Different strategies of tree deep water uptake, storage and transport

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Abstract QR →

Introduction

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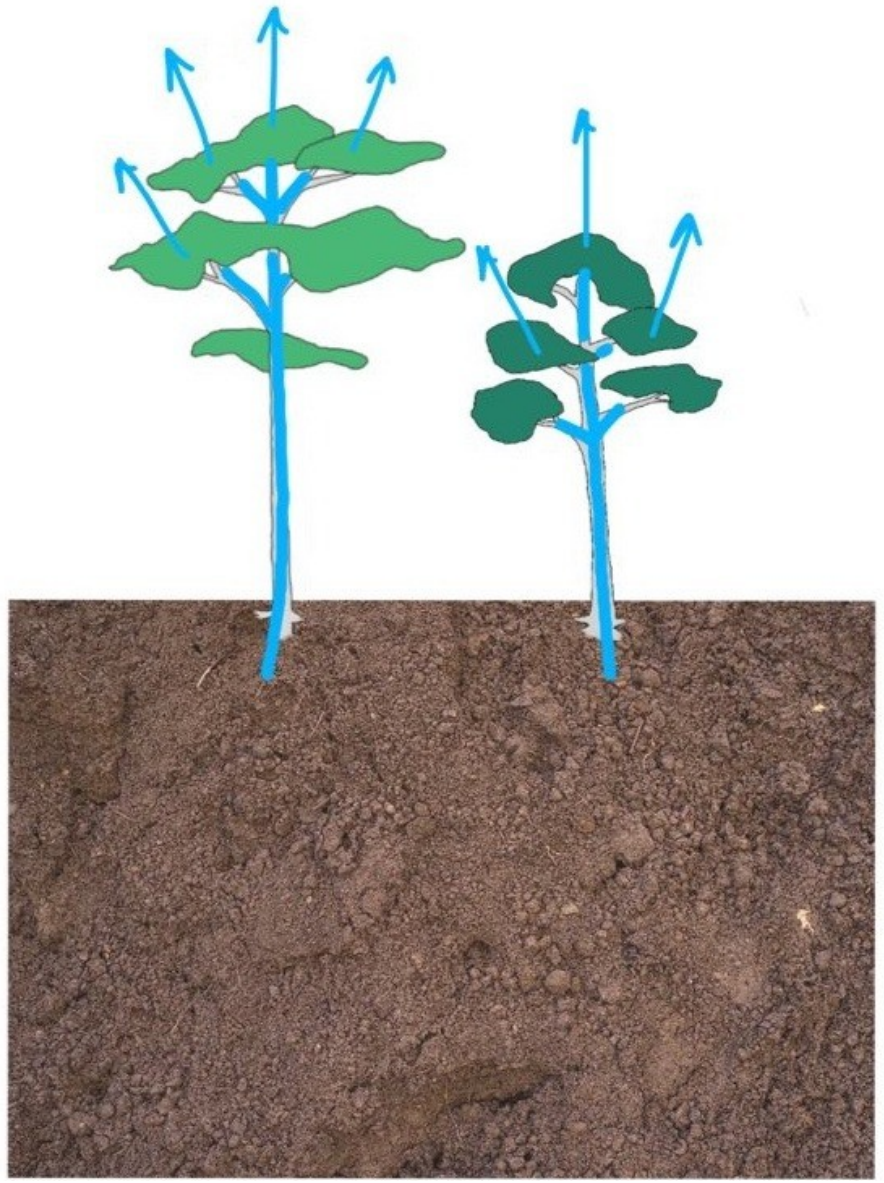

Plant water uptake plays a crucial role in terrestrial water cycling

Especially trees with their extensive root system return lots of water to the atmosphere also from deep soil

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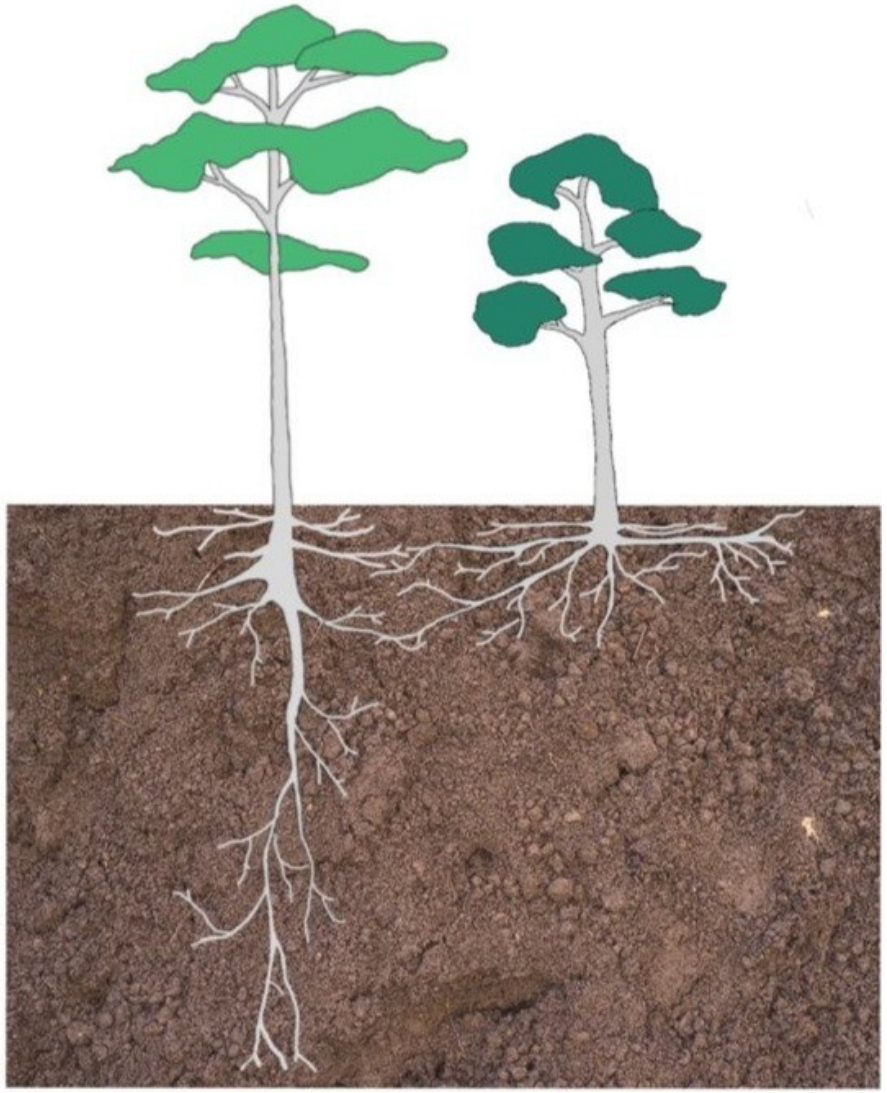

It is not only important how much water is returned to the atmosphere but also which water source trees use.

The water source or soil depth from which trees take up their water impacts water availability underground, e.g. for understorey species and how much water contributes to groundwater recharge.

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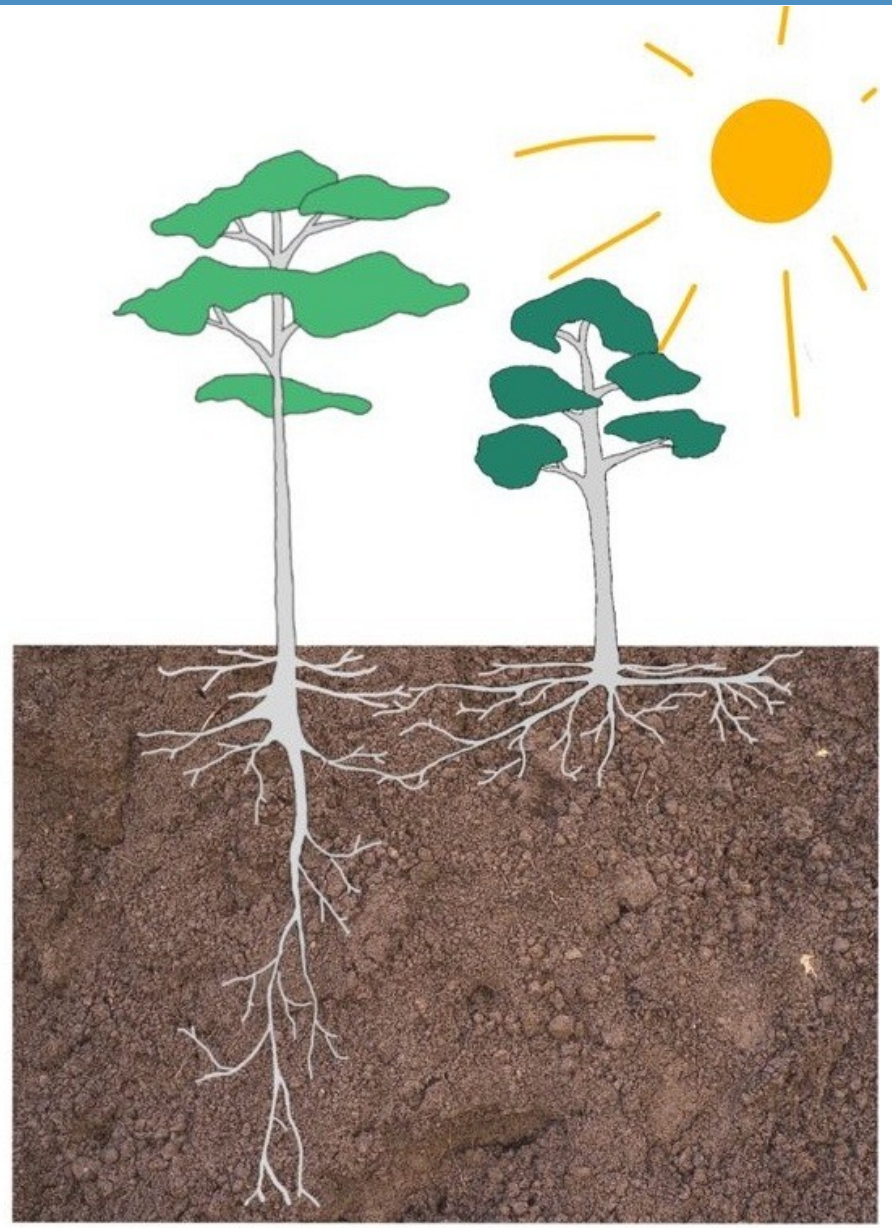

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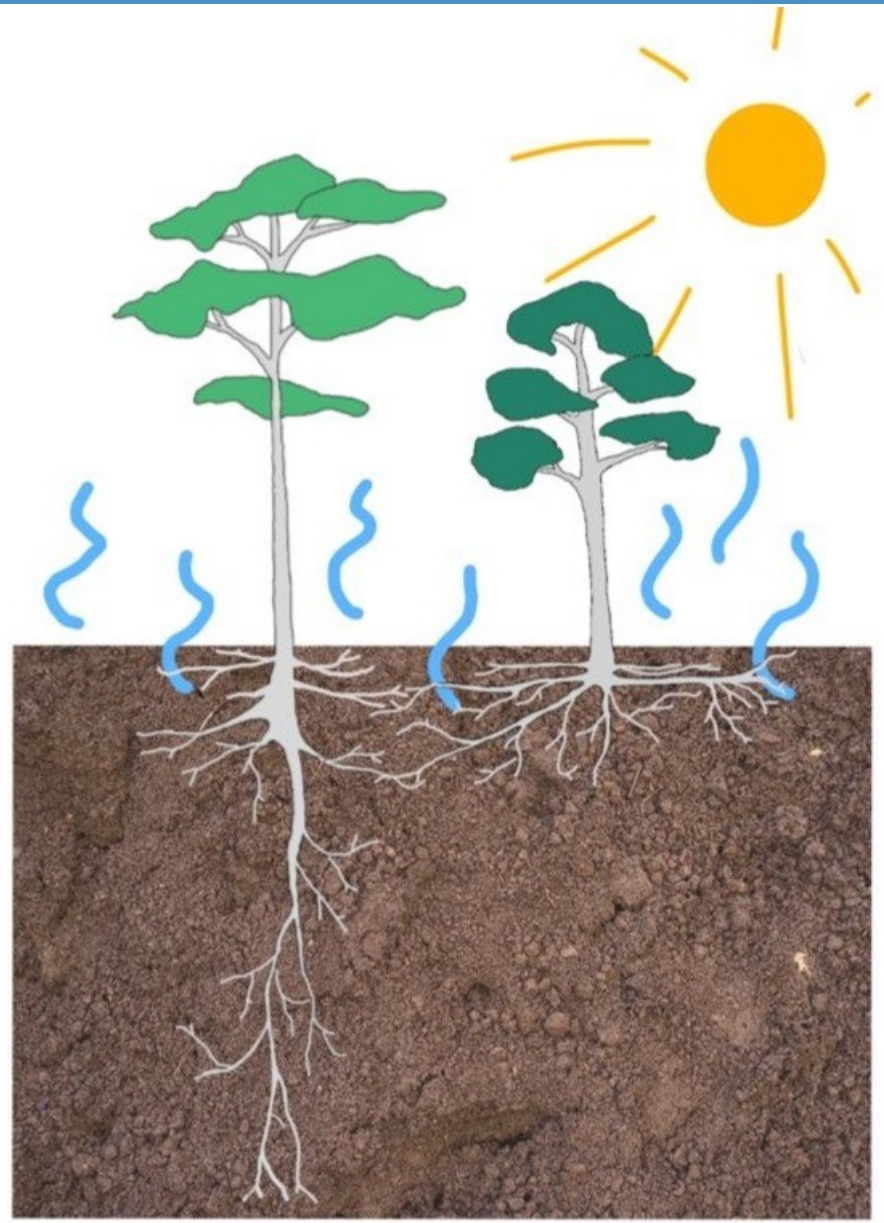

Also, trees with deeper root systems are likely less affected by intensifying droughts due to climate change.

Trees of the humid tropics might be especially vulnerable to variations in surface soil water because they are adapted to conditions of unlimited water availability.

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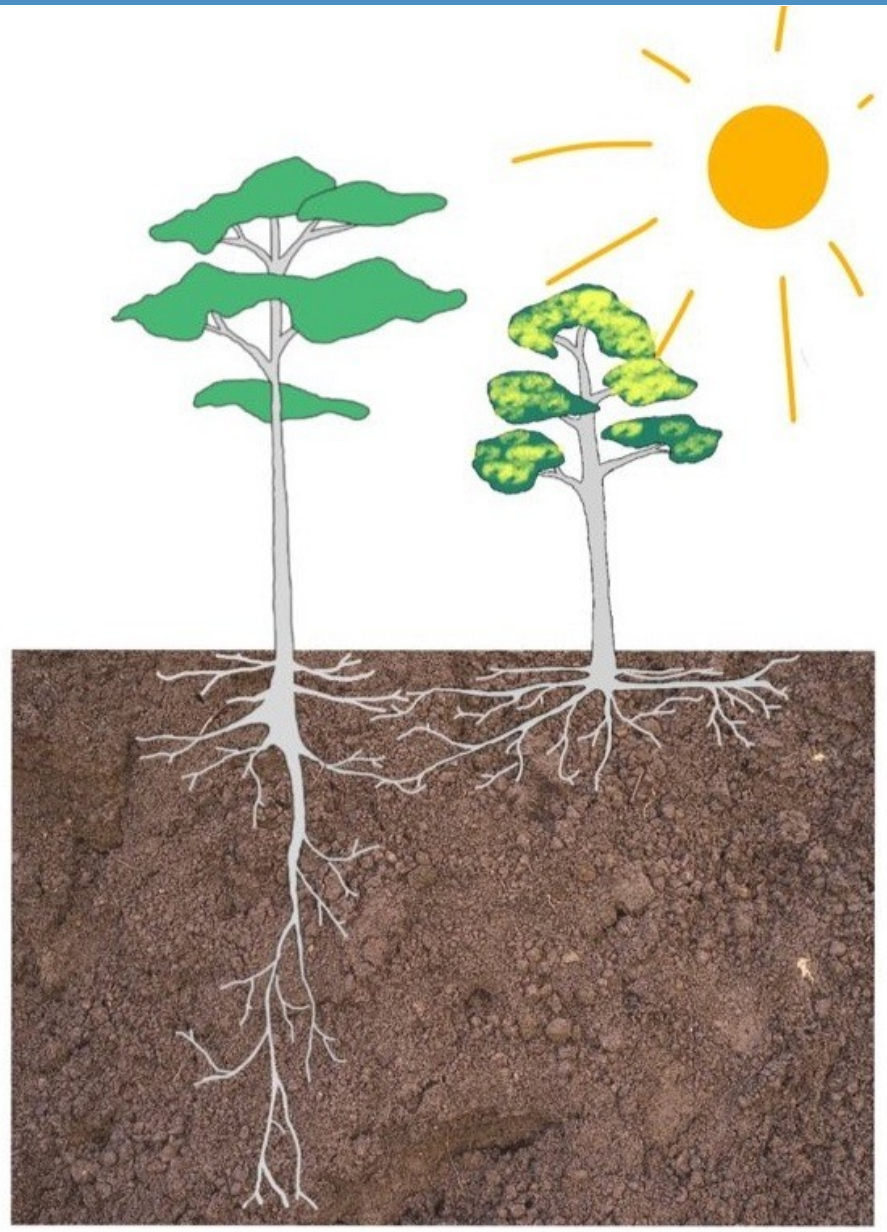

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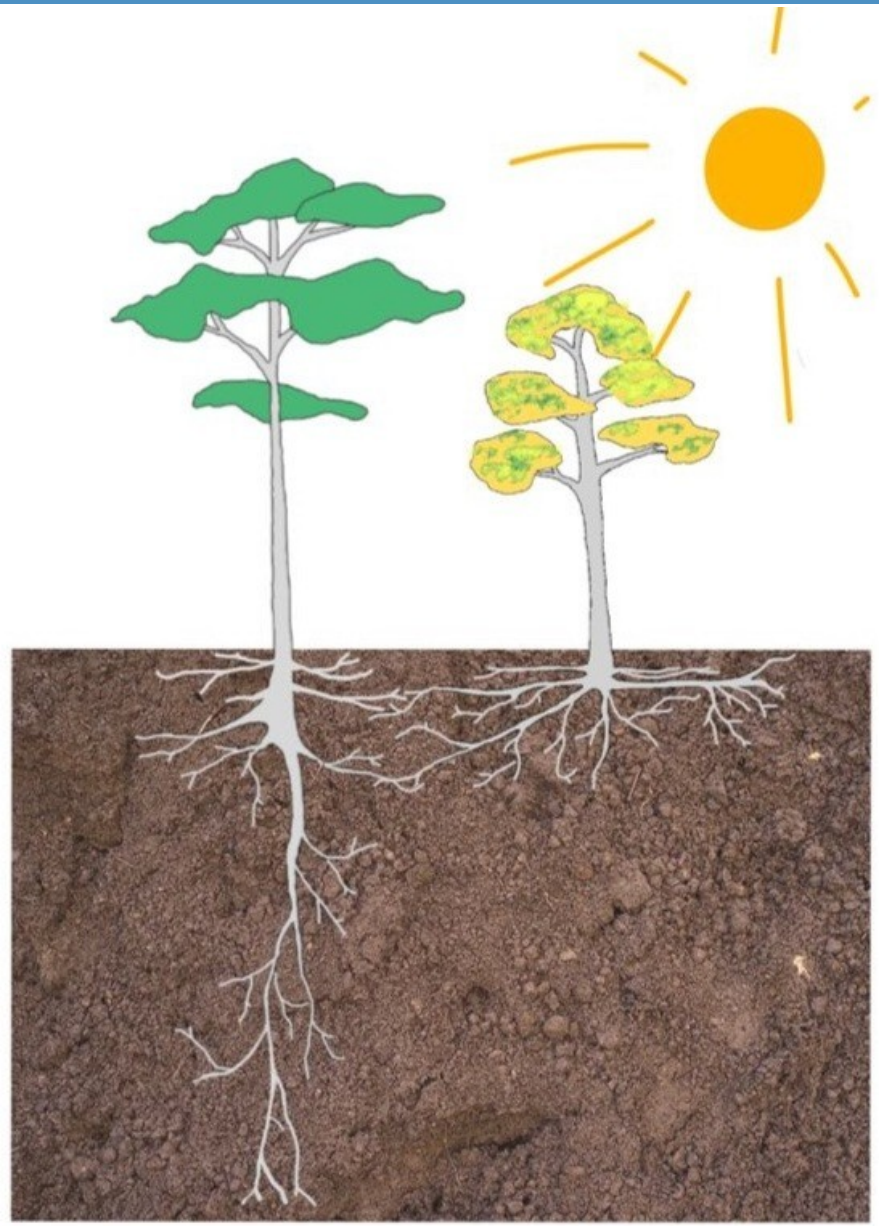

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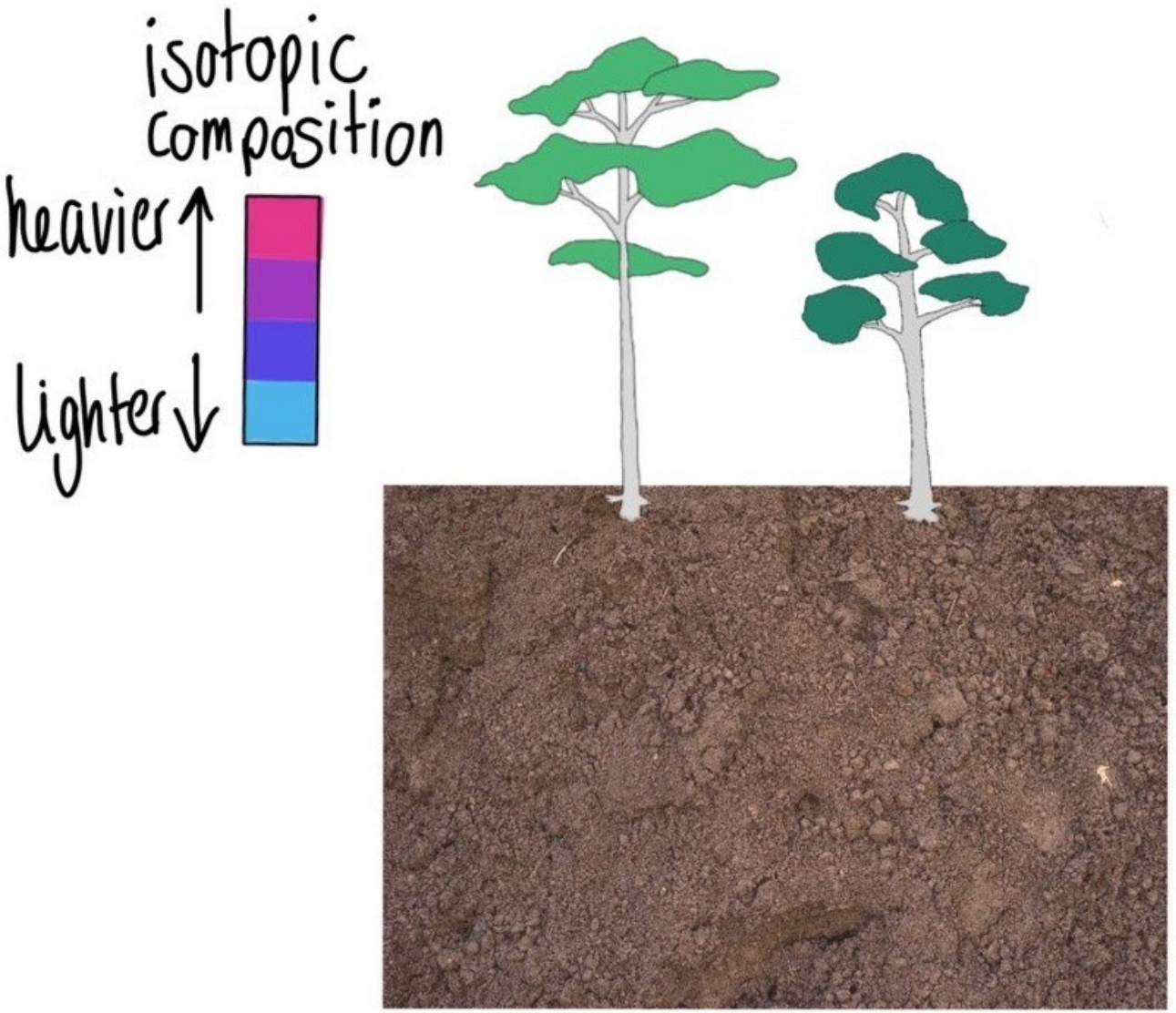

Water stable isotopes have been used to investigate plant water uptake depth for decades.

Scientists use natural differences arising from e.g. distinct inputs from precipitation and alterations due to physical processes like soil evaporation.

