Listening to Plants: Plant-Based Sensors and Physiology for Digital Agriculture

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

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Giornate tecniche SOI - Bari 2026
10 - 11 settembre 2026

If my title starts with Listening to Plants…

Am I saying that **plants can talk**?



- ❑ *flamenco palmas* (hand clapping)
- ❑ plant speaking

If my title starts with Listening to Plants…

Am I saying that **plants can talk**?





- ❑ *flamenco palmas* (hand clapping)
- ✓ plant **acoustic emissions (AE)**

(produced when water columns inside a plant's xylem break under extreme tension during drought >> cavitation).

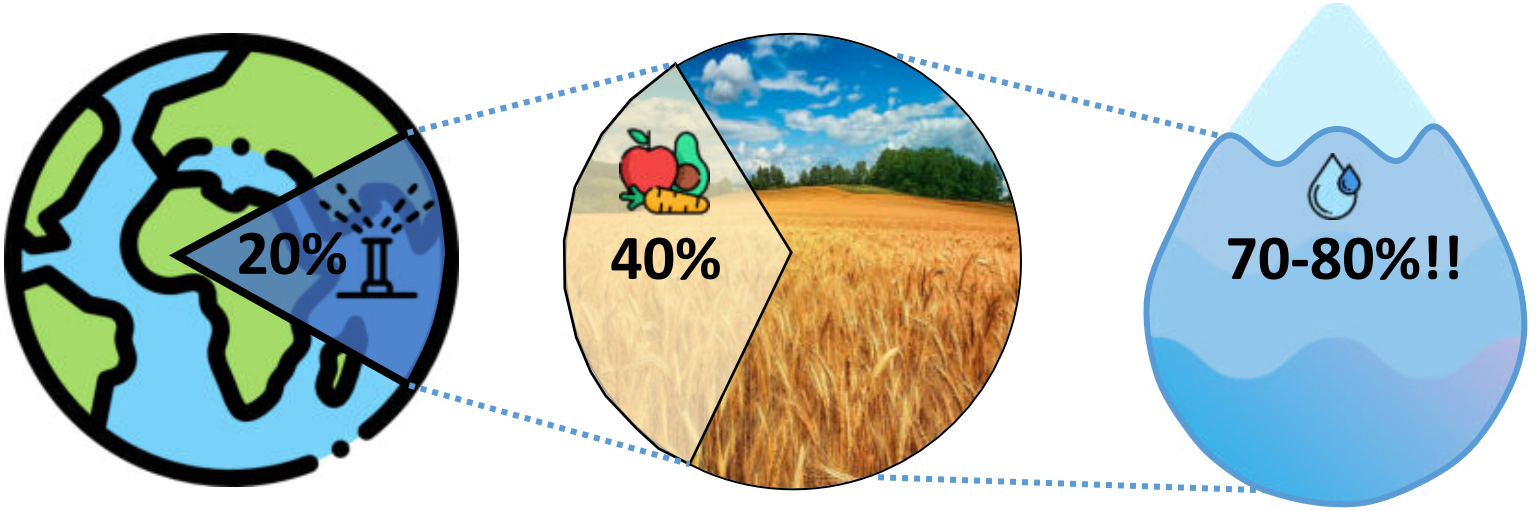
Captured by acoustic emission **sensors** (operating in the ultrasonic frequency range >20 kHz), attached to stems or leaves

Detection of cavitation and construction of hydraulic vulnerability curves using acoustic emission signals
D.M. Johnson, S. Mayr, S. Rosner, K. Steppe
Prometheus Protocol

The importance of sensing technologies in agriculture



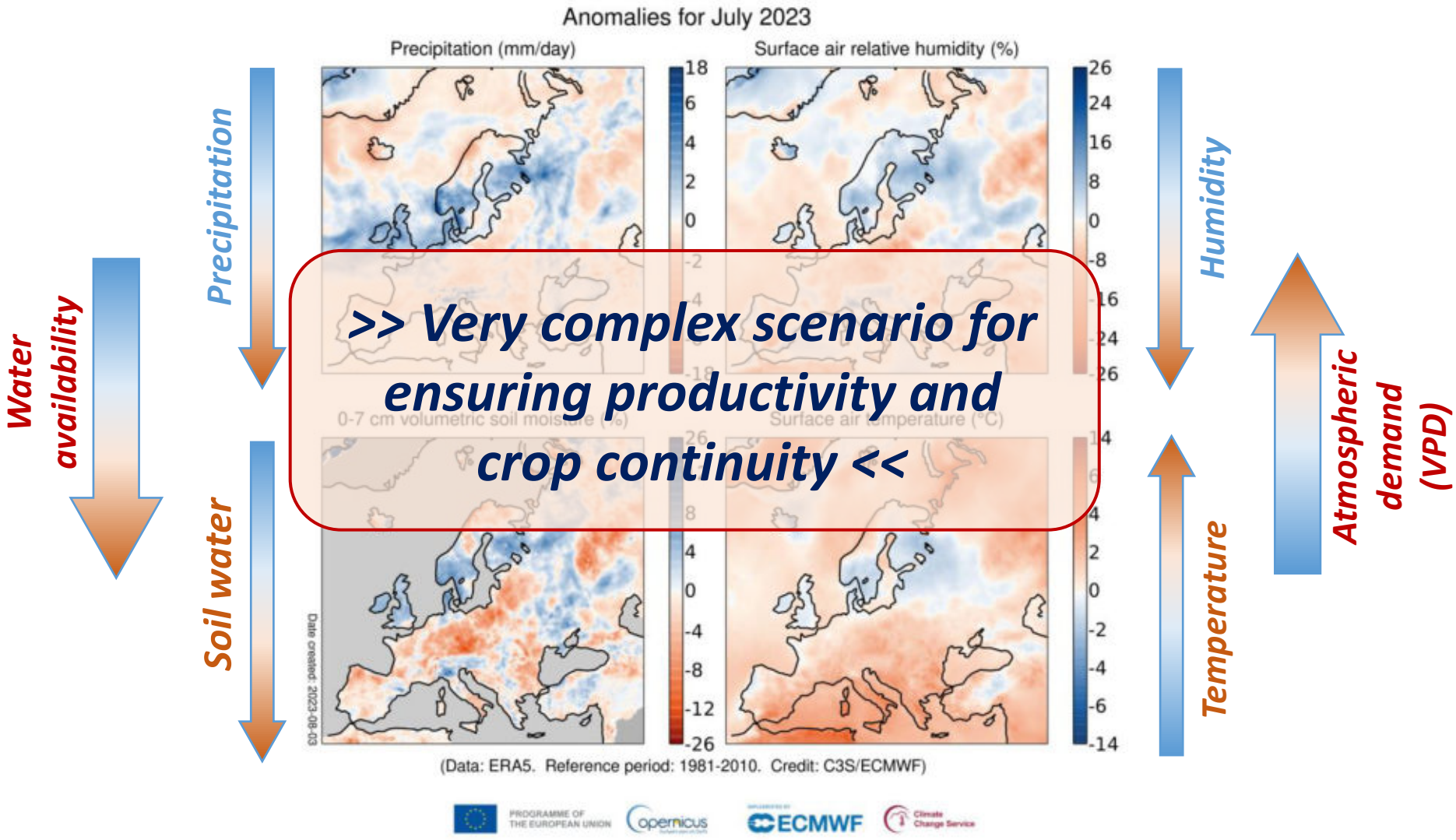




FAOSTAT 2023

Fereres & Soriano 2007

The importance of sensing technologies in agriculture



The importance of sensing technologies in agriculture



The importance of sensing technologies in agriculture



The importance of sensing technologies in agriculture





Agriculture 'under pressure' → ***URGENT Solutions***





The importance of sensing technologies in agriculture



Evaporation tank



Soil moisture



Meteorological measurements

Kc method

$ET_c = K_r K_c ET_o$





Remote sensing



Plant measurements



Plant-based sensors

Speaking plants: towards bio-sensors for irrigation



Plant=passive component within the soil-plant-atmosphere continuum

>>Plant water needs infered from environmental conditions

Soil moisture

Meteorological measurements

Kc method

$ET_c = K_r K_c ET_o$

Remote sensing

Plant measurements

Plant based sensors

Plant=bio sensor

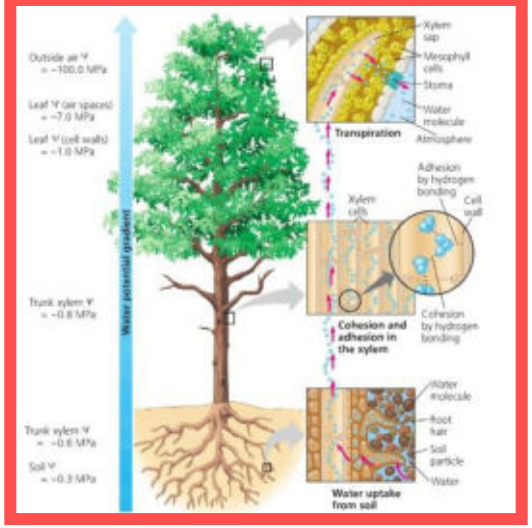
>>Plant centric approach; plant is the source of information for irrigation decisions



Speaking plants: towards bio-sensors for irrigation

Plant Physiology

Plant ecophysiology under water stress



Process-based model

To predict global change impacts on plants by integrating disparate physiological responses

$$A_c = V_{cmax}\frac{C_i - \Gamma^*}{C_i + K_c[1+(o_i/K_o)]}$$

$$\chi_s = \chi\frac{\alpha(\psi_s + \pi_e) - \pi_e}{1 + \chi(\alpha R + f_g r_{eg})D_s}$$

$$E_p = K(\psi)(\psi_{sr} - \psi_{pc})$$

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

Plant-based sensor

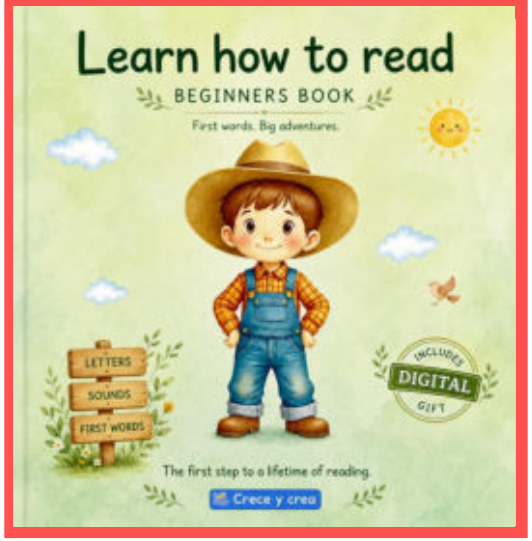
To optimize irrigation strategies by monitoring water stress in real time



