Tree water use and climate – emerging trends and drivers

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Water-Use Efficiency

- **WUE = Photosynthesis (growth) : Transpiration**
  - measured by sap-flow measurements, flux towers, tree chambers, etc.

➢ **‚Intrinsic WUE‘ = assimilation rate (A) : stomatal conductance (g)**

- A:g can be estimated from carbon isotopes stored in tree rings (dendrochronology)

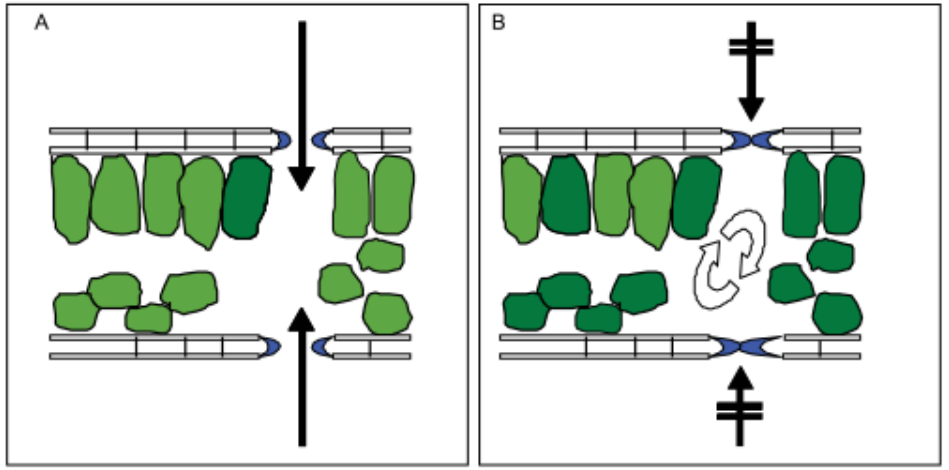
Van der Sleen 2015 Nature CC,
Frank et al. 2015 Nature Geoscience

Why carbon isotopes for WUE? because plants discriminate..

- C-fixing RuBisCO discriminate ‚big' ^{13}C molecule and prefer ‚light' ^{12}C, if stomata are open (e.g. Farquhar et al. 1989, Loyd and Farquhar 1994)

- From **^{13}C:^{12}C** ($\delta^{13}C$, stored in tree rings), we can reconstruct, whether stomata were closed or open in the past → time series of **iWUE**

Maximum discrimination | Lower discrimination

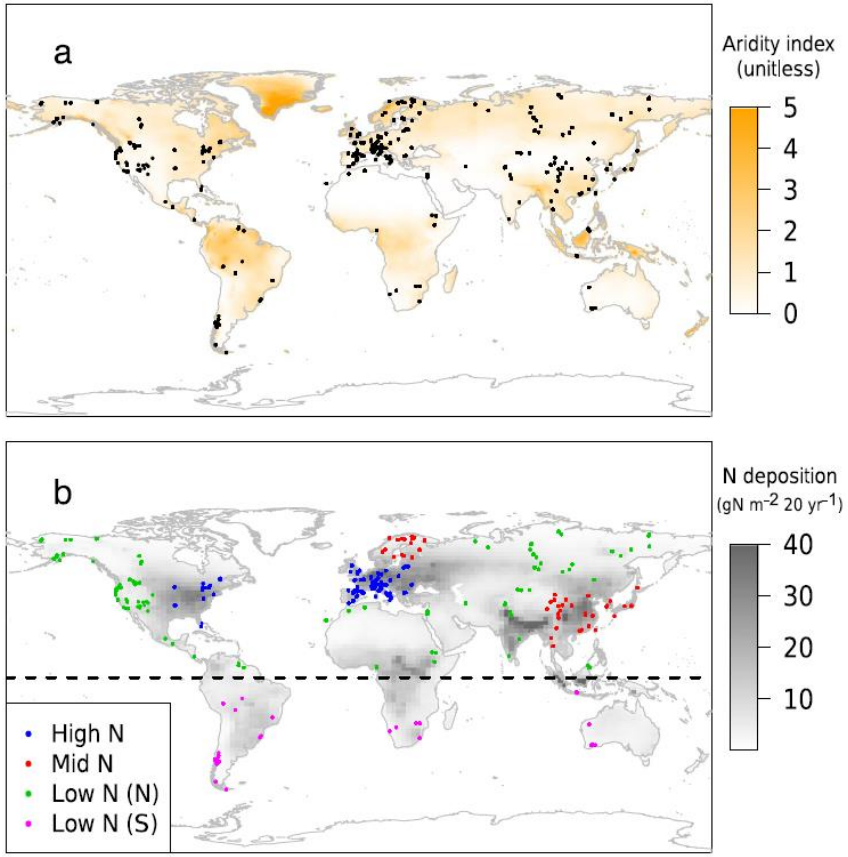


Green cells rich in ^{13}C

Lomax et al. 2013 G[3]

