Optimizing plant water uptake source depths estimation by stable water isotope labeling

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Motivation

Naturally occurring stable water isotope depth profiles in the soil may not be ideal for accurate estimations of the source depths of plant water uptake (PWU).

In order to increase the informational content of isotope depth profiles, they can be altered by irrigation with isotopically distinct water pulses.

But which points are most important for the experimental design of isotope labeling studies?

Objectives

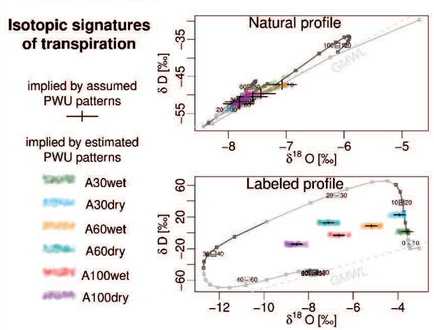
This study aimed to assess the effects of different decisions regarding an isotope labeling for the purpose of PWU pattern estimations.

In particular we wanted to **assess the influence of**:

- **amounts** of labeling water
- **isotopic signatures** of labeling waters
- **order of labeling pulses**
- **isotope measurement depth schemes**
- **isotope measurement accuracies**

Results

Improvement of PWU pattern estimation through isotopic labeling



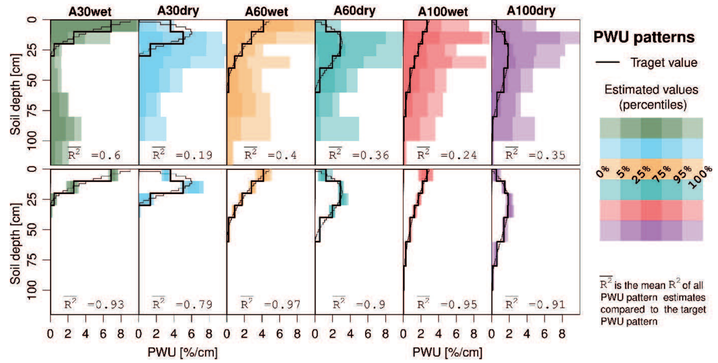
natural isotope depth profile

Left hand figure shows isotopic signatures of soil water and transpiration.

Right hand figure shows the respective assumed and estimated PWU patterns.

Labeling clearly improves estimate goodness for all PWU patterns.

labeled isotope depth profile



Methods

Virtual experiments simulating different experimental scenarios

Richards equation based, single pore 1-D simulation of soil water household and isotopic signature

Same initial conditions for all simulations

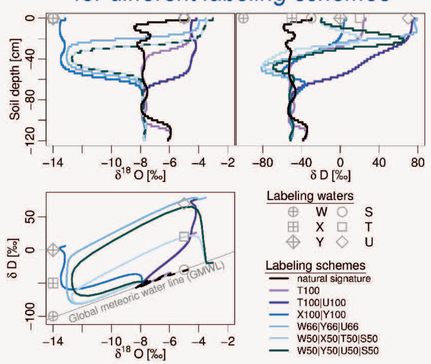
Multiple irrigation schemes with varying amounts of different labeling waters

Model simulation until four weeks after last irrigation pulse

Isotopic signatures of virtual labeling waters

water	origin	δD [‰]	δ18O [‰]
S	summer rain	-30	-5
T	S + D_2O	20	-5
U	T + D_2O	70	-5
W	winter rain	-100	-14
X	W + D_2O	-50	-14
Y	X + D_2O	0	-14

Simulated isotope depth profiles for different labeling schemes



PWU source depths estimation

A 2-parameter beta distribution, scaled by a third maximum depth parameter, was used to model PWU patterns.