Speaking plants: towards bio-sensors for irrigation

Plant Physiology

Plant ecophysiology under water stress



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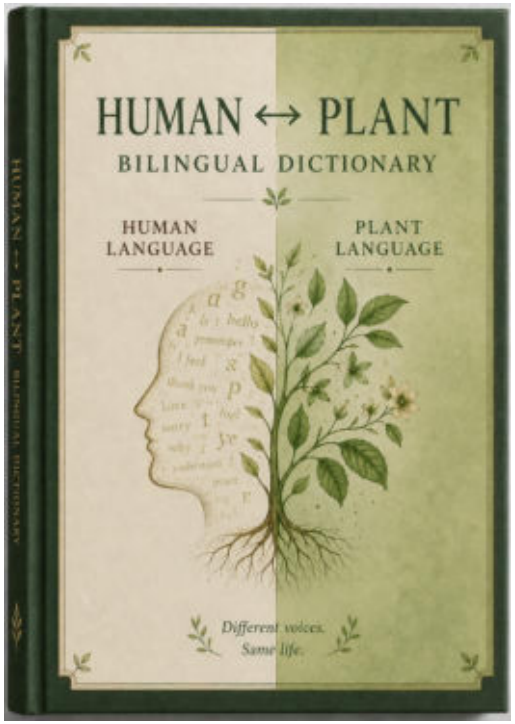


Plant-based sensor

To optimize irrigation strategies by monitoring water stress in real time



Speaking plants: towards bio-sensors for irrigation

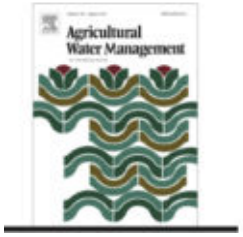
Scientia Horticulturae
Volume 364, June 2026, 114908



Editorial

Challenges and limitations towards integration of plant-based sensing and modeling of irrigation requirements in perennial fruit production

Manuela Zude-Sasse [a], Alon Ben-Gal [b], Diego S. Intrigliolo [c], Kathy Steppe [d], Pasquale Losciale [e], George A. Manganaris [f], Joaquim Bellvert [g], Virginia Hernandez-Santana [h], Brunella Morandi [i]



Review article Get rights and content ↗

Review

Plant-based sensing to monitor water stress: Applicability to commercial orchards

J.E. Fernández Show more

OXFORD ACADEMIC
Journal of Experimental Botany

Irrigation scheduling: advantages and pitfalls of plant-based methods

Hamlyn G. Jones

Journal of Experimental Botany, Volume 55, Issue 407, November 2004, Pages 2427–2436, https://doi.org/10.1093/jxb/erh213

Speaking plants: towards bio-sensors for irrigation



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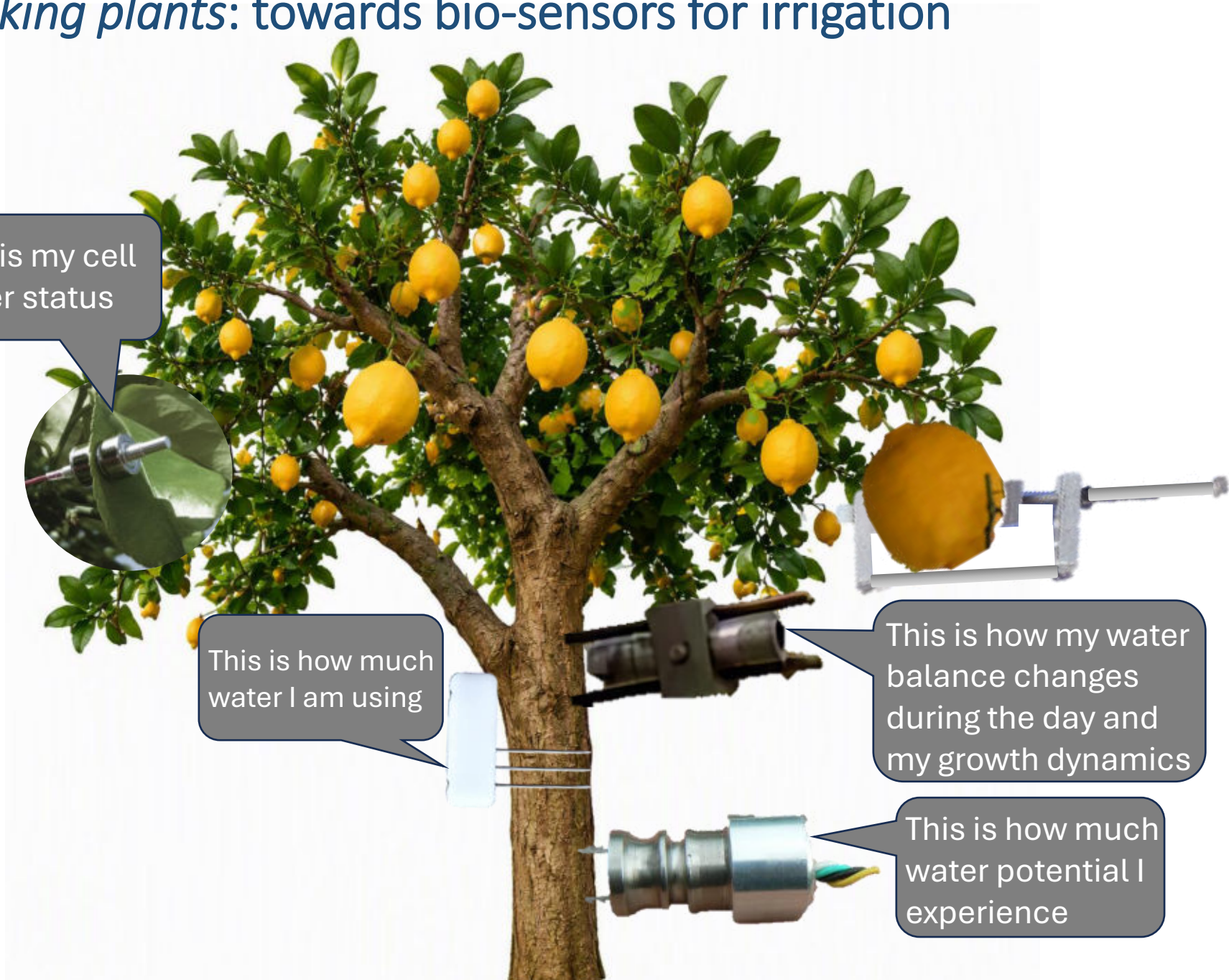
Key characteristics of an ideal plant sensor:

- Directly linked to plant water status
- Continuous and automated
- Non-destructive
- Robust under field conditions
- Easy to scale from the tree to orchard level
- Able to provide actionable irrigation thresholds
- Compatible with DSS and AI-based irrigation systems

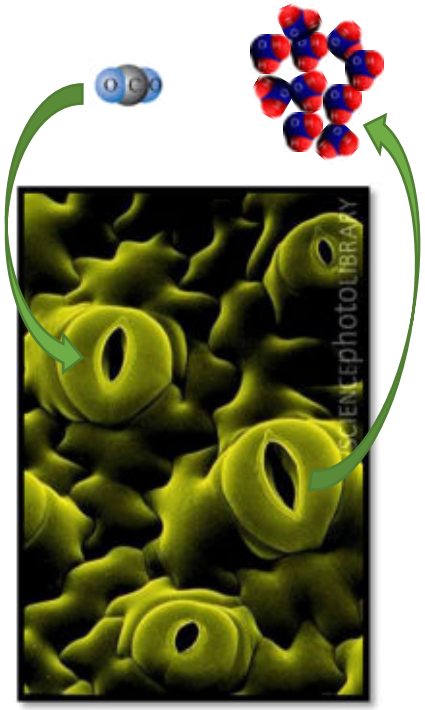
Speaking plants: towards bio-sensors for irrigation

