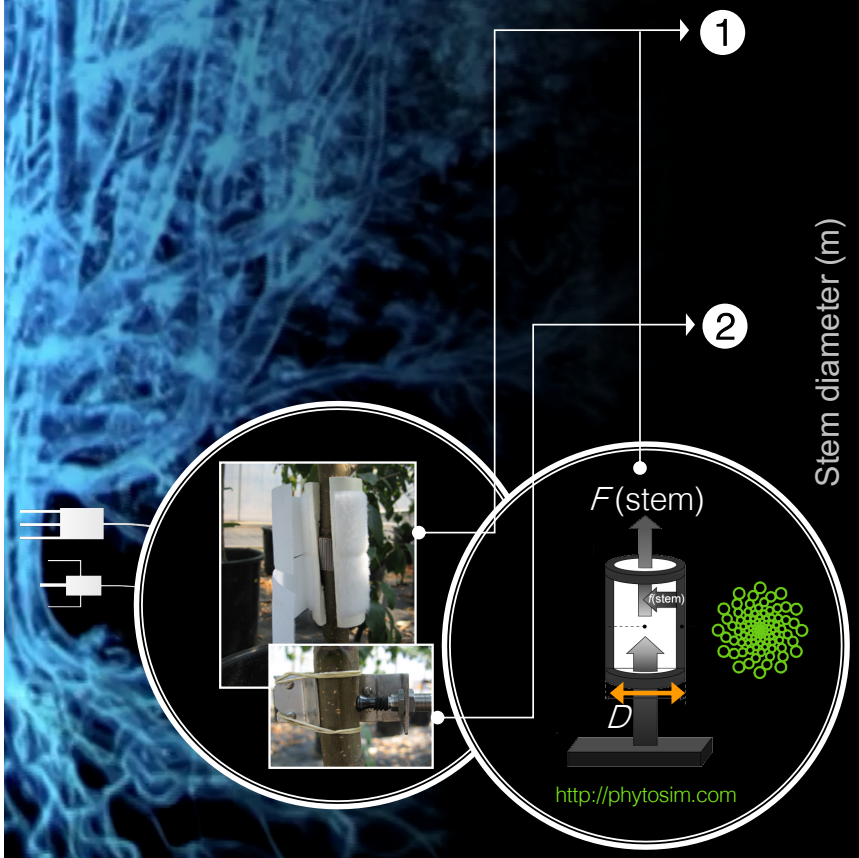

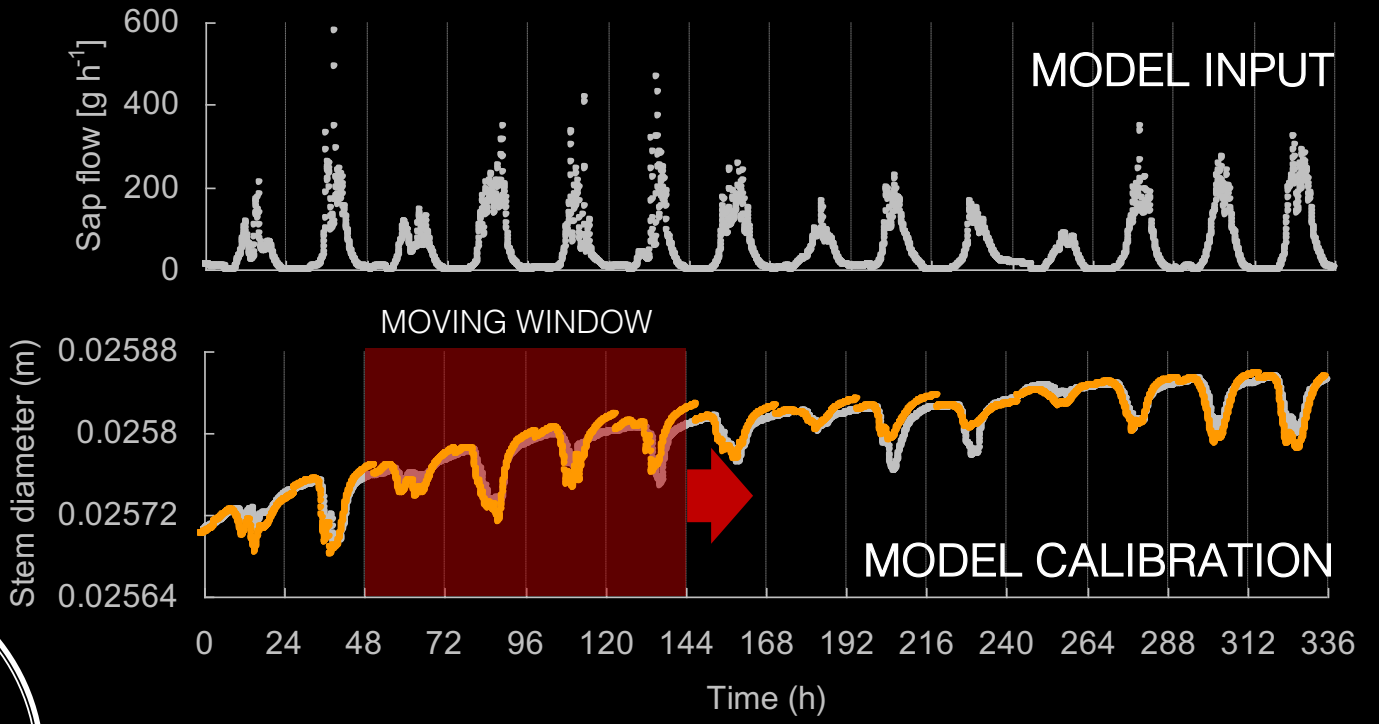

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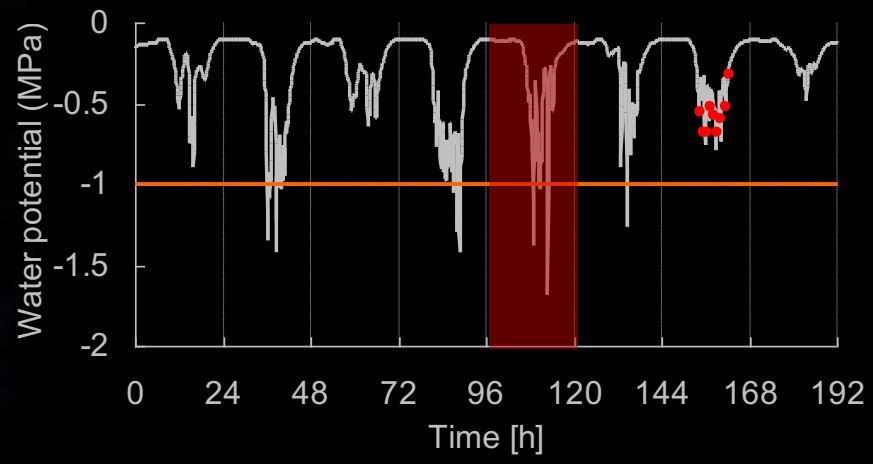
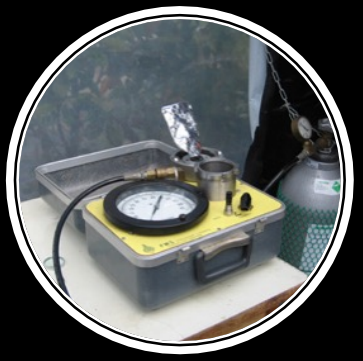
