Assessing the wood architecture of conifer species and cell-level adjustments linked to hydraulic safety and efficiency

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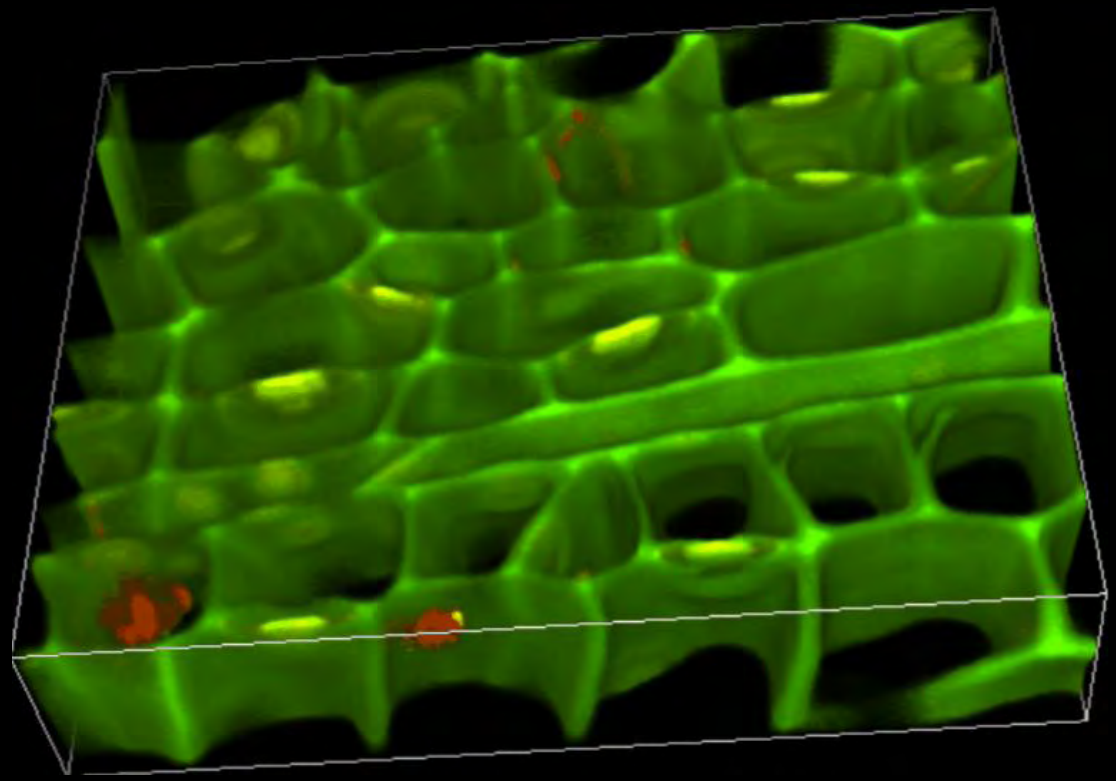
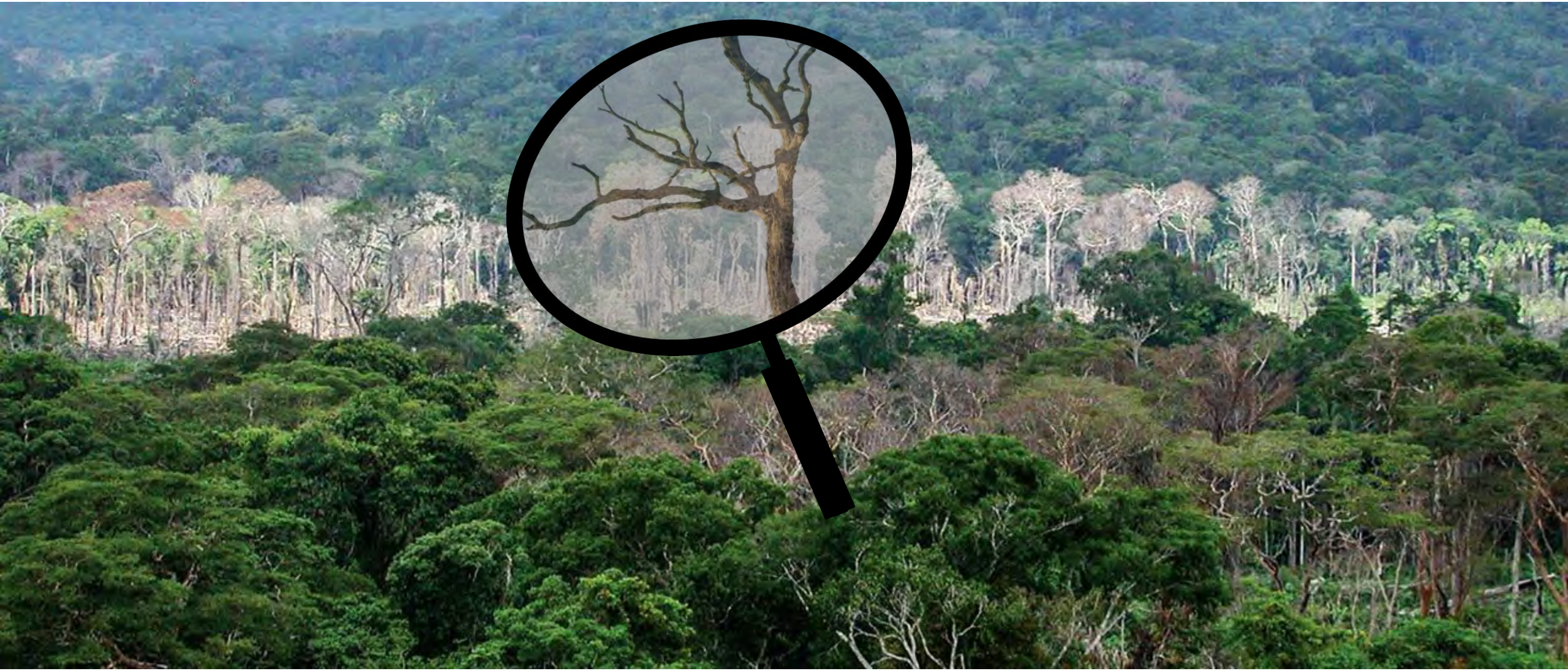
@jehovajr