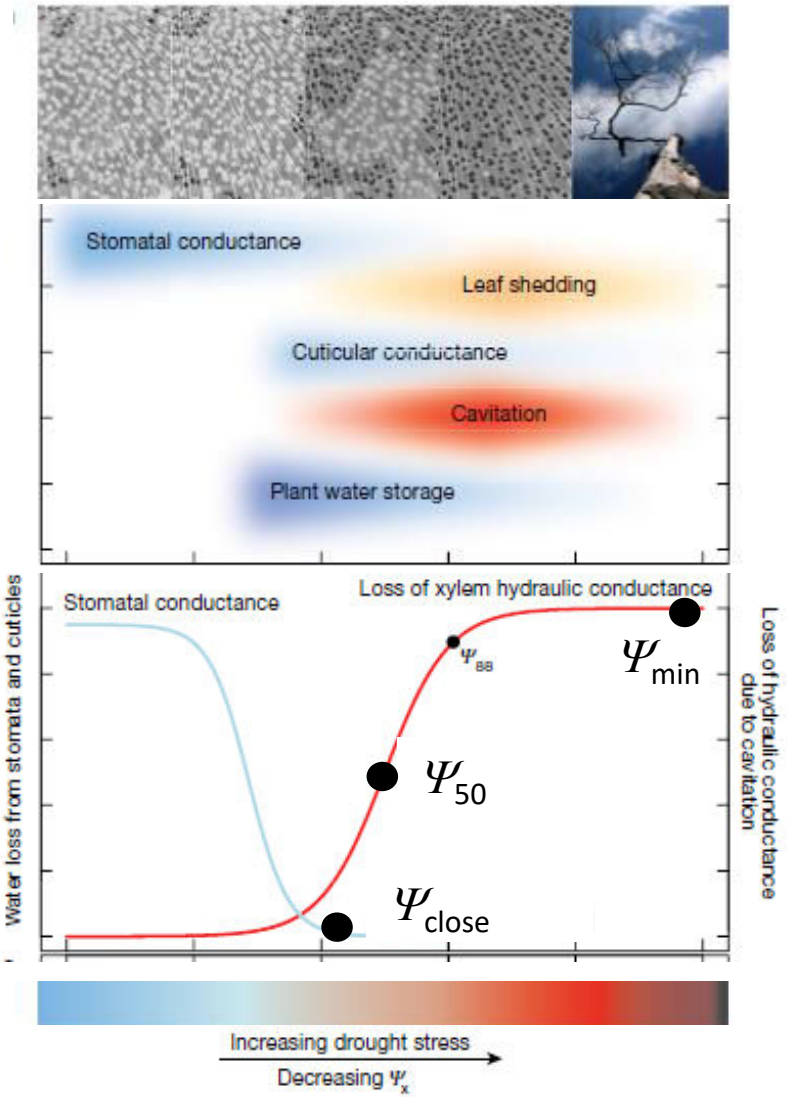


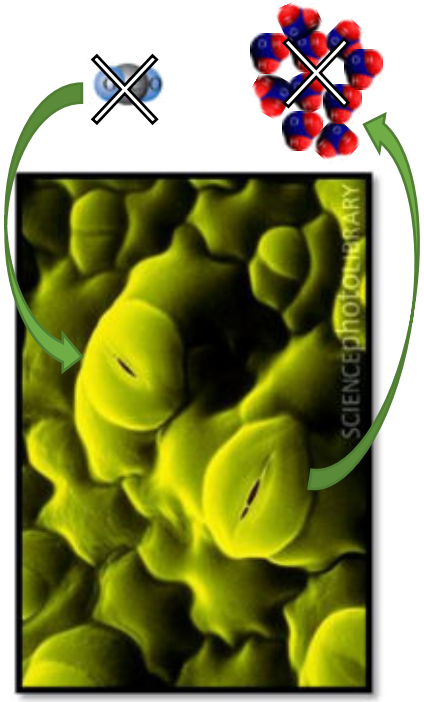
Speaking plants: the stomatal conductance example

Water stress indicator

At the crossroad of water and carbon fluxes

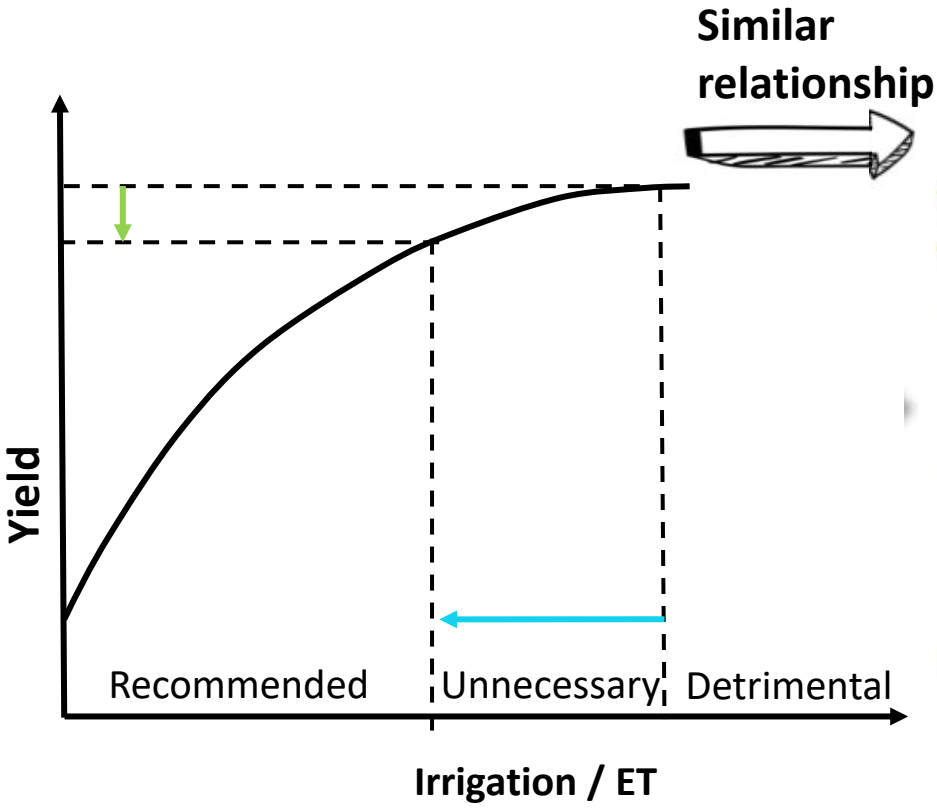


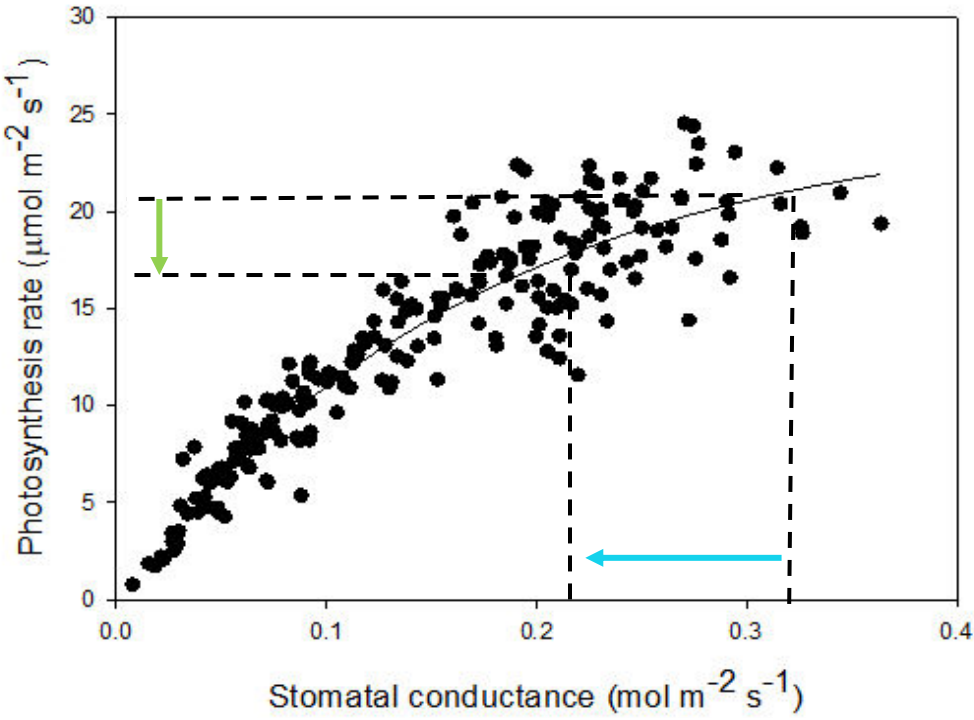




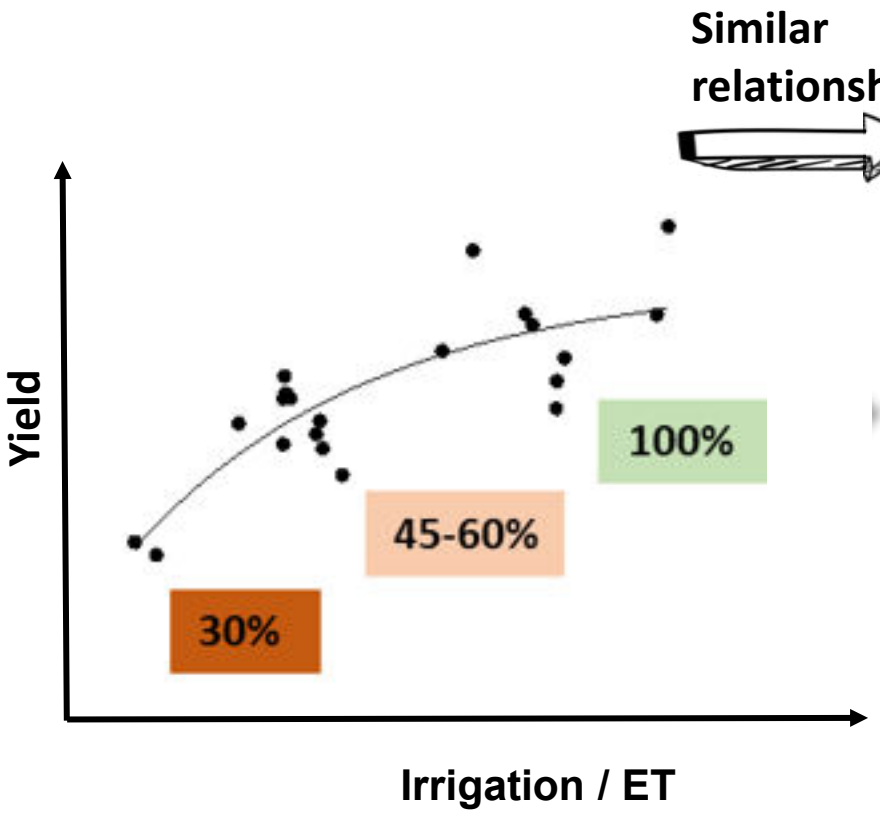
Choat et al. (2018)