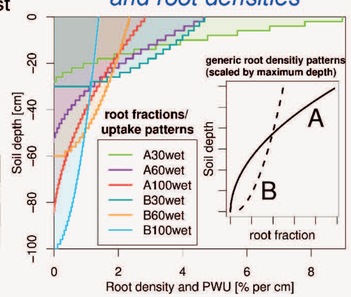
By Monte-Carlo-Simulation we obtained 100 parametrizations whose implied isotopic transpiration signatures agreed with the respective assumed transpiration signature (± measurement accuracy).

PWU patterns were estimated for simulated isotope depth profiles and isotopic transpiration signatures resulting from assumed PWU patterns and simulated isotope depth profiles.

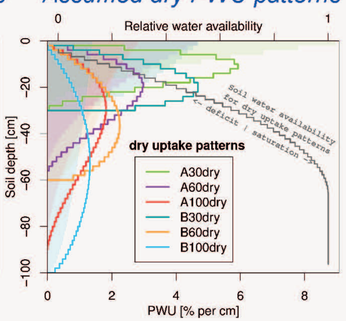
Assumed measurement accuracies

accuracy	δD [‰]	δ18O[‰]
high	± 2.5	± 0.5
medium	± 5.0	± 1.0
low	± 10.0	± 2.0

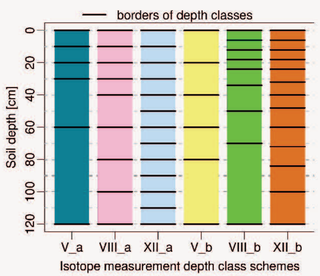
Assumed wet PWU patterns and root densities



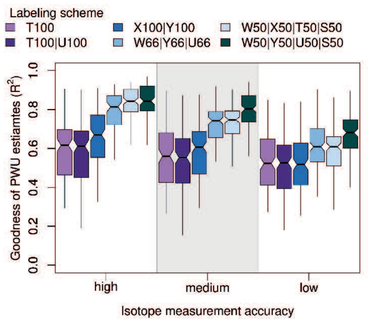
Assumed dry PWU patterns



Depth class schemes for soil isotope measurements



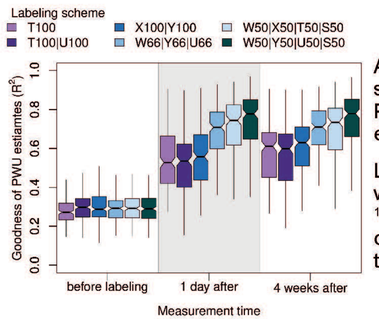
Evaluation of measurement accuracies



Differences between medium and high accuracies are smaller than between more and less suitable labeling schemes.

At lower measurement accuracies some labeling schemes can become more suitable than at high measurement accuracy.

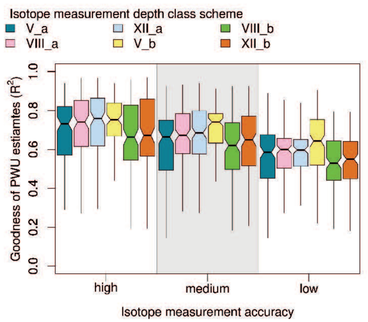
Evaluation of labeling schemes



All tested labeling schemes improve PWU pattern estimations.

Labeling schemes which alter D and ^{18}O signatures independently lead to best results.

Evaluation of measurement depth class schemes



Higher depth resolutions (VIII_a and XII_a) for soil isotope measurements only pay off for high measurement accuracies.

Increasing the depth resolution at the top of the profile (VIII_b and XII_b) may decrease estimate quality.

For lower measurement accuracies a lower depth resolution (V_b) may lead to better estimates.

Conclusions

Virtual labeling experiments can be used to asses the effects of different decisions during the designing process of real world experiments.

The presented virtual experiment can help to optimize the use of resources like labeling waters, lab time, measurement probes, etc.

PWU pattern estimates greatly benefit from artificial labeling and best results are achieved when the Deuterium and ^{18}O concentrations vary independently from each other within the soil profile.

Good knowledge of actual soil properties and the initial isotopic depth profile is essential!

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