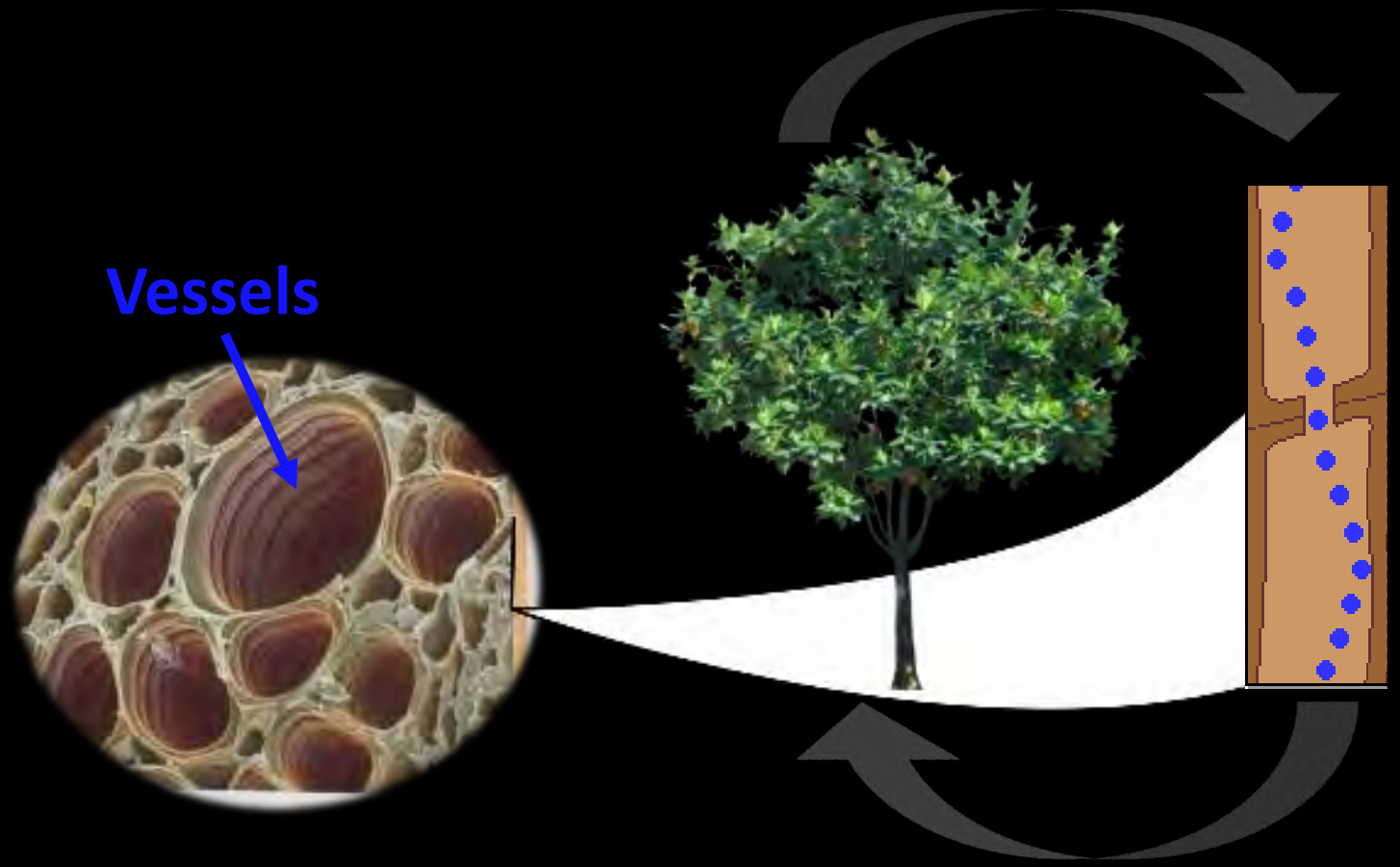


Why tree species are differently affected by drought?



Sugden A. M. 2019. *Drought in tropical forests*. Science – West Africa

Drought affects plants via cell-level traits (vessels)