Speaking plants: the stomatal conductance example

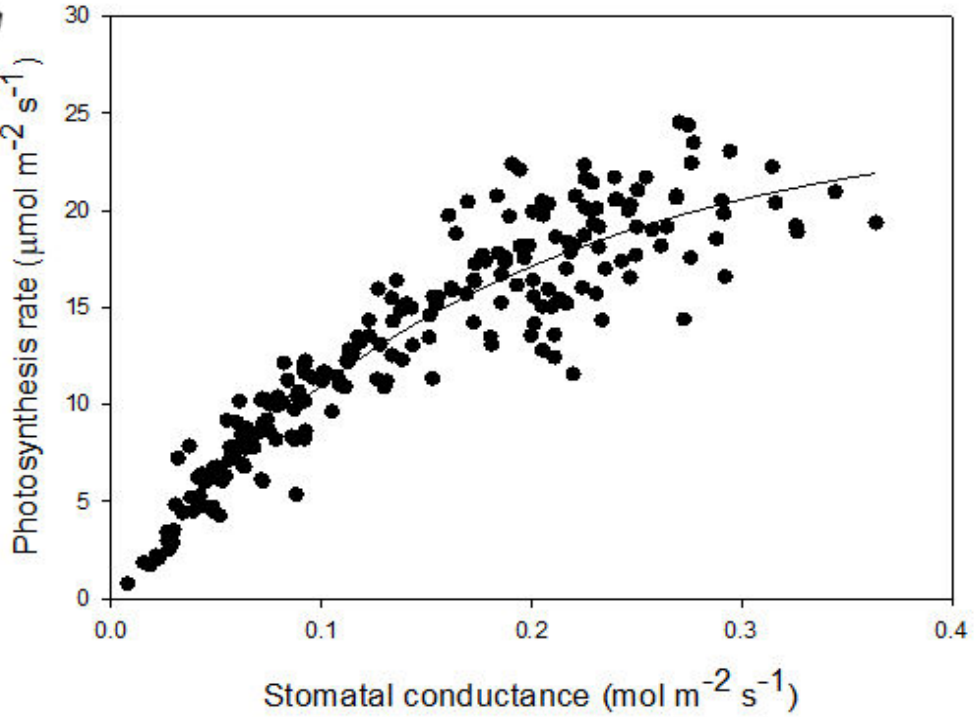




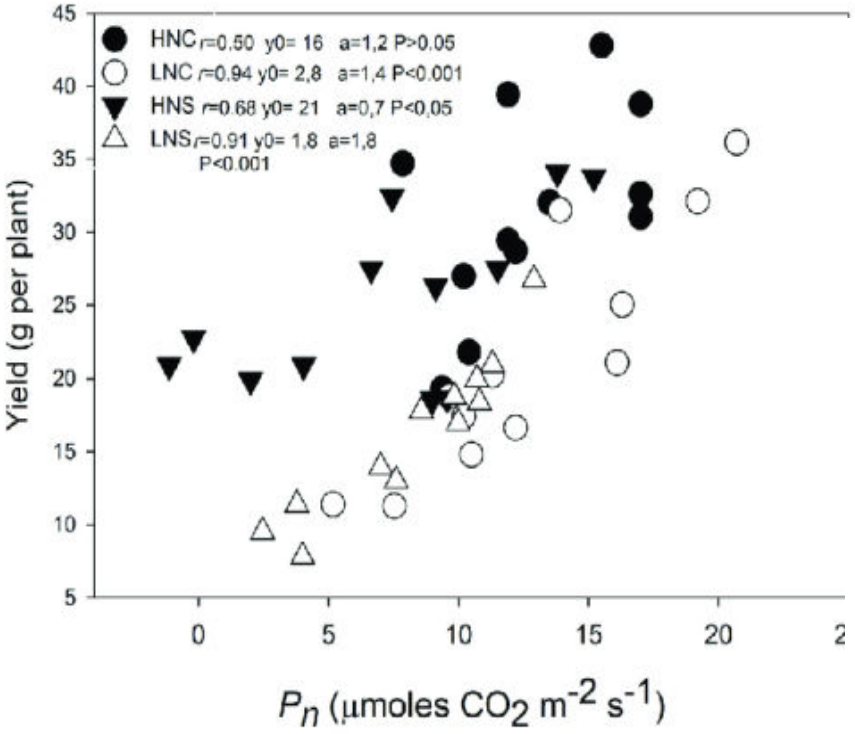
Speaking plants: the stomatal conductance example



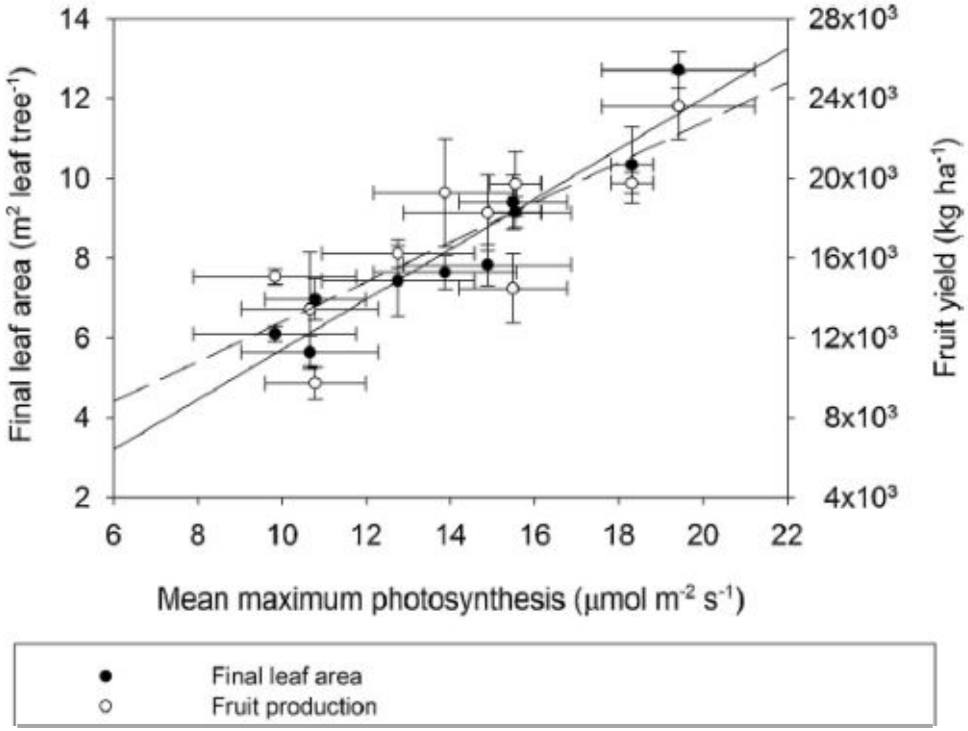
Similar relationship



Speaking plants: the stomatal conductance example



Bascuñan-Godoy et al. (2018)



Hernandez-Santana et al. (2017)

Speaking plants: the stomatal conductance example

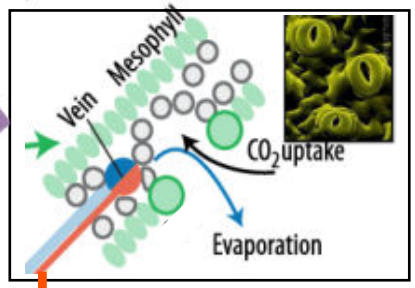
To **model photosythesis** in a continuos manner to quantify its effect over vegetative and reproductive growth

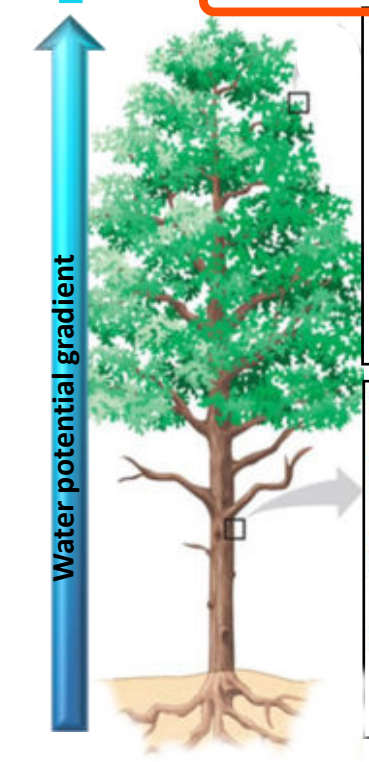


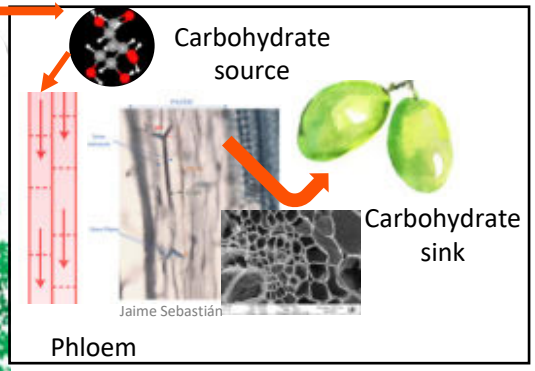
$E = g_s \cdot D \cdot A_l$

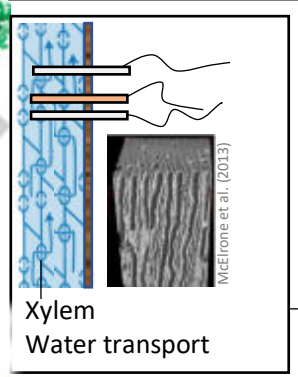
$g_s \propto J_s / D$

g_s : stomatal conductance
J_s: sap flux density
D: vapor pressure deficit
A_l: Leaf area
E: transpiration







