Reading
03/12/2018

DO PLANTS FOLLOW A PROFIT-MAXIMISATION APPROACH DURING DROUGHT?

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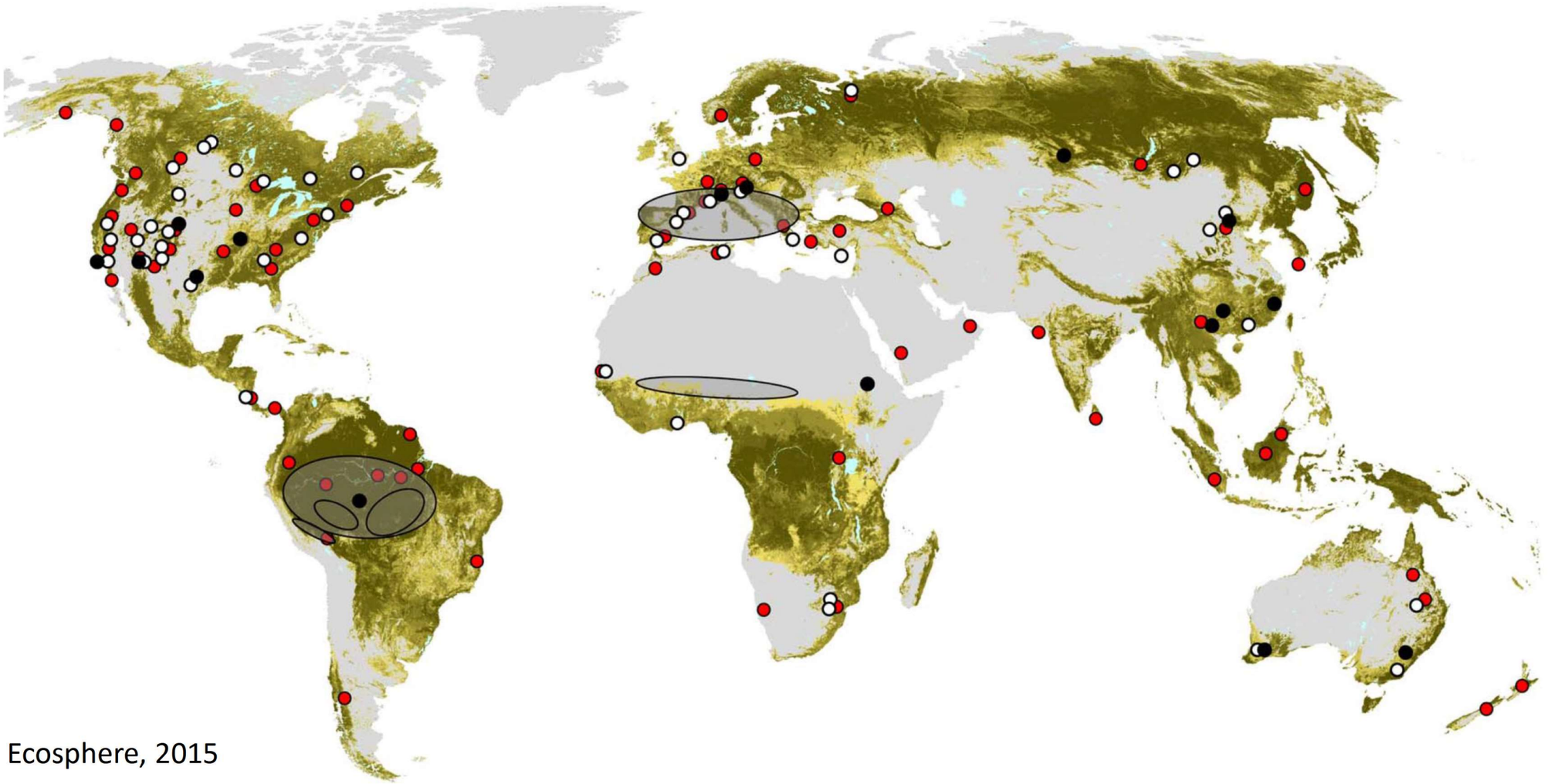
Why does understanding plant response to drought matter?



Allen et al., Ecosphere, 2015

Why does understanding plant response to drought matter?

nature climate change

LETTERS

PUBLISHED ONLINE: 18 MAY 2015 | DOI: 10.1038/NCLIMATE2641

Darcy's law predicts widespread forest mortality under climate warming

Nathan G. McDowell[1]* and Craig D. Allen[2]

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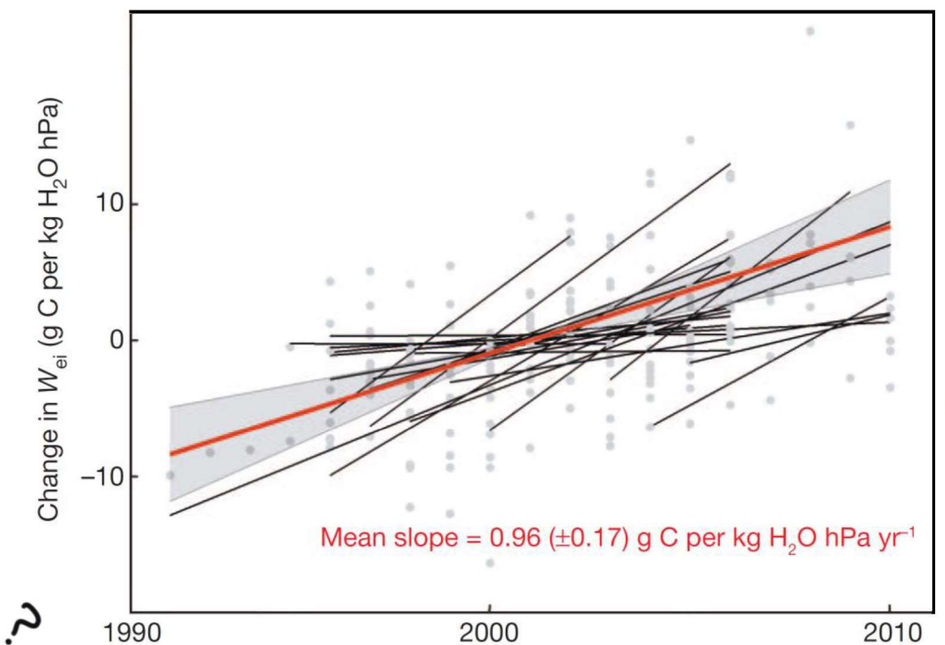
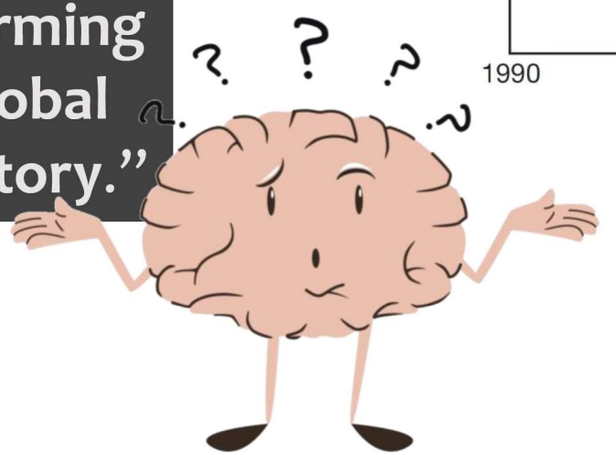
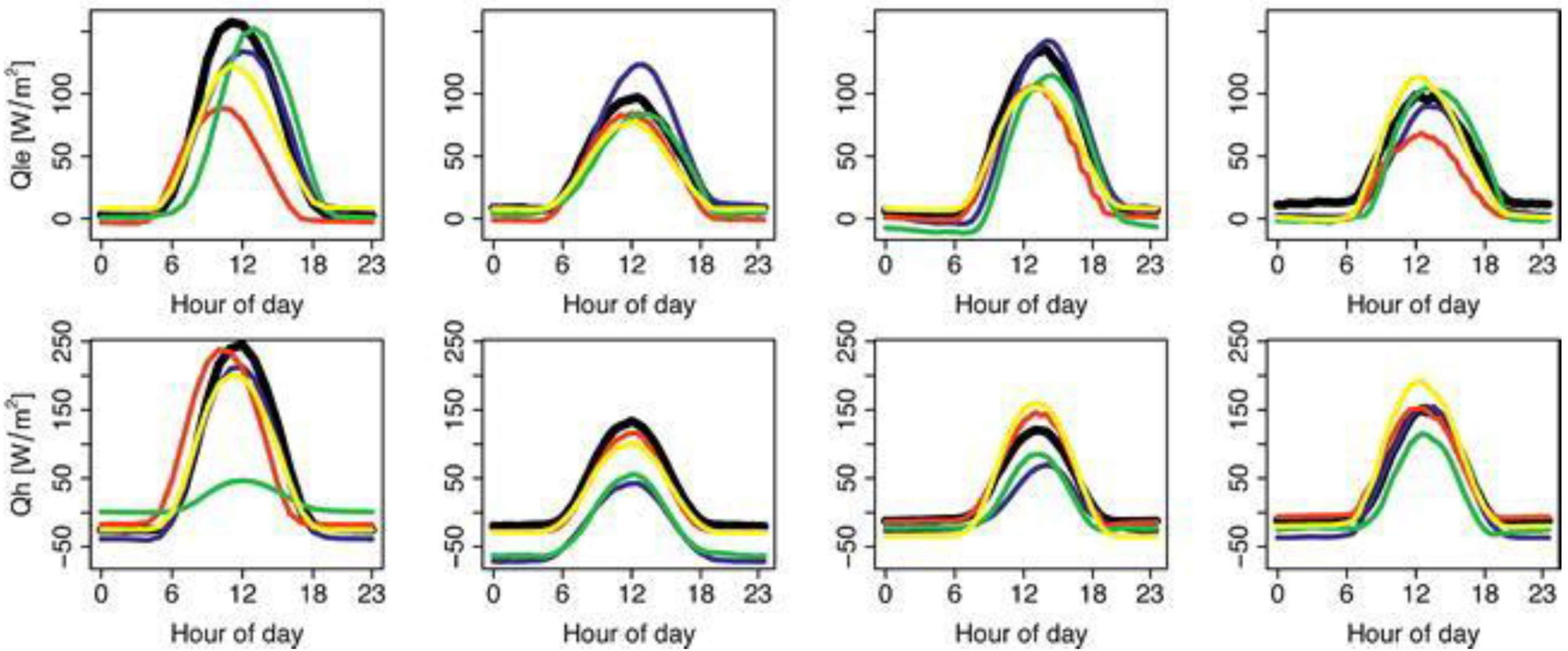


