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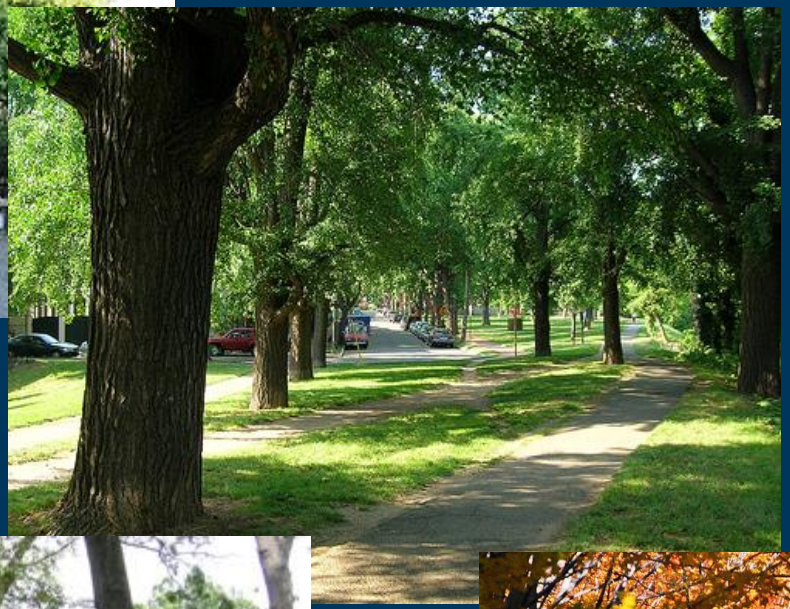
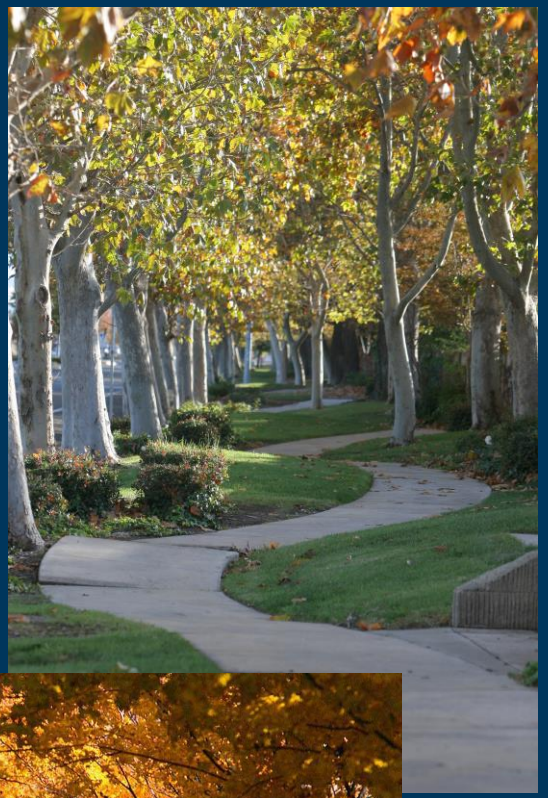
PLANT HYDRAULICS IN THE CITY

Andrea Nardini

DIPARTIMENTO DI
SCIENZE DELLA VITA

International Workshop on
Plant Physiology in the Urban Environment
Pisa, Italy, 23.06.2014

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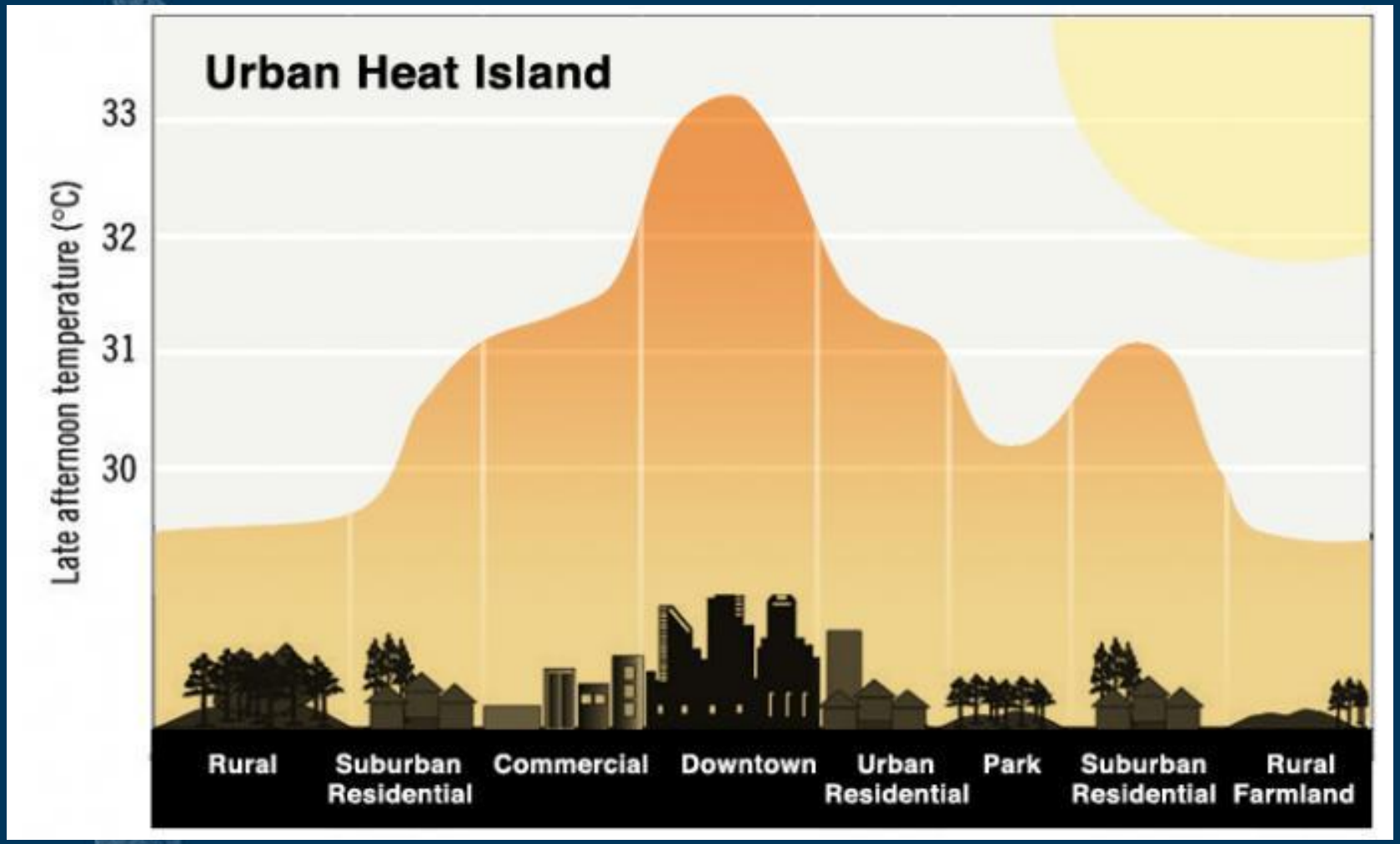
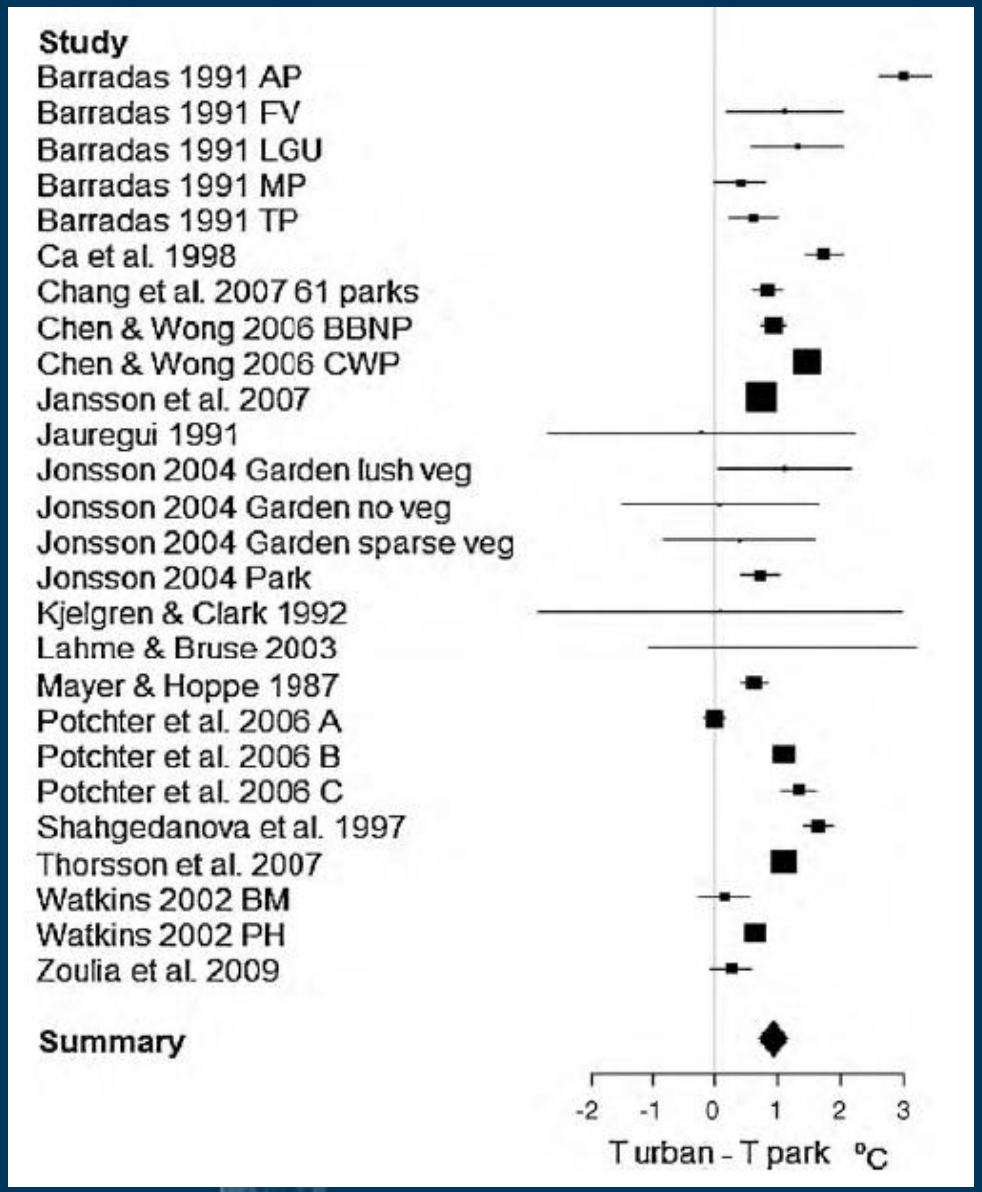

Urban Heat Island
Late afternoon temperature (°C)
33
32
31
30
Rural
Suburban Residential
Commercial
Downtown
Urban Residential
Park
Suburban Residential
Rural Farmland



Contents lists available at ScienceDirect

Landscape and Urban Planning

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

Review

Urban greening to cool towns and cities: A systematic review of the empirical evidence

Diana E. Bowler, Lisette Buyung-Ali, Teri M. Knight, Andrew S. Pullin*

Centre for Evidence-Based Conservation, School of Environment, Natural Resources and Geography, Bangor University, UK

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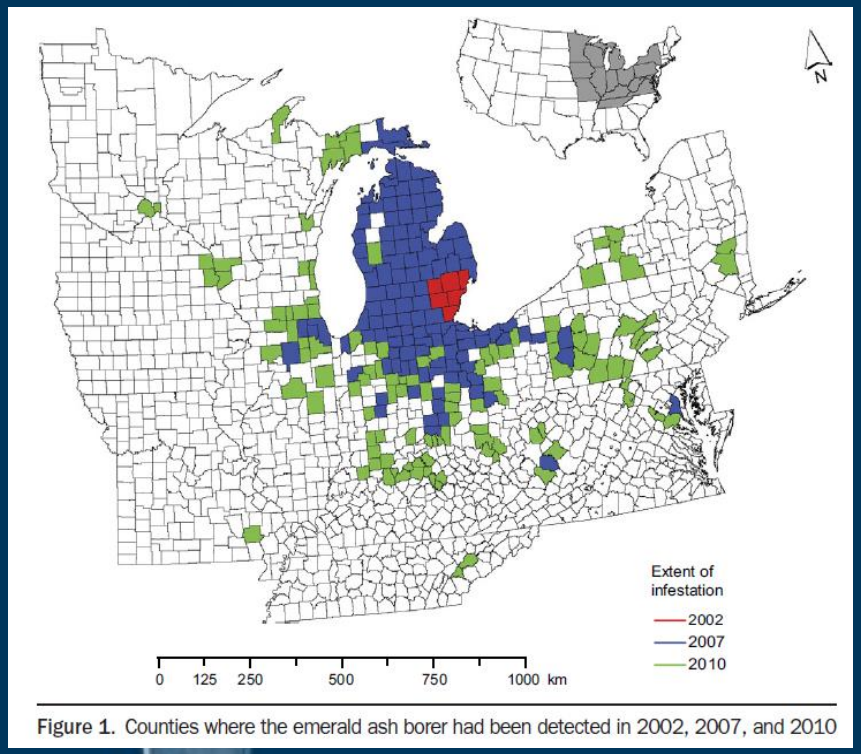

Figure 1. Counties where the emerald ash borer had been detected in 2002, 2007, and 2010

The Relationship Between Trees and Human Health

Evidence from the Spread of the Emerald Ash Borer

Geoffrey H. Donovan, PhD, David T. Butry, PhD, Yvonne L. Michael, ScD, Jeffrey P. Prestemon, PhD, Andrew M. Liebhold, PhD, Demetrios Gatziolis, PhD, Megan Y. Mao

Table 2. Estimated marginal effects of the emerald ash borer on lower-respiratory-tract disease–related mortality by years of infestation

Years of infestation	Number of observations	Marginal effect (95% CI)	*p*-value
1	126	3.80 (2.08, 5.52)	<0.001
2	102	5.96 (4.13, 7.79)	<0.001
3	72	8.09 (5.92, 10.27)	<0.001
4	50	10.09 (7.41, 12.77)	<0.001
5	22	13.24 (9.96, 16.53)	<0.001
6	6	15.32 (12.78, 17.86)	<0.001
Across all years		6.77 (4.84, 8.69)	<0.001
Wald test: all variables[a]=0			

[a]Emerald ash borer, years of infestation, and interaction terms

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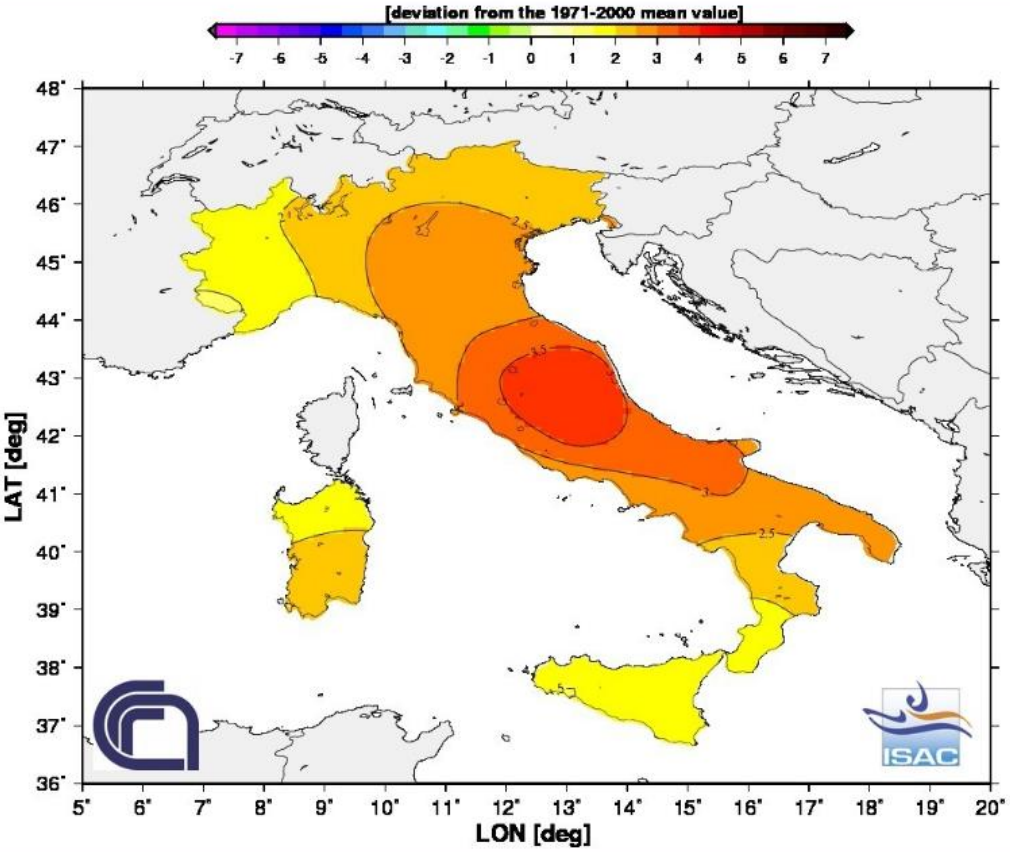
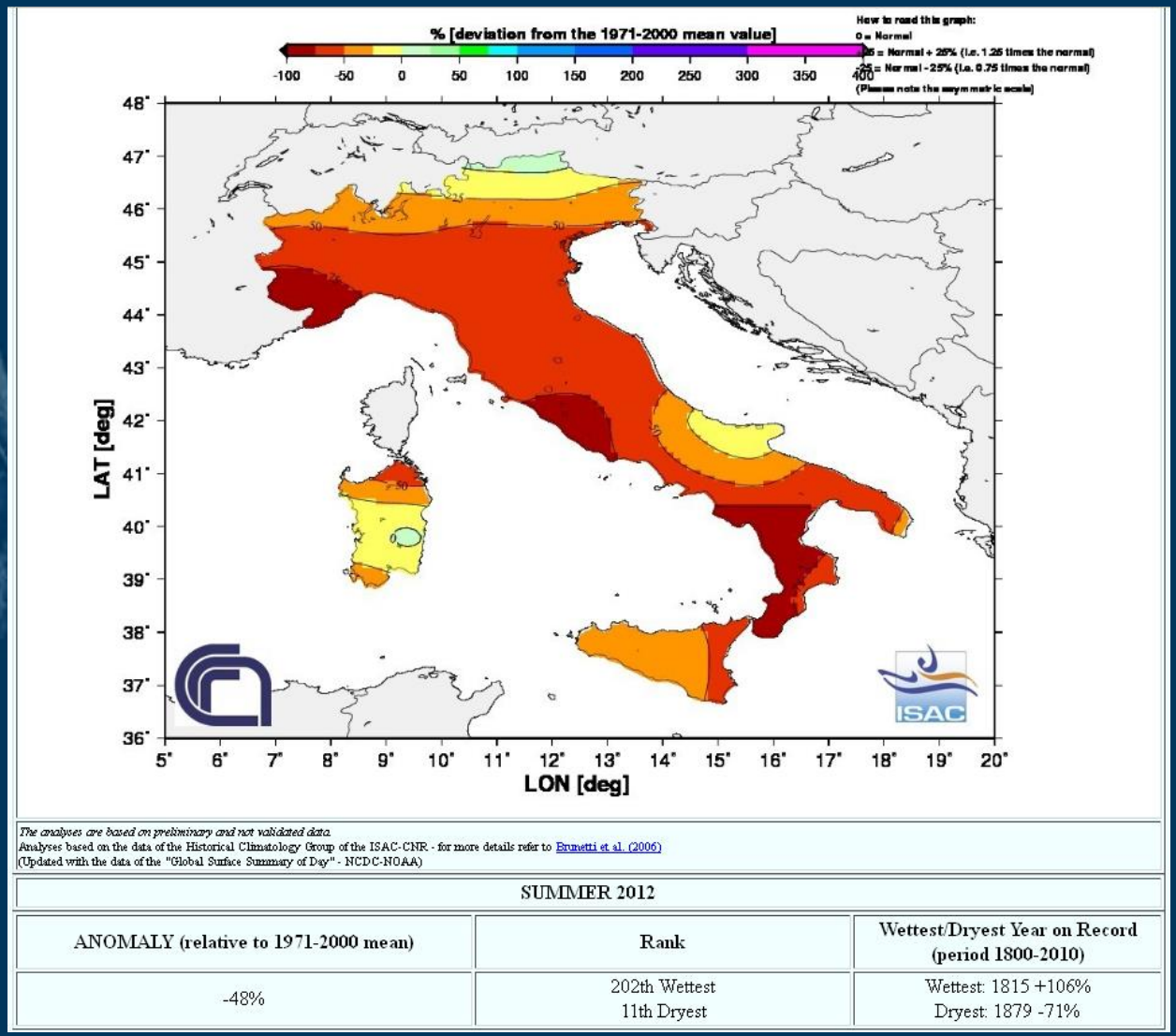