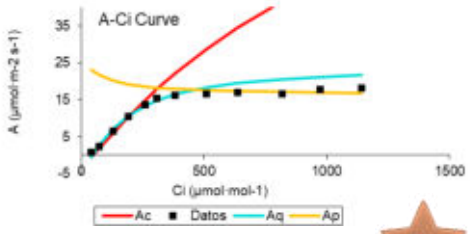


Sap flow sensors



$g_s \propto J_s / D$

Stomatal conductance

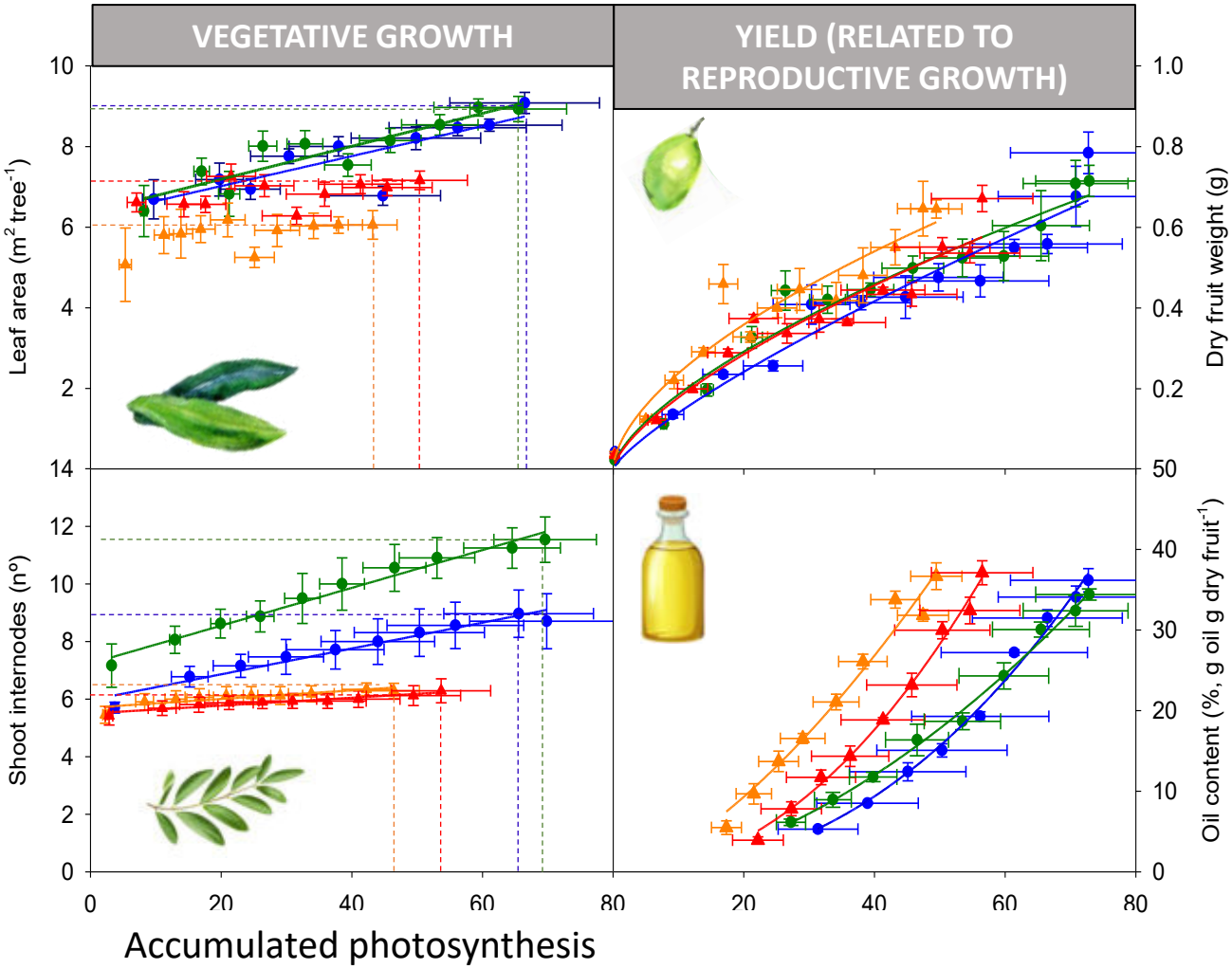


Farquhar et al. model

Photosynthesis

Hernandez-Santana et al. 2016

Speaking plants: Stomatal conductance



Hernandez-Santana al. 2018

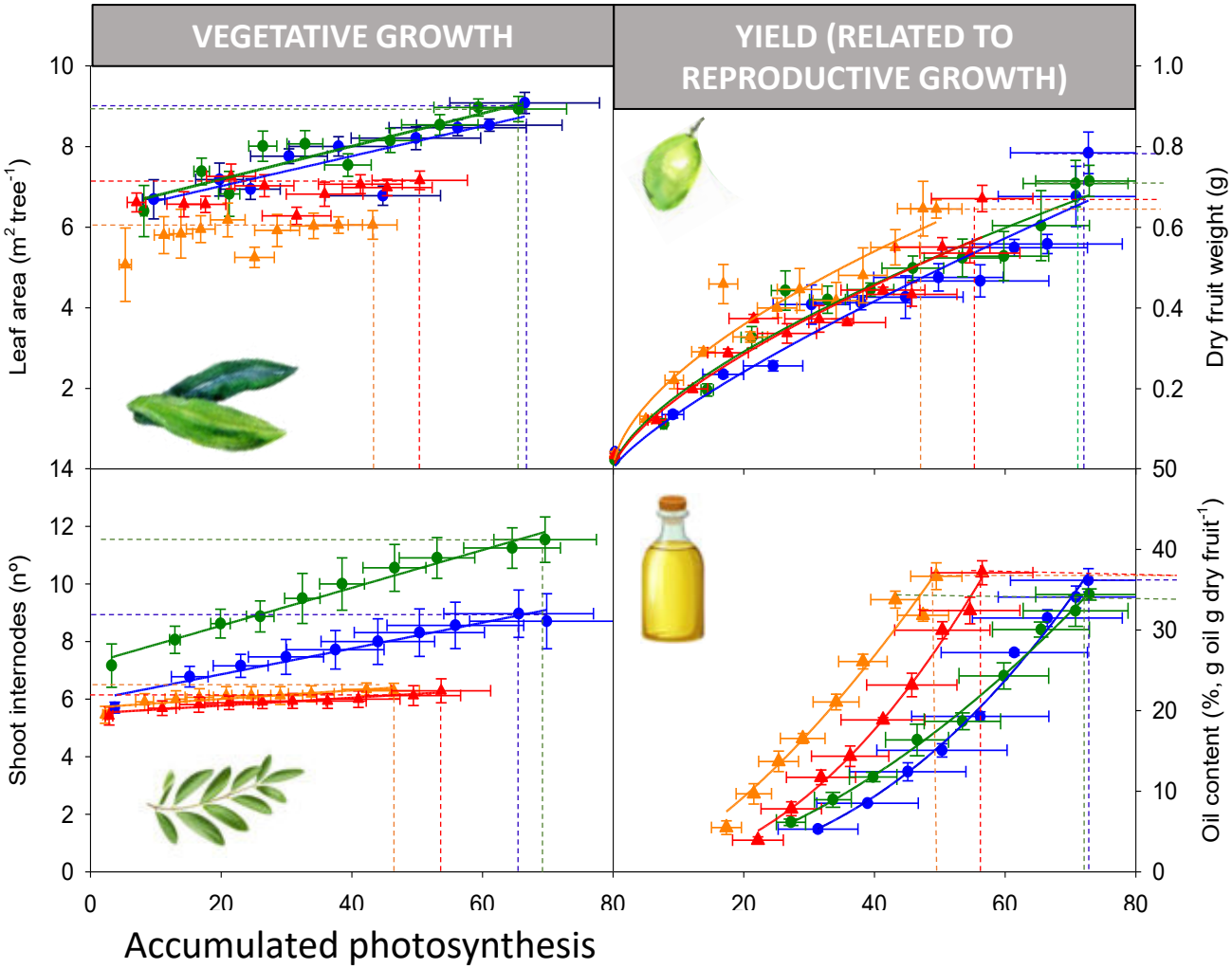
WW trees (1-2 irrigation lines)

WS trees (1-2 irrigation lines)