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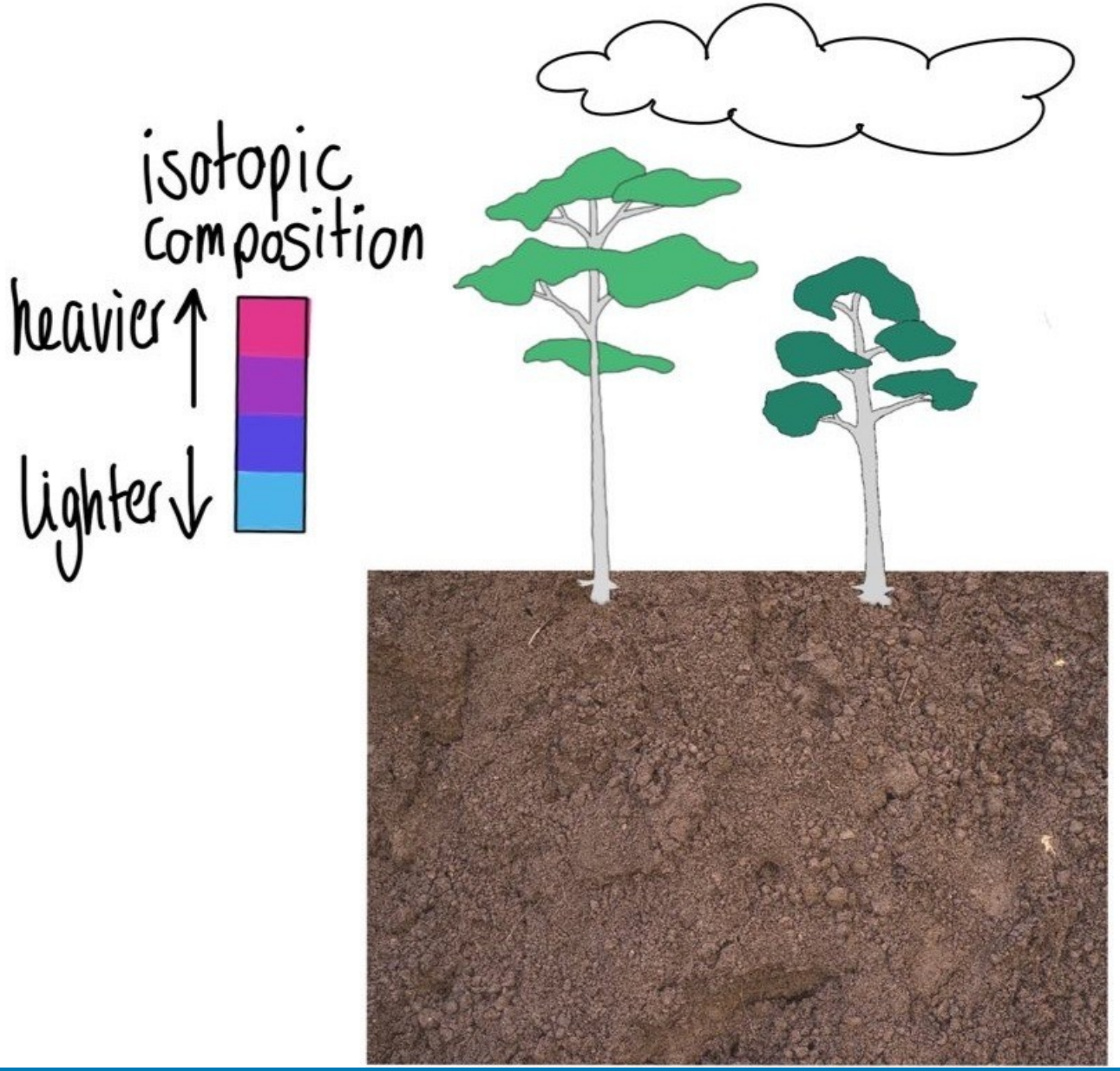

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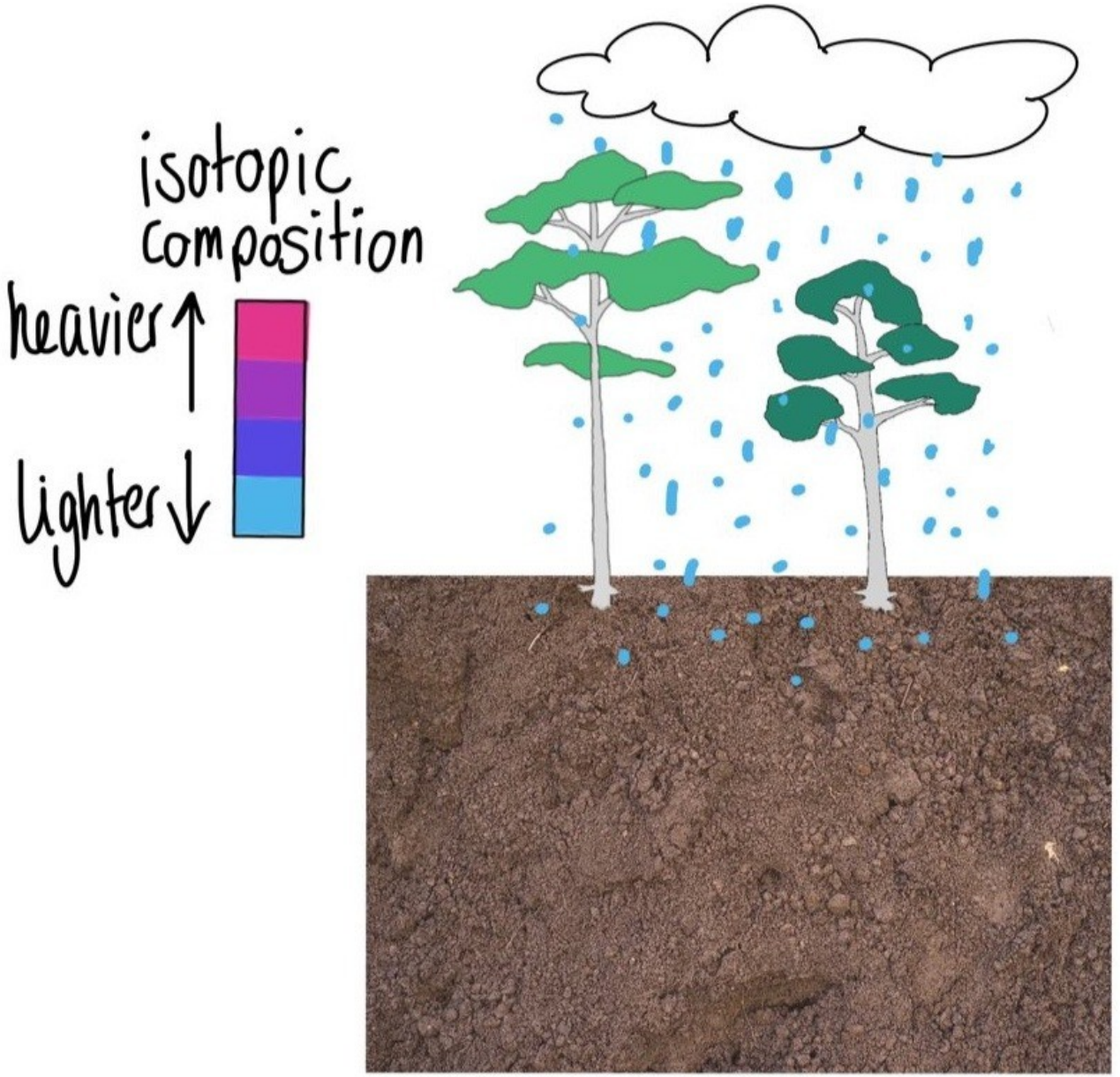

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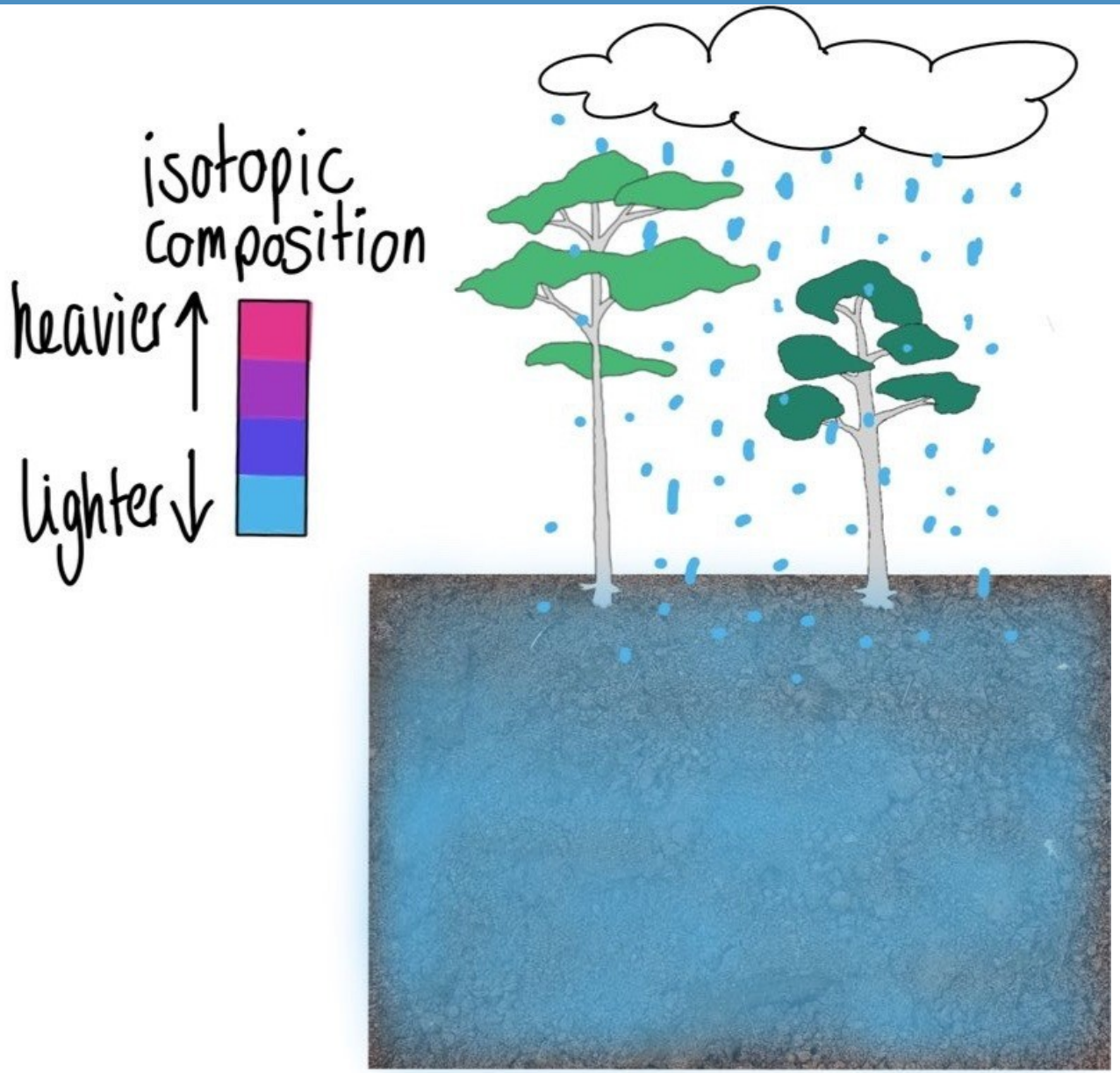

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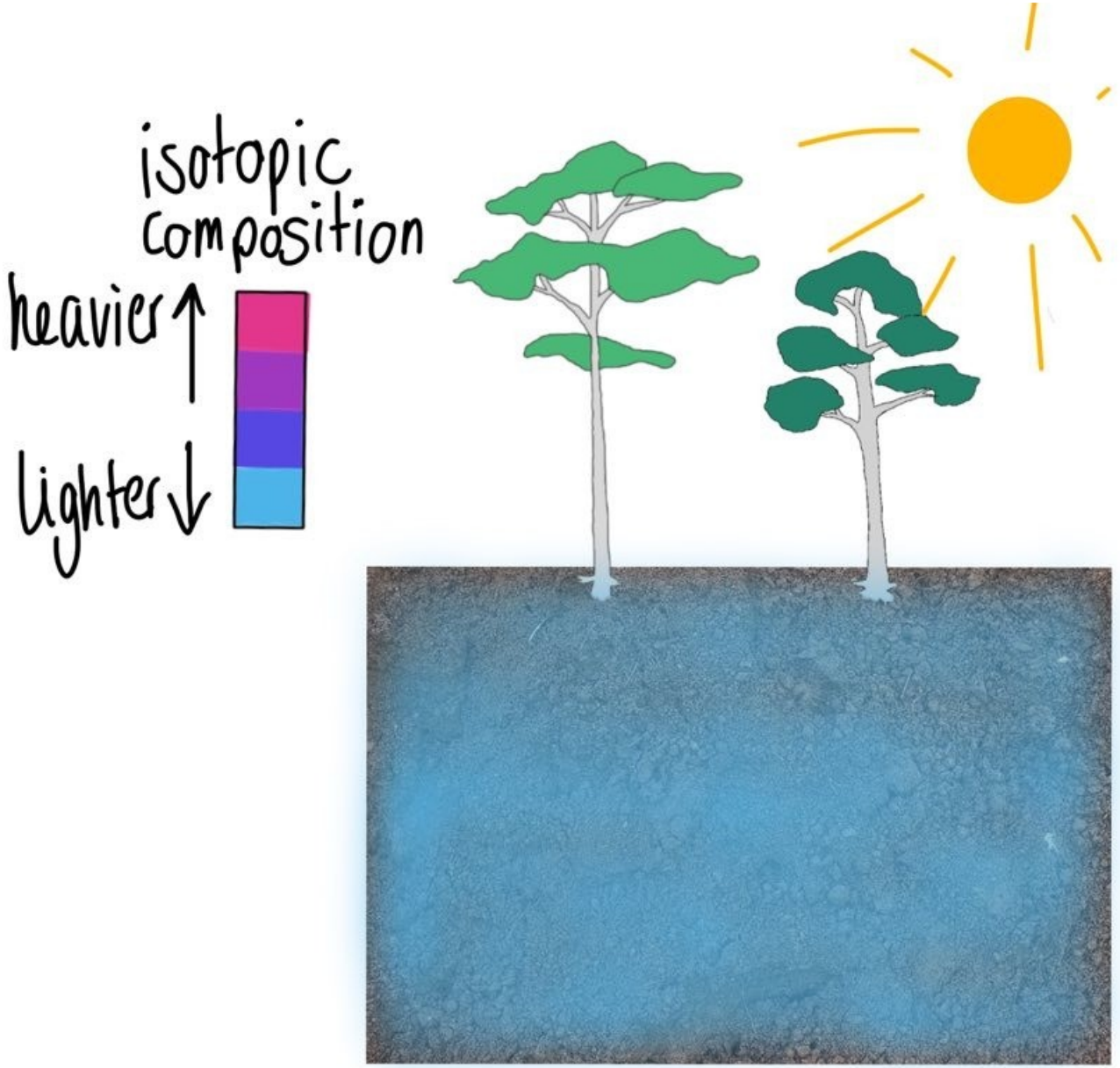

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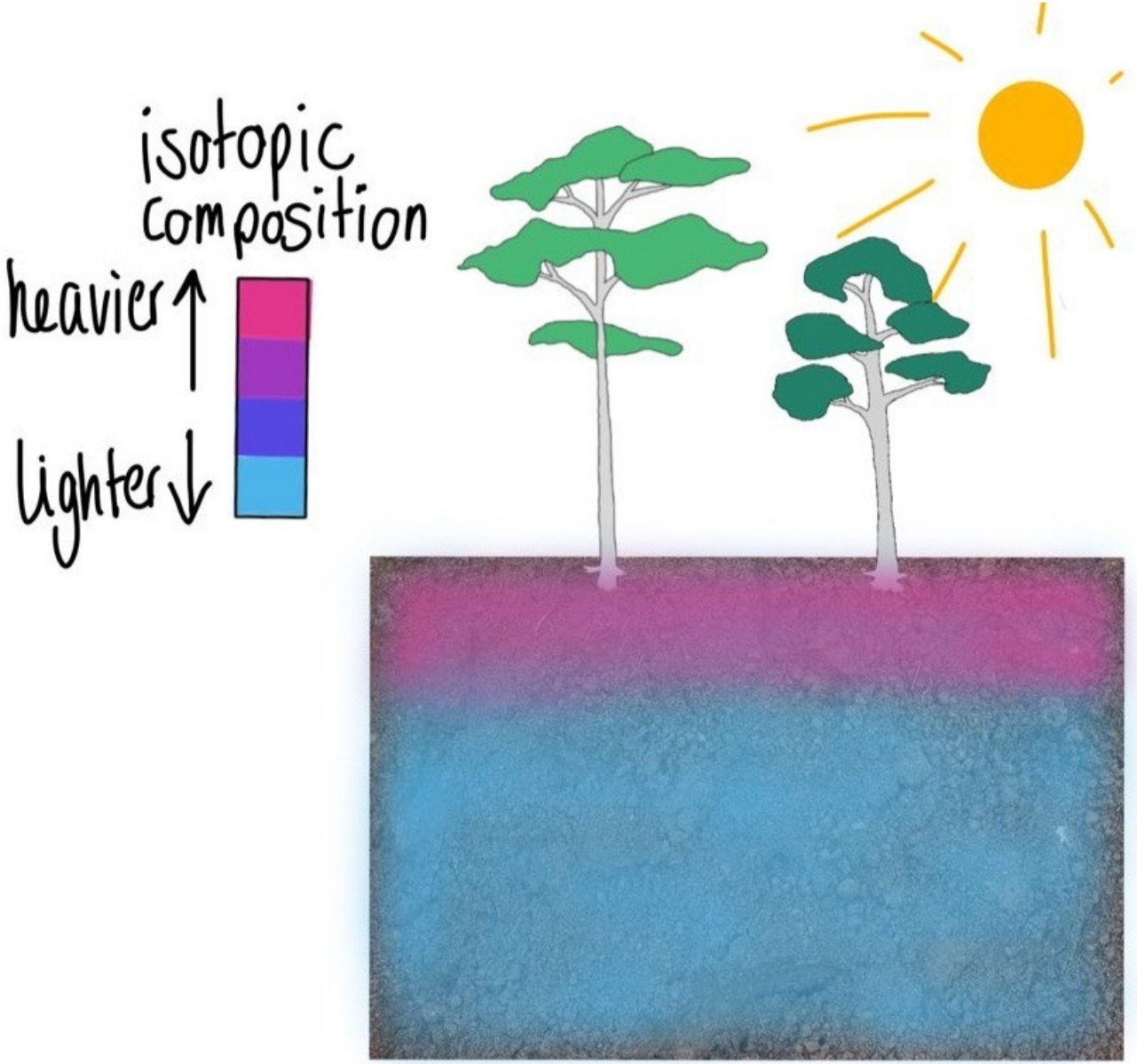

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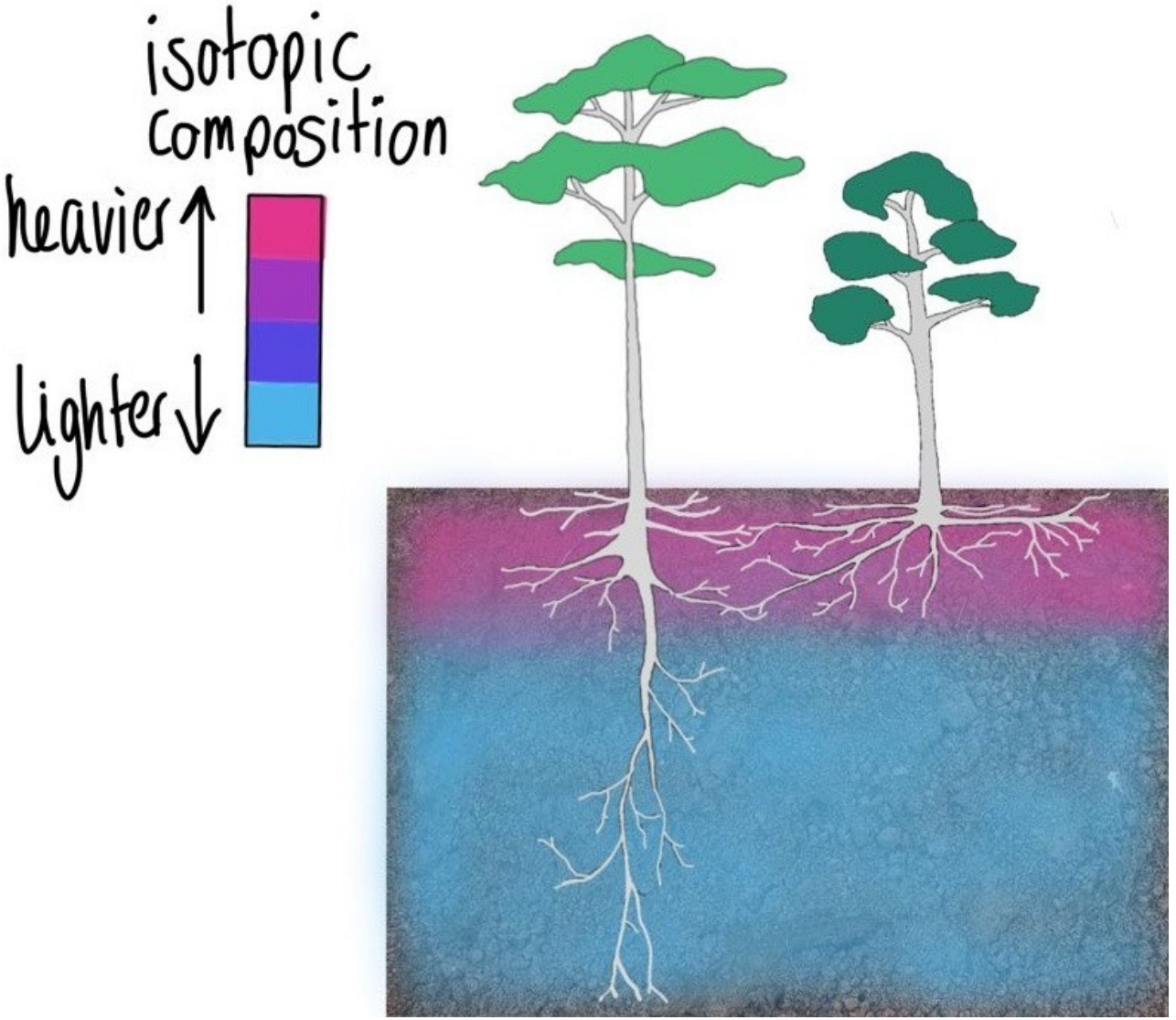

The tree xylem water reflects the isotopic composition of all water taken up from the ground.

