Tracing plant water fluxes in ecosystems by stable isotopes along the soil-plant and plant-atmosphere interfaces

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BIOSPHERE 2 | WATER ATMOSPHERE AND LIFE DYNAMICS

WALD

European Research Council
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Isotopes tracing soil-plant and plant-atmosphere exchange

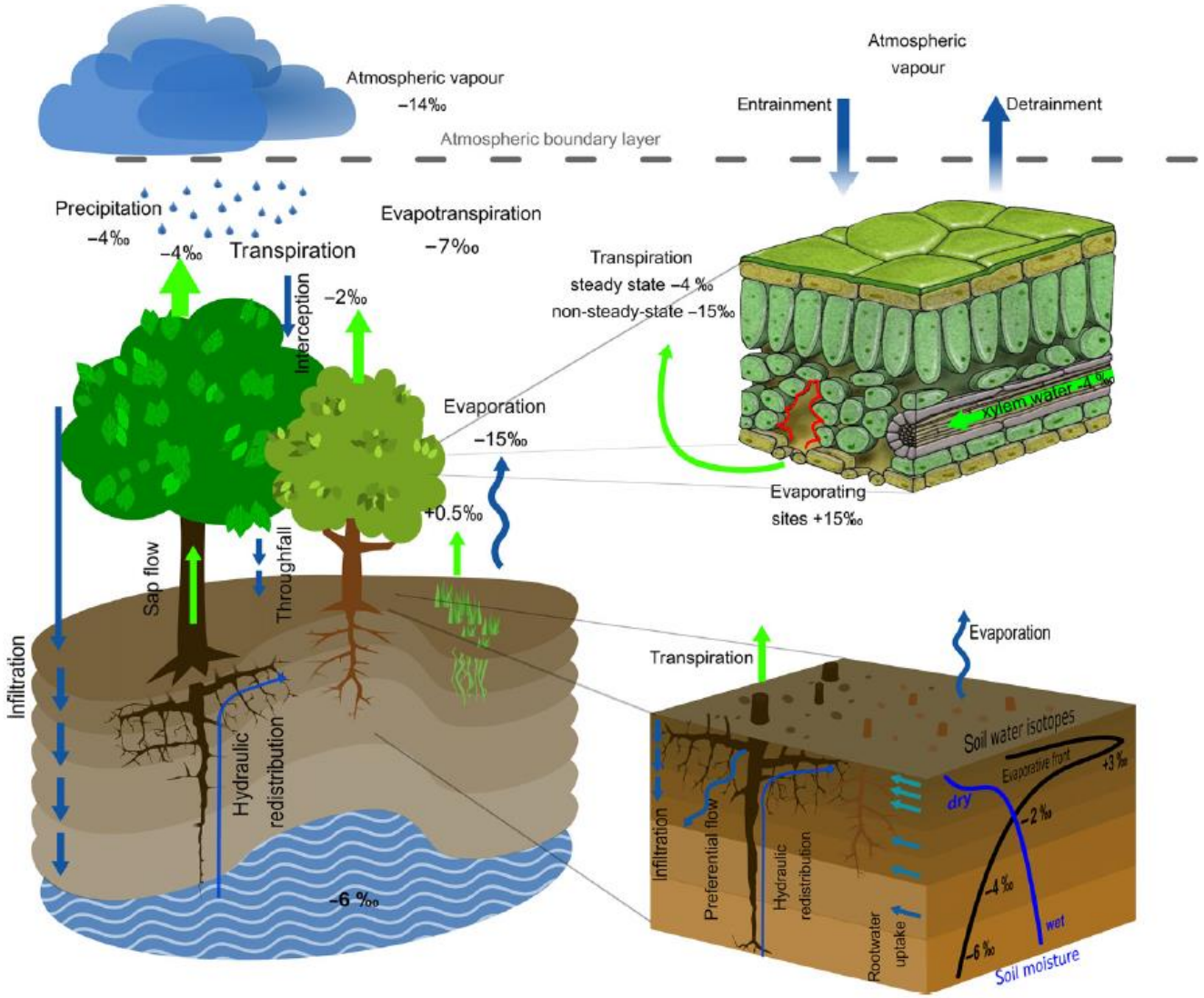


Fig. 1 Schematic overview on selected water flow paths through an ecosystem. Numbers denote oxygen isotope signatures (per mil values are approximations) of major water pools. Green and blue arrows symbolize biotic and abiotic water flow paths, respectively. The insets inform on processes at the soil–plant and plant–atmosphere interface (adapted from Werner & Dubbert (2016); depiction of the leaf cross-section with permission from www.digitalfrog.com).

