Measuring tree water content with a portable, unilateral magnet

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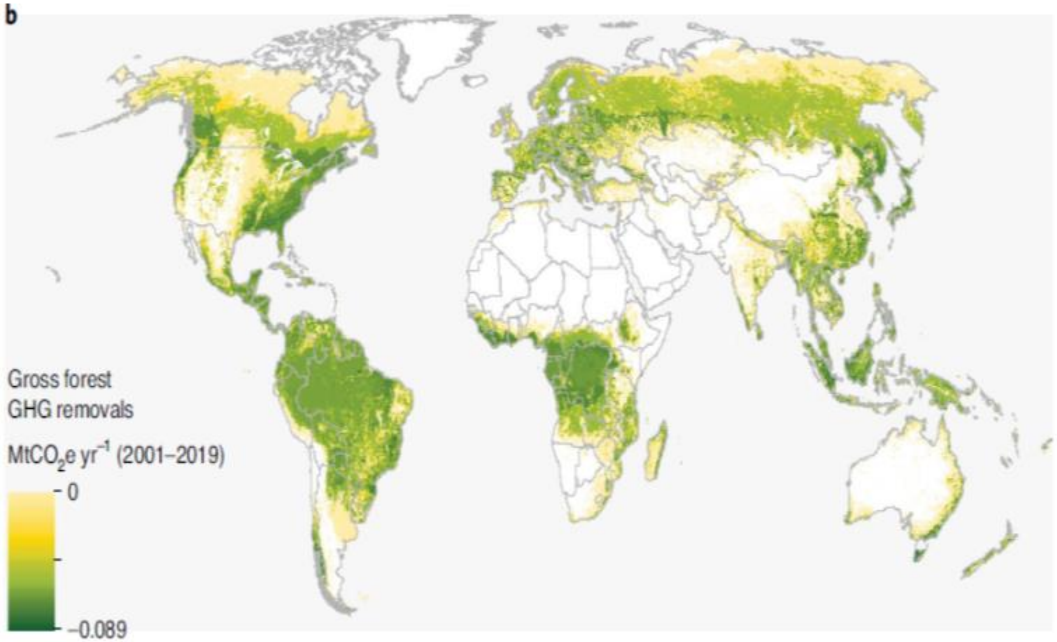
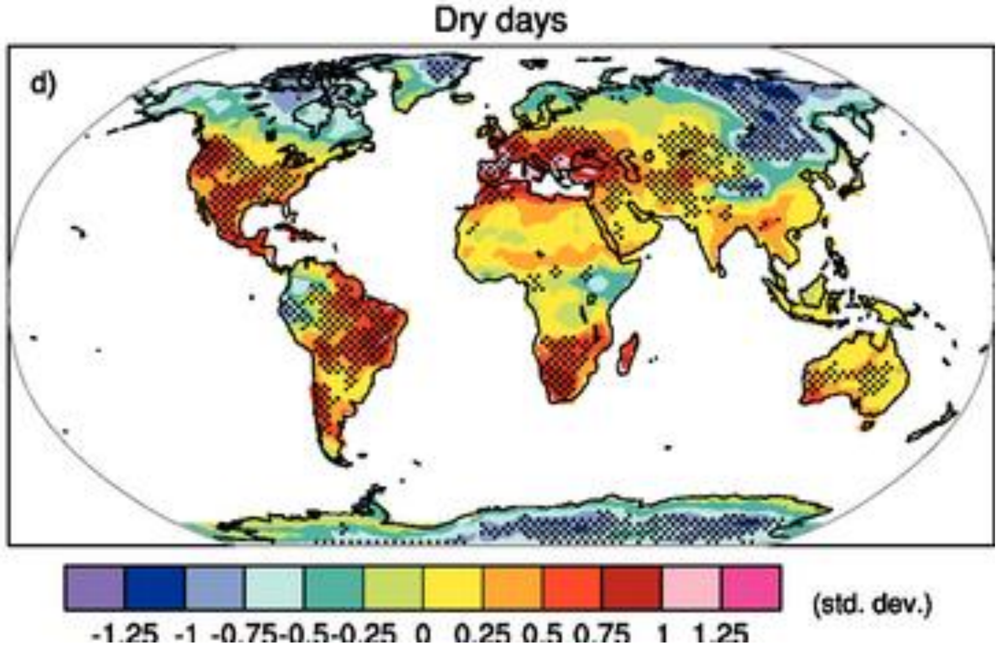
The future of forests as carbon sinks in a changing climate