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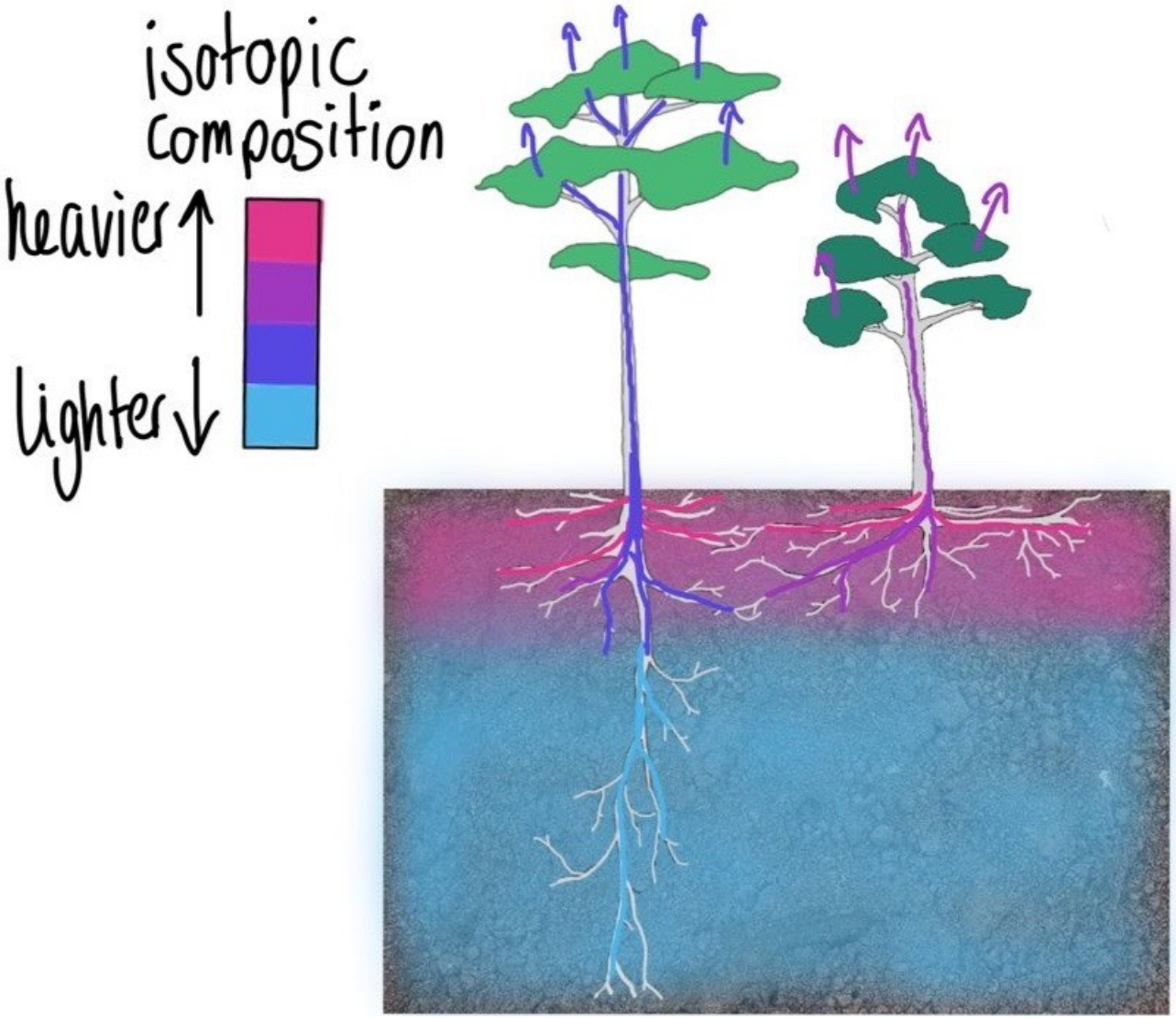

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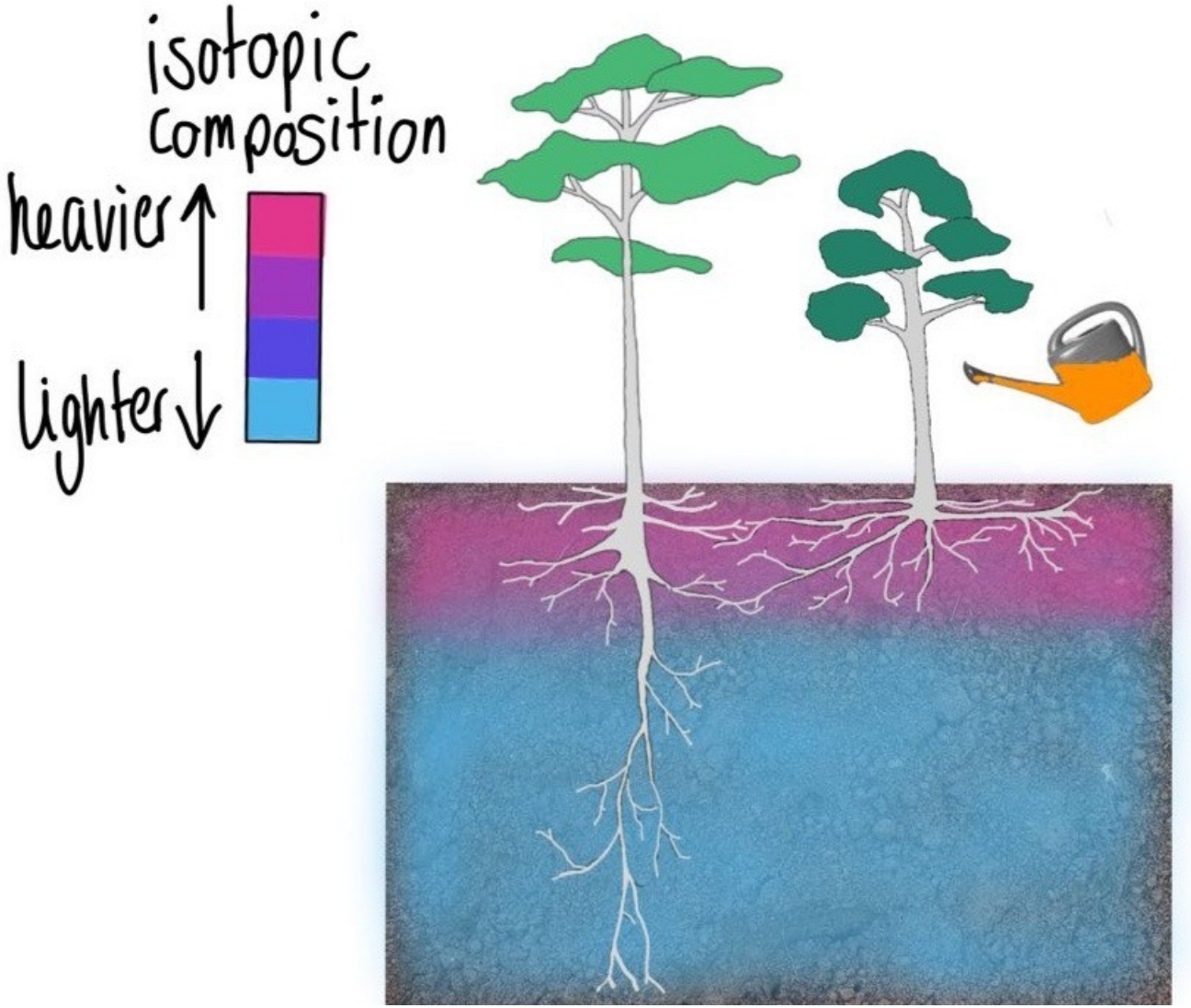

Often labeled water (usually enriched in ^{2}H) is applied to enhance or alter natural differences in the soil water isotopic composition.

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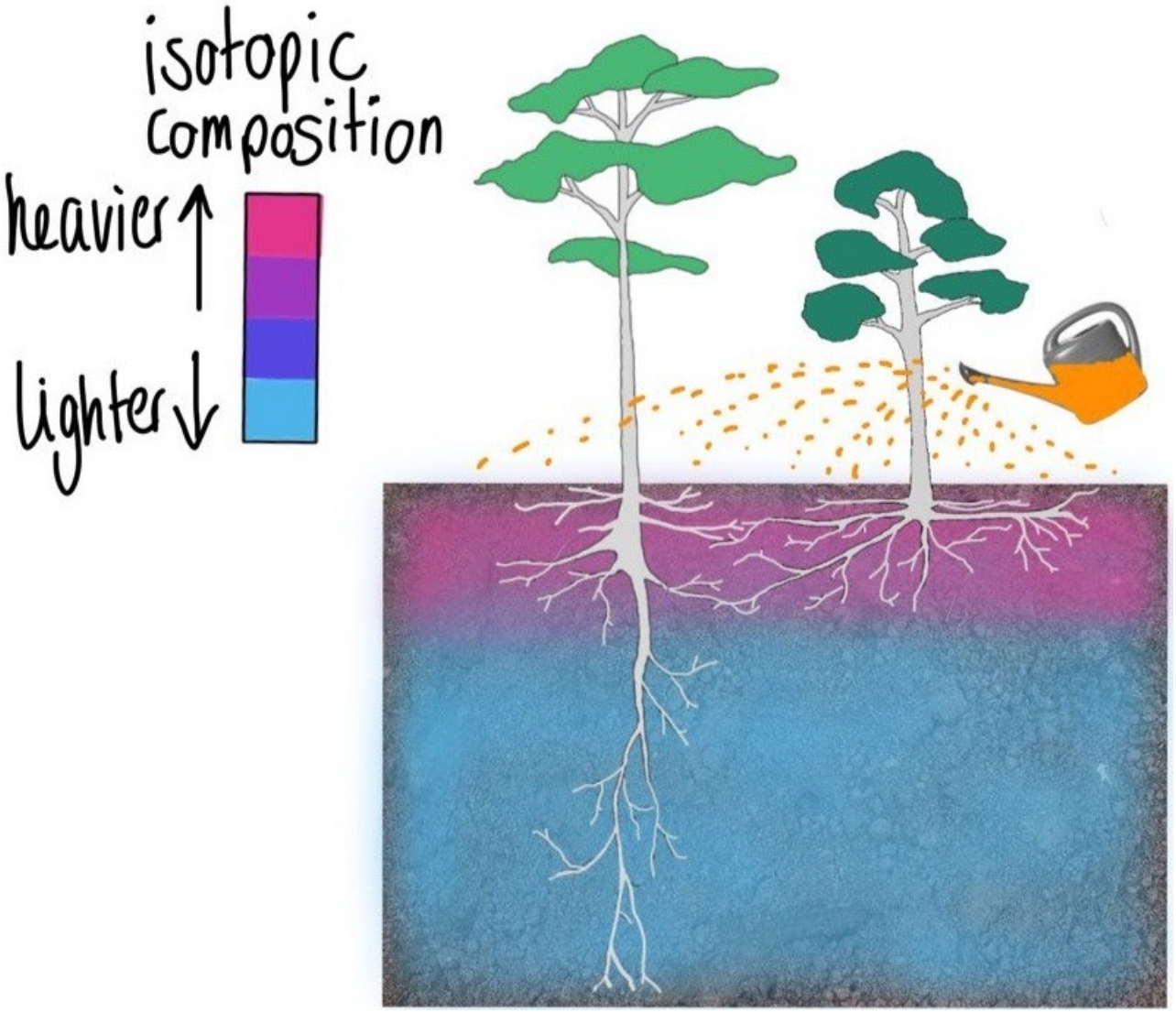

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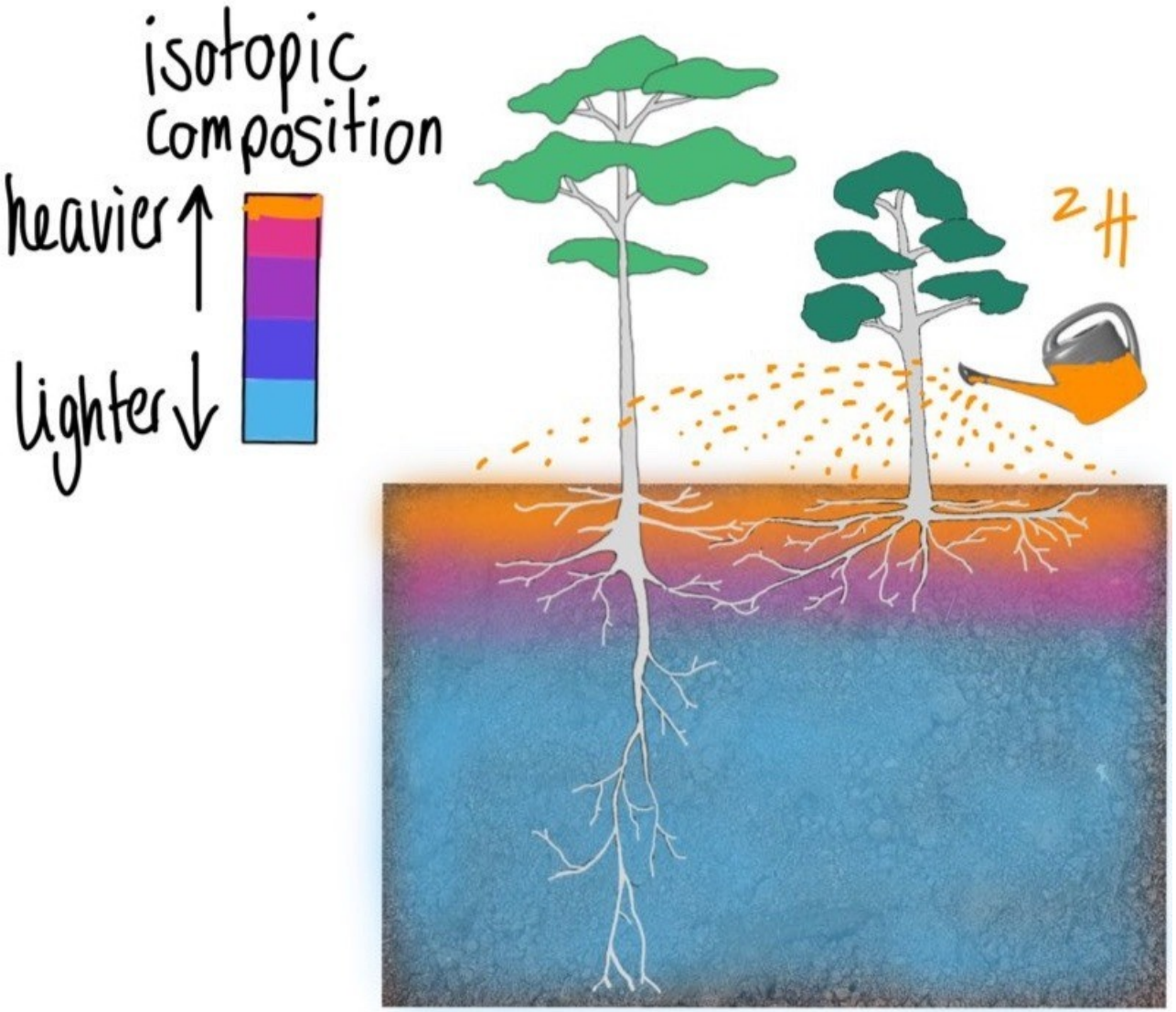

However, in the field it is not possible to label deep soil water homogeneously.

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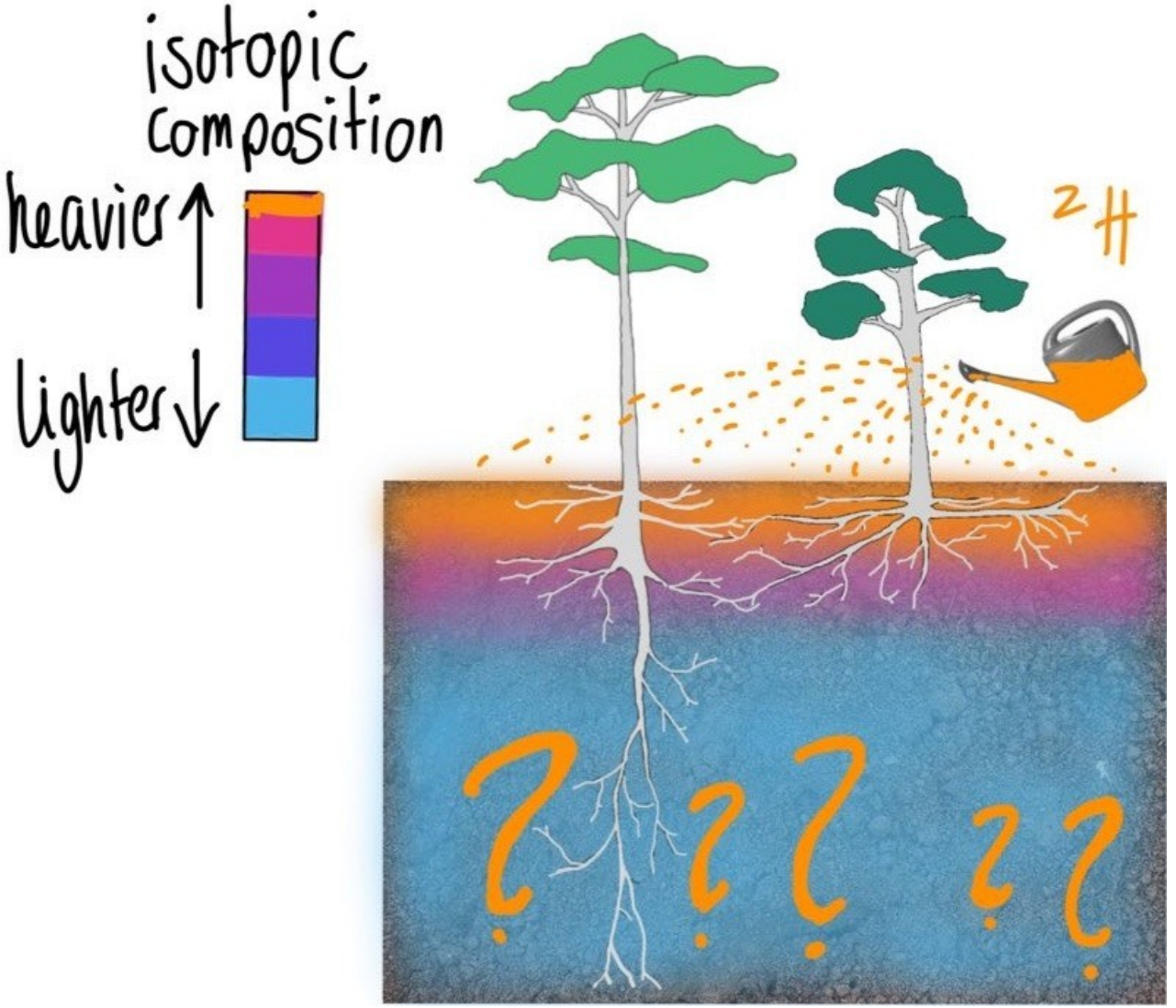
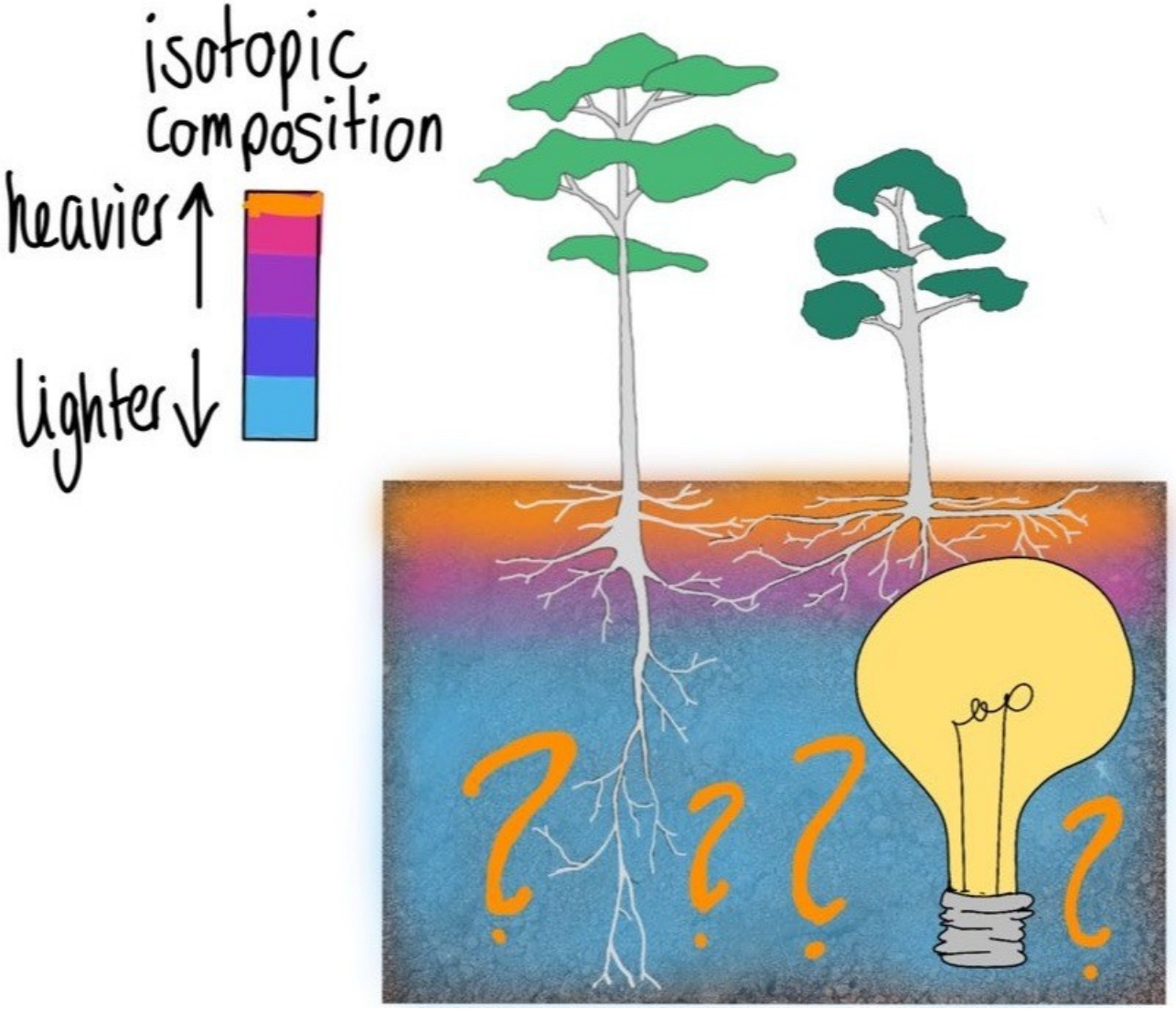


However, in the field it is not possible to label deep soil water homogeneously.

Hence, deep roots, their depth, occurrence and contribution to root water uptake over time are not well studied and knowledge gaps persist.

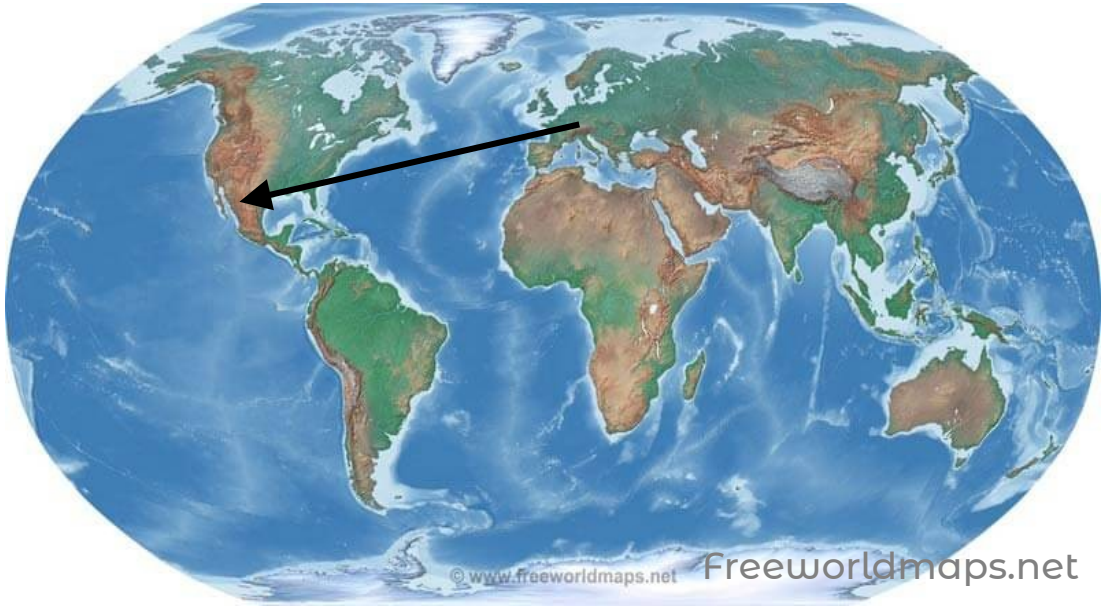
Introduction

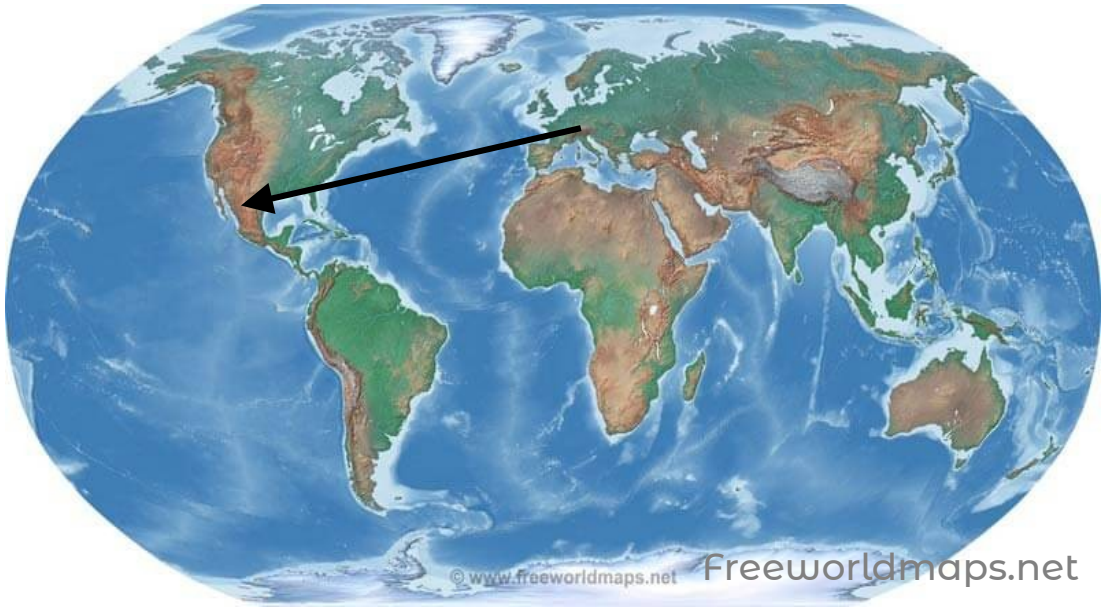
But we had an idea.



We took part in an interdisciplinary drought experiment at Biosphere 2.

There we had the unique opportunity to label soil water in about 3 m depth homogeneously using drainage pipes.
We inserted the label at peak drought and followed changes in tree water isotopic composition and amount thereafter. We also observed changes in response to the onset of precipitation 10 days after labelling.

