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Title: Vegetation under changing climate: What determines who survives, and what can we do about it?

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Vegetation under changing climate: What determines who survives, and what can we do about it?

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Duke University, April 8th. 2022

LA-UR-XXXX

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-Material Sciences
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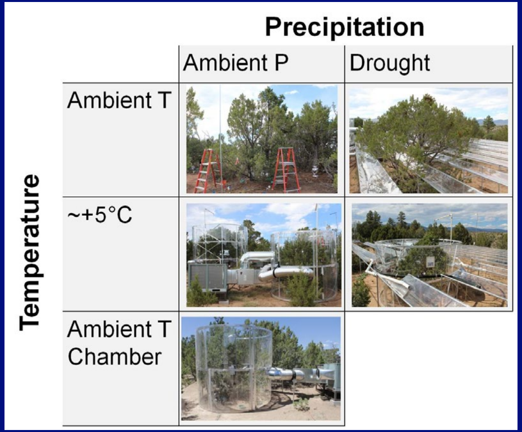
Goal of this talk

Give an overview of how we predict plant responses to climate change and create discussion about what we know, and what we should study

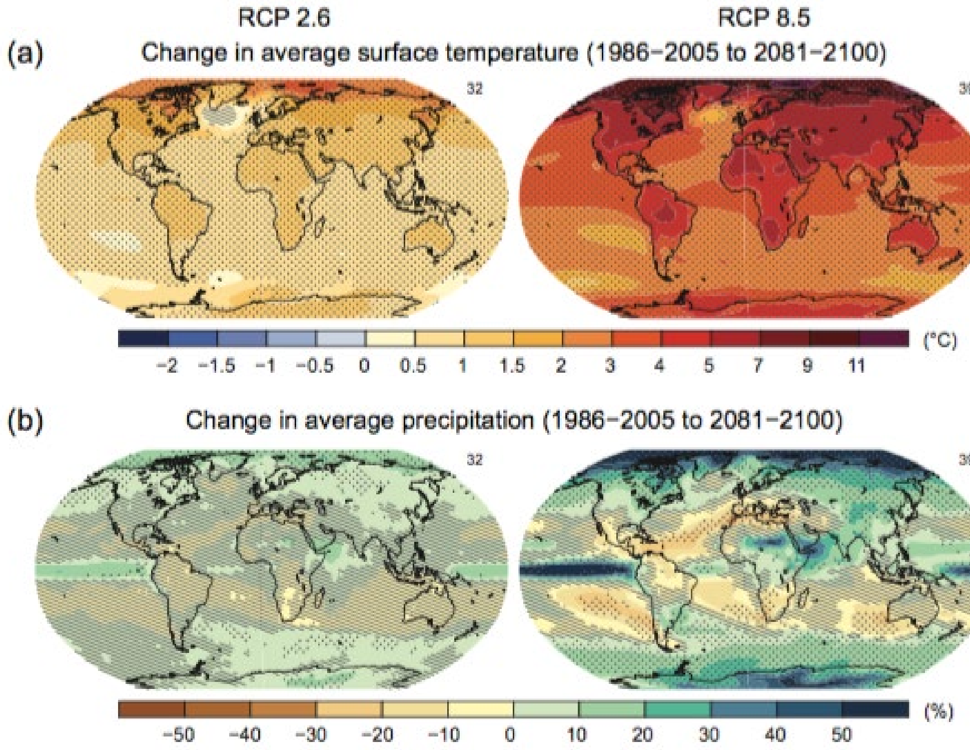
Survival and Mortality experiment, Los Alamos NM, 2012-2016



Greenhouse experiment, Los Alamos, NM 2010

Precipitation manipulation experiment, Sevilleta, NM 2006-2016

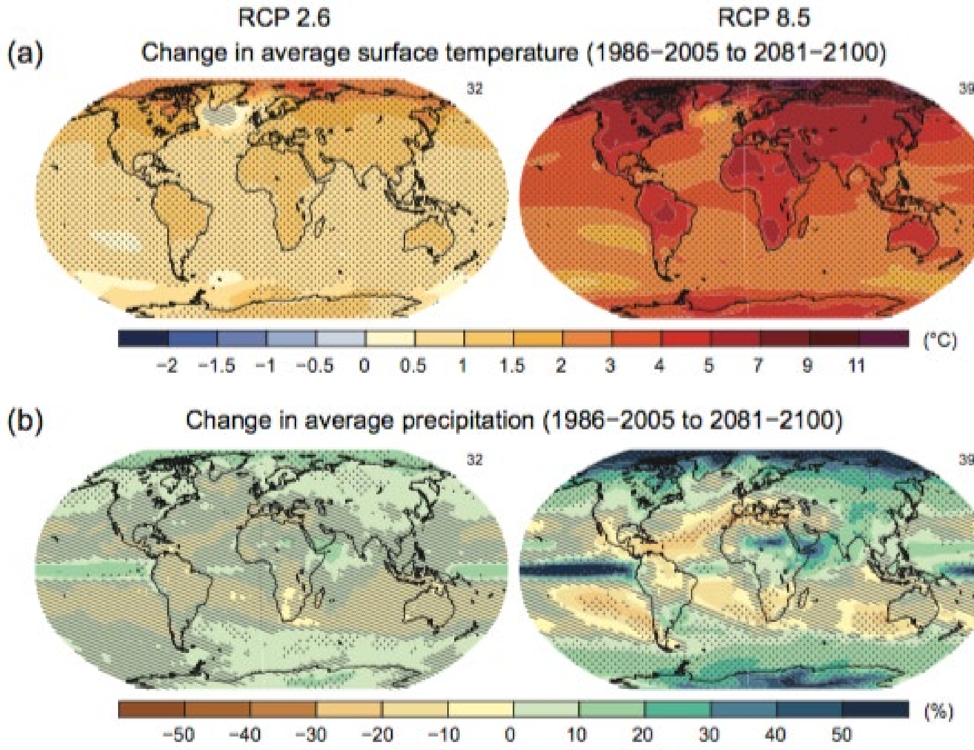
What will climate change bring us?



+5°C by 2100 under business-as-usual scenario

More extreme precipitation events

What will climate change bring us?



Higher evaporative demand

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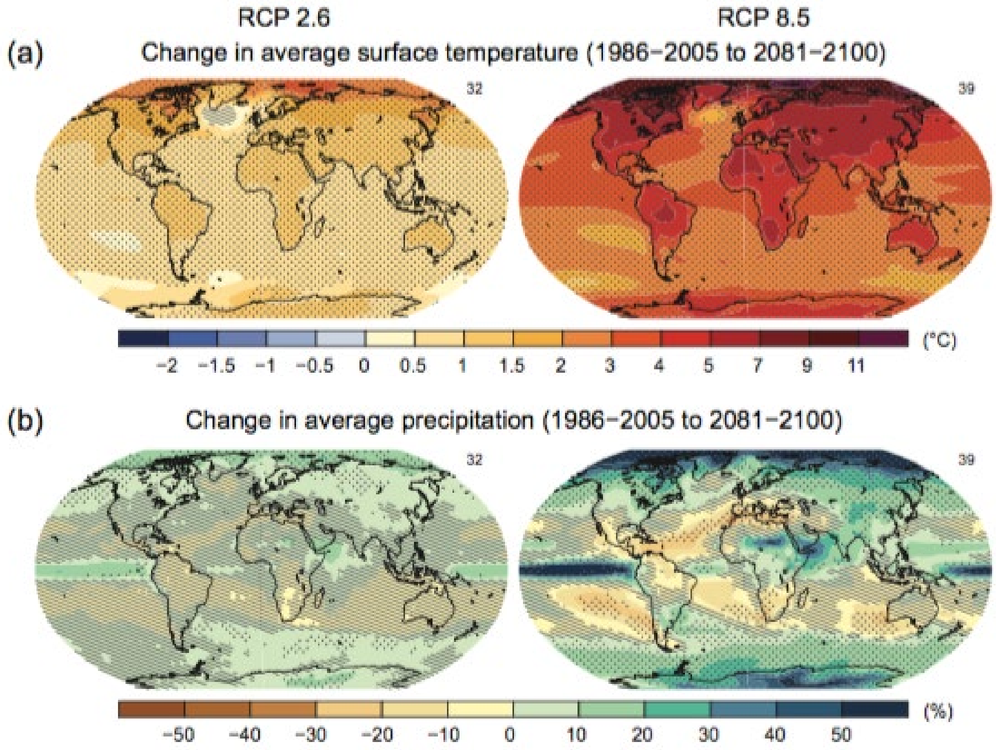
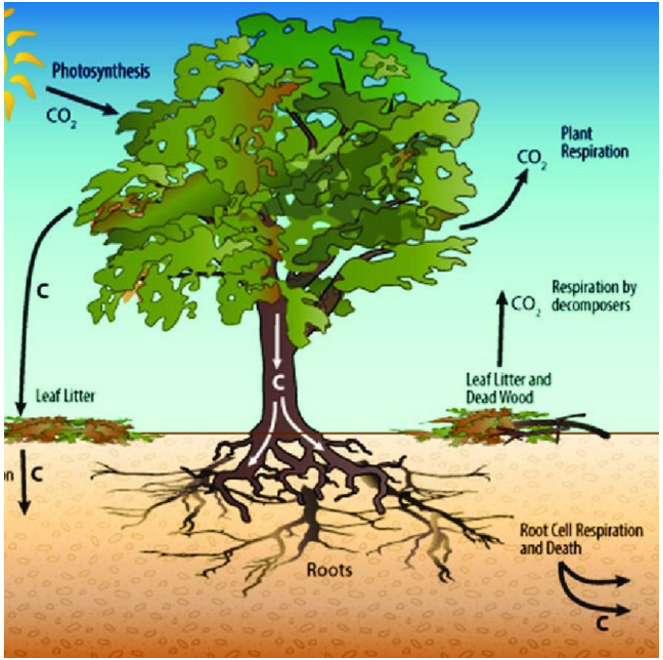
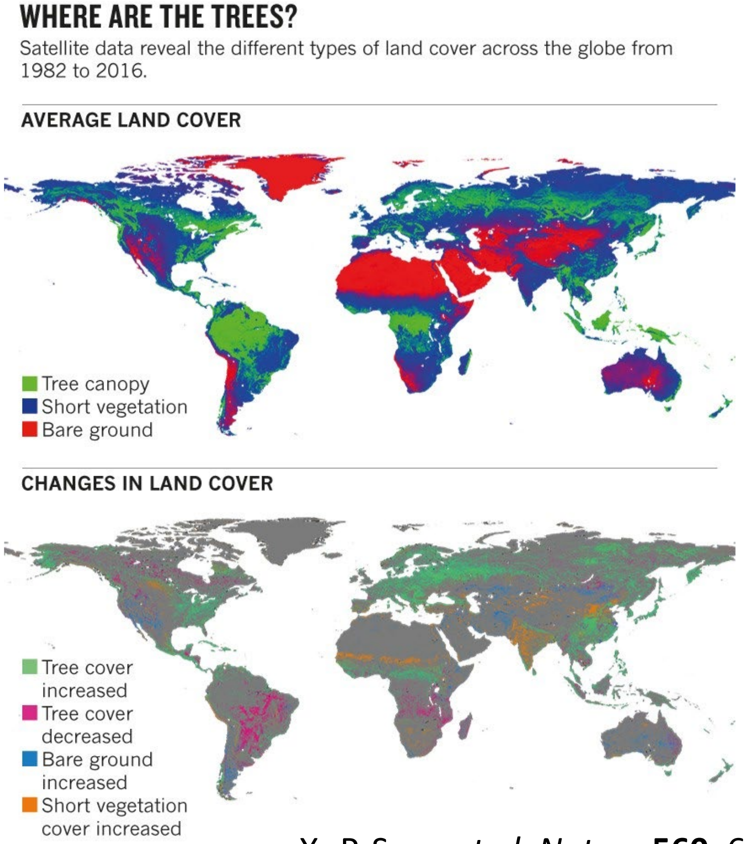
What will climate change bring us?