Keenan et al., Nature, 2013

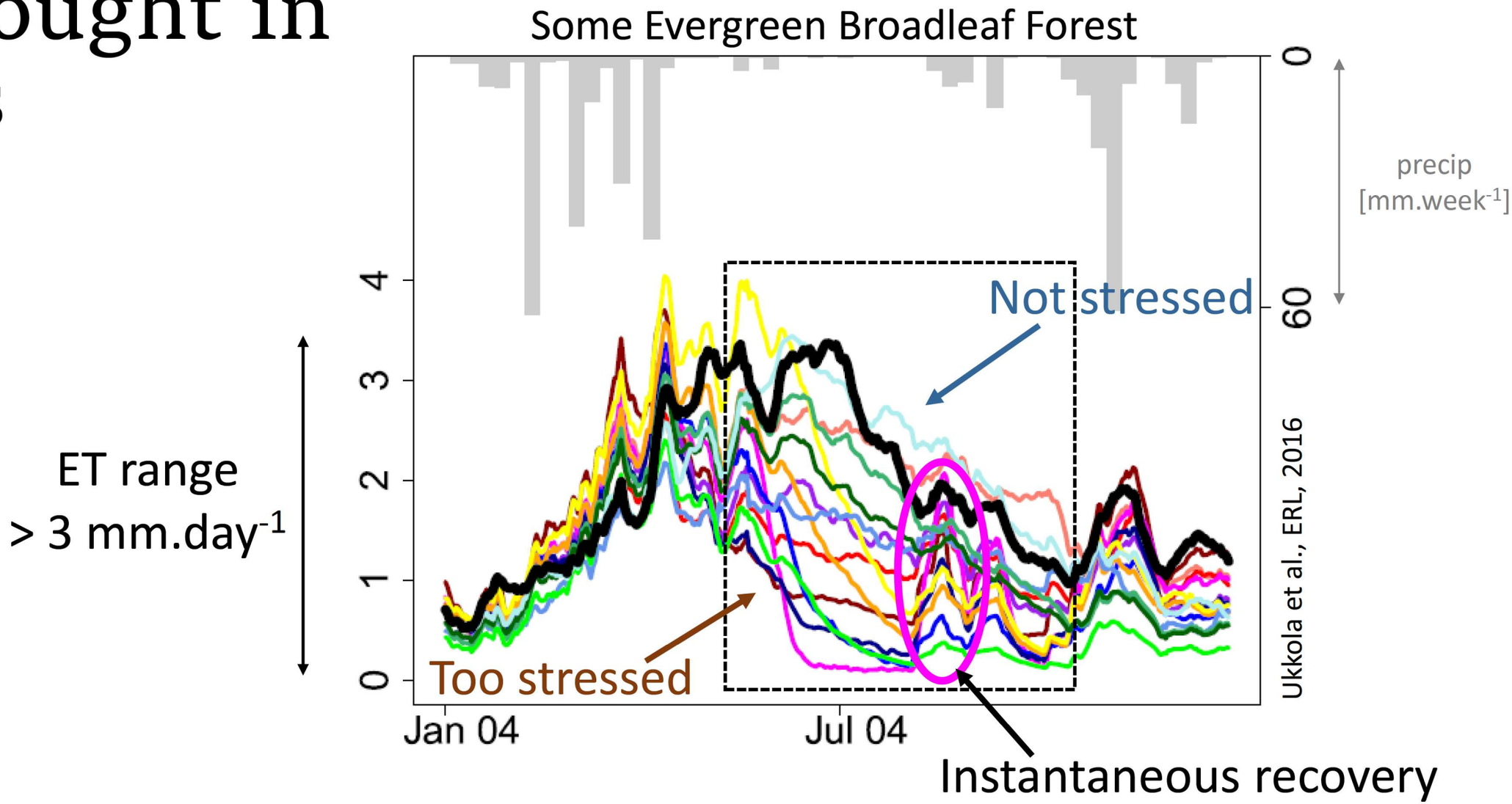


Land surface models were developed for large scales and average conditions



Abramowitz et al., Journal of Climate, 2007

Representation of drought in LSMs



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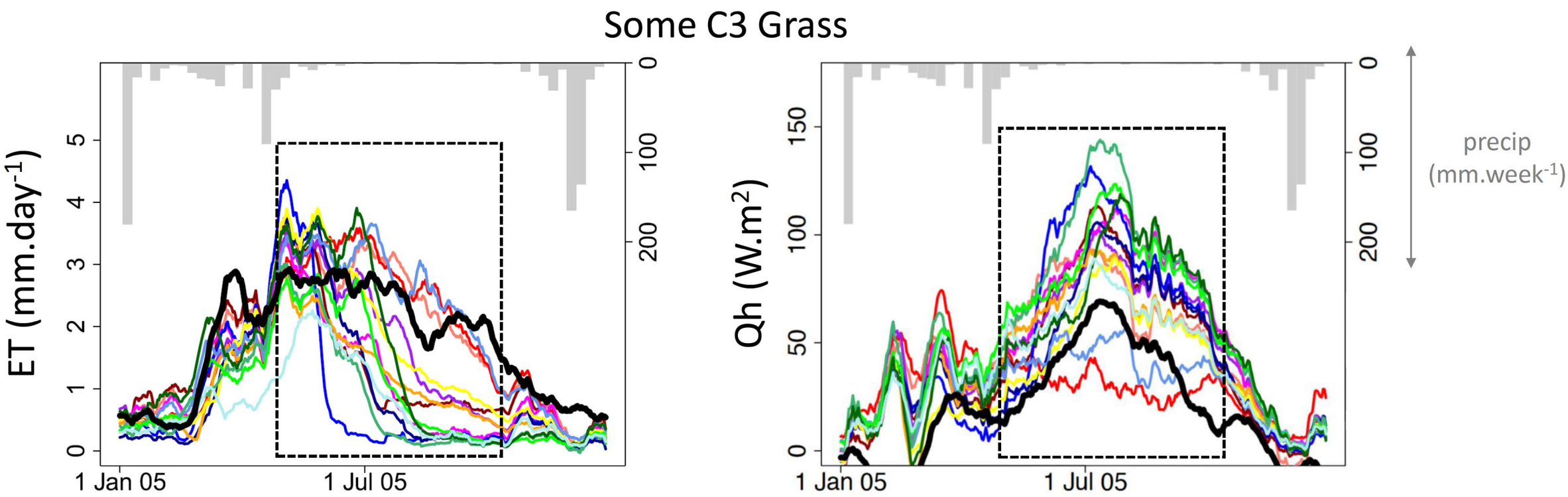
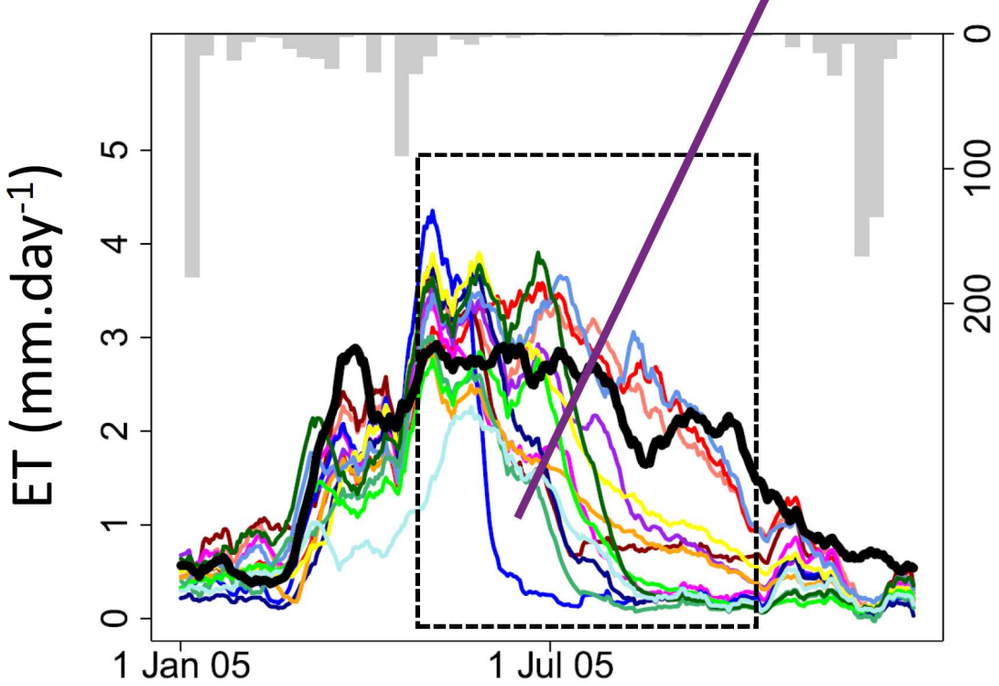
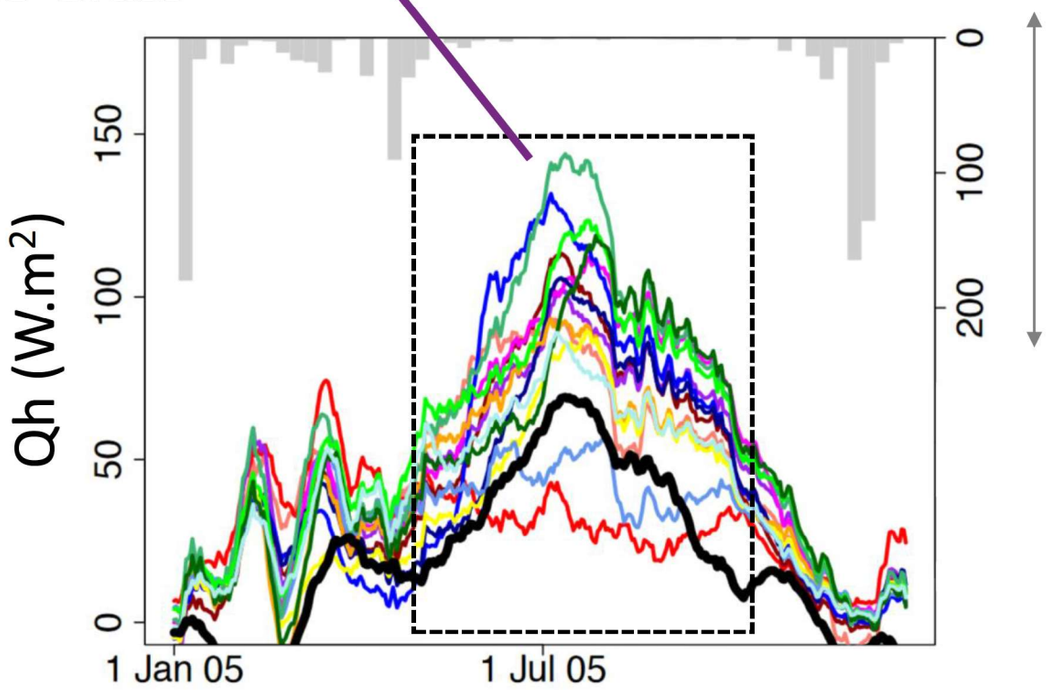


Ukkola et al., ERL, 2016

Representation of drought in LSMs

Some C3 Grass





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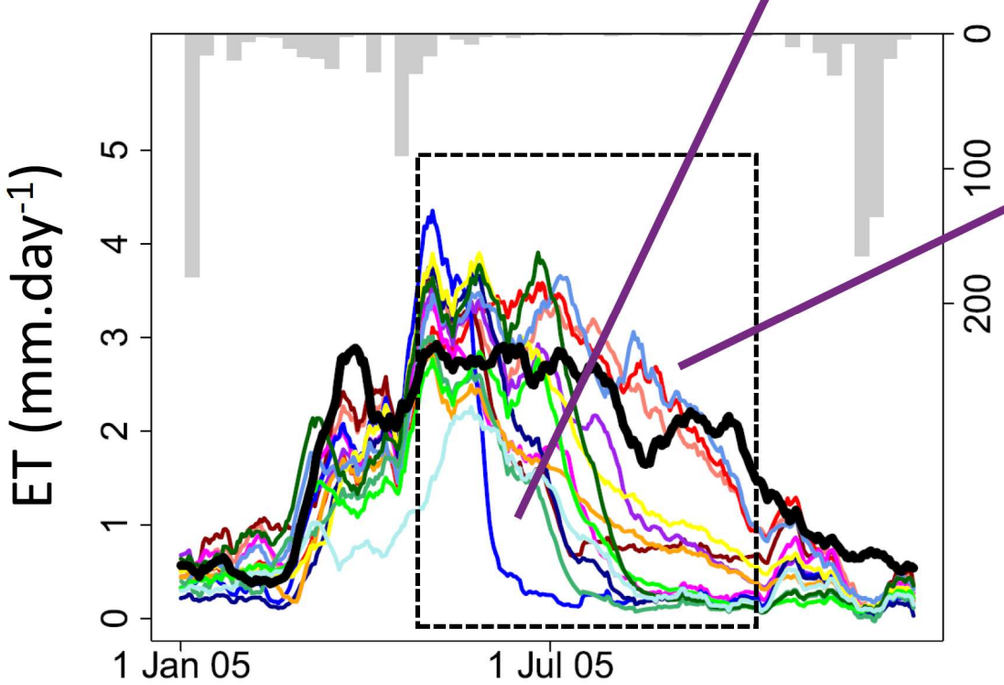

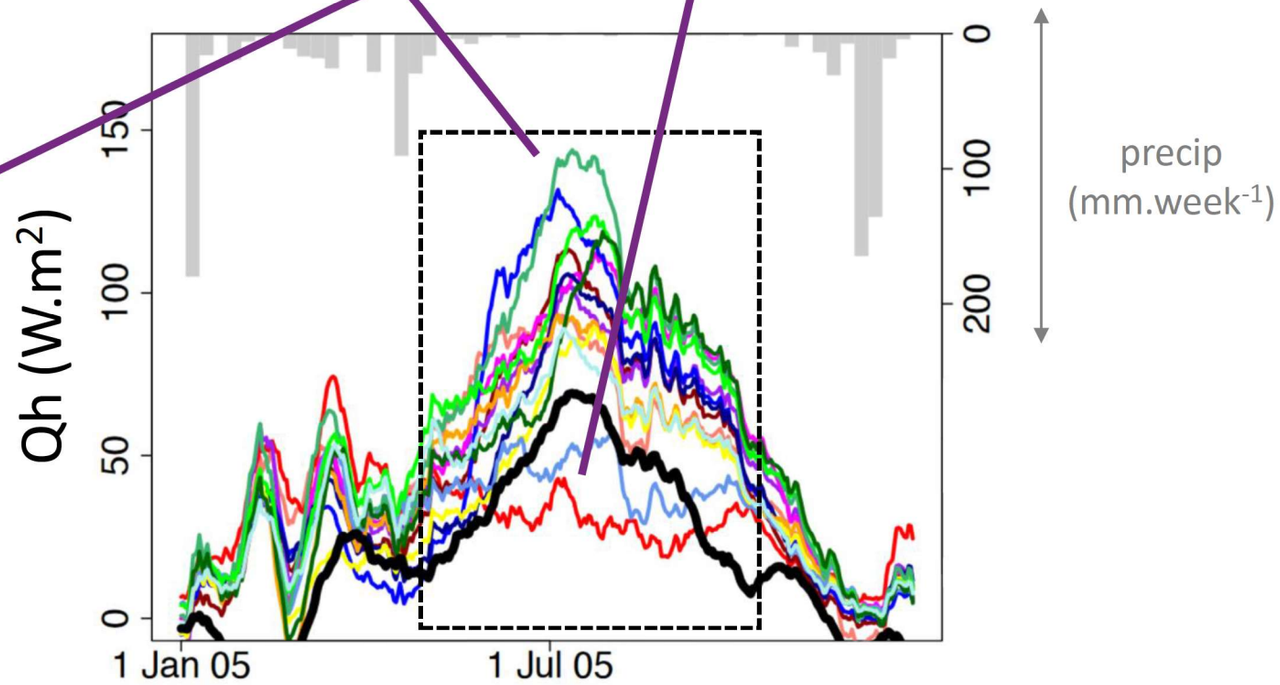

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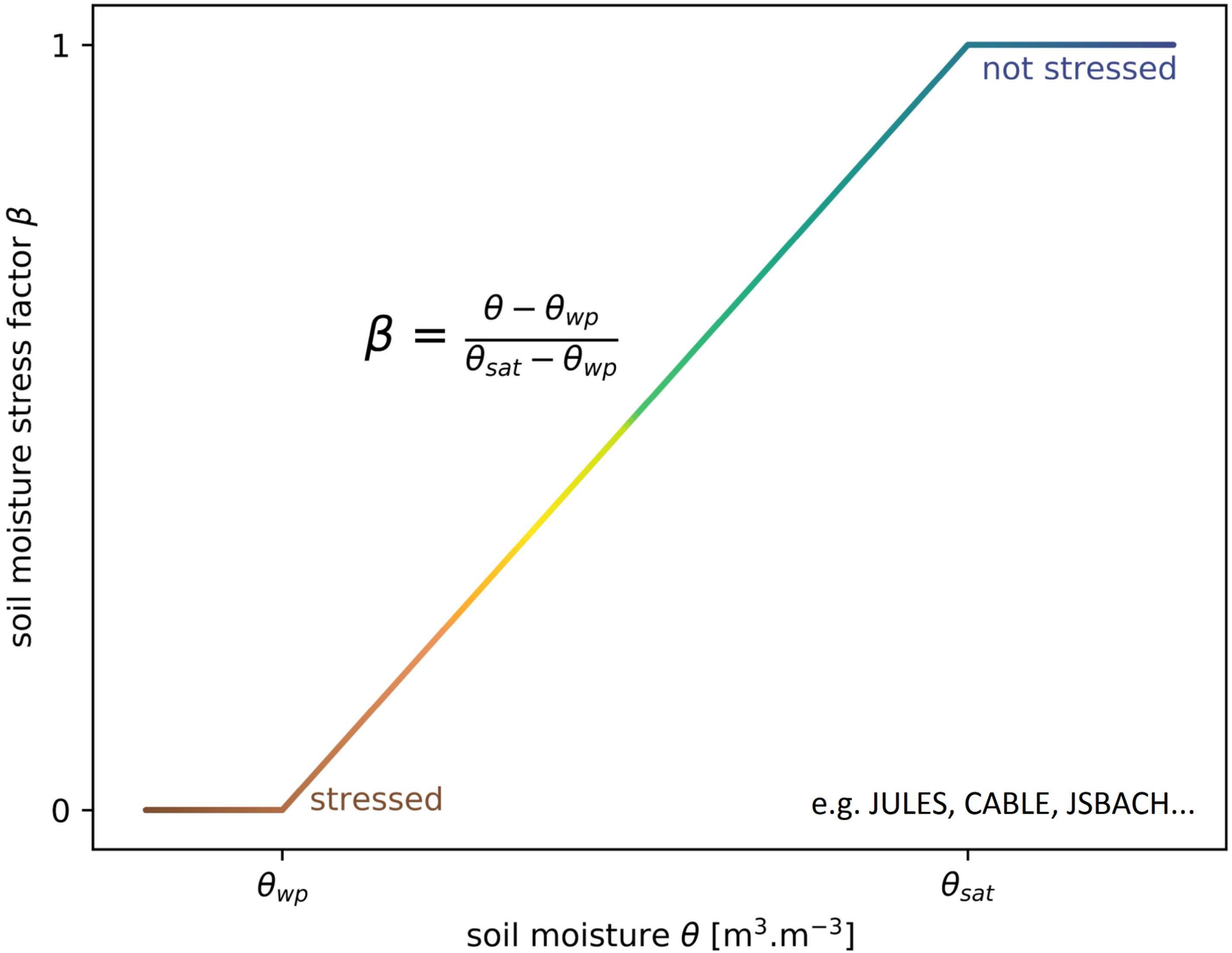
Soil moisture stress factor with scarce empirical support