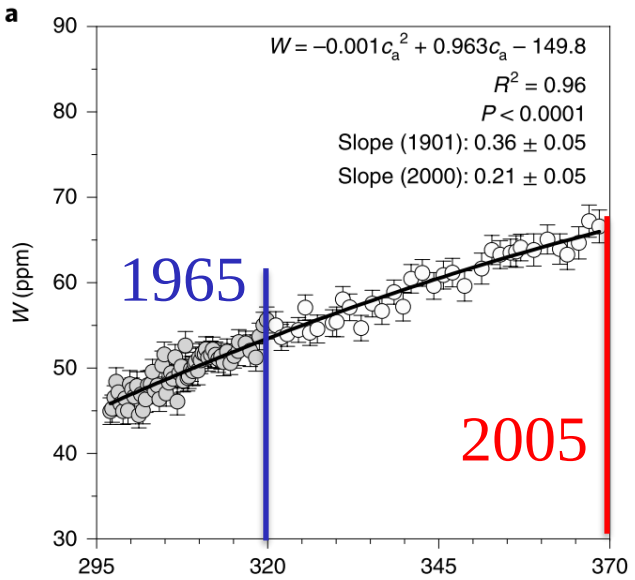
Global meta-analysis of iWUE

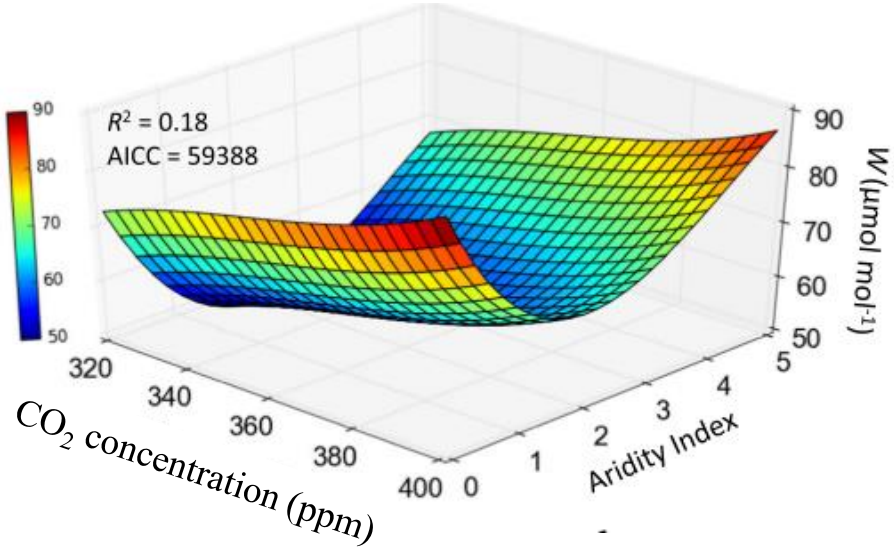
- Expanding earlier studies (Adams et al. 2019, 2020 Nature CC): +400 trees, +11,000 tree rings
- Linking with climate, CO_2 concentration and nitrogen deposition
- Aridity Index (precip.:evapotransp.) – measure for water availability



Adams et al 2021 Nature Comms

- ✓ iWUE has been **increasing** over last century
- ✓ **Non-linear** patterns between iWUE~CO_2 and iWUE~aridity
- ✓ Globally, **aridity is stronger driver for iWUE** than CO_2
- ✓ Nitrogen deposition important (40-60% of explained variation) in southern hemisphere (low atmospheric N deposition)





Adams et al 2020, 2021

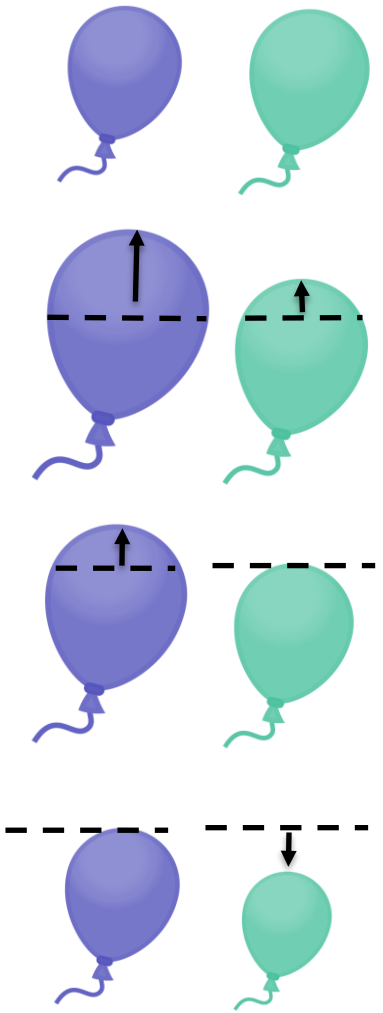
WUE increases, what does this mean?

- WUE = Photosynthesis / water use
- Scenarios:

➢ More water use, but even more photosynthesis? (case 1)

➢ Constant water use and more photosynthesis? (case 2)

➢ Less water use and constant photosynthesis? (case 3)



Next steps:

- Quantify transpiration (sap flow meters, SAPFLUXNET, FLUXNET, etc.)
- Develop sapwood area allometries
- Link with forest growth data

Thank you for attention!