Dubbert & Werner New. Phyt. (2018)

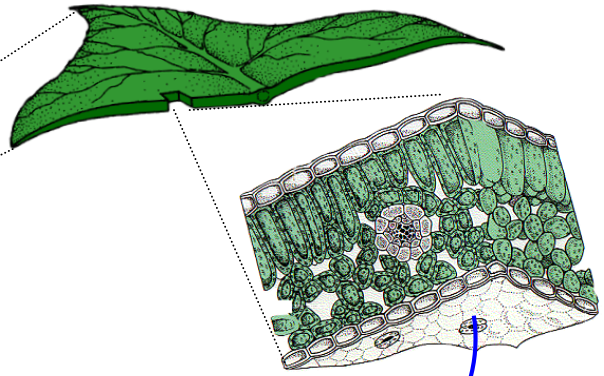
Background

- Terrestrial vegetation is a main driver of ecosystem water fluxes, as plants mediate the water fluxes within the soil-vegetation-atmosphere continuum. Stable isotopologues of water are efficient tracer to follow the water transfer in soils, uptake by plants, transport in stems and release into the atmosphere through stomata.
- The development of real-time in-situ water vapour isotopologue measurements reveals high spatial and temporal dynamics, such as adaptations in root water uptake depths (within hours to days) or the impact of transpirational fluxes on atmospheric moisture.

Tracing water fluxes by stable isotopes

Precipitation (- 4 ‰)

Evapotranspiration



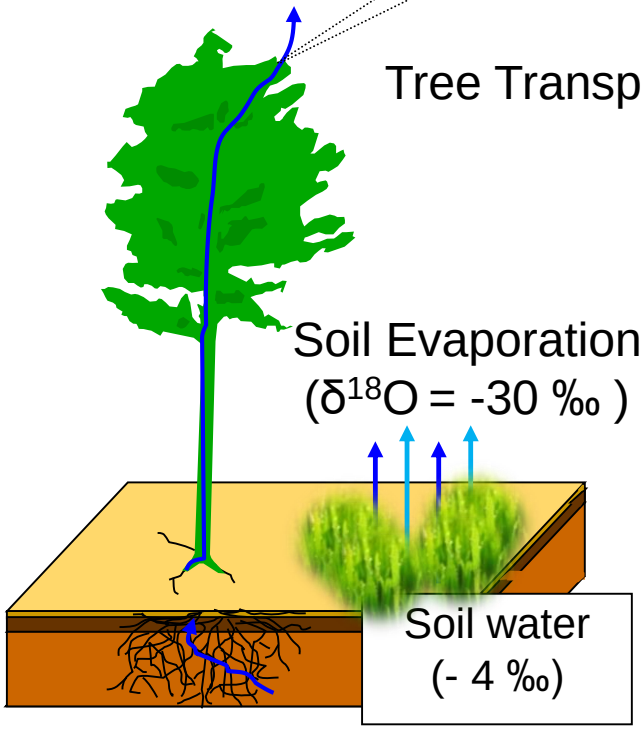
Tree Transpiration

H_2O

$\delta^{18}O$ =-4

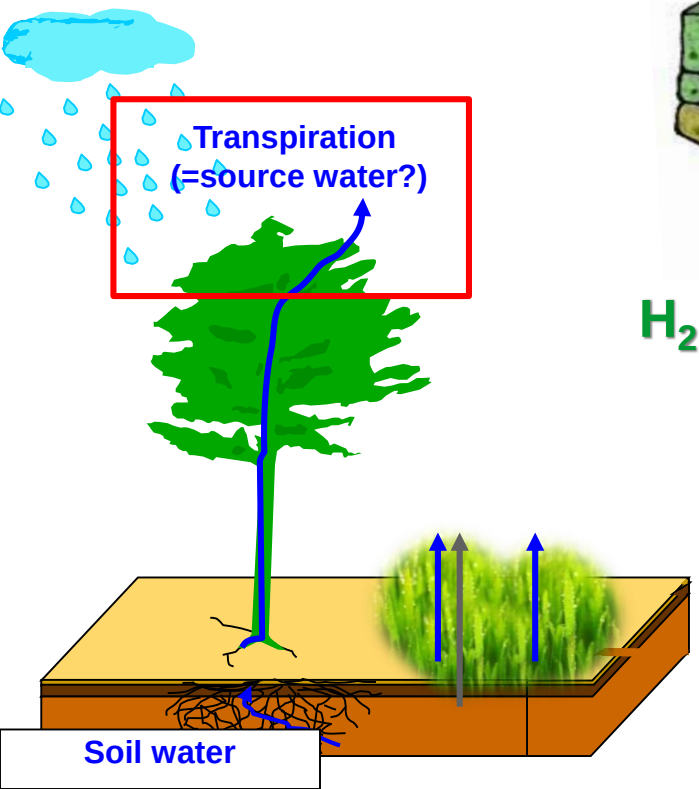
Soil Evaporation
($\delta^{18}O$ = -30 ‰)

