Isotope labelling experiment to infer ecohydrological travel times

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Aim: Soil-tree-atmosphere continuum

water travel times into the crown?

tree water uptake? water travel times within the stem?

root water uptake? soil water pools?

Fig 1: Potential research fields / question (selection)

Trees play a crucial role in terrestrial ecosystem's water fluxes. Thus, better understanding of soil-tree-atmosphere interactions are important for current and future climate conditions.
Stable water isotopes are promising tracers to analyse water travel times within trees, root water uptake patterns and used soil water pools. Here, we use *in-situ* measurements in a semi-controlled tracer experiment for our investigations:

Objective 1: Can we use stable water isotopes to analyize water uptake times and compare results with sap flow velocity?

Objective 2: Do travel velocities derived from stable isotope tracers and from sap flow velocity correlate with the same explanatory variables such as soil- or weather condition?

Methods

Setup:

Trees:

Pinus pinea, Alnus incana, Quercus suber
20 years old, 4-6 m high,
planted into soil pots

Probes installed (for locations s. Fig. 2):
- *in-situ* stable water isotopes (SI)
- sap flow velocity (SF)
- soil moisture (SM) and temperature
- soil matric potential
- photosynthesis (LI-COR)
- climate station: Ta, RH, vapor pressure deficit (VPD)

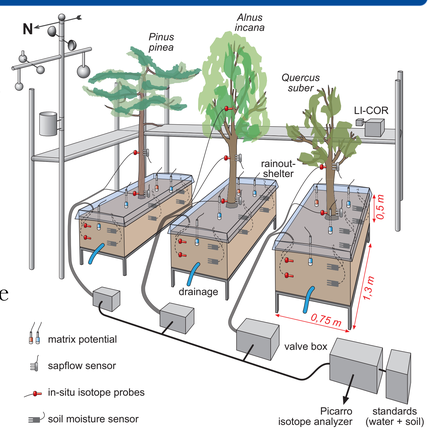


Fig 2: Experiment set-up and probes locations

Experiment implementation:

Controlled irrigation / labelling events with deuterated water

Calculations and Statistics:

a) Minimum water travel velocity (stable water isotopes):

$$\frac{\text{minimum distance (= height of isotope probes)}}{\text{time until tracer arrival after tracer input}}$$

- compared with average daily sap flow velocity, both in [cm / h]

b) Dependency SF and SI on soil, tree or weather conditions:
- use directed correlation anlysis (Generalized Linear Model, GLM) for sap flow velocity: SF ~ SM * VPD
- use Kandall rank correlation (undirected) for SI vs. SF, SM, VPD

In-situ isotope measurements with high temporal resolution are powerful tools to better understand ecohydrological processes such as plant water uptake or water travel times

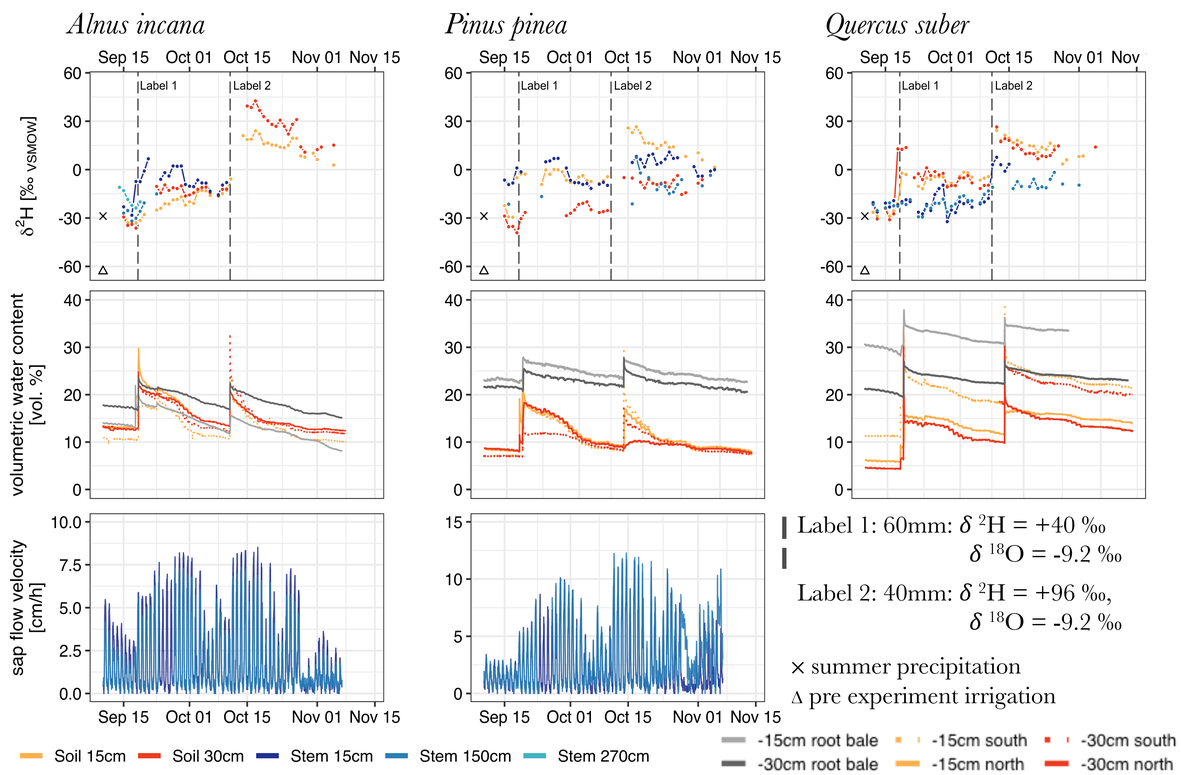
Water travel times / velocity:

Tab 1: Average water travel velocity in [cm/h] for sap flow velocity sensor and stable water isotopes calculated from xylem probes in 15cm height and first labelling event (s. Fig. 3). Note: probe failure for sap flow in *Quercus* temp. resolution was higher than in Fig. 3

	Alnus	*Pinus*
sap flow velocity	1.9	1.9
isotope tracer	0.7	0.9

- for *Quercus* no clear tracer arrival is visible in the xylem isotope probes for labelling 1
- *Alnus* and *Pinus* show clear first tracer arrival for xylem probes in 15cm but not for xylem probes in 150cm
  → water travel velocity from soils into the tree can be calculated with xylem probes in 15 cm height (Tab. 1)
- tracer arrival for *Alnus* and *Pinus* are visible with 2nd measurement after tracer injection (21h / 17h after labelling); first measurements after labelling show no tracer arrival (≤ 5h)

Generall results:



Label 1: 60mm: $\delta\,^2H$ = +40 ‰
$\delta\,^{18}O$ = -9.2 ‰

Label 2: 40mm: $\delta\,^2H$ = +96 ‰,
$\delta\,^{18}O$ = -9.2 ‰

× summer precipitation
Δ pre experiment irrigation

Fig 3: Stable water isotopes measurements (daily median values), soil moisture and sap fow velocities

Differences in travel times derived from sap flow and isotope tracer

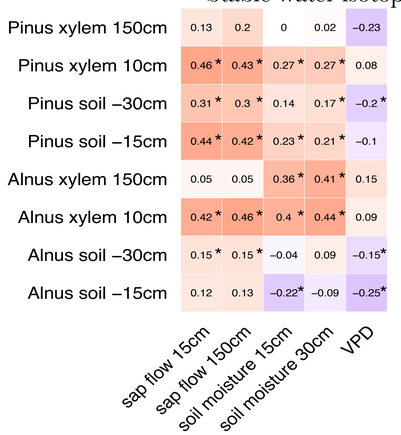


Fig 3: Kandall's τ (* = significant correlation)

- $\delta\,^2H$ shows no strong correlation pattern between sap flow velocity, soil condition or VPD (Fig. 3)
- $\delta\,^2H$ correlation with sap flow velocities is slightly higher than with soil moisture

Sap flow velocity:
- highly depends for most trees on VPD not on soil moisture

Conclusion:

- stable water isotope tracers allow to derive water travel times, but higher temporal resolution is necessary for more accurate results
- in-situ isotope probes in 150 cm stem height are most likely effected by diffusion processes, showing wide range of water travel velocities
- sap flow velocity captures tree response to weather conditions, while stable water isotope show clear response to labelling events
- in-situ measurements are a powerful tool for advanced ecohydrological process analysis

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