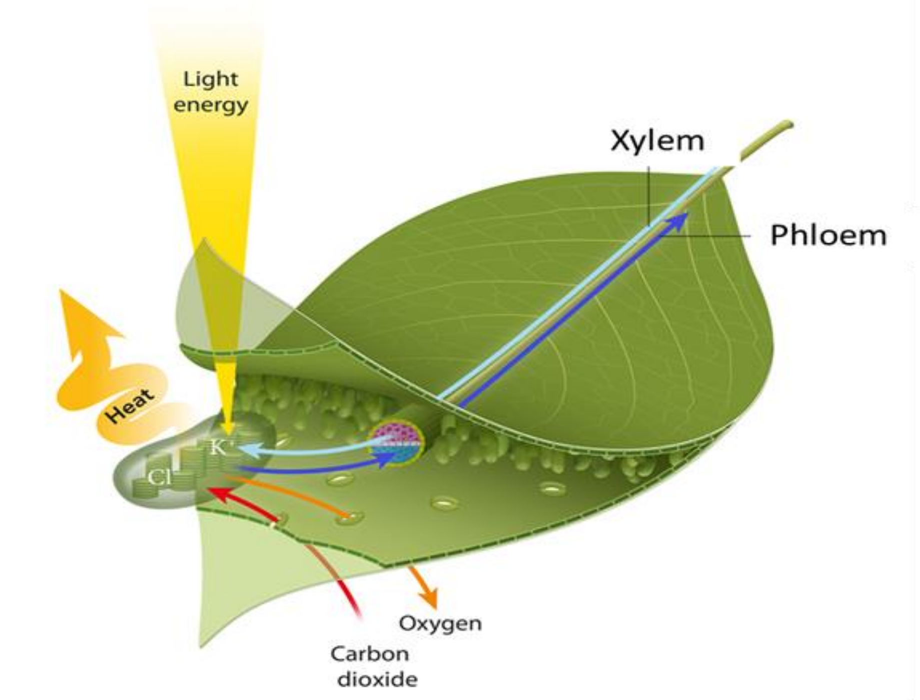


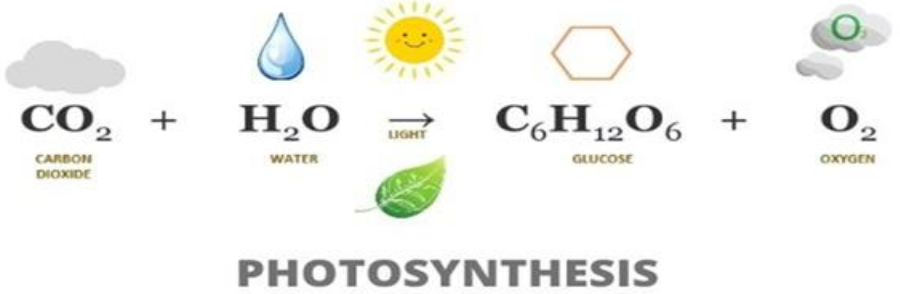


→ **Climate change will bring :**

- **More extreme weather events (drought, etc)**
- **Increased temperatures**

The water and carbon cycles are coupled





- **Water is a reactant**
- **Water loss during transpiration +++**

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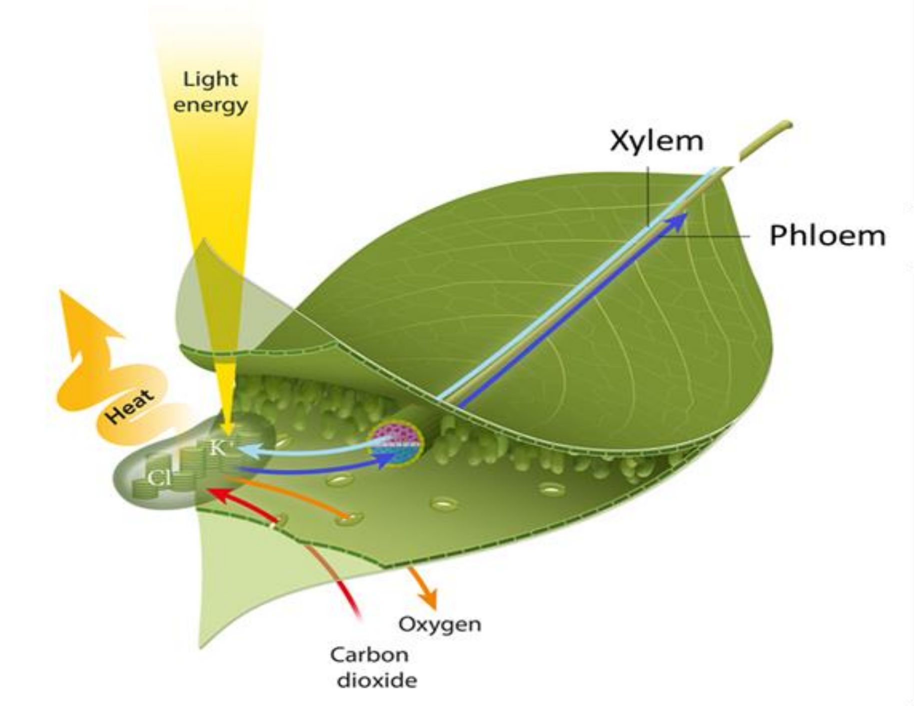
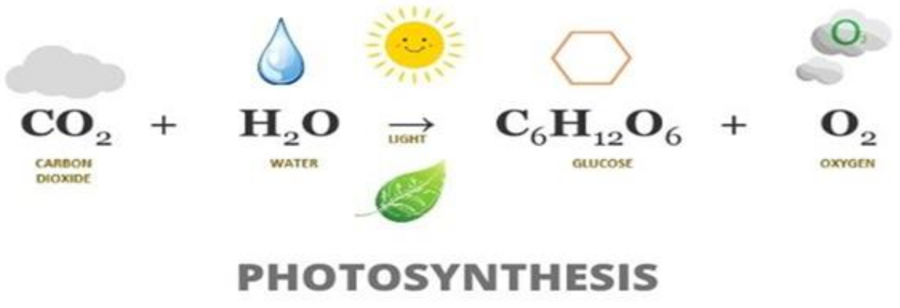


- **Water and carbon cycles coupled**
- **High water loss during transpiration**



Water dynamics key to understanding the future of forests as carbon sinks

How to measure water dynamics

- **Water content** : Fresh/dry weights, NIRS, high-field NMR
- **Xylem flow** : Sap flow meters, porometers, gravimetric methods, isotopic tracing, high-field NMR