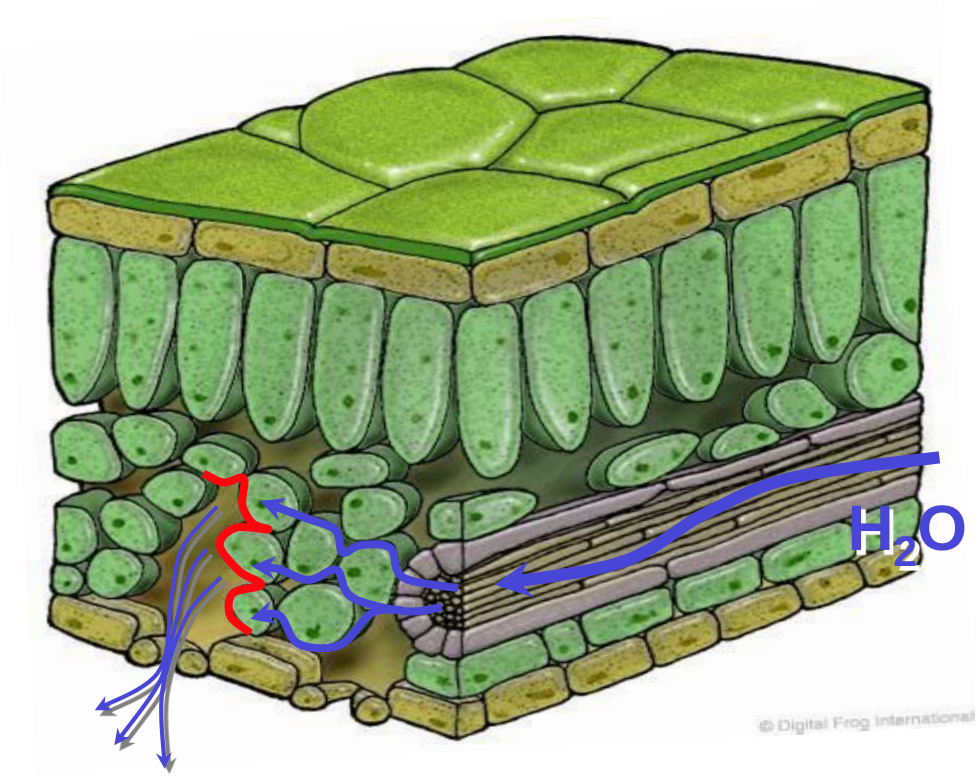
Herbaceous
Transpiration



Adapted from Yakir &Sternberg (2003)