Future droughts will be superimposed on warmer conditions

Vegetation influences ecosystem carbon, water and energy balance with feedbacks to climate



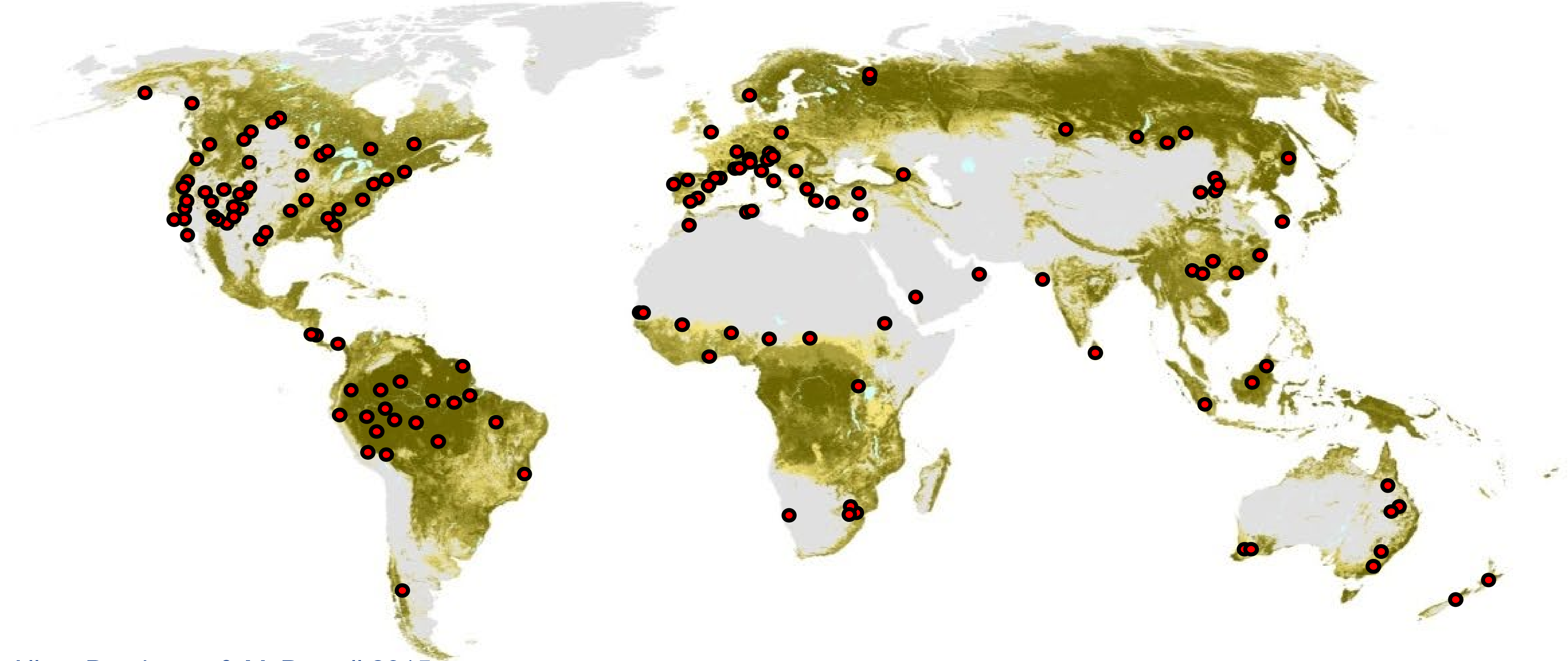


X.-P. Song *et al. Nature* **560**, 639–643 (2018).

What else makes vegetation important?

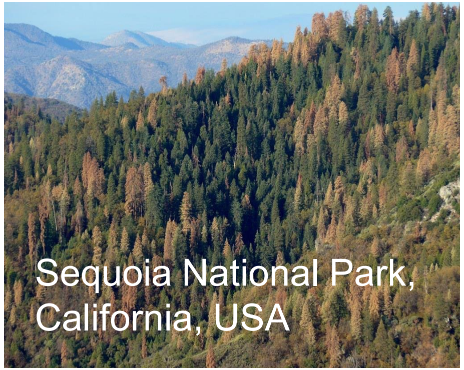
Forests have been impacted by climate change

Locations of observed forest die-off events



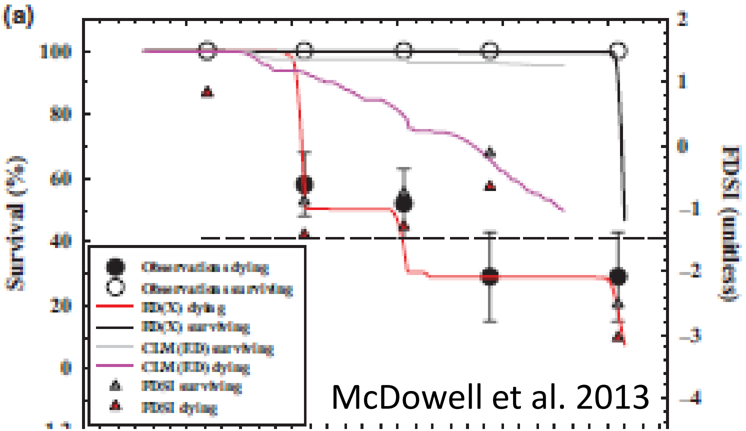
Allen, Breshears & McDowell 2015

One of our challenges:



Forest mortality is often patchy

Models predict collapse of the whole population



How do we predict who survives?

Old foresters' approach:

Trees that perform poorly compared to their peers die first

-Slow or abnormal growth

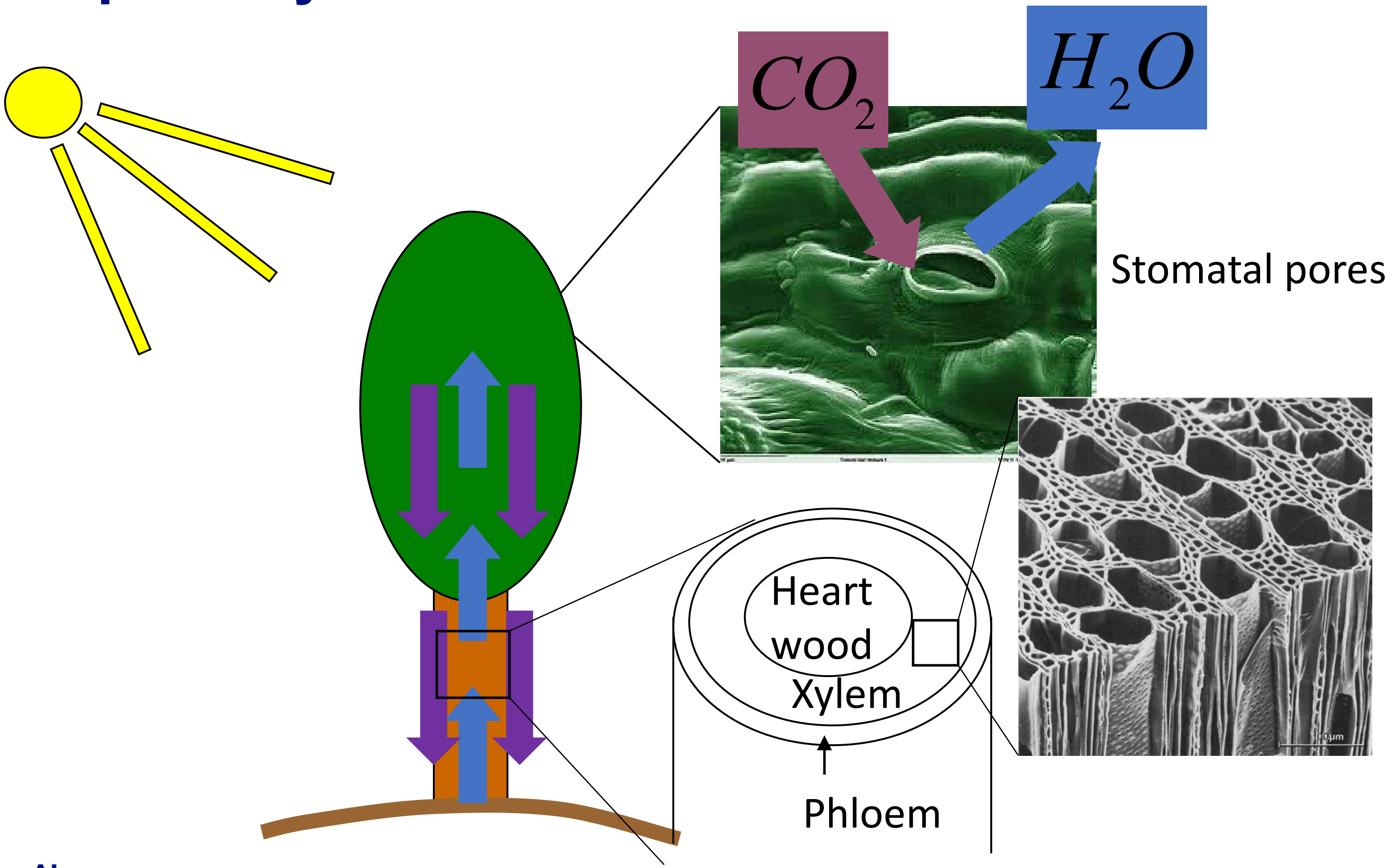
-Low light-use or growth efficiency

} **Tree vigor matters most**

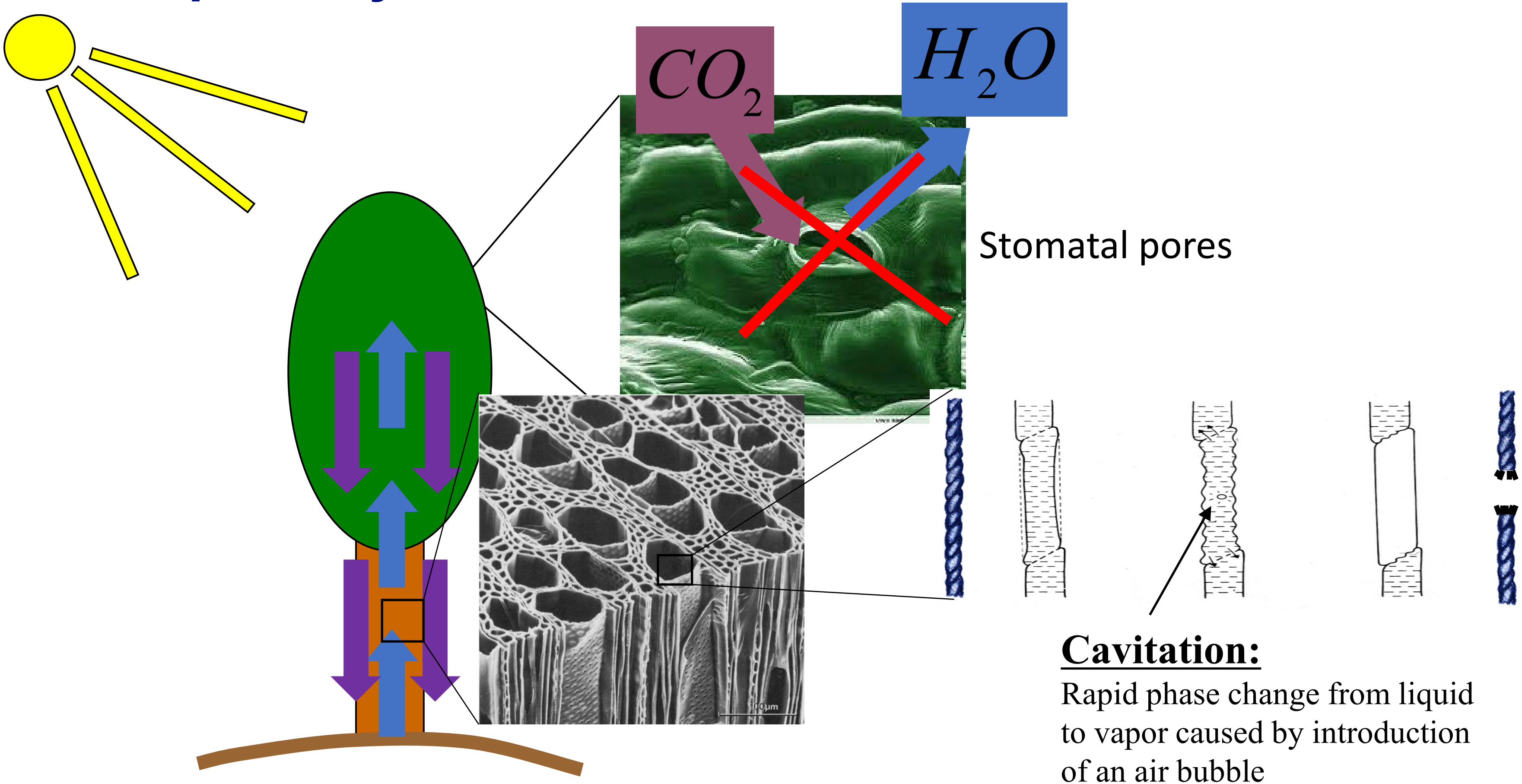
Physiological approach:

Try to find bottlenecks in structure and function that allow building theories to predict tree fate under different climates

Basic plant hydraulics



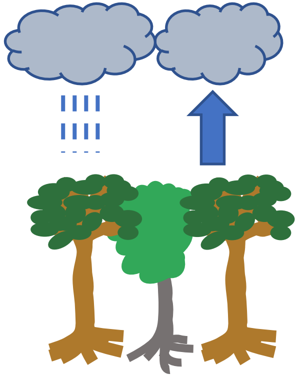
Basic plant hydraulics



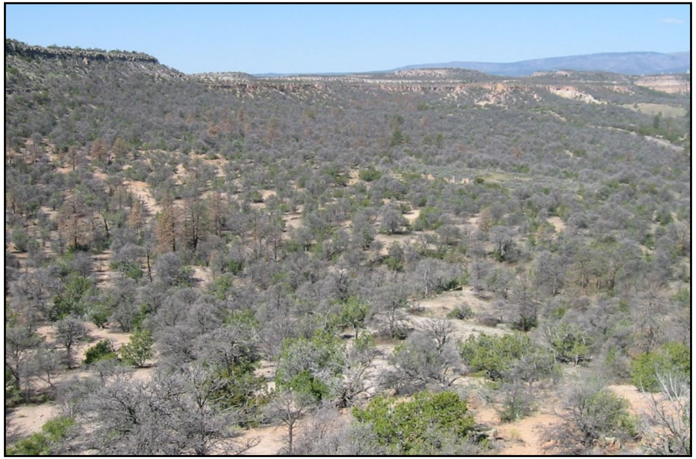
Cavitation:
Rapid phase change from liquid to vapor caused by introduction of an air bubble