- **Phloem flow** : Aphids, ^{11}C PET imaging, high-field NMR

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→ **However, all of these methods are either destructive, limited to the laboratory, or indirect**

Advantages of MRI in the plant sciences

- Non-invasive
- Sensitive to $^{1}H \longrightarrow$ water in biological systems
- Information about water movement in multiple water populations can be obtained (relaxometry)
- Multitude of information can be gathered with one instrument

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- Information about water movement in multiple water populations can be obtained (relaxometry)
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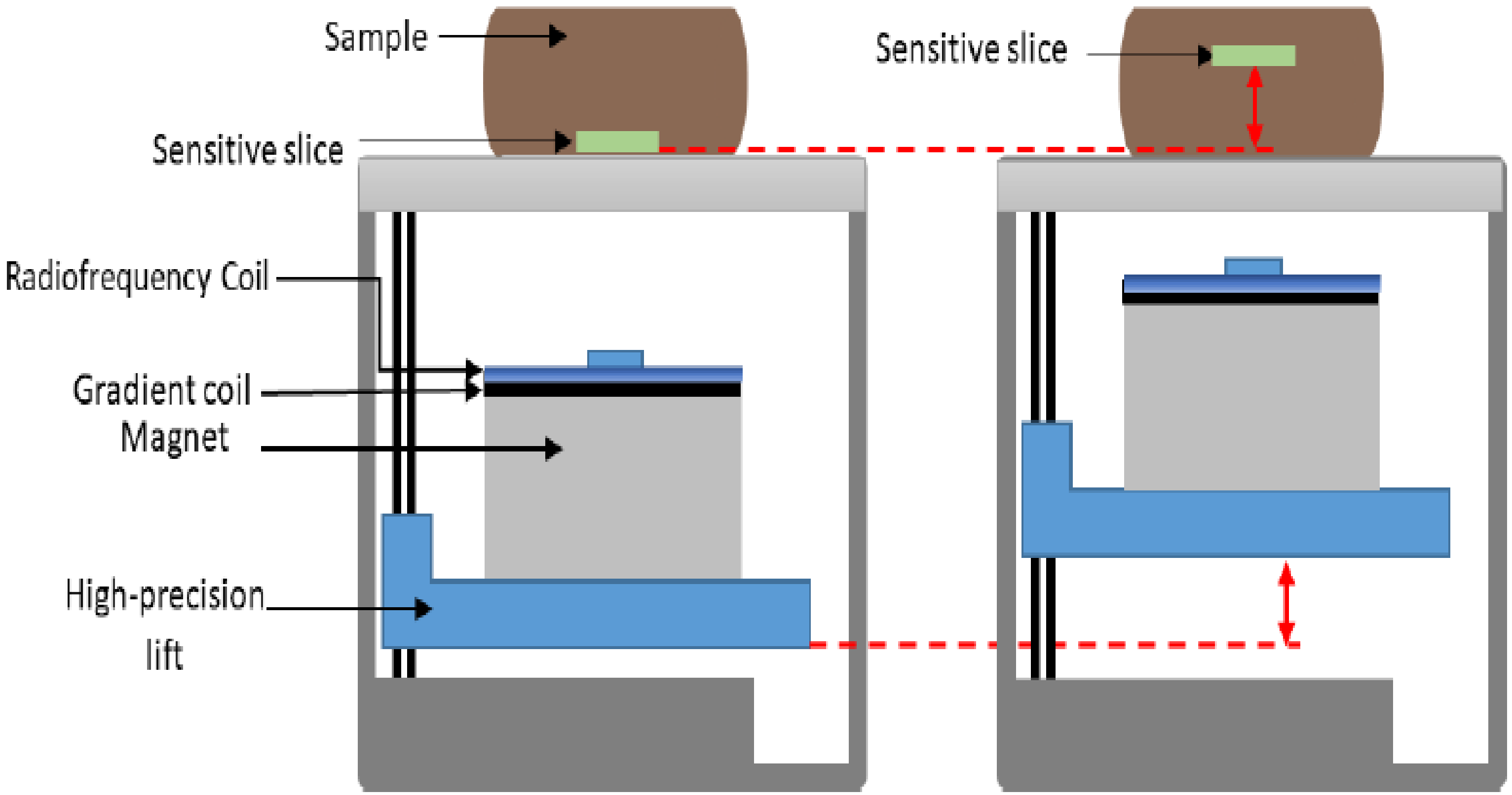
⟶ **But typically restricted to the lab**

