Comparing tree species-specific water uptake strategies via continuous in-situ monitoring of stable water isotopes

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Introduction

Research Questions:

- Where do trees get their water from and how long does it take from water uptake to transpiration?
- Do different tree species have different water use strategies to access soil water resources?

Approach:

- To understand how soil water is used by different tree species, we setup a semi-controlled outdoor pot experiment with three different tree species.
- We took advantage of stable water isotope techniques by tracing plant water uptake through isotopically labelled irrigation water.
- We followed the isotopic composition of soil and xylem water in high temporal resolution via in-situ isotope probes, which were directly attached to an isotope analyzer.

Expected Implications:

- These questions are fundamental in order to estimate how trees will be affected by a change in available soil water resources under predicted climate change.

Experimental setup

- Three 20 year-old trees (4-6 m high): pinus, alnus, quercus
- Planted into clayey loamy substrate (Fig. 1)

Equipment:

- In-situ porous-membrane isotope probes in the soils and tree xylem
- Soil moisture and temperature probes
- Soil matrix potential probes
- Sapflow sensors
- Portable photosynthesis system (LI-COR)
- Climate station

Comparison with destructive samples:

- Soils (2 depths) and tree xylem (two heights) were sampled destructively four times for the vapour equilibration technique (Fig. 3)

Isotope labeling:

- Deuterated water was applied as irrigation water (three campaigns) (Fig. 2, dashed line)

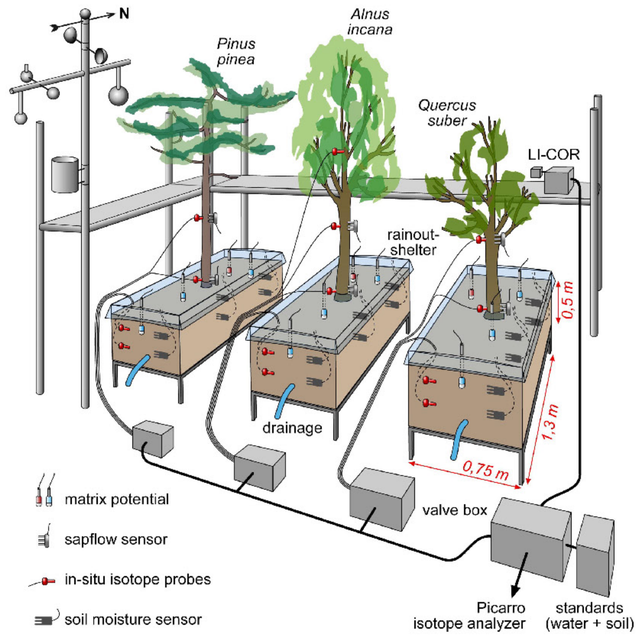

Fig. 1: Overview of experimental setup and measurement equipment.

Conclusions

- In-situ isotope measurements in tree xylem and soil compared reasonably well to isotope values gained by destructive sampling but yield **much higher temporal resolution**.

  ➔ In-situ isotope measurements are a **powerful tool** to trace ecohydrological fluxes.
- Very heterogeneous behavior in **tree specifies water uptake patterns** under controlled conditions.
- Species showed distinguishably different sapflow dynamics, but quick responses to the isotope label uptake

Implications & Outlook:

- Integrating information on species-specific event-water use and root-water uptake dynamics will deliver first hints on **how trees may funnel water towards their active root zones.**
- This will become important under **future climatic conditions** in terms of development of **adaptation strategies** for sustainable **forest management**.
- **Additional labeling experiments in 2020.**