Photosynthesis =/+

Photosynthesis ++

Speaking plants: Stomatal conductance



Hernandez-Santana al. 2018

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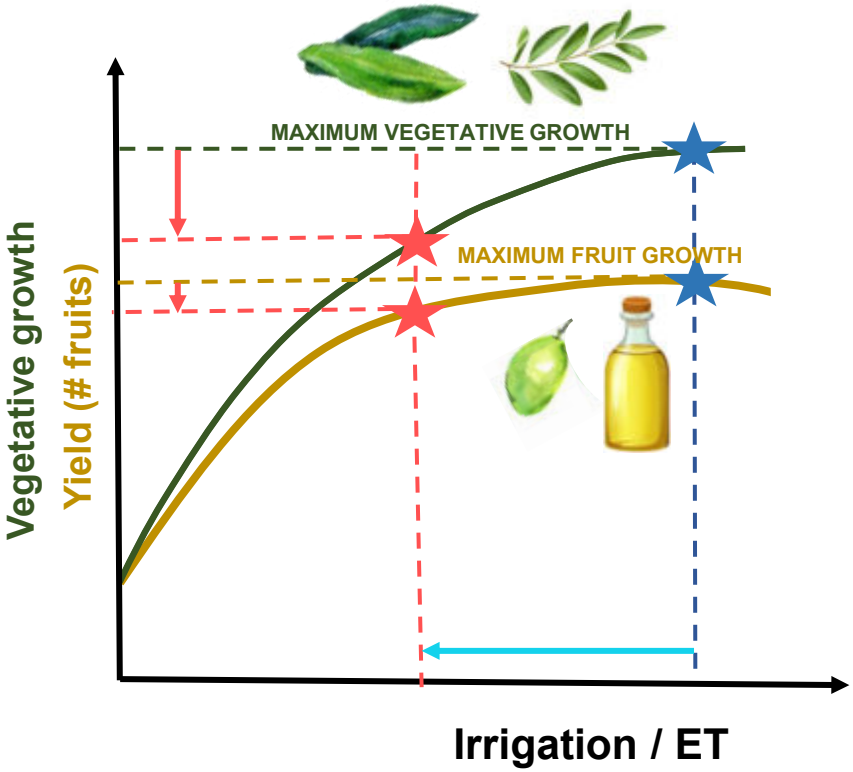
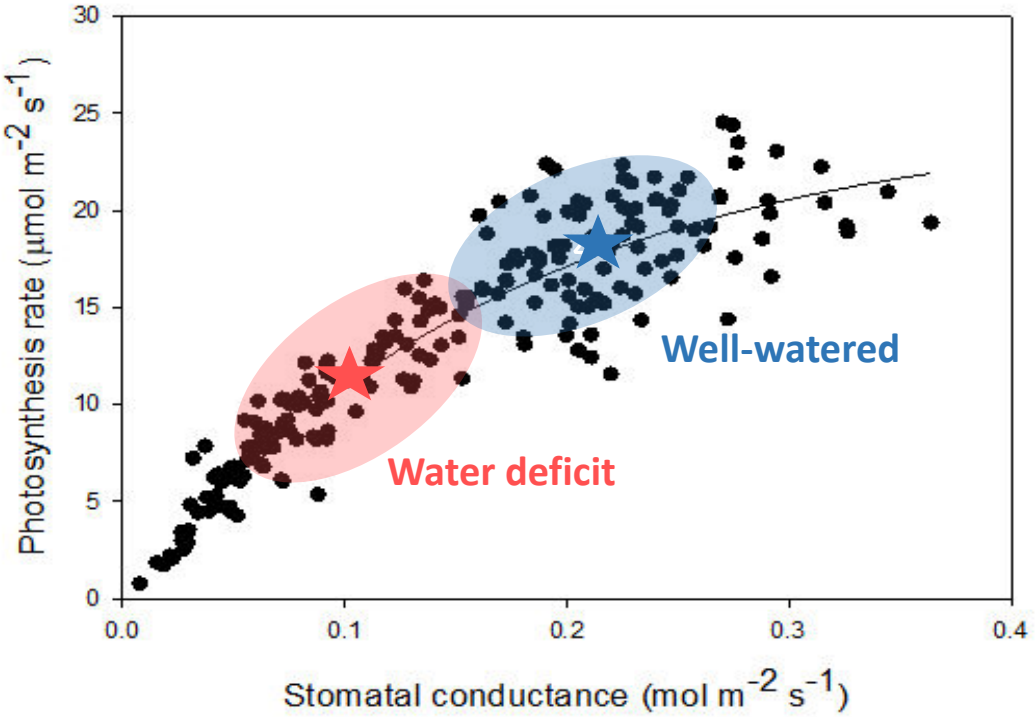
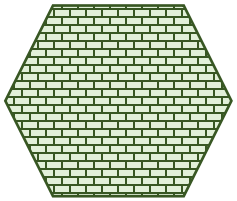
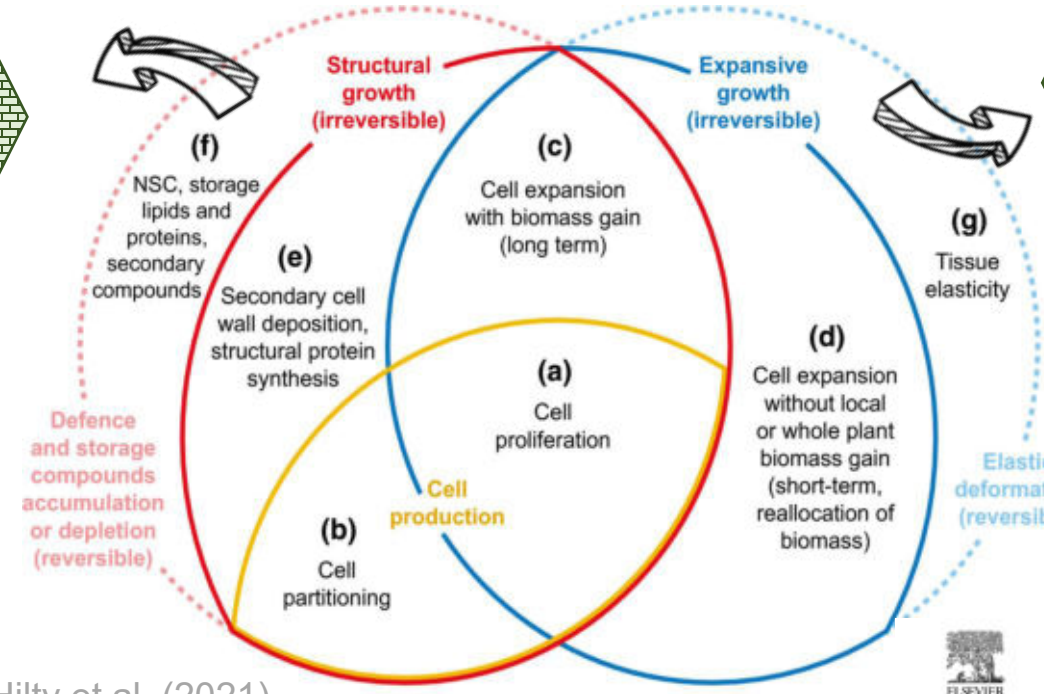
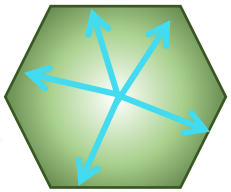




Speaking plants: cell turgor

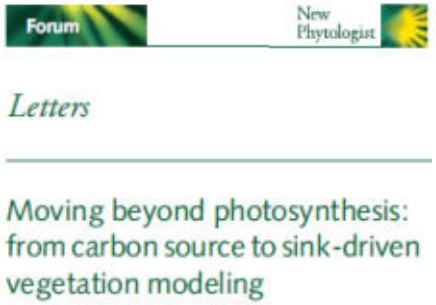


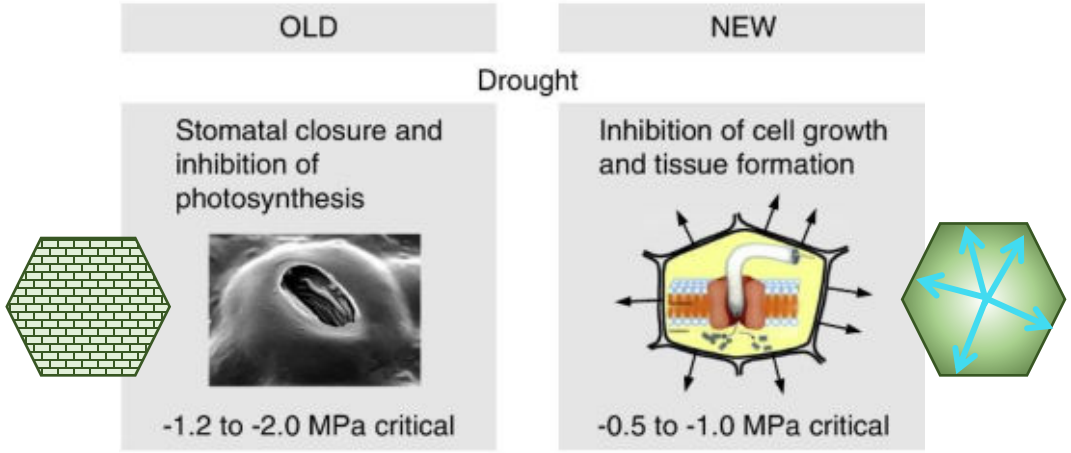




Hilty et al. (2021)

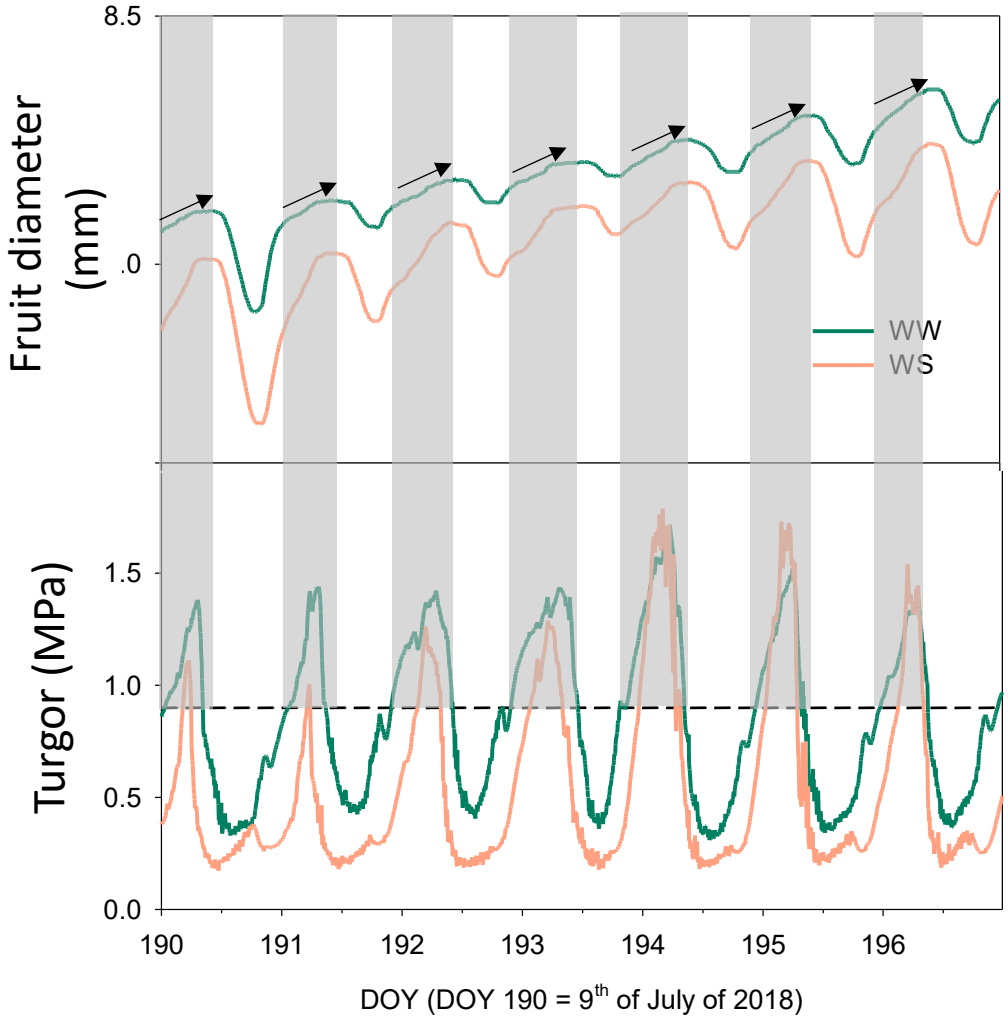






Speaking plants: cell turgor

- To examine the relative importance of turgor and photosynthesis in the cessation of fruit growth