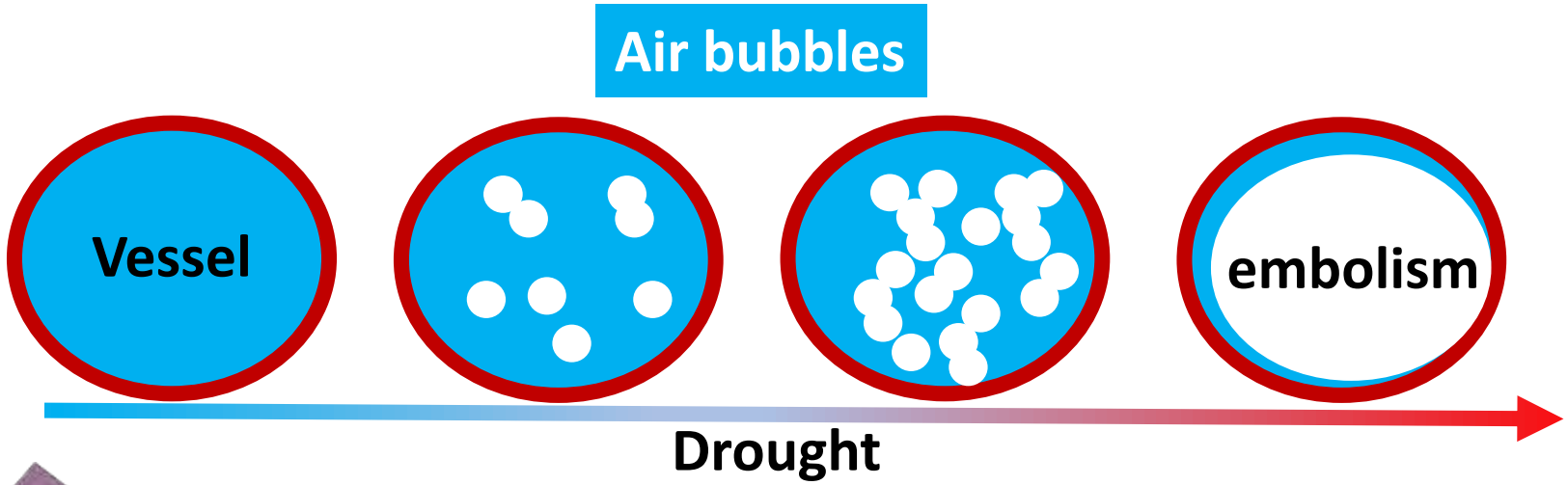
- ✓ Drought resistance
  Chenlemuge et al., 2015
- ✓ Growth strategies
  Roskilly et al., 2019
- ✓ Tree mortality
  Klein et al. 2018
- ✓ Species distribution
  Lourenco Jr. et al. 2020 (in review)

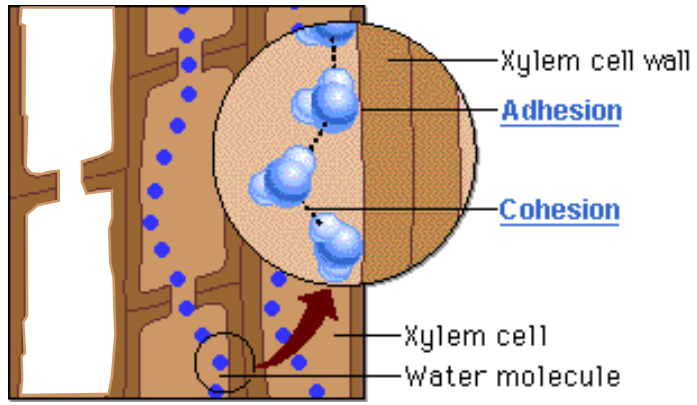
...

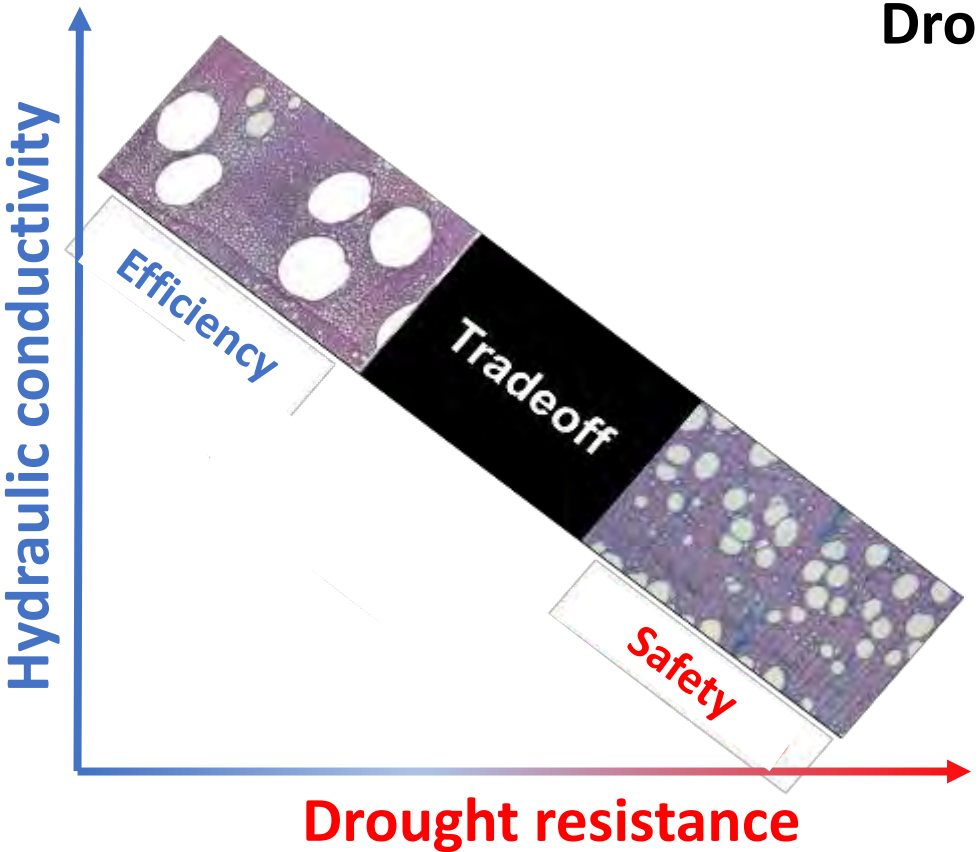
Moving toward a study of the conductive system as an integrated whole

(McCulloh et al., 2019; Soriano et al., 2020).