Results & Discussion

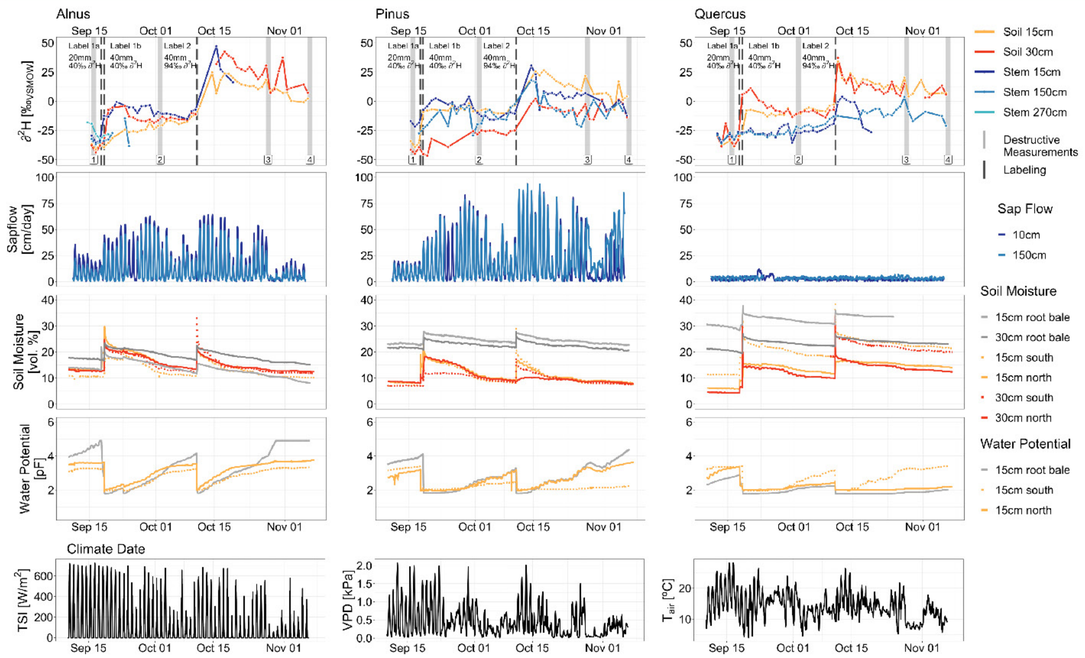

Fig. 2: Variation of δ^2H, sapflow, soil moisture, water potential and climatic parameters (solar radiation (TSI), vapour pressure deficit (VPD) and air temperature (T_{air})) over the course of the experiment.

Tree-specific label water uptake (Tab.1):

Alnus:

- Distinct response in xylem and soil (30cm) δ^2H values after 1 day for both labelings. Soil isotopic signature more responsive in 30cm than in 15cm soil depth.

Pinus:

- Distinct response in xylem δ^2H values (15cm) after 1 day; stronger effect for label 1
- Despite highest sapflow rates, isotopic label difference was lower than for other species
- Similar isotopic dynamic but higher δ^2H values in 15cm than in 30cm soil depth.

Quercus:

- More moderate response of increasing xylem δ^2H signatures (low sapflow rates), but quick response in the soil.

In-situ vs. destructive sampling (Fig. 3):

- Destructive samples show a wider isotopic spread but were mostly consistent with in-situ measurements.

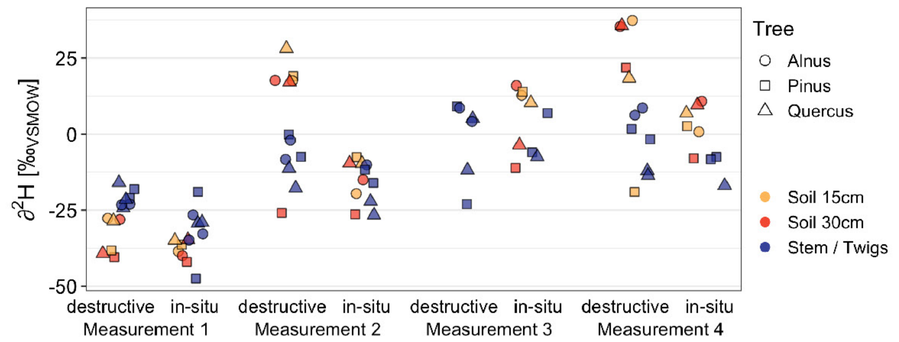

Fig. 3: Comparison of destructive vapour equilibration samples with continuous in-situ measurements (three-day median, for date of measurements see Fig. 2, grey bars).

Tab. 1: In-situ measurement response after label 1 (a&b) and 2. * significant differences ($p<0.05$) between δ^2H values three days before and after labeling (ANOVA), -- no visible change in δ^2H values within one week after labeling, ++ visible change, but no delay time, due to five days measurement failure.

		Alnus				Pinus				Quercus			
		Soil		Stem		Soil		Stem		Soil		Stem	
		15cm	30cm	15cm	150cm	15cm	30cm	15cm	150cm	15cm	30cm	15cm	150cm
Label 1	delay [days]	6	< 1	< 1	> 6	< 1	--	< 1	ca. 6	< 1	< 1	--	--
	difference [δ^2H ‰]	+ 20	+ 40 *	+ 40 *	+ 20	+ 20 *	--	+ 20 *	+ 20	+ 20 *	+ 20 *	--	--
Label 2	delay [days]	++	< 1	< 1		< 1	++	++	++	< 1	< 1	--	--
	difference [δ^2H ‰]	+ 30	+ 35	+ 35		+ 20	+ 20	+ 20	+ 20	+ 30 *	+ 30 *	--	--

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Acknowledgments
Funding: Scientific Society Freiburg