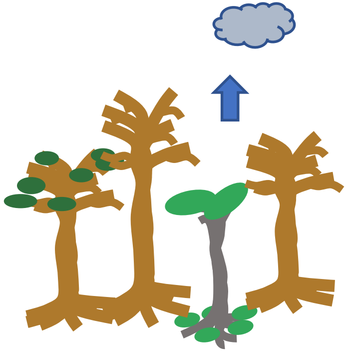
How did the theories start

2002, during drought

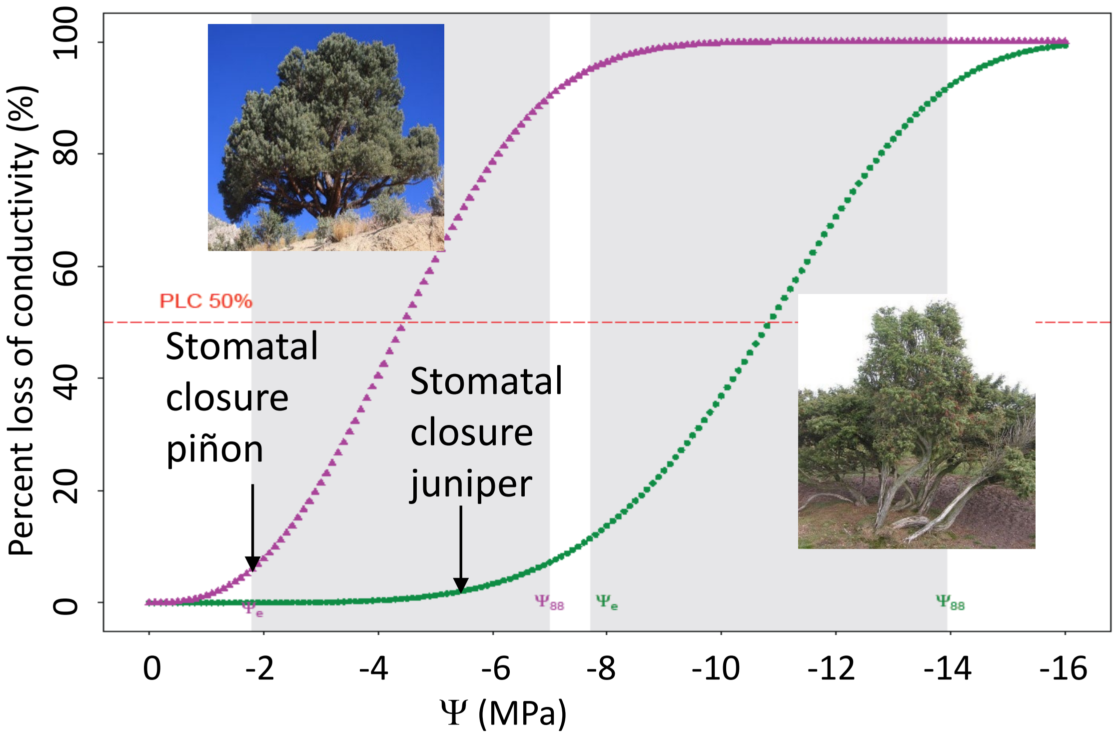


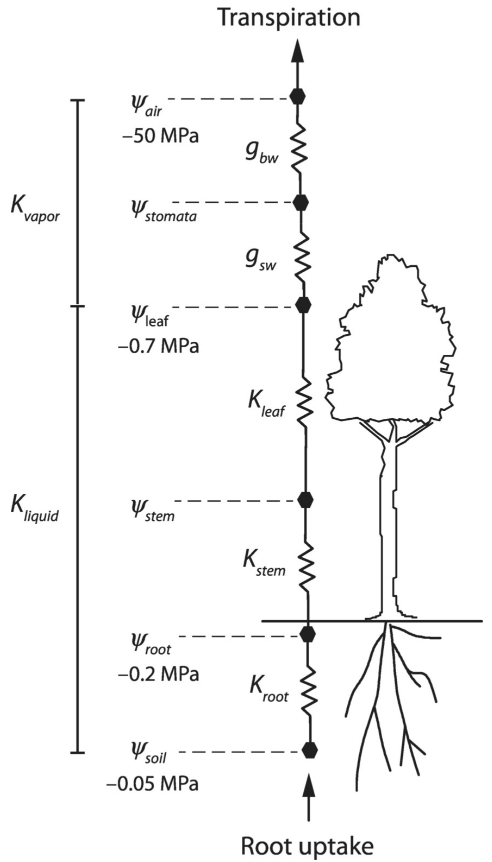
2004, after drought





Different plants close stomata at different drought severity





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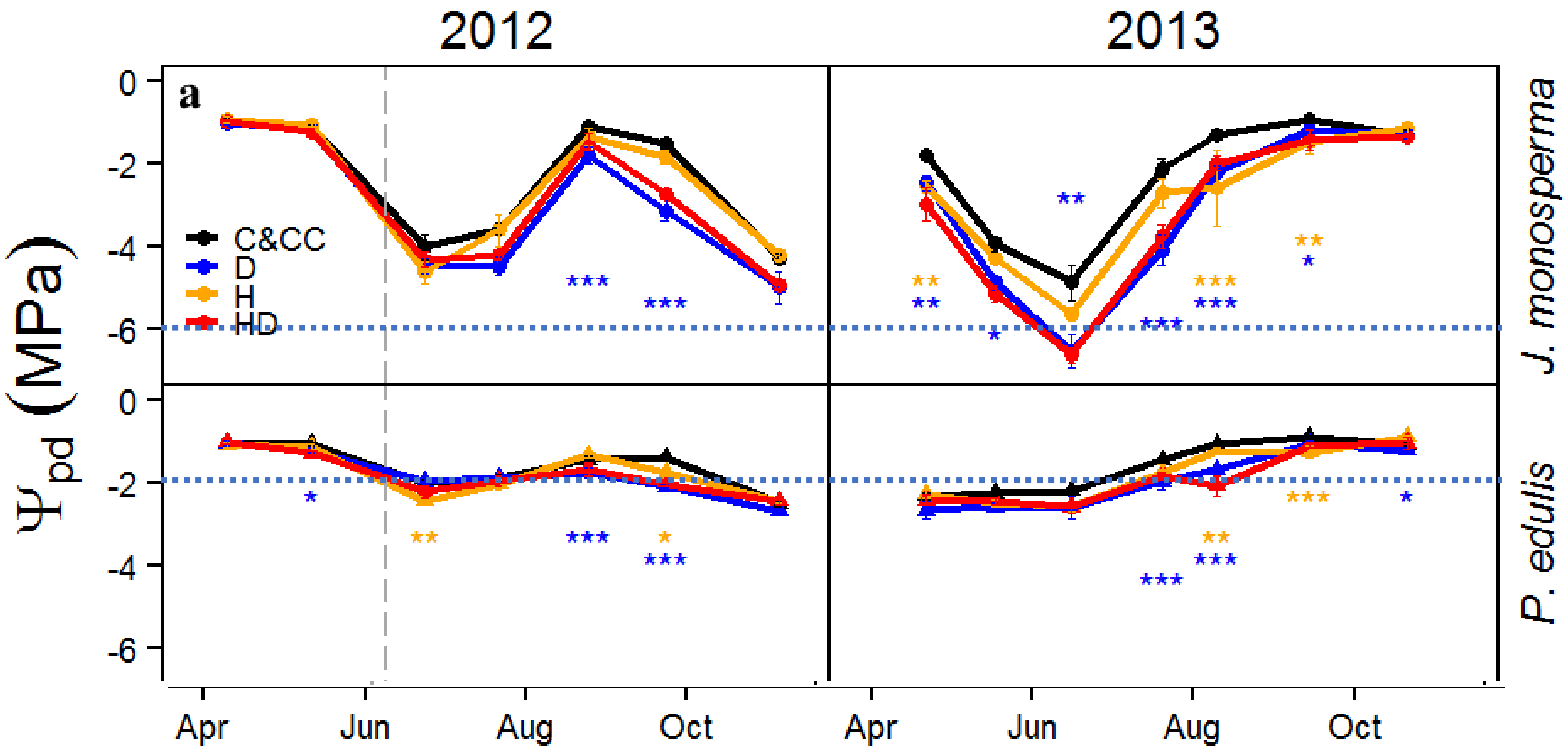
Stomatal closure point determines when carbon uptake ends



Garcia-Forner et al. 2016, Plant, Cell and Environment

What kind of theories do we have?

Hydraulic failure:

-Run-away embolism leads to loss of conductivity

-Plants can survive long droughts, but not very severe ones

McDowell et al. 2008, New Phytologist

Carbon starvation:

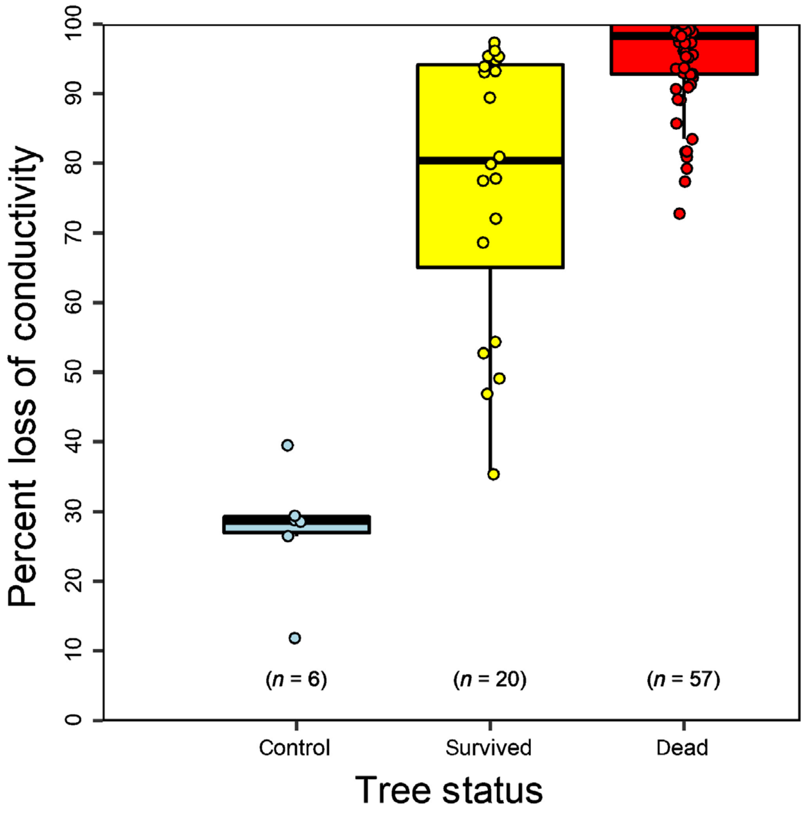
-Negative carbon budget leads to mortality when carbohydrate reserves run out

-Plants can survive very severe droughts, but not longer than their carbon reserves allow

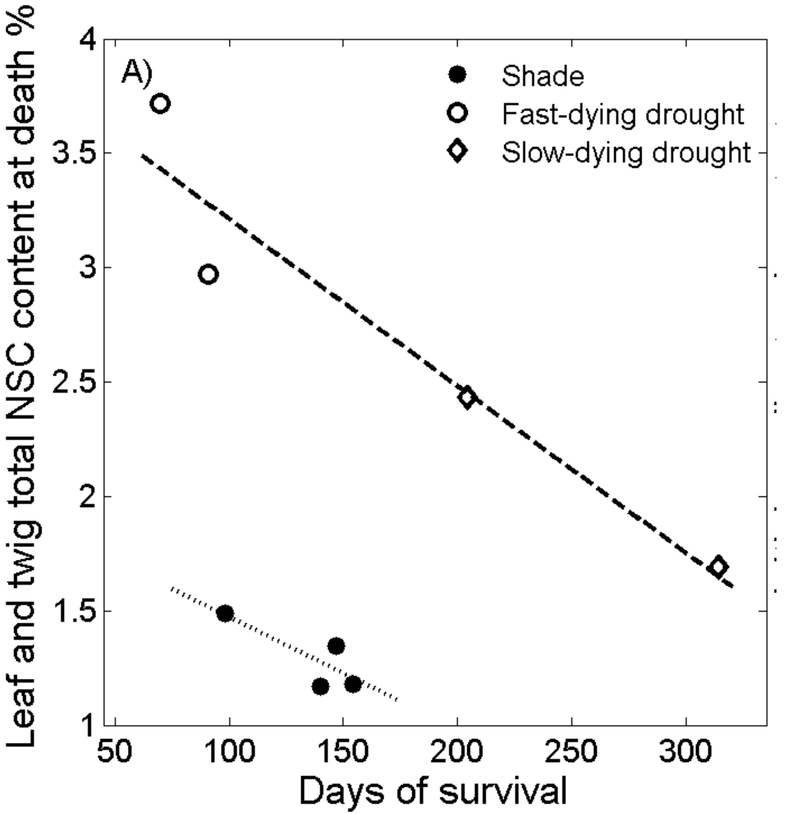
Plant characteristics:
-Stomatal closure only at low water potential (anisohydric)
-Embolism-resistance xylem (small conduit diameter) -> slow growing

Plant characteristics:
-Stomatal closure at high water potential (isohydric)
-Xylem embolizes easily (large conduit diameter) -> fast growing

One of the challenges with this:

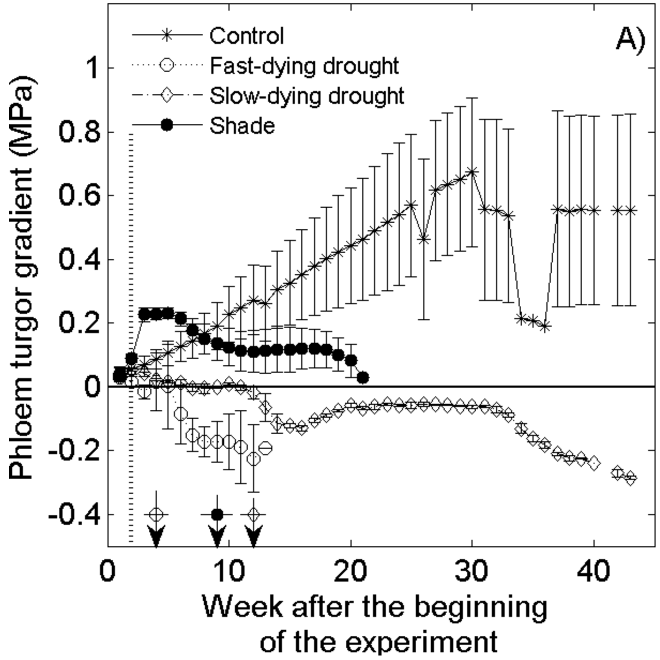


Hammond et al. 2019 New Phytologist



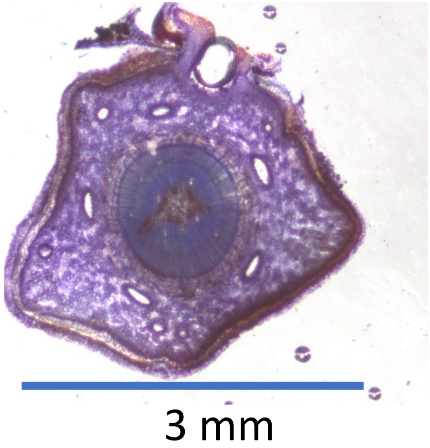
Sevanto et al. 2013 Plant, Cell and Environment

Alternative hypothesis: Phloem failure



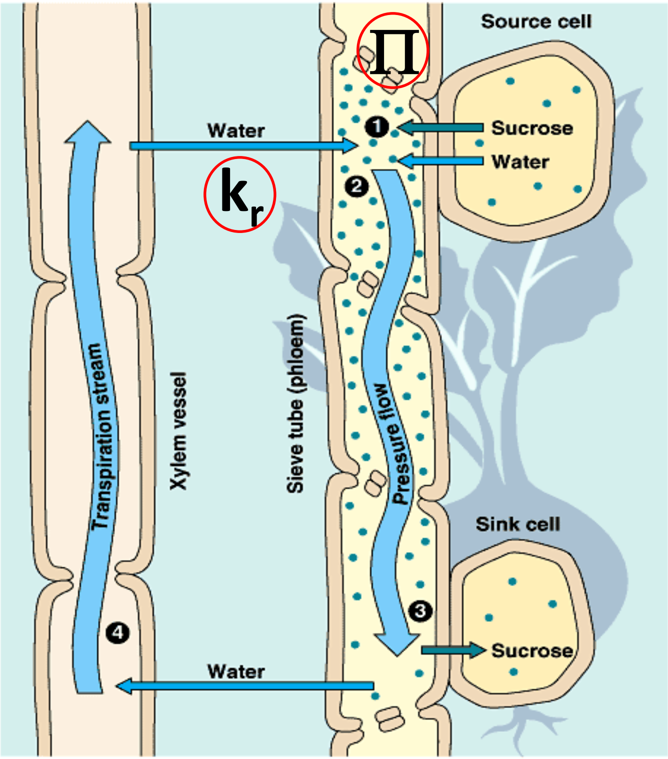
Turgor collapse occurred two weeks prior to permanent stomatal closure.