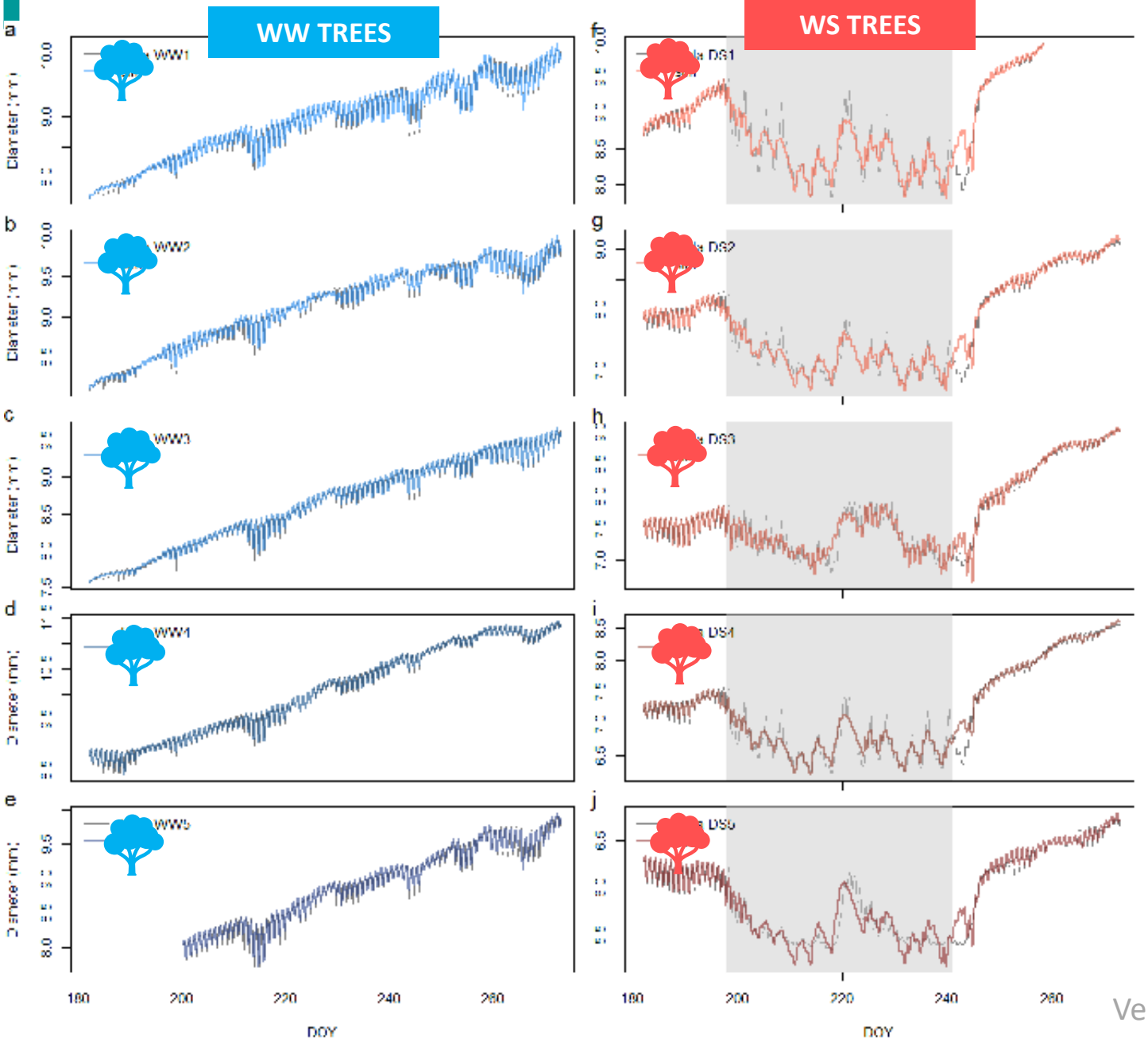


Growth threshold



Hernandez-Santana et al. (2021)

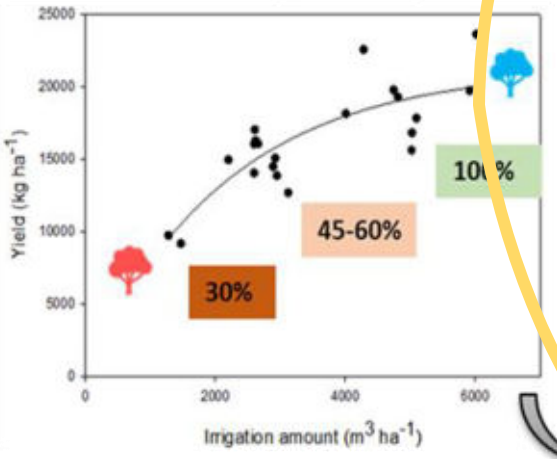
Speaking plants: cell turgor



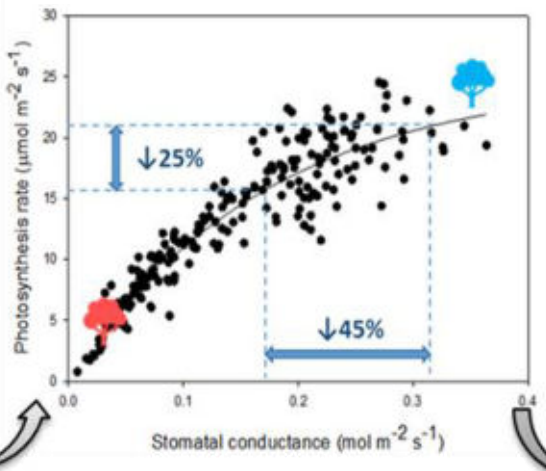
Verbeke et al. under review

Speaking plants: cell turgor

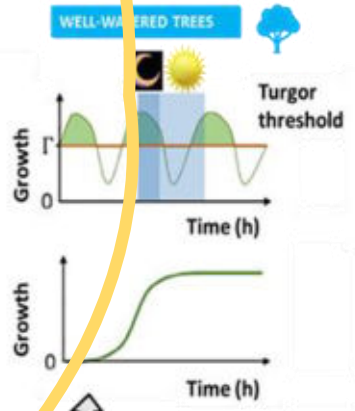
Classical yield response

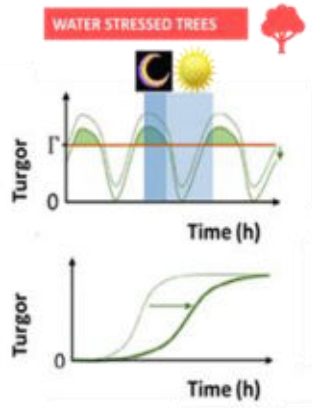


Model proposed based on photosynthesis



Model proposed based on the turgor loss





Modified from Coussement et al. (2021)

Speaking plants: does it work?











树干液流监测



气孔导度测定



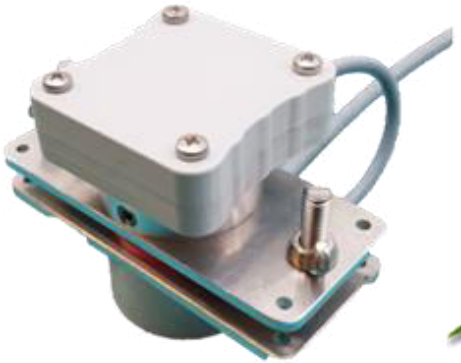
Speaking plants: towards bio-sensors for irrigation