The analyses are based on preliminary and not validated data.
Analyses based on the data of the Historical Climatology Group of the ISAC-CNR - for more details refer to Brunetti et al. (2006)
(Updated with the data of the "Global Surface Summary of Day" - NCDC-NOAA)

SUMMER 2012		
ANOMALY (relative to 1971-2000 mean)	Rank	Warmest/Coldest Year on Record (period 1800-2010)
+2.32°C	2nd Warmest 211th Coldest	Warmest: 2003 +3.72°C Coldest: 1816 -3.63°C

http://www.isac.cnr.it/~climstor/index.html

2012 Temperature anomaly: +2.32 °C



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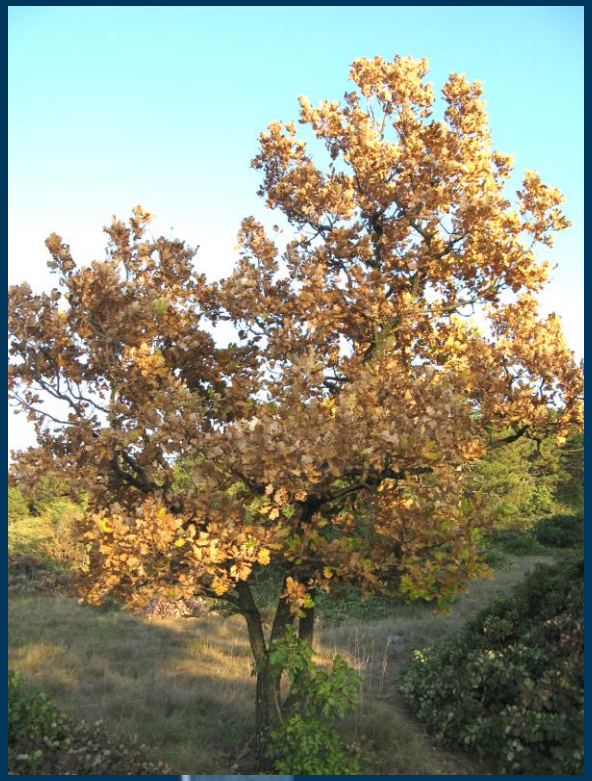
Analyses based on the data of the Historical Climatology Group of the ISAC-CNR - for more details refer to Brunetti et al. (2006)
(Updated with the data of the "Global Surface Summary of Day" - NCDC-NOAA)

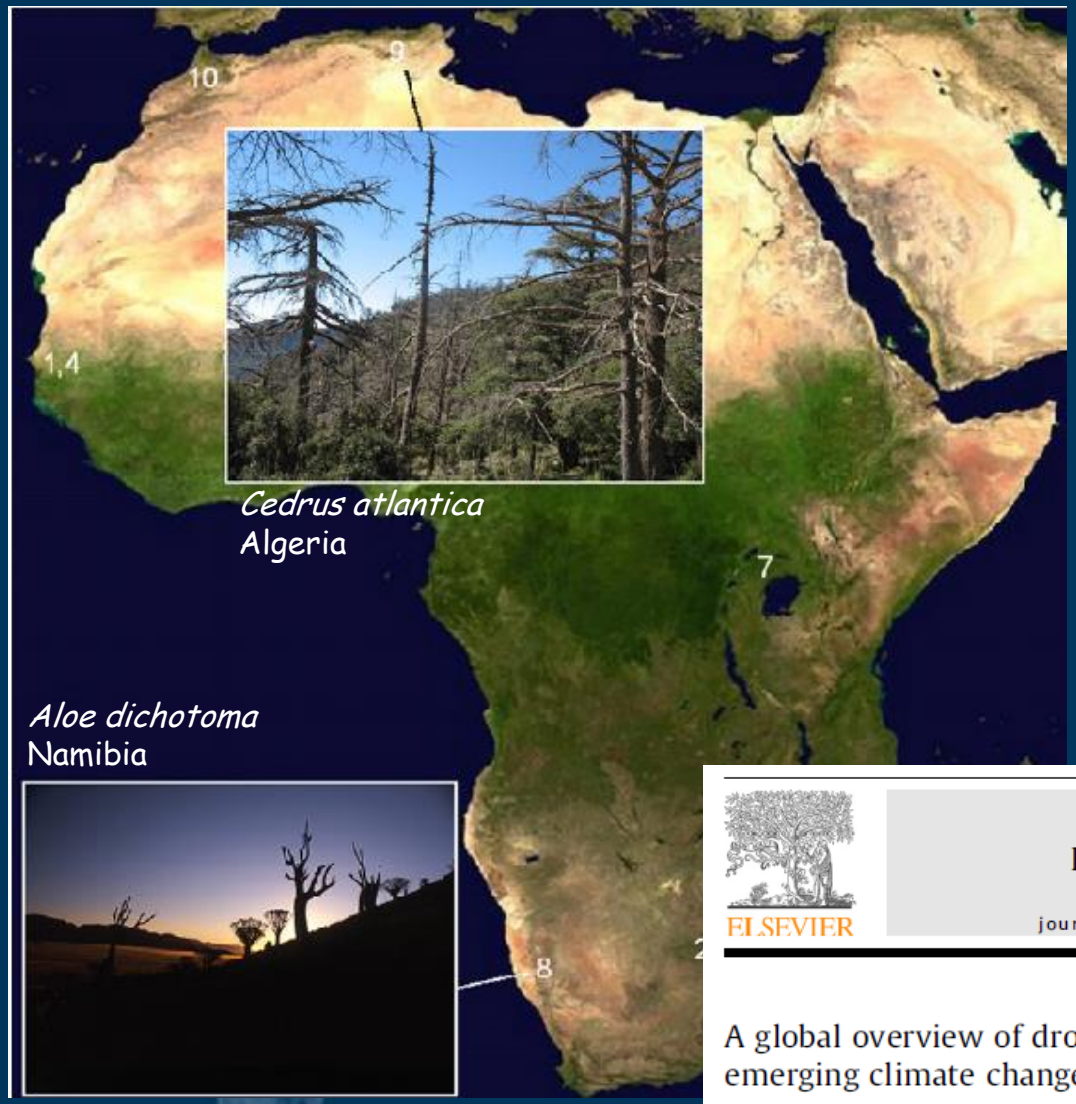
SUMMER 2012		
ANOMALY (relative to 1971-2000 mean)	Rank	Wettest/Dryest Year on Record (period 1800-2010)
-48%	202th Wettest 11th Dryest	Wettest: 1815 +106% Dryest: 1879 -71%

http://www.isac.cnr.it/~climstor/index.html

2012 Precipitation anomaly: -48%



August 2012
Mixed oak, ash and pine forests nearby Trieste



Cedrus atlantica
Algeria

Aloe dichotoma
Namibia

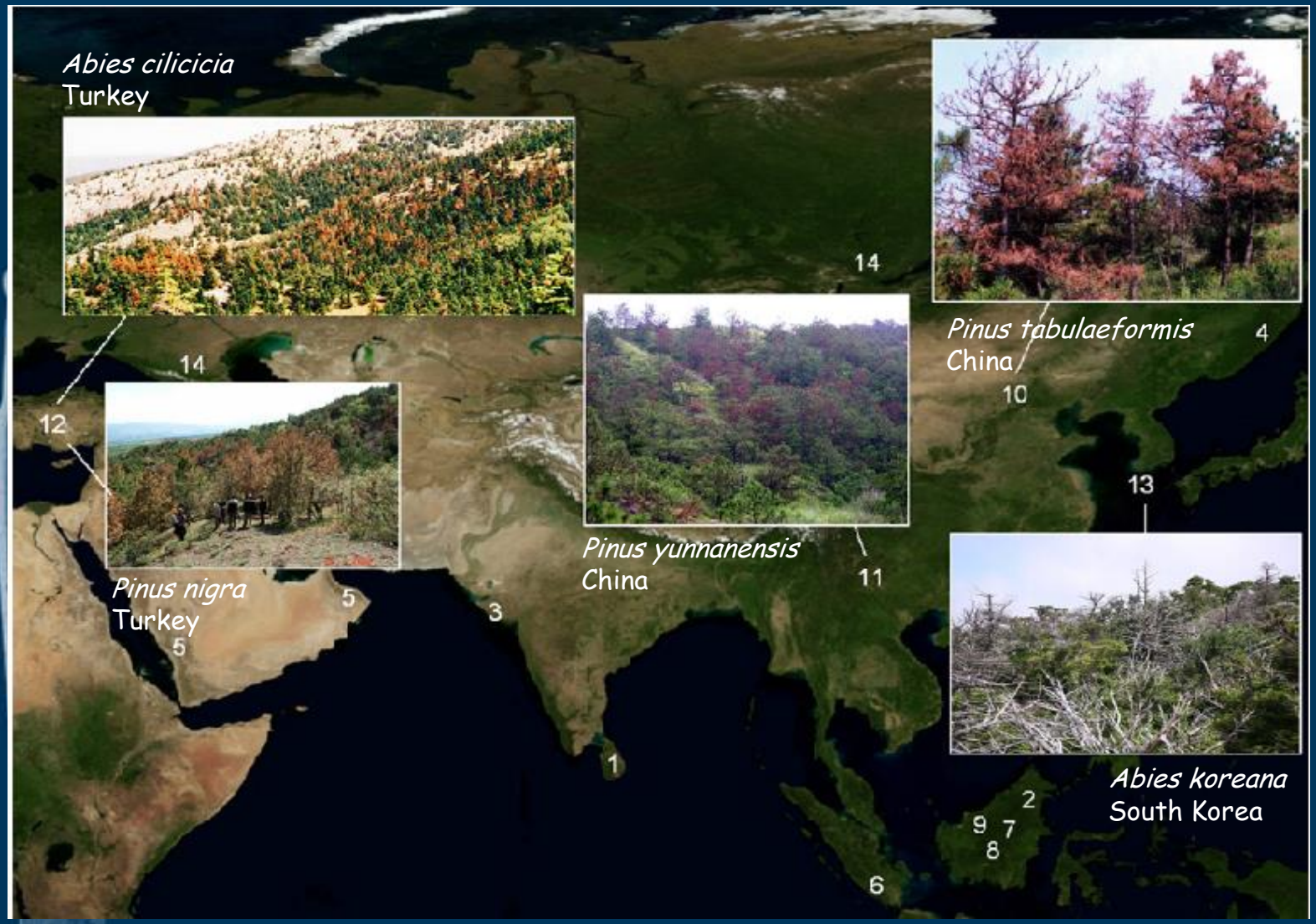
Contents lists available at ScienceDirect

Forest Ecology and Management

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

A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests

Craig D. Allen [a,*], Alison K. Macalady [b], Haroun Chenchouni [c], Dominique Bachelet [d], Nate McDowell [e], Michel Vennetier [f], Thomas Kitzberger [g], Andreas Rigling [h], David D. Breshears [i], E.H. (Ted) Hogg [j], Patrick Gonzalez [k], Rod Fensham [l], Zhen Zhang [m], Jorge Castro [n], Natalia Demidova [o], Jong-Hwan Lim [p], Gillian Allard [q], Steven W. Running [r], Akkin Semerci [s], Neil Cobb [t]


Abies cilicicia
Turkey
Pinus tabulaeformis
China
Pinus nigra
Turkey
Pinus yunnanensis
China
Abies koreana
South Korea
14
14
12
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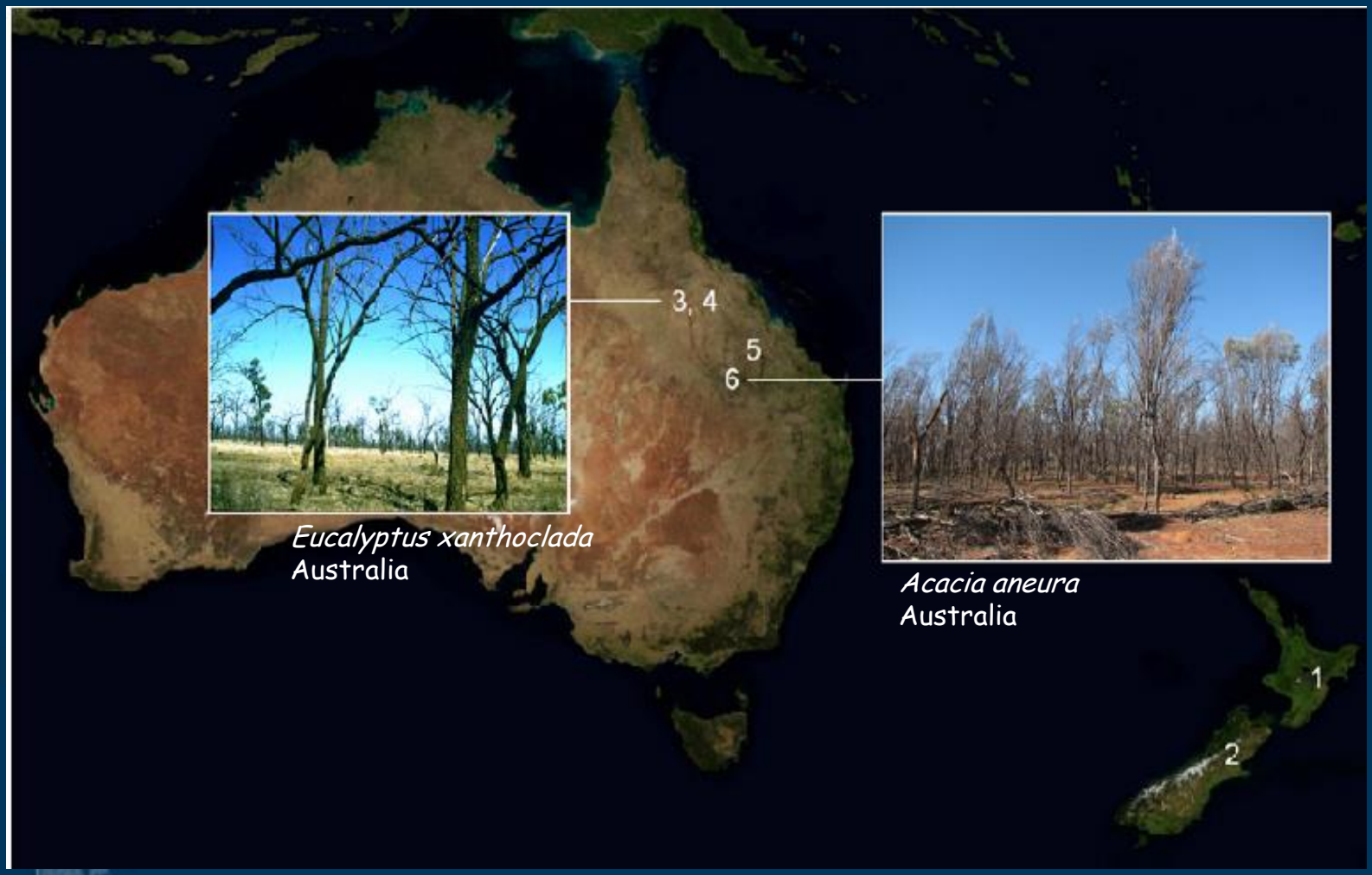
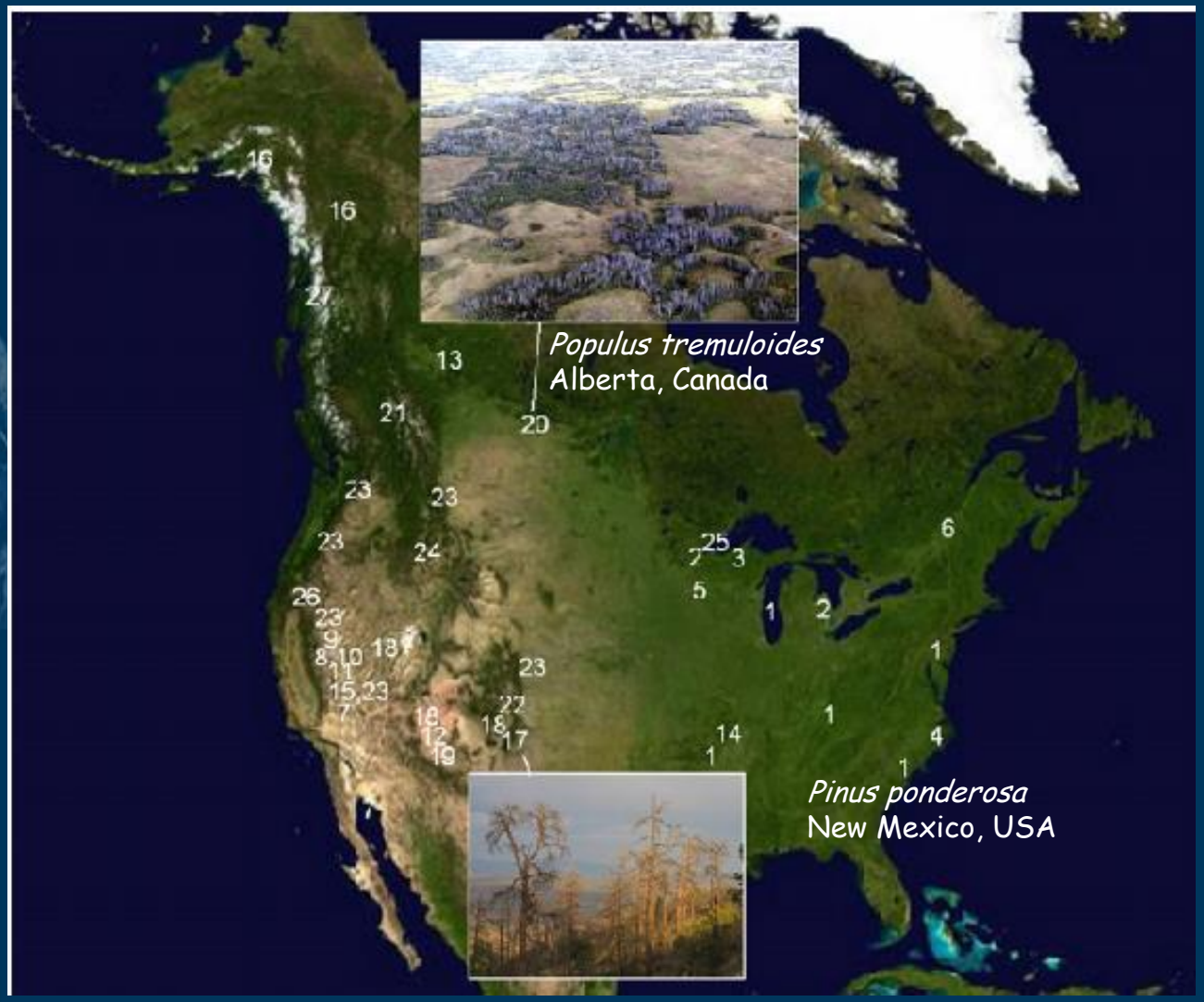
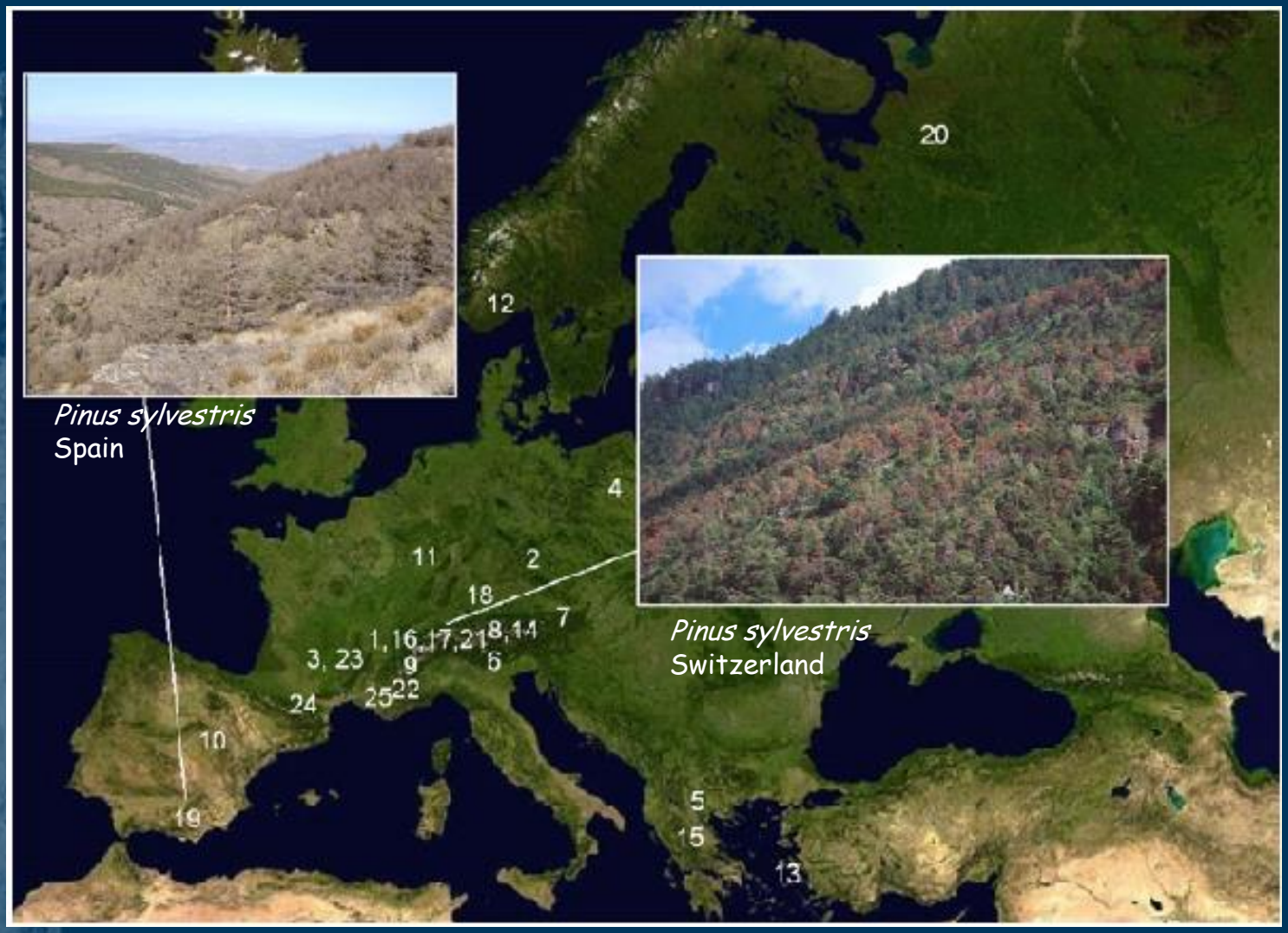
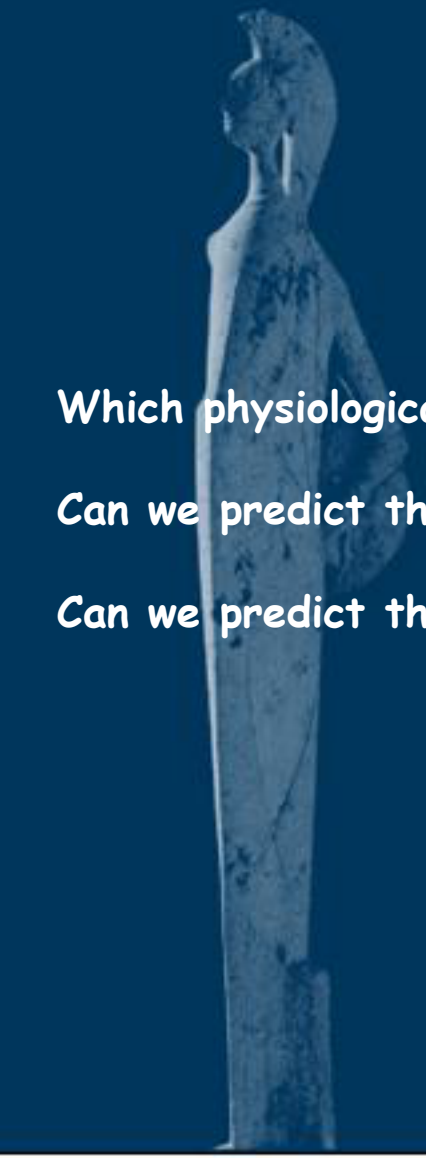