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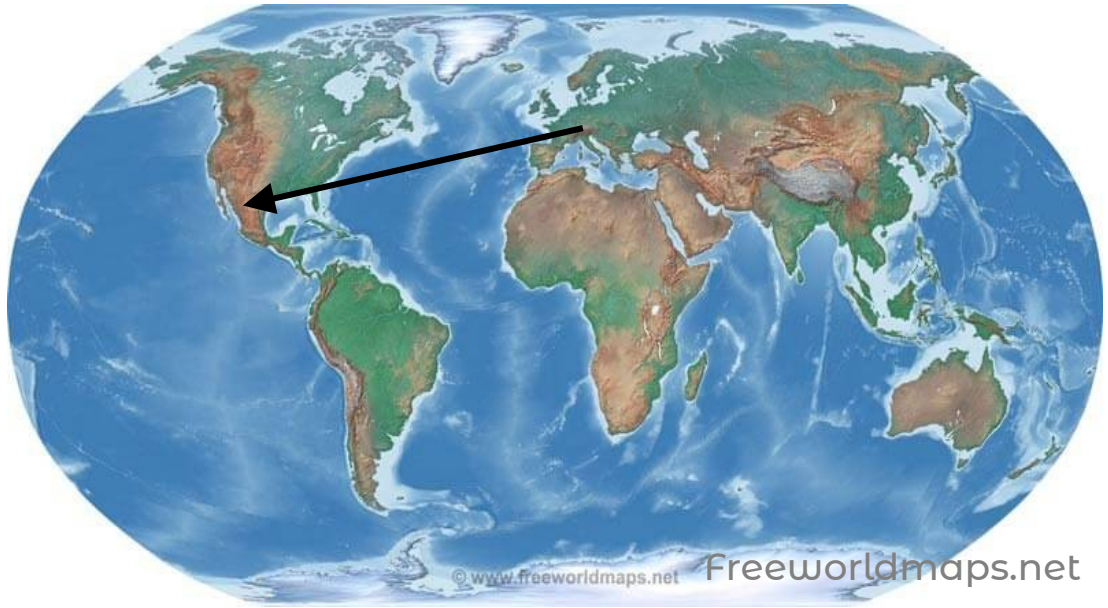
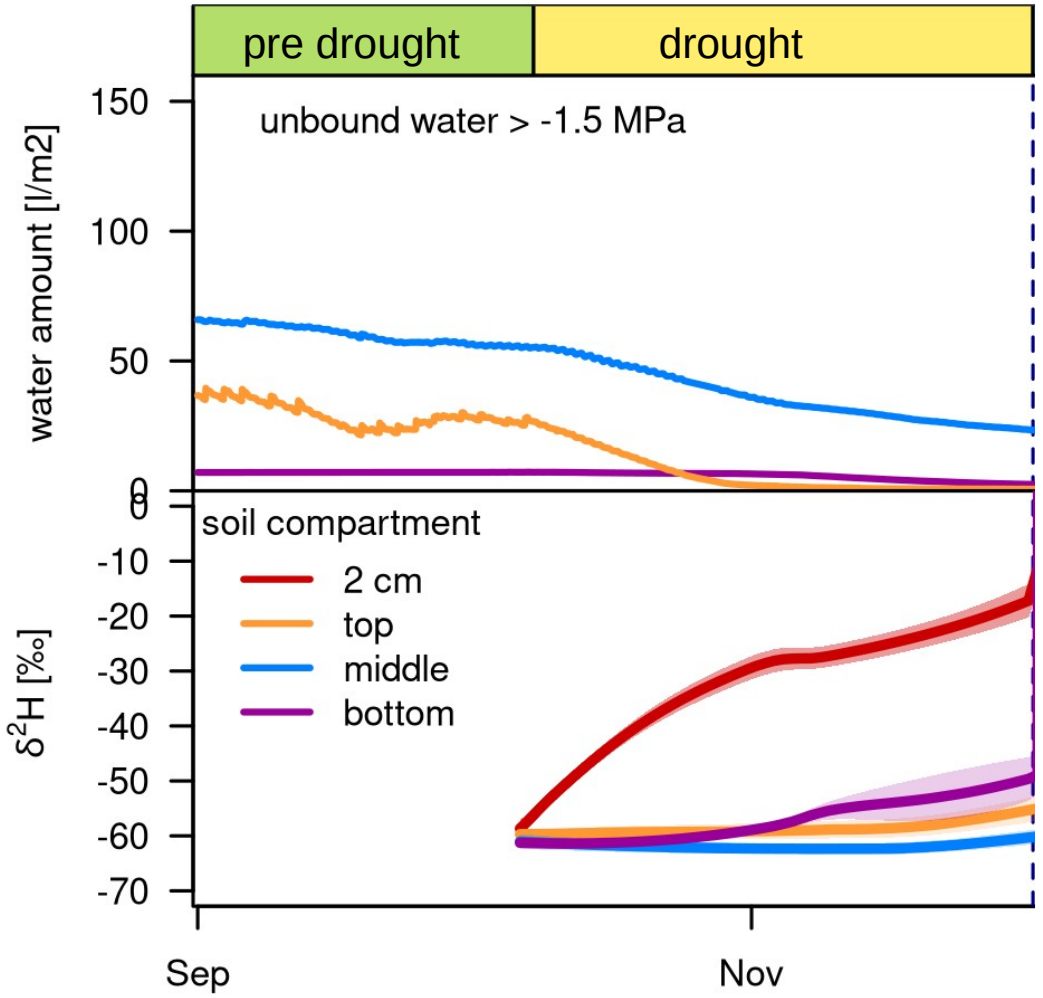
This pyramid glasshouse contains a tropical rainforest



Experimental timeline



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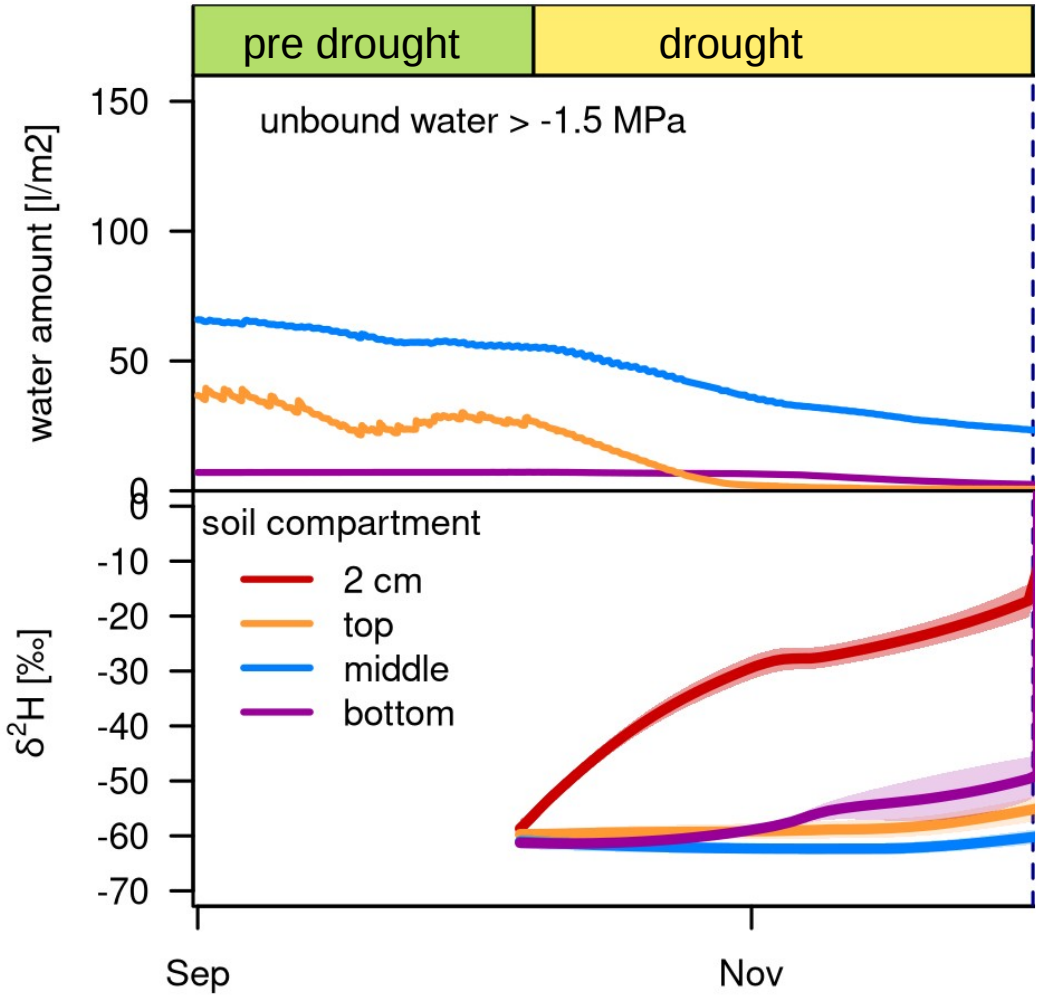
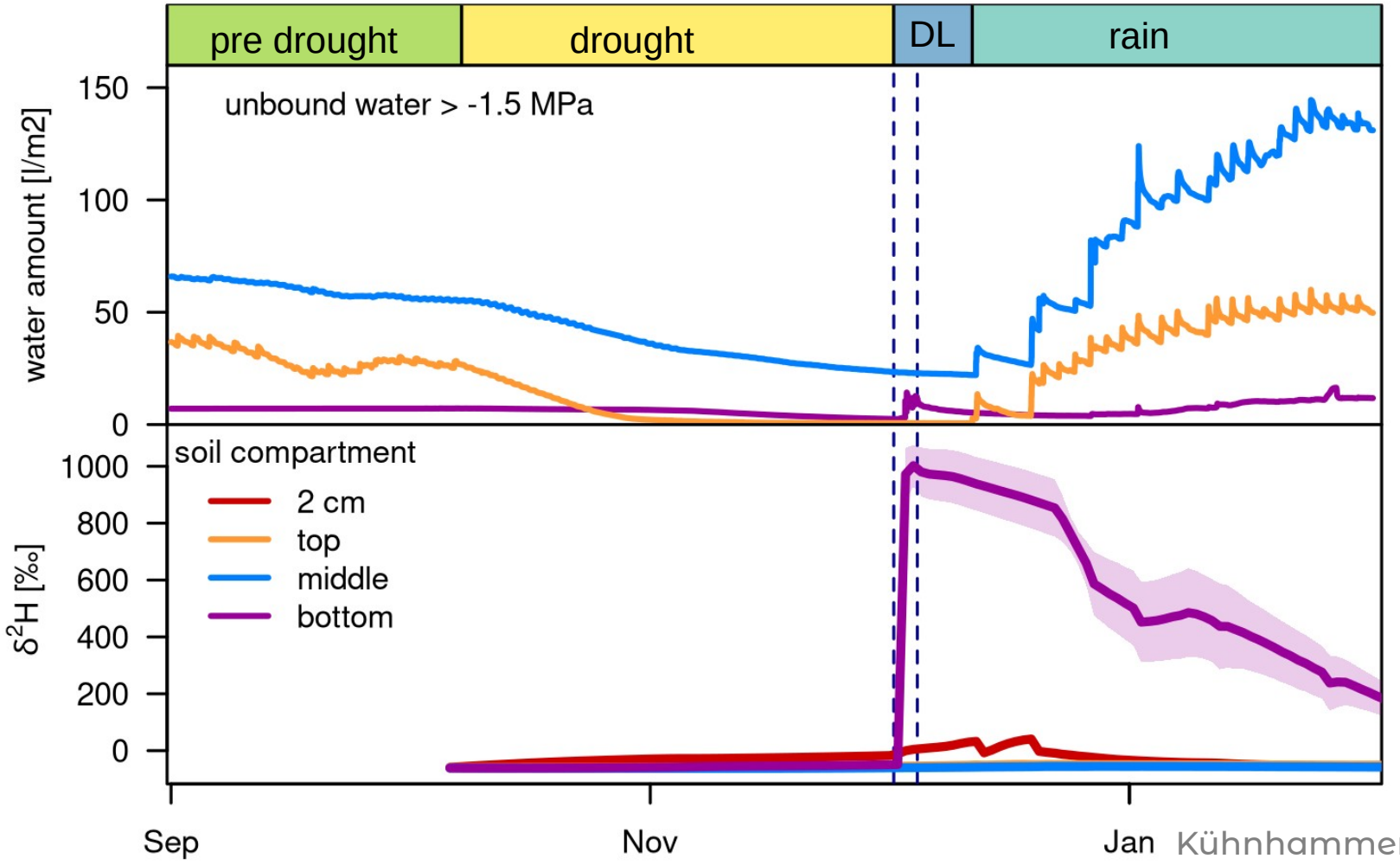
Experimental timeline



Labeling through the drainage pipes

Experimental timeline



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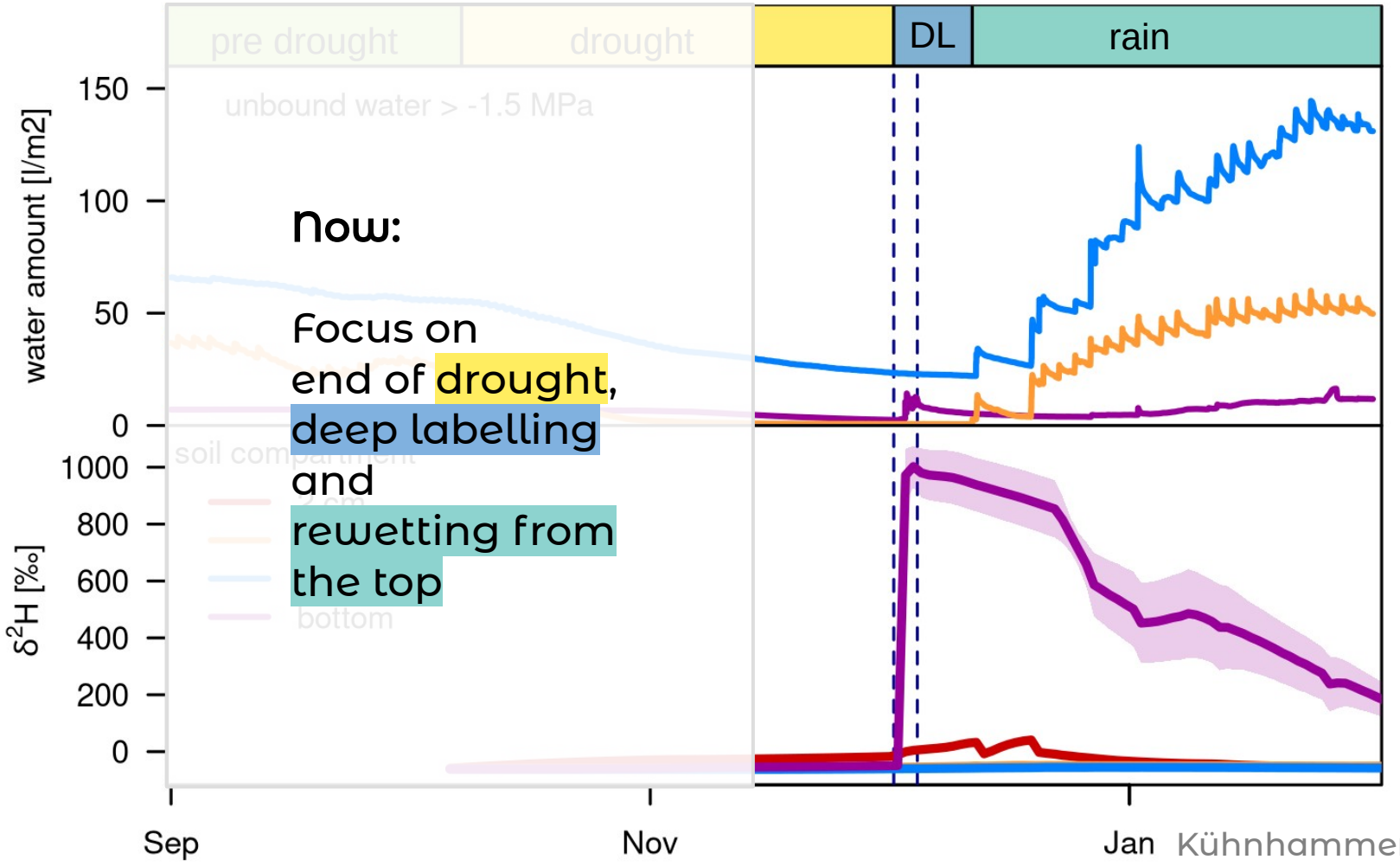
Experimental timeline



Now:

Focus on end of drought, deep labelling and rewetting from the top

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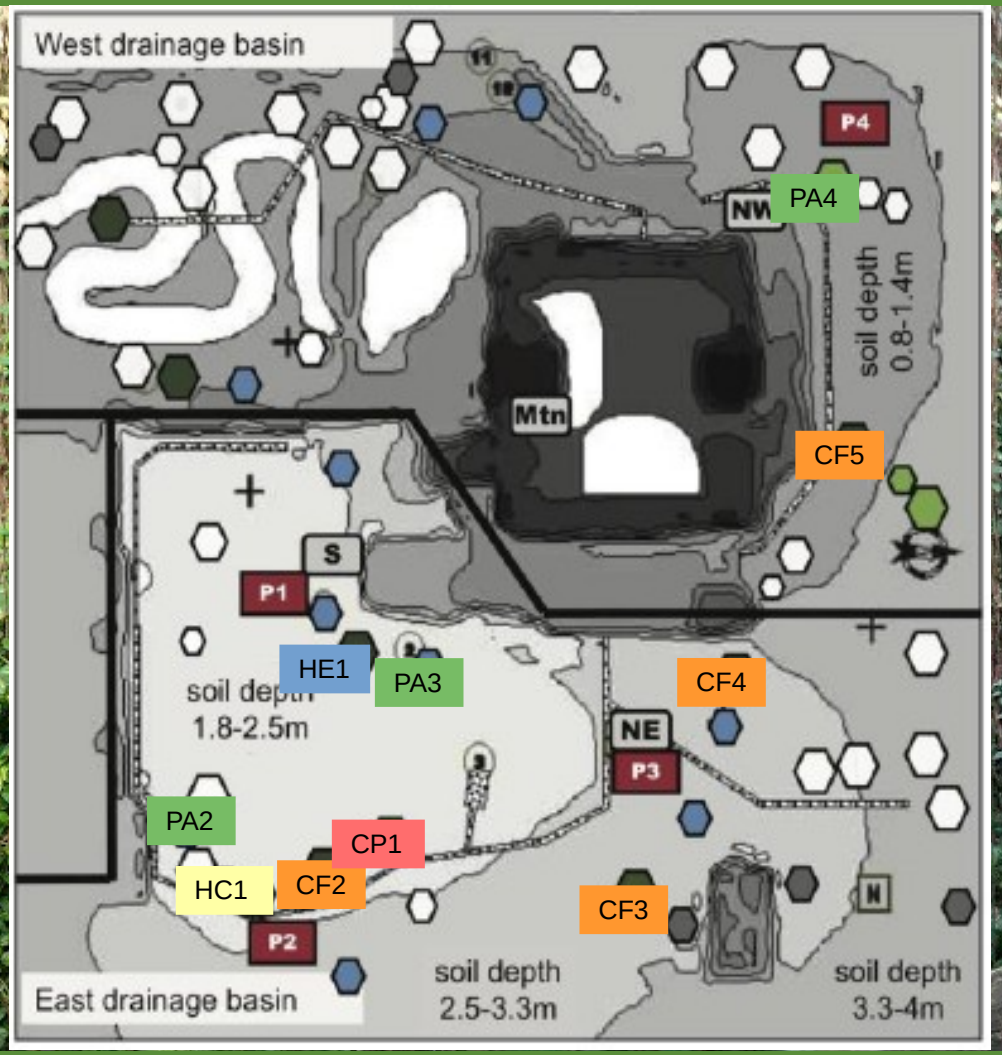
Tree species (10 individuals)

- CF: Clitoria fairchildiana (4x)
- CP: Ceiba pentandra (1x)
- HT: Hibiscus tilliaceous (1x)
- HC: Hura crepitans (1x)
- PA: Pachira aquatica (3x)

measurements

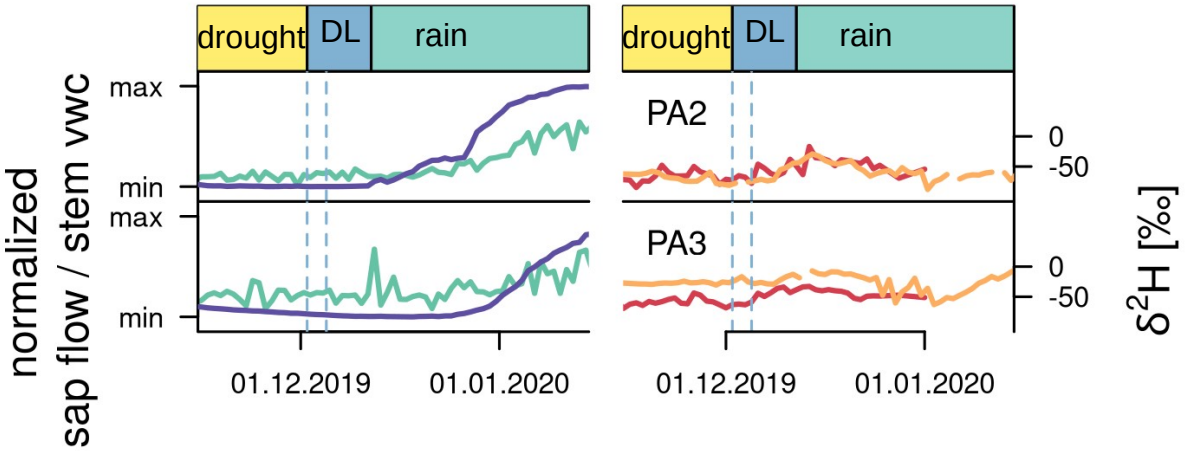
- Sap flow
- Stem water content
- Water stable isotopes in tree trunks and transpiration (in situ)

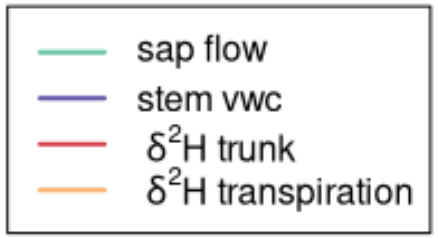


Tree deep water usage

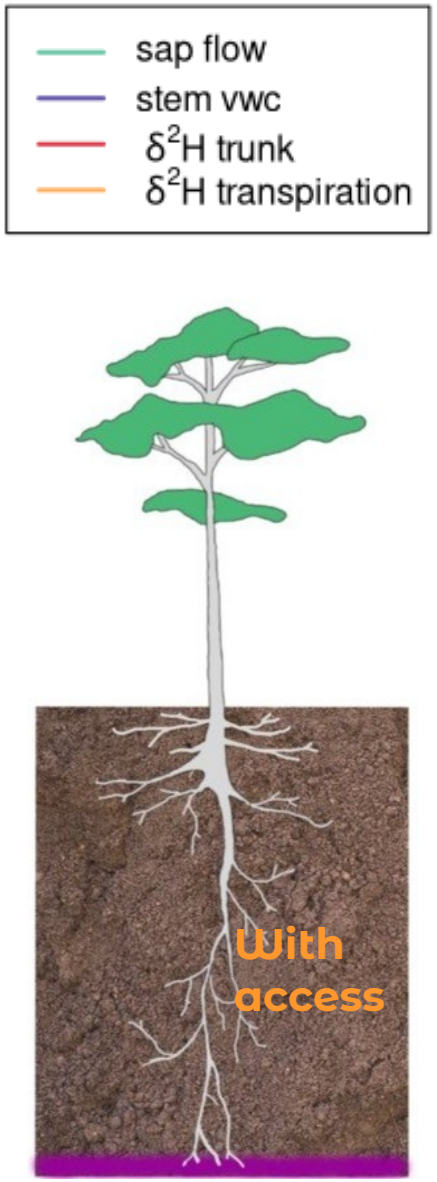
sap flow
stem vwc
δ^2H trunk
δ^2H transpiration

Tree deep water usage

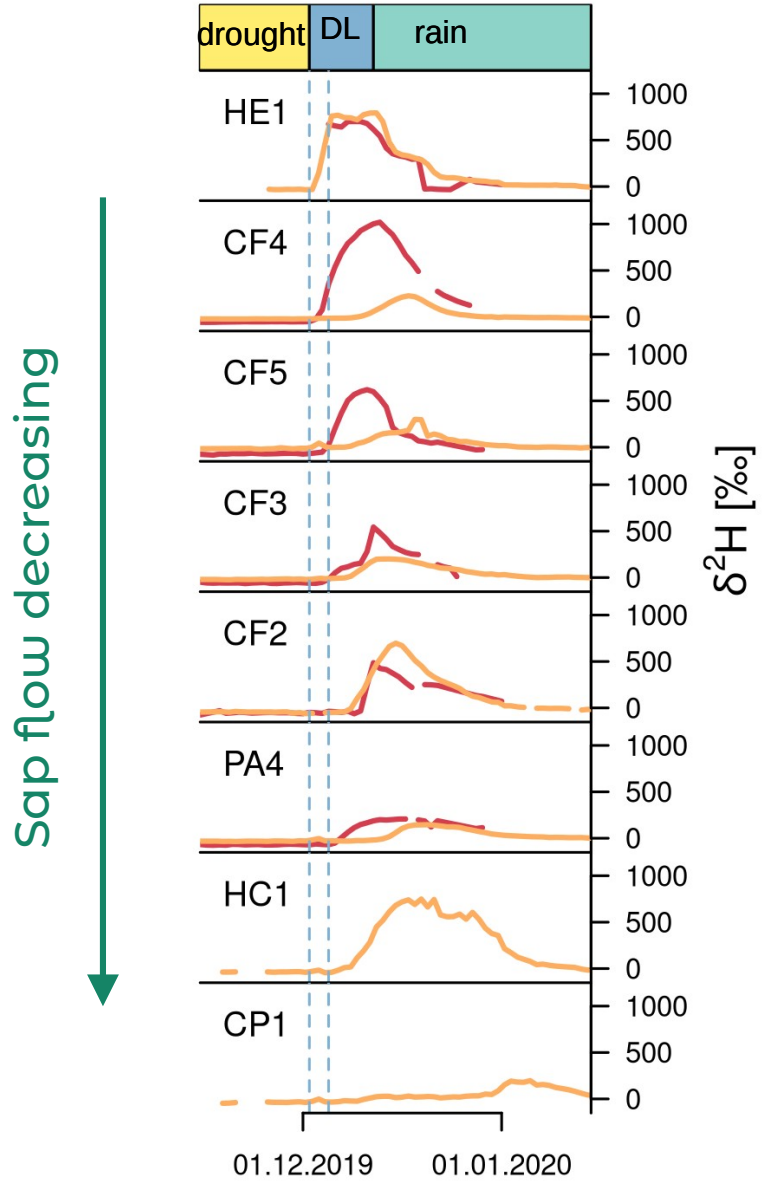


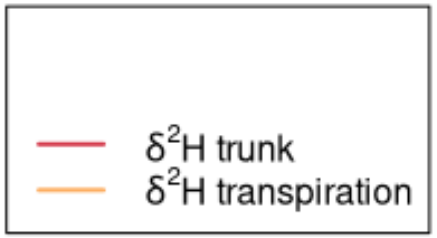


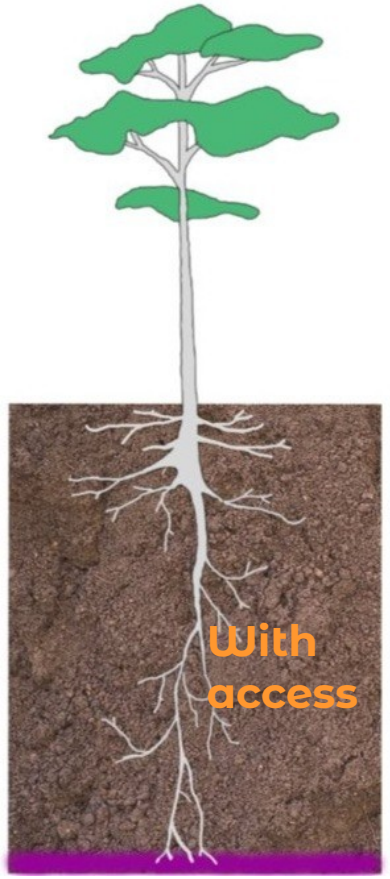
Tree deep water usage



Tree deep water usage







Different temporal dynamics and degree of mixing

How did they use deep water source?