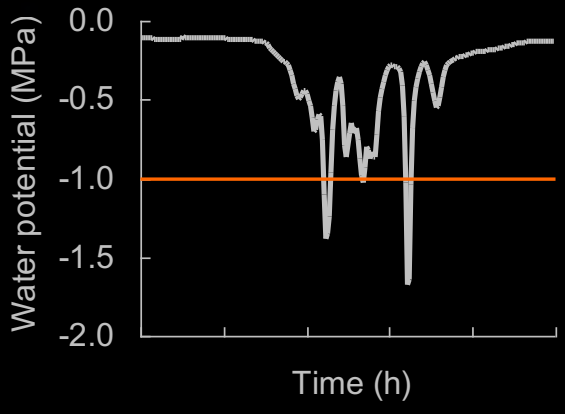
3 MODEL OUTPUT: online simulated stem water potential

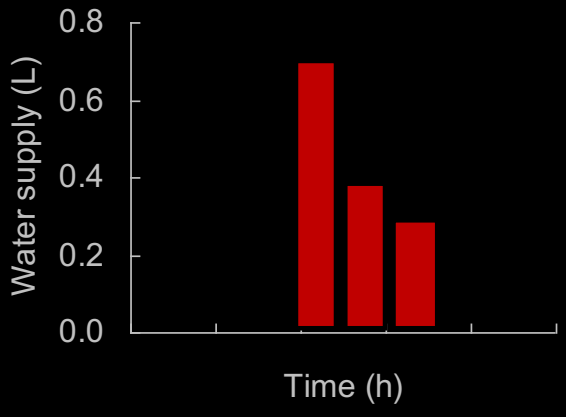




WHEN?

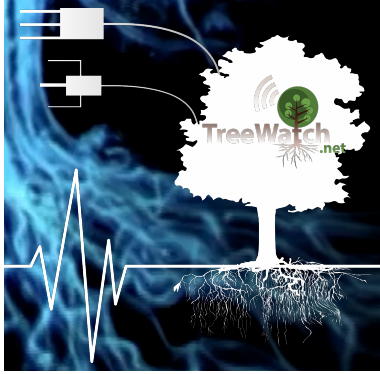


HOW MUCH?