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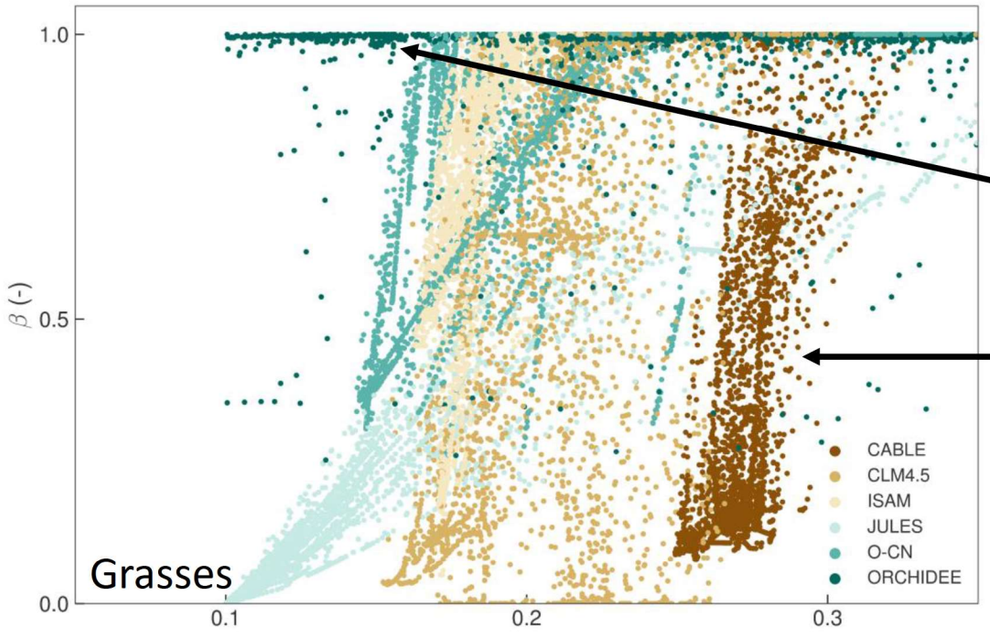
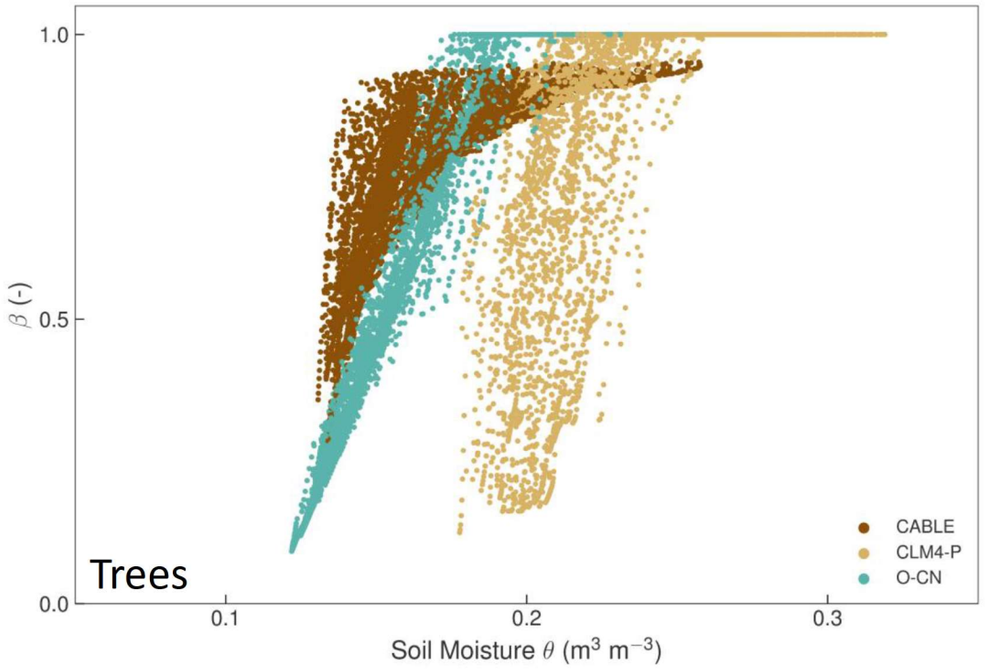




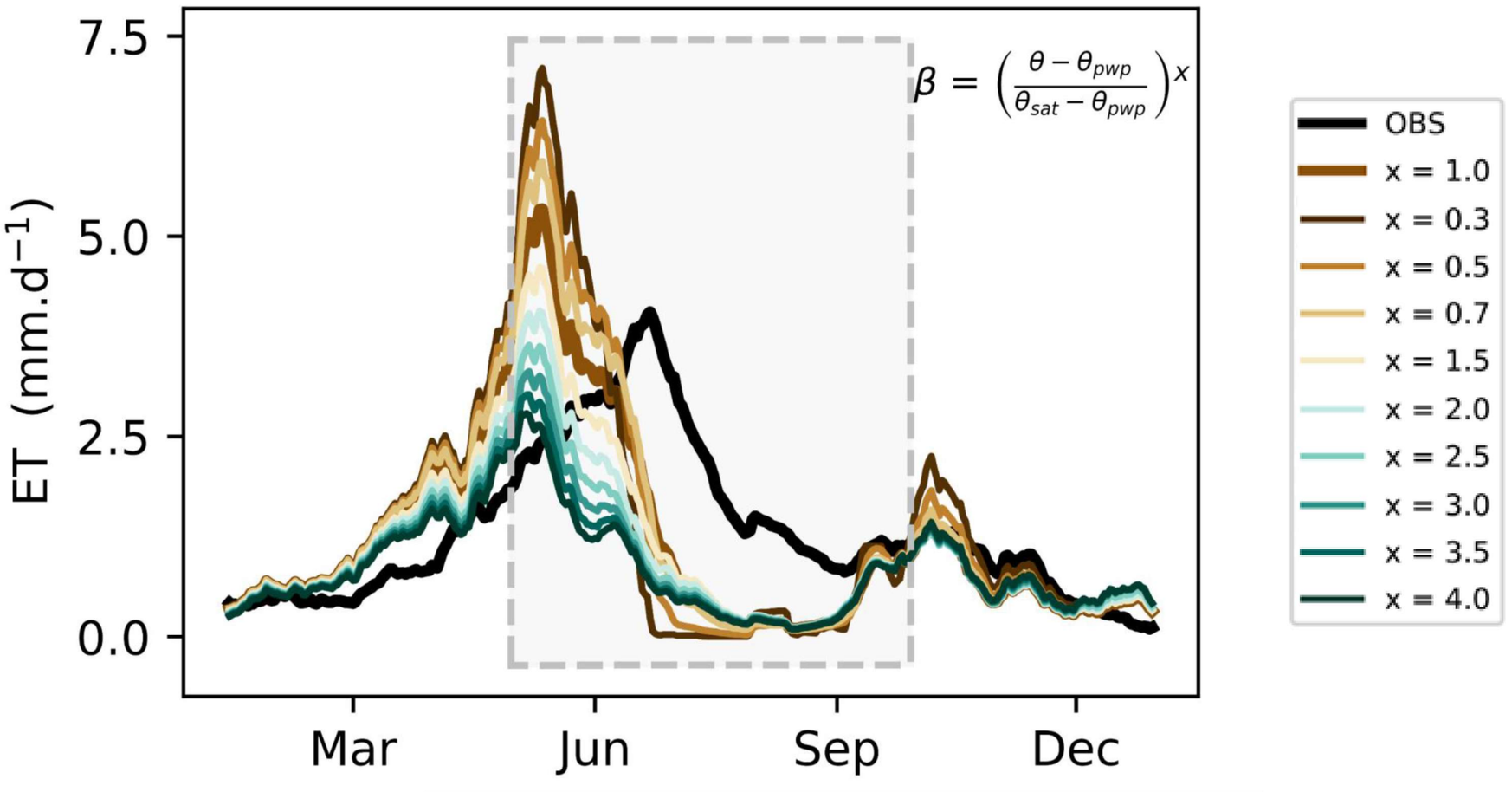
Not stressed

Rapid critical stress

De Kauwe et al., GCB, 2017

Medlyn et al., GCB, 2016

Calibrating β is not a viable long-term solution



Implications for the future

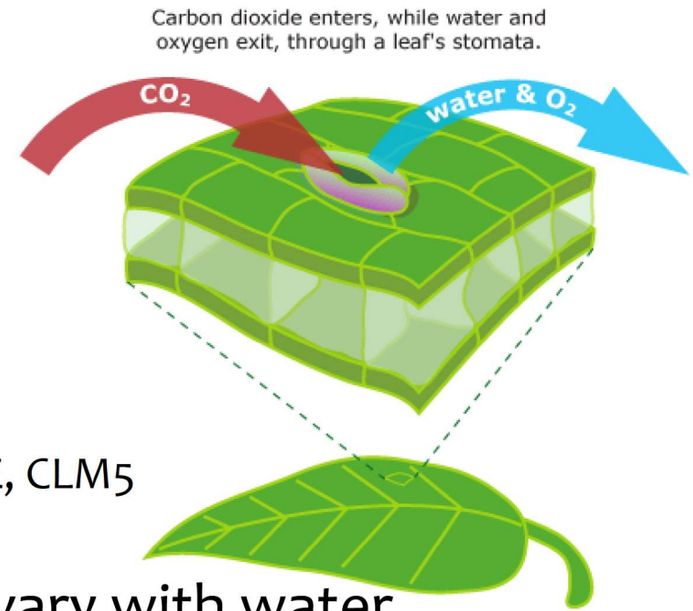
Do we know the sign of change in future drought?

- Increased evaporative demand
- Increased water use efficiency

Do we know the magnitude of the land feedback on future heatwaves or droughts?

- Do we do moisture stress well?
- Can we say anything about plant mortality?

Plant water/carbon use strategies – optimisation theories



Classic Water Use Efficiency Hypothesis (WUEH):

$$\frac{\partial A_n}{\partial g_s} = \lambda \frac{\partial E}{\partial g_s}$$

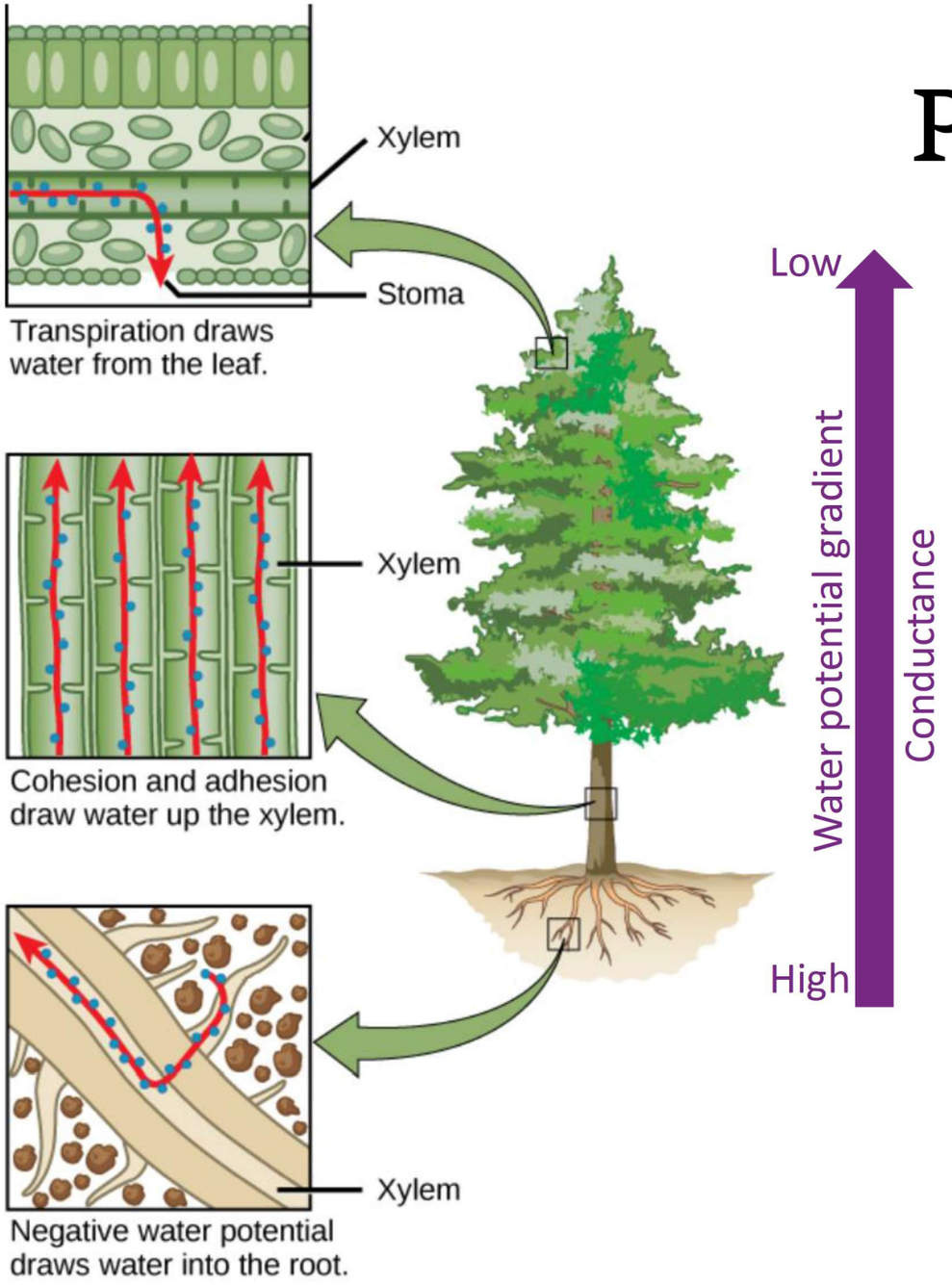
e.g. CABLE, CLM5

But what is λ? On what time scale is this true? How does it vary with water stress?

Least-cost hypothesis:

$$a \frac{\partial (V_{cmax}/A_n)}{\partial (C_i/C_a)} = -b \frac{\partial (E/A_n)}{\partial (C_i/C_a)}$$

Plant hydraulics account for water stress



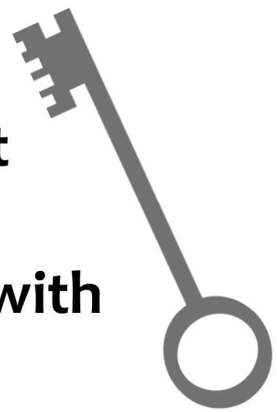
Mechanistic approach

Relies on measurable parameters

But computentially expensive

Comparison to data or to other methods when implemented in a LSM?