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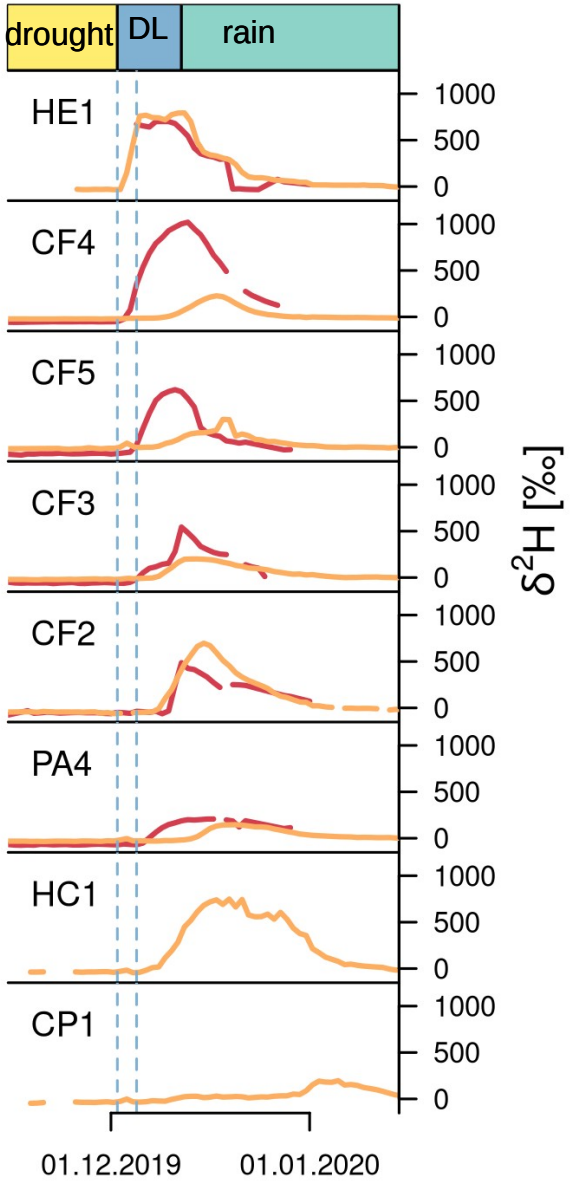
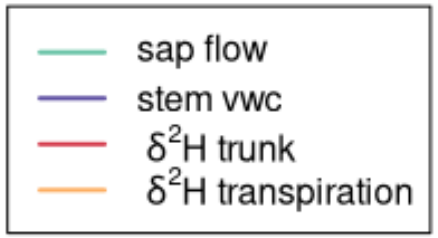
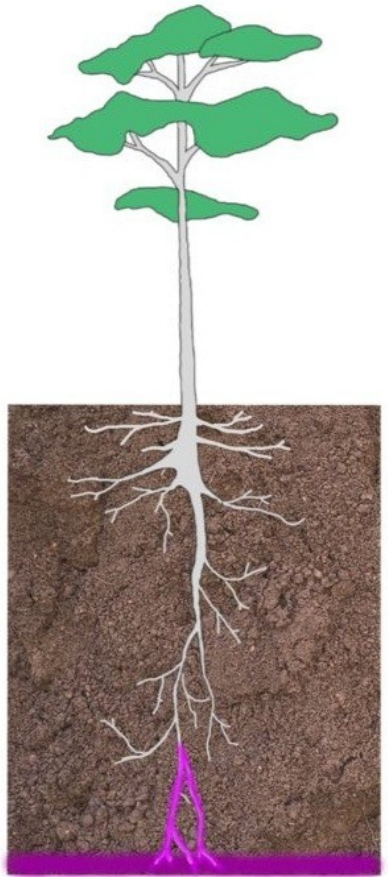
Tree deep water usage







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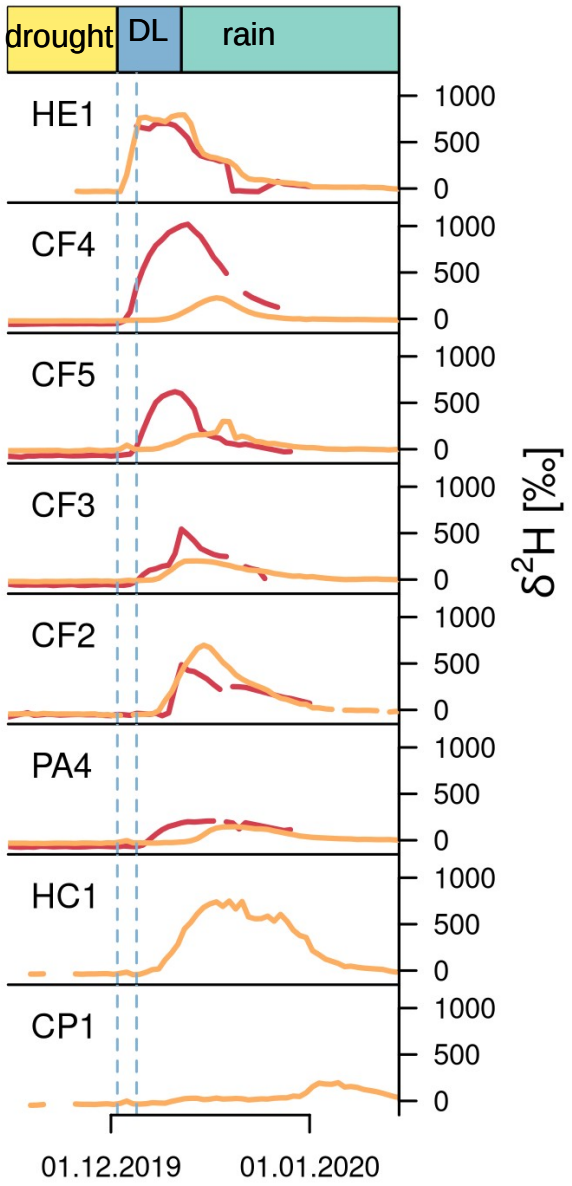
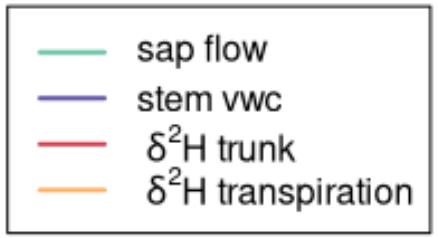
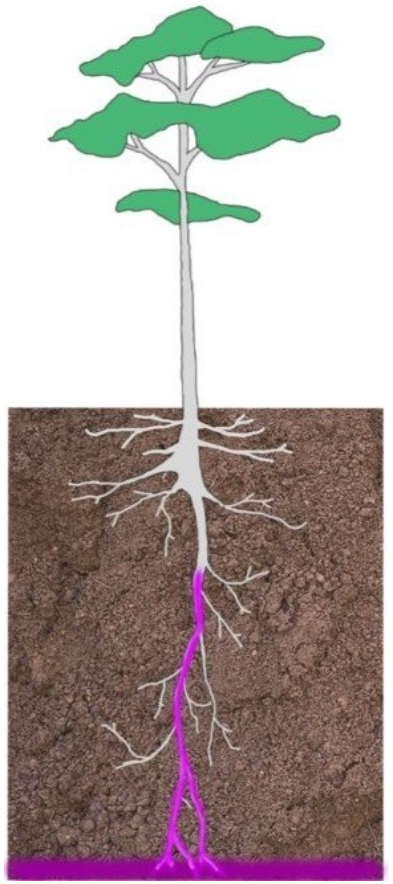
Tree deep water usage







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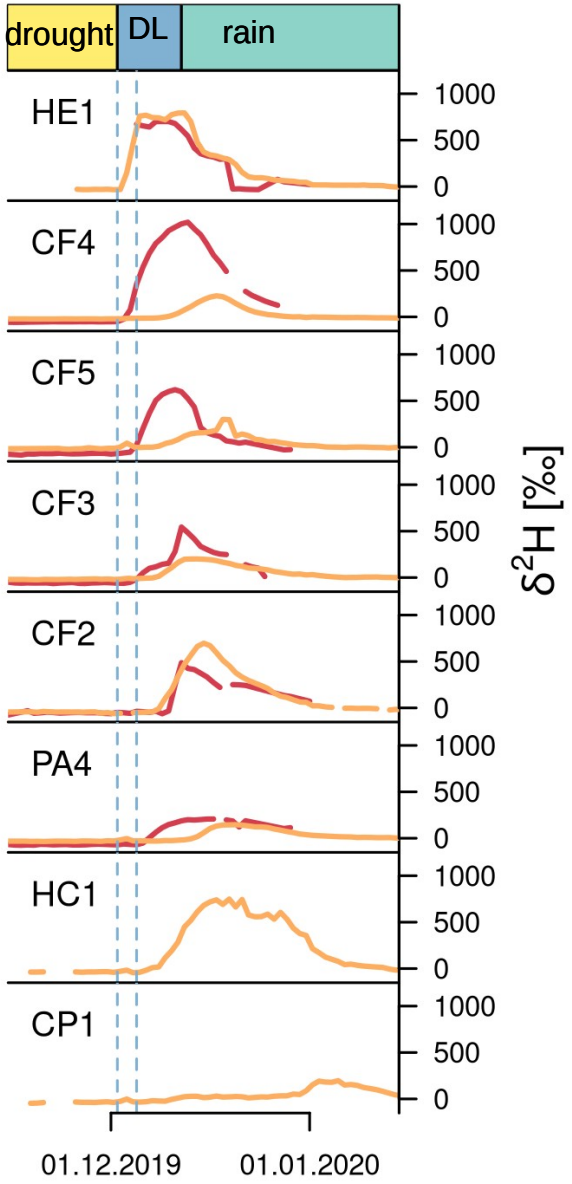

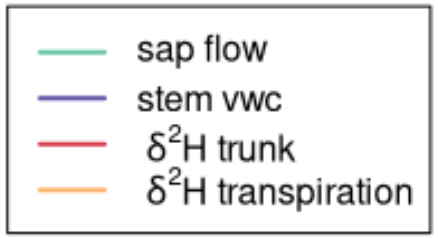

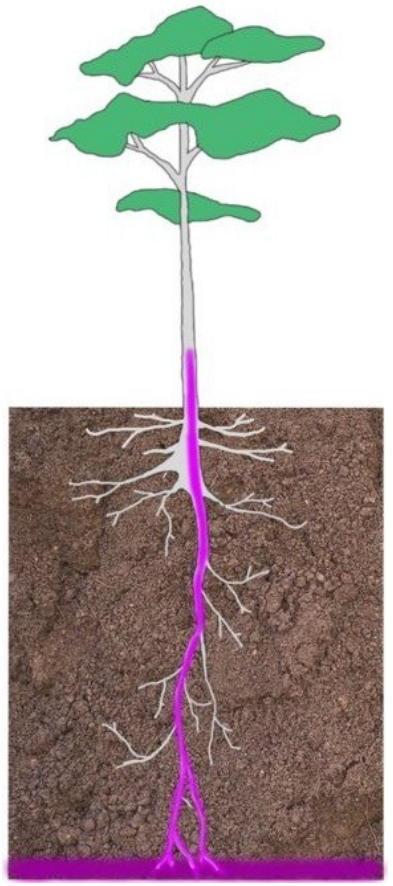

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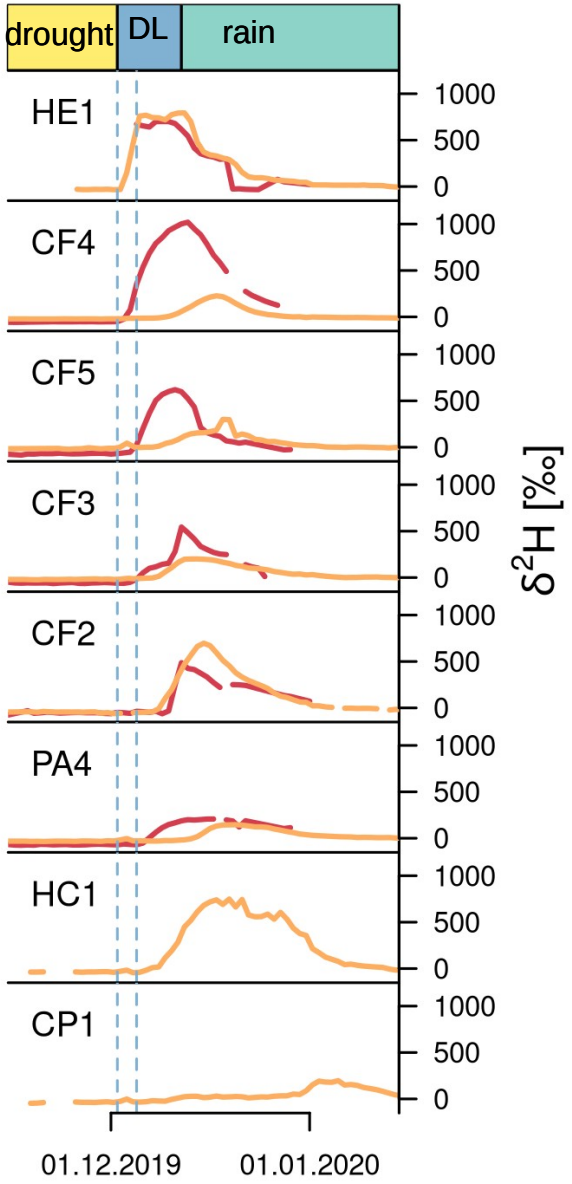

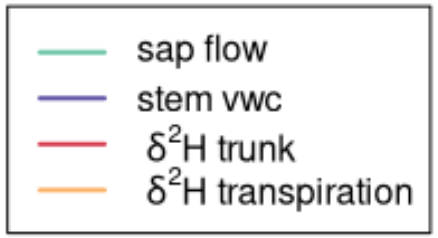

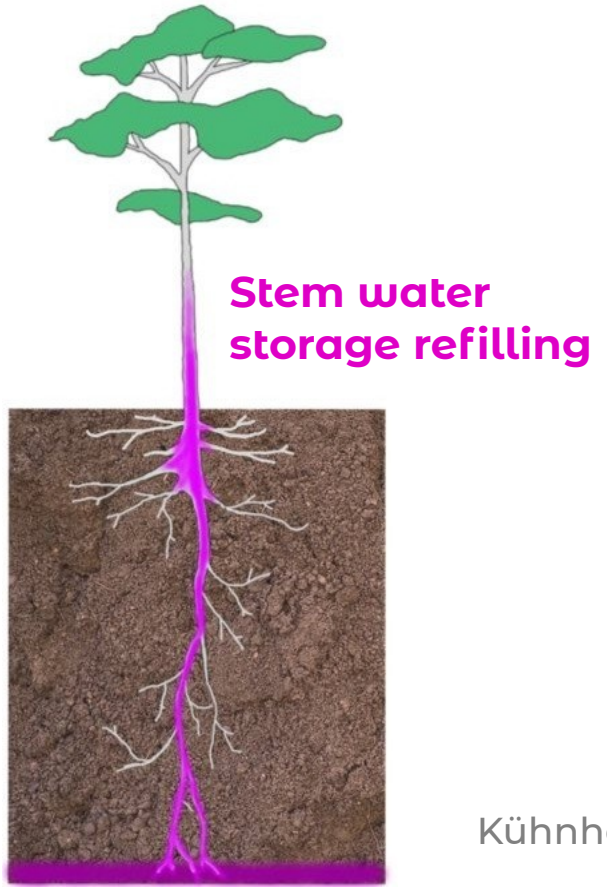

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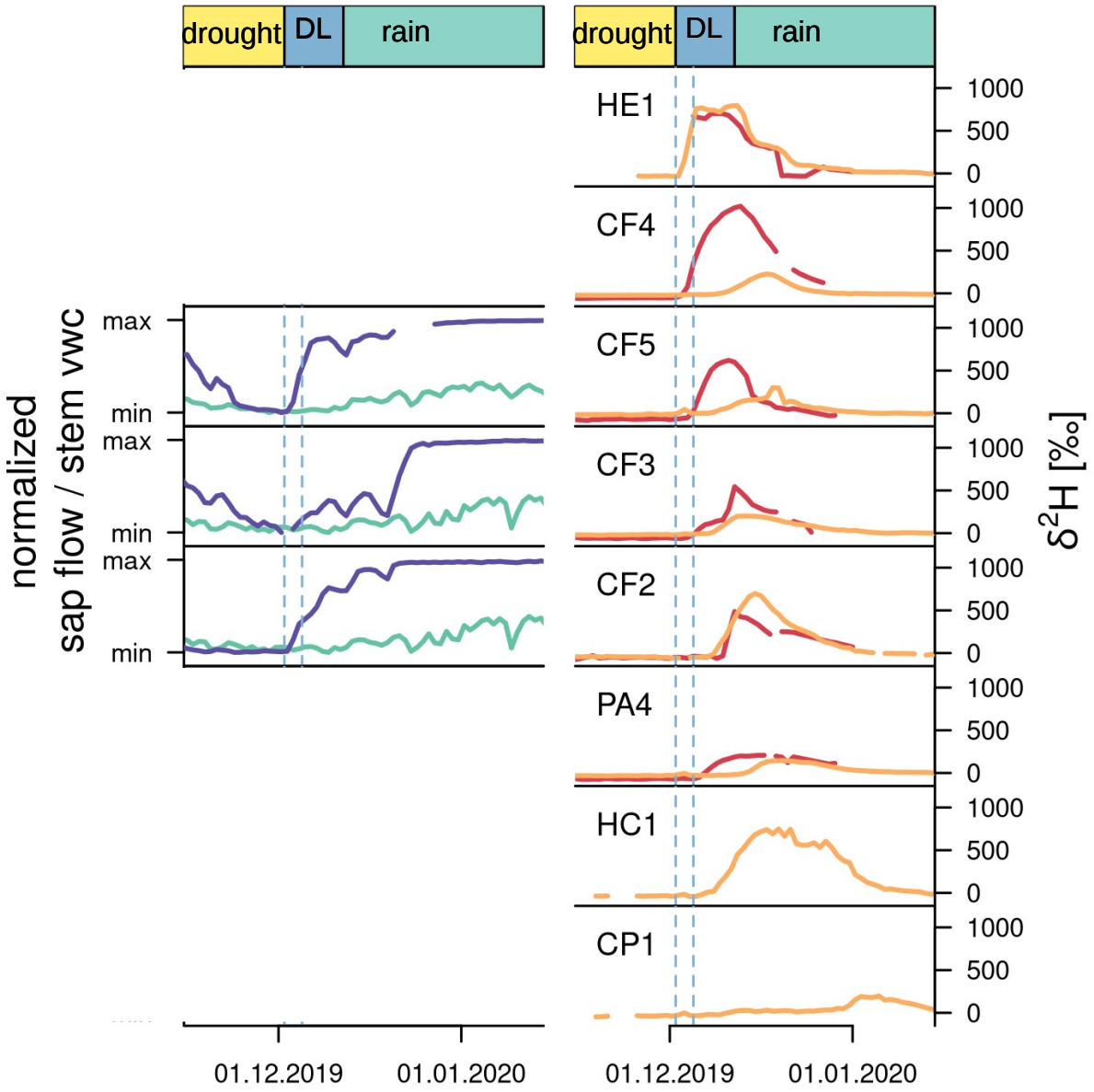

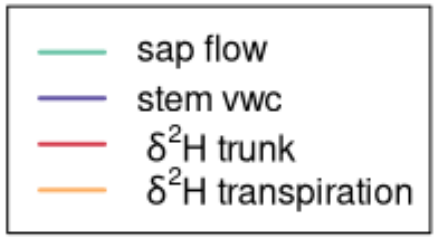

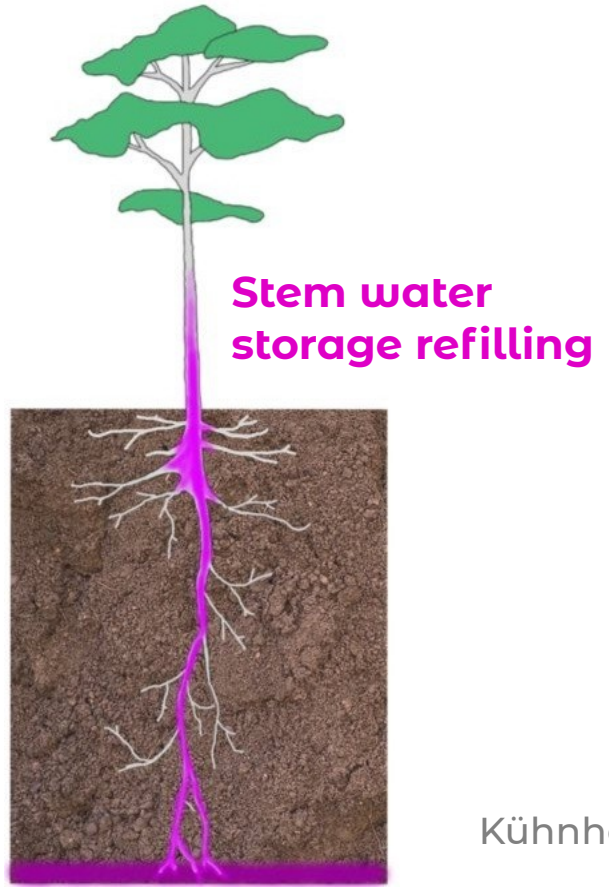

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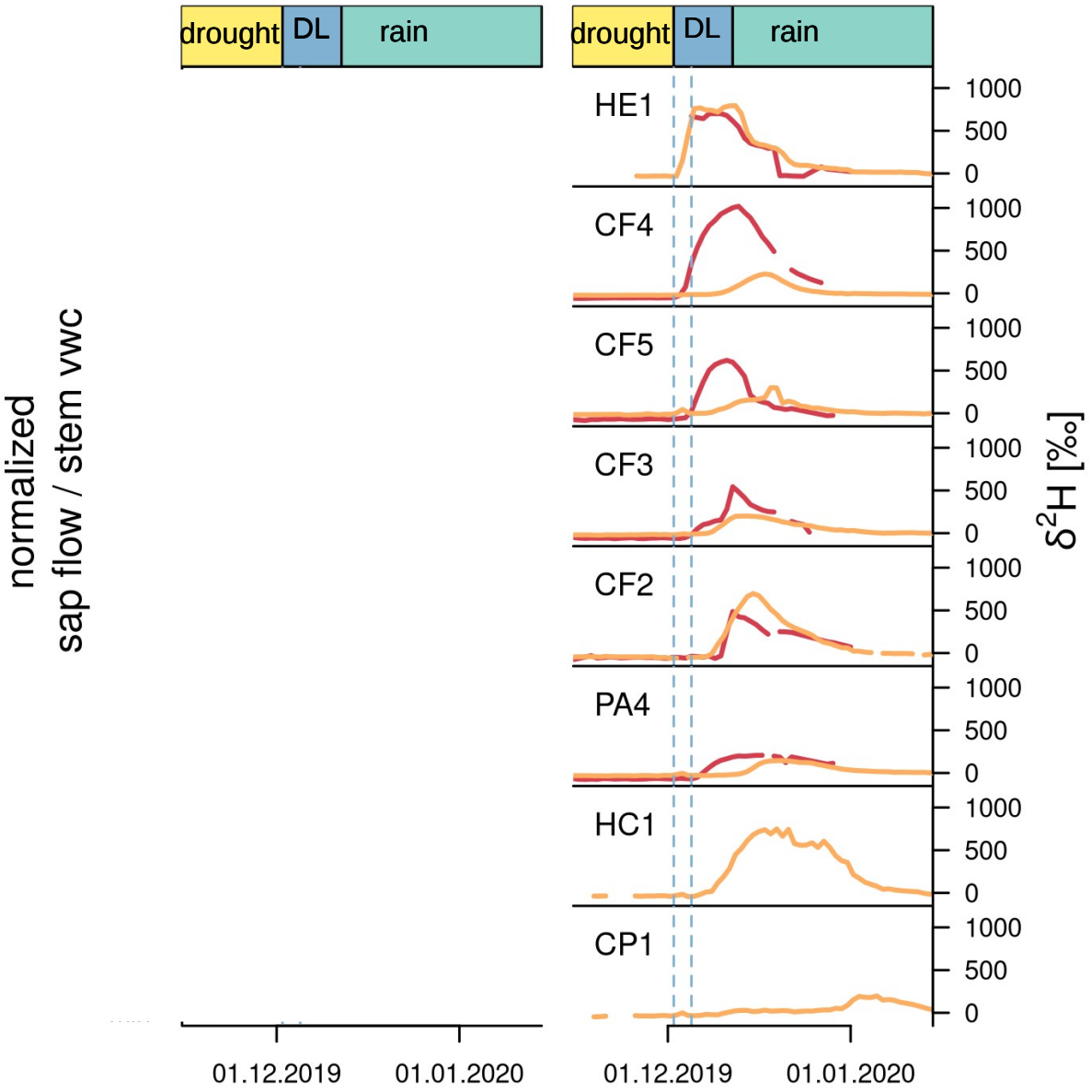