3, 4
5
6
1
2
Eucalyptus xanthoclada
Australia
Acacia aneura
Australia


Populus tremuloides
Alberta, Canada
Pinus ponderosa
New Mexico, USA


20
12
4
11
2
18
7
1,16,17,21
8,14
3, 23
9
6
24
25
22
10
19
5
15
13
Pinus sylvestris
Spain
Pinus sylvestris
Switzerland



Which physiological mechanisms drive plant mortality under drought?

Can we predict the impact of extreme drought on different species/growth conditions?

Can we predict the impact on urban trees?

Three possible, not mutually exclusive, mechanisms:

Hydraulic failure

Carbon starvation

Biotic attacks

Some daily totals of water transpired…

Picea abies: 175 liters

Quercus robur: 400 liters

Eperua purpurea: 1200 liters

Atmosphere

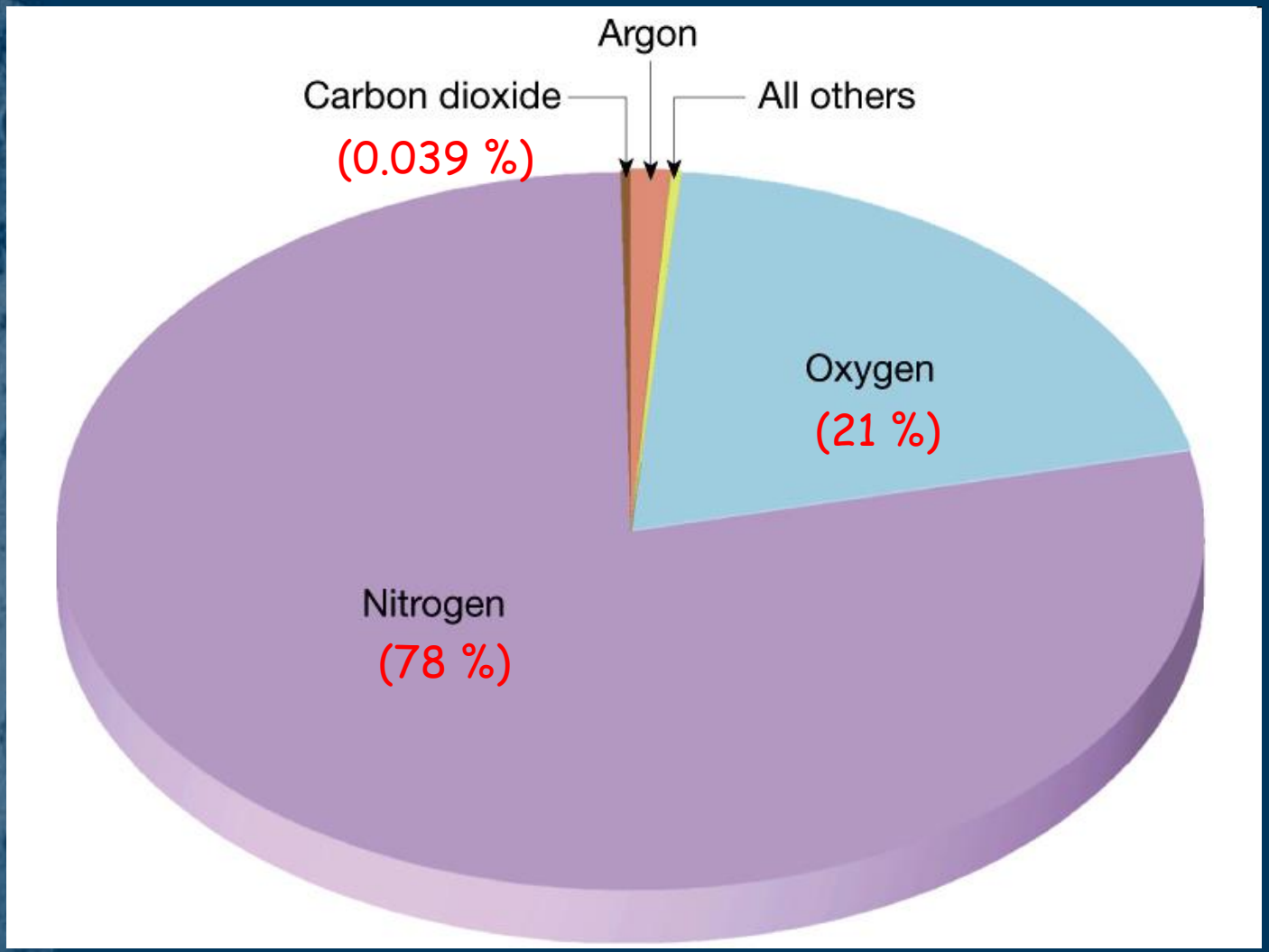


Table 2.2.1. Water use and resources acquisition (CO_2 in plants and O_2 in animals) at 20 °C and 50% relative humidity and taking into account the diffusability of gases which depends on their molecular weight. A human with a body temperature of 36.6 °C acts as an example for the animal kingdom

	Plants		Human	
	CO_2	H_2O	O_2	H_2O
Concentration (ppm)				
– in the atmosphere	350	12000	210000	12000
– in the mesophyll or in breathed air	250	24000	160000	62000
Gradient	100	12000	50000	50000
Relationship between H_2O/CO_2 or H_2O/O_2		192		1.3

CO_2, M_w = 44
O_2, M_w = 32
H_2O, M_w = 18

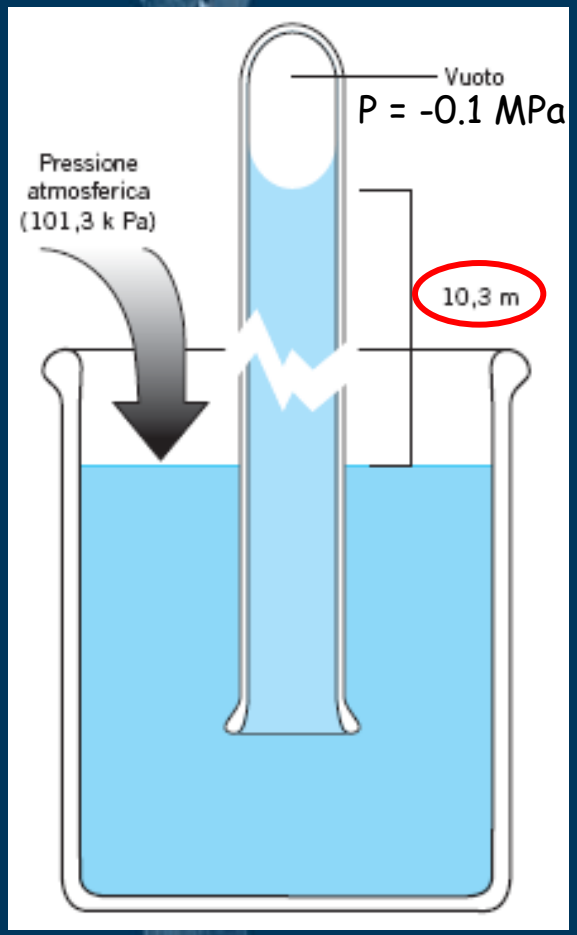
CO_2 diffusion in air is slower than H_2O diffusion: $\sqrt{(44/18)} = 1.6$

Hence, $H_2O/CO_2 = (12000/100) \times 1.6 = 192$

The physics of gas diffusion and the relative concentration of CO_2 and H_2O in the atmosphere are at the basis of the functional dilemma of plants…

Die of thirst or die of famine?

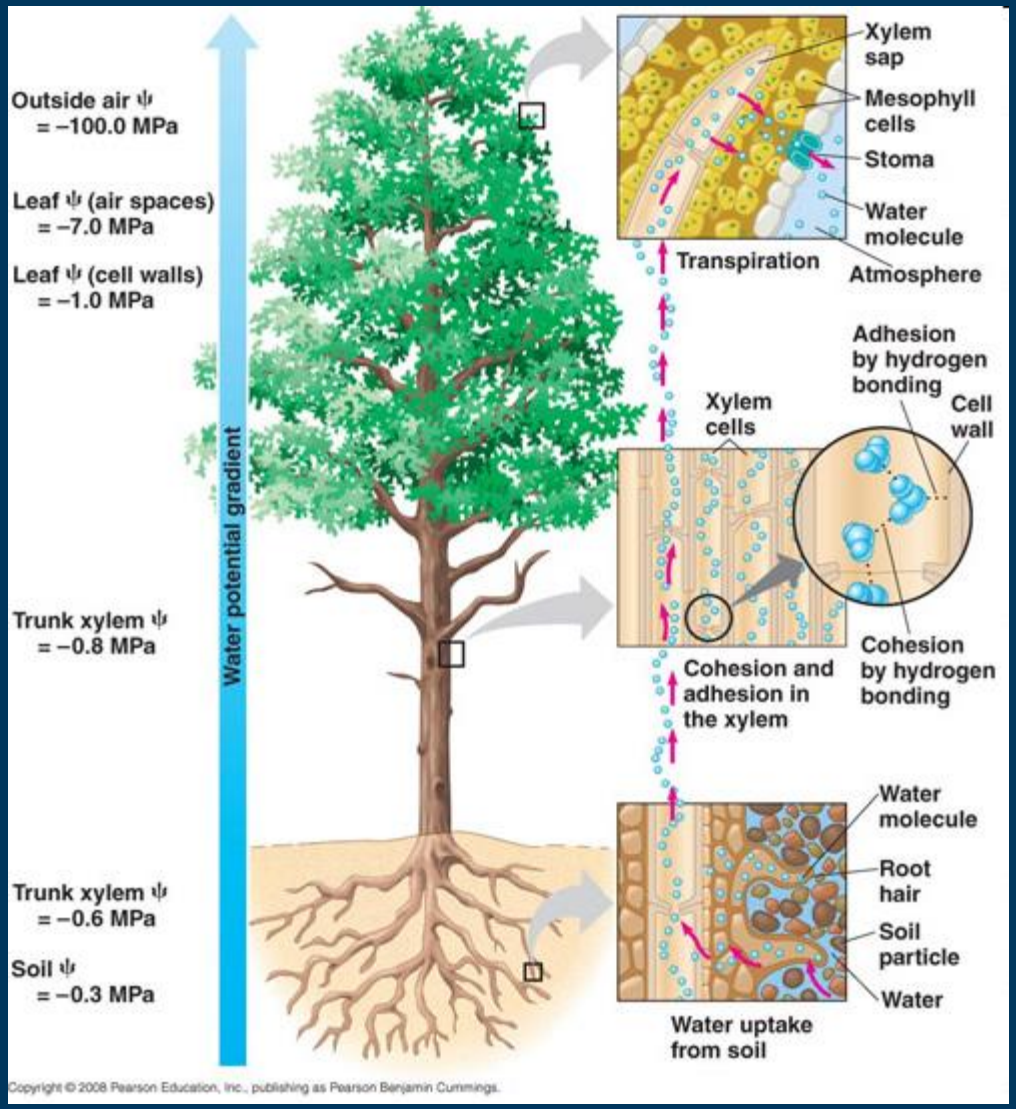
A vacuum pump would not be enough to transport water to the top of trees…



Sequoia sempervirens, 112 m

Eucalyptus regnans, 150 m ?

