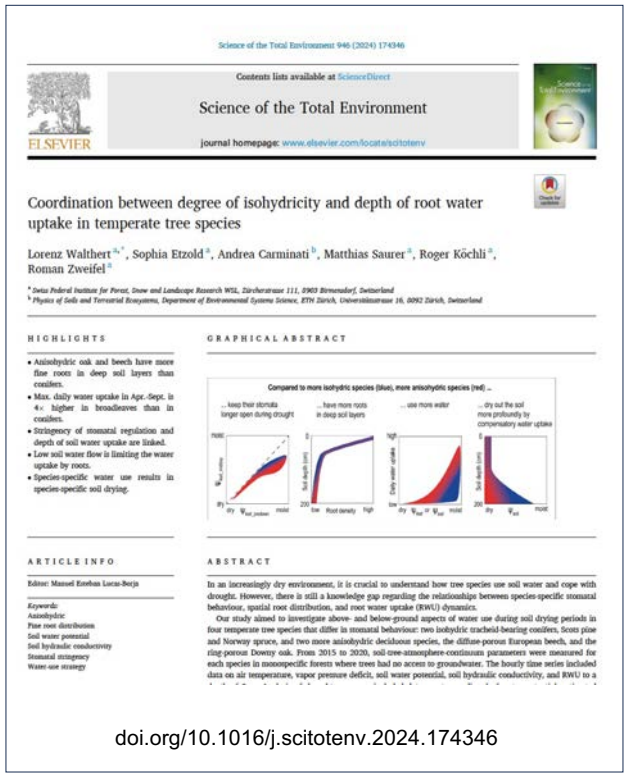
A new paper based on TreeNet data

"Coordination between degree of isohydricity and depth of root water uptake in temperate tree species"

L. Walthert, S. Etzold, A. Carminati, M. Saurer, R. Köchli, R. Zweifel



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Coordination between degree of isohydricity and depth of root water uptake in temperate tree species

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HIGHLIGHTS

- Anisohydric oak and beech have more fine roots in deep soil layers than conifers.
- Max. daily water uptake in Apr.-Sept. is 4× higher in broadleaves than in conifers.
- Stringency of stomatal regulation and depth of soil water uptake are linked.
- Low soil water flow is limiting the water uptake by roots.
- Species-specific water use results in species-specific soil drying.

GRAPHICAL ABSTRACT

ARTICLE INFO

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Stomatal stringency
Water-use strategy

ABSTRACT

In an increasingly dry environment, it is crucial to understand how tree species use soil water and cope with drought. However, there is still a knowledge gap regarding the relationships between species-specific stomatal behaviour, spatial root distribution, and root water uptake (RWU) dynamics.

Our study aimed to investigate above- and below-ground aspects of water use during soil drying periods in four temperate tree species that differ in stomatal behaviour: two isohydric tracheid-bearing conifers, Scots pine and Norway spruce, and two more anisohydric deciduous species, the diffuse-porous European beech, and the ring-porous Downy oak. From 2015 to 2020, soil-tree-atmosphere-continuum parameters were measured for each species in monospecific forests where trees had no access to groundwater. The hourly time series included data on air temperature, vapor pressure deficit, soil water potential, soil hydraulic conductivity, and RWU to a

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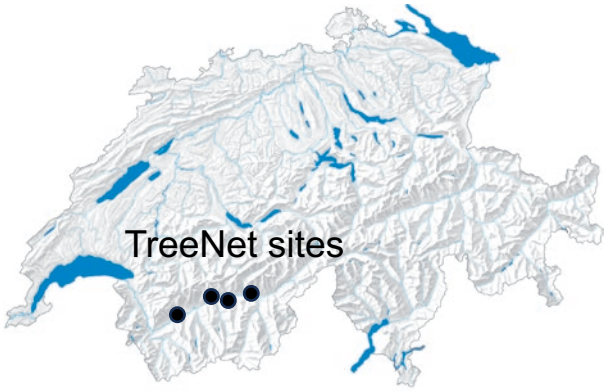
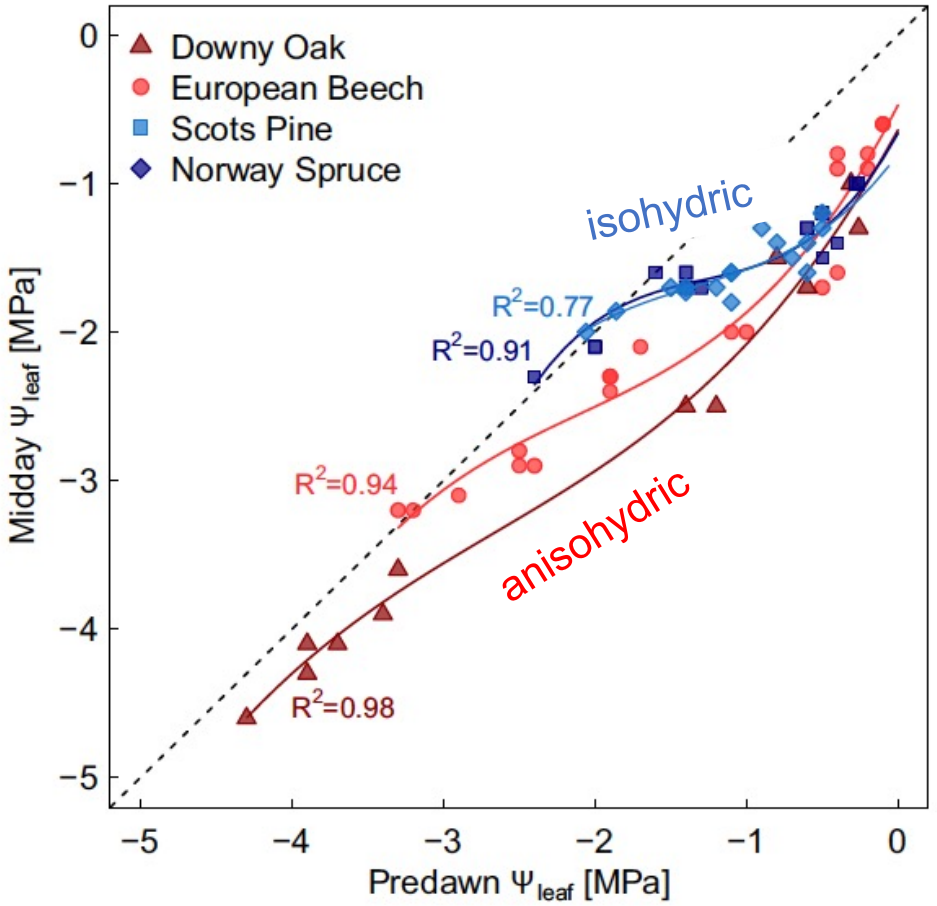
The water use of

- European beech
- Downy oak
- Norway spruce
- Scots pine

Motivation for this study





Spruce and Scots pine

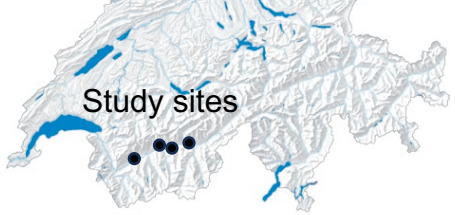
weak decrease of Ψ_{leaf_md} during drought (keep stomata more closed)