Linking optimality theories with plant hydraulics



the marginal cost increases instantaneously with moisture stress

Wolf et al. , PNAS, 2016
Sperry et al., PCE, 2017

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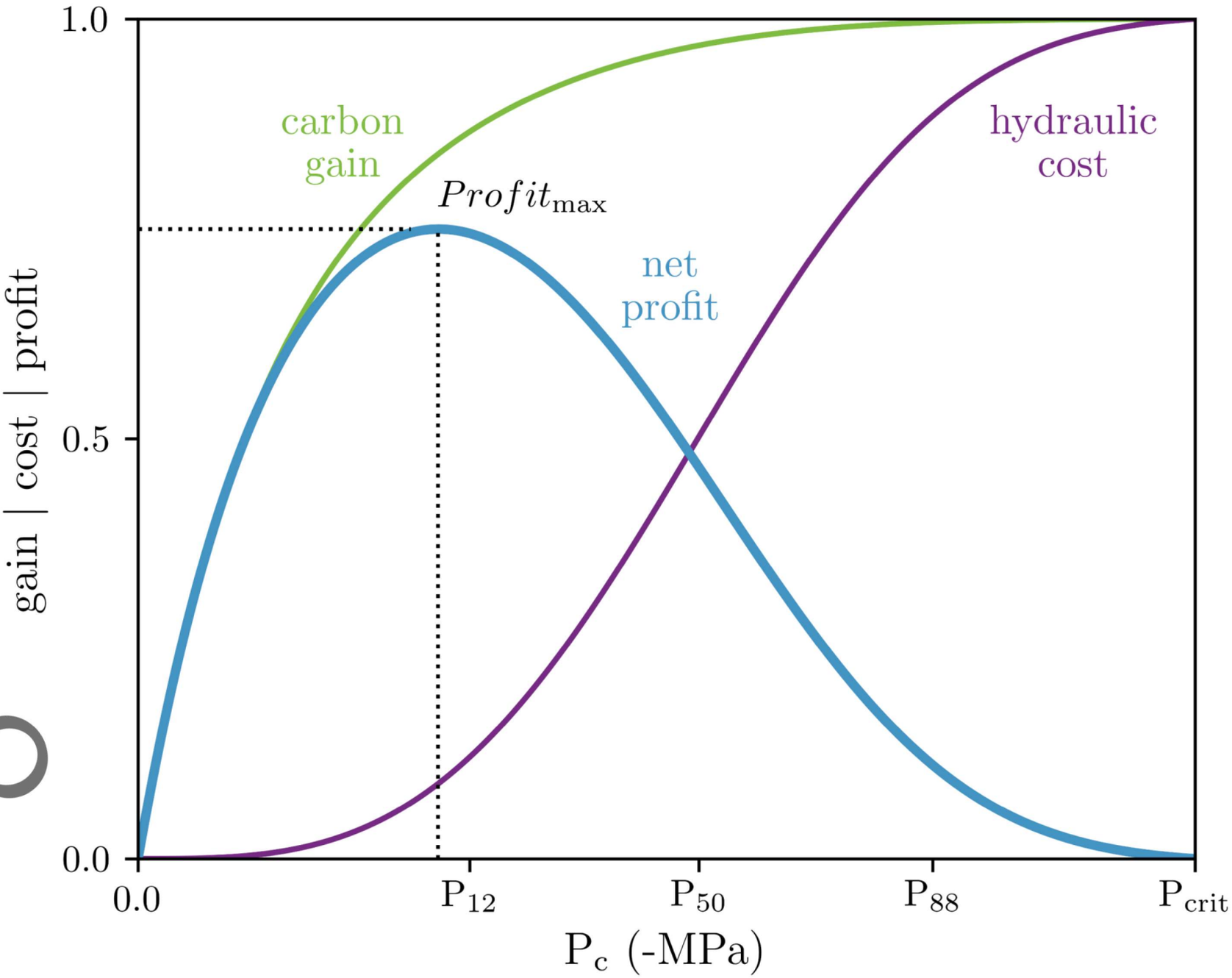

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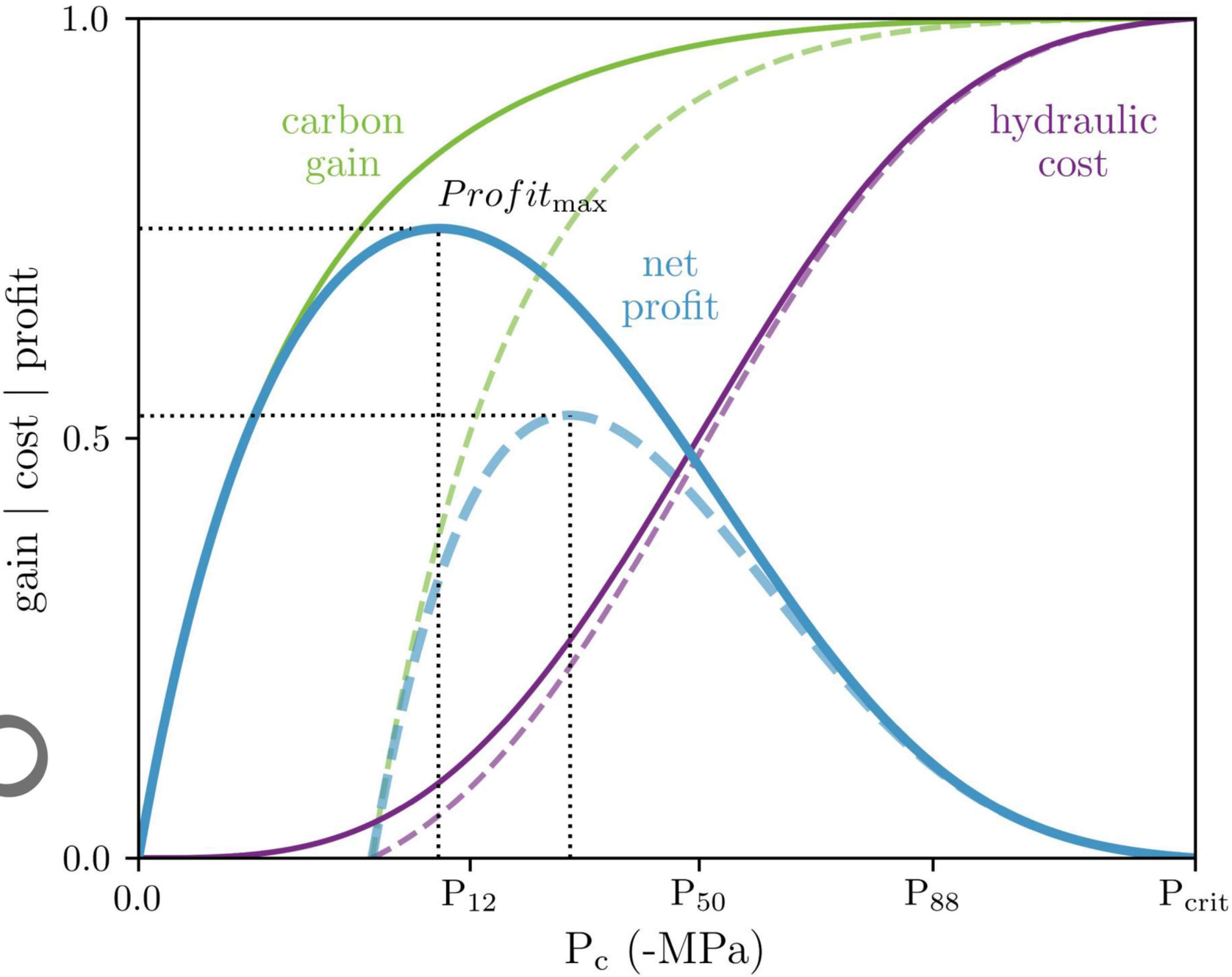
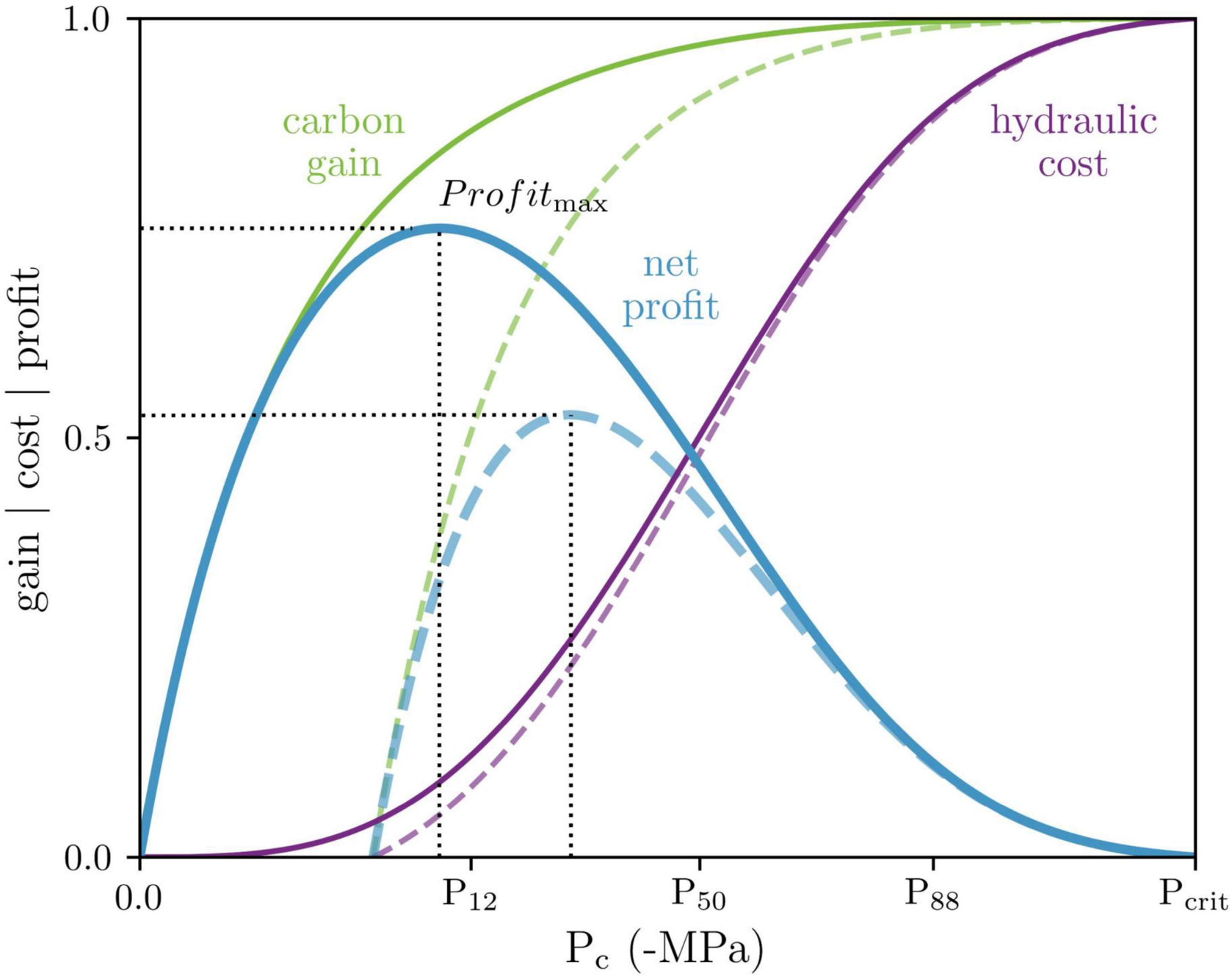


Linking optimality theories with plant hydraulics

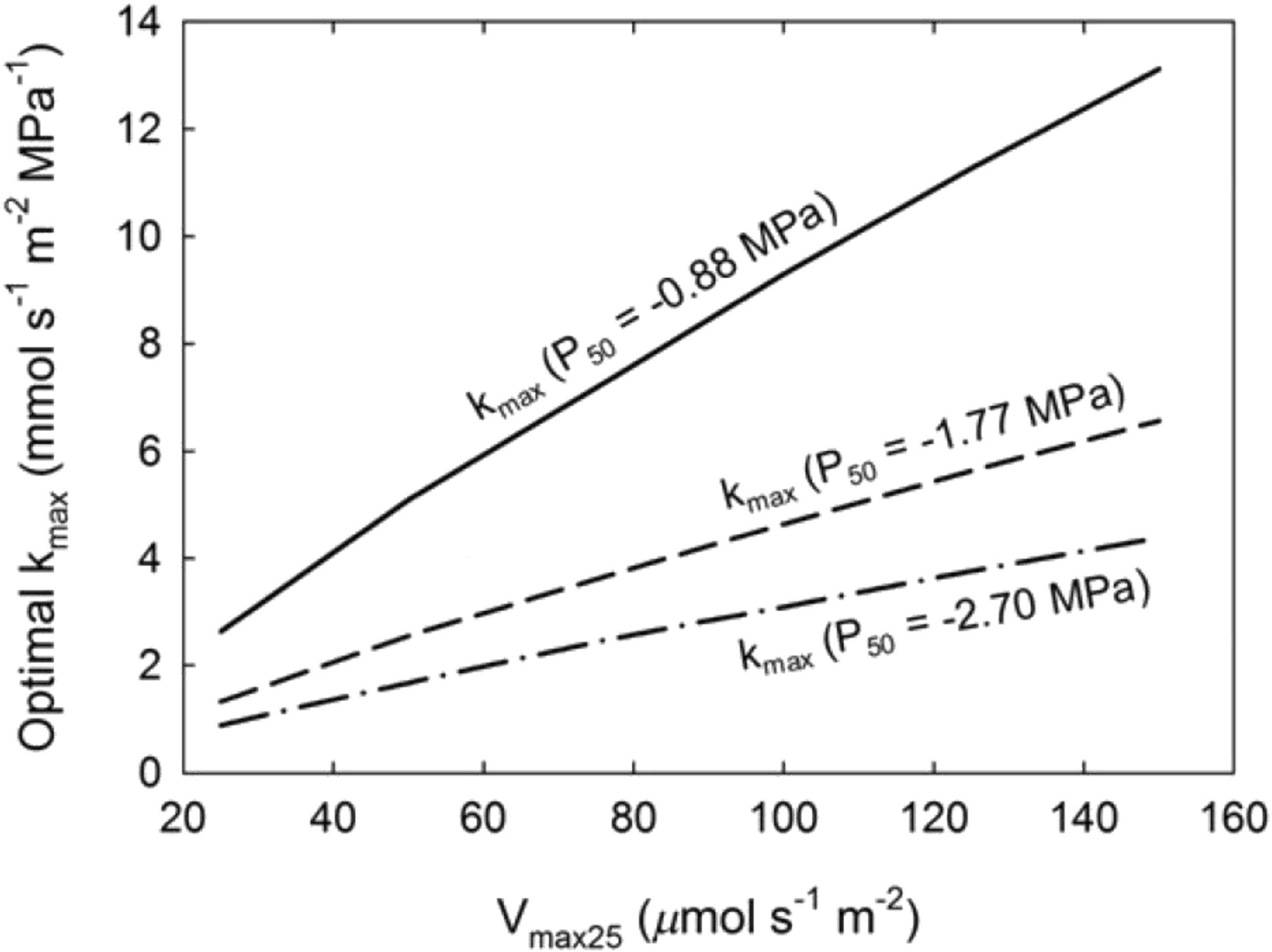
minimum of three parameters: P_{x1}, P_{x2}, k_{max}