Speaking plants: towards bio-sensors for irrigation

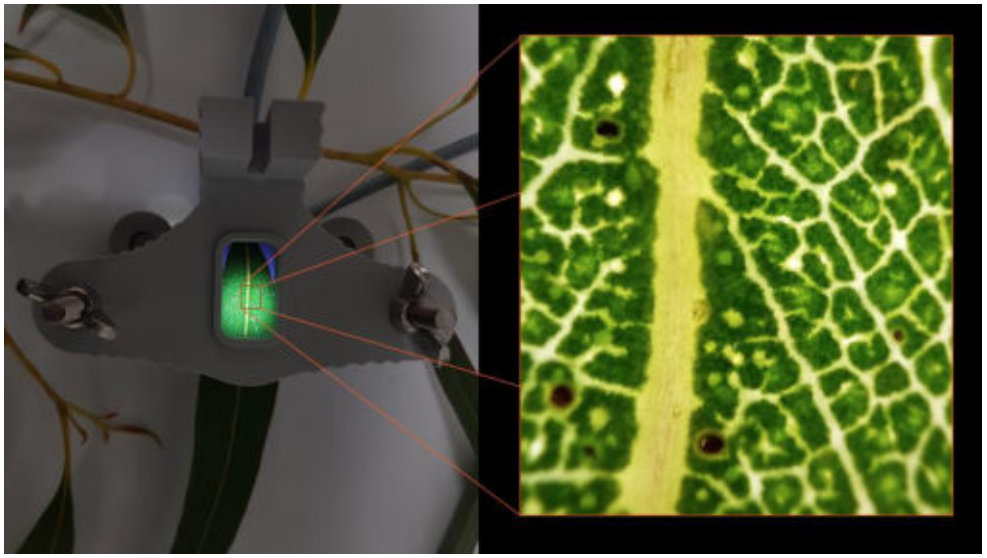


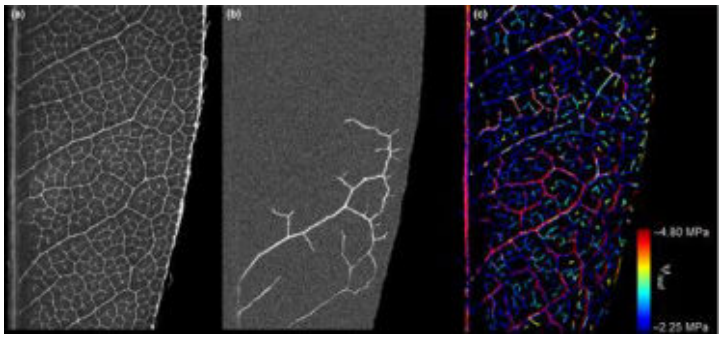
Novel sensors: cavicams



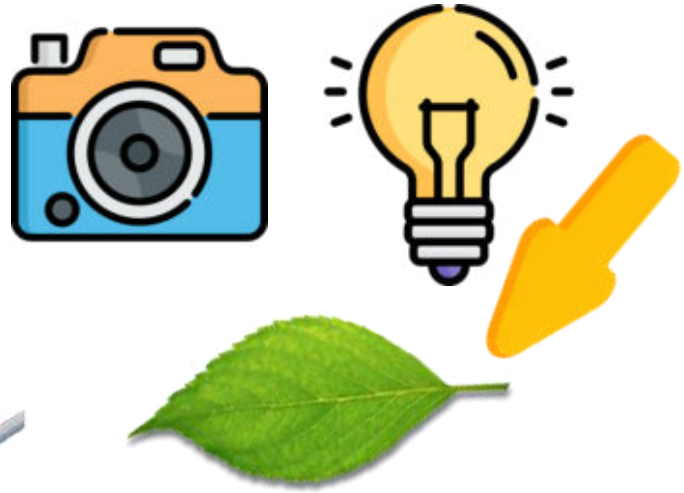


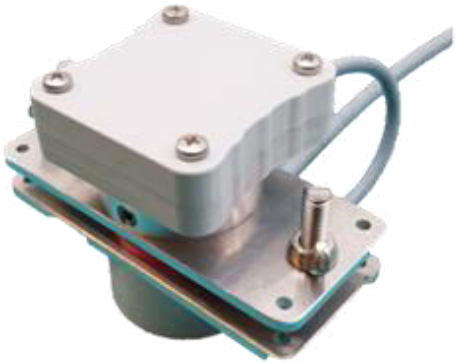


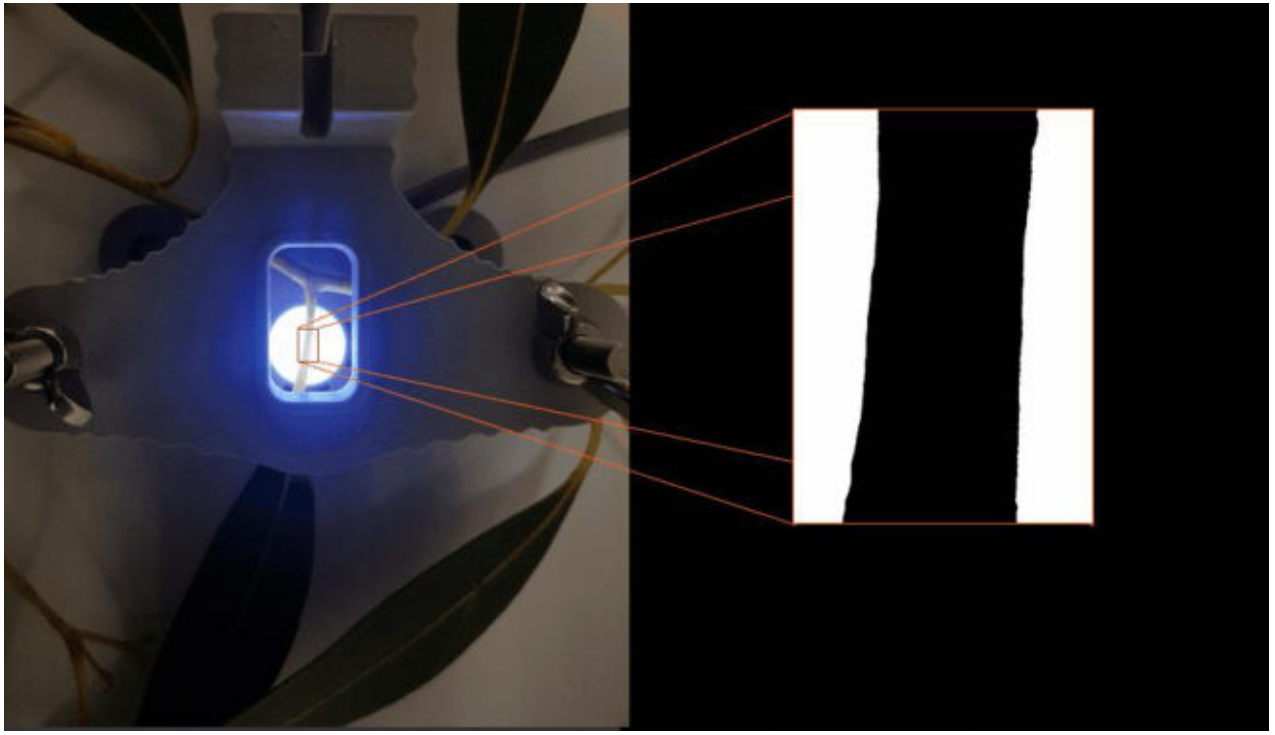




Novel sensors: cavicams can be used as optical dendrometers







New sensors: cavicams can be used as optical dendrometers …and thus to estimate water potential?

Journal of Experimental Botany
https://doi.org/10.1093/jxb/erac241 Advance Access Publication 21 June, 2022
This paper is available online free of all access charges (see https://academic.oup.com/jxb/pages/openaccess for further details)

RESEARCH PAPER

Constant hydraulic supply enables optical monitoring of transpiration in a grass, a herb, and a conifer

Ibrahim Bourbia, Christopher Lucani and Timothy J. Brodribb*

Based on the linear relationship between tissue width - Ψ_{leaf}



Agricultural and Forest Meteorology 331 (2023) 109328

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Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

A new technique for monitoring plant transpiration under field conditions using leaf optical dendrometry

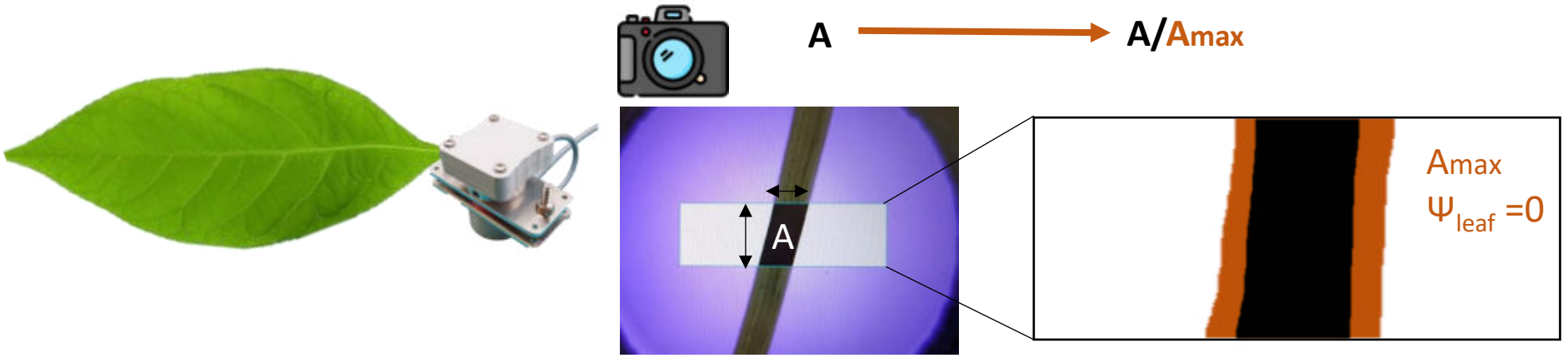
Ibrahim Bourbia *, Timothy J Brodribb *



- Range of water potentials over which linearity applies?
- Possibility of avoiding new empirical calibrations to predict Ψ_{leaf} each time the sensors are installed?

New sensors: cavicams can be used as optical dendrometers …and thus to estimate water potential?

Mechanistic approach to calibrate optical dendrometers, as non-invasive tools for continuous Ψ_{leaf} estimation in non-growing tissues



A/A_{max} from optical dendrometers can serve as a proxy for **RWC** (0-1)

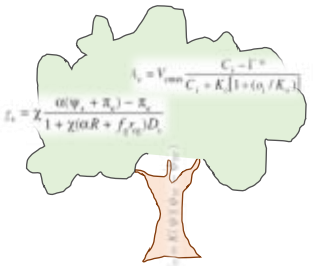
Hernandez-Santana et al. in preparation

Conclusions



Remote sensing





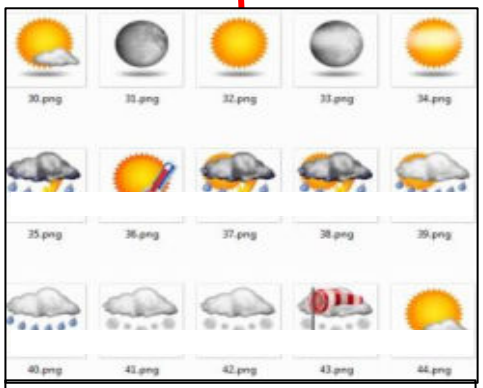
Plant sensors and models



Field data

Hybrid Decission Support System

- plant sensors
- mechanistic models
- *AI-driven analytics*



Weather forecast

Conclusions

- **Advanced use of plant sensors to measure ecophysiological variables (such as stomatal conductance, turgor, and others), includes mechanistic modelling that can support more efficient irrigation management and contribute to the development of irrigation decision-support tools.**
- **Despite the promising results obtained in both experimental and commercial settings, further work is needed on management, economic and social aspects to enable broader adoption and implementation of these approaches.**
- **Some emerging sensors show great potential, but additional research and development are needed before they can be reliably used in the field.**

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Thanks for your attention!!

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