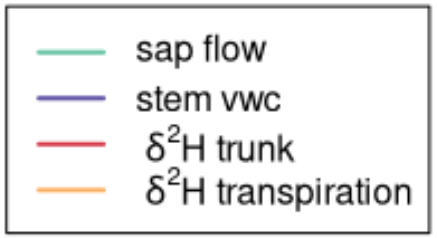

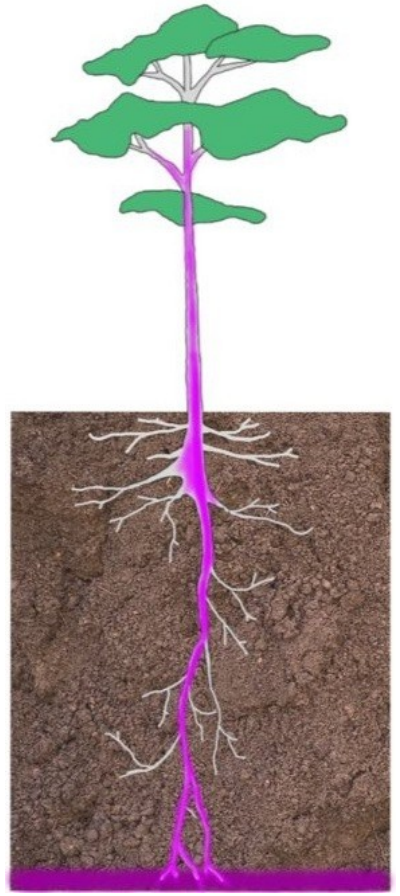

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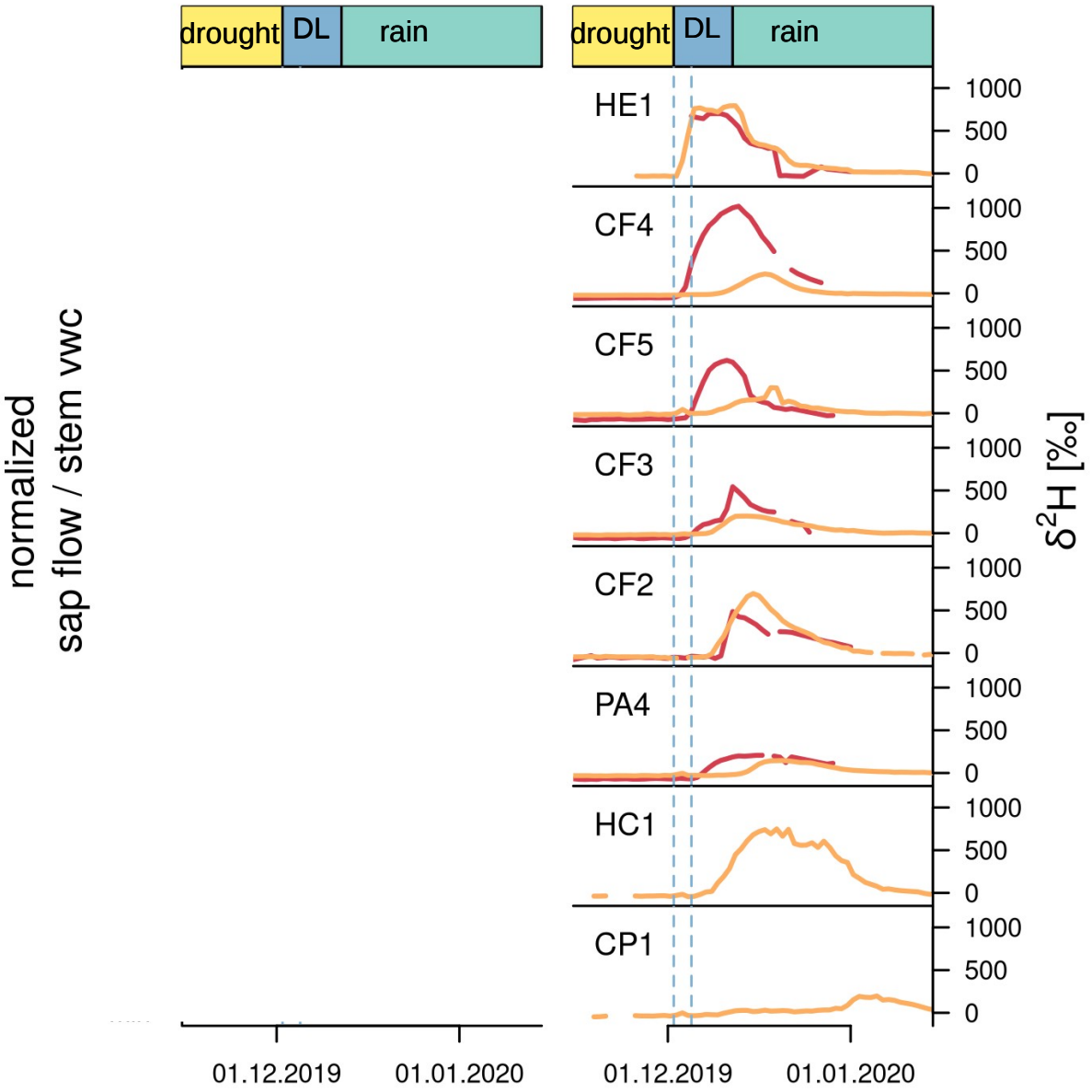
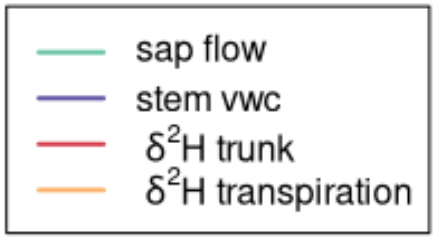
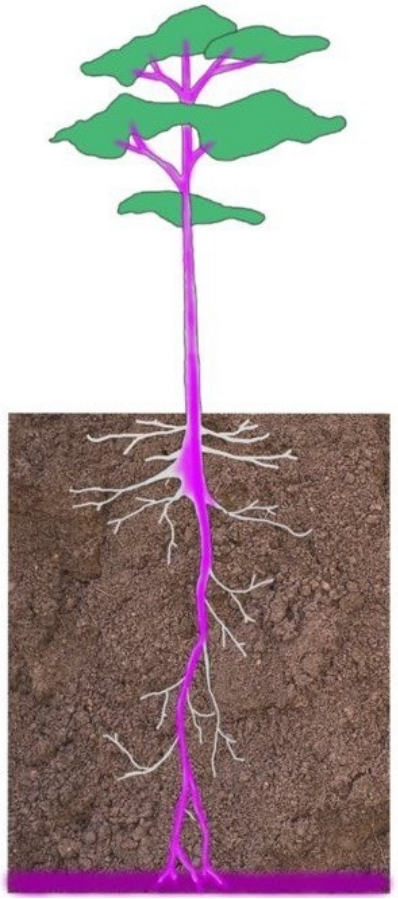
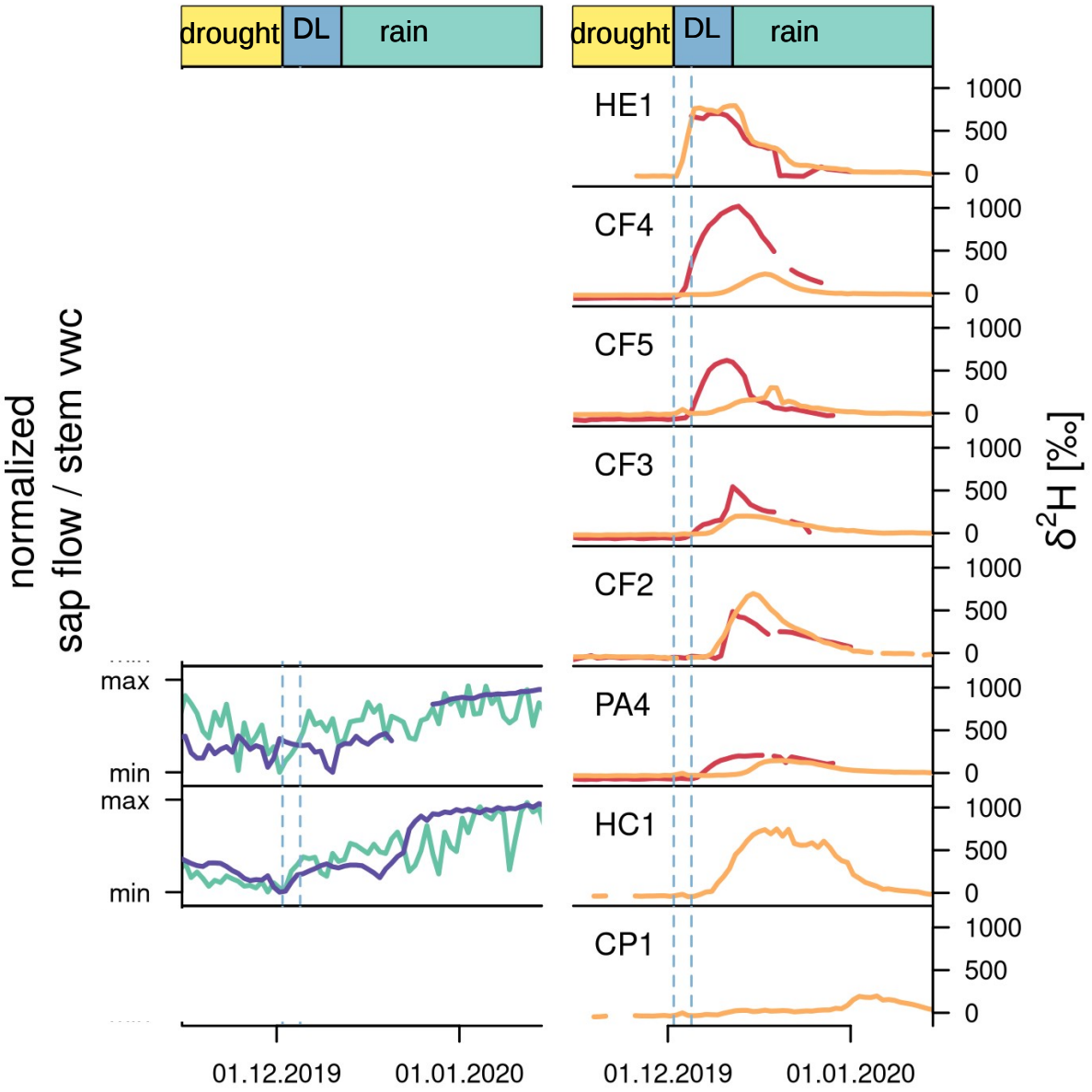


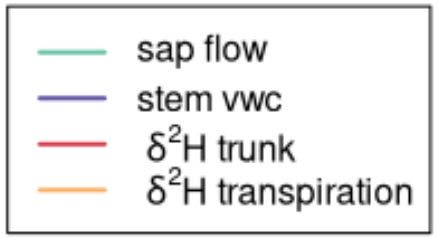


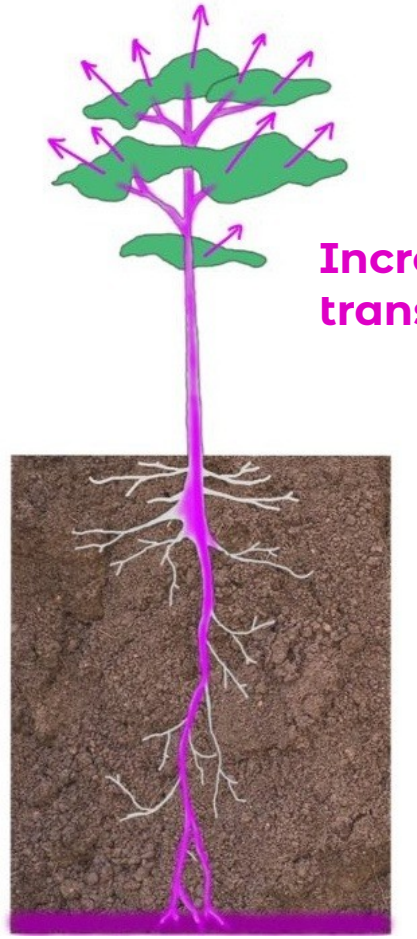


Kühnhammer et al (2022, in preparation)

Tree deep water usage



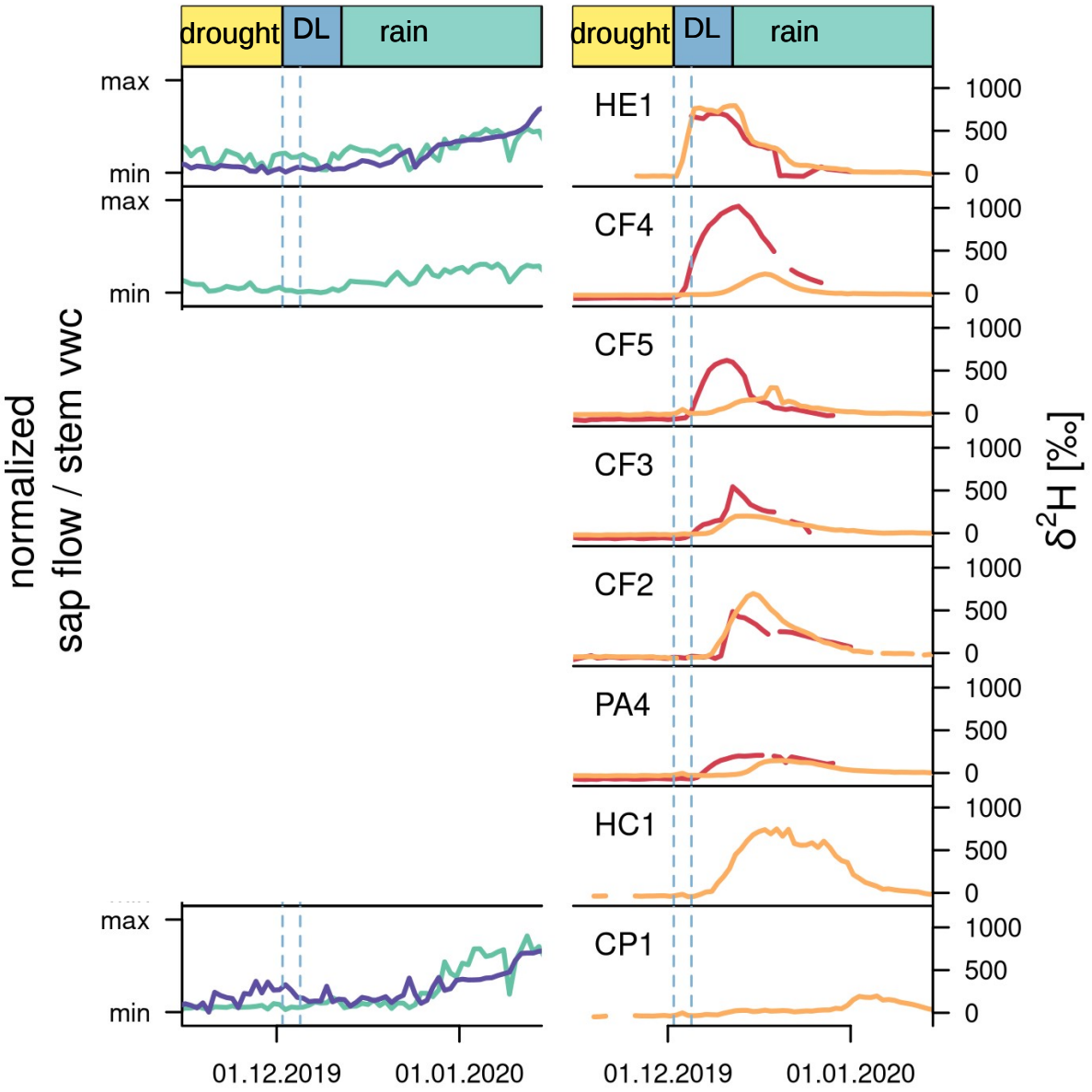


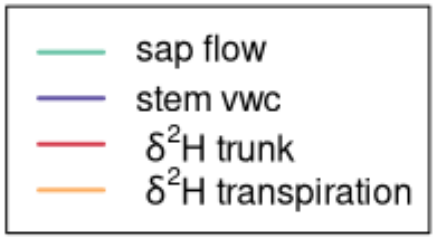


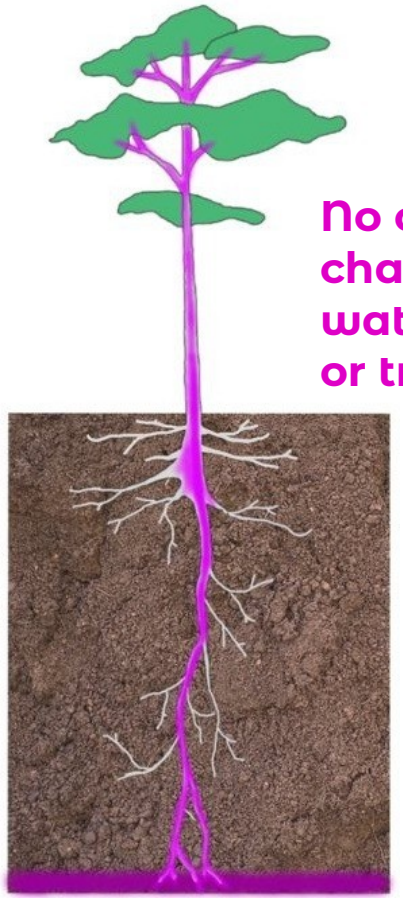
Increase of transpiration

Kühnhammer et al (2022, in preparation)

Tree deep water usage



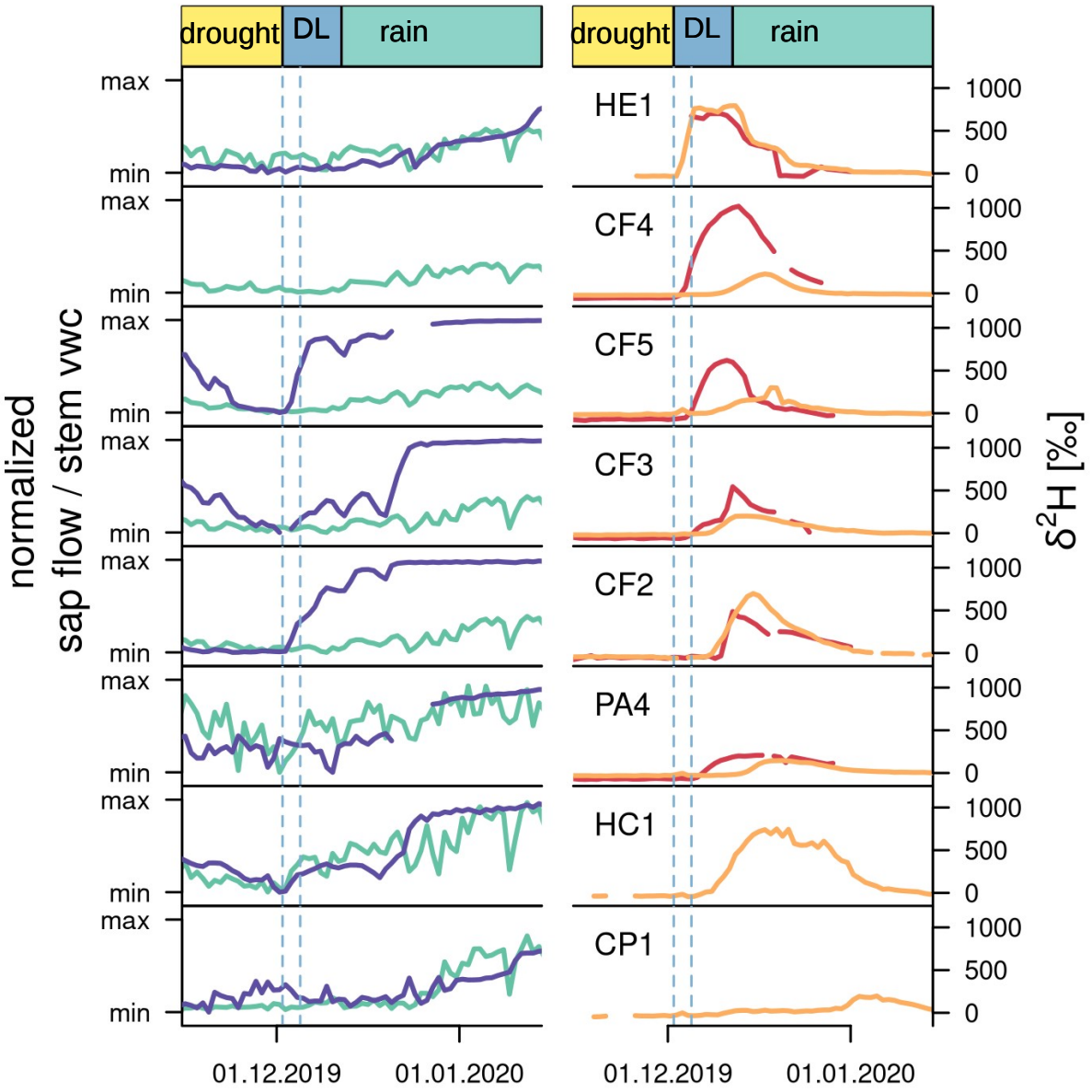


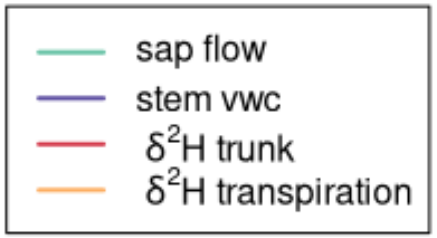


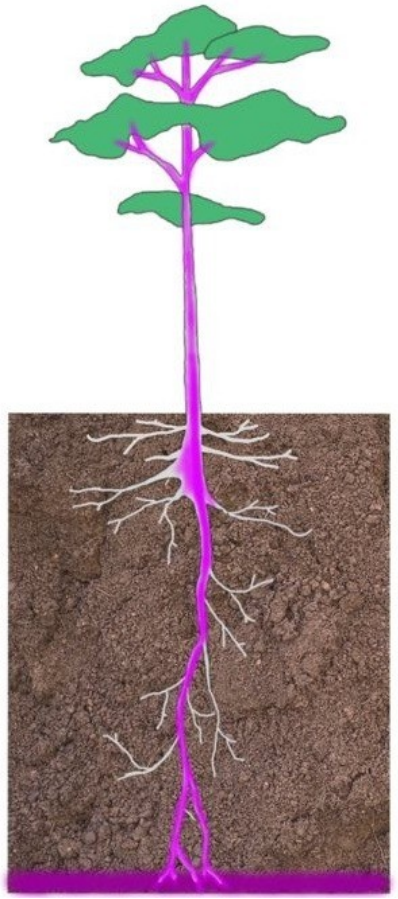
No obvious change in water storage or transport

Kühnhammer et al (2022, in preparation)