The cohesion-tension theory

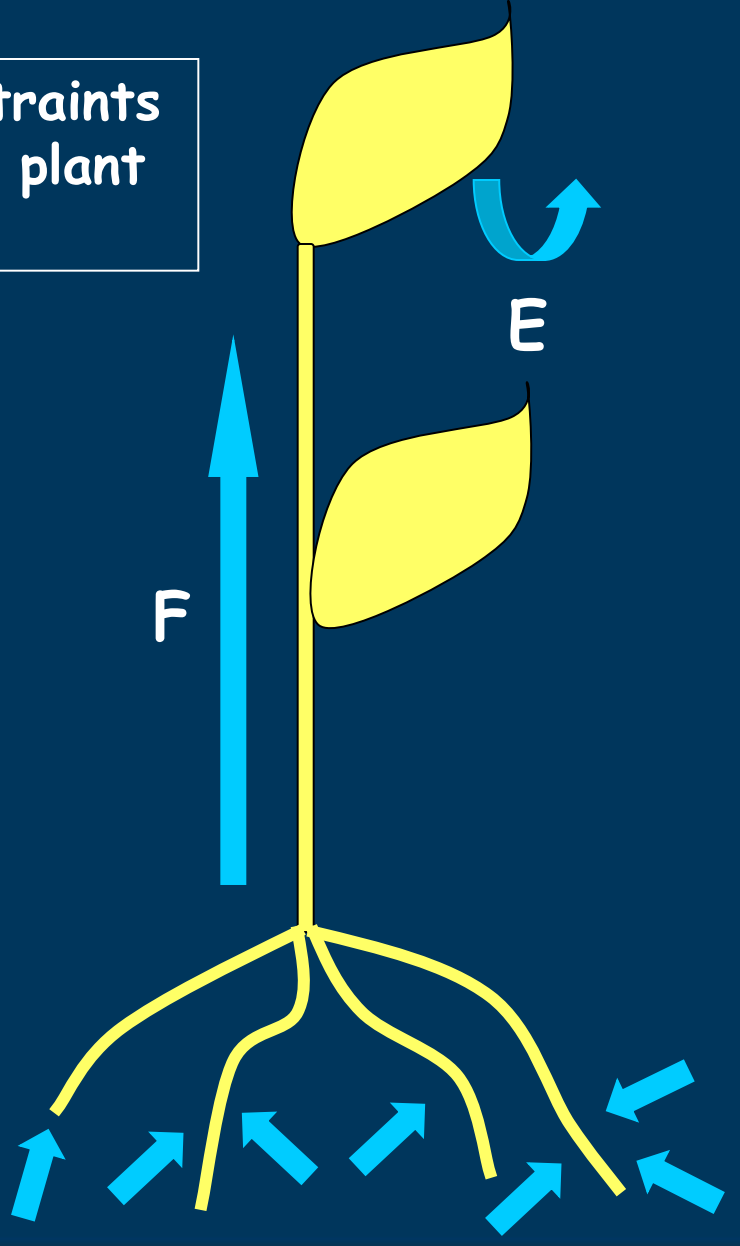


Plant hydraulic conductance place constraints over gas exchange, photosynthesis and plant productivity

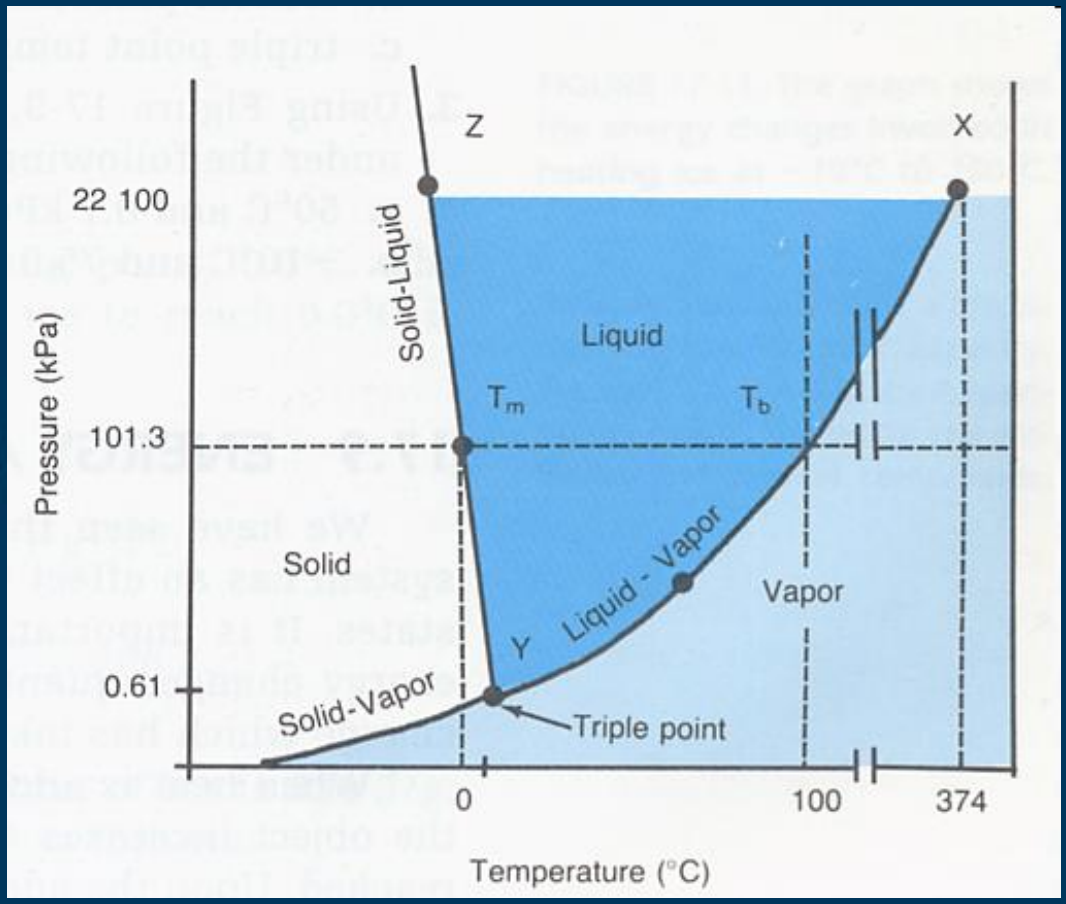
Under steady-state flows: $E = F$

$$E = (\Psi_{soil} - \Psi_{leaf}) \times K_{plant}$$

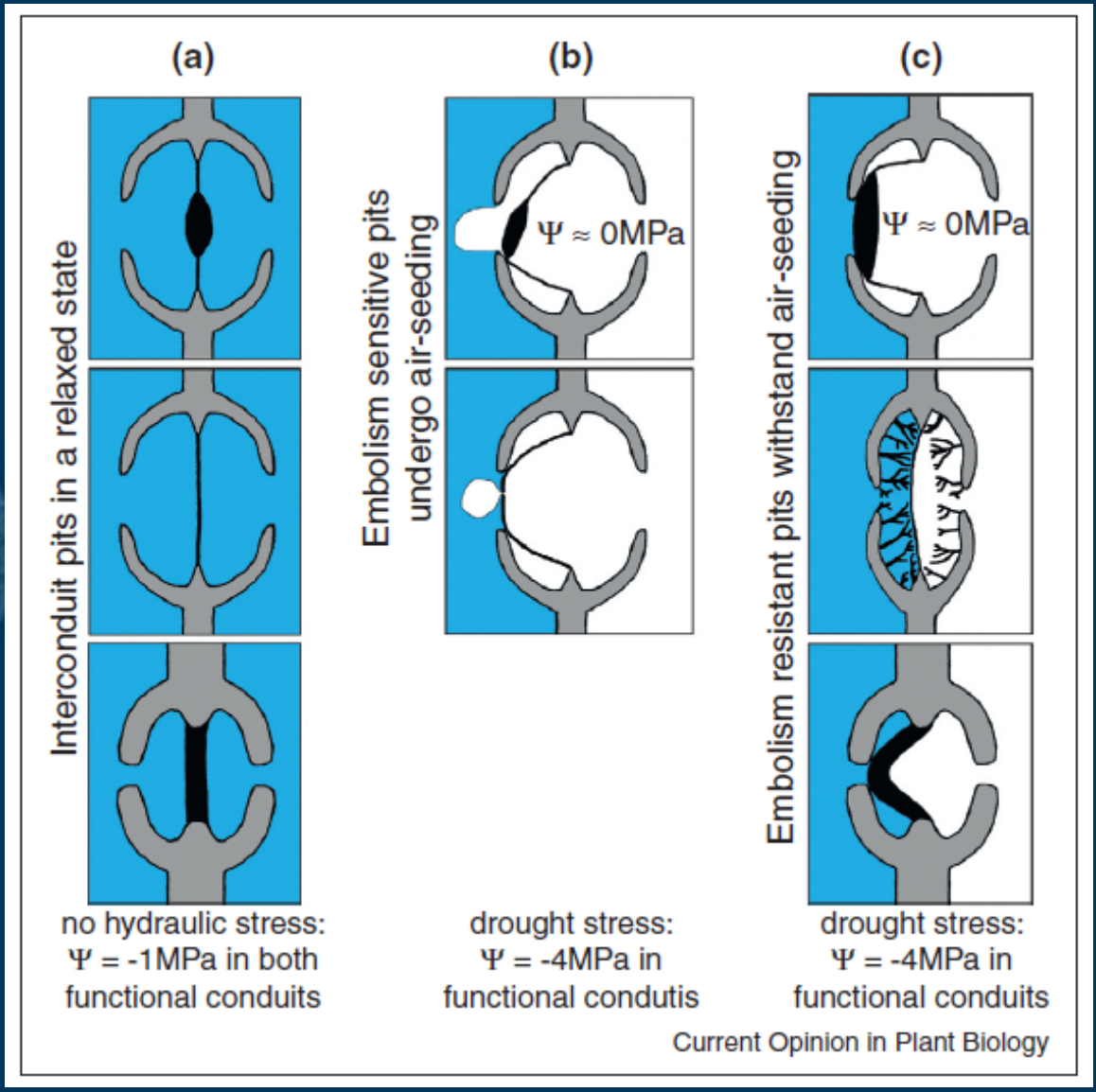
Plants want $\Psi_{leaf} > \Psi_{critical}$ (turgor loss and/or xylem cavitation)



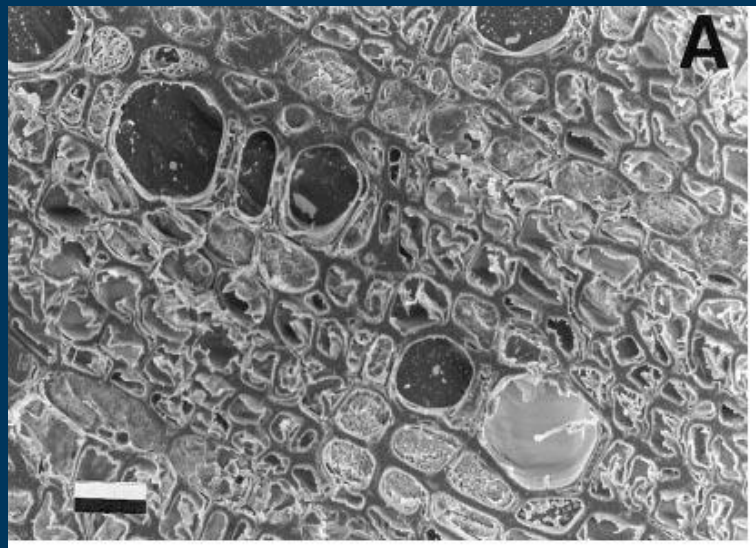
Living at the edge…

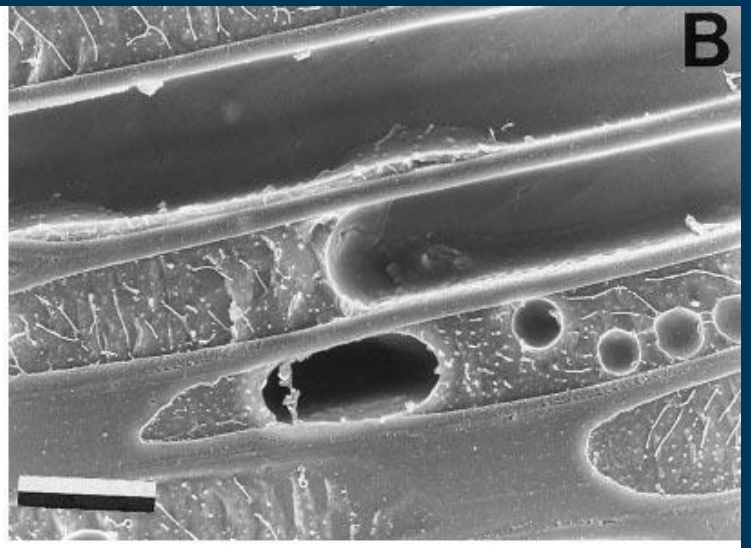


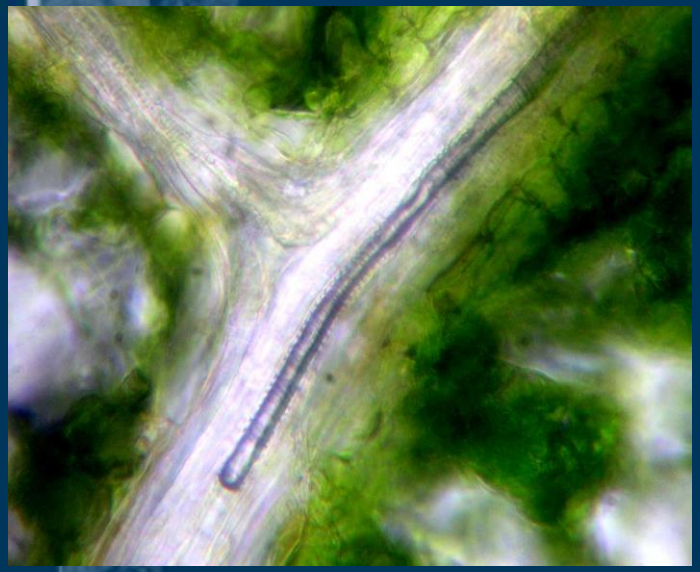
Xylem water is liquid while at P below its vapour pressure.
This is a metastable state!