The role of non-steady-state transpiration





Evaporative front

steady state:
$\delta^{18}O$-source water

Farquhar & Lloyd 1993

Non-steady state:
$\delta^{18}O$-depleted transpired vapour

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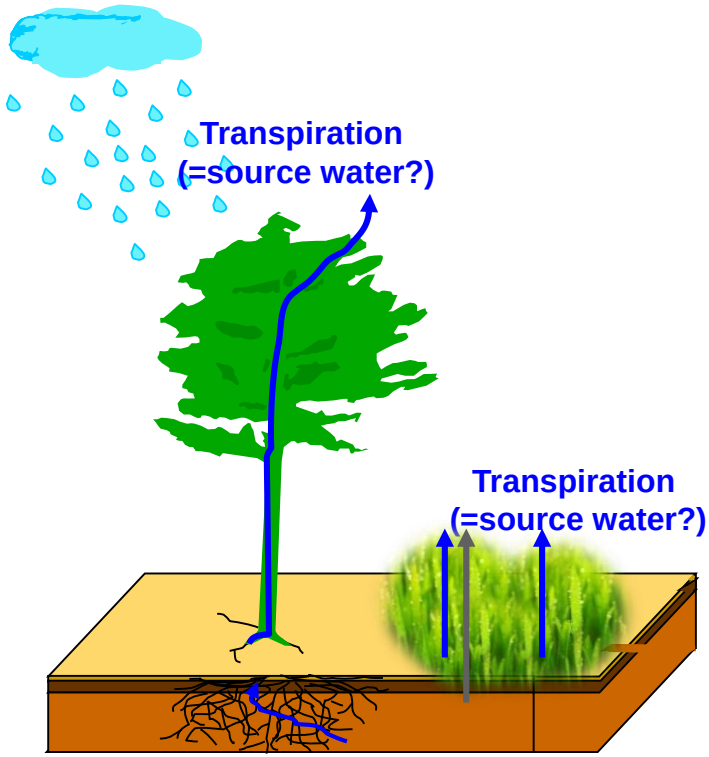
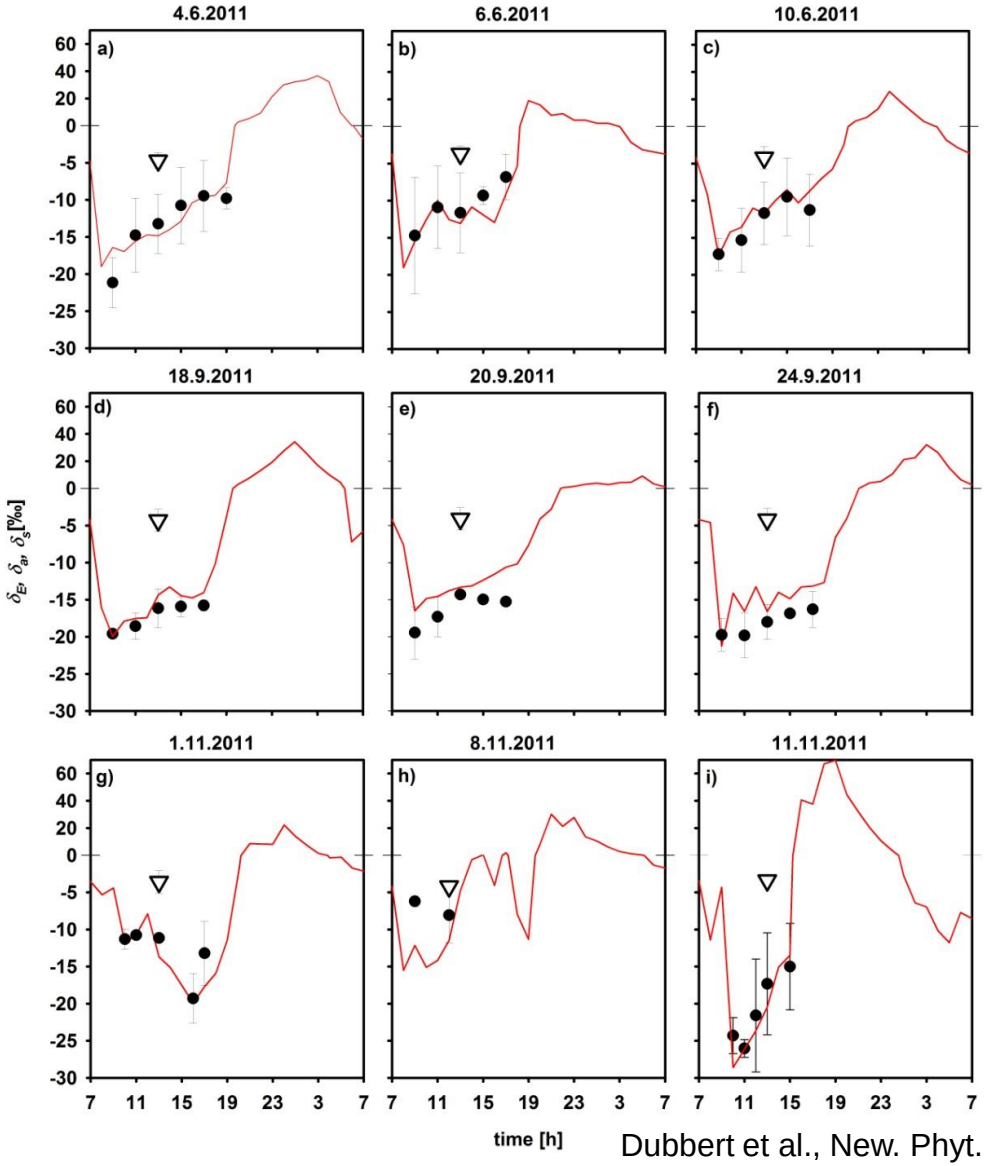
The role of non-steady-state transpiration