Downy oak and beech

strong decrease of Ψ_{leaf_md} during drought (keep stomata more open)

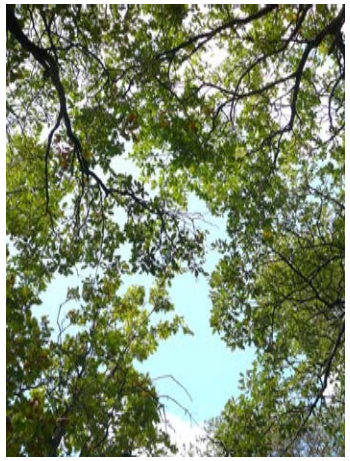
→ Species differ in their degree of isohydricity

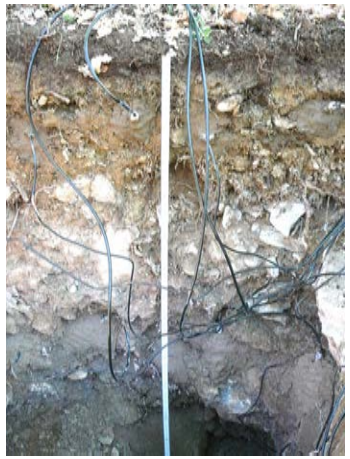
Relationship between the degree of isohydricity, root distribution, and root water uptake.



4 TreeNet sites in Valais

Downy oak





Chippis, 630 masl
Rockslide

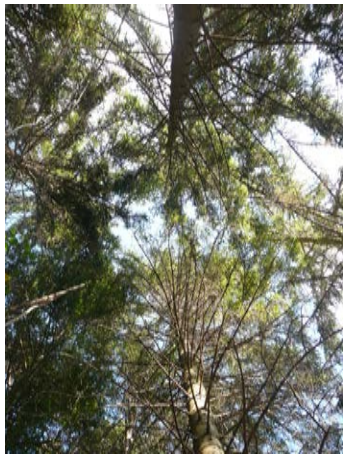
Beech

Saillon, 850 masl
Loess

Each of the four study sites had a monospecific forest

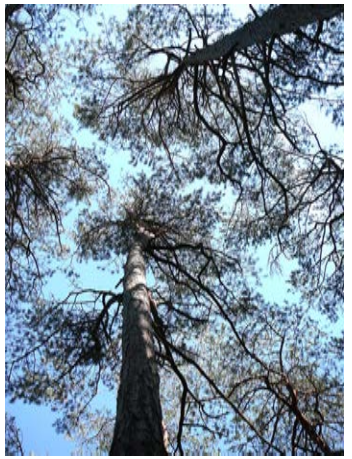
Soil and soil moisture data were available for deep soil profiles (2 m depth)

Spruce

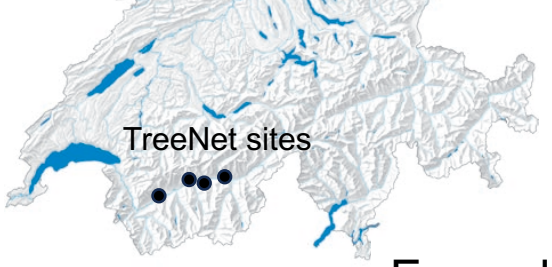


Hohtenn, 1120 masl
Moraine

Scots pine

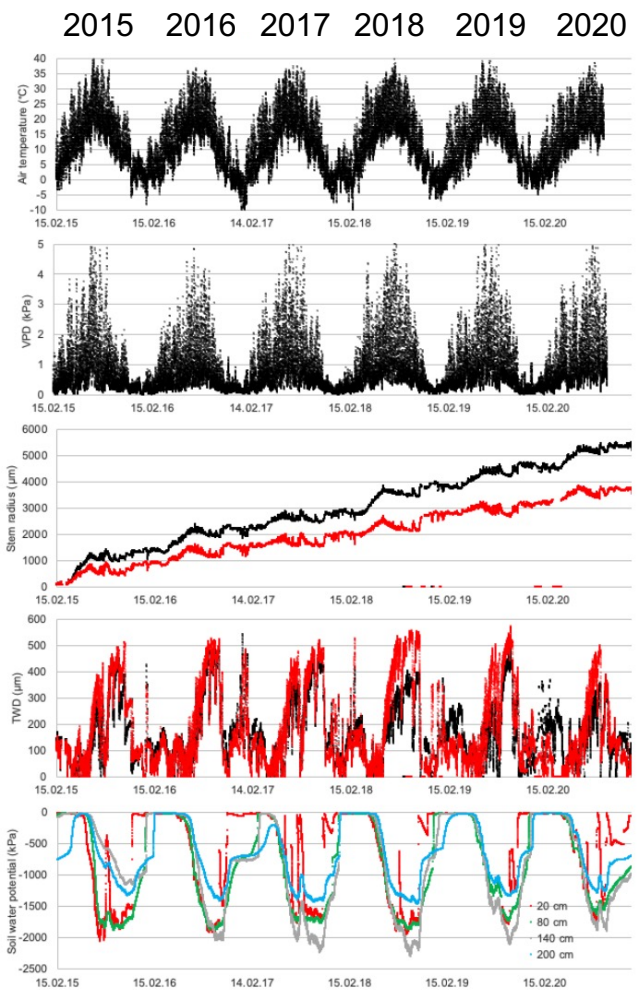


Chippis, 600 masl
Rockslide



Methods: time series (2015–2020, hourly)

Example: Downy oak



Air temperature

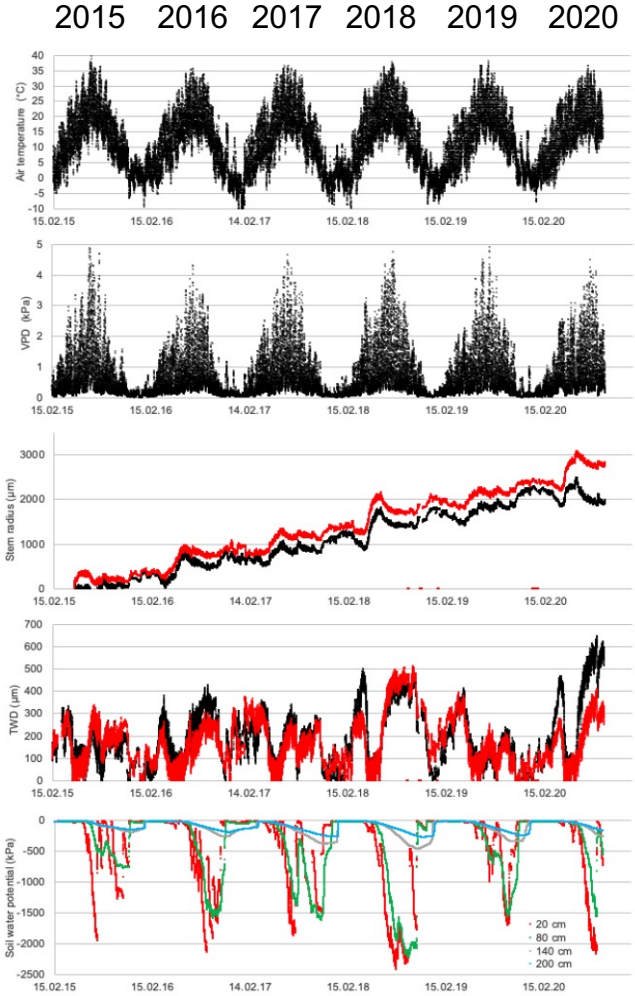
VPD

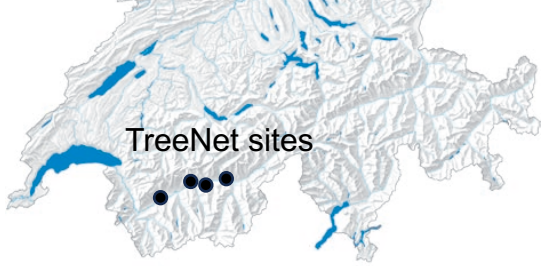
Stem radius (2 trees)