Wolf et al. , PNAS, 2016
Sperry et al., PCE, 2017



Linking optimality theories with plant hydraulics

$C_i/C_a = 0.7$
$T_{air} = 25\ ^\circ C$
VPD = 1 kPa
$P_s = -0$ MPa



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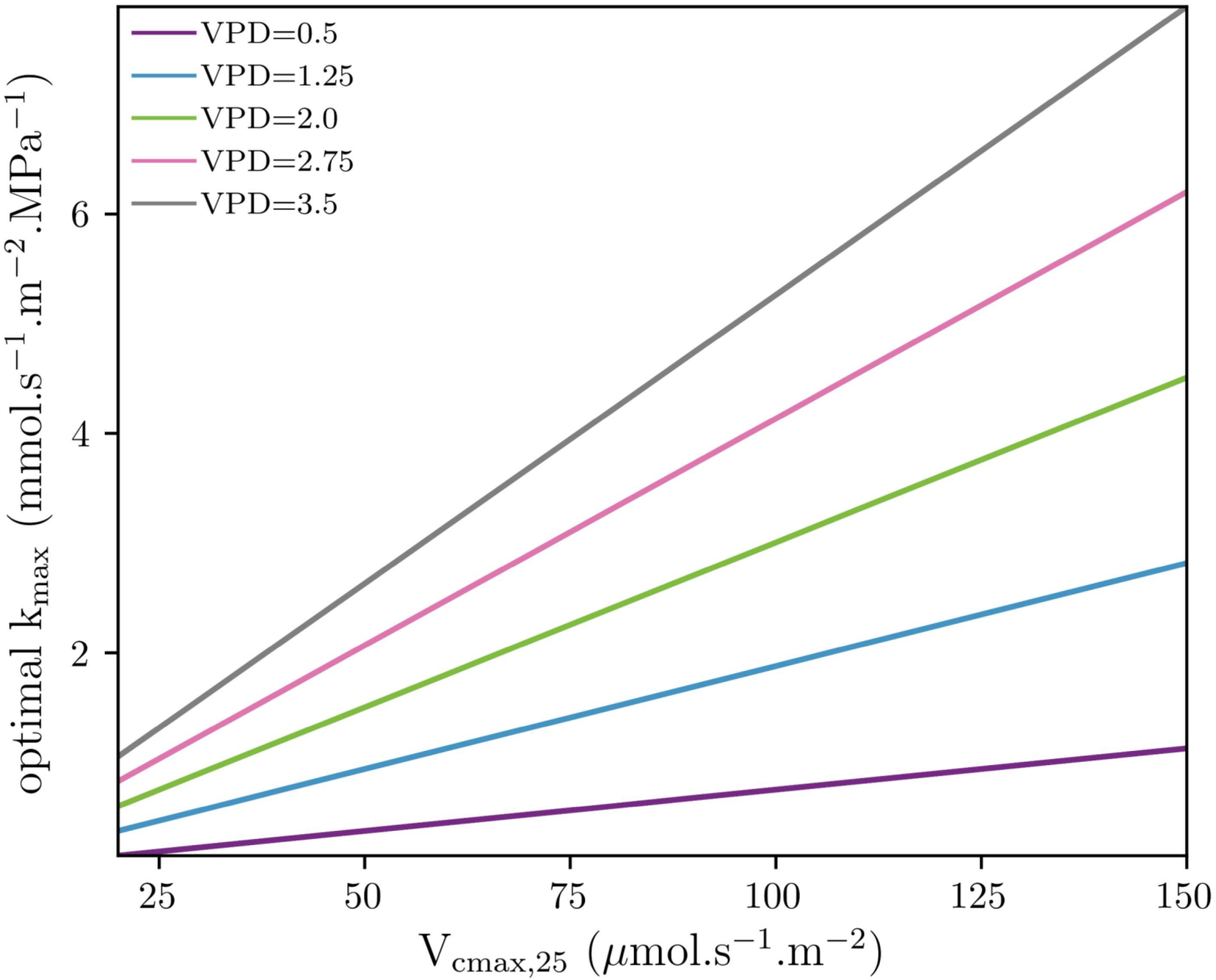

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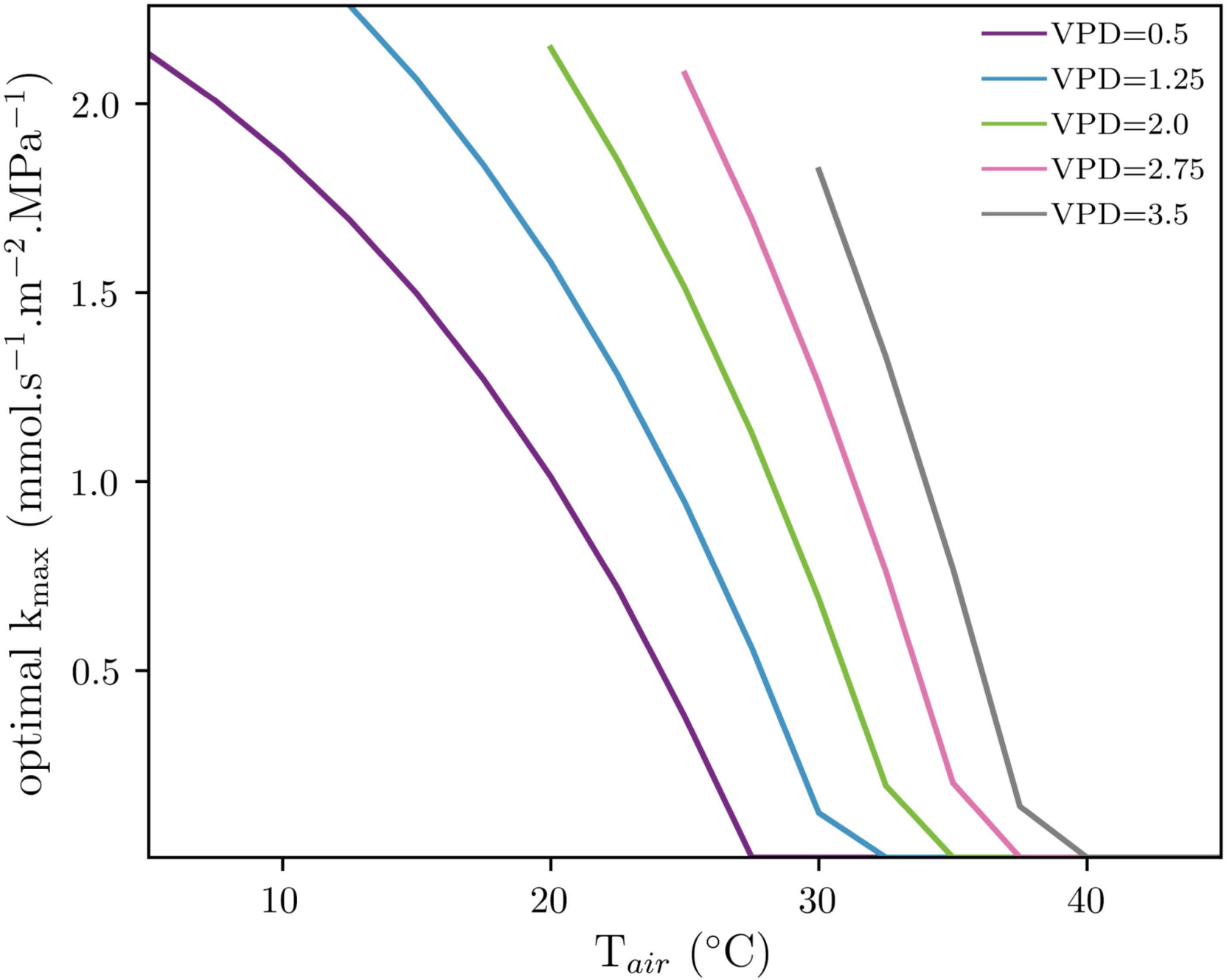

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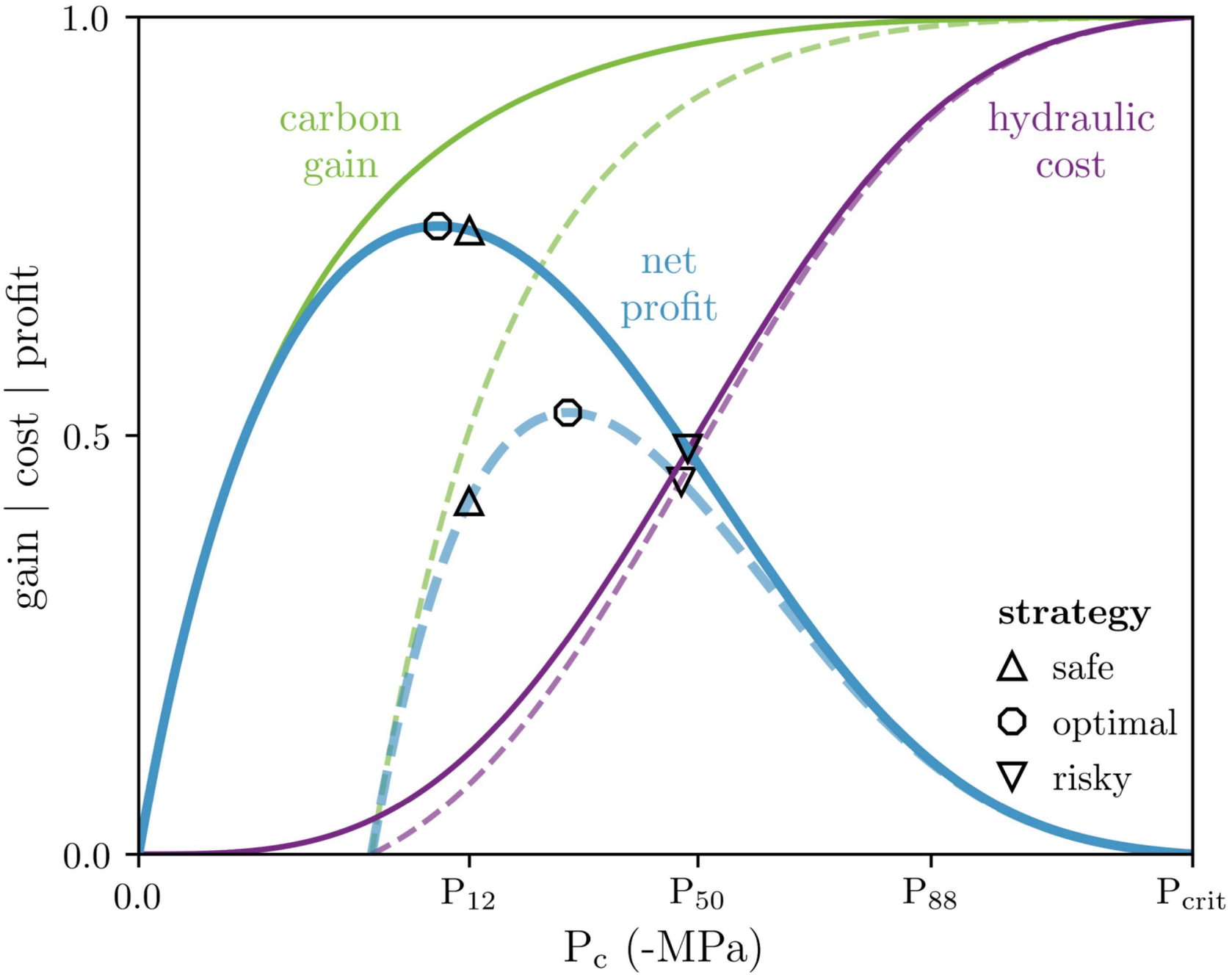