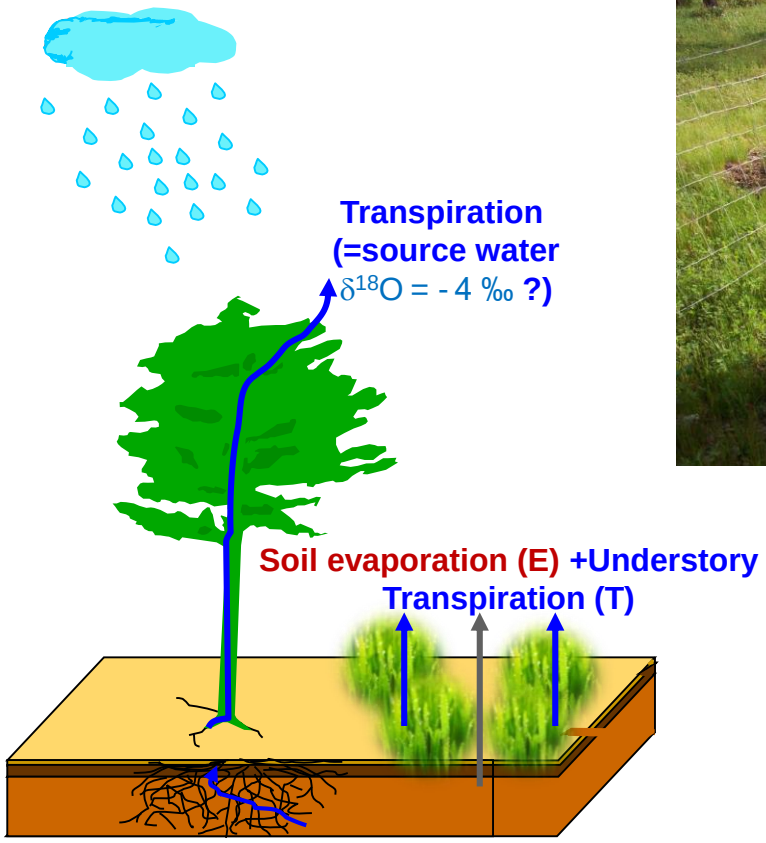


Dubbert et al., New. Phyt. (2014)

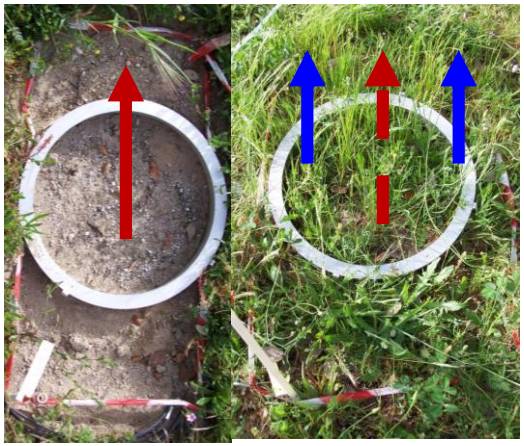
Patitioning of evapotranspiration

Partitioning Evapotranspiration

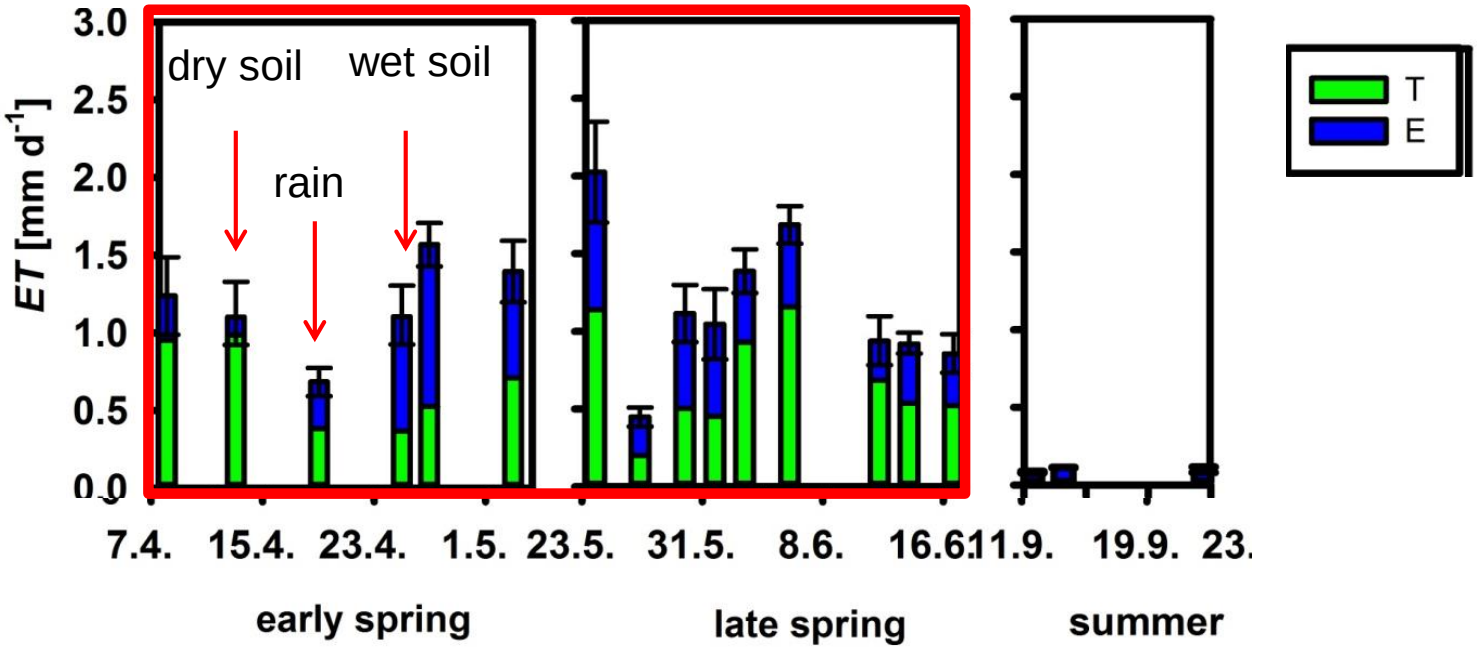
- Laser spectrometer (CRDS, Picarro; H_2O and ^{18}O) connected to an open gas exchange system with soil chambers