Tree water deficit TWD

Soil water potential Ψ_{soil}
20, 80, 140, 200 cm depth

Example: Scots pine





Methods: some key information

Root distribution

with volumetric soil samples down to a depth of 2 m

Daily root water uptake (RWU)

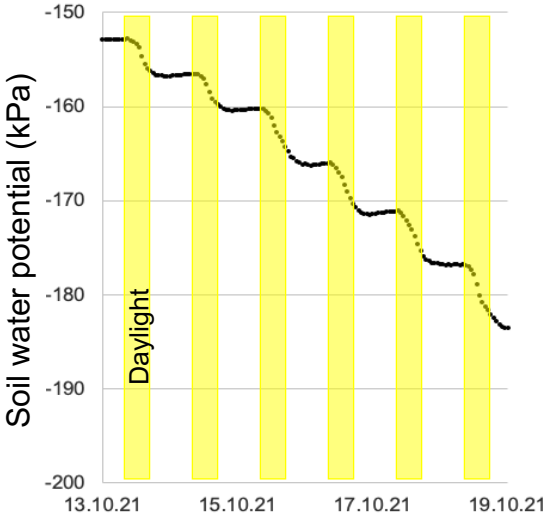
from daily decreases of Ψ_{soil} in the different soil depths

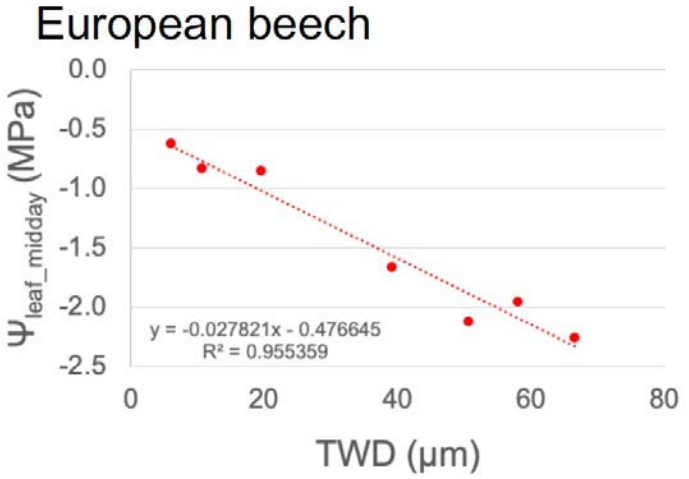
Continuous leaf water potential (Ψ_{leaf_pd} and Ψ_{leaf_md})

based on the relationship between TWD and Ψ_{leaf} measured during several bright days

Volumetric soil samples for root distribution

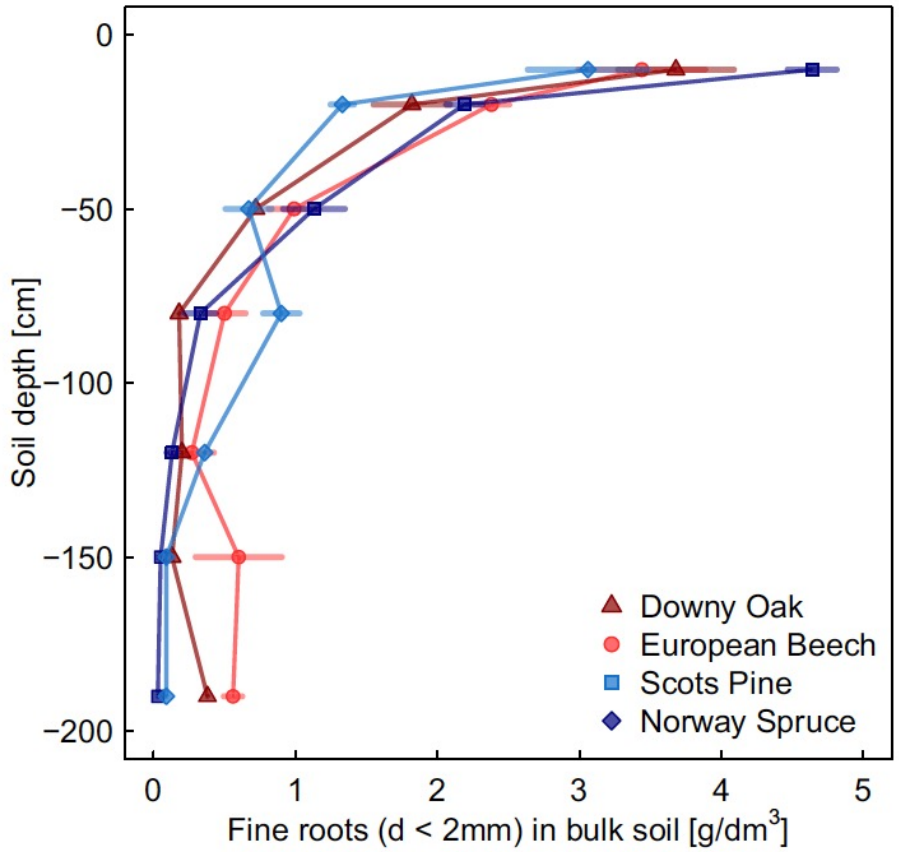
Daily RWU was calculated from daily decreases of Ψ_{soil}





Results: Fine root distribution

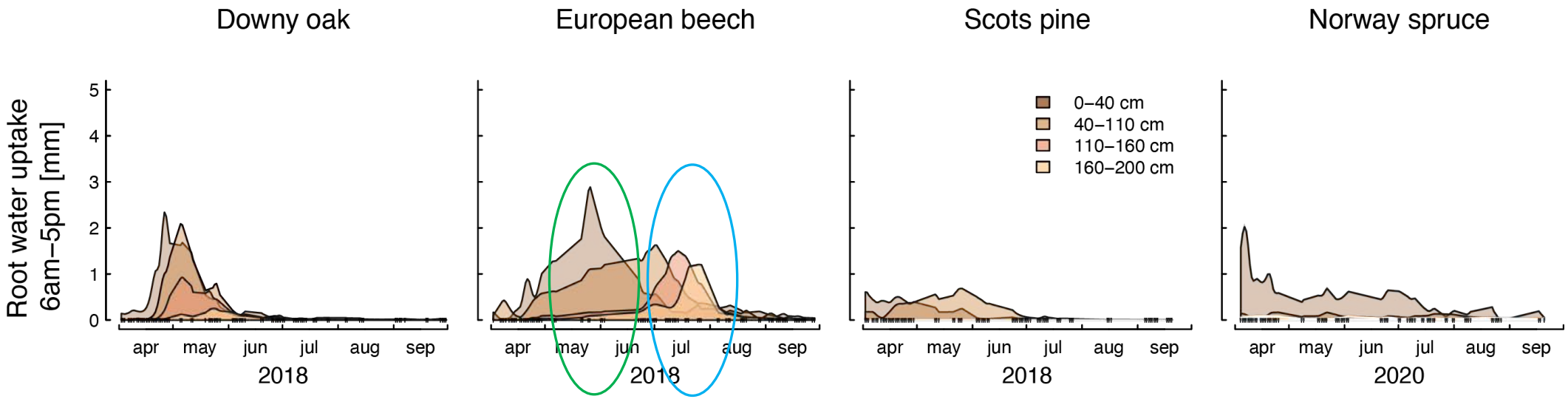
Oak and beech have significantly more fine roots in deep soil layers than spruce and pine



Results: Depth shift of root water uptake as soil drought progresses

With progressing drought, oak and beech shift their root water uptake to deeper soil layers.