Species differences: hydraulic safety vs. efficiency







Hydraulic safety-efficiency tradeoff

Important mechanism for plant ecology and evolution (Sperry, 2003)

Controversy

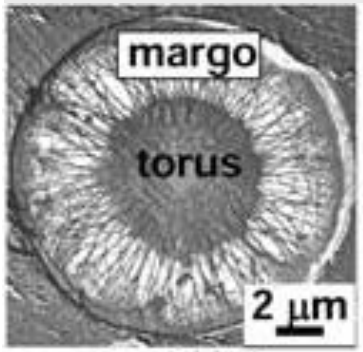
Weak tradeoff (Gleason, 2016).

Species differences: hydraulic safety vs. efficiency

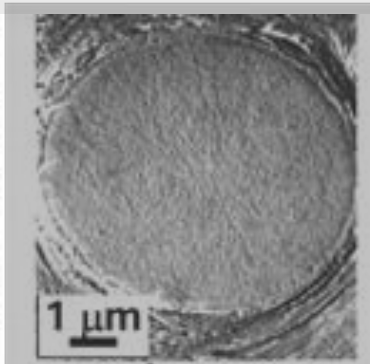
New pathways

Many cell traits in the wood…
multiple functions (Venturas…, 2017)

Conifer pits: Higher capacity to transport water while controlling the spread of embolism.

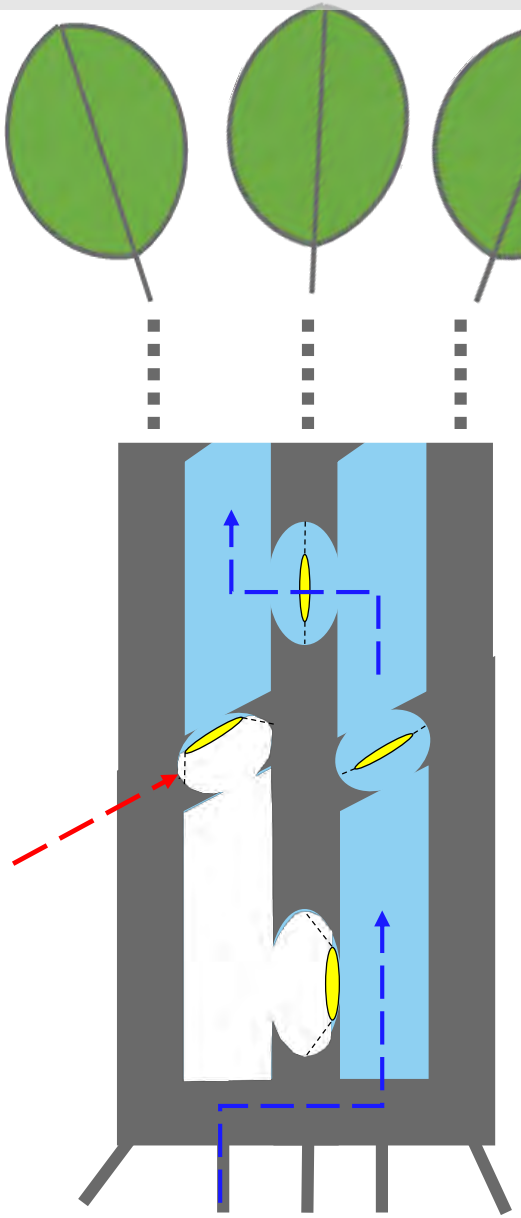


conifer

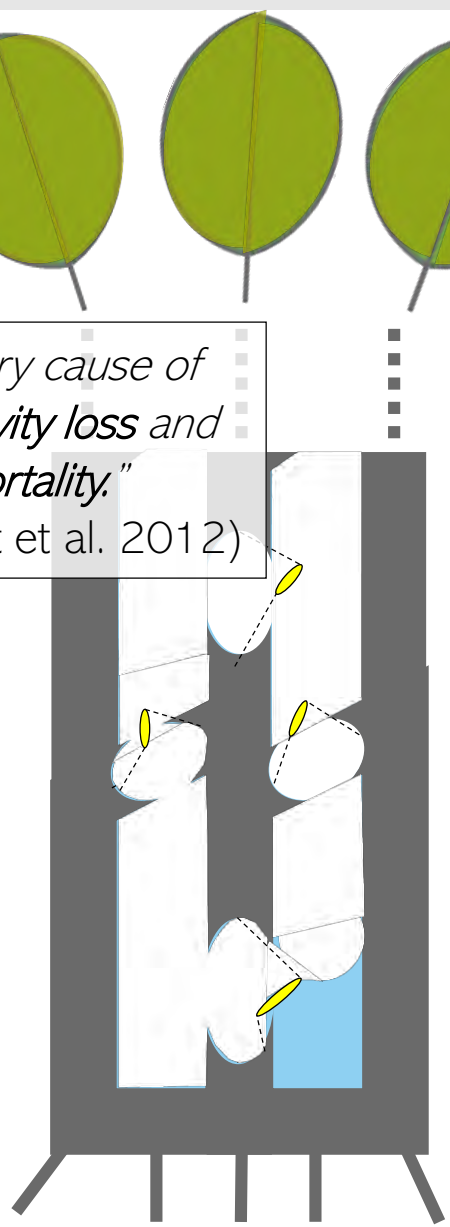


angiosperm
(Plants with flower)

Interconduit pits
(hydraulic valve)


Root system

*"A primary cause of **productivity loss** and **plant mortality.**"*
(Choat et al. 2012)


Root system

Pittermann et al. (2005). Torus-margo pits help conifers compete with angiosperms

Investigating the hydraulic architecture of conifers

Rain-exclusion experiment (2014-2019)

Objective

Assessing the changes in hydraulic architecture of trees growing in different soil water conditions over time.