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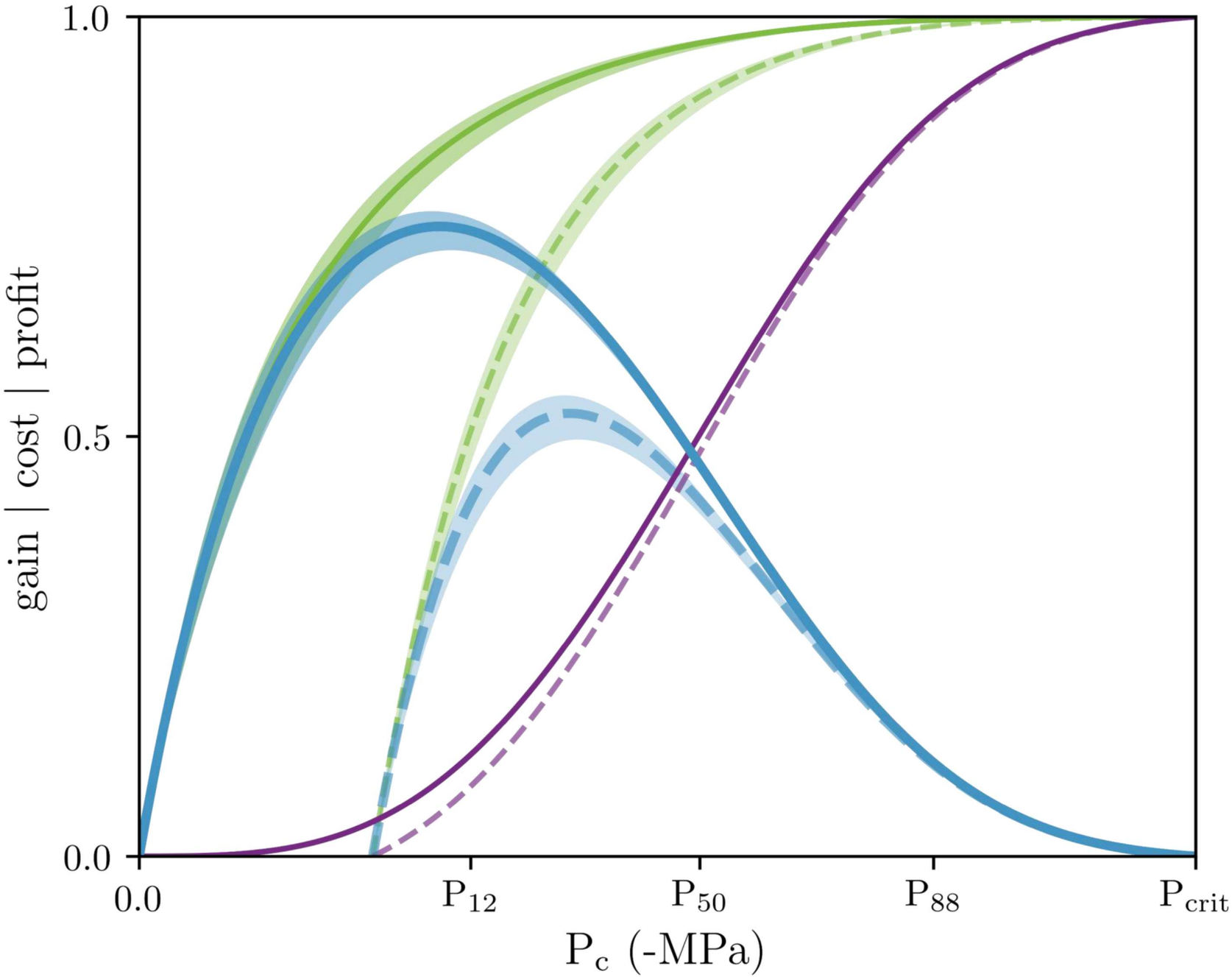
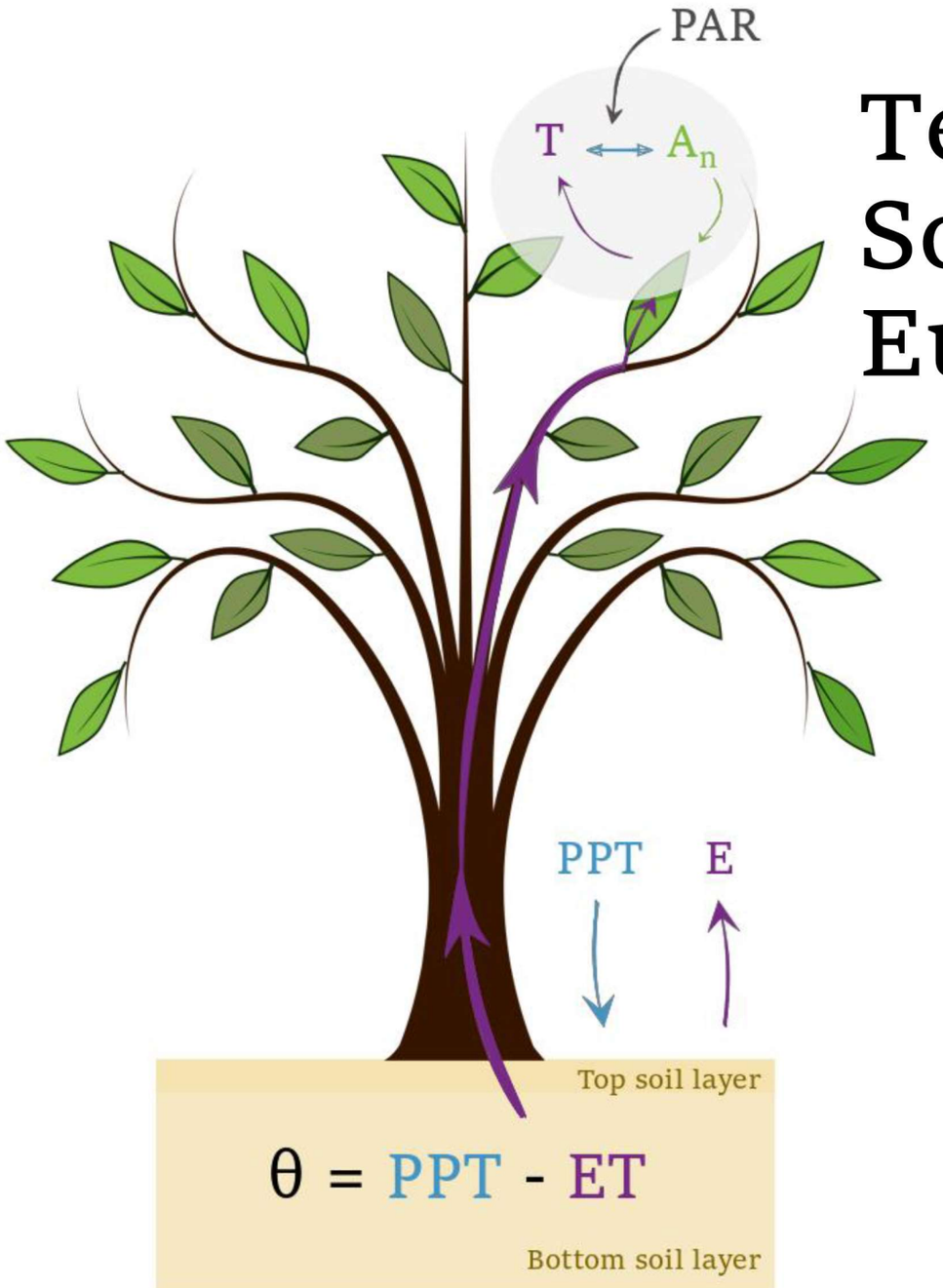
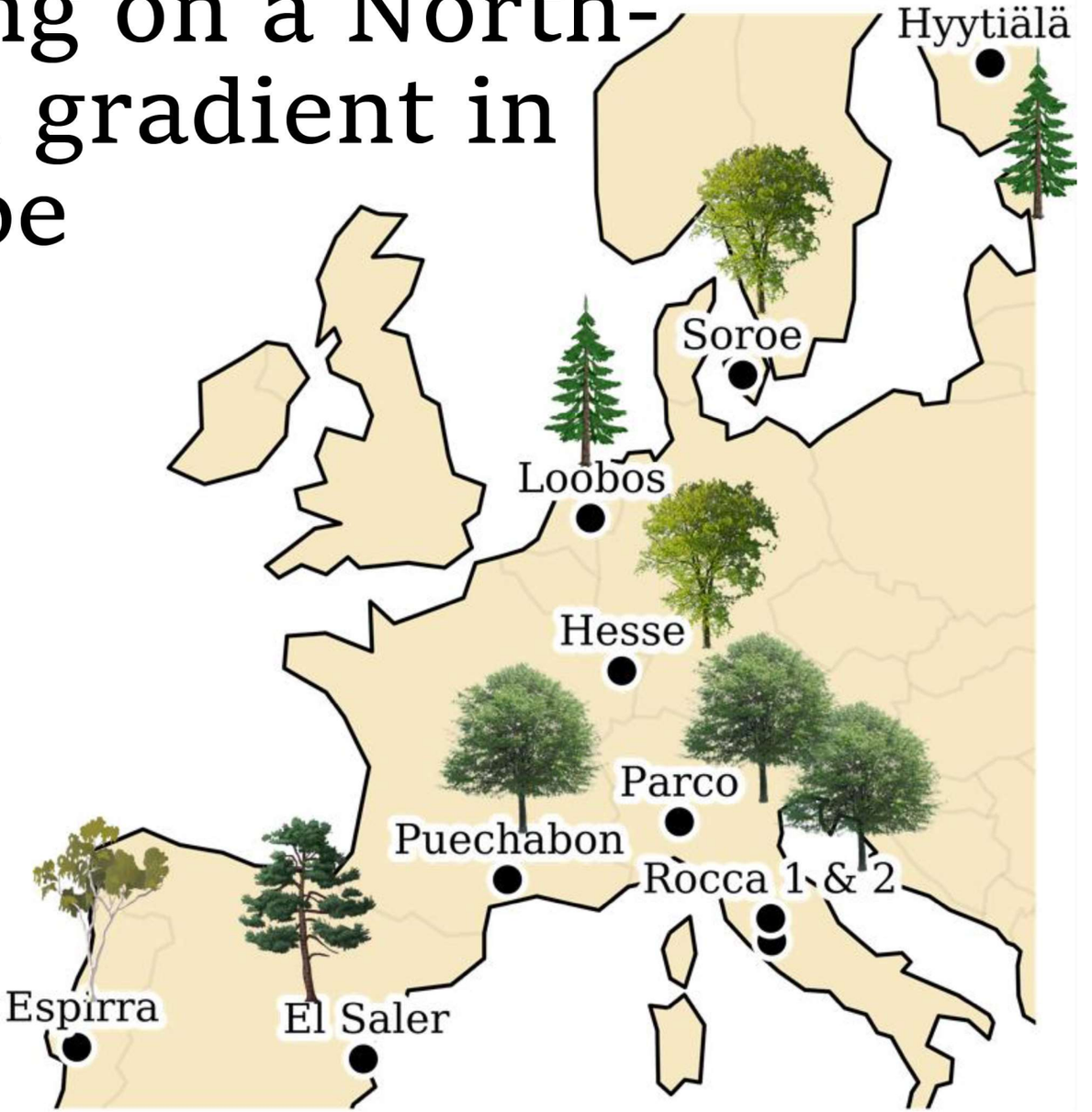




Testing on a North-South gradient in Europe



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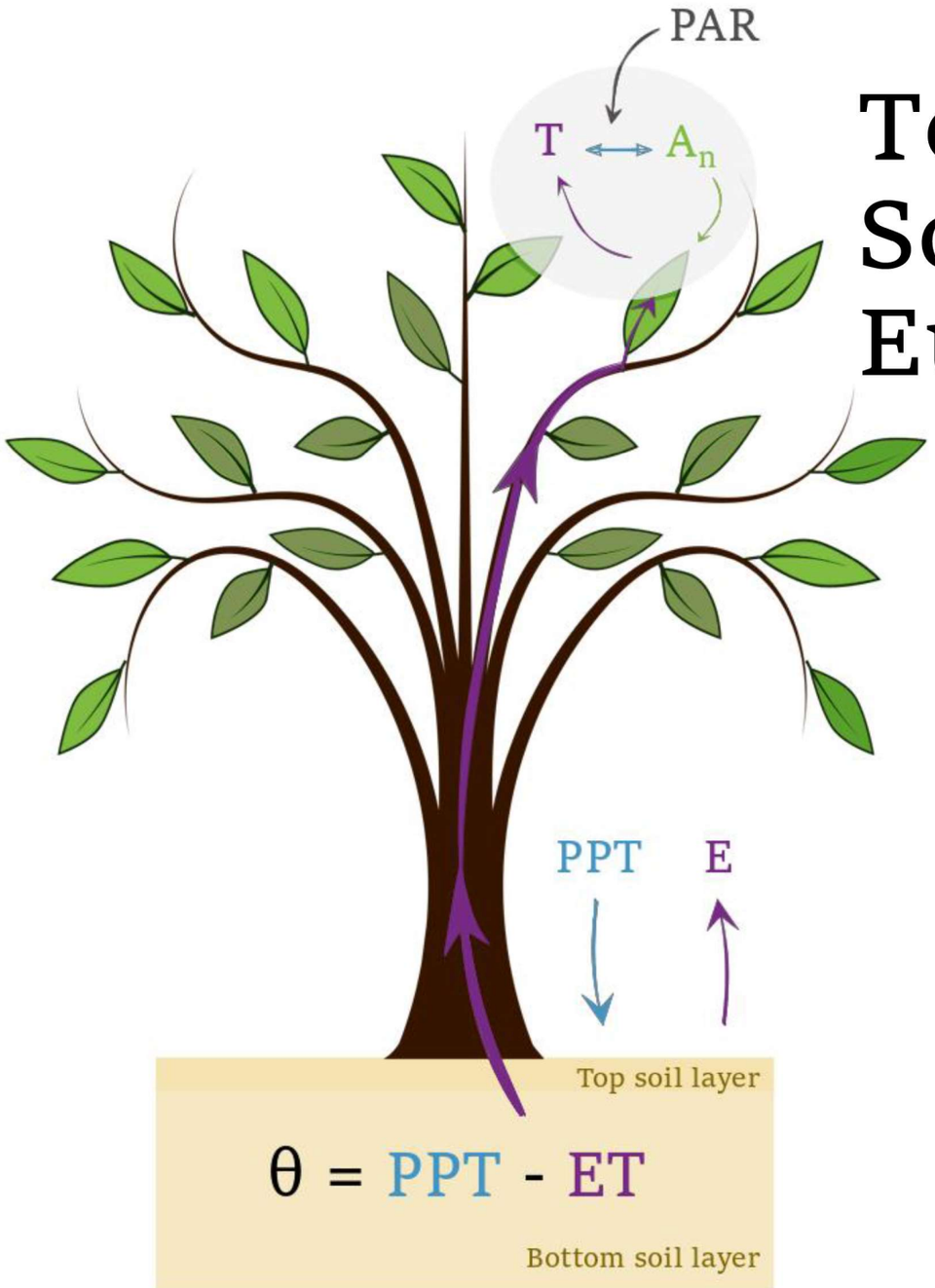
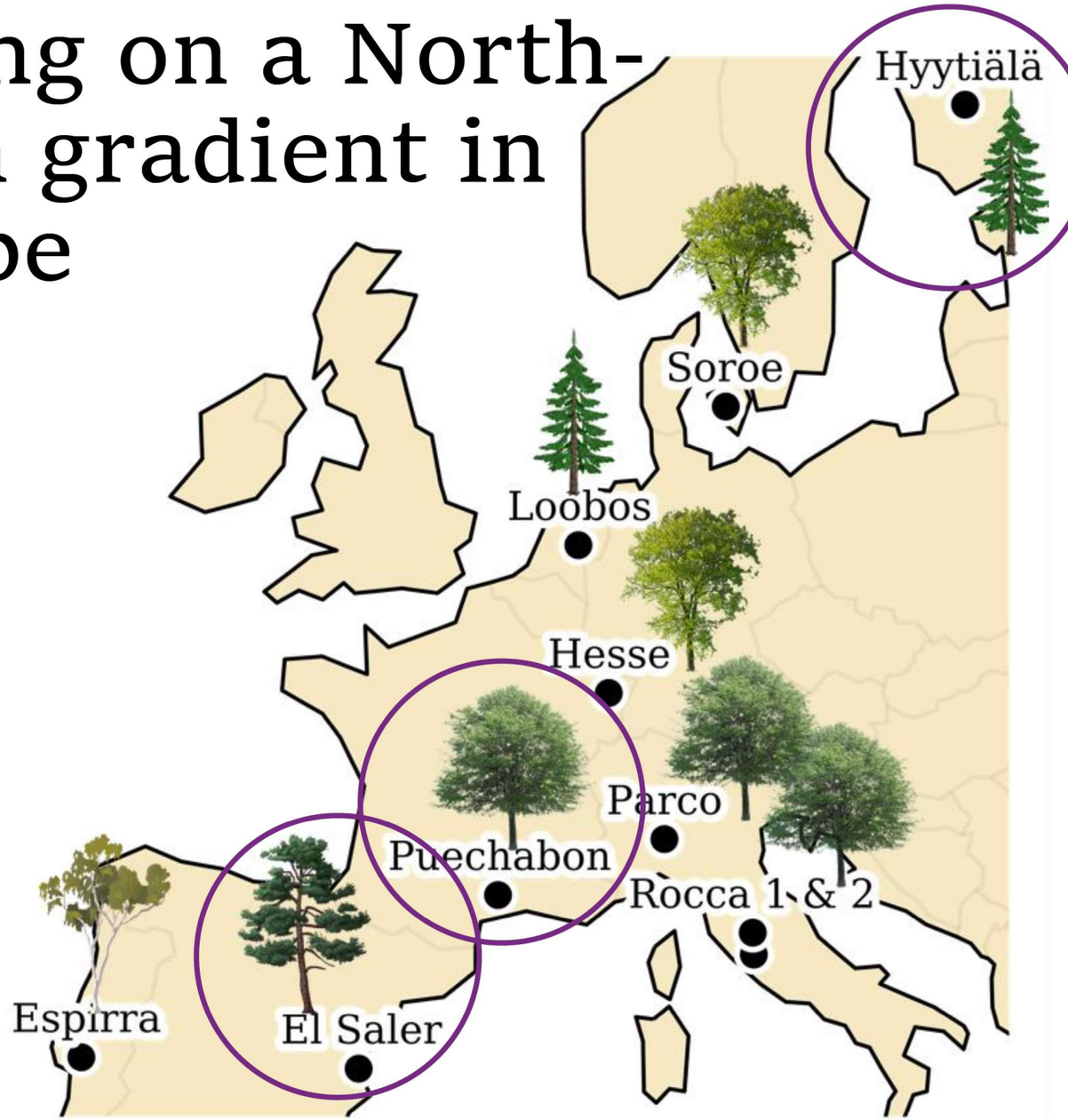
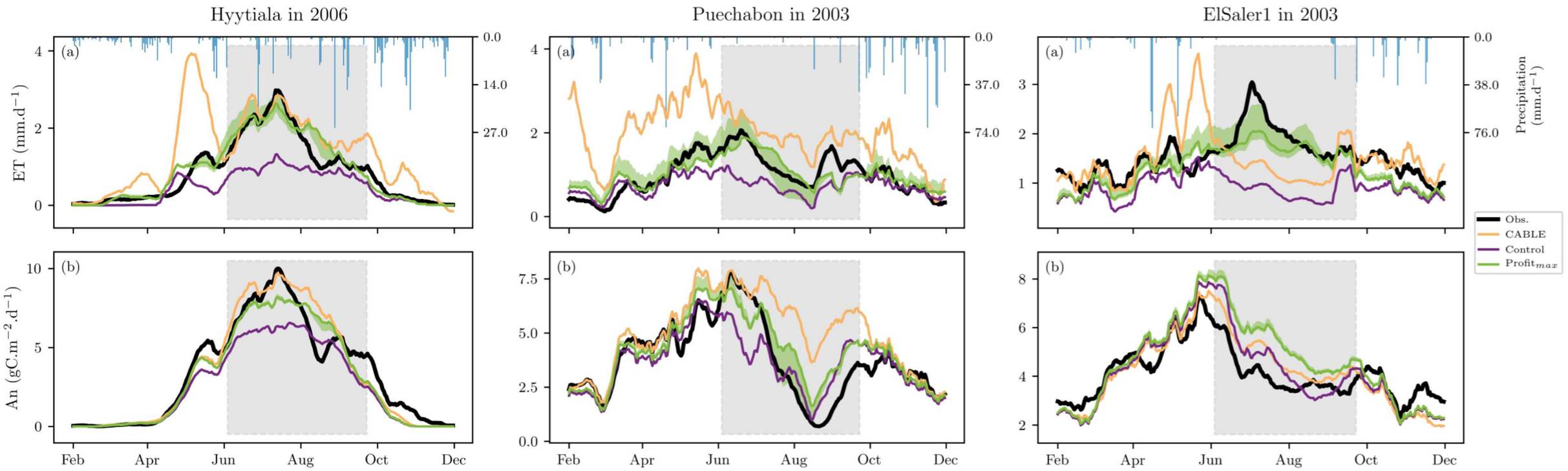




It is promising!