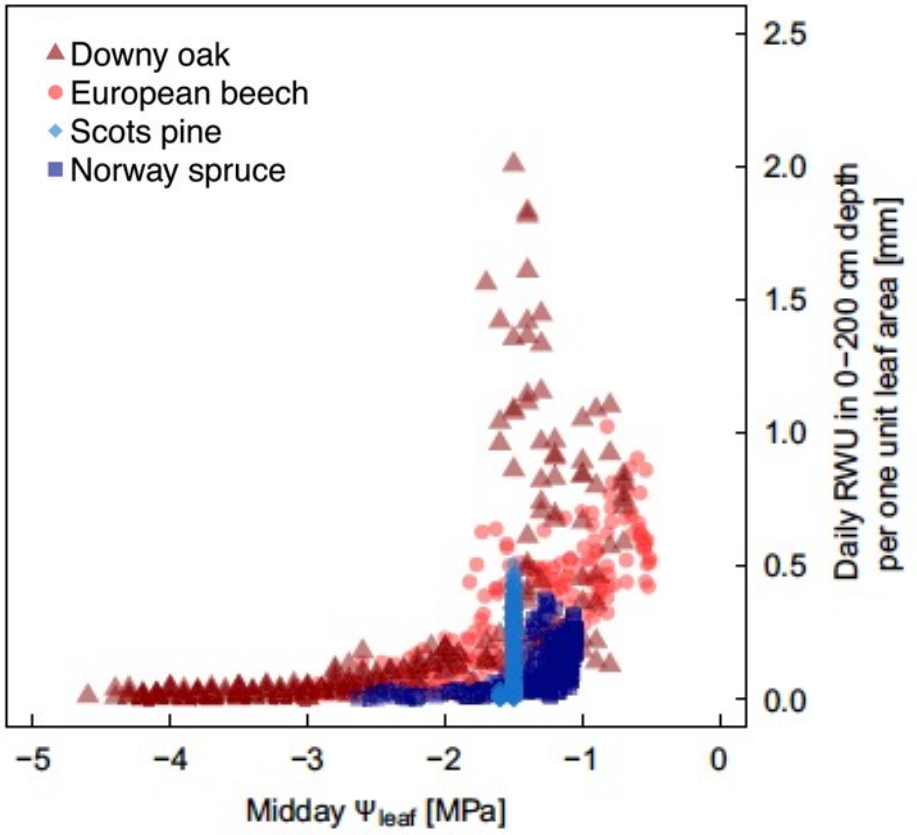
Conifers shift their water uptake much less than oak and beech, even when the topsoil is very dry.



In May and June, beech trees take water mainly from the moist topsoil.

In July and August, when the topsoil is dry, they take water mainly from below 1 m depth.

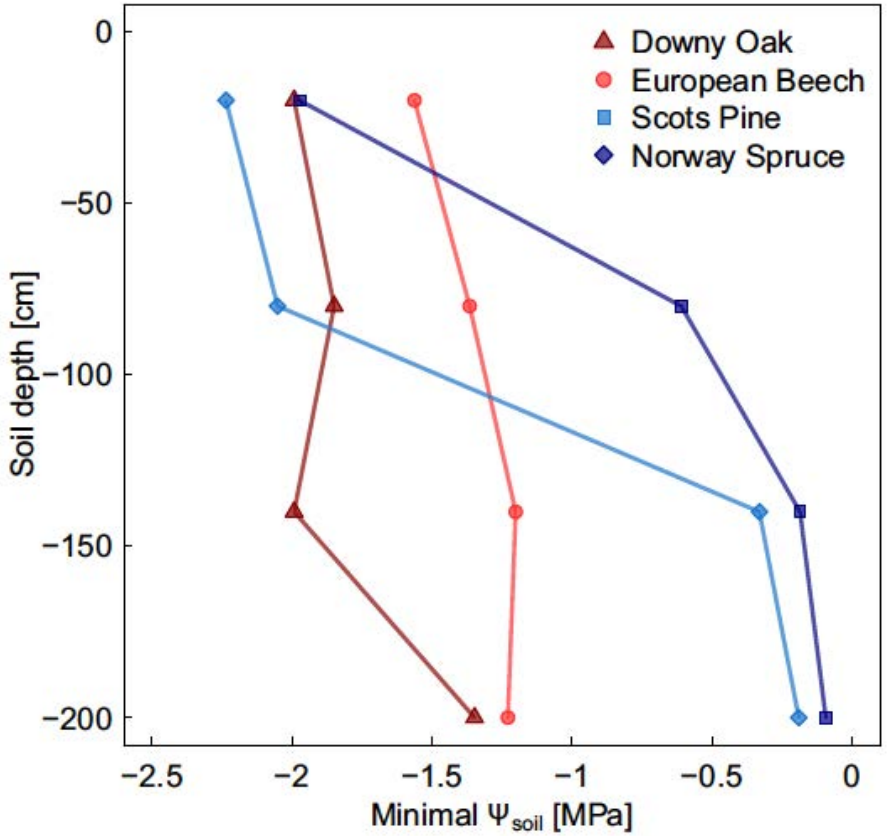
Results: Daily root water uptake (from 0-200 cm depth) per one unit of leaf area



dry moist

- Oak and beech have a much higher maximum RWU than conifers
- Downy oak sheds water when the soil is moist
- As drought progresses, oak and beech maintain higher levels of RWU than conifers

Results: Maximum soil desiccation in the study period (2015–2020)



dry moist

Topsoil
soil drying was similar for all four species

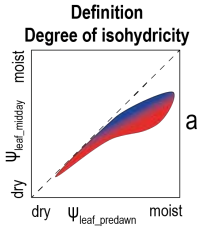
Deep soil layers (> 1m depth)
only oak and beech dried out the soil a lot