(within and between tree-rings)

Jack pine

Drought tolerance

(Subedi N, Sharma M. 2013)

Black spruce

Wet soils

(Subedi N, Sharma M. 2013)

White spruce

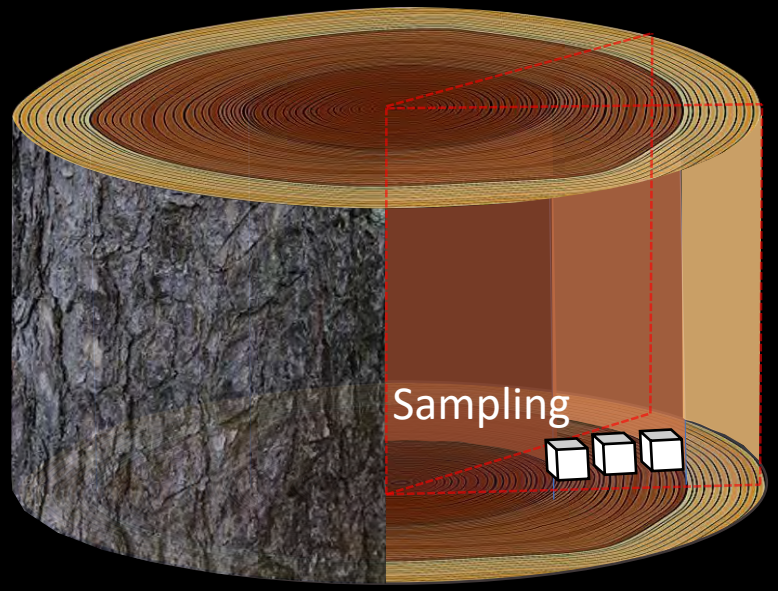
Well-drained soils

(Viereck *et al.*, 1992)

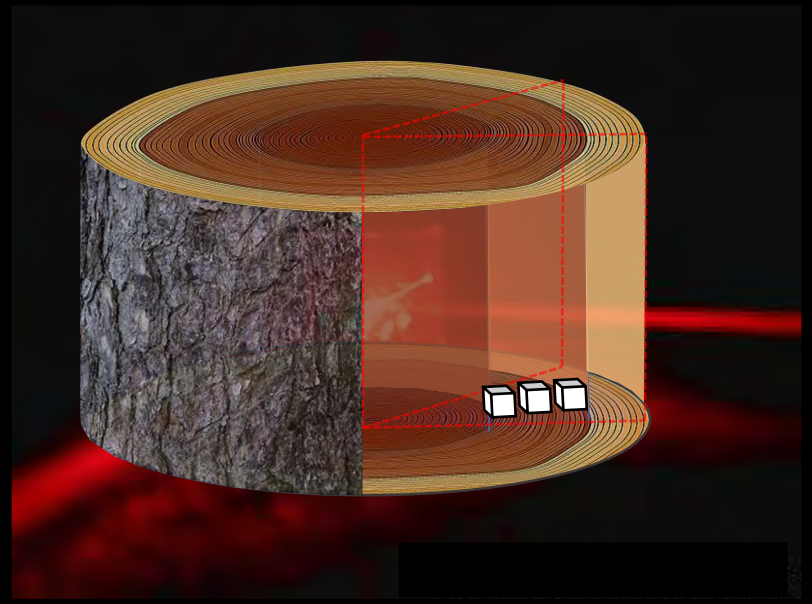
Balsam fir

Moderately wet soil

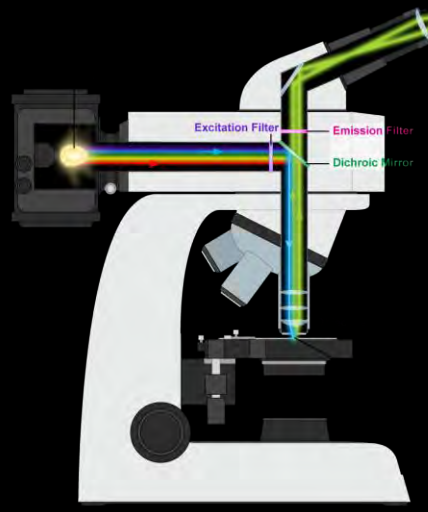
(Chang & Bourque, 2020).