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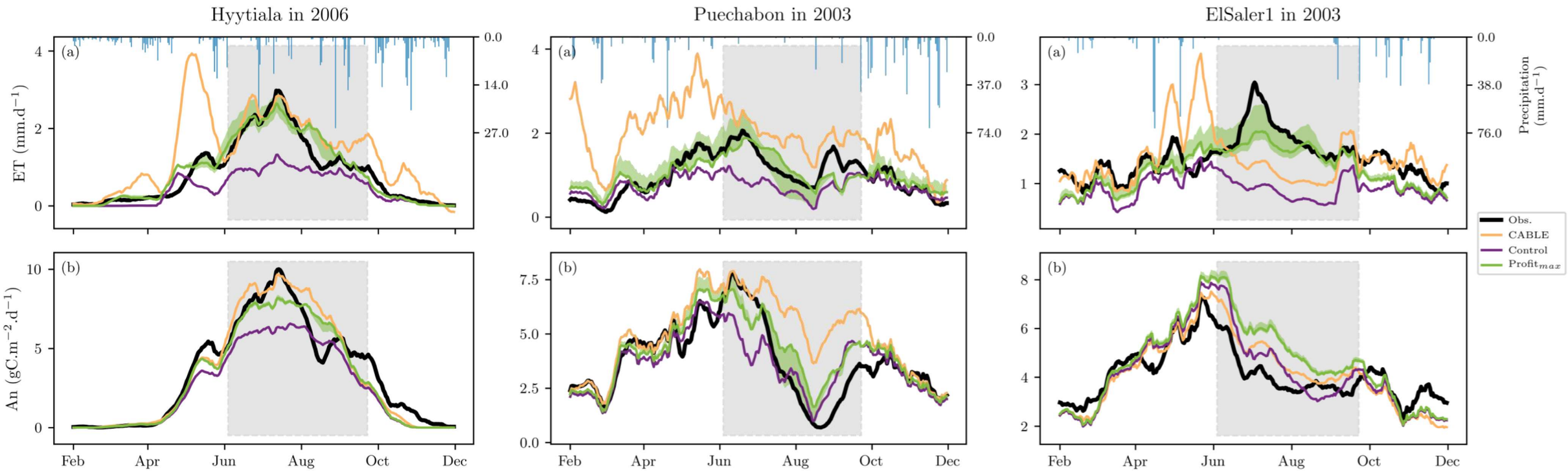

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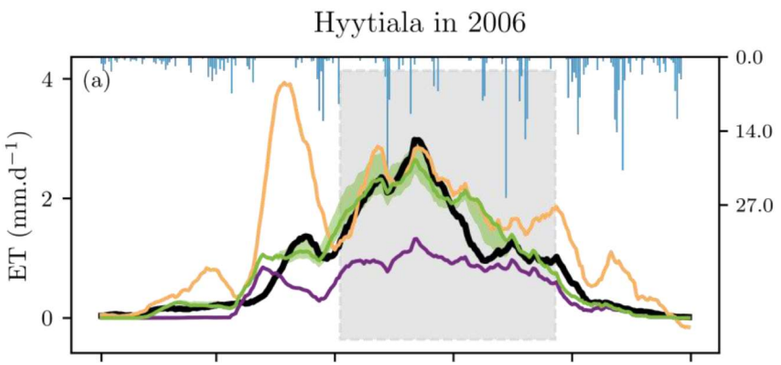
Relationship to extreme climate?

Relationship to average climate?

Relationships to climate?



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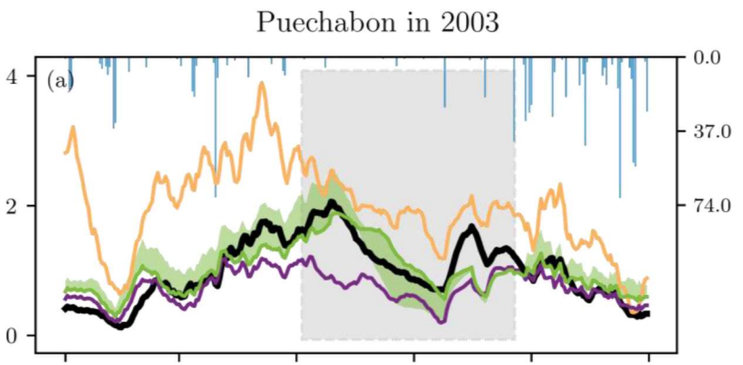

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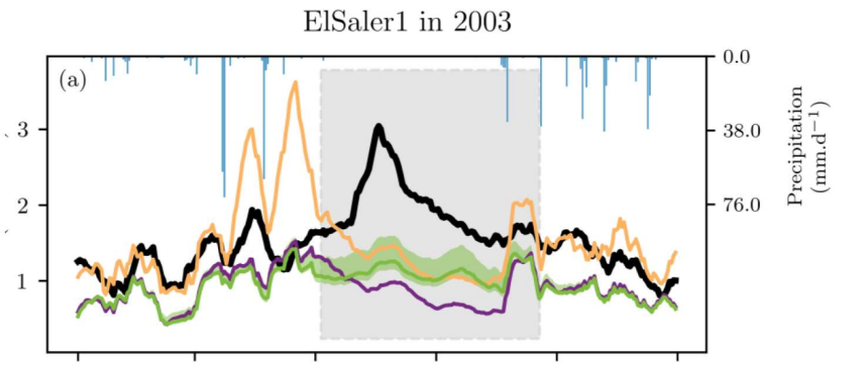

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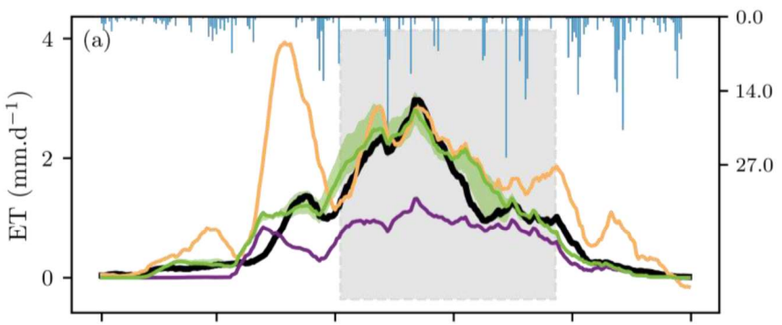

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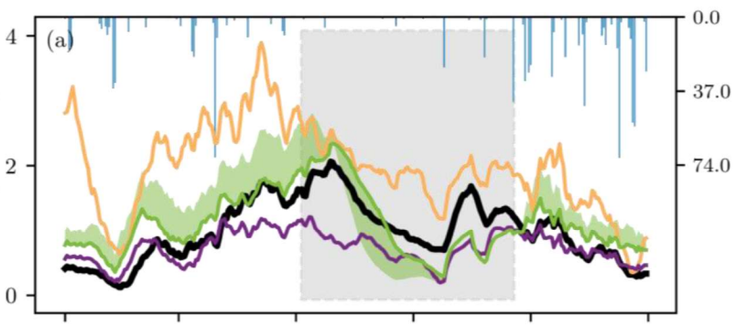

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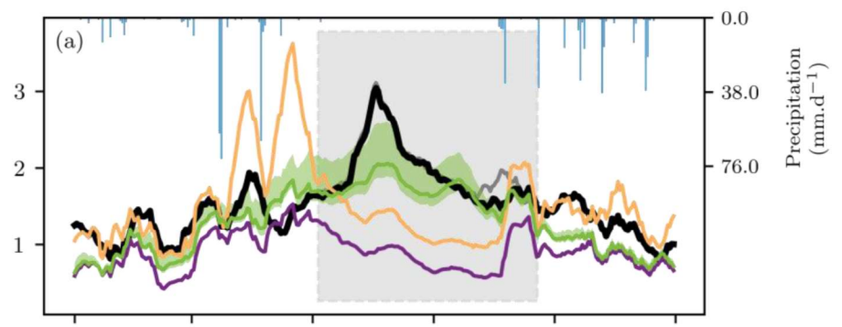
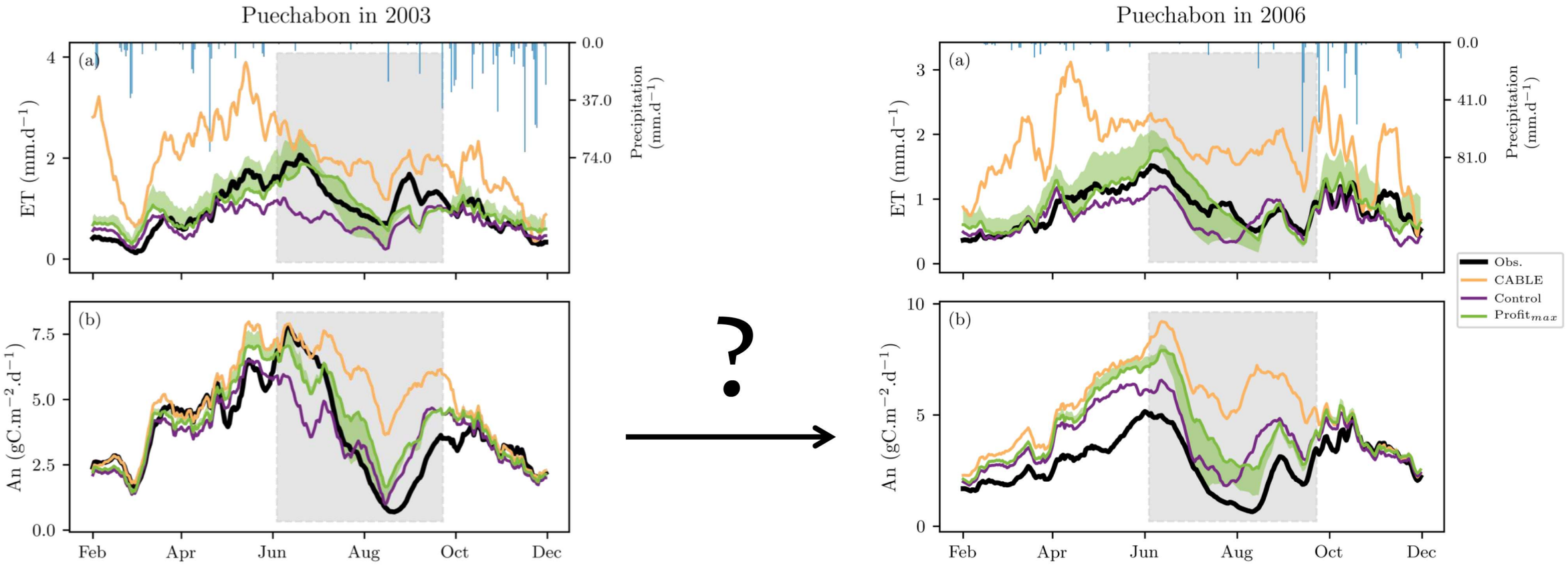


RMSE = 0. 4829

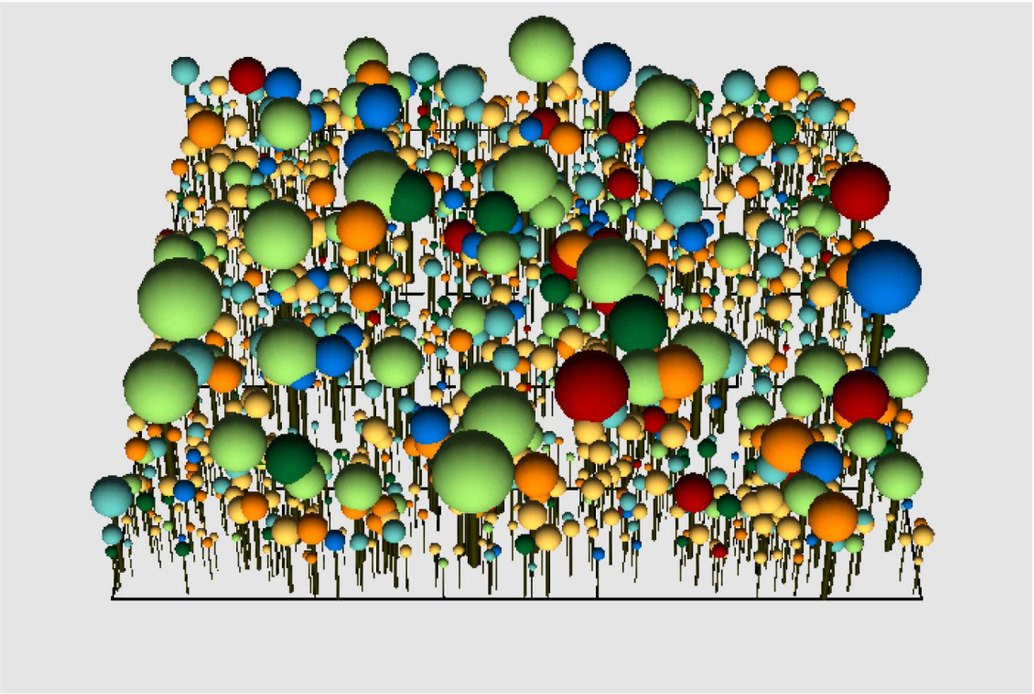
Directions



Structural damage?

Directions

Investing carbon gain to dynamically simulate rooting depth and/or dynamic LAI?

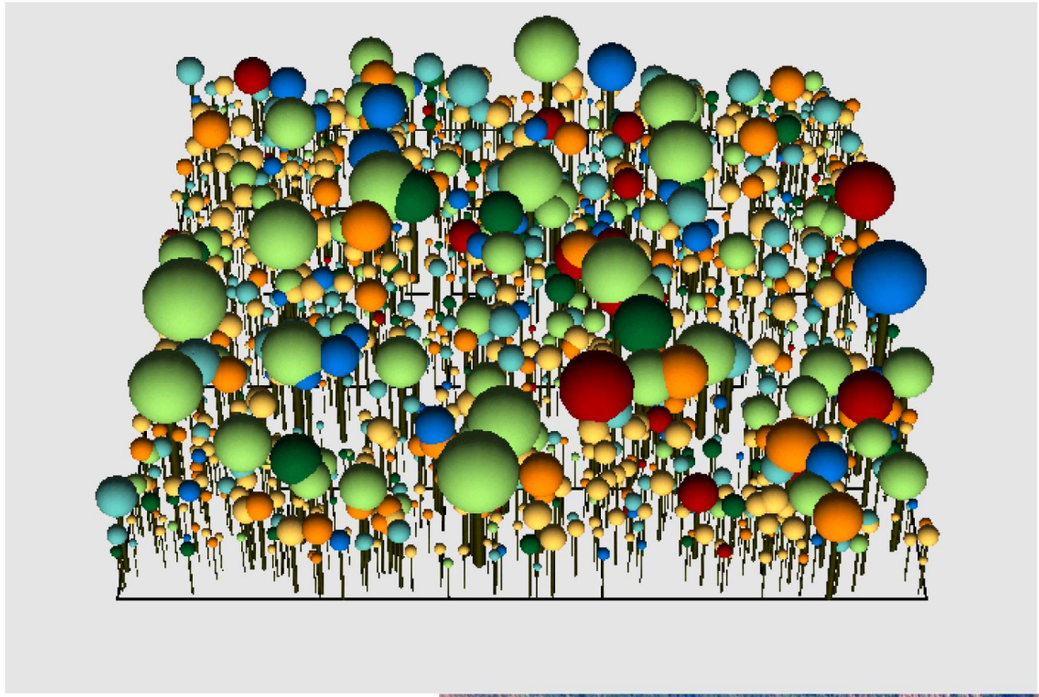


Directions

Investing carbon gain to dynamically simulate rooting depth and/or dynamic LAI?