PTFE-coated acylic chamber



Partitioning understory evapotranspiration



- Evaporation and Transpiration are controlled by different environmental factors!
- Strong short term changes in T/ET

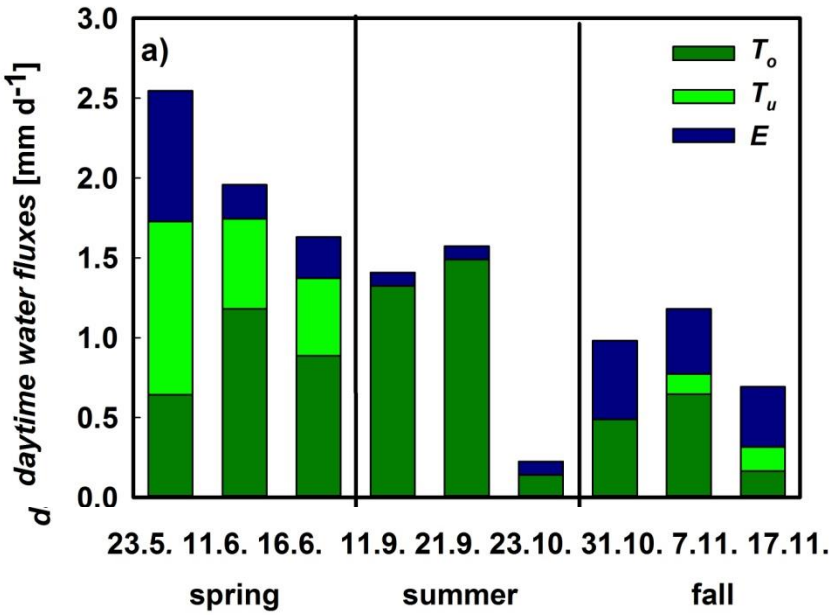
Dubbert et al. (2014); Frontiers in Plant science

Impact on ecosystem fluxes

Relative contributions (%):

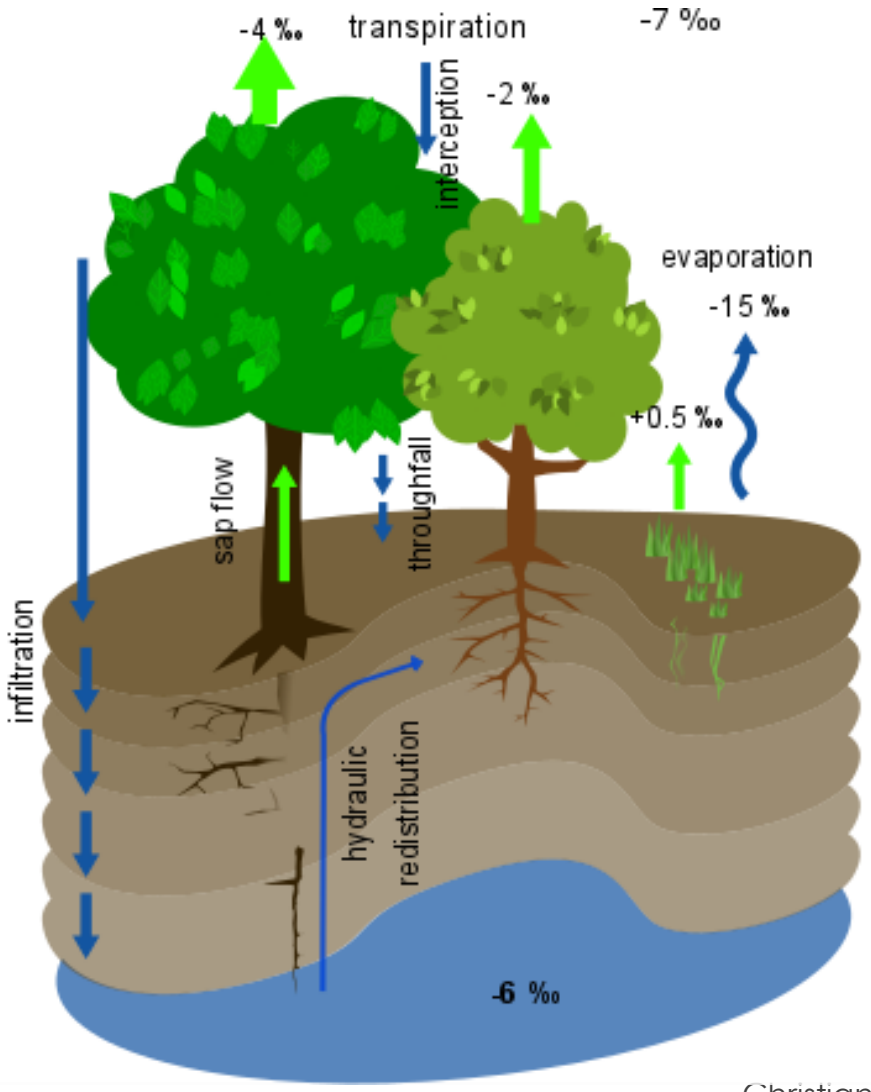
ET *Transpiration* *Evaporation*

	oaks	herbs	soil
Spring	47	34	19
Summer	84	0	16
Fall	44	10	46



Dubbert et al. (2014); Fr. Pl . Sc.