Investigating the hydraulic architecture of conifers



Laser microscope



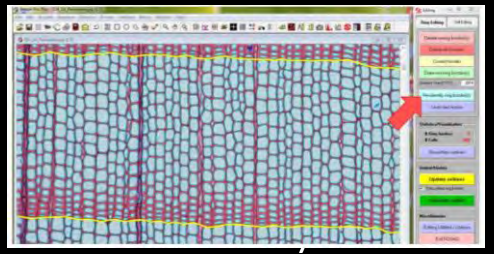
Methods

3D

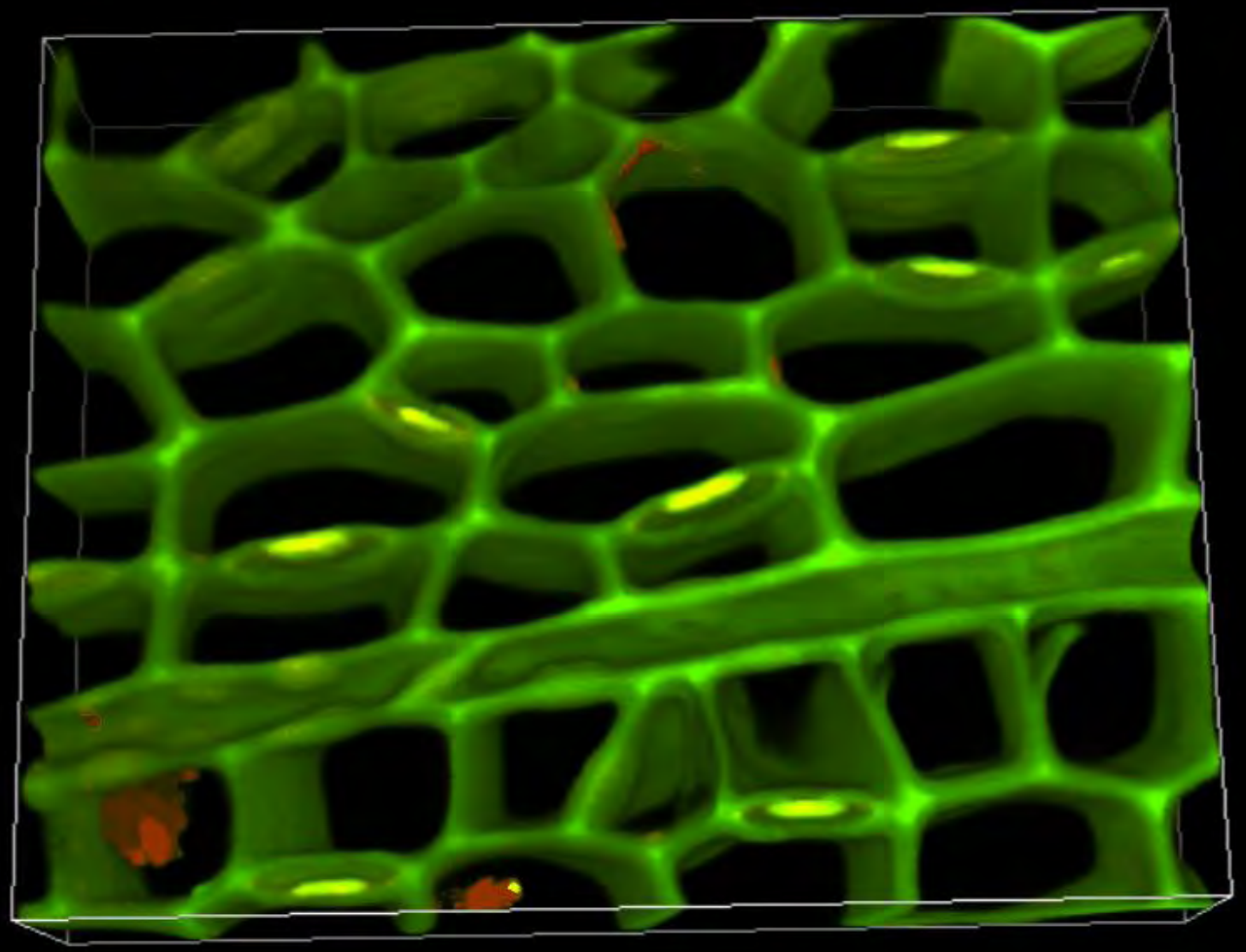
Traditional bidimensional methods

- Thin cuts → Stain → photograph → Image edition → analysis

(10-20um) (Safranin) (Microscope + camera) (PTGui) (ROXAS and Image Pro)



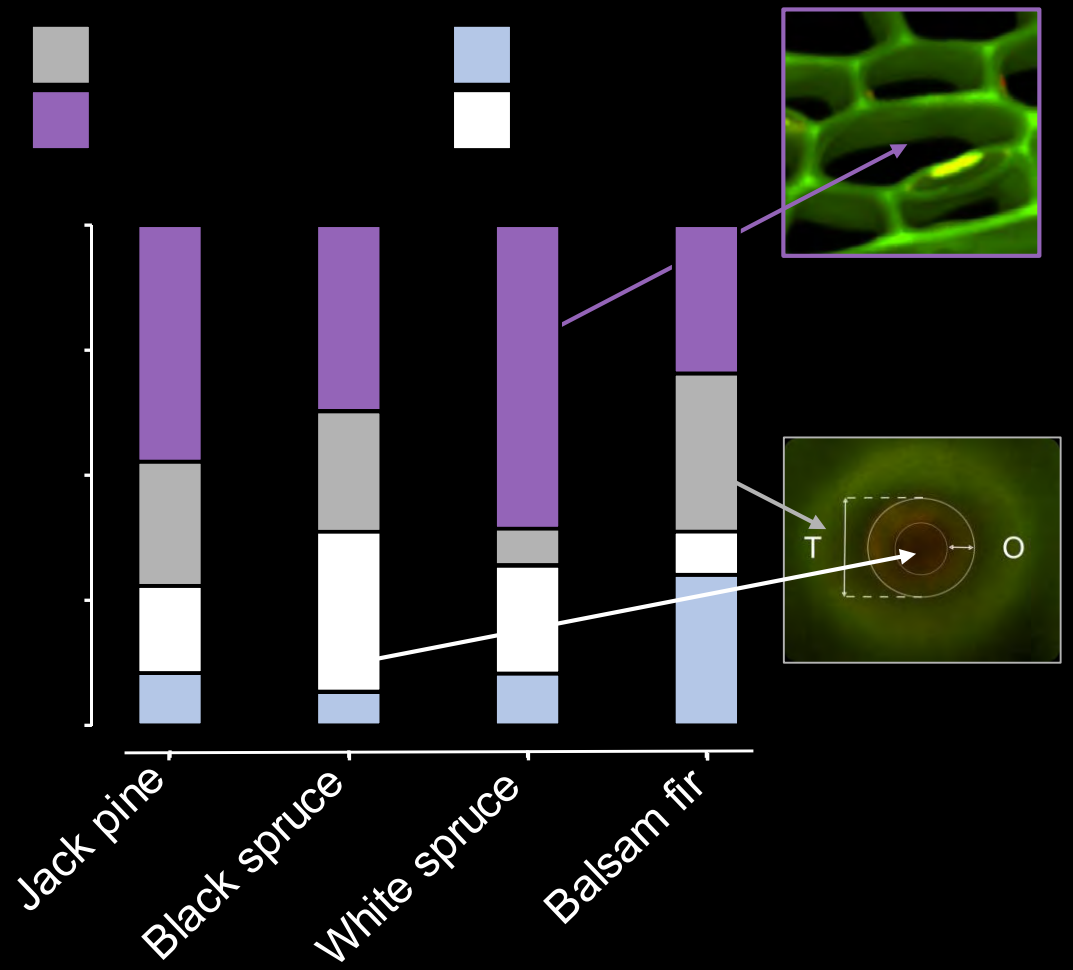
Investigating the hydraulic architecture of conifers