Summary water use: compared to **isohydric species**, **anisohydric species** …

Legend

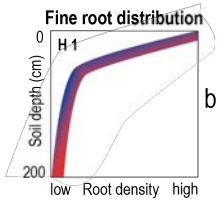
isohydric

anisohydric



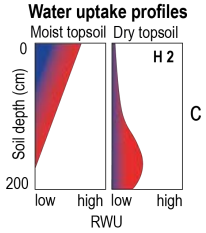
a

… keep their stomata longer open during drought,



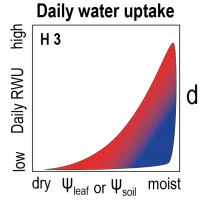
b

… have more fine roots in deep soil layers,



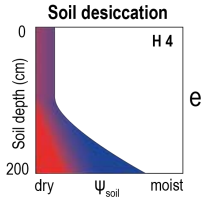
c

… shift water uptake to deeper soil layers during topsoil drought,



d

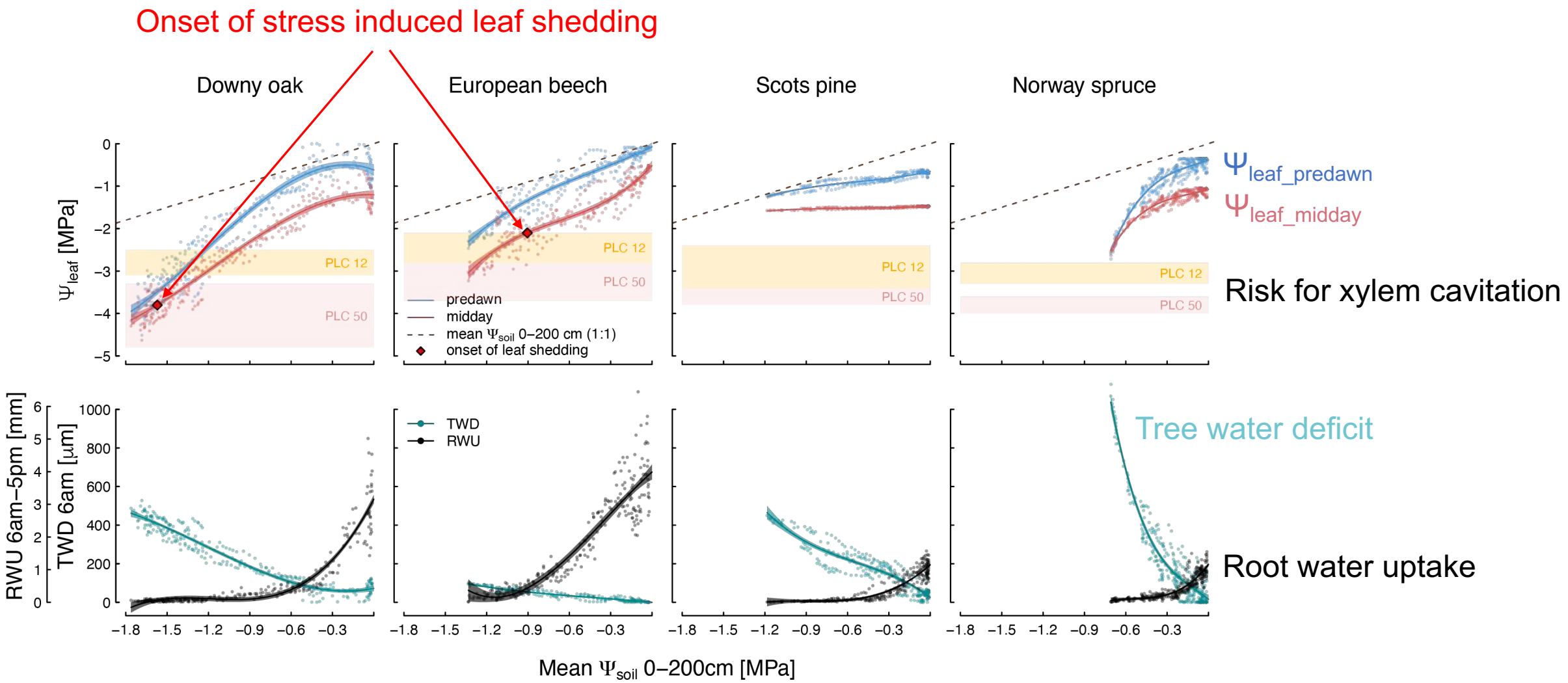
… use more water,



e

… and dry out the soil more profoundly.

Results: Tree responses to decreasing soil water potential



Conclusions

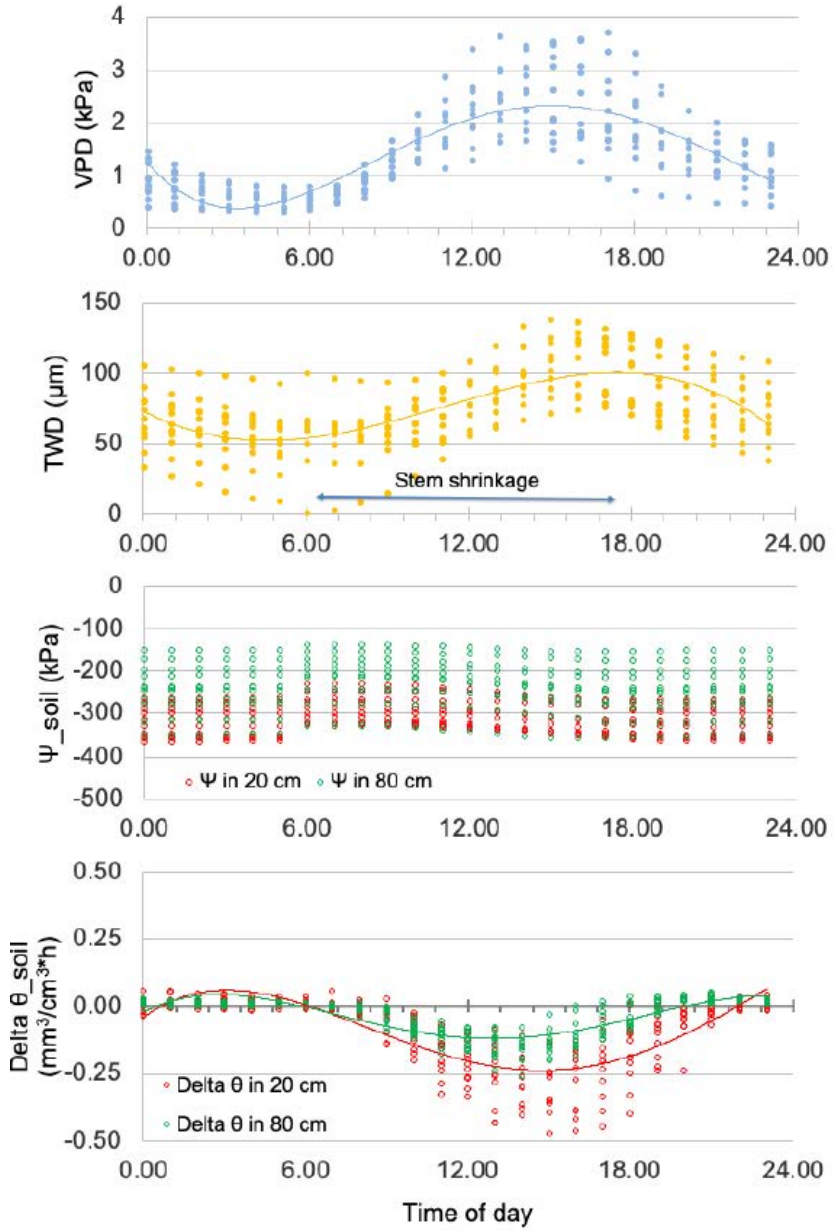
Isohydric and anisohydric tree species differ in aboveground and belowground water use,

There is a coordination between Ψ_{leaf}, root distribution, and the amount and depth of root water uptake,

Species-specific water use results in species-specific dynamics and degrees of soil drying.