Tracing deep water uptake by stable ^{18}O or ^{2}H isotopes



Deep-rooted trees are known to perform hydraulic lift which may be an important process under drought.

Quantification of water transport from deep water reserves and its importance for microbial processes and ecosystem water balance

Dubbert and Werner 2018

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WALD

B2 WALD lead by Laura Meredith (UA), Nemiah Ladd and Christiane Werner (Uni FR)

50 scientists from **20 research groups** and **13 institutions**

- **Investigating how drought impacts ecosystem interactions at the soil-plant-atmosphere interfaces covering metabolomics, genomics, volatilomics to ecosystem fluxes**
- **First whole ecosystem deep water D- labelling**

Christiane Werner

Photo: Laura Meredith

^{13}VOC, $^{2}H_2O$, $^{13}CO_2$, COS, CH_4, $^{15}N_2O$ fluxes from atmosphere, vegetation, soils, and microbes

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Ecosystem - Meredith (Tucson), Werner (Freiburg) groups

Atmosphere (VOC)-Misztal (Texas), Williams (Mainz) groups, Krechmer (Aerodyne)

Soil, Rhizosphere - Bahn (Insbruck), Dippold (Göttingen), Tfaily (Tuscon) groups

Phyllosphere - U'Ren (Tucson)

Hydrology -Beyer (Braunschweig), van Haren (Tucson) group

Carbon allocation/Metabolomics - Schnitzler (Munich), Hartman (Jena), Lehman (Zurich)

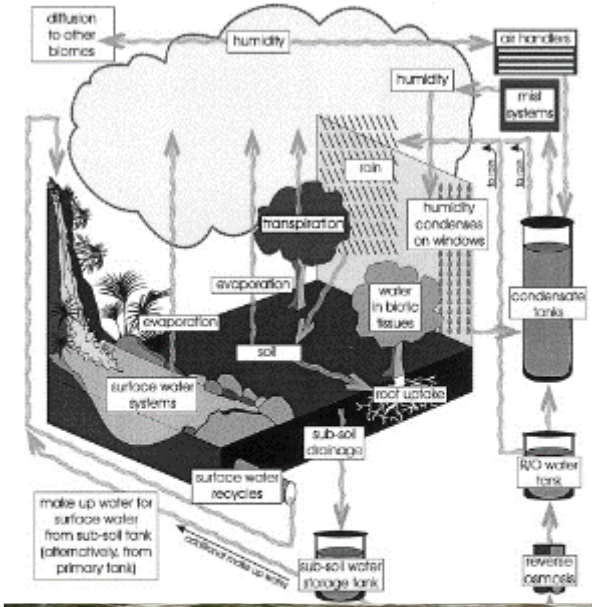
Data scientist – Hurwitz group (Tucson)