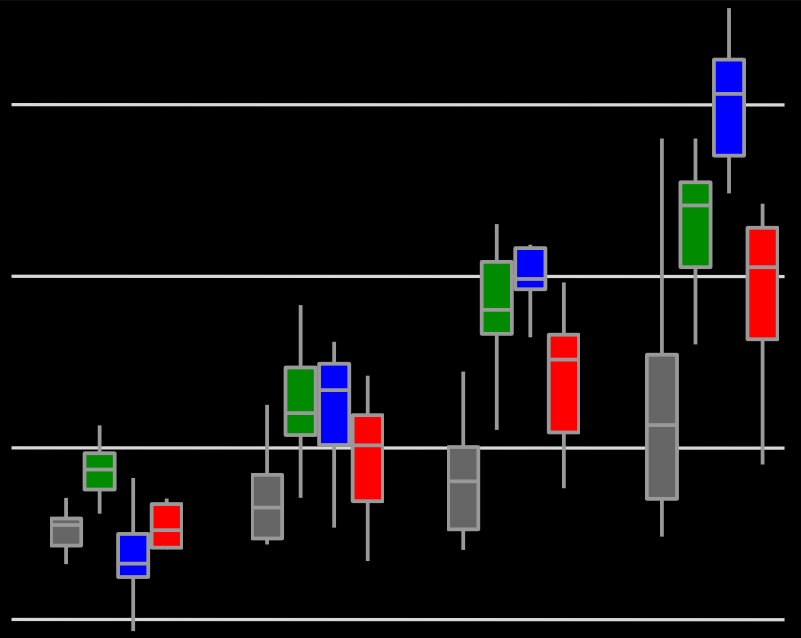


High resolution images in 3D

Calibration x:0.21 µm, y:0.21 µm, z:0.17 µm
Width:117.46 µm Height:91.98 µm Depth:25.20 µm

Growth performance is mostly associated with changes in tracheid lumen, while the effects of soil water are low





Jack pine

Black spruce

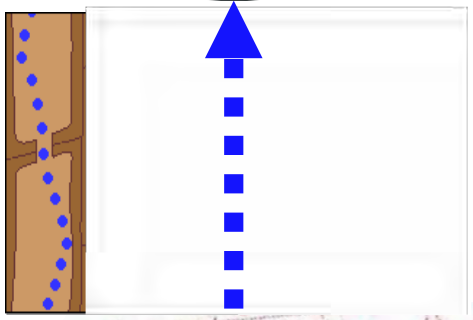
Balsam fir

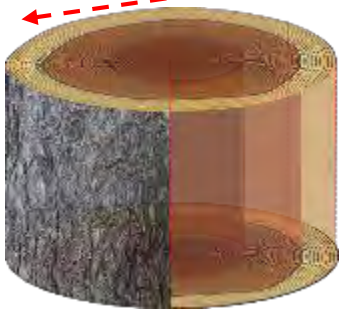
White spruce

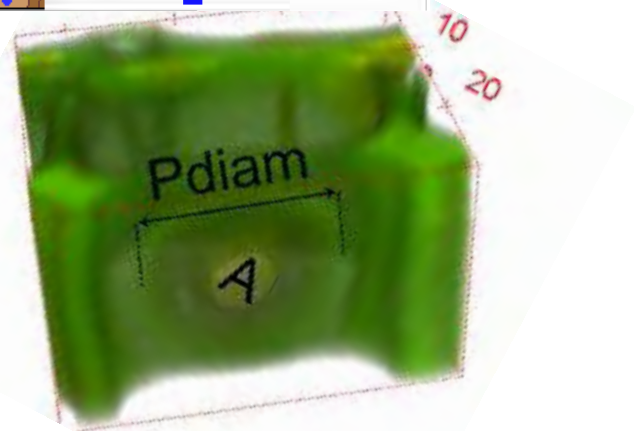
Jack pine: *High capacity of transporting water & fast-growth*

"***Photosynthesis*** *and* ***growth*** *are maximized"*
(Schulte *et al.*, 2015)

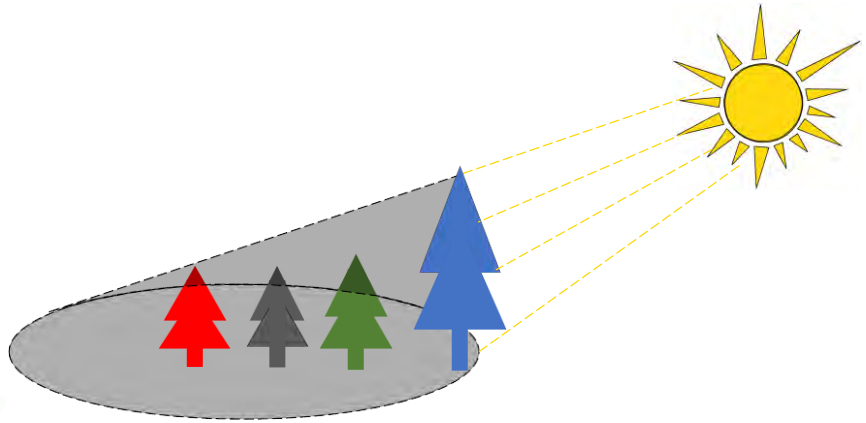
"Conduit widening ***minimize*** *the increase in* ***hydraulic resistance*** *as plants* ***grow taller****"*
(Olson et al. 2020)