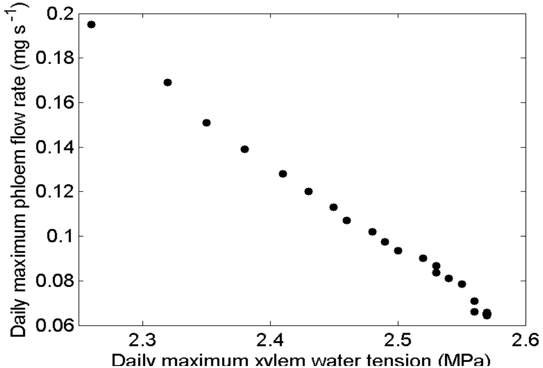
One week delay in turgor collapse led to four weeks of additional survival time

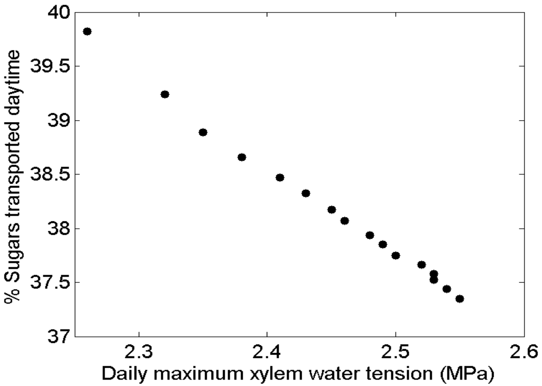


Sevanto et al. 2013 Plant, Cell and Environment

How could phloem failure cause mortality?



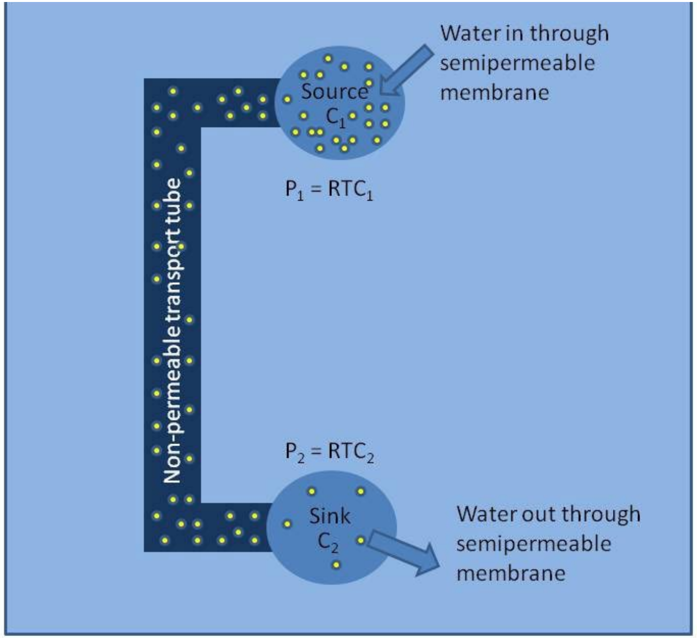




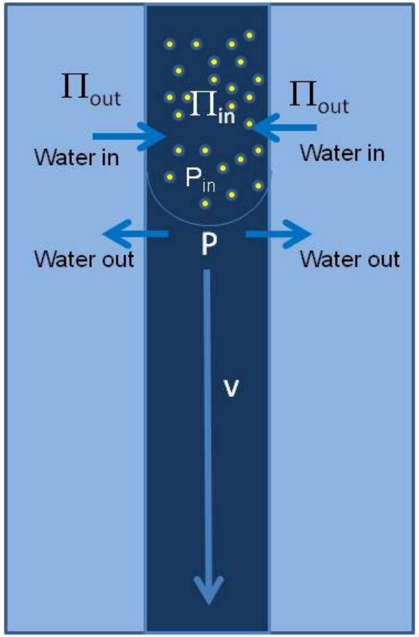
Hölttä et al. 2009 Journal of Theoretical Biology

But does phloem transport fail under drought?

Non-permeable conduits walls

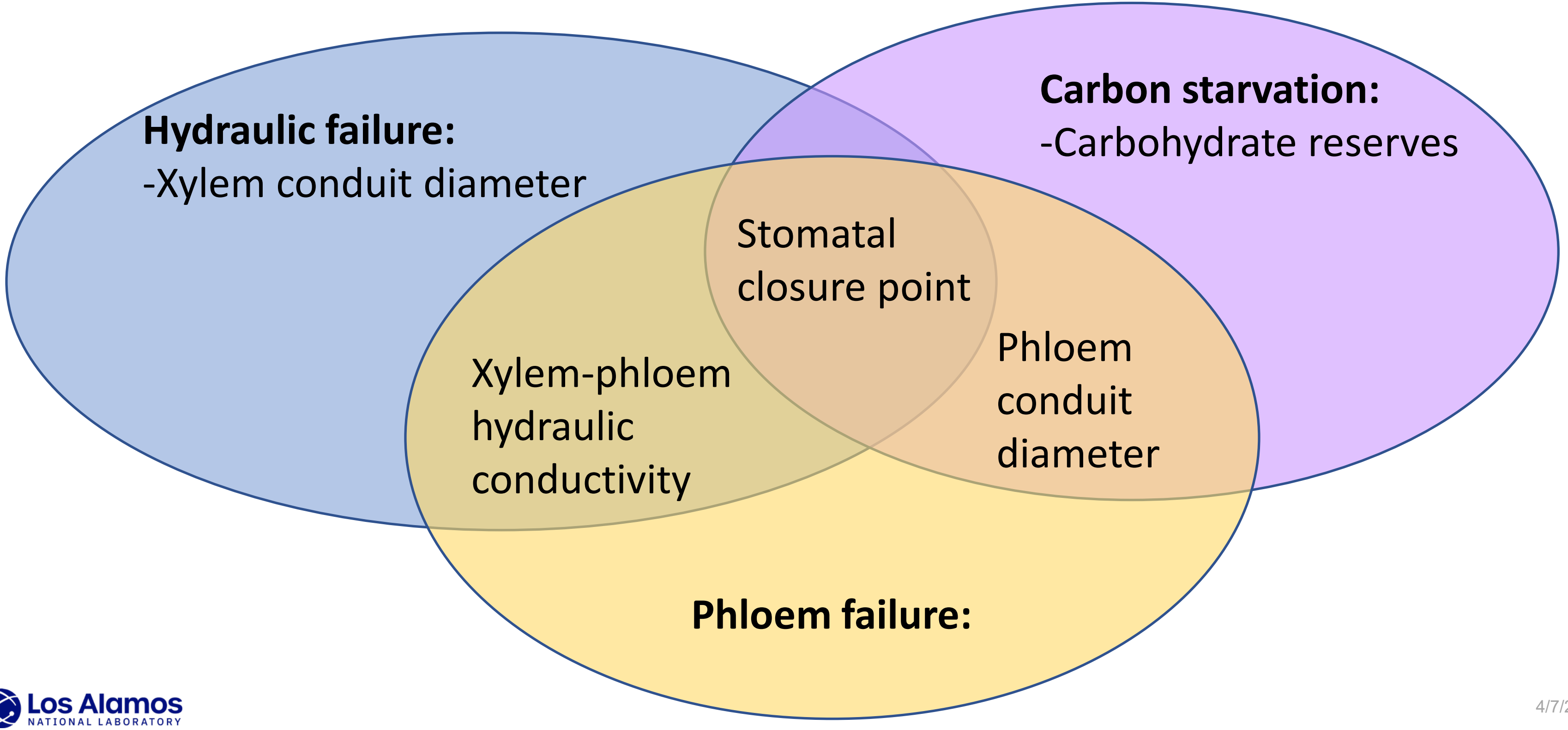


Semi-permeable conduits walls



Sevanto 2014 Journal of Experimental Botany

Structural and functional parameters that theoretically affect plant survival under drought



What can plants do to promote survival?

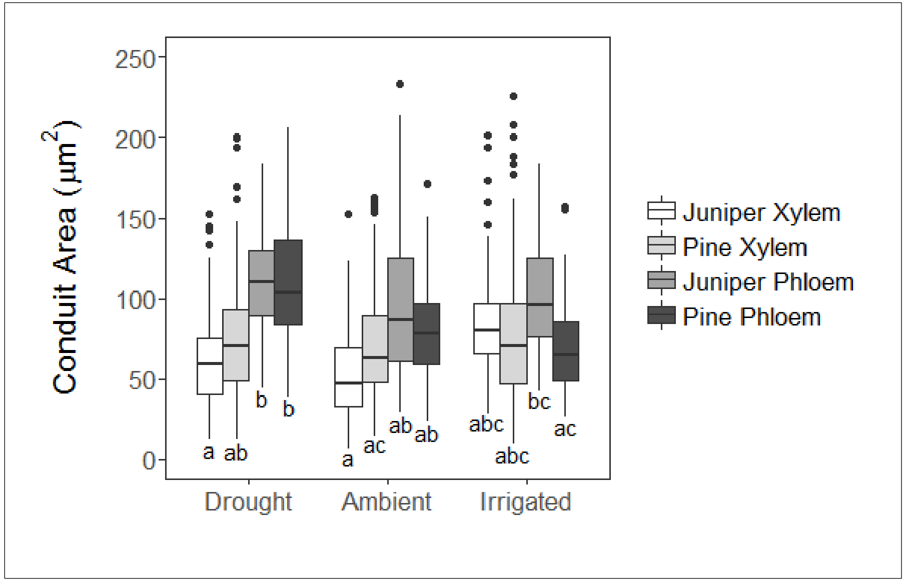
Migration 60-250 m yr^{-1}

Adaptation 50-5000 years

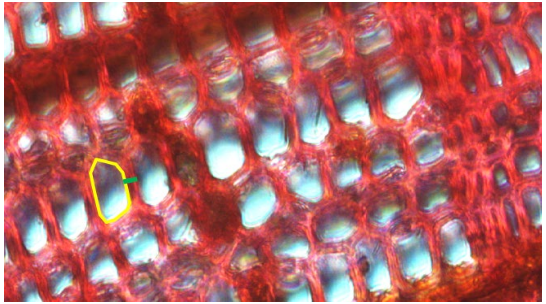
Right now!