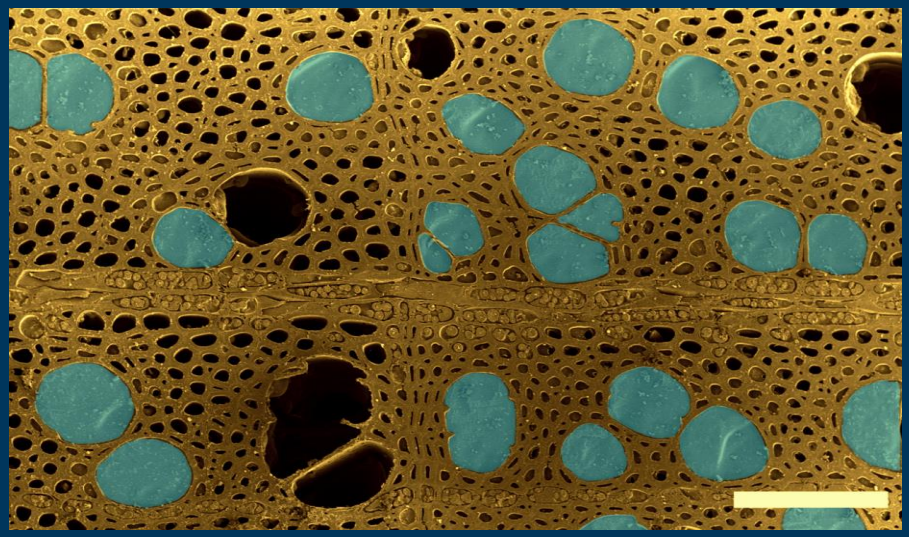


Cavitation-induced embolism put at risk the water transport system of plants

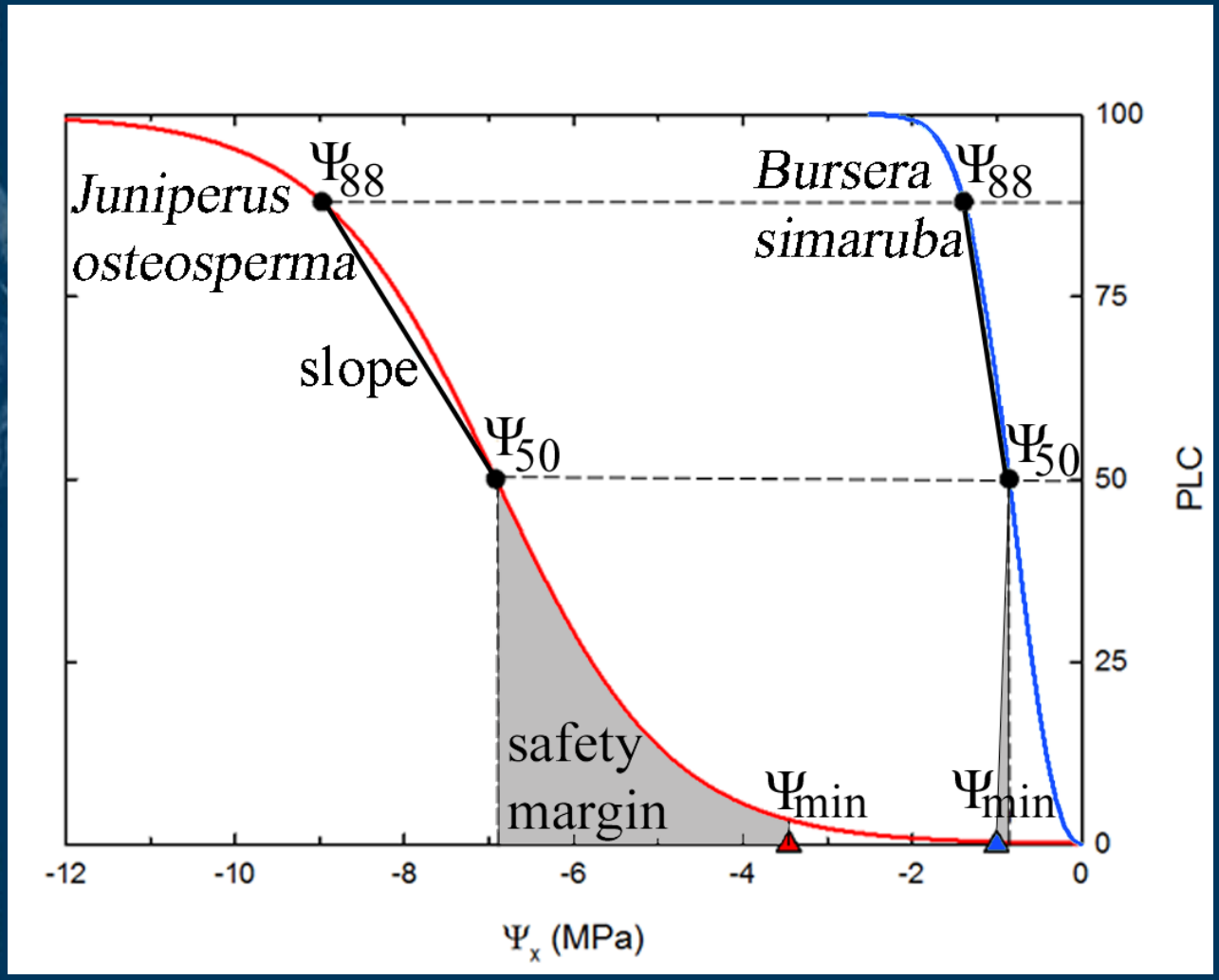

A


B





Quantifying plant's vulnerability to cavitation: vulnerability curves and P50



480 woody species from 172 sites around the globe

Ψ_{50} and Ψ_{min} values

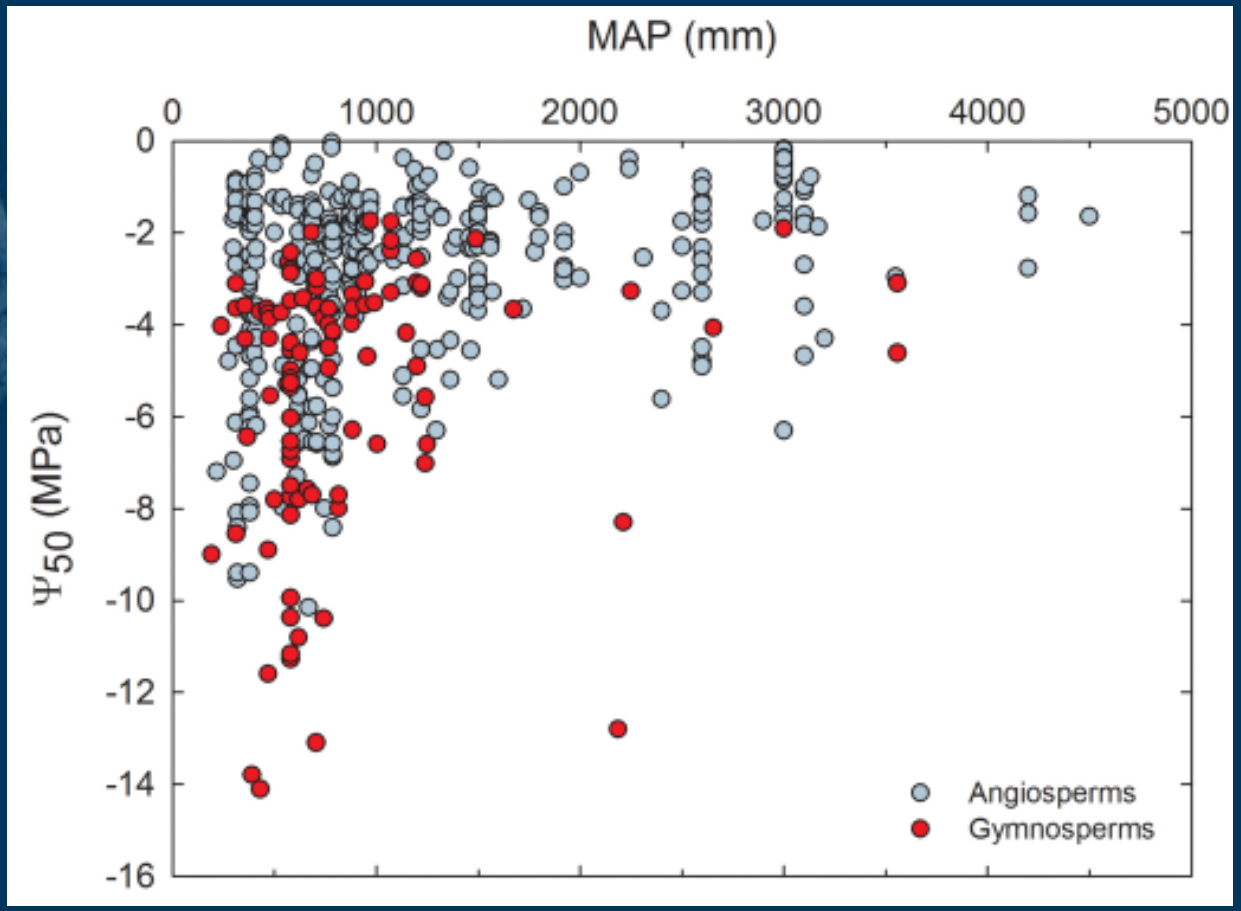
LETTER

doi:10.1038/nature11688

Global convergence in the vulnerability of forests to drought

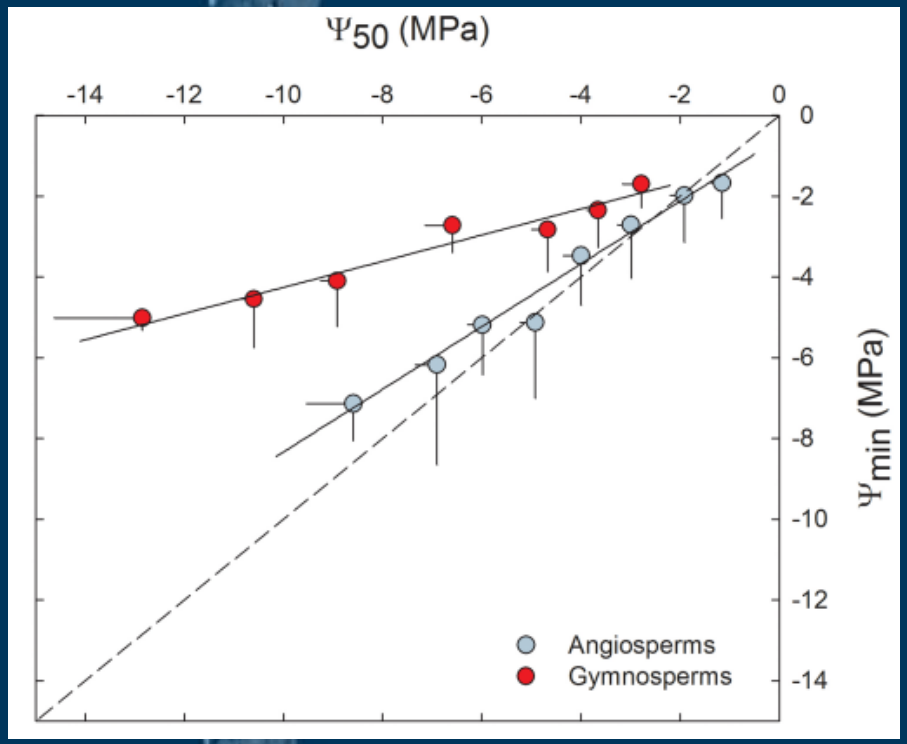
Brendan Choat[1]*, Steven Jansen[2]*, Tim J. Brodribb[3], Hervé Cochard[4,5], Sylvain Delzon[6], Radika Bhaskar[7], Sandra J. Bucci[8], Taylor S. Feild[9], Sean M. Gleason[10], Uwe G. Hacke[11], Anna L. Jacobsen[12], Frederic Lens[13], Hafiz Maherali[14], Jordi Martínez-Vilalta[15,16], Stefan Mayr[17], Maurizio Mencuccini[18,19], Patrick J. Mitchell[20], Andrea Nardini[21], Jarmila Pittermann[22], R. Brandon Pratt[12], John S. Sperry[23], Mark Westoby[10], Ian J. Wright[10] & Amy E. Zanne[24,25]

Increased resistance to cavitation as a key functional trait in adaptation to dry habitats!

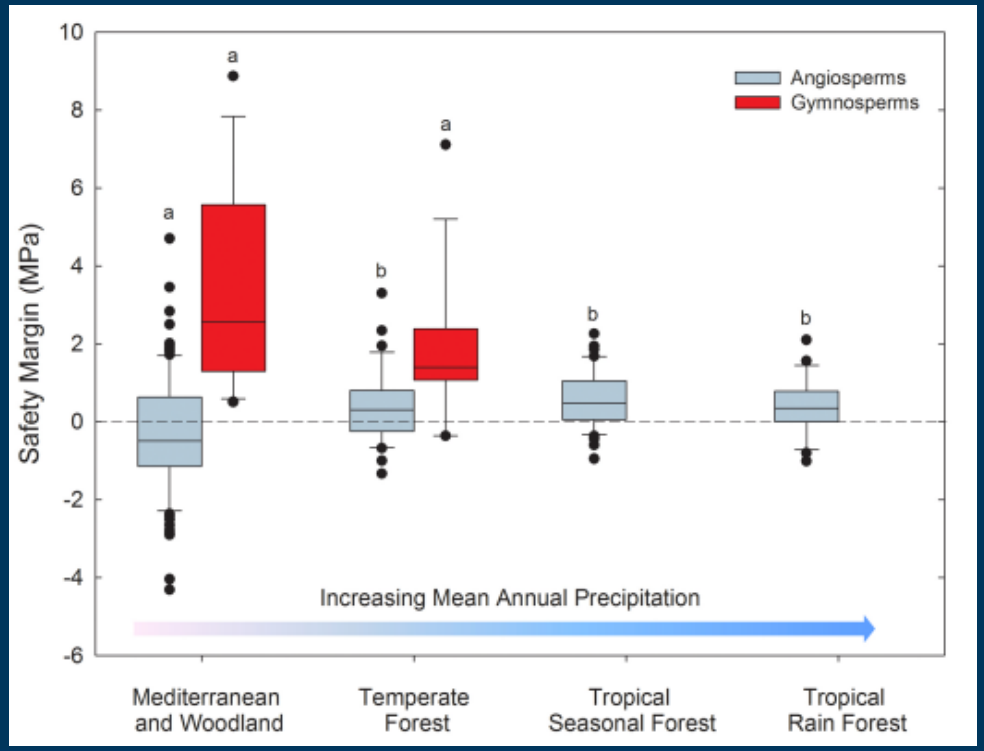


Choat et al. 2012, *Nature*

In all biomes plants operate with narrow safety margin.
Risk of extensive dieback during anomalous drought events!



Choat et al. 2012, *Nature*



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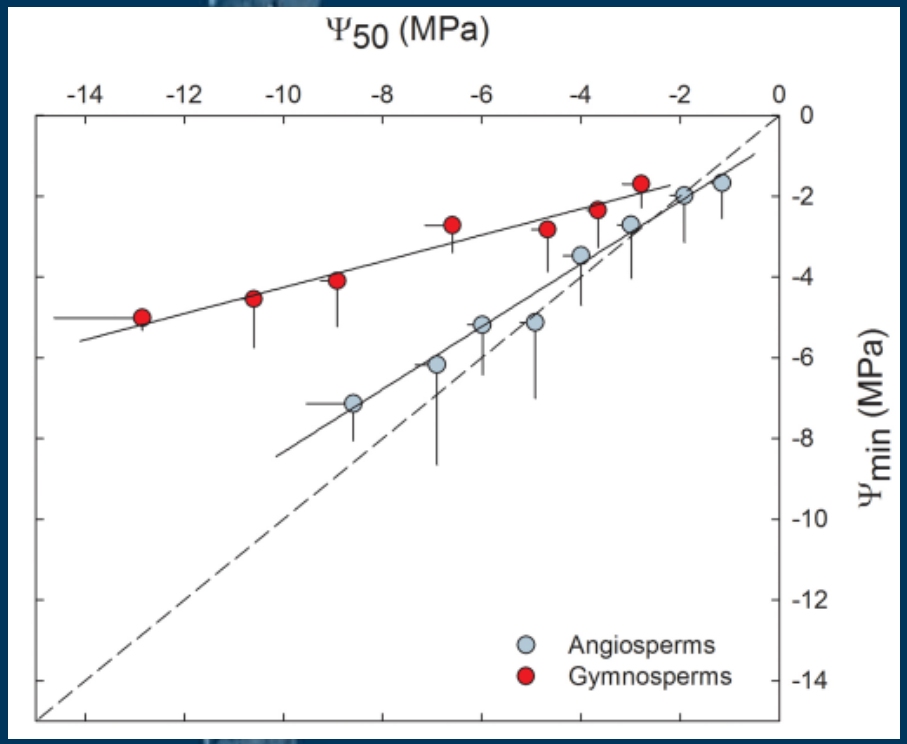
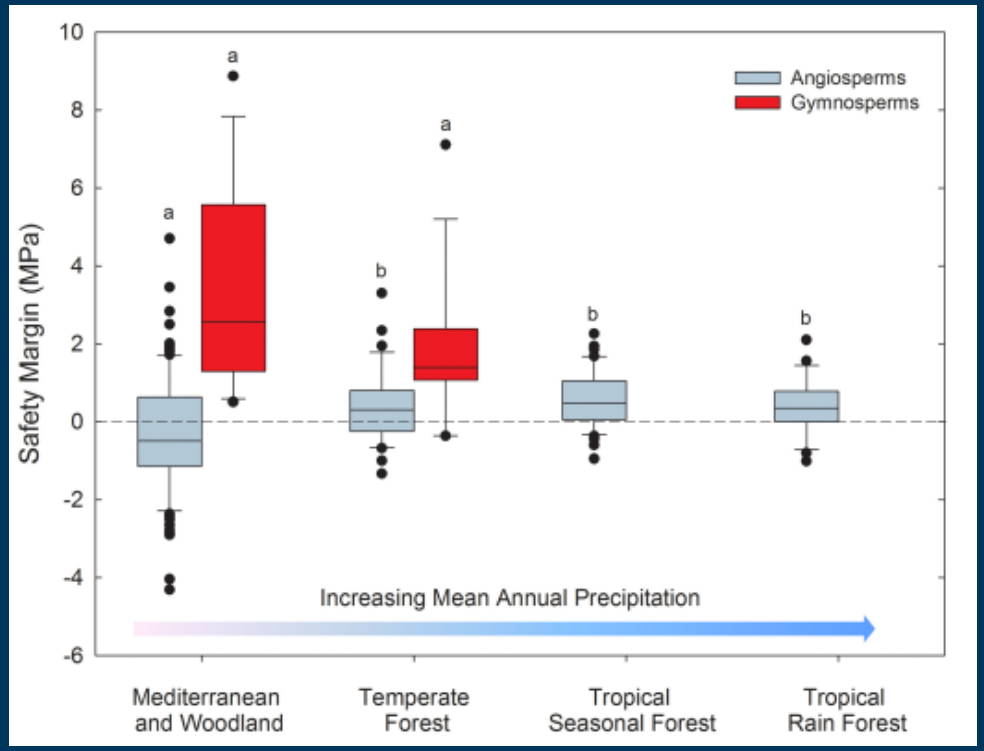
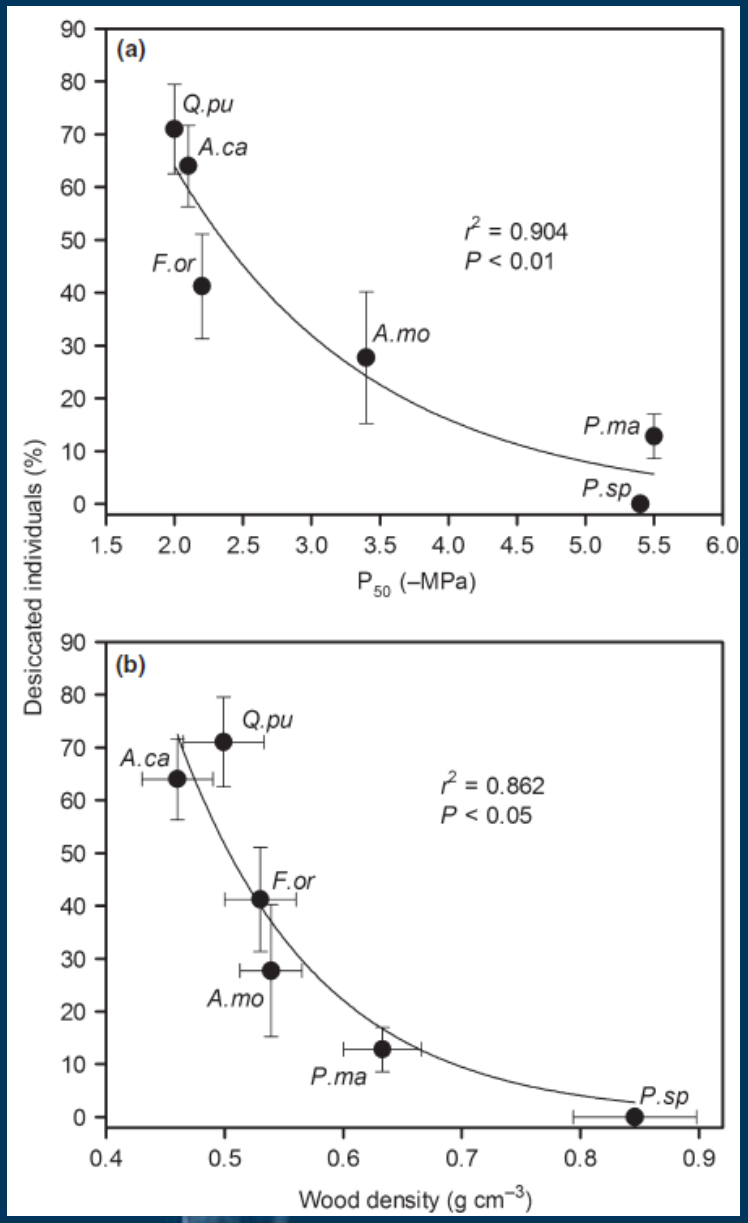
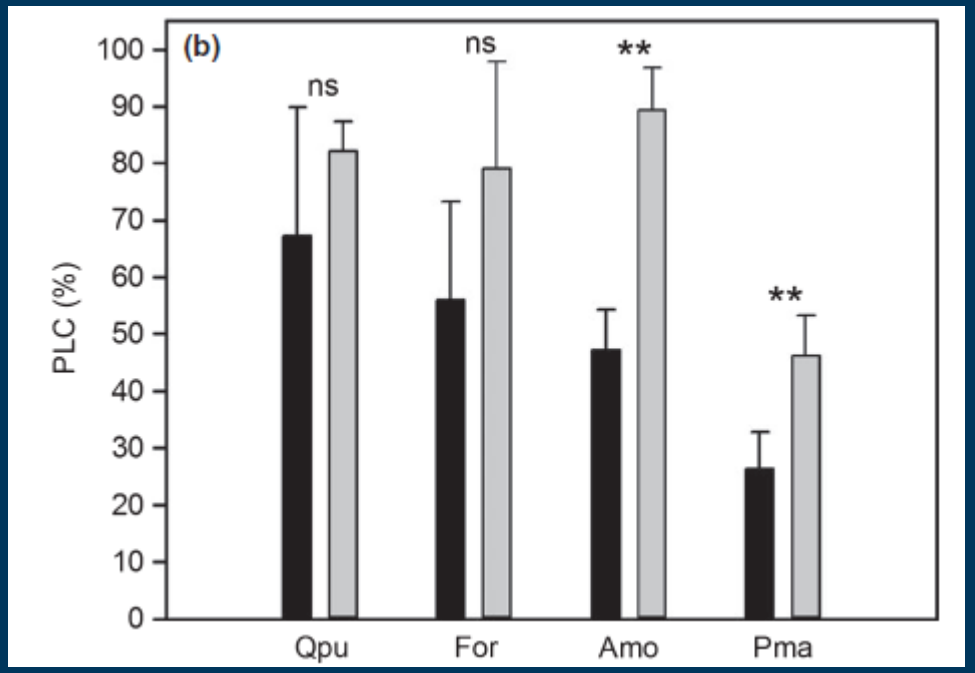
Risk of extensive dieback during anomalous drought events!



Choat et al. 2012, *Nature*







Research

New Phytologist

Rapid report

Shoot desiccation and hydraulic failure in temperate woody angiosperms during an extreme summer drought

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Andrea Nardini
Tel: +39 040 5583890
Email: nardini@units.it

Andrea Nardini, Marta Battistuzzo and Tadeja Savi
Dipartimento di Scienze della Vita, Università di Trieste, Via L. Giorgieri 10, 34127 Trieste, Italy

International Workshop on
Plant Physiology in the Urban Environment
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Do woody plants show significant genotypic/phenotypic variability in their vulnerability to cavitation?

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Fagus sylvatica L.