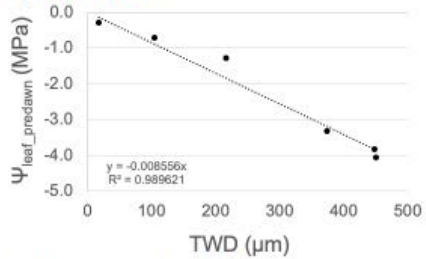
Thank you for your attention!

Figure S2 a: Downy oak

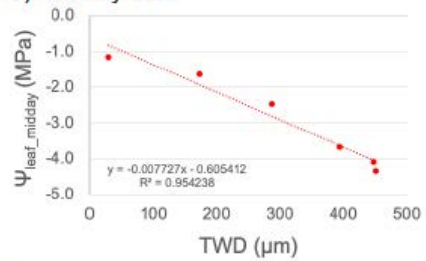


Predawn **Midday**

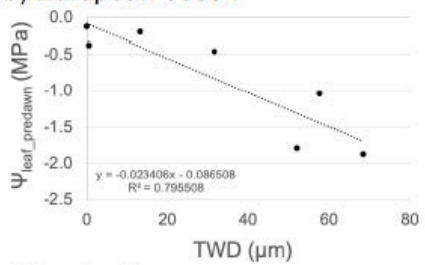
a) Downy oak



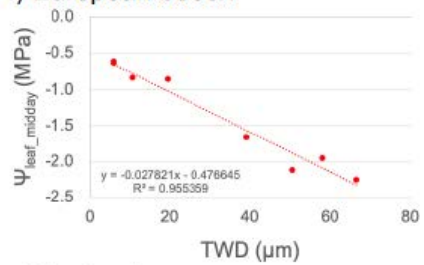
e) Downy oak



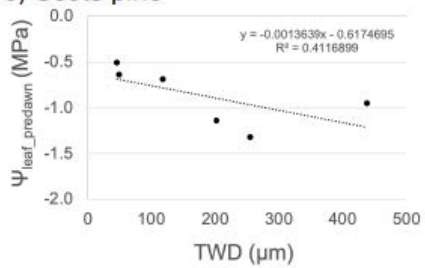
b) European beech



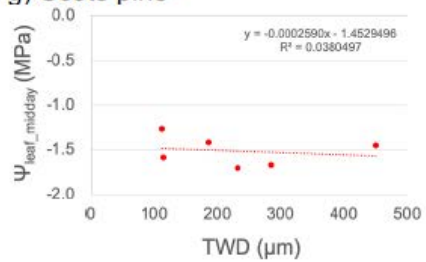
f) European beech



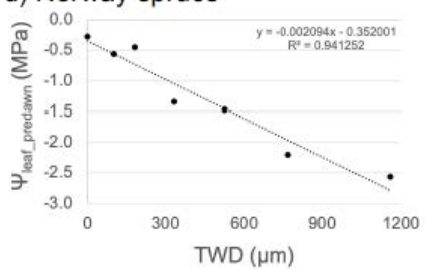
c) Scots pine



g) Scots pine



d) Norway spruce



h) Norway spruce

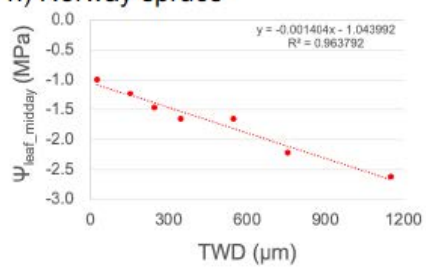
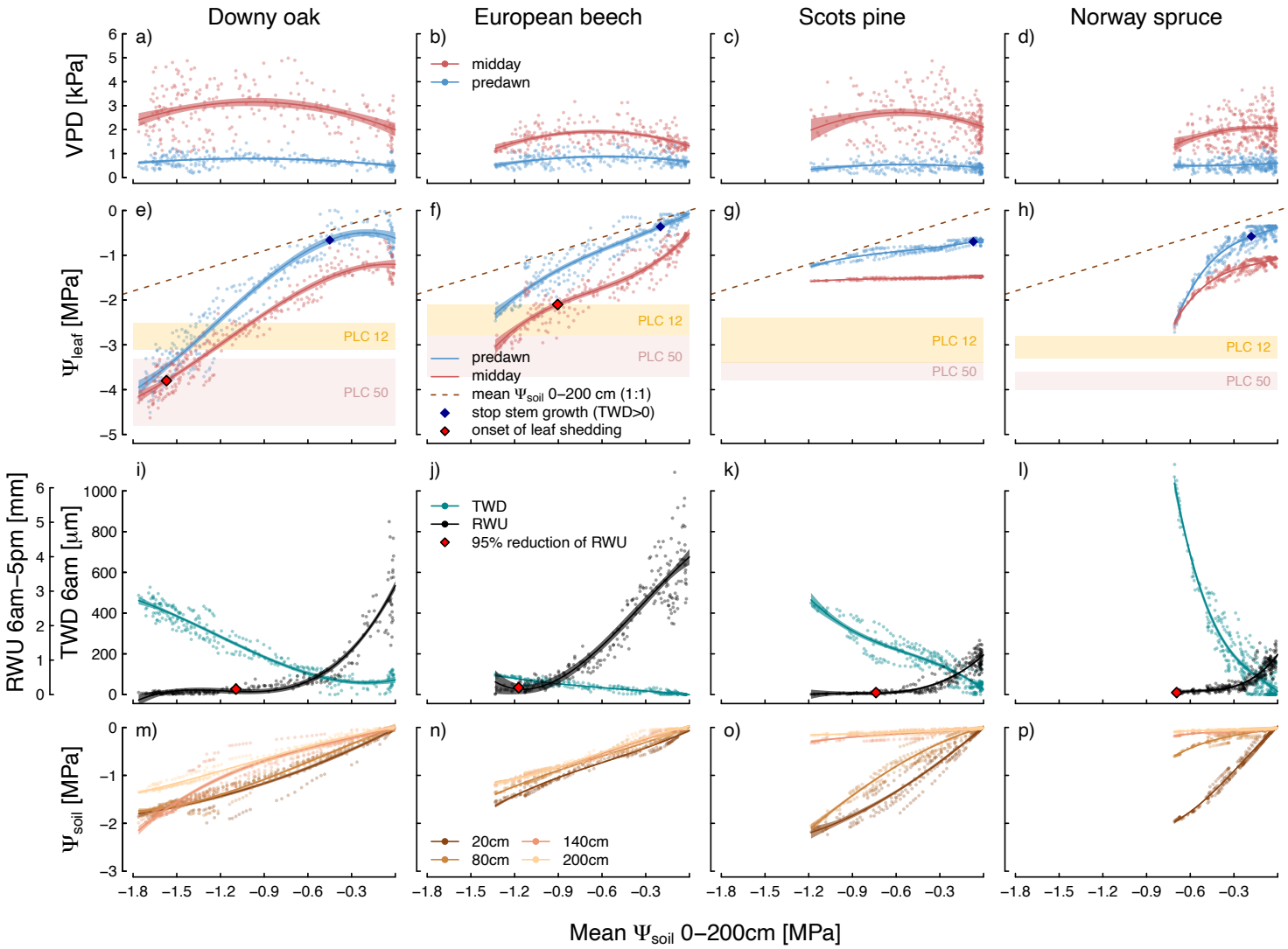


Table 3

Species' water use in response to progressive soil desiccation. More anisohydric species (red), more isohydric species (blue). +++ very high, ++ high, + moderate, (+) low, 0 null. Ψ_{leaf_pd}, Ψ_{leaf_md}: leaf water potential at predawn or midday; RWU: root water uptake; P 50: pressure at 50 % xylem cavitation.