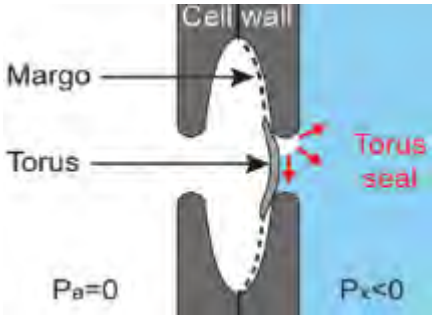


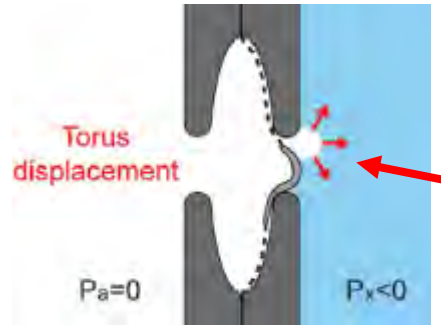


Strong competitor for water and light



Jack pine: *Well-coordinated adjustments in pit traits*

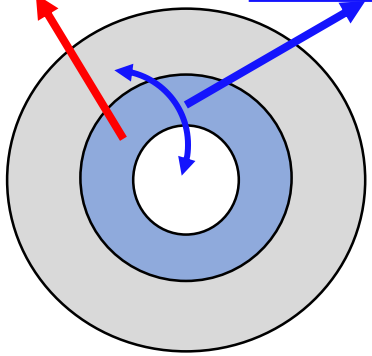


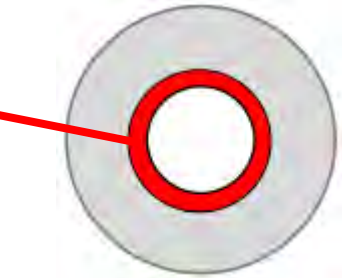


(Venturas et al, 2017)

Embolism resistance

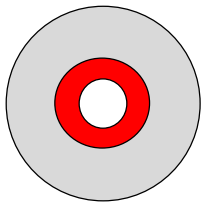
Hydraulic efficiency



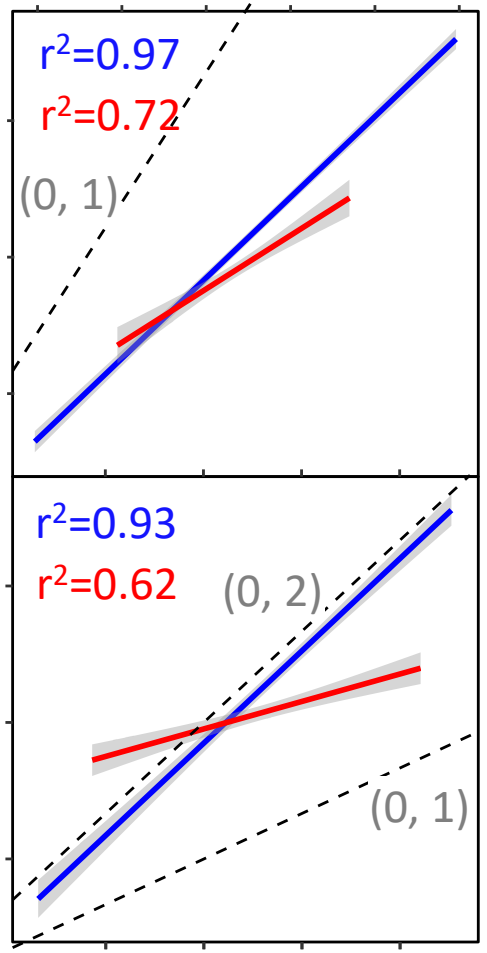


"The tight scaling relationship between pit traits optimize hydraulic conductivity."
(Hacke et al., 2004)

Jack pine



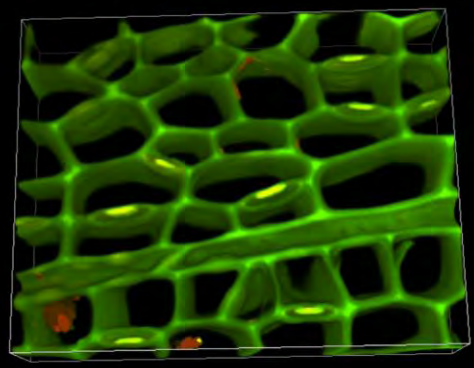
Balsam fir



Time (growing season)

Jack pine

Jack pine has evolved a mechanism that adjusts its hydraulic architecture to optimize both hydraulic safety and efficiency, resulting in high growth performance.



Summarizing:

- Methods in laser microscopy can provide a feasible way to rapidly assess the hydraulic architecture of trees;
- The growth performance is the outcome of the ability to quickly widen conduits, minimizing the hydraulic resistance as plants grow taller;
- The tight scaling relationship between pit traits optimizes hydraulic safety and efficiency in conifers, likely allowing then skip the hydraulic tradeoff hypothesis (e.g. jack pine).

Acknowledgements

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Thank you!