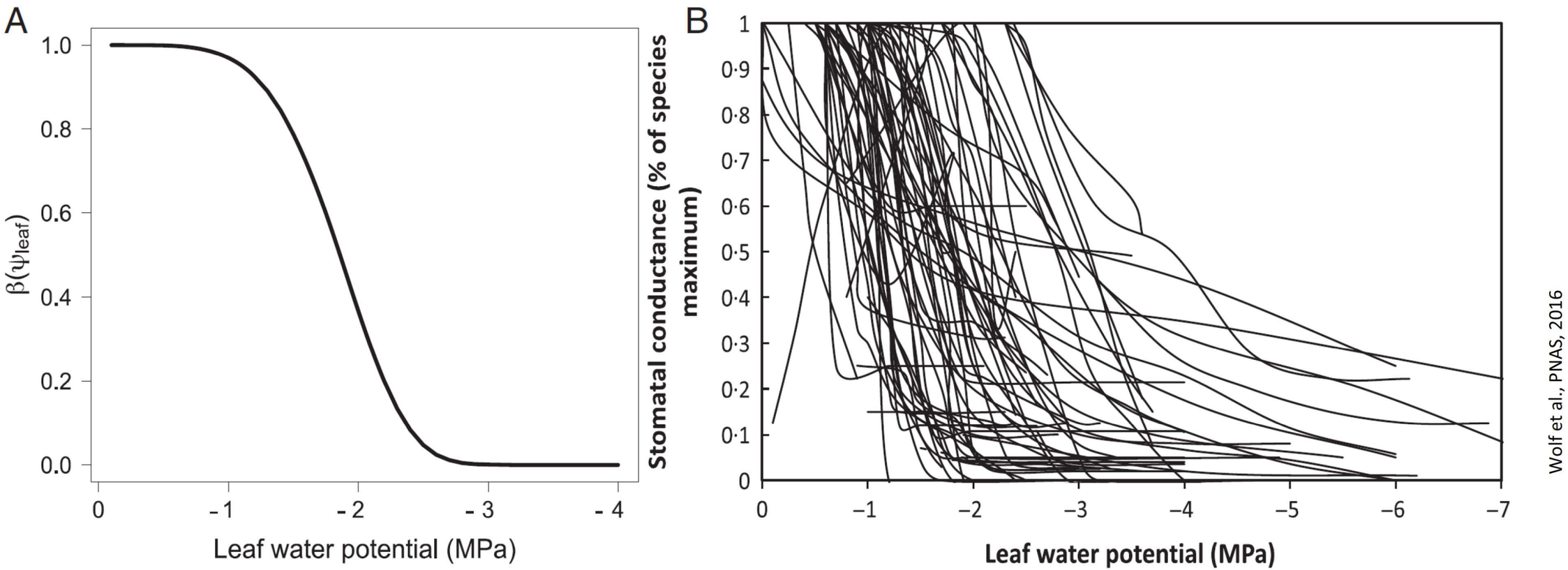
Using hydraulic cost to infer plant mortality?

Grasses and their post-drought recovery?



Thank you
m.e.b.sabot@gmail.com
climate extremes
ARC centre of excellence
UNSW
SYDNEY

Vulnerability curves



Wolf et al., PNAS, 2016

Fig. 1. (*A*) Stomatal conductance response as a function of leaf water potential [$\beta(\psi_{leaf})$] with a Weibull-like functional form. (*B*) Observed stomatal conductance response (normalized to species-level maximum) as a function of leaf water potential (MPa) from 70 woody plant species from around the globe Reprinted with permission from ref. 82.

C-H_2O optimization

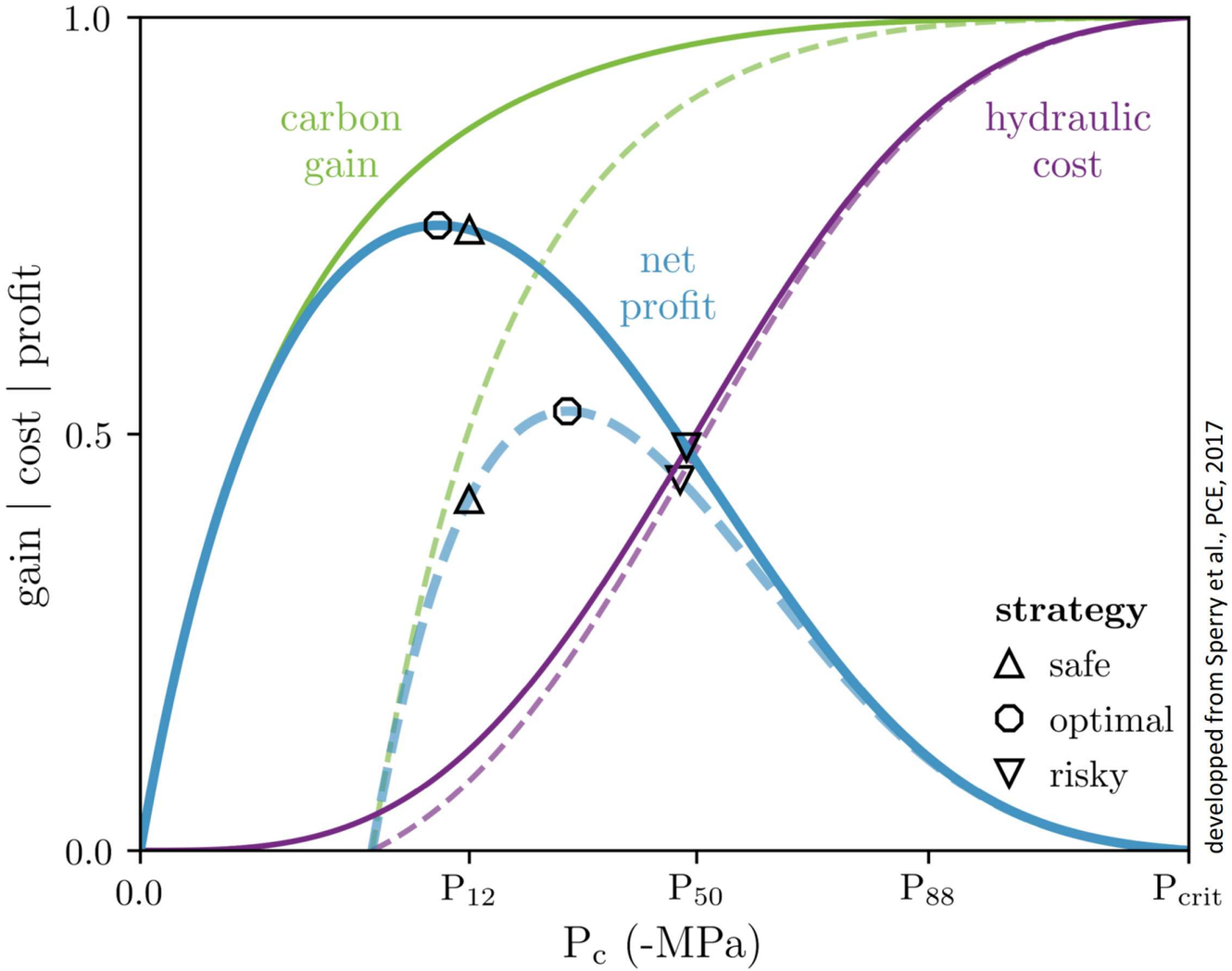
- Hydraulic cost:

$$\frac{kmax - k}{kmax - kcrit}$$

- Photosynthetic gain:

$$\frac{A}{Amax}$$

where $A(P) = g_c(P)(C_a - C_i(P))$



Farquhar Photosynthesis Model

$$A_n = \frac{J_e + J_c - \sqrt{(J_e + J_c)^2 - 4c_1 J_e J_c}}{2c_1} - R_d$$

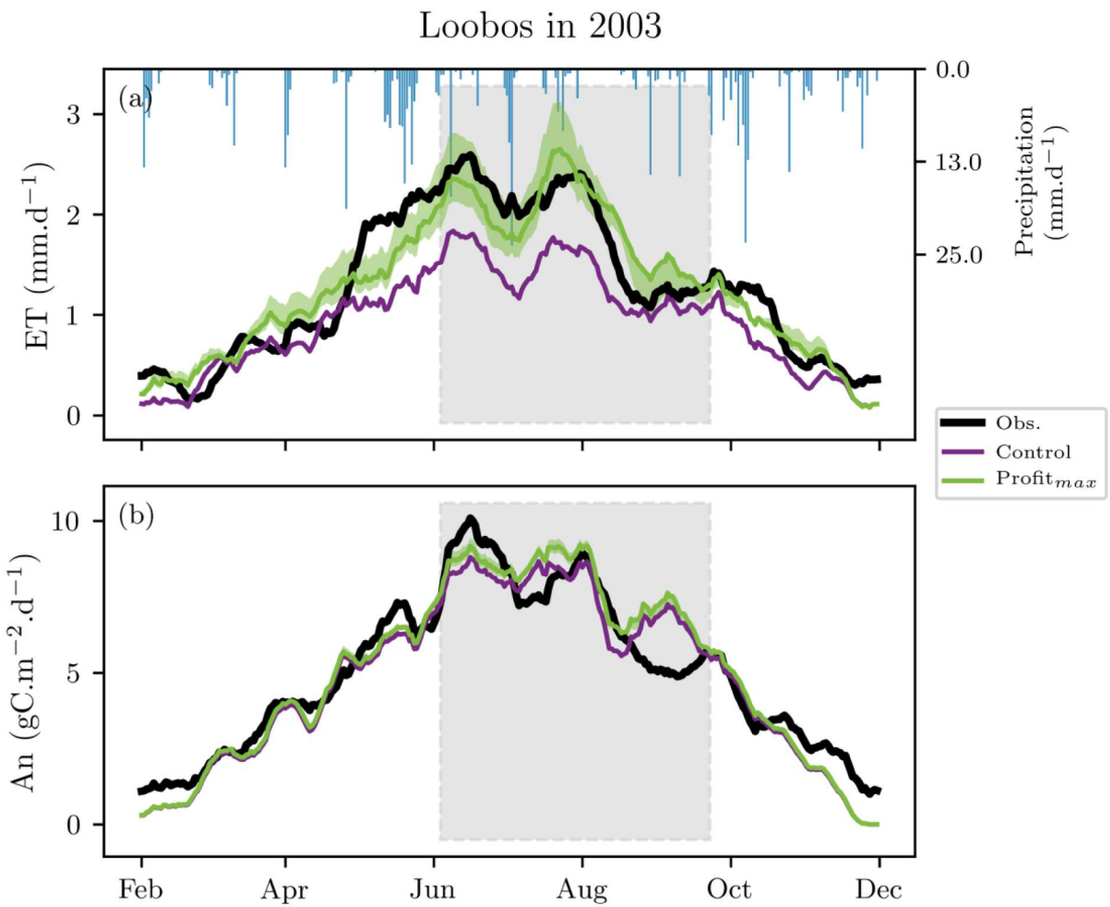
where c1 is a curvature factor,

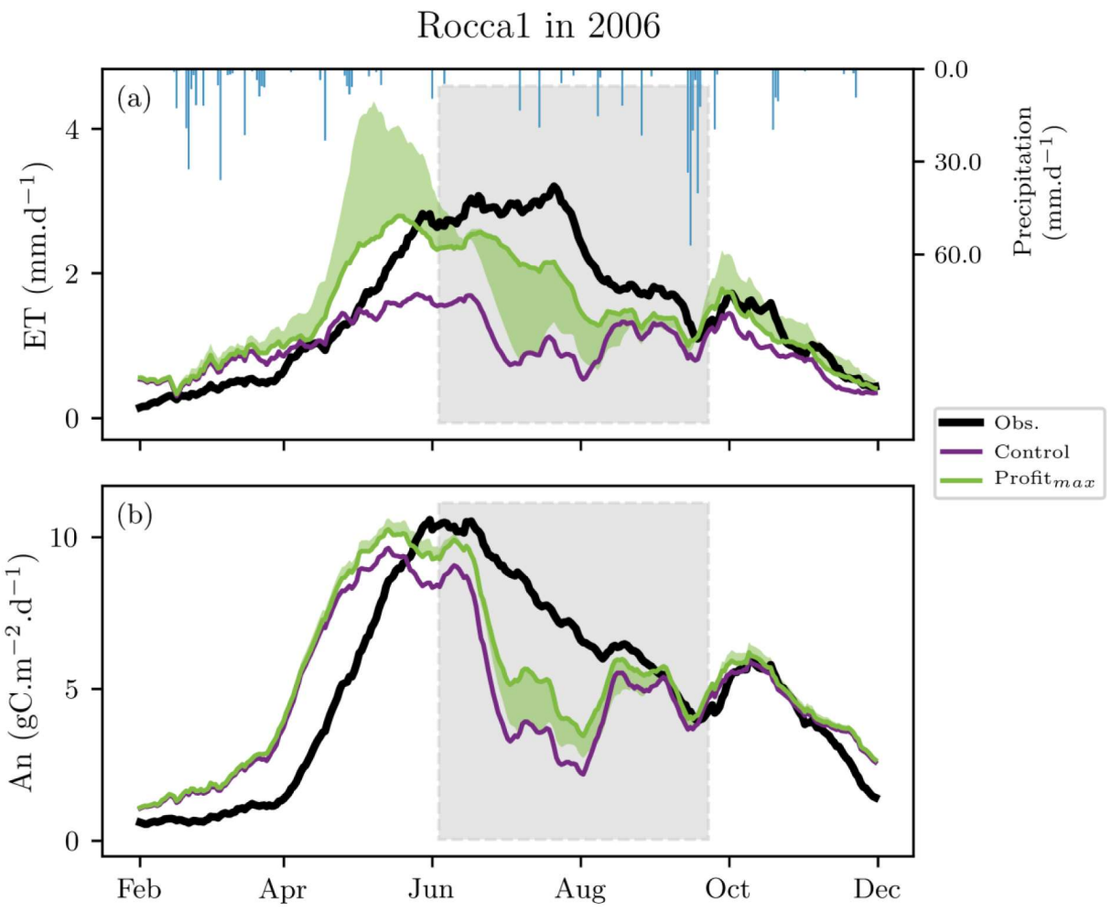
Je is the electron transport-limited photosynthetic rate,

Jc is the rubisco-limited photosynthetic rate,

Rd is leaf dark respiration

Other sites...


Loobos in 2003
(a)
(b)
ET (mm.d^{-1})
Precipitation (mm.d^{-1})
An (gC.m^{-2}.d^{-1})
0.0
13.0
25.0
Obs.
Control
Profit$_{max}$
Feb
Apr
Jun
Aug
Oct
Dec


Rocca1 in 2006
(a)
(b)
ET (mm.d^{-1})
Precipitation (mm.d^{-1})
An (gC.m^{-2}.d^{-1})
0.0
30.0
60.0
Obs.
Control
Profit$_{max}$
Feb
Apr
Jun
Aug
Oct
Dec

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