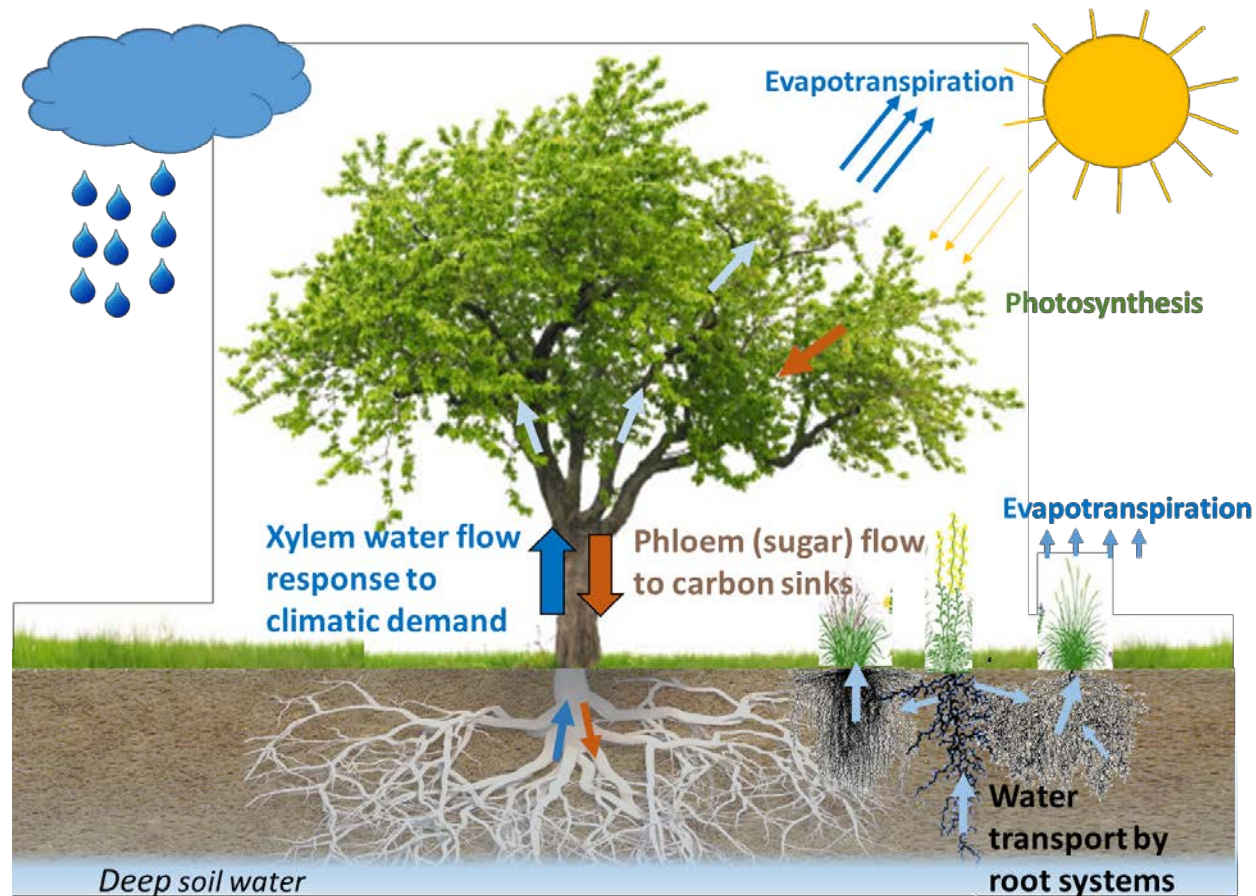


> Can NMR become a tool of choice to study ecosystems directly in the fields?

Guilhem Pagés

➤ Carbon sequestration

✓ Critical to limit global warming



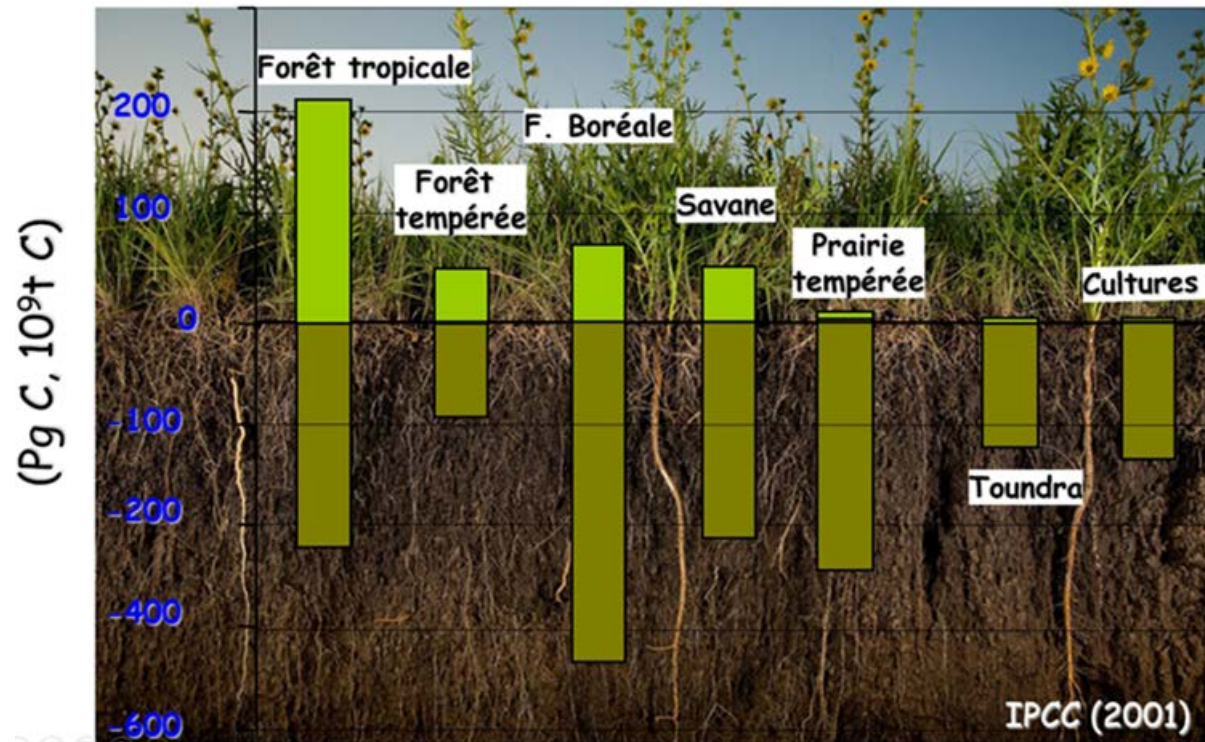
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➤ Carbon sequestration

- ✓ Critical to limit global warming
- ✓ Forest and grasslands are playing a major role in the sequestration of carbon



> Carbon sequestration

- ✓ Critical to limit global warming
- ✓ Forest and grasslands are playing a major role in the sequestration of carbon

 Critical to have knowledge on water content/flux in plants

 What are the analytical methods to estimate sap flows?



➤ Sap flow measurements

✓ *In situ* measurements

- Indirect methods (gravimetric measurements, lysimeters)
- Direct methods (heat balance, gas exchange)



➤ Sap flow measurements

- ✓ *In situ* measurements
 - Indirect methods (gravimetric measurements, lysimeters)
 - Direct methods (heat balance, gas exchange)
- ✓ Laboratory analytical methods
 - X-ray
 - MRI



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➤ Sap flow measurements

✓ *In situ* measurements

- Indirect methods (gravimetric measurements, lysimeters)
- Direct methods (heat balance, gas exchange)

✓ Laboratory analytical methods

- X-ray
- MRI

 There is a need to develop new sensor performing localized measurements directly *in situ*

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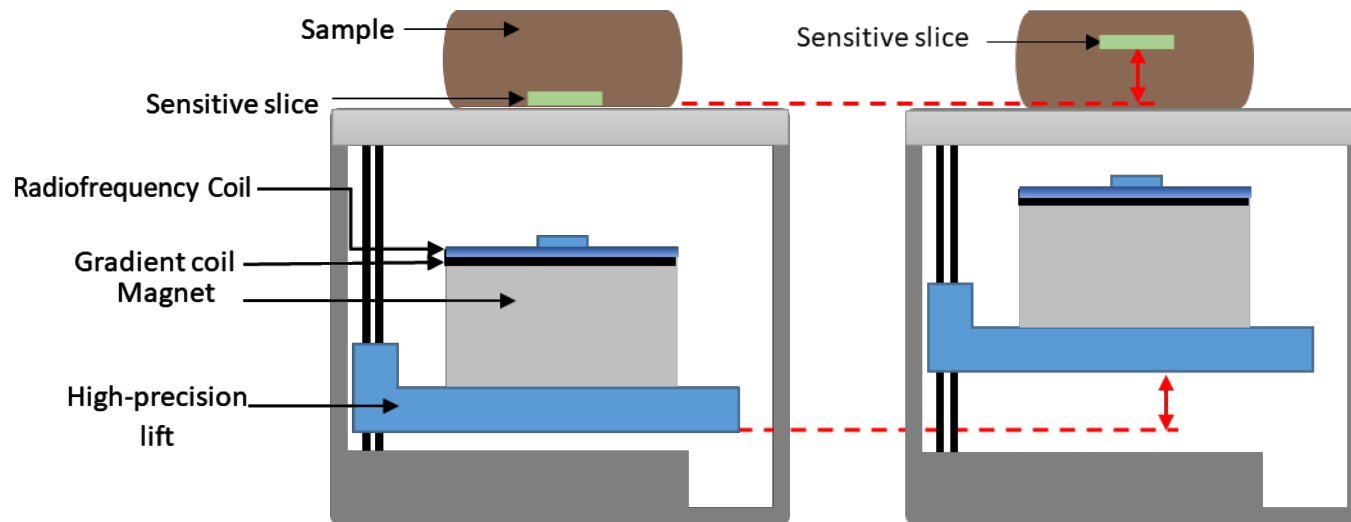
Low-field MRI an interesting solution

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➤ Going outside with an MRI

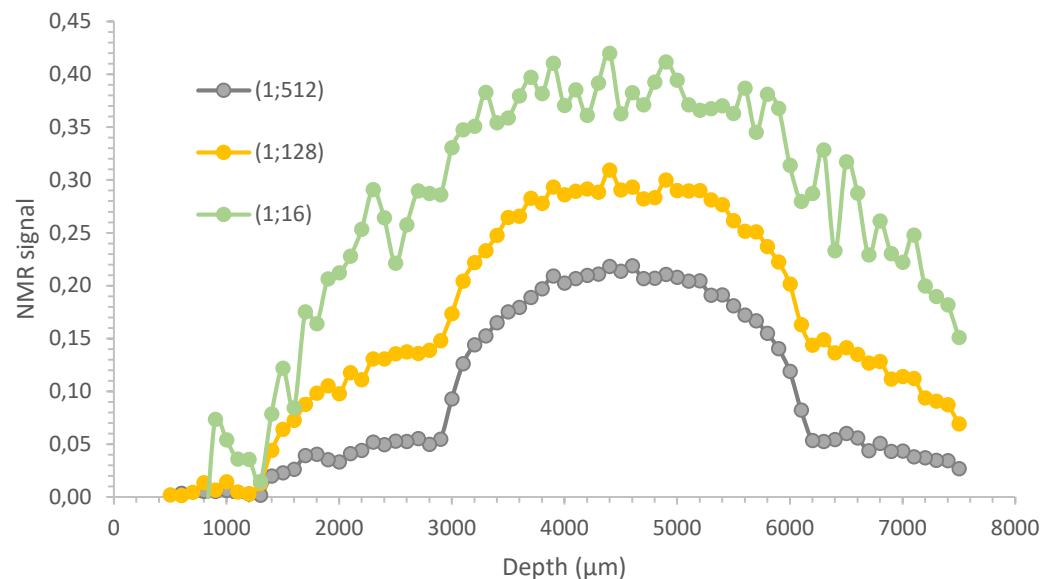
➤ Portable MRI

- ✓ Chose commercial solution able to match our needs
 - Spatial localization
 - NMR MOUSE => Background gradient perpendicular to the magnet surface



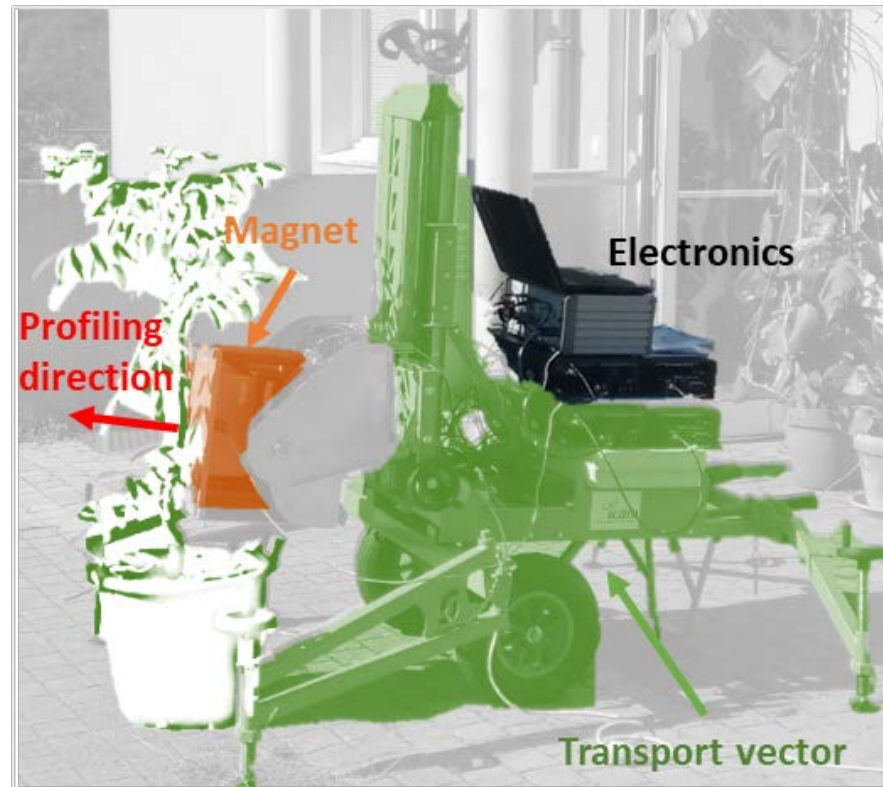
➤ 1D Images

- ✓ MRI signal in function of the measurement depth (lift position)
 - CPMG pulse train to record signal decay
 - Increase SNR
 - Signal might be T_2 -weighted



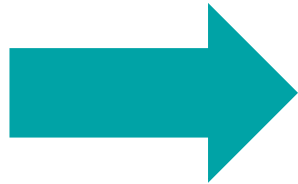
> Movable MRI

- ✓ Design of a vector to position the magnet against the plant

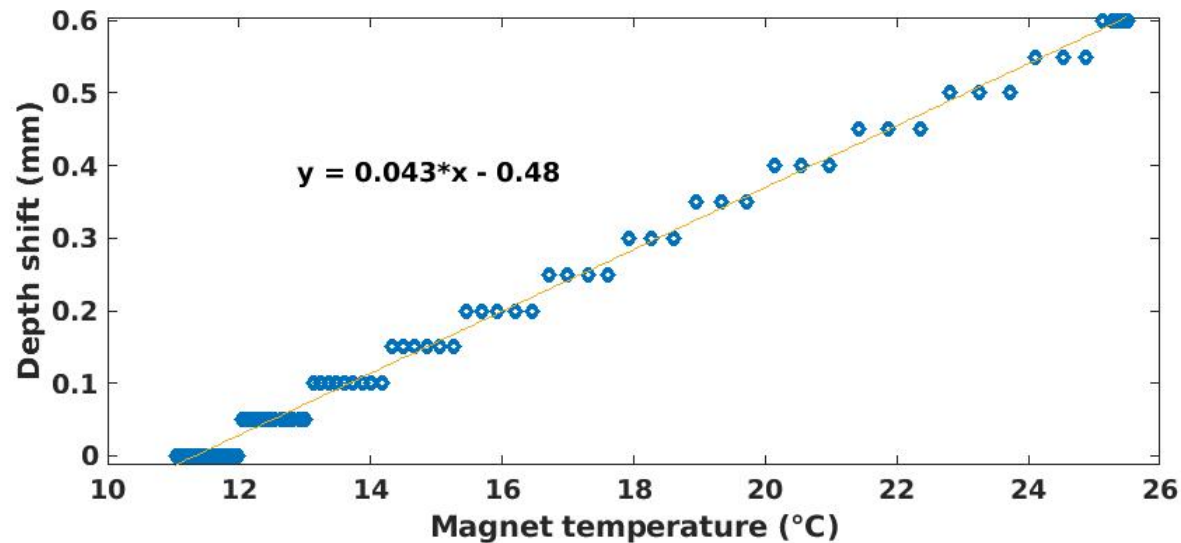


➤ Magnet temperature changes

- ✓ Magnetic field intensity of permanent magnet is temperature dependent

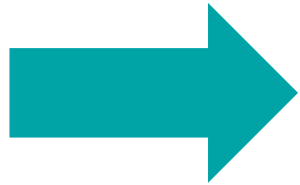


Slice position is moving with magnet temperature changes

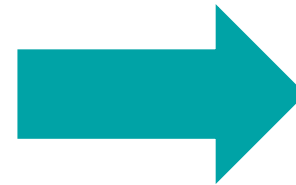
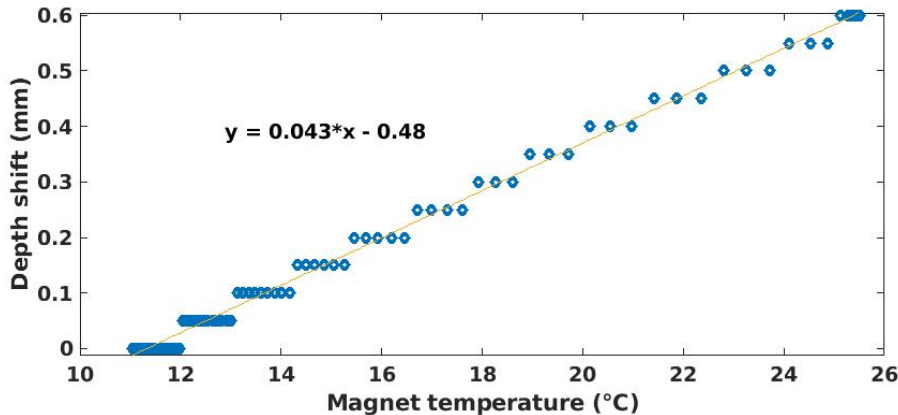


> Magnet temperature changes

- ✓ Magnetic field intensity of permanent magnet is temperature dependent



Slice position is moving with magnet temperature changes



$\sim 45 \mu\text{m}/^\circ\text{C}$



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Collaboration AgroScan, INRAE Rennes

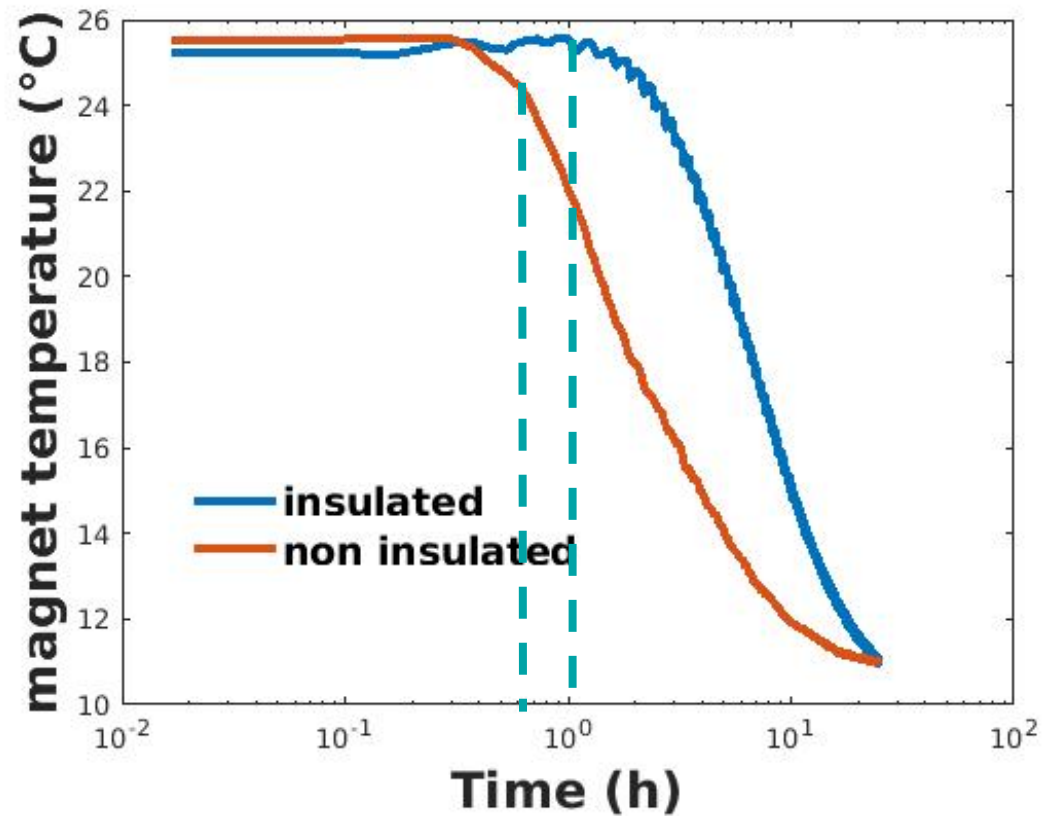
> Slice position correction

- ✓ Insulation to delay magnet temperature variation



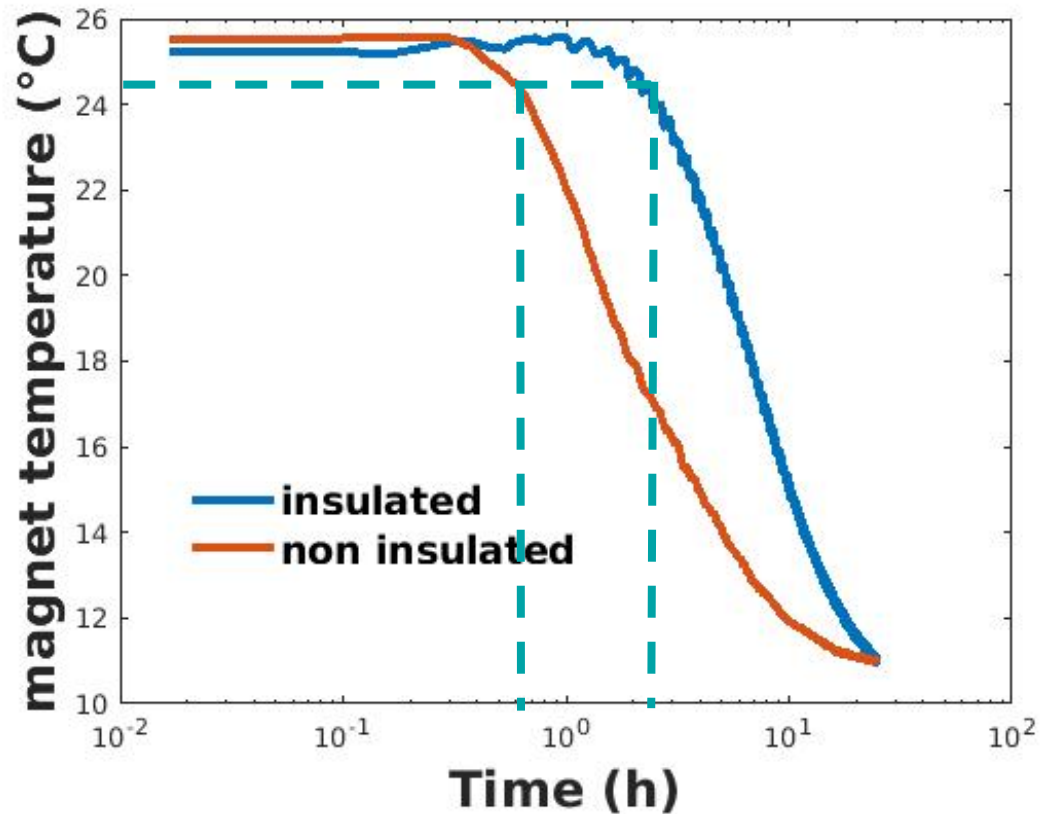
➤ Slice position correction

- ✓ Insulation to delay magnet temperature variation



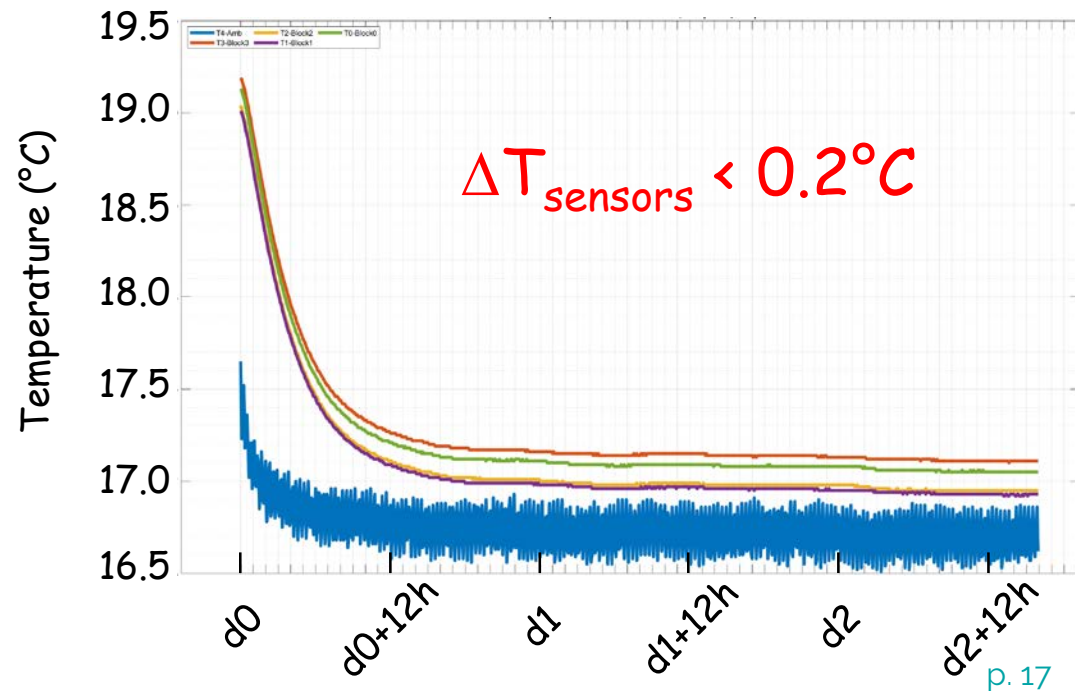
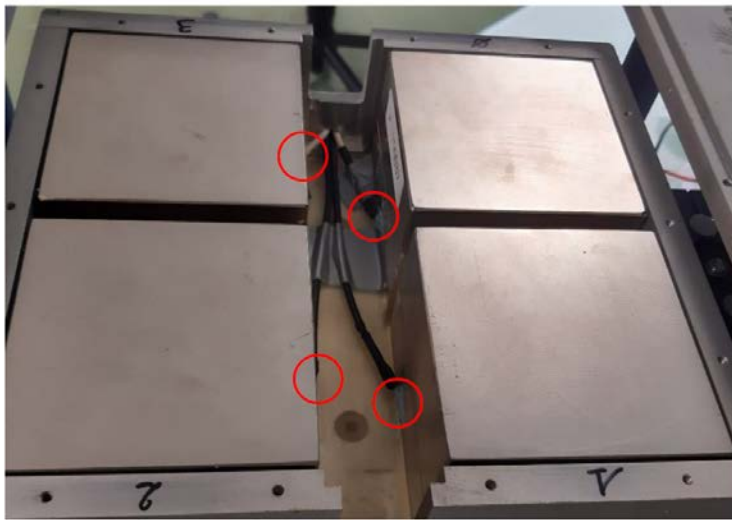
➤ Slice position correction

- ✓ Insulation to delay magnet temperature variation



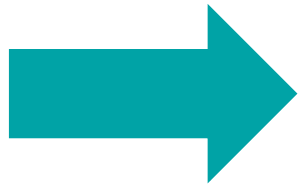
➤ Slice position correction

- ✓ Insulation to delay magnet temperature variation
- ✓ Retroaction on the magnet position when temperature changes detected



➤ Slice position correction

- ✓ Insulation to delay magnet temperature variation
- ✓ Retroaction on the magnet position when temperature changes detected






Work in progress

> Studying agroecosystems

Article

Circadian Variation of Root Water Status in Three Herbaceous Species Assessed by Portable NMR

Magali Nuixé^{1,2,3}, Amidou Sissou Traoré^{1,2,*} , Shannan Blystone^{1,2,3}, Jean-Marie Bonny^{1,2}, Robert Falcimagne³, Guilhem Pagès^{1,2}  and Catherine Picon-Cochard^{3,*} 

Plants 2021, 10, 782. <https://doi.org/10.3390/plants10040782>

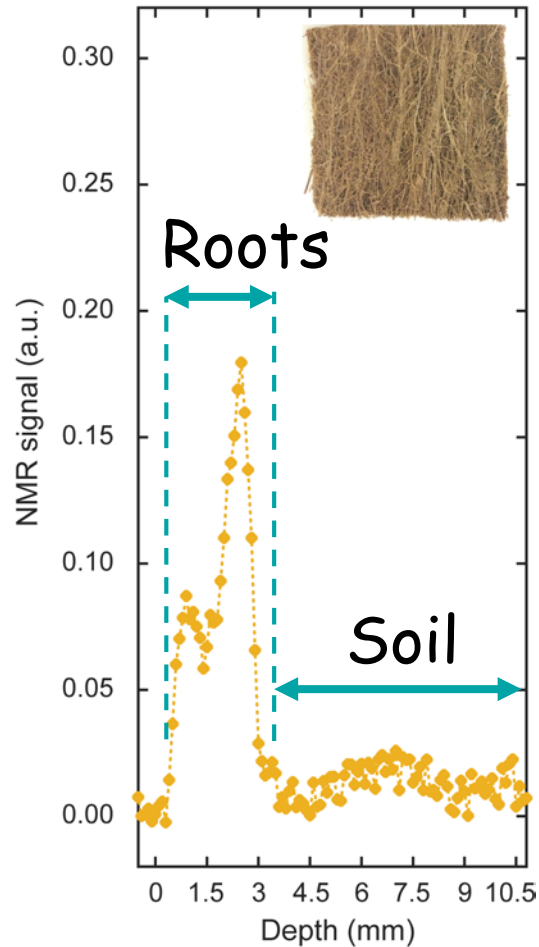
➤ Root system

- ✓ Roots: 1st organ involved to meet plant water demand
- ✓ Key to know their hydration conditions
- ✓ Three species in rhizotrons inside a climatic chamber
 - 1D profile (NMR signal vs depth)
 - T_2 at 1 depth



➤ Rhizotron NMR profile analysis

Dactylis



✓ Differentiate the different rhizotron compartments



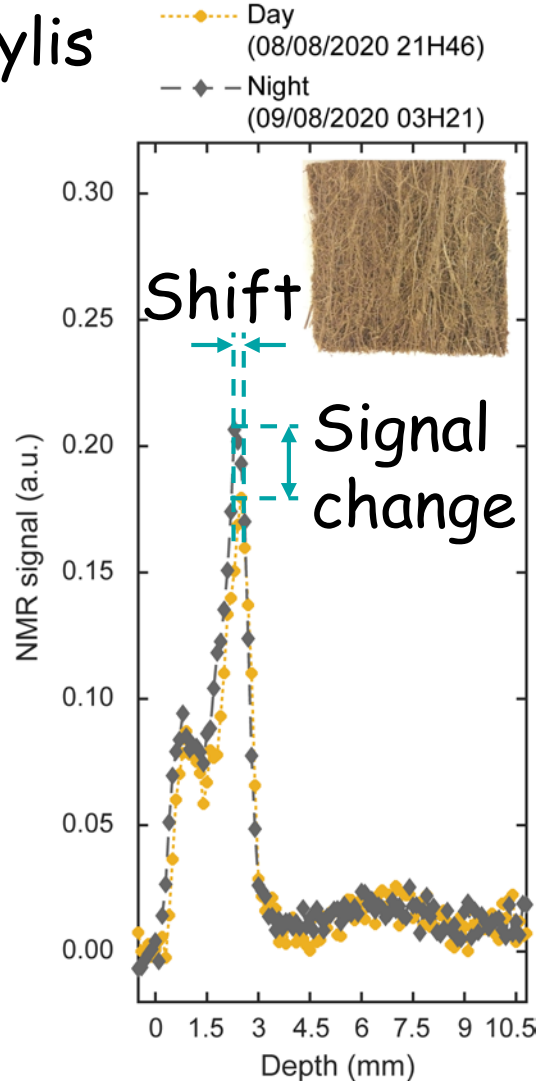
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➤ Rhizotron NMR profile analysis

Dactylis

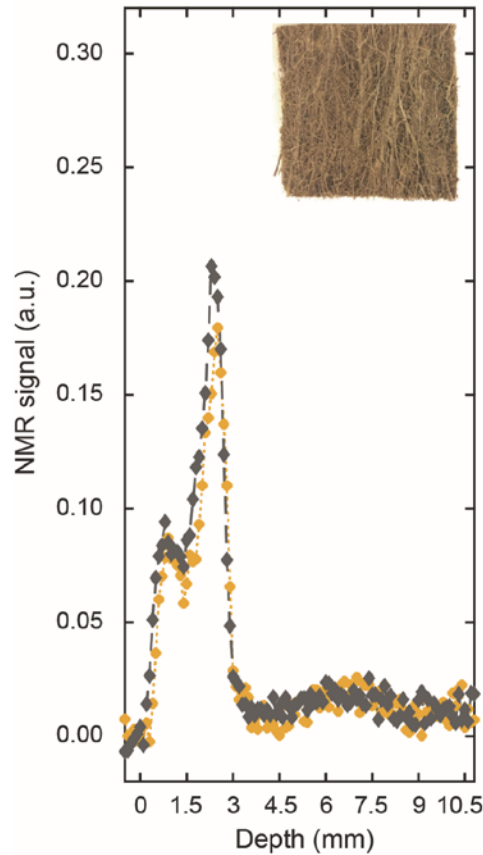


- ✓ Differentiate the different rhizotron compartments
- ✓ ~200 μm shift due to 3°C temperature difference between day and night
- ✓ Signal intensity weighted by water diffusion and transpiratory flux

> Species comparison

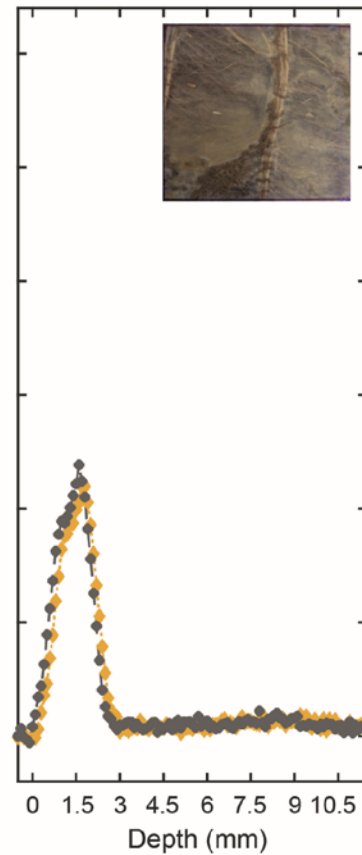
Dactylis

---◆ Day
(08/08/2020 21H46)
-◆- Night
(09/08/2020 03H21)



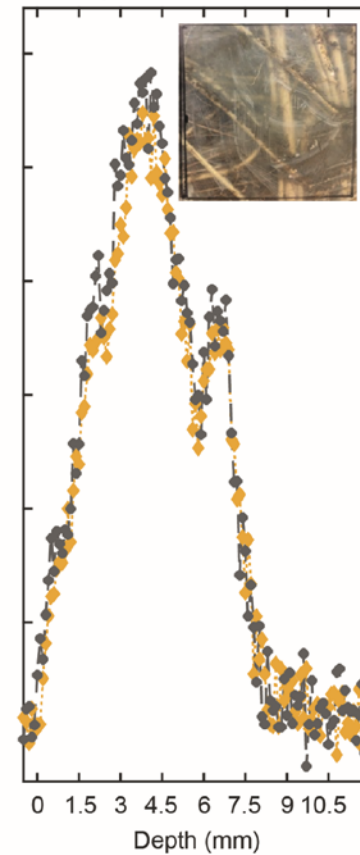
Plantain

---◆ Day
(24/07/2020 21H59)
-◆- Night
(25/07/2020 03H39)



Luzerne

---◆ Day
(05/09/2020 21H36)
-◆- Night
(06/09/2020 03H22)



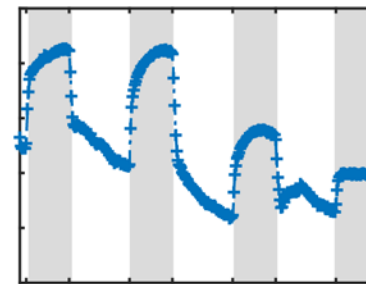
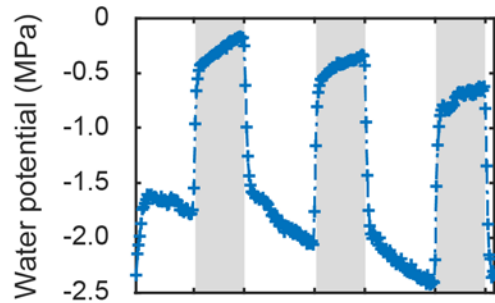
➤ Comparison NMR and ecophysiological parameters

Dactylis

Plantain

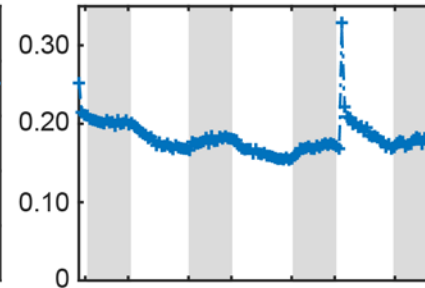
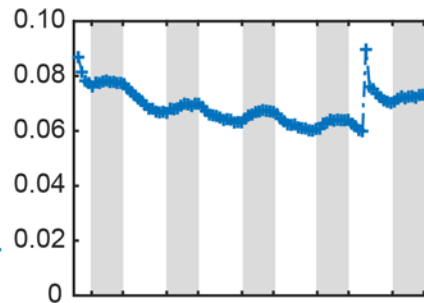
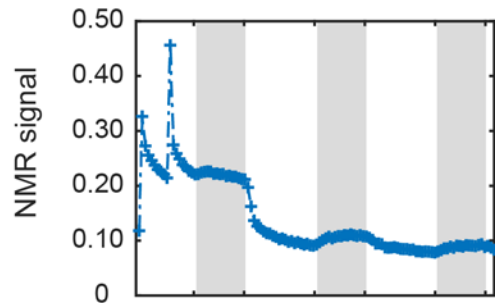
Luzerne

Leaves



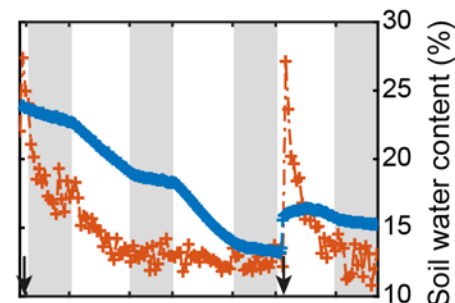
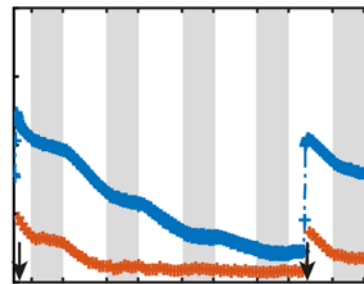
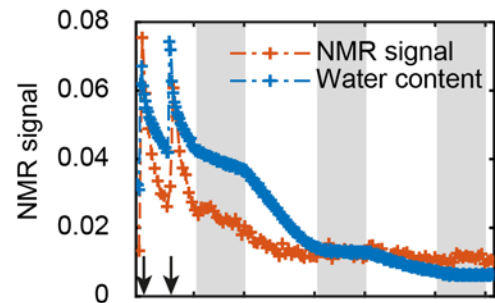
No hydric stress

Roots



Circadian variation

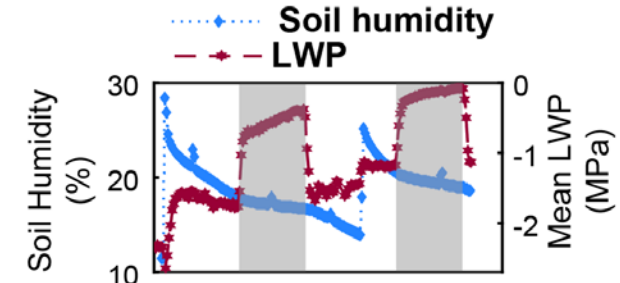
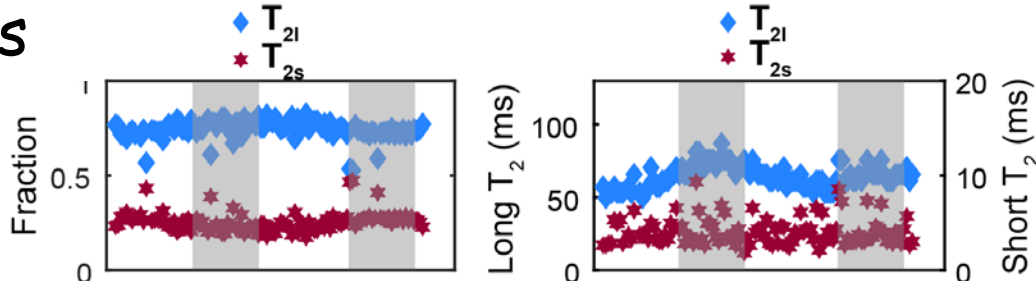
Soil



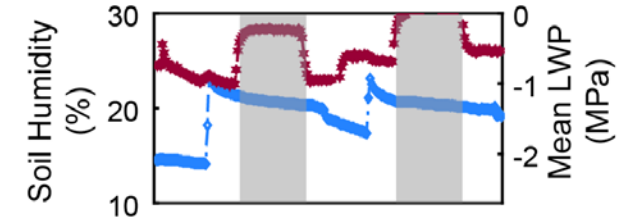
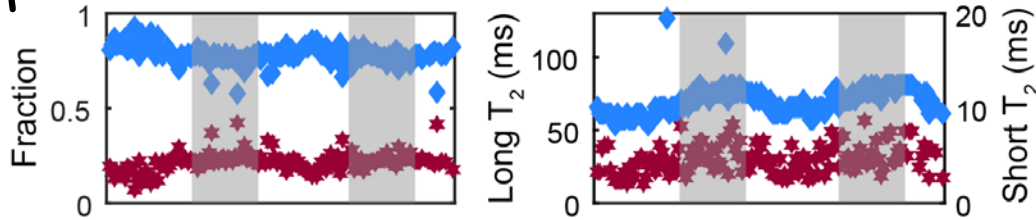
Similar signal evolution

➤ Relaxation analysis

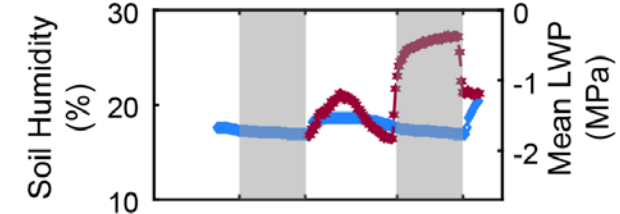
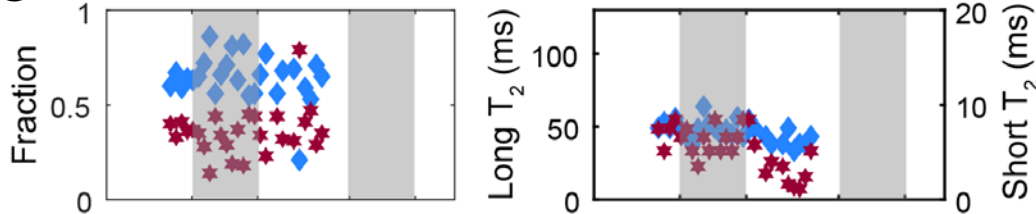
Dactylis



Plantain



Luzerne



No change

Circadian
variation
for T_{2s}

Luzerne
stressed?



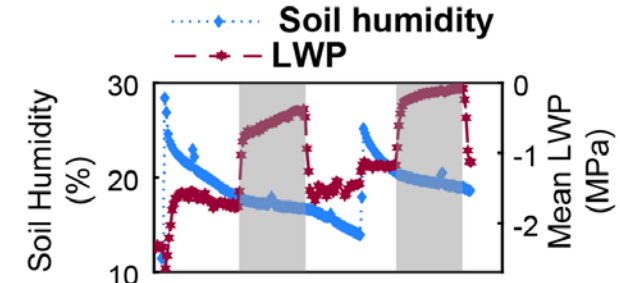
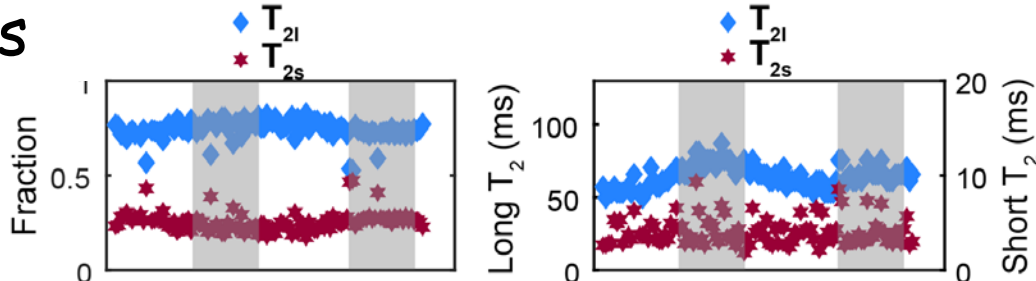
INRAE

In situ NMR

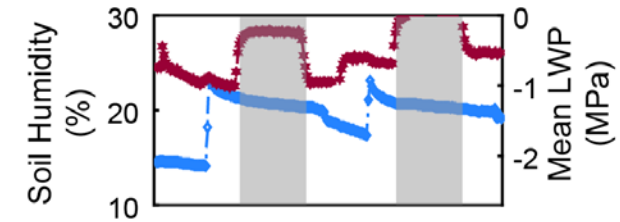
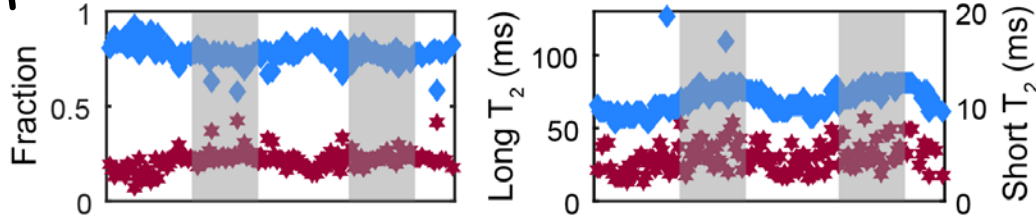
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➤ Relaxation analysis

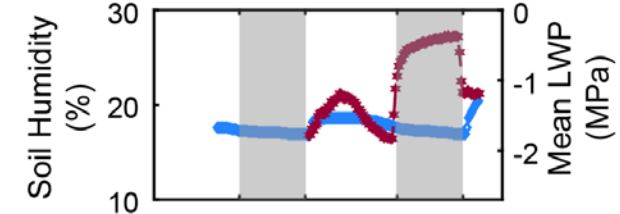
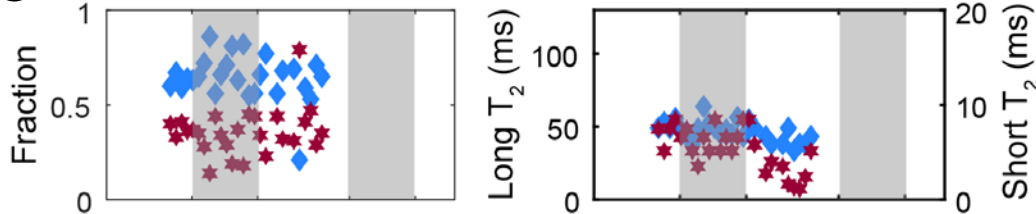
Dactylis



Plantain



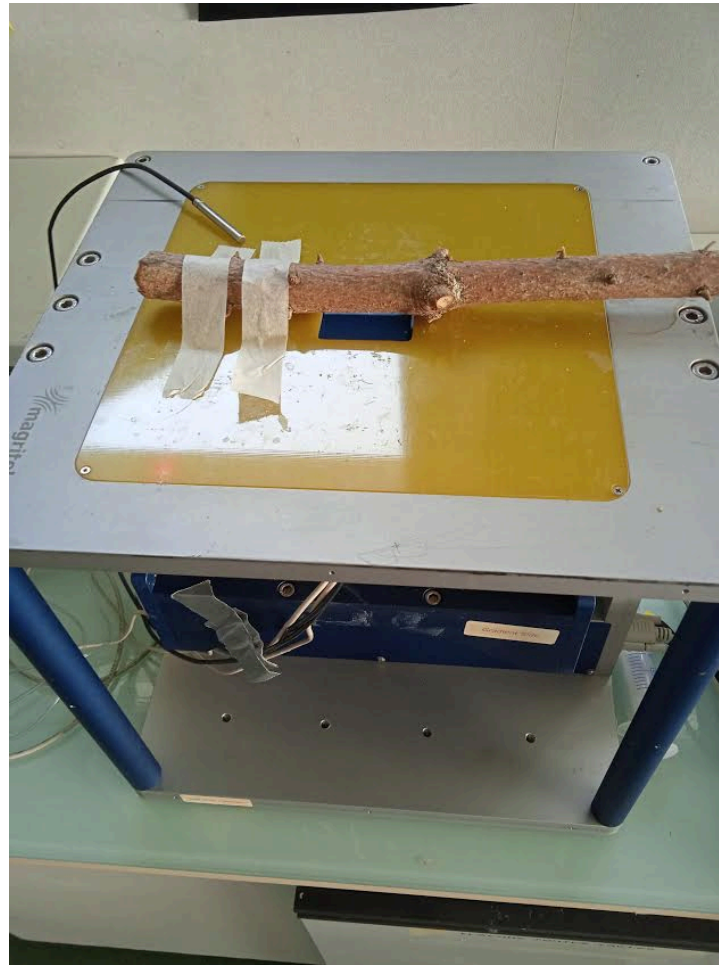
Luzerne



Does T_{2s} variation depend on water flux?

WIP

➤ Wood hydration

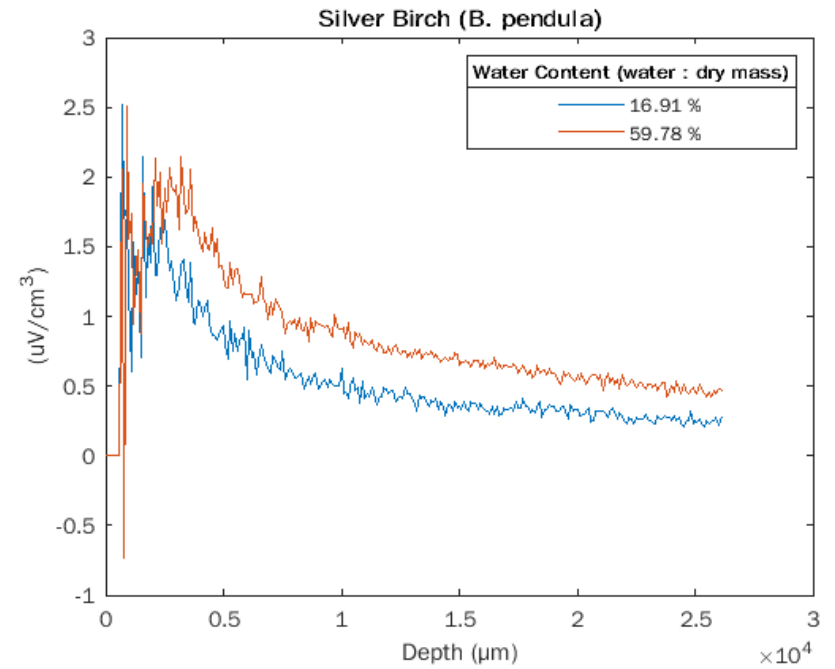
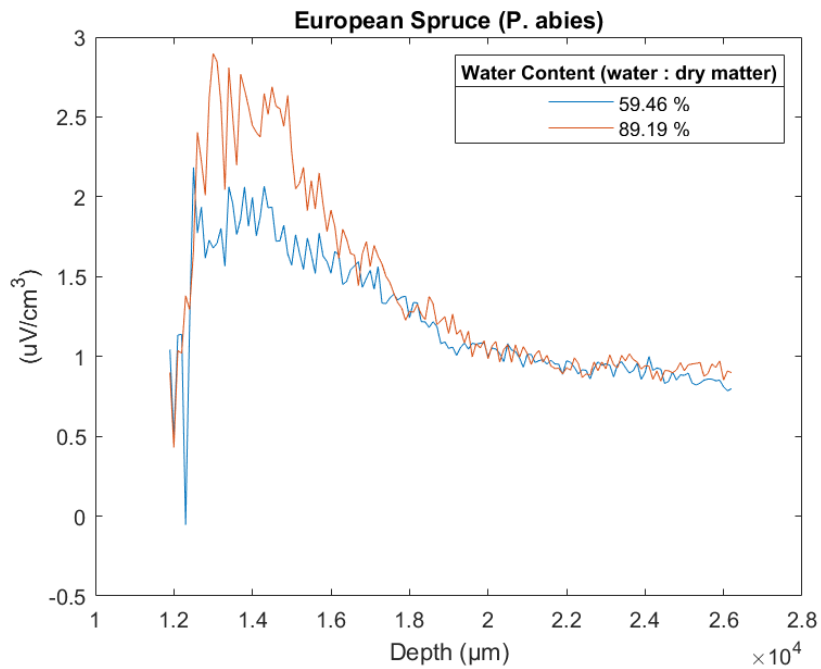


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➤ Wood hydration



➤ Take-home message

- ✓ NMR-MOUSE is a useful magnet to characterize agroecosources directly into the fields
- ✓ Needs development to take into account daily temperature variations
- ✓ Despite possible sensitivity issues, first results are highly encouraging



➤ Acknowledgements



**I-SITE
CLERMONT**
Clermont Auvergne Project



VEGEPOLYS VALLEY
CULTIVONS L'AUDACE VÉGÉTALE

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