Structural acclimation

Some conduit size shifts in response to changing precipitation in 10 years (Sevilleta experiment)

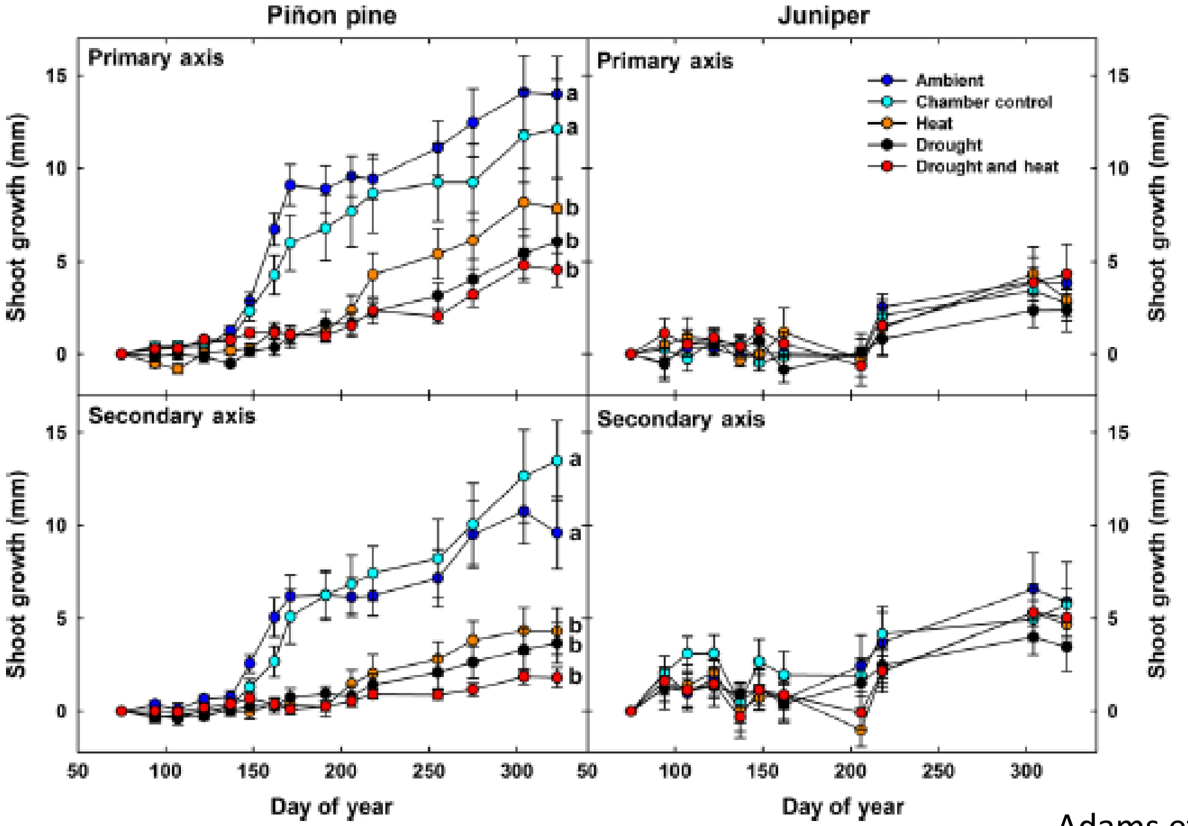


Sevanto et al. 2017, Plant, Cell and Environment



The SUMO experiment was too short to show any (4 years).

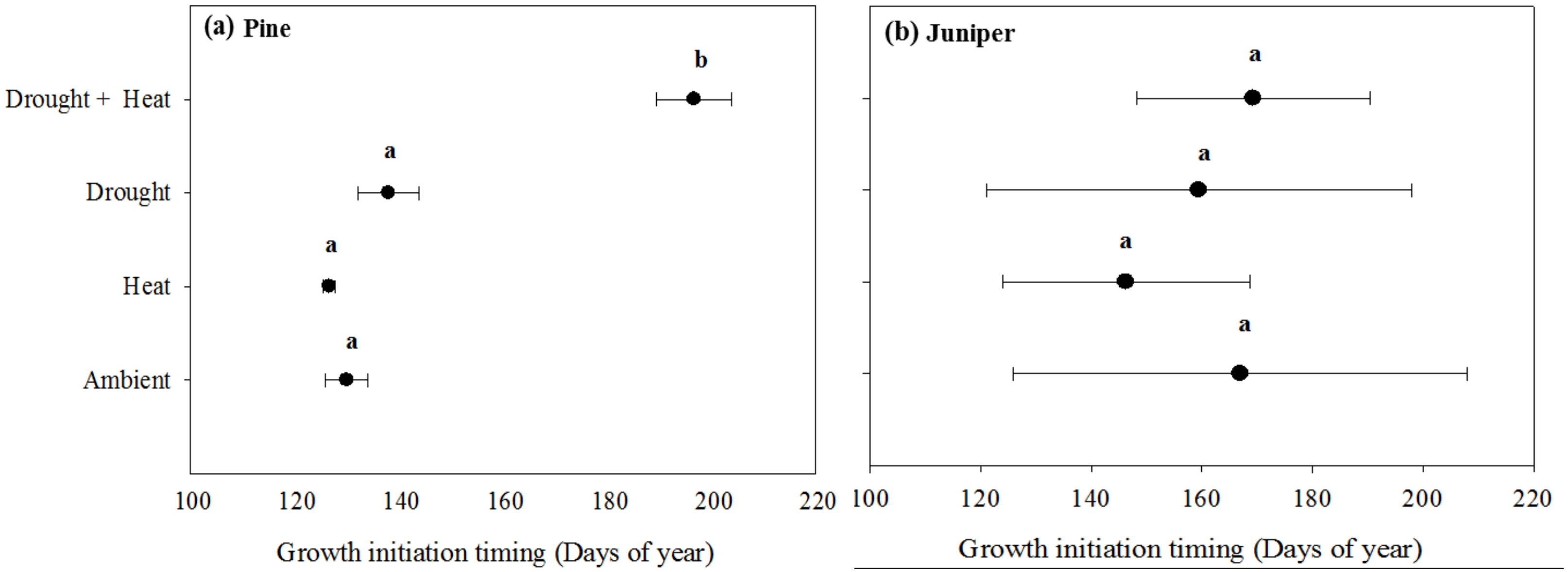
Structural acclimation



Growth responds to drought and heat in pinon immediately

Adams et al. 2015 Global Change Biology

Functional acclimation: Phenology

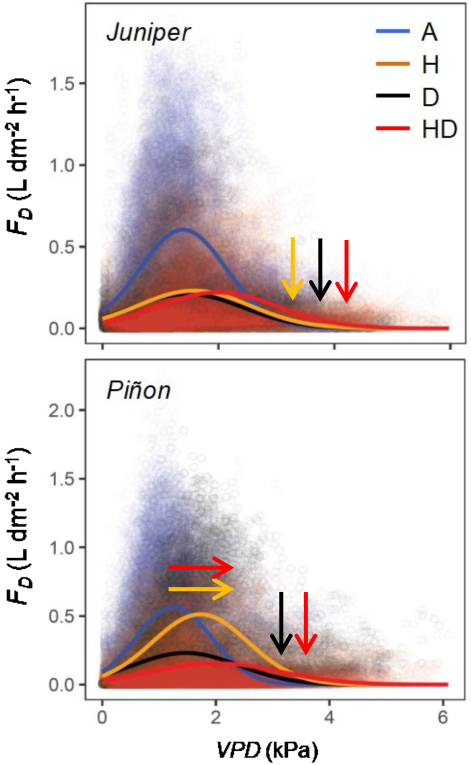


Manrique-Alba et al. 2018 Plant, Cell and Environment

Functional acclimation: Stomatal sensitivity to VPD

No shift in optimum VPD + reduced sensitivity to VPD

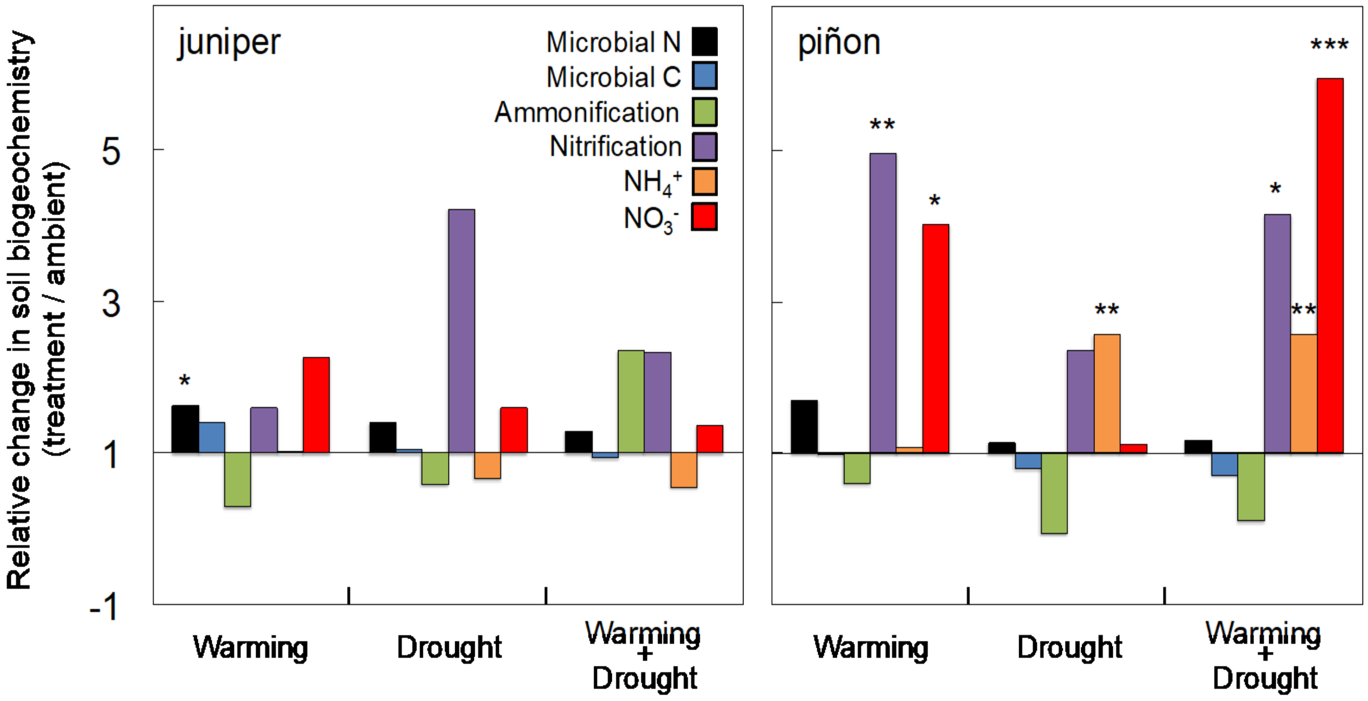
Shift in optimum VPD under warming + reduced sensitivity to VPD under drought