Tree deep water usage

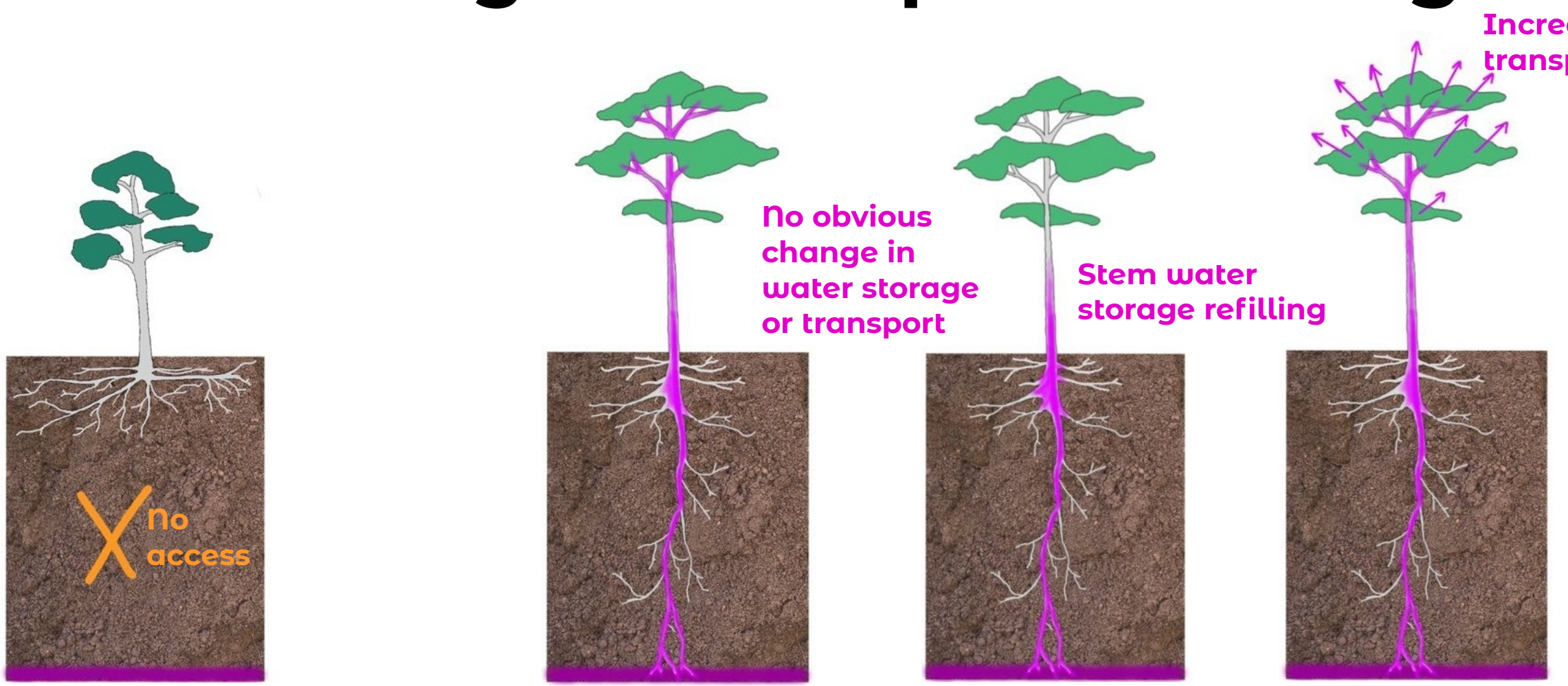




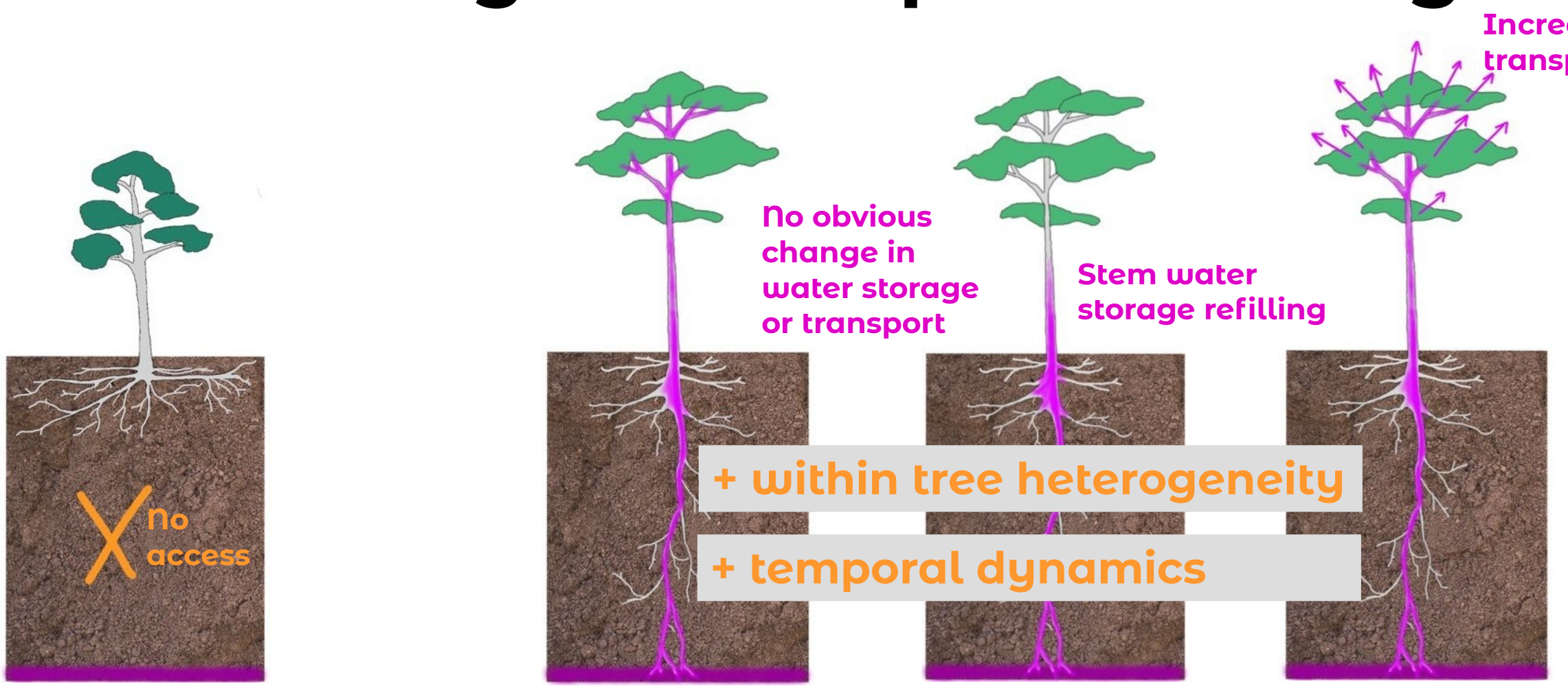


Kühnhammer et al (2022, in preparation)

Summary tree deep water usage



Summary tree deep water usage



Thank you for your attention!

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Homepage: https://www.isodrones.com/

And follow us on Instagram, Facebook, Twitter or YouTube (links on Homepage)

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References and further reading

- Beyer, M., Kuehnhammer, K., & Dubbert, M. (2020). In situ measurements of soil and plant water isotopes: a review of approaches, practical considerations and a vision for the future. Hydrology and Earth System Sciences, 24(9), 4413-4440.
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- Werner, C., Meredith, L. K., Ladd, S. N., Ingrisch, J., Kübert, A., van Haren, J., ... & Williams, J. (2021). Ecosystem fluxes during drought and recovery in an experimental forest. Science, 374(6574), 1514-1518.

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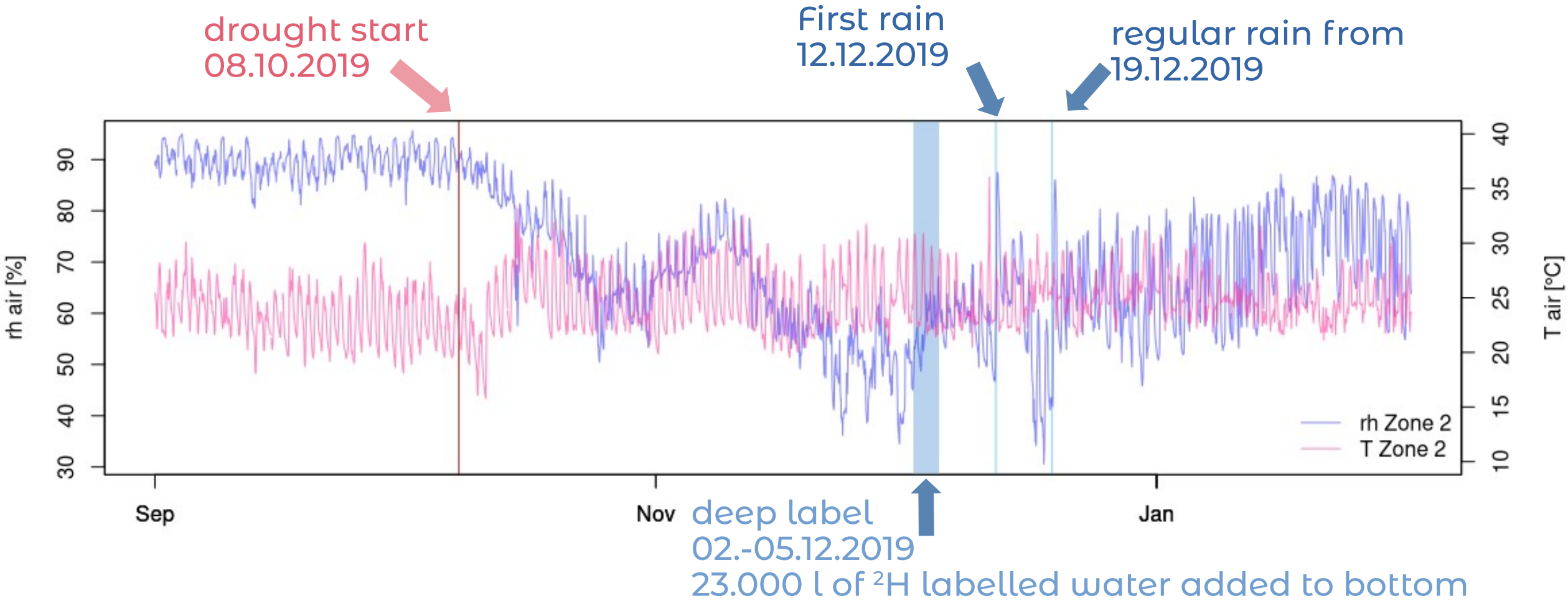
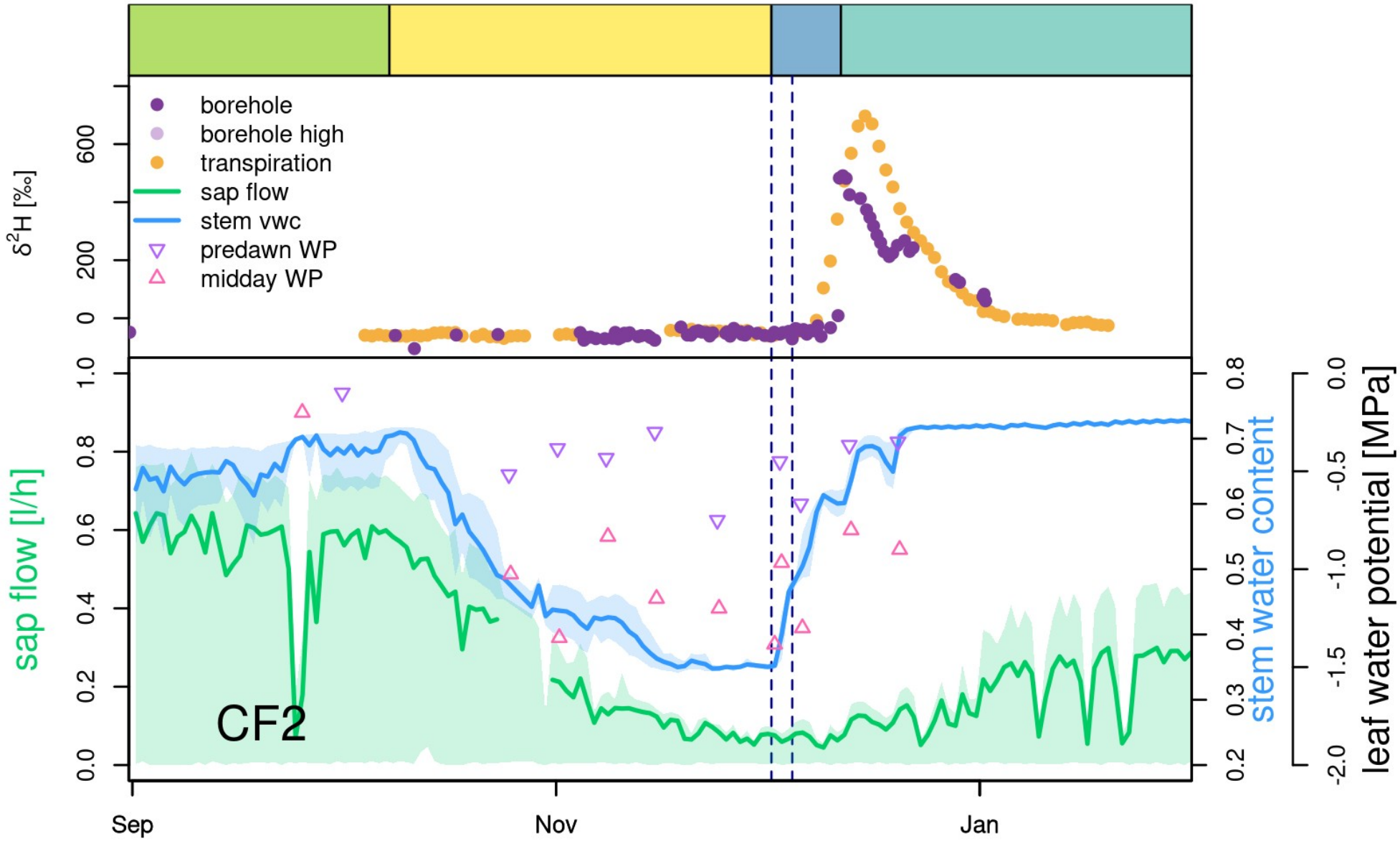
Ambient conditions

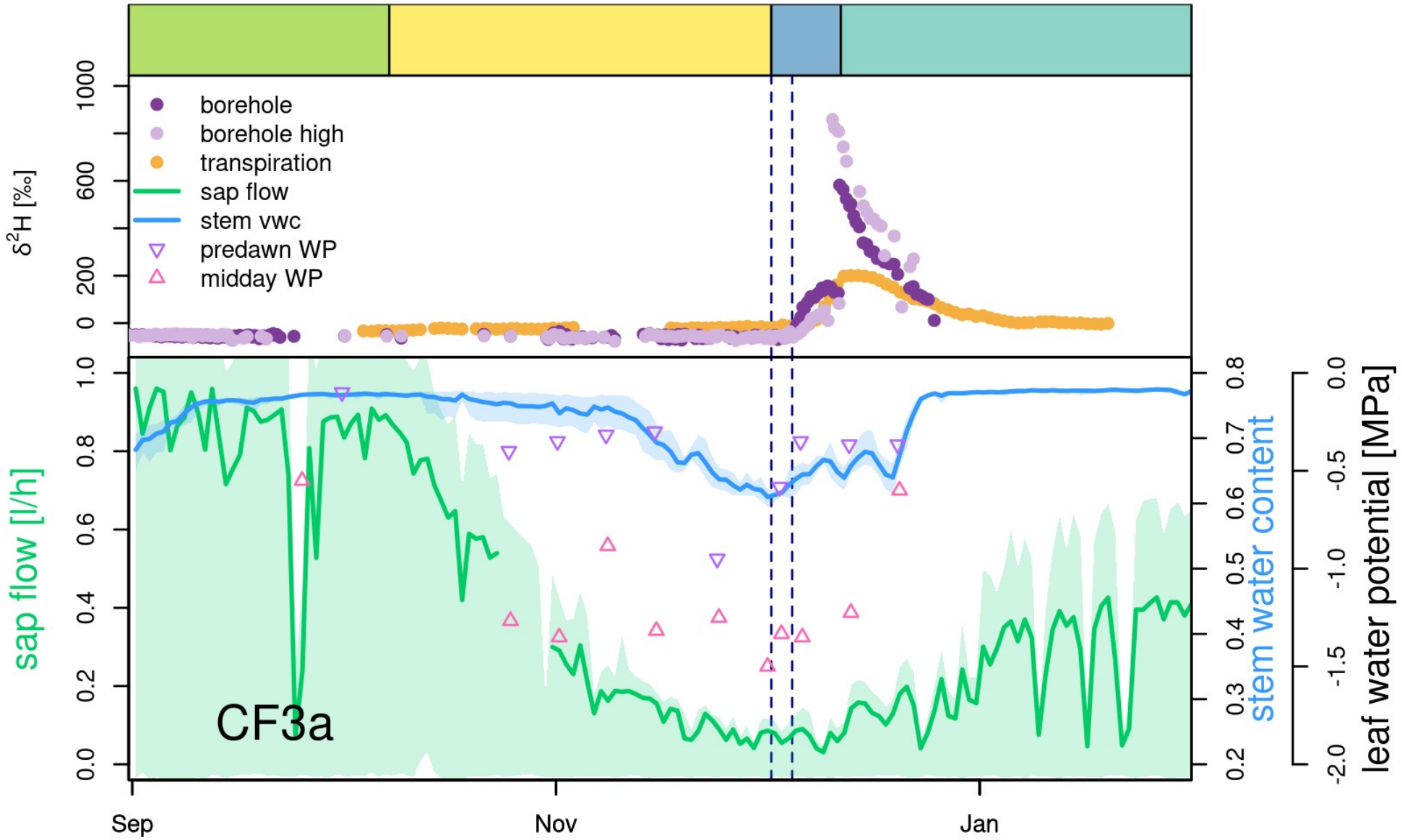
Here some more info and a closer look into the data for every single tree investigated



tree data


borehole
borehole high
transpiration
sap flow
stem vwc
predawn WP
midday WP
δ2H [‰]
600
200
0
1.0
0.8
0.6
0.4
0.2
0.0
sap flow [l/h]
CF2
0.8
0.7
0.6
0.5
0.4
0.3
0.2
stem water content
0.0
-0.5
-1.0
-1.5
-2.0
leaf water potential [MPa]
Sep
Nov
Jan

tree data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sap flow
stem vwc
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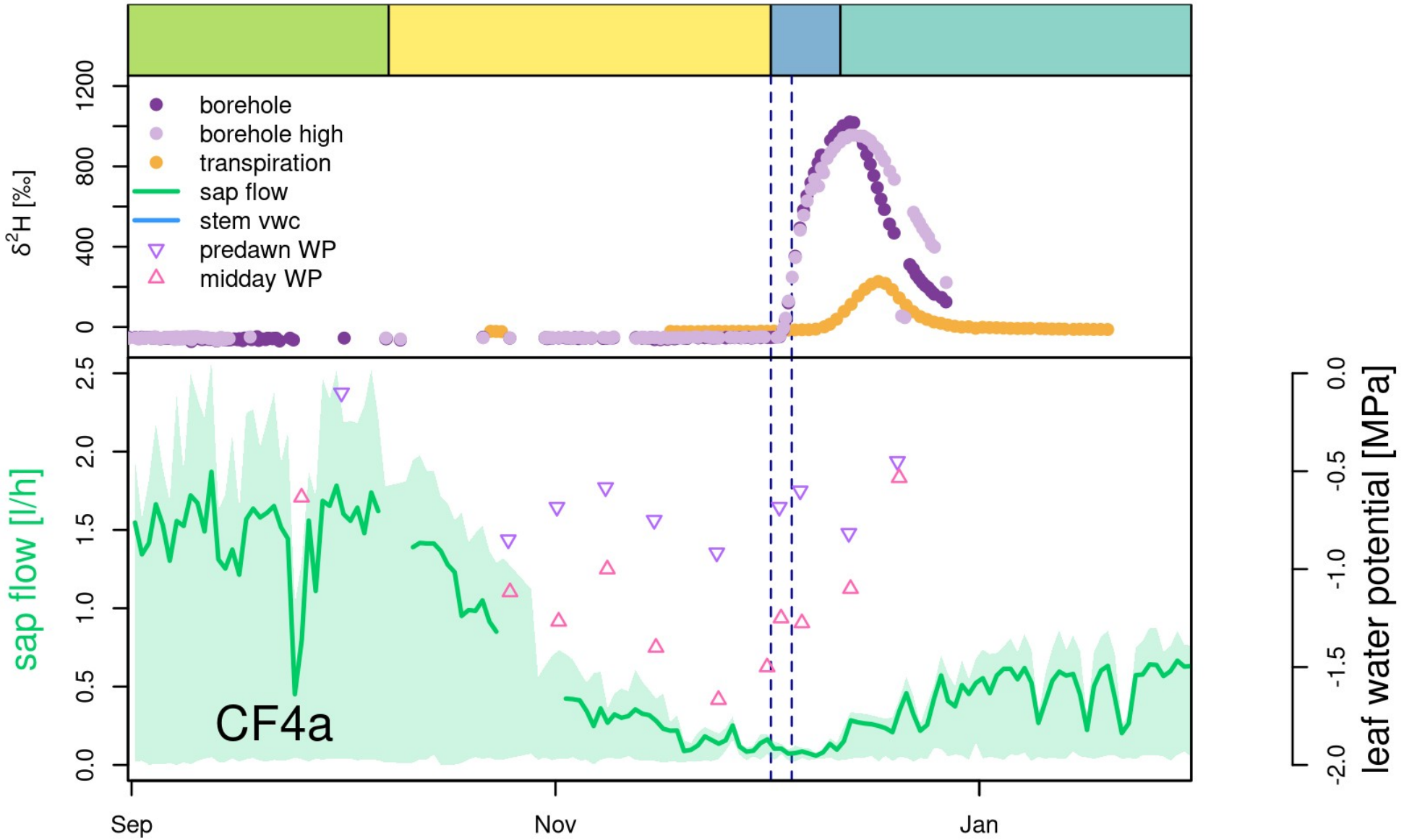
midday WP
δ2H [‰]
sap flow [l/h]
stem water content
leaf water potential [MPa]
CF3a
Sep
Nov
Jan

tree data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transpiration
sap flow
stem vwc
predawn WP
midday WP
δ2H [‰]
1200
800
400
0
sap flow [l/h]
2.5
2.0
1.5
1.0
0.5
0.0
CF4a
Sep
Nov
Jan
leaf water potential [MPa]
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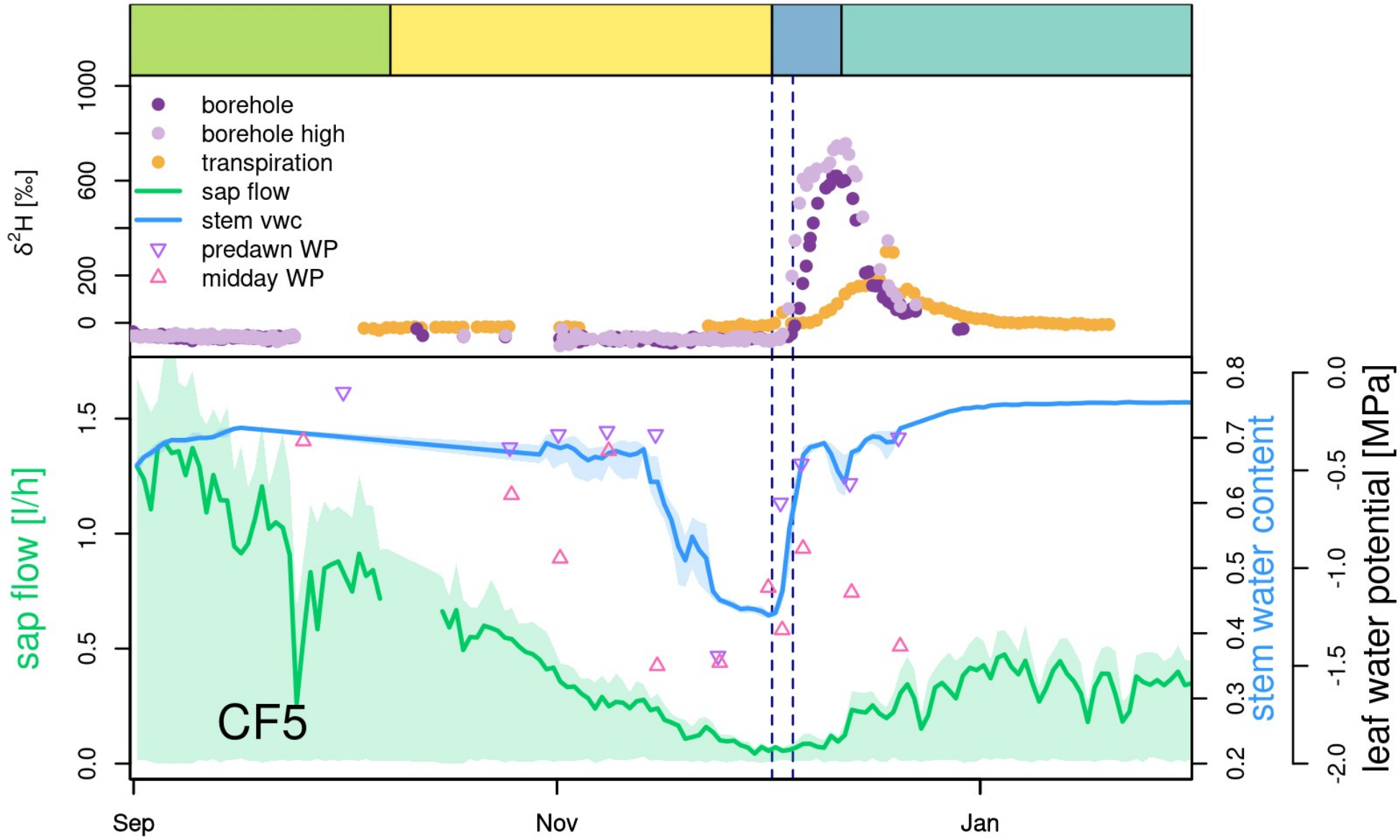
-0.5
-1.0
-1.5
-2.0