Drought response / trait	Oak	Beech	Pine	Spruce
Decrease of Ψ_{leaf_md} with decreasing Ψ_{leaf_pd}	+++	++	+	+
Fine root density in deep soil > 1 m depth	++	+++	+	+
Compensatory RWU from deep soil > 1 m depth	++	++	(+)	0
Maximum RWU per one unit of leaf area	+++	++	+	+
Maximum dryness in deep soil > 1 m depth	+++	++	+	(+)
Risk for reaching P 50 xylem vulnerability	+++	++	0	0

Figure 5 complete



Beech trees can take up soil water to at least 4 m depth

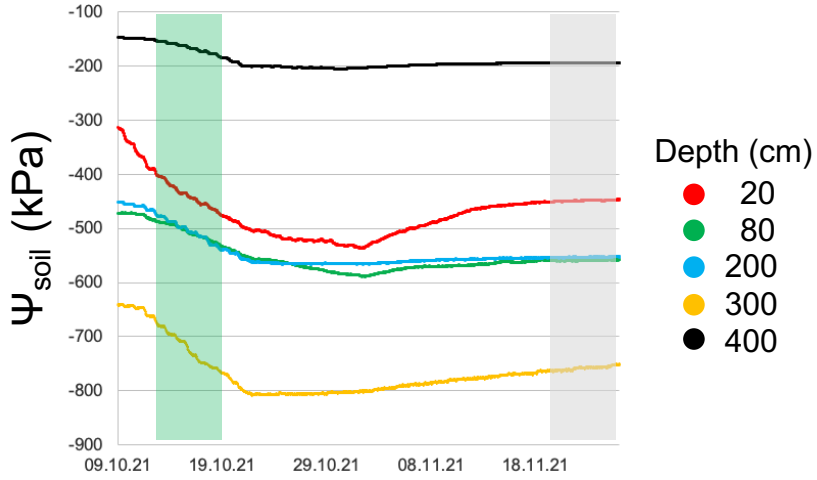
from not redoximorphic, well aerated soils

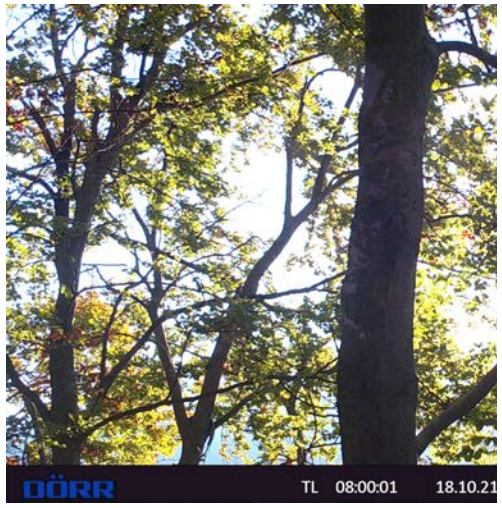
Site Saillon (Valais, CH)
Loess soil > 4 m deep
Mature beech trees
Ψ_{soil} sensor: Decagon MPS-2
Ψ_{soil} corrected to 22°C