Grossiord et al. 2017 Plant, Cell and Environment

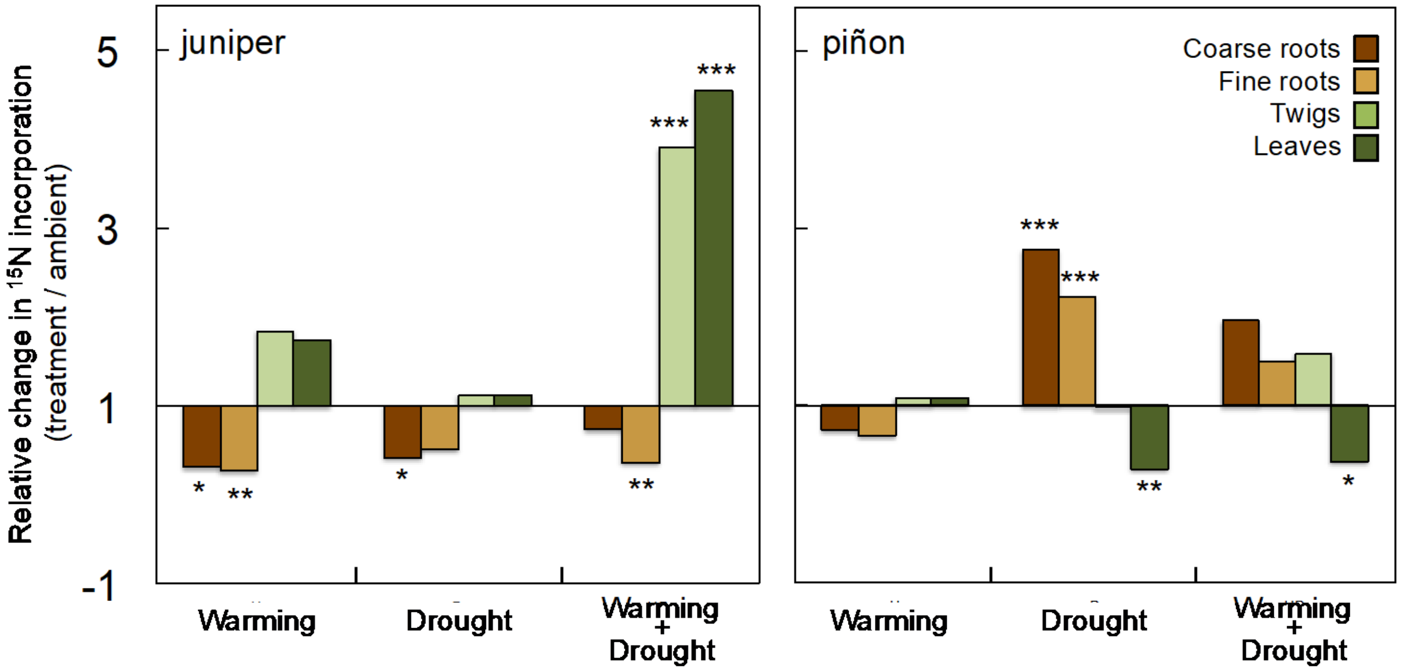
Ecosystem scale acclimation

Warming increased several soil biochemistry metrics



Grossiord et al. 2018 Plant, Cell and Environment

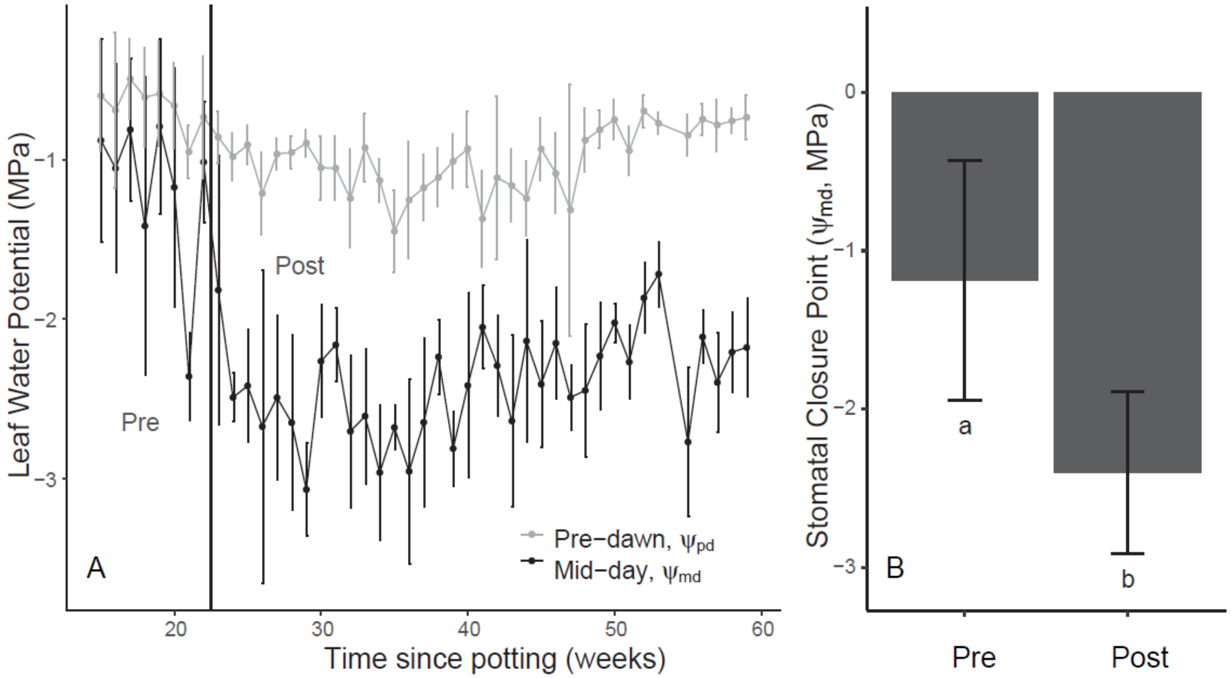
Ecosystem changes manifest differently in different plants



Grossiord et al. 2018 Plant, Cell and Environment

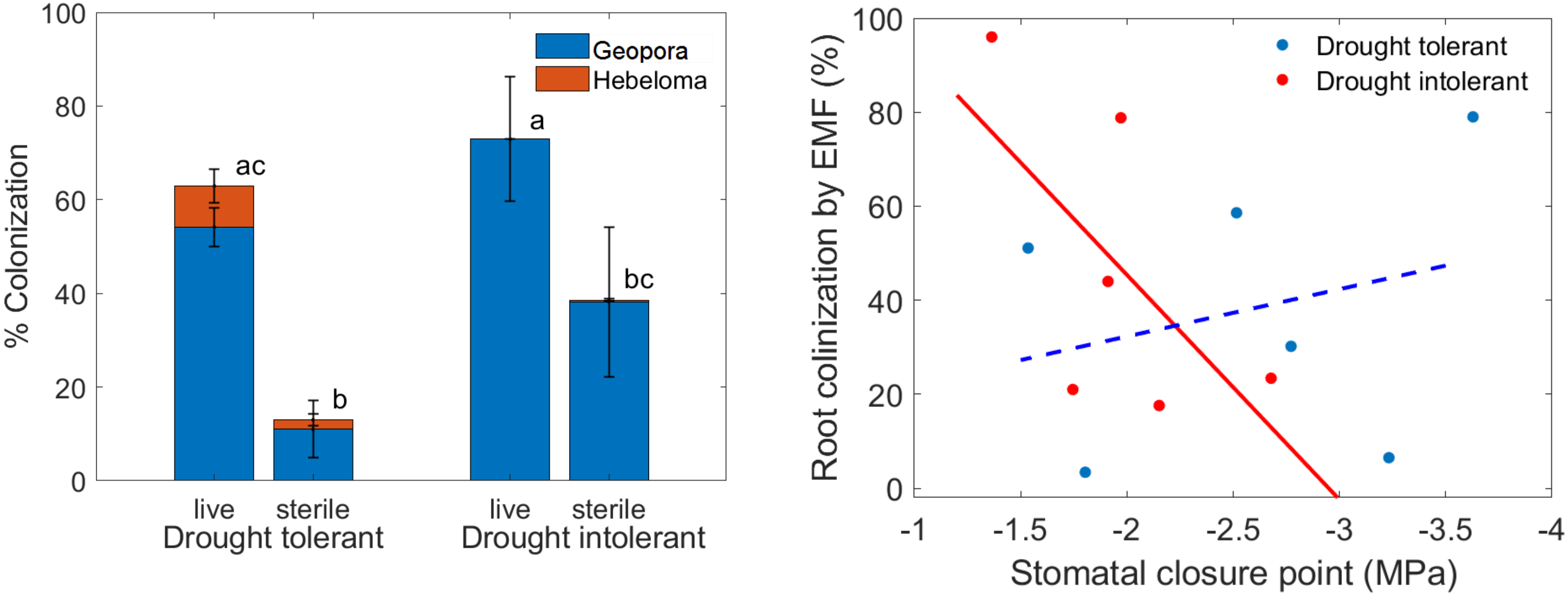
Is this acclimation, or response to environment?

Greenhouse experiment, control trees



Dickman et al. in prep

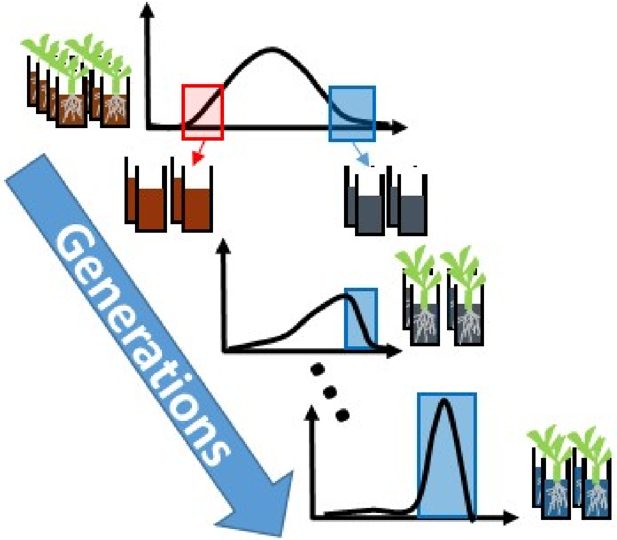
Is acclimation controlled by genetics or the environment?