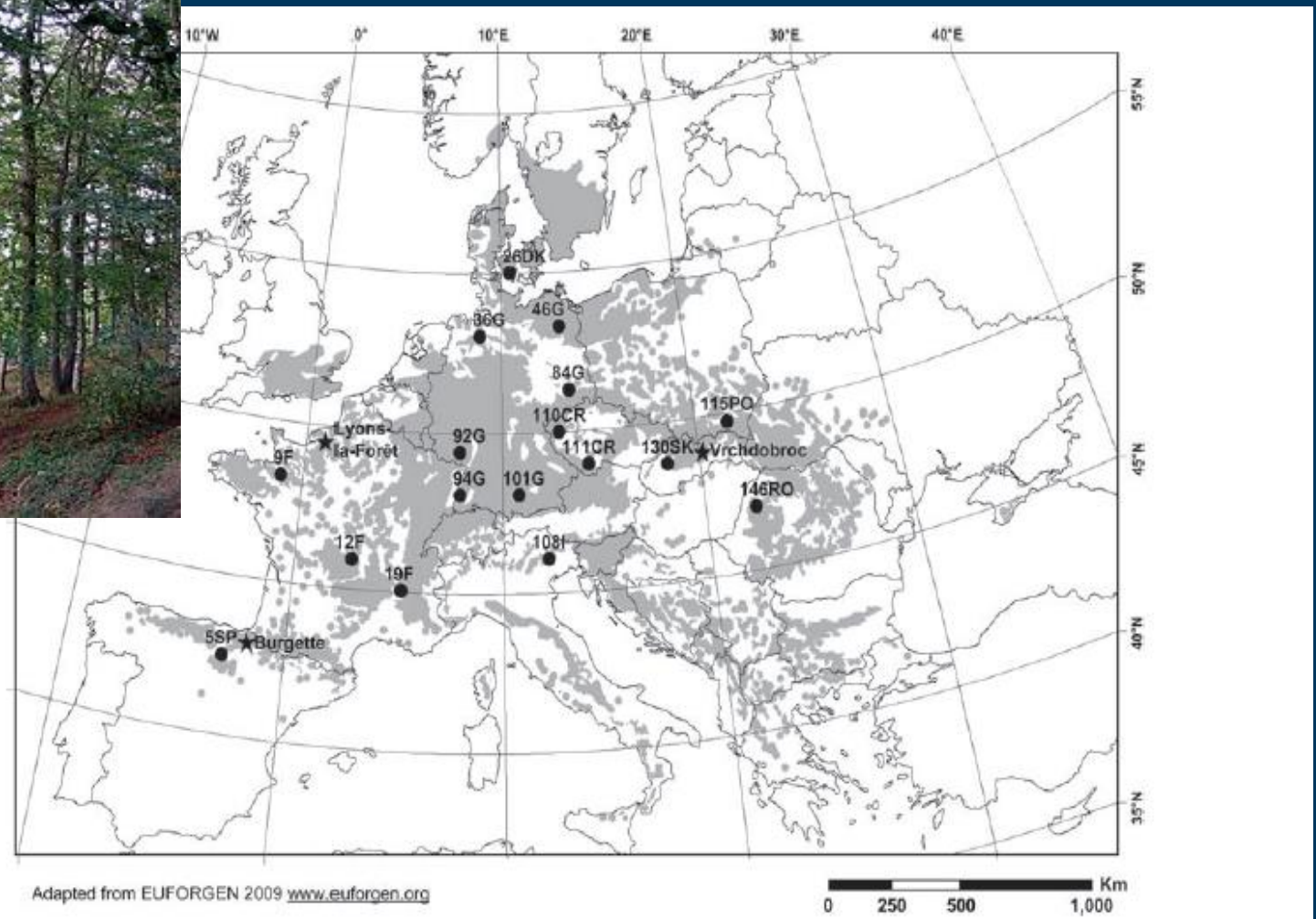


Figure 1. Current distribution map of *F. sylvatica* in Europe. The different populations evaluated in this study are identified by black circles and trials by black stars.

Wortemann et al. 2011, *Tree Physiology*

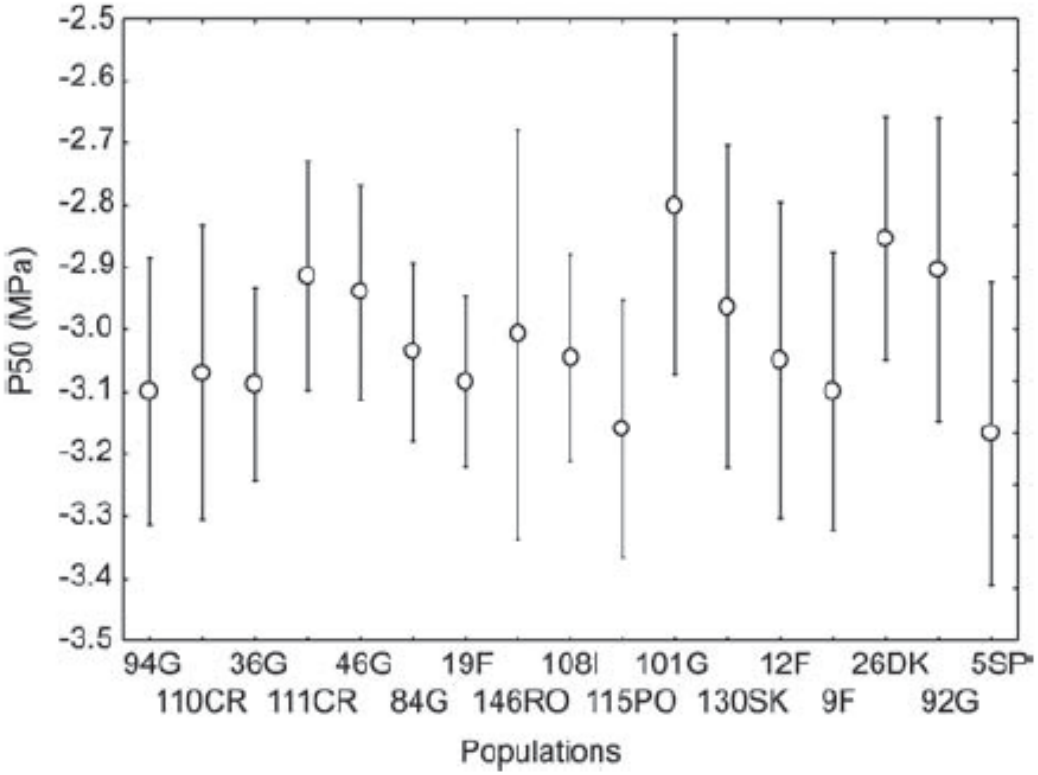
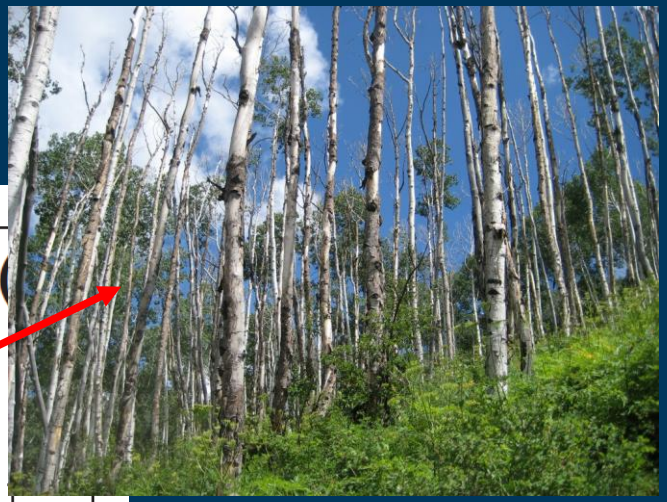
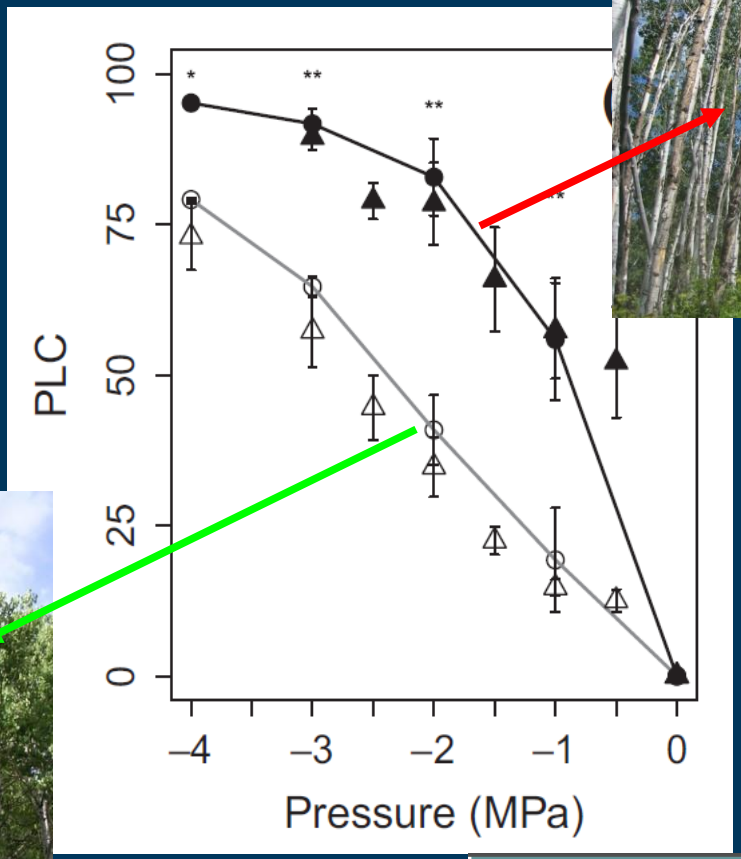


Figure 2. Genotypic variability of cavitation resistance (P_{50}, MPa) across 17 beech populations grown in the same common garden in France. The plot indicates the mean (open circle) and the 0.95 confidence intervals for each population. No statistically significant differences were found between populations.

Wortemann et al. 2011, *Tree Physiology*

Extreme drought stress events induce increased xylem vulnerability in Aspen: hydraulic deterioration!





Global Change Biology

Global Change Biology (2013) **19**, 1188–1196, doi: 10.1111/gcb.12100

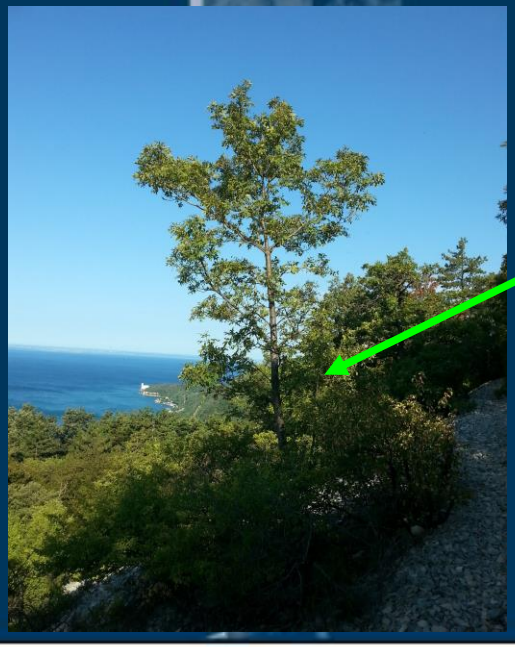
Drought's legacy: multiyear hydraulic deterioration underlies widespread aspen forest die-off and portends increased future risk

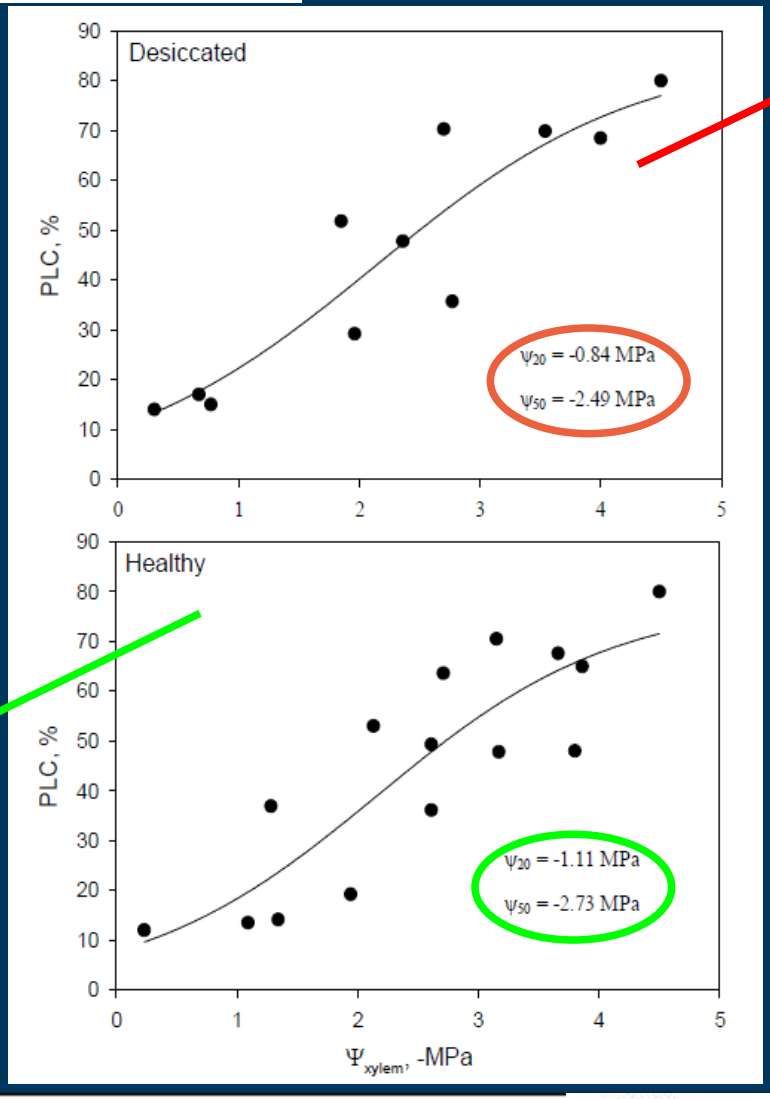
WILLIAM R. L. ANDEREGG*†, LENKA PLAVCOVÁ‡, LEANDER D. L. ANDEREGG†, UWE G. HACKE‡, JOSEPH A. BERRY† and CHRISTOPHER B. FIELD†

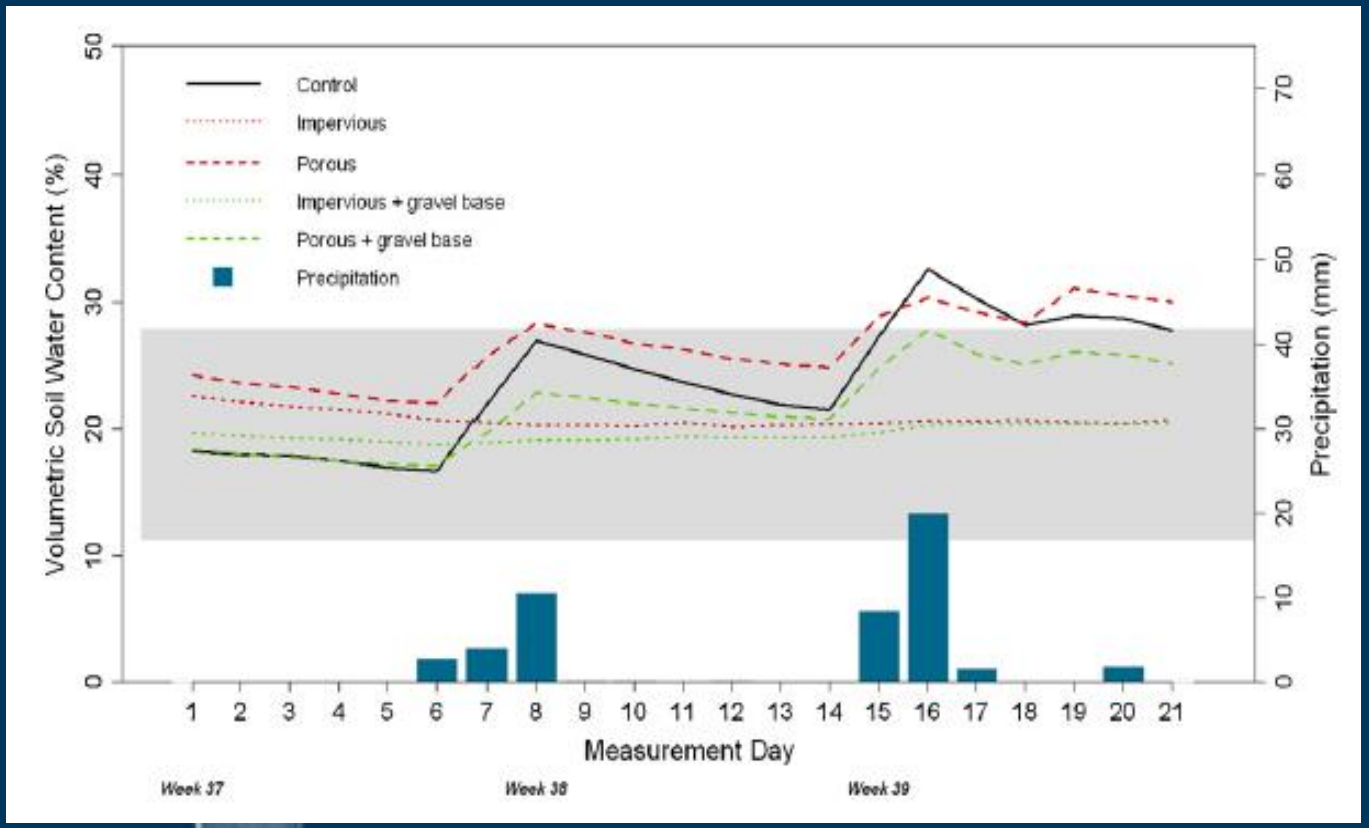
Agrochimica, Vol. LVIII – Special Issue

Droughts, heat waves and plant hydraulics: impacts and legacies

A. NARDINI*, T. SAVI, M. NOVAK
Dipartimento di Scienze della Vita, Università di Trieste, Via L. Giorgieri 10, 34127 Trieste, Italy







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Belowground effects of porous pavements—Soil moisture and chemical properties

Justin Morgenroth[a,*], Graeme Buchan[b], Bryant C. Scharenbroch[c]

International Workshop on
Plant Physiology in the Urban Environment
Pisa, Italy, 23.06.2014

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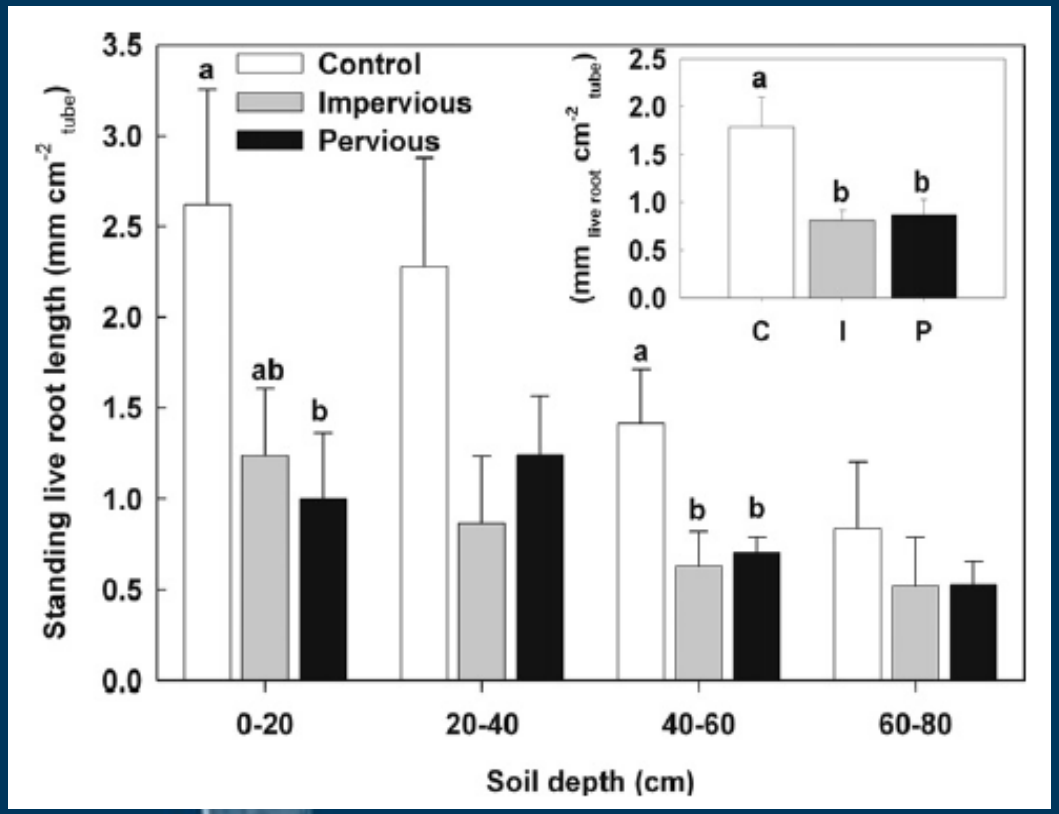