Ψ_{soil}: Soil water potential

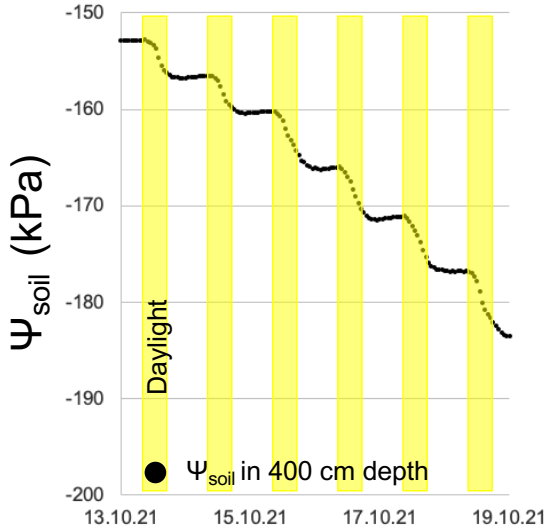
Trees with leaves with transpiration

Trees without leaves no transpiration

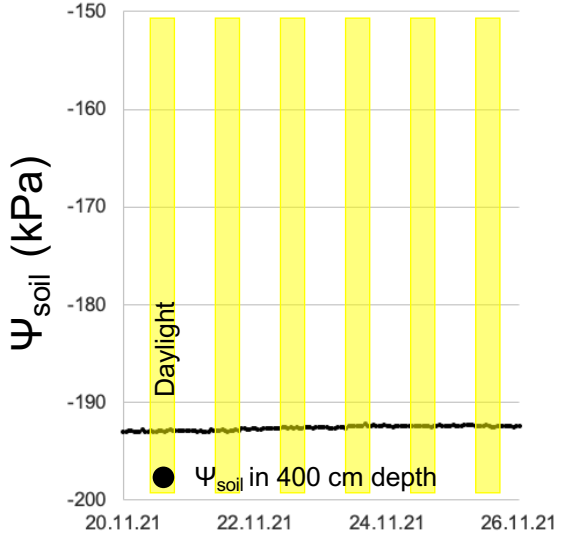




With transpiration

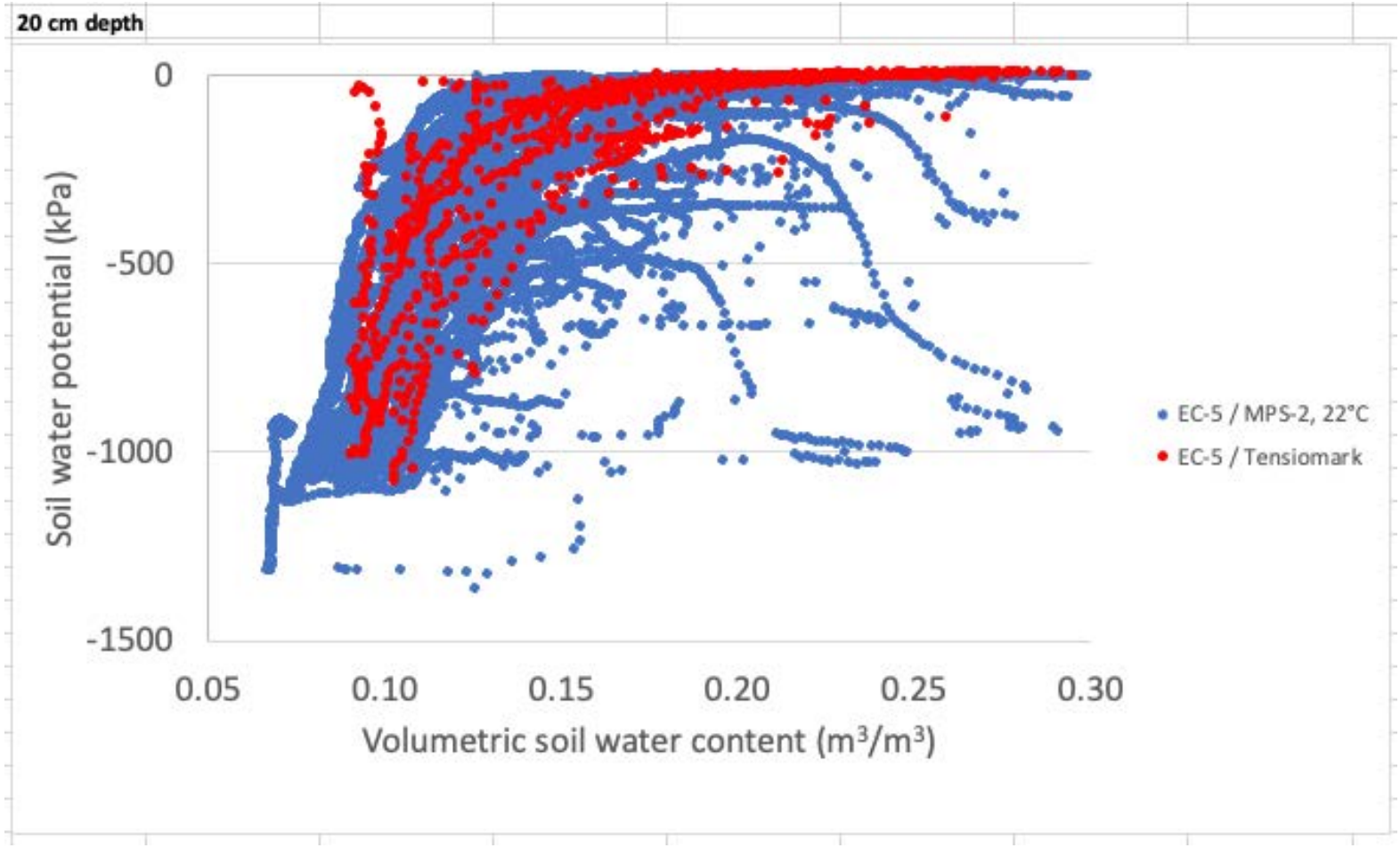


Without transpiration

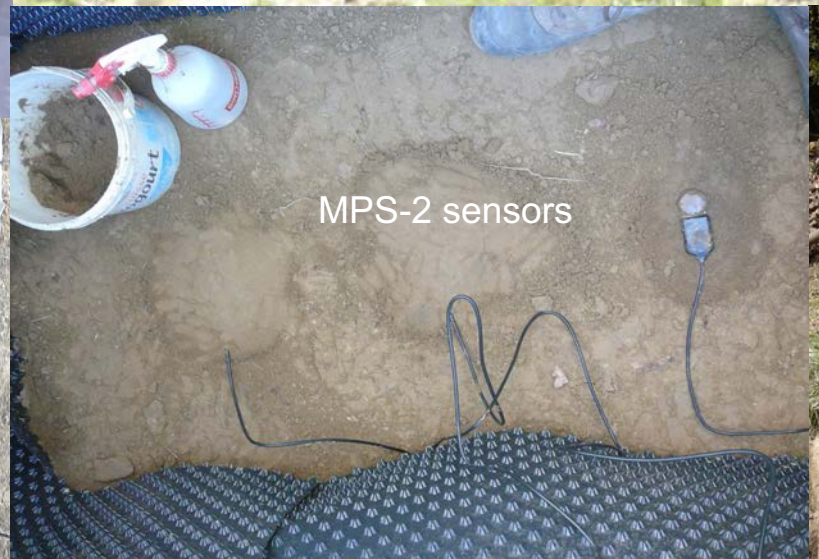


High variability of soil water retention under field conditions

Data collection: hourly, over several years



Why forest soils dry down?



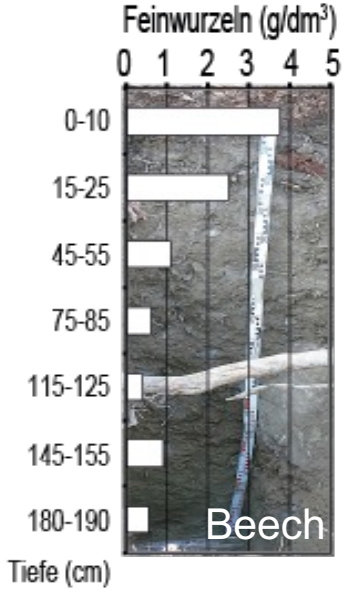
Beech

Beech

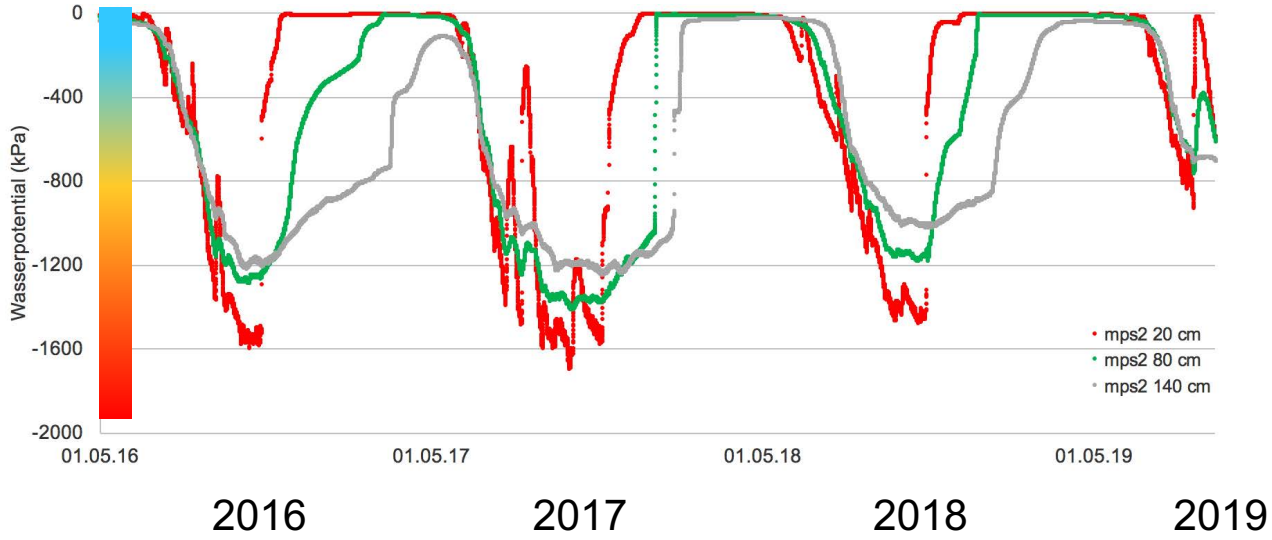
Oak

Saillon, Valais, 850 masl, Exp SE

Soil drying mainly because of transpiration



With roots



Without roots