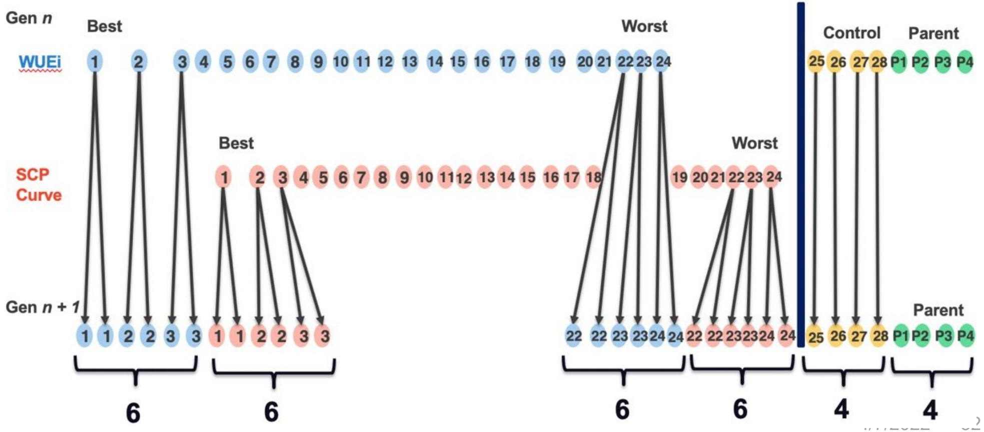


Sevanto et al. submitted to PNAS

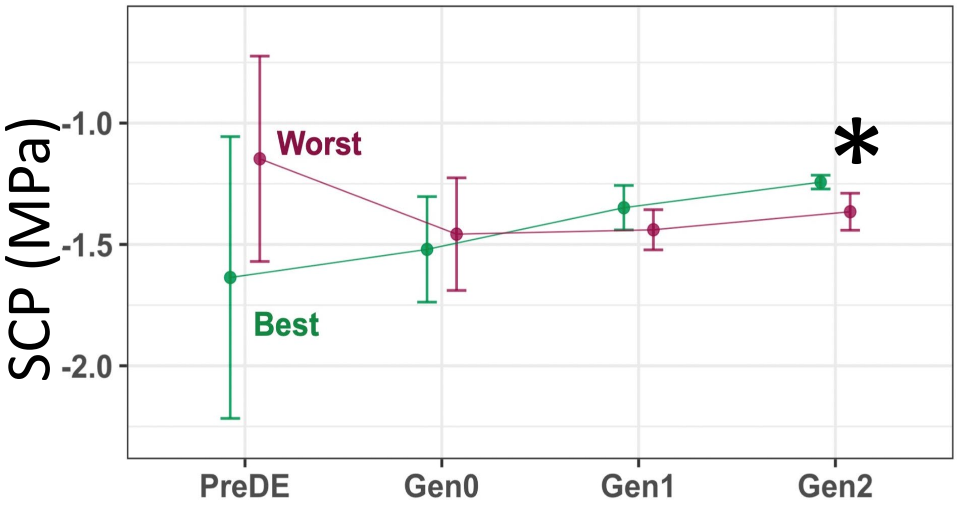
Can we manipulate the environment to make a difference?

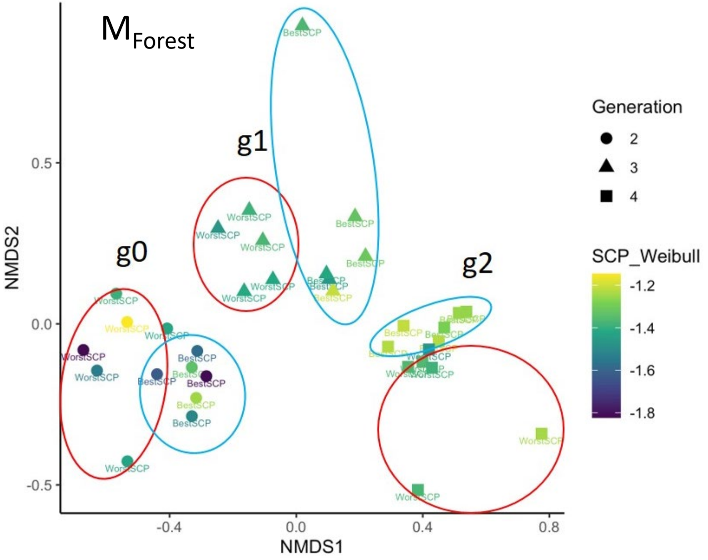
Directed Plant-Microbiome Evolution





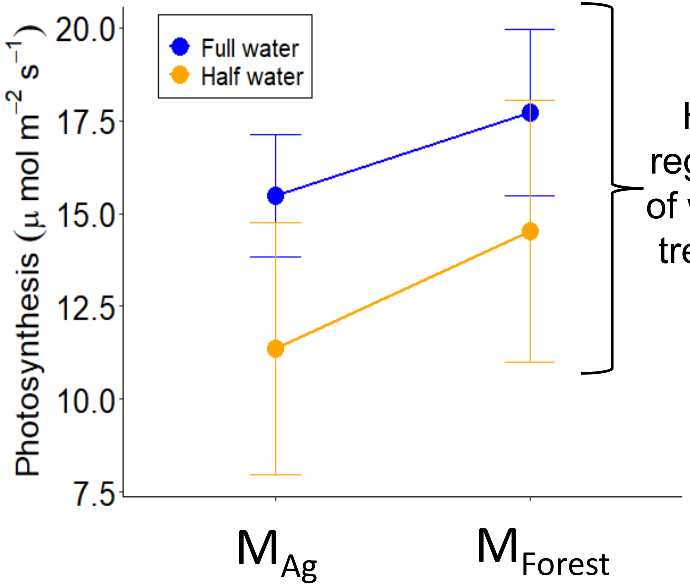
Microbiomes can be driven to impact plant function in a desired way



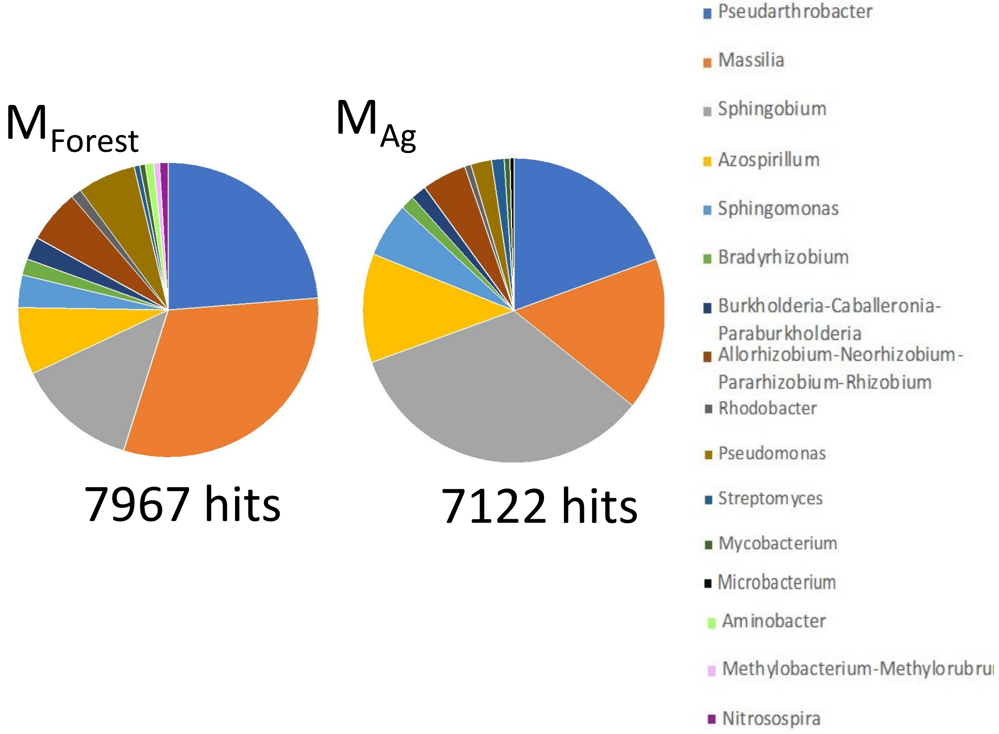


Sevanto et al. in prep

Forest microbiome affects plant function better than agricultural microbiome



Higher regardless of watering treatment

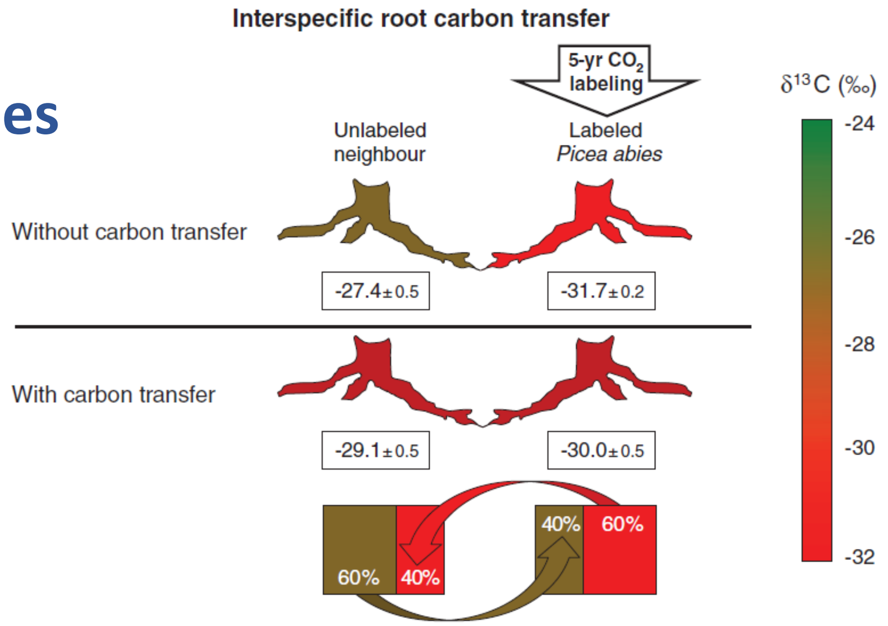


Or maybe it's the best support team that determines who survives?

Trees trade carbon across species

"Forest is more than the sum of its trees"

Klein et al. 2016 *Science*



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