Christiane Werner

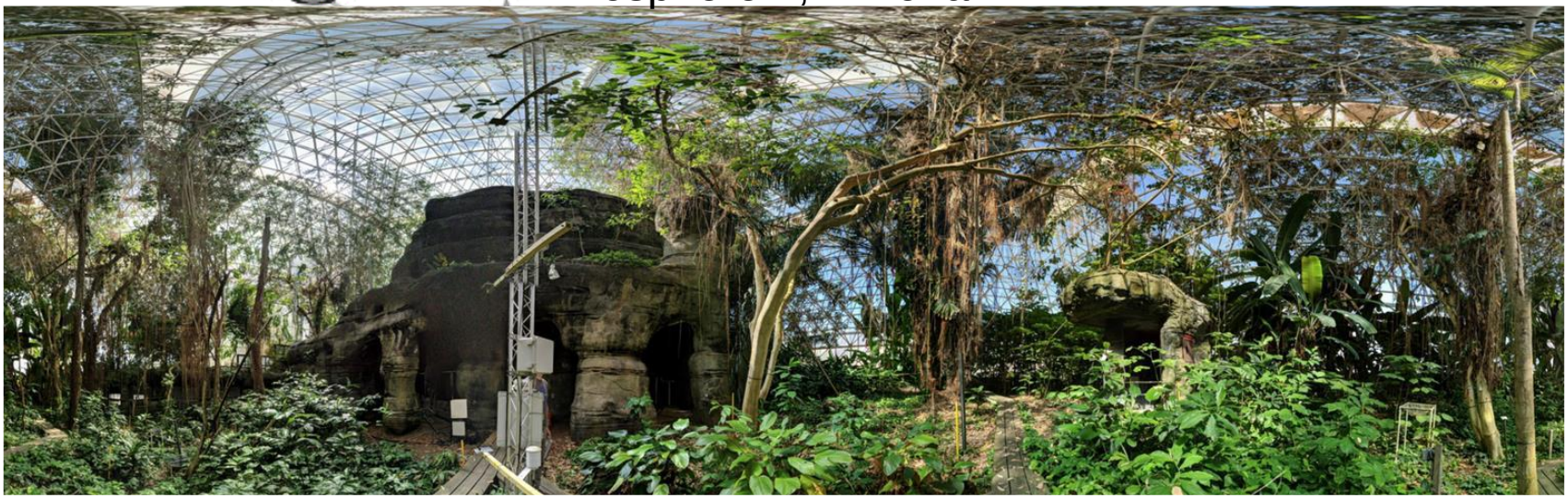
Photo: Laura Meredith

Challenges in setting up large scale experiments

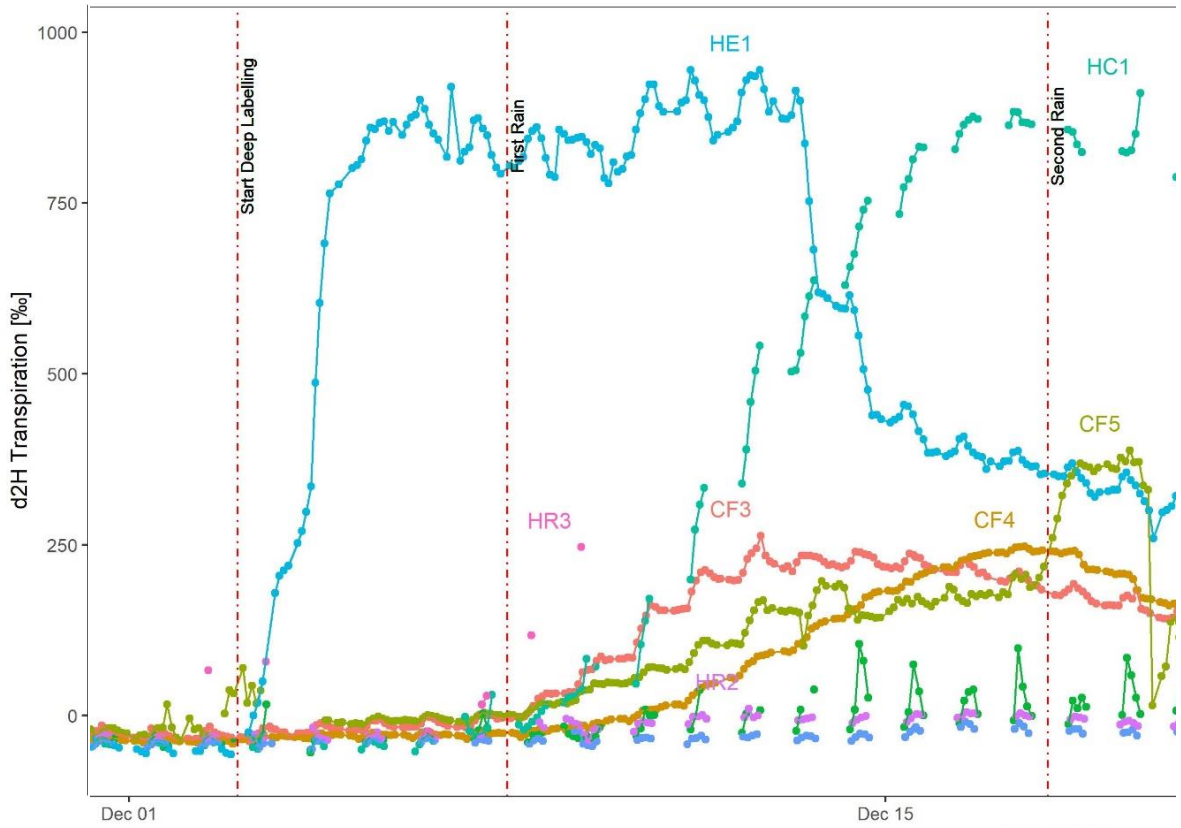
How to manipulate and label an entire ecosystem?
Deep water D- labelling after dought



Biosphere 2, Arizona



First results: water uptake from deep soil layers after drought indicates large differences in dynamics between species



Angelika Kübert[1], Kathrin Kühnhammer[2], Ines Bamberger[1], Erik Daber[1], Jason De Leeuw[3], Kinzey Bailey[3], Jia Hu[3], S. Nemiah Ladd[1], Laura Meredith[3], Joost van Haren[3], Matthias Beyer[2], Maren Dubbert[1], and Christiane Werner[1] Unpublished

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