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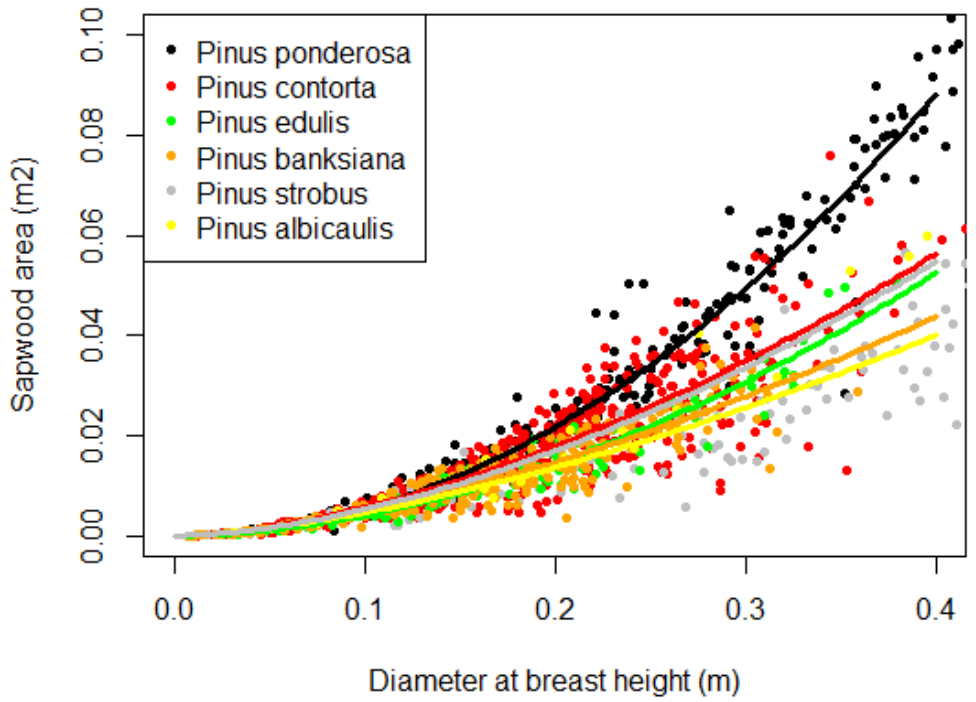
Sapwood allometry

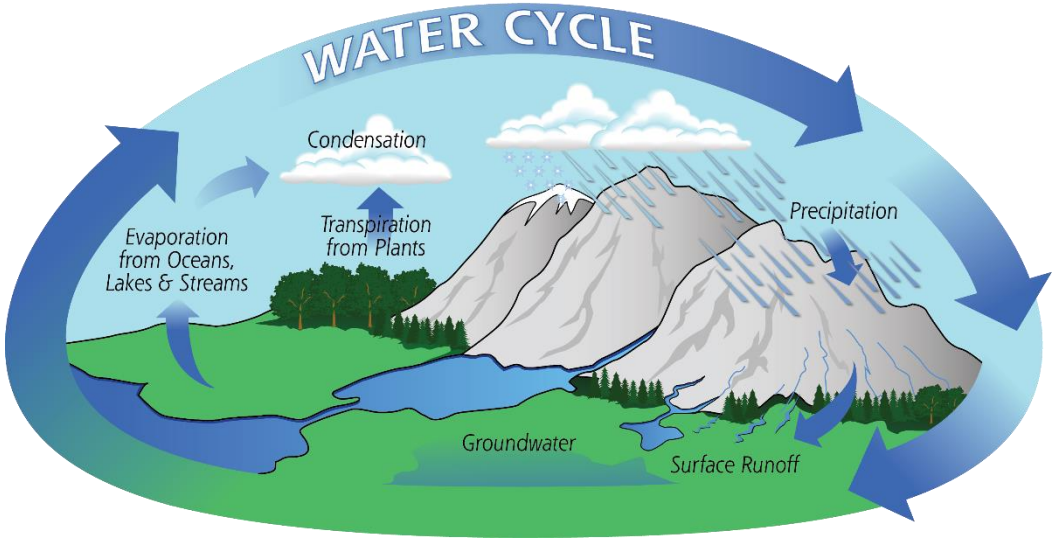
- Conductive sapwood area (SA) data available for +11,000 trees
- **Diameter** is key variable for modelling SA
- Species identity explain more SA variation than climate

➢Basis for mapping sapwood area (see Thurner et al. 2019 GEB) and modelling water use?!



Neumann, unpublished

- Water needed by plants for internal transport, growth and gas exchange
- Terrestrial vegetation transpire every year **40% of global land precipitation** (70% of evapotranspiration)
- CO_2 concentration increases efficiency of water use



Source: NASA

Poyatos et al. 2021 ESSD,
Hatfield 2019 Frontiers,
Adams et al. 2021 Nature Comms