From tree monitoring to applications

TreeWatch.net → Steppe et al. (2016) Frontiers in Plant Science 7: Article 993



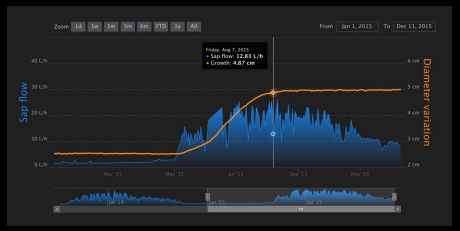
PlantHub cloud service

Tree as biological indicator

Real-time visualisation

PlantHub web application

TreeWatch.net website



PlantHub cloudservice

- Data storage
- Real-time data conversion
- Auto-correction
- Real-time model calibration and simulation
- Warnings

Building Biospheres - Biennale Architettura 2025

Giving trees a voice in nature-inspired architecture

Bio-airco

PROTOTYPE

Ghent University – Faculty of Bioscience Engineering
18.11.2024 – 31.03.2025 | Ghent (BE)

TREE MONITORING

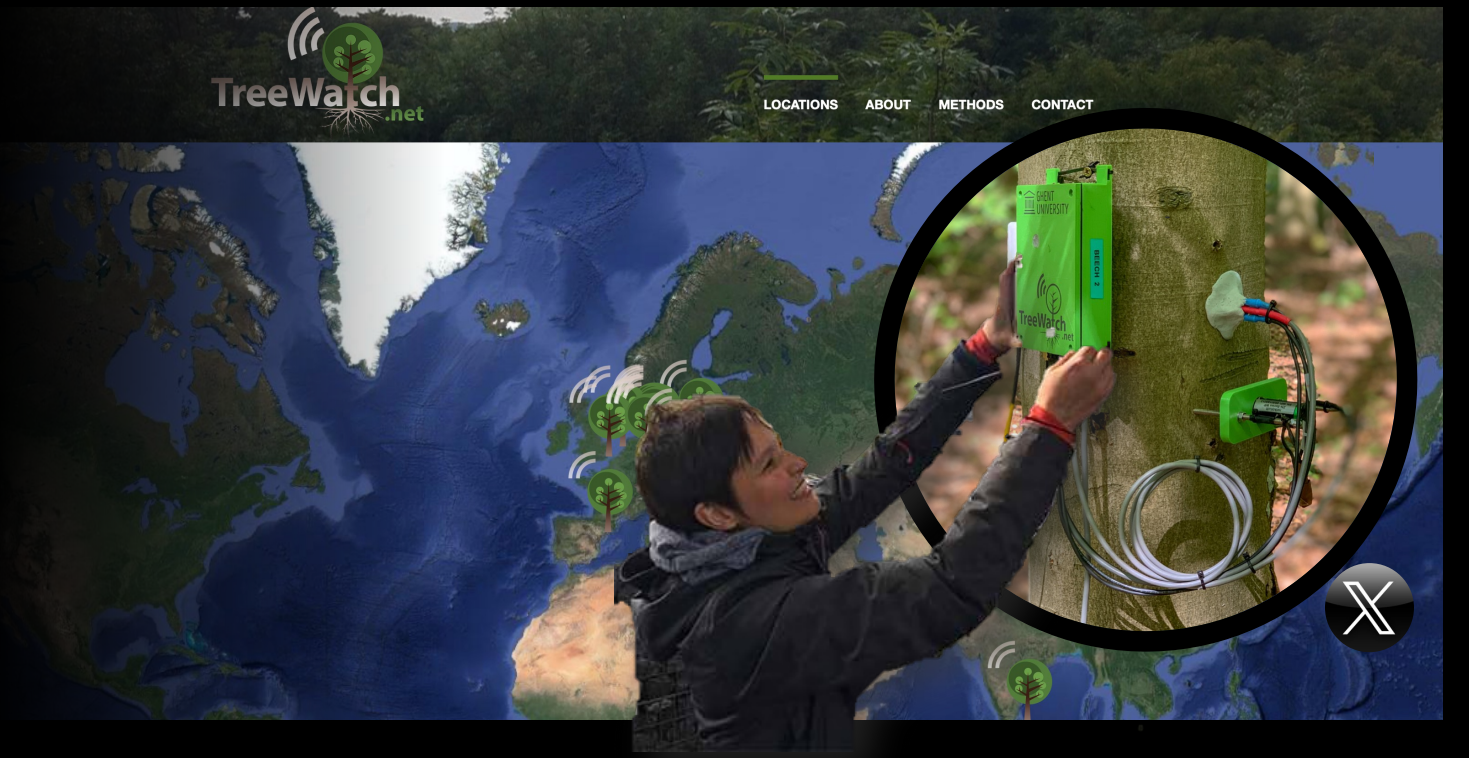
TreeWatch technology
giving trees a voice

Move from
Ghent to Venice
on 01.04.2025

BELGIAN PAVILION

Biennale Architettura 2025
10.05.2025 – 23.11.2025 | Giardini, Venice (IT)

Thank you



BOMEN BETER BEHEREN

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