tree data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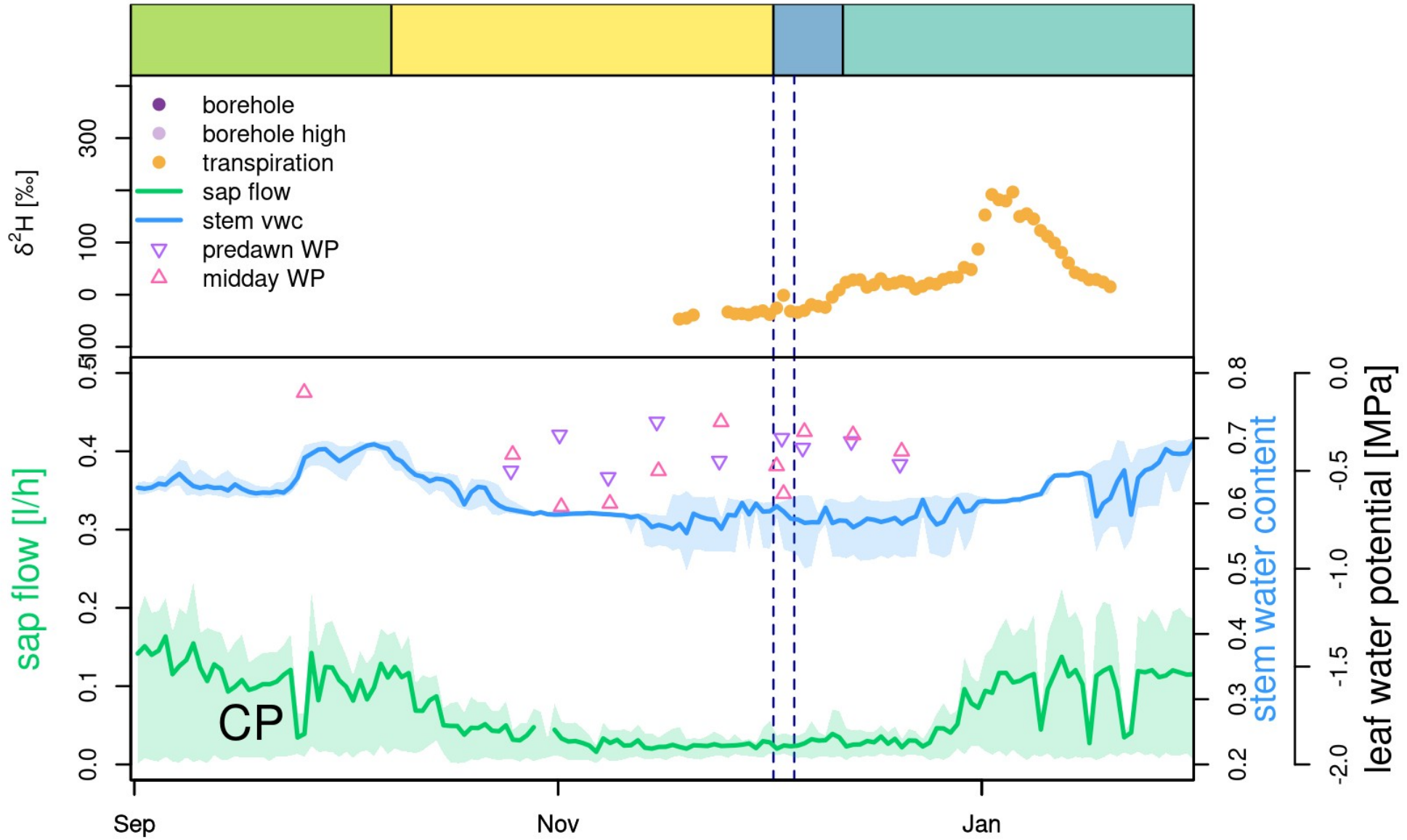
borehole high
transpiration
sap flow
stem vwc
predawn WP
midday WP
δ2H [‰]
1000
600
200
0
sap flow [l/h]
1.5
1.0
0.5
0.0
CF5
stem water content
0.8
0.7
0.6
0.5
0.4
0.3
0.2
leaf water potential [MPa]
0.0
-0.5
-1.0
-1.5
-2.0
Sep
Nov
Jan

tree data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transpiration
sap flow
stem vwc
predawn WP
midday WP
δ²H [‰]
300
100
0
-100
sap flow [l/h]
0.5
0.4
0.3
0.2
0.1
0.0
CP
stem water content
0.8
0.7
0.6
0.5
0.4
0.3
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leaf water potential [MPa]
0.0
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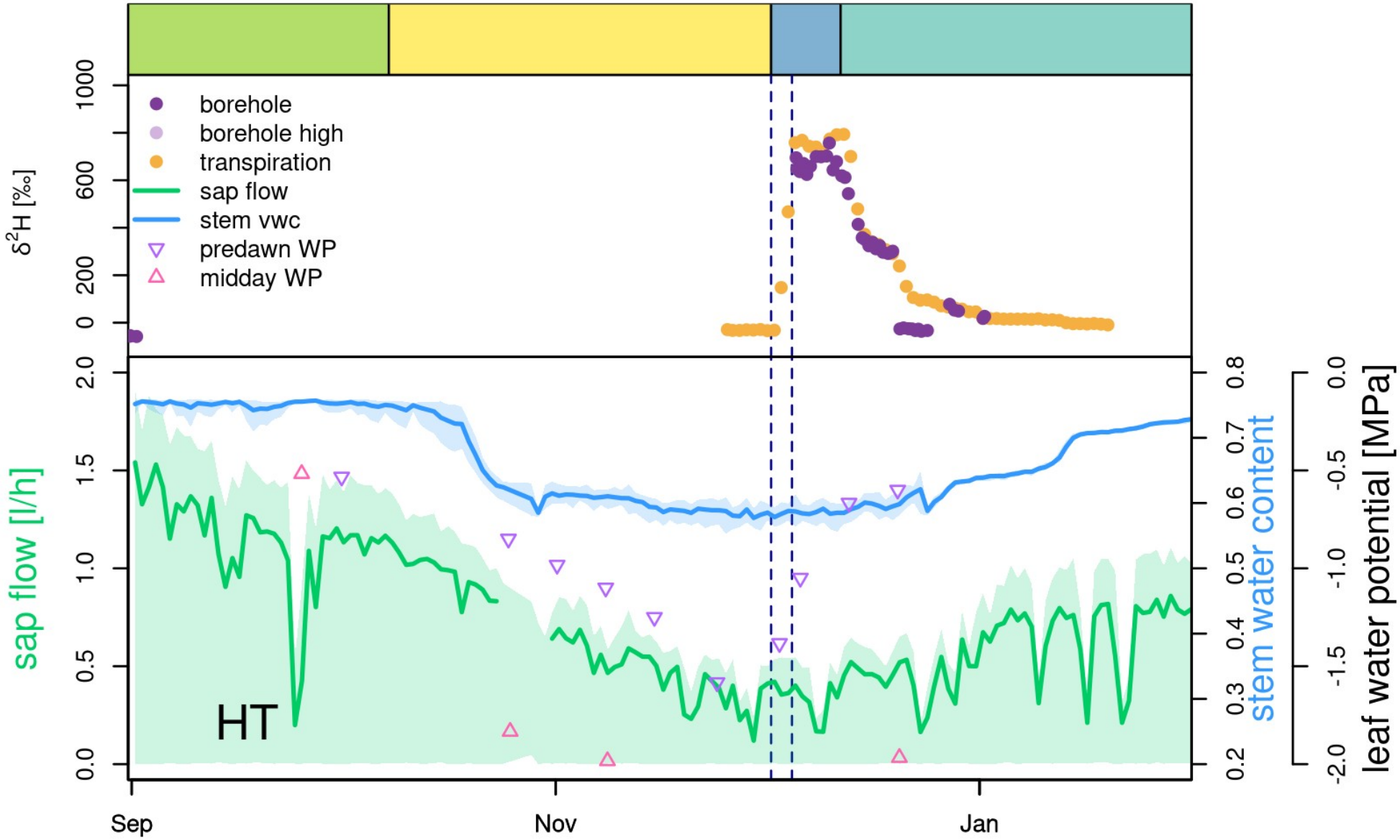
-1.0
-1.5
-2.0
Sep
Nov
Jan

tree data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borehole high
transpiration
sap flow
stem vwc
predawn WP
midday WP
δ2H [‰]
1000
600
200
0
2.0
1.5
1.0
0.5
0.0
sap flow [l/h]
HT
0.8
0.7
0.6
0.5
0.4
0.3
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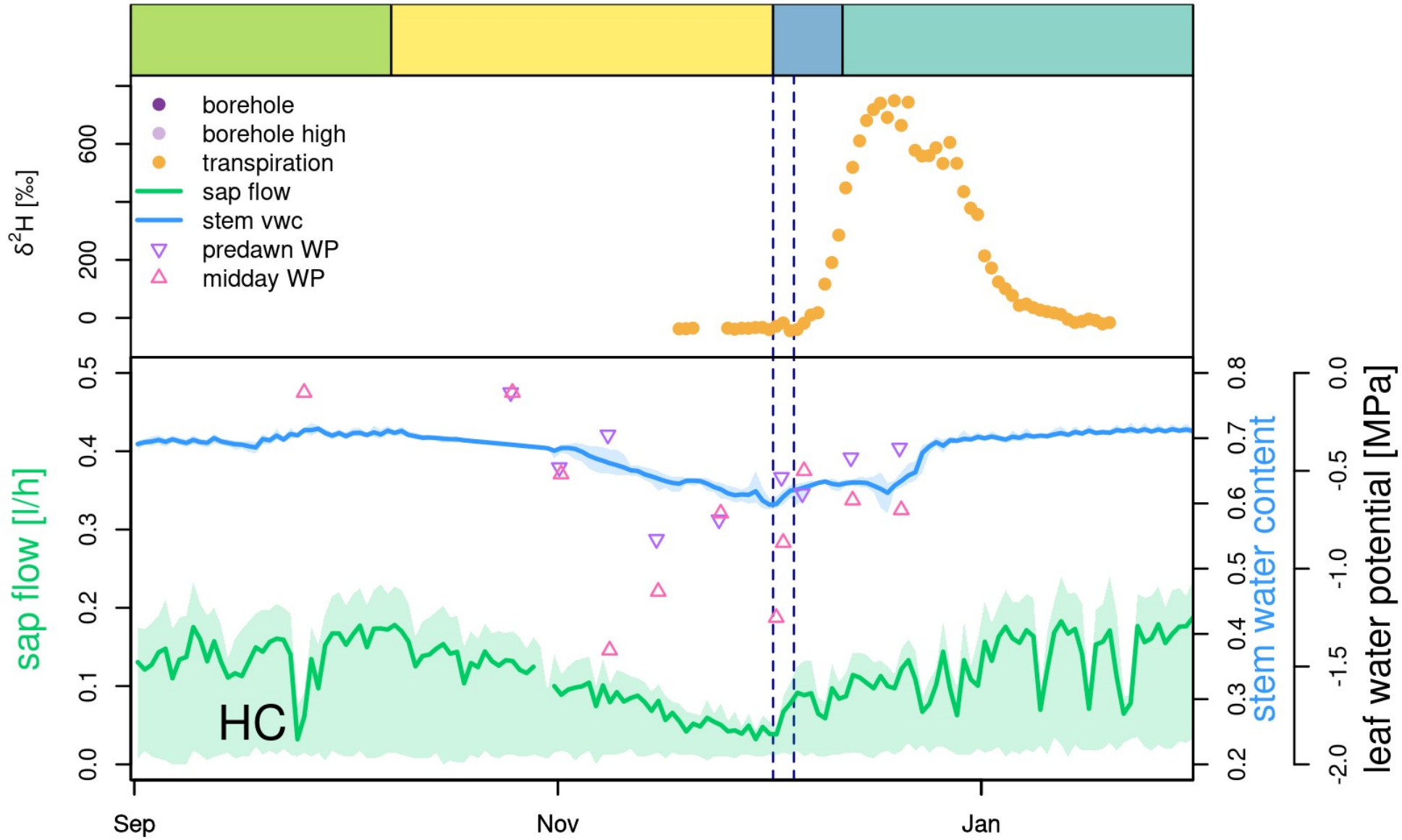
leaf water potential [MPa]
Sep
Nov
Jan

tree data


borehole
borehole high
transpiration
sap flow
stem vwc
predawn WP
midday WP
δ2H [‰]
600
200
0
sap flow [l/h]
0.5
0.4
0.3
0.2
0.1
0.0
HC
stem water content
0.8
0.7
0.6
0.5
0.4
0.3
0.2
leaf water potential [MPa]
0.0
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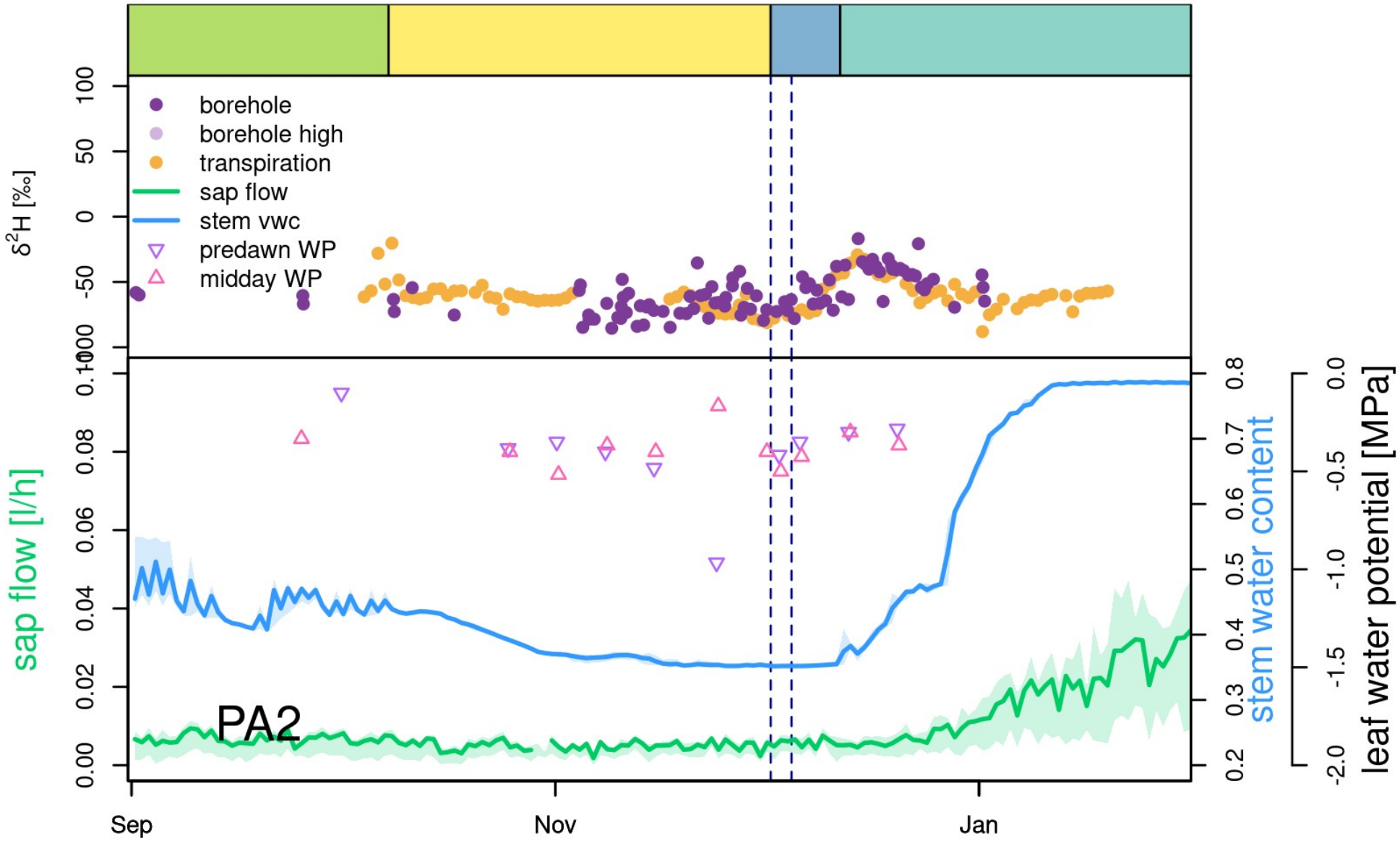
-1.0
-1.5
-2.0
Sep
Nov
Jan

tree data


borehole
borehole high
transpiration
sap flow
stem vwc
predawn WP
midday WP
δ2H [‰]
100
50
0
-50
-100
sap flow [l/h]
0.00
0.02
0.04
0.06
0.08
0.10
PA2
stem water content
0.2
0.3
0.4
0.5
0.6
0.7
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leaf water potential [MPa]
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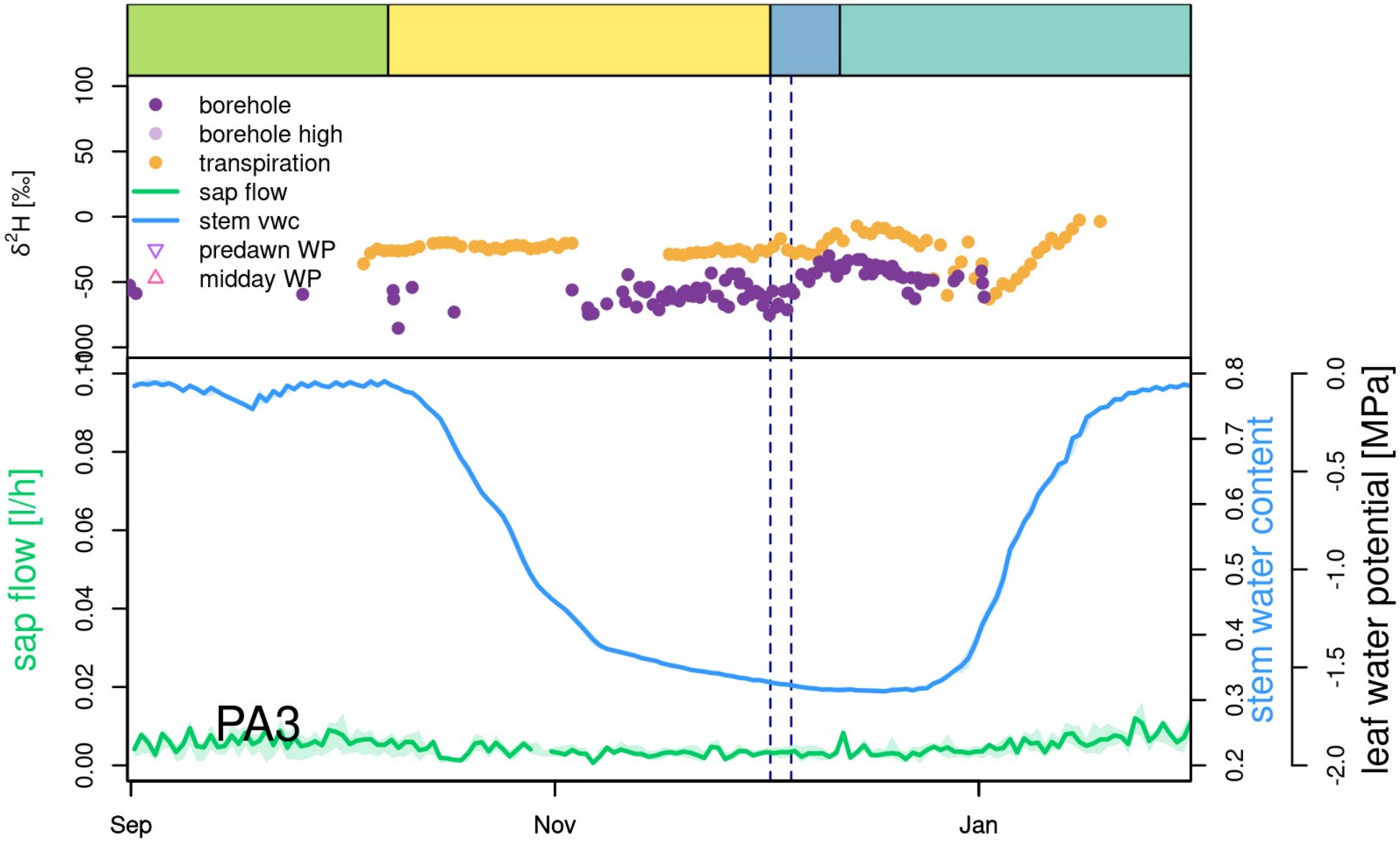
-1.5
-2.0
Sep
Nov
Jan

tree data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midday WP
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0.06
0.04
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PA3
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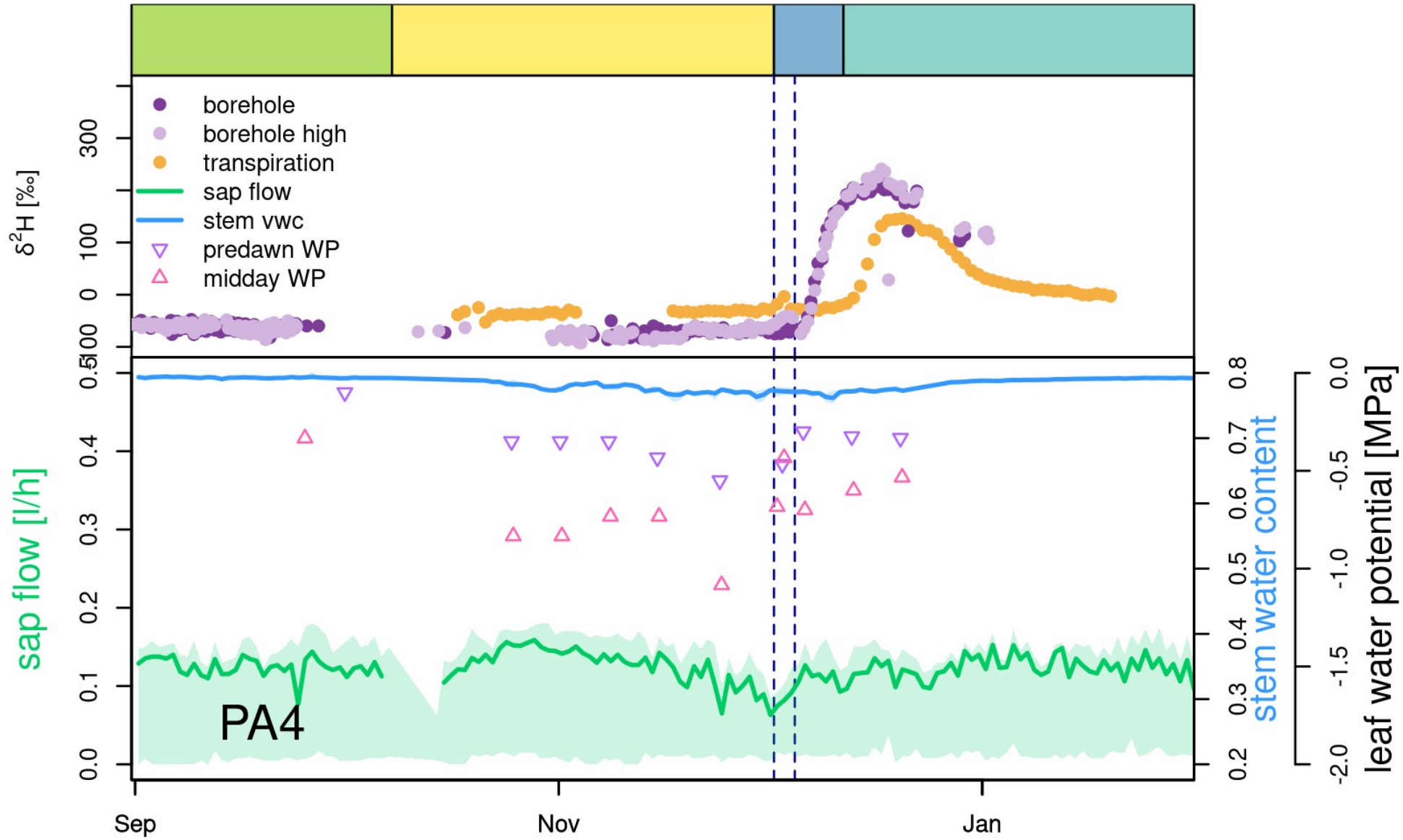
-2.0
Sep
Nov
Jan

tree data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transpiration
sap flow
stem vwc
predawn WP
midday WP
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0.4
0.3
0.2
0.1
0.0
sap flow [l/h]
PA4
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0.3
0.2
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-1.5
-2.0
leaf water potential [MPa]
Sep
Nov
Jan