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Impervious and pervious pavements increase soil CO_2 concentrations and reduce root production of American sweetgum (*Liquidambar styraciflua*)

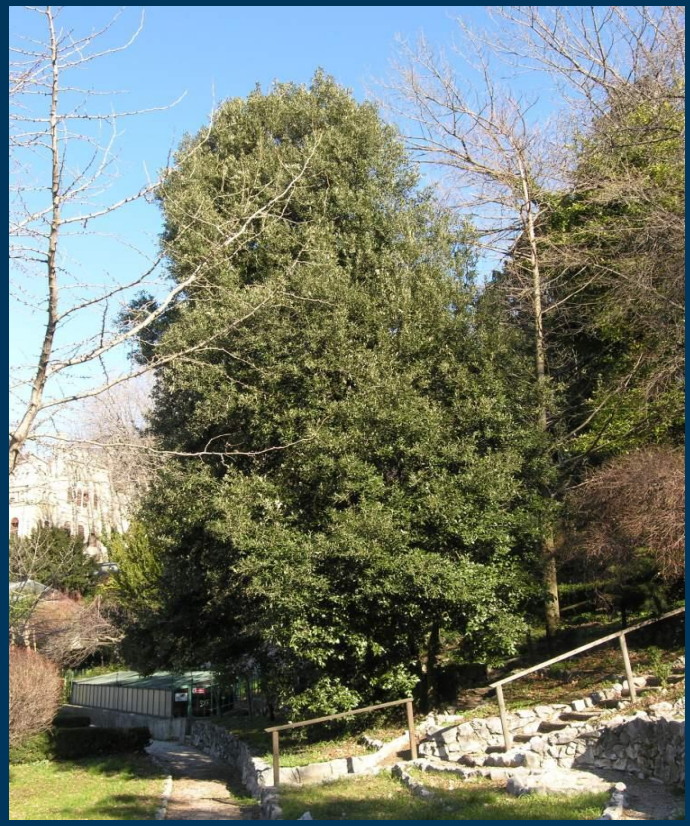
Bhavana Viswanathan[a], Astrid Volder[a,*], W. Todd Watson[b], Jacqueline A. Aitkenhead-Peterson[c]

TreeCity

An International Project for a Better Quality of Life in Our Cities

Sponsored by MIUR PRIN

Quercus ilex L.



STReESS

STReESS – Studying Tree Responses to extreme Events: a SynthesiS

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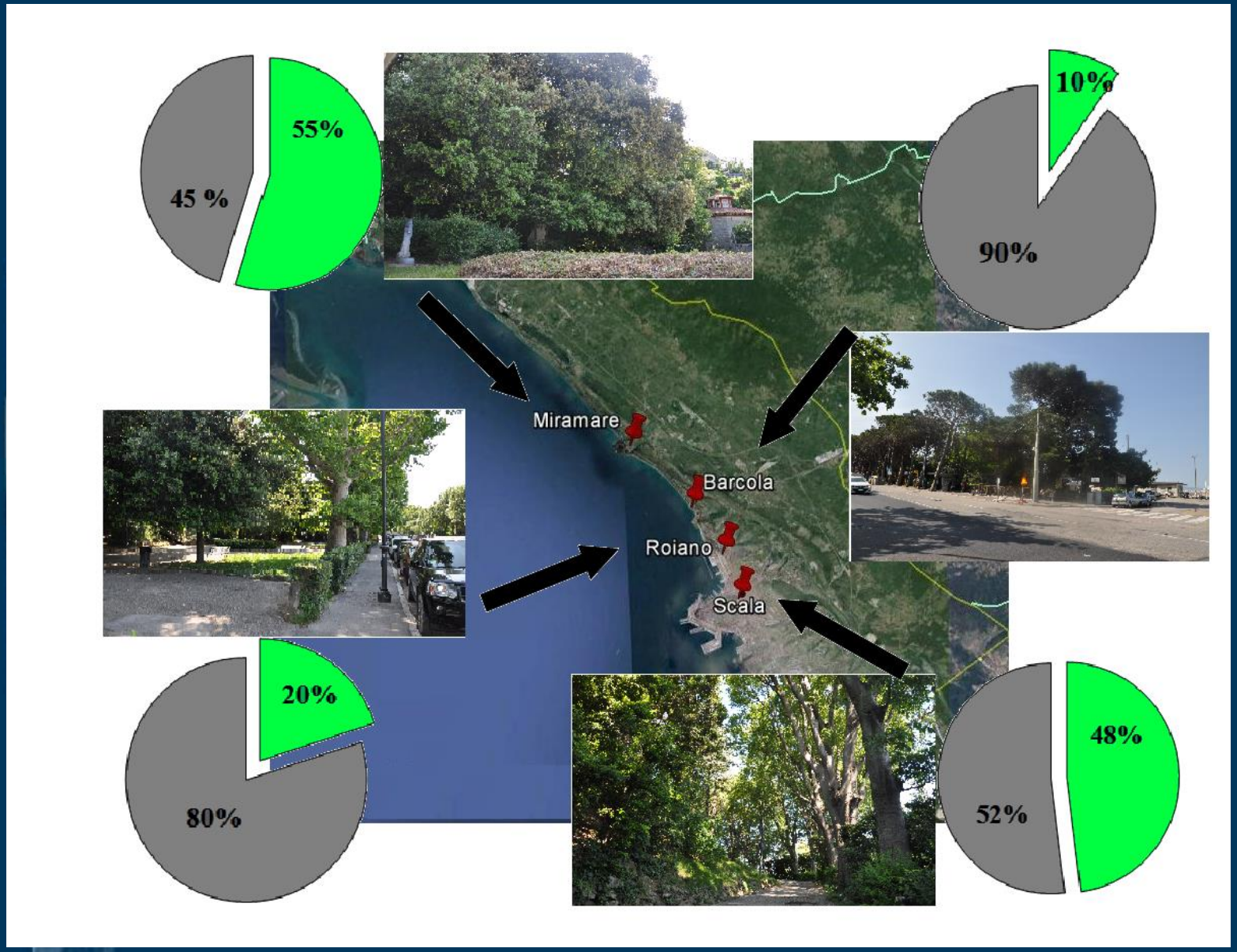
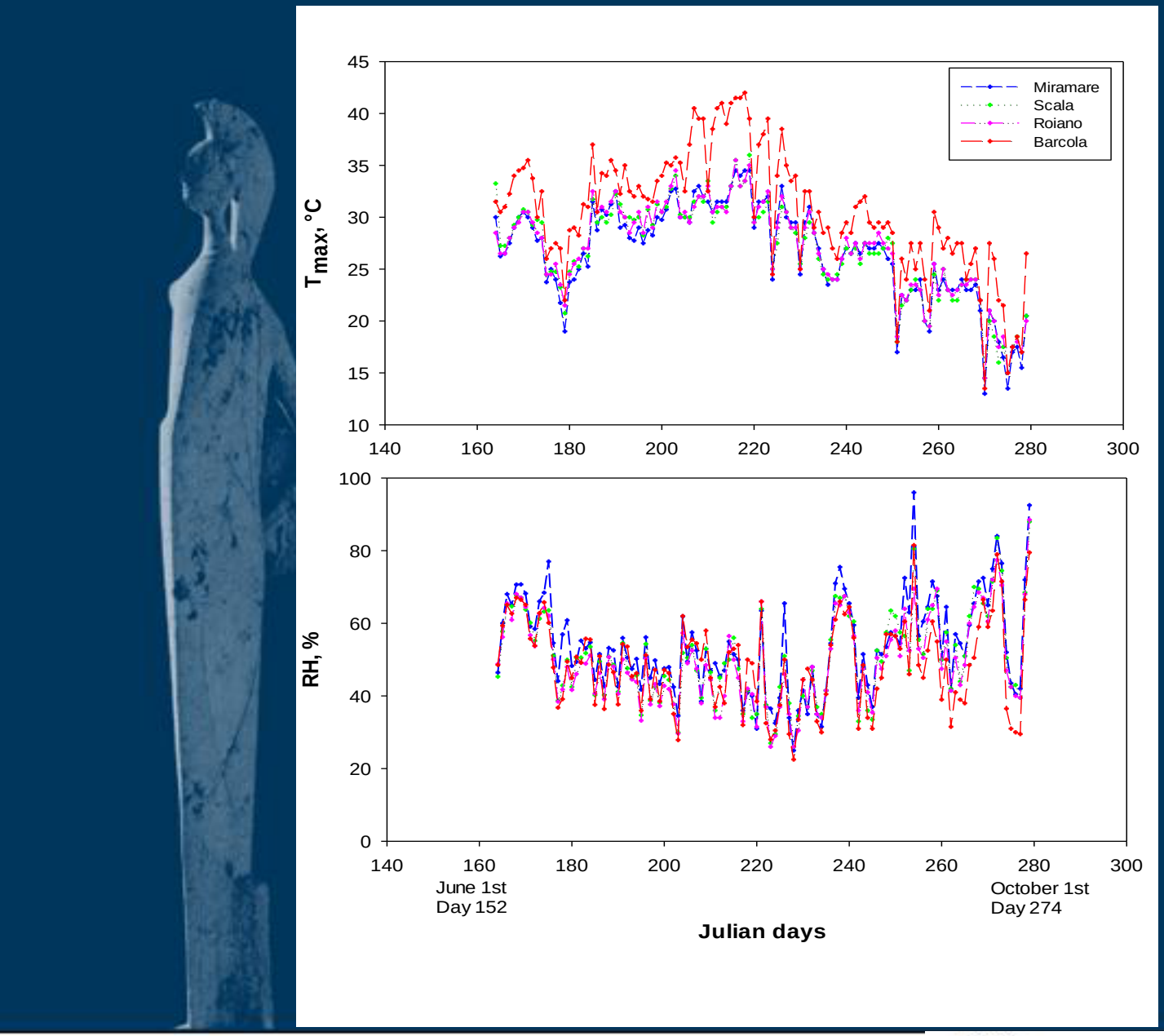


Savi et al. 2014, *submitted*



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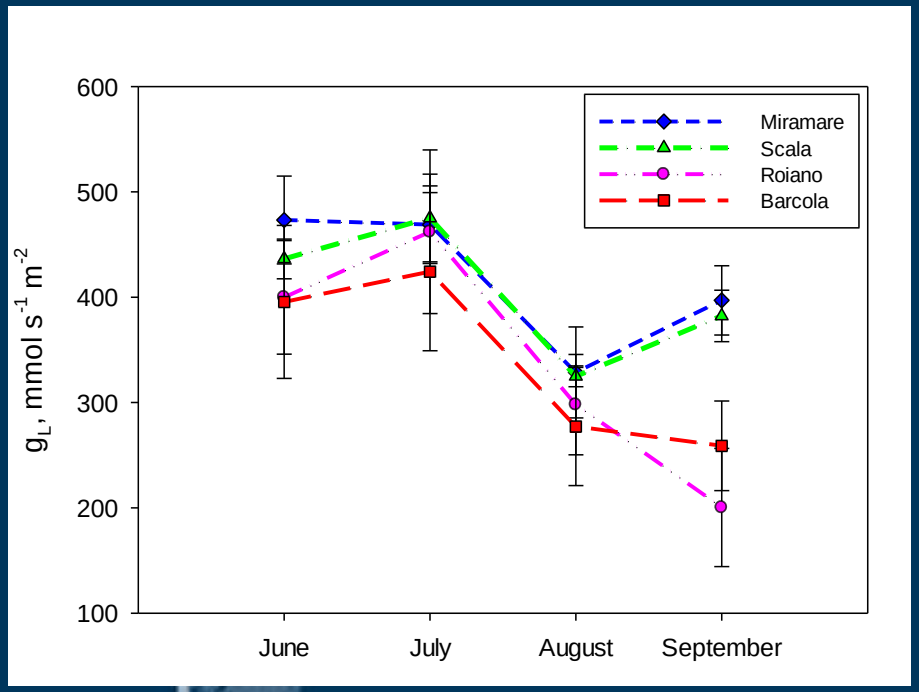

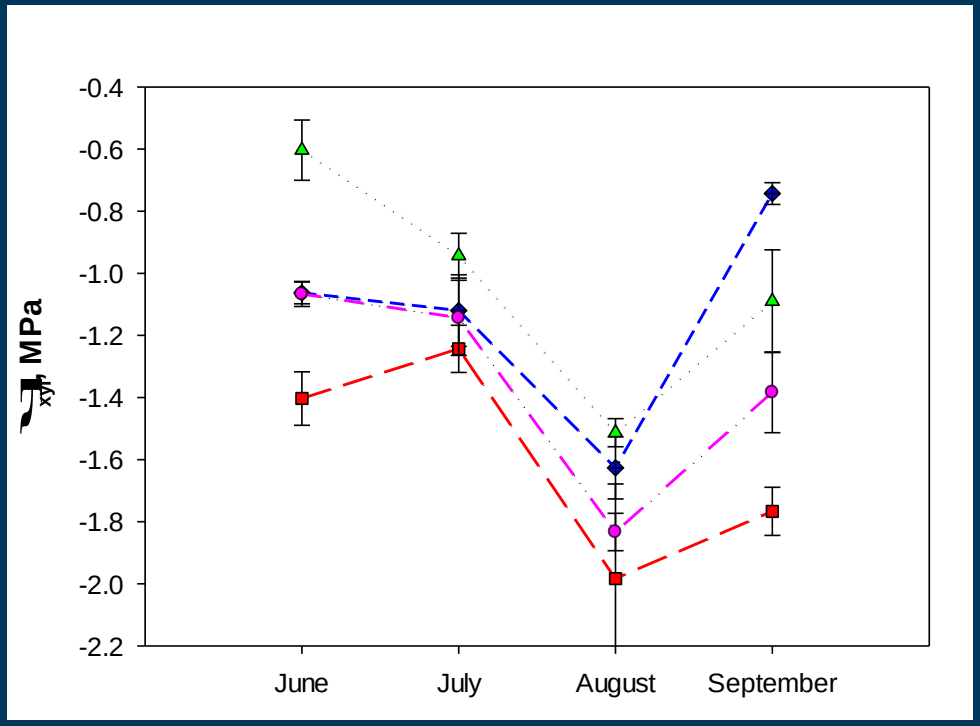

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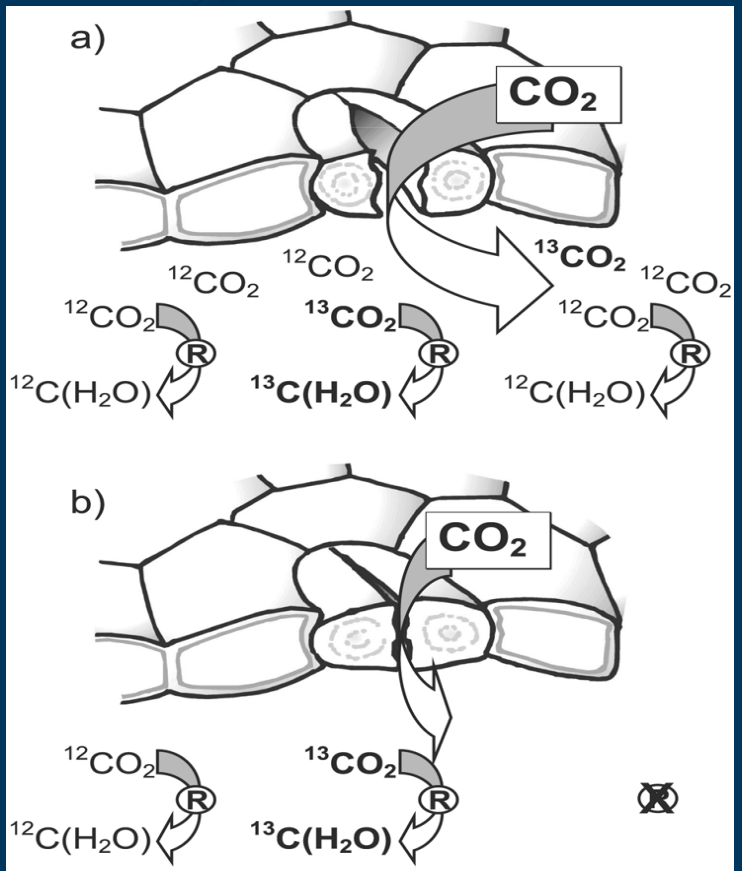
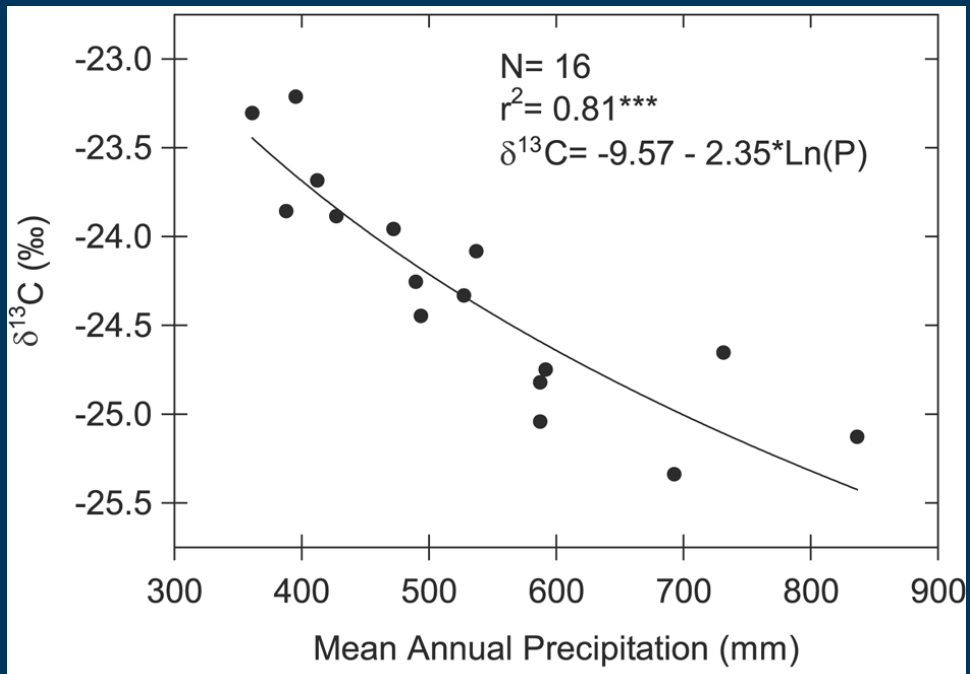
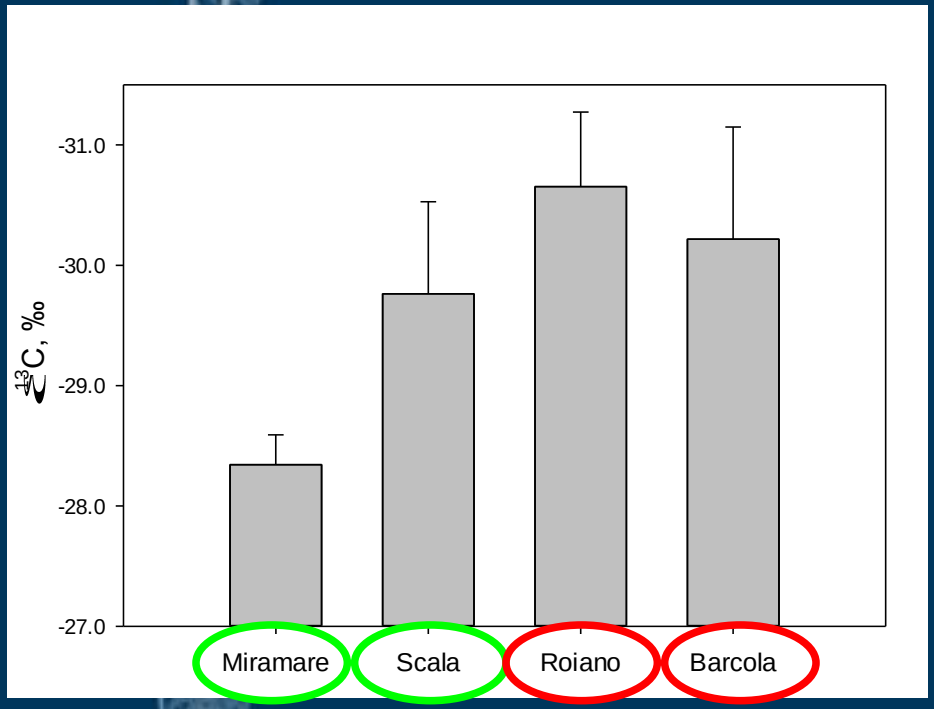


Note: R = RuBisCO. See text for further explanation



Note: Ferrio *et al.* (2002)

An unexpected trend...



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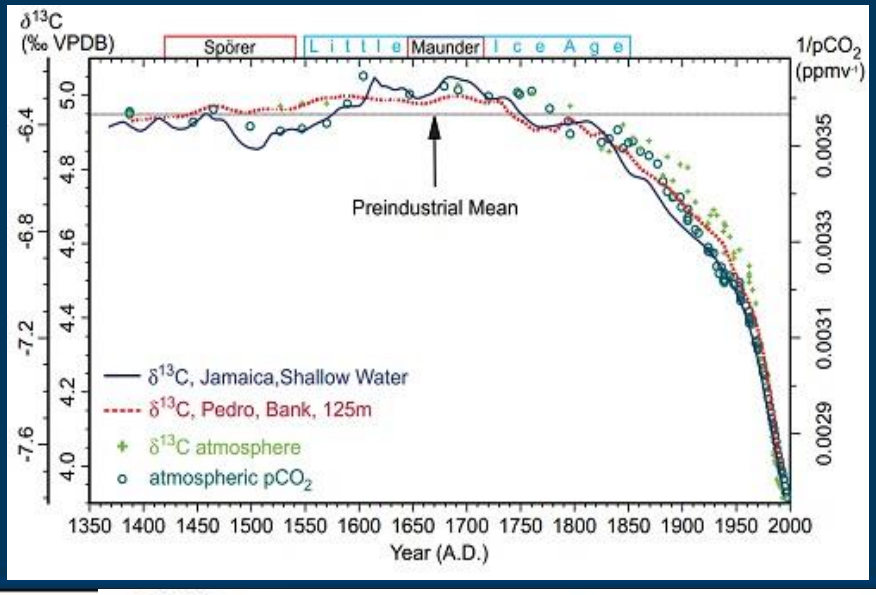

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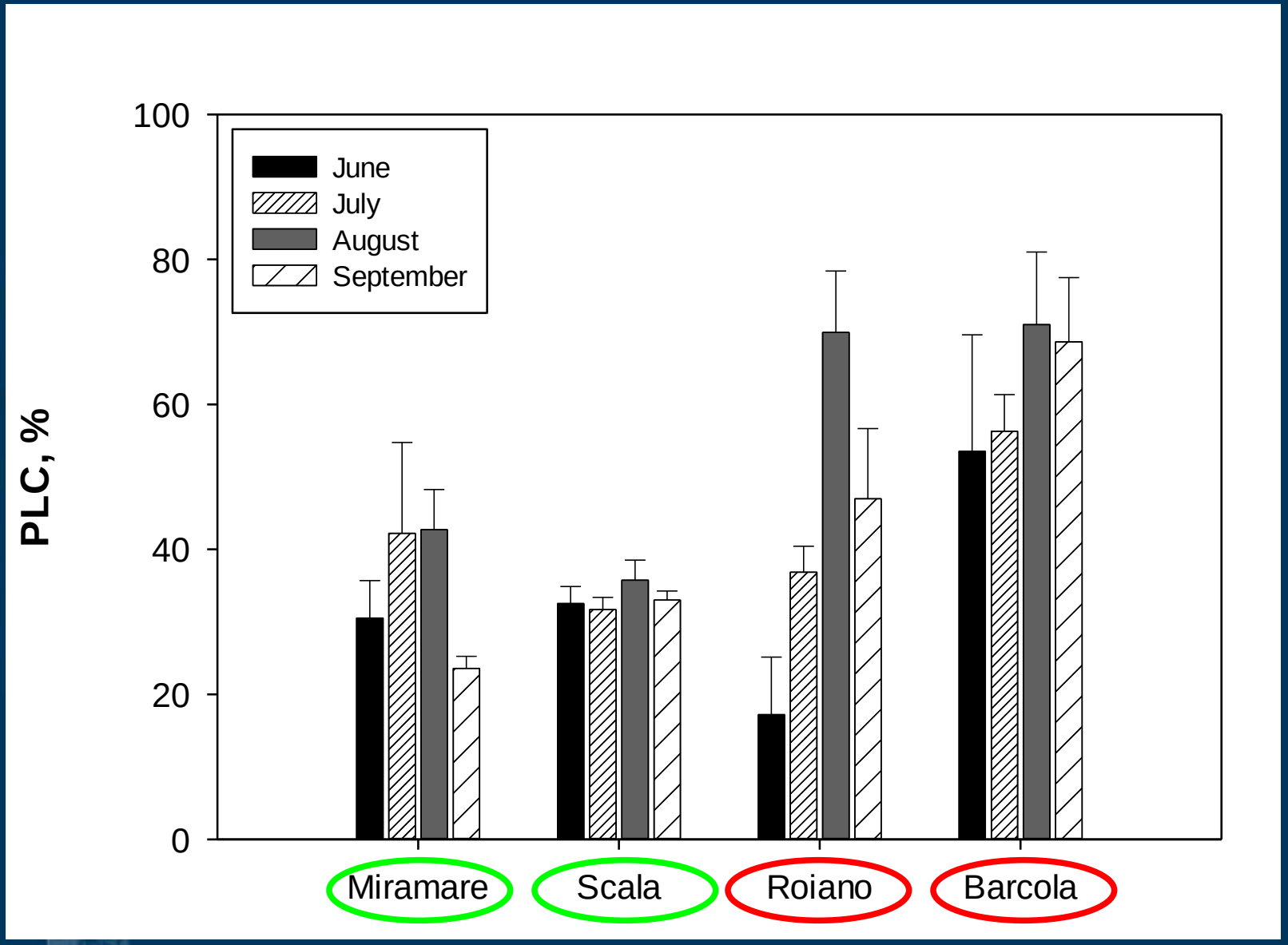

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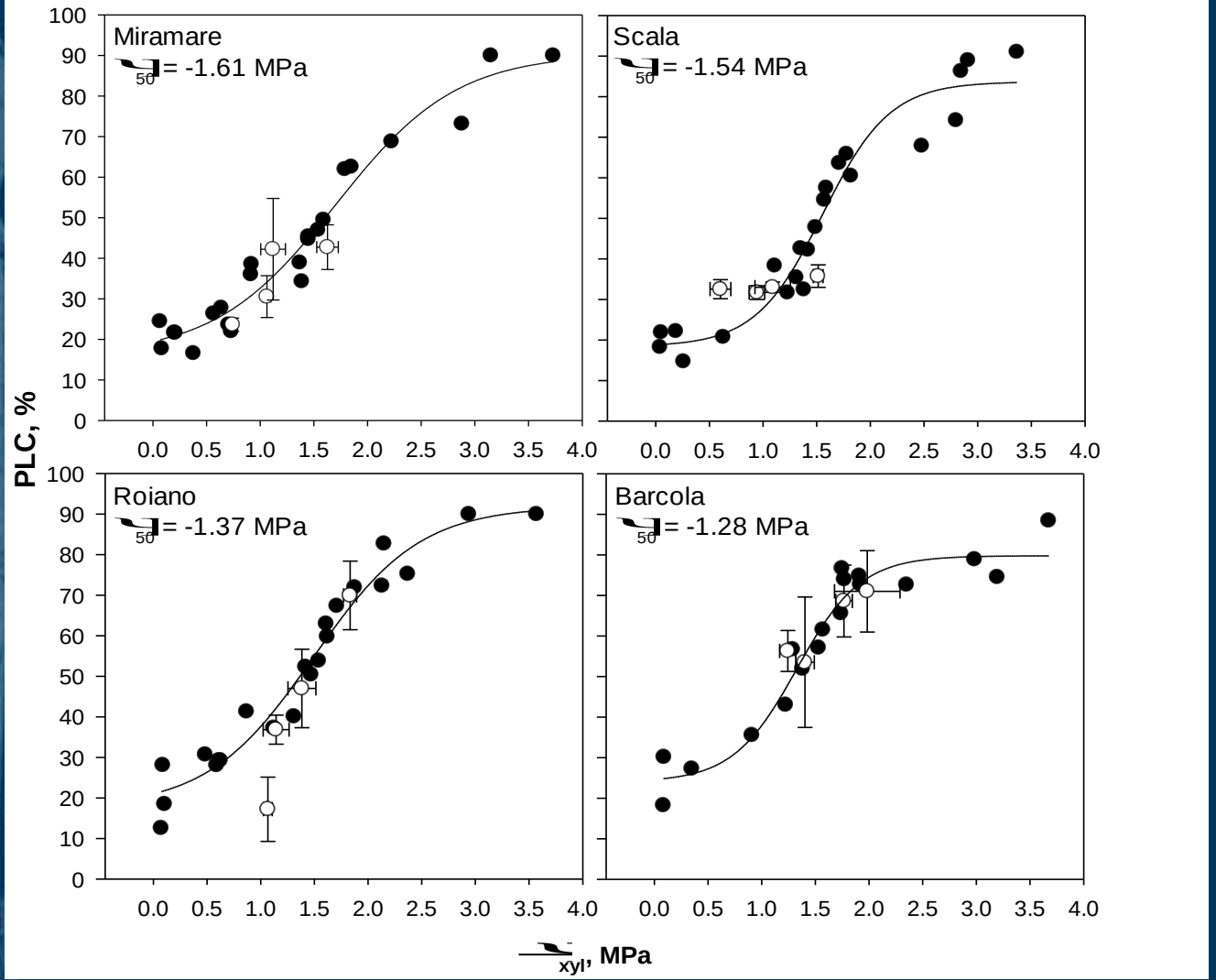

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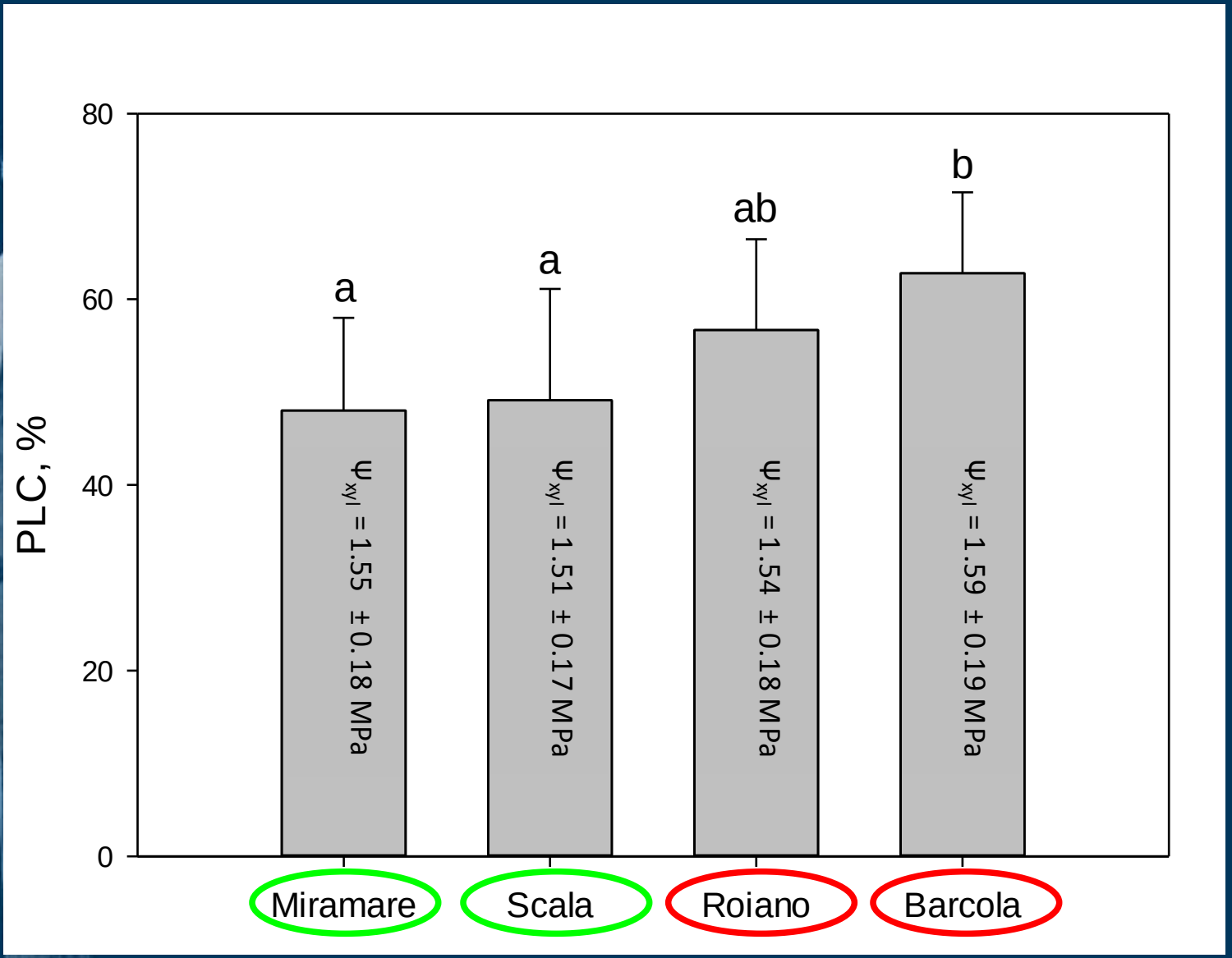

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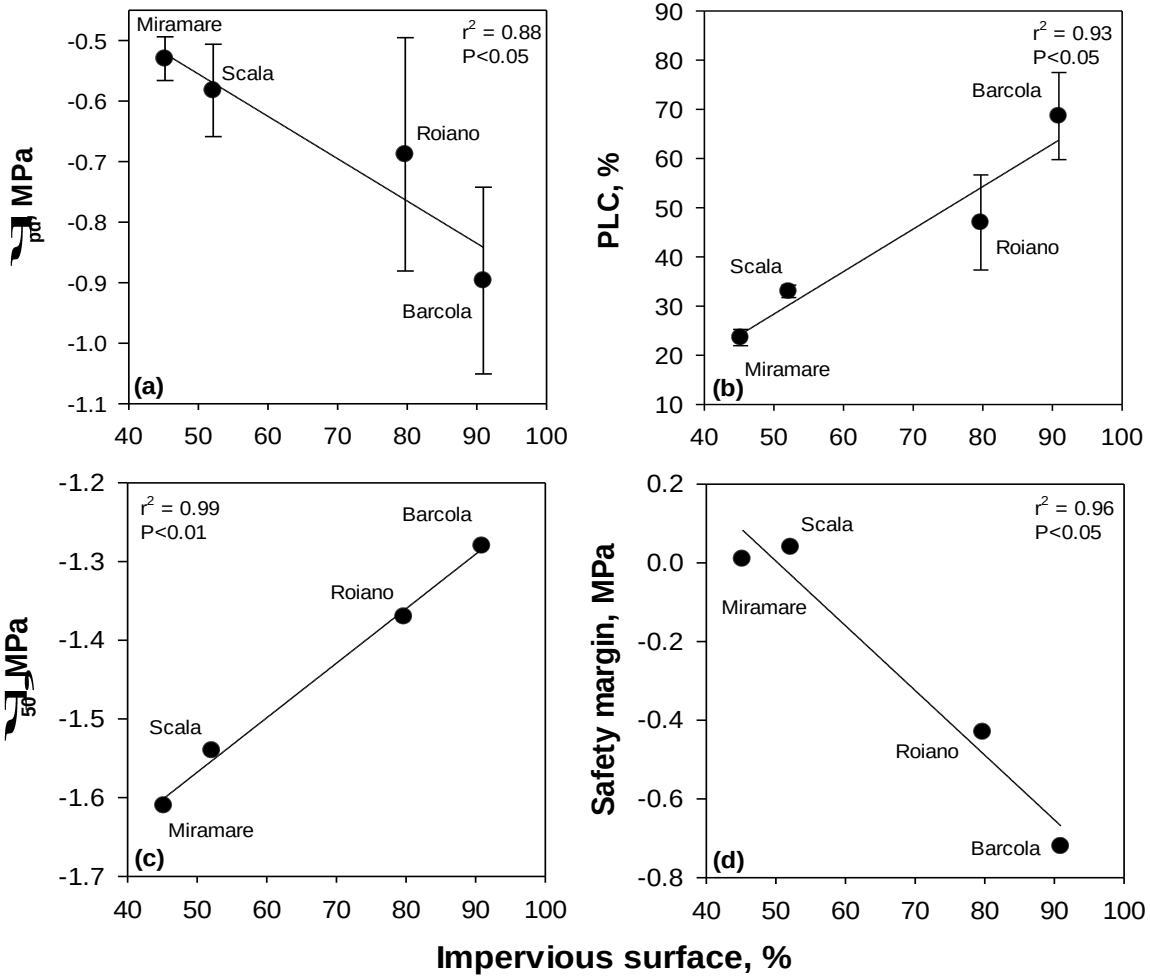

Savi et al. 2014, *submitted*

Take home message...

- Street trees can be subjected to considerable water stress, depending on site characteristics (pavement)

- Water-stressed street trees are exposed to the risk of embolism, which reduces stomatal aperture (and transpirational cooling)

- Chronic water stress causes hydraulic deterioration and increased Vulnerability to cavitation, portending increasing risks of canopy die-back under global change-type drought and heat waves

- Selection of street trees for climate change mitigation strategies should take into account plant hydraulics, with special reference to cavitation resistance

- Carbon isotopic composition of street trees as a possible bio-indicator of fossil fuel pollution

Thank you for your attention!