A portable, unilateral device to study plants

The Nuclear Magnetic Resonance Mobile Universal Surface Explorer (NMR-MOUSE)



Taking the device into the field

The Nuclear Magnetic Resonance Mobile Universal Surface Explorer
(NMR-MOUSE)

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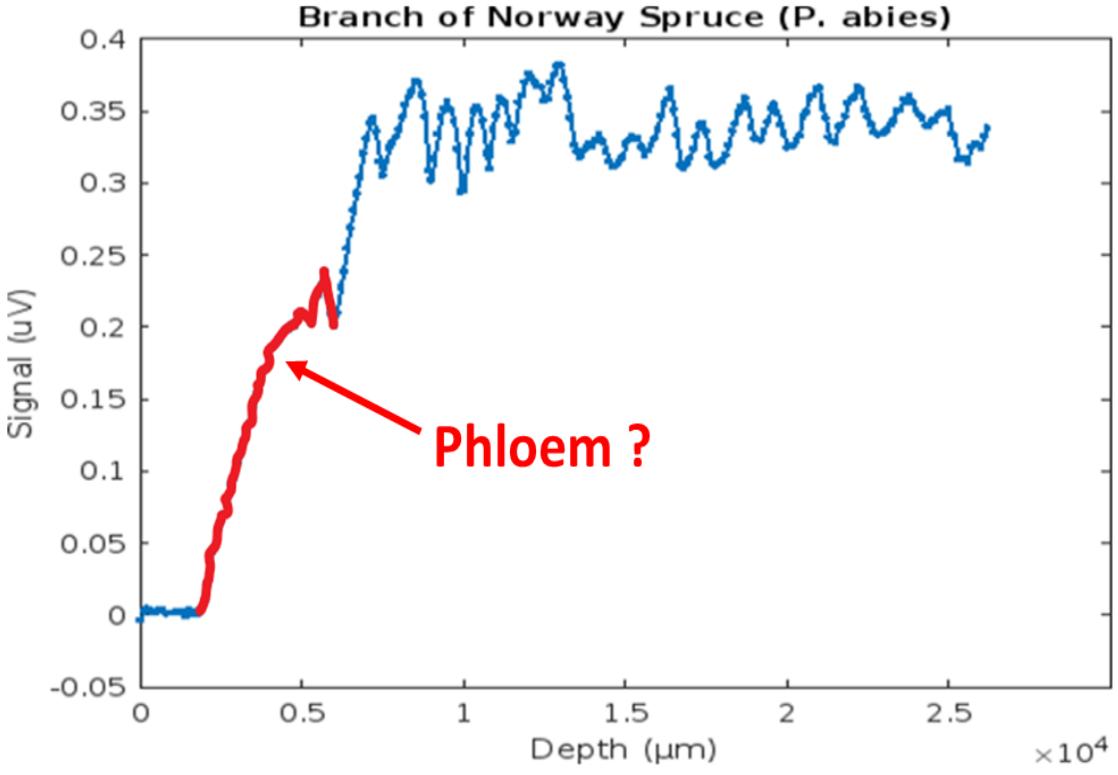

→ **Is it quantitative ?**

Methods

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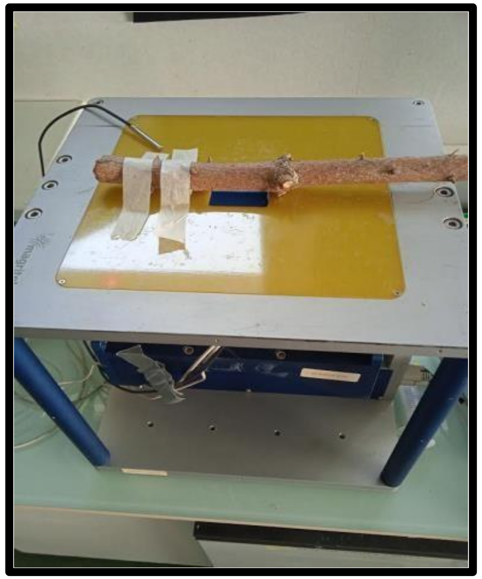
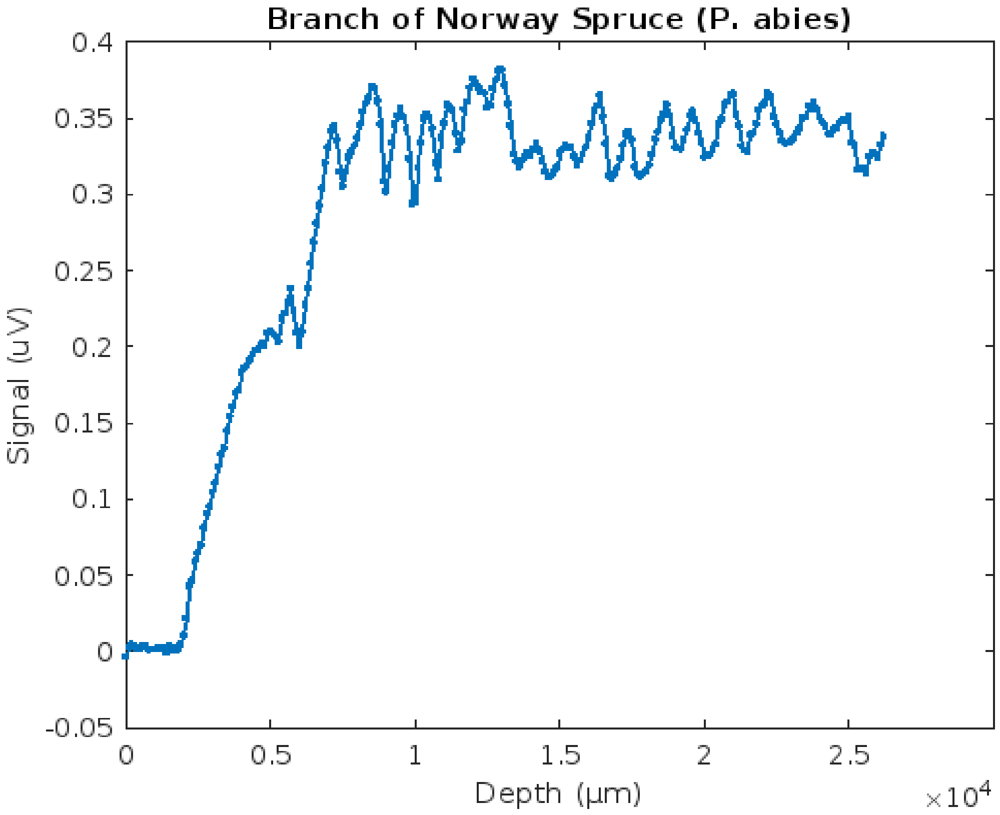
- 30 branches cut and measured over time as they dehydrated
- 6 species, including 2 functional types
- X-ray tomography scans performed to validate the location of the tissues
- Model of NMR signal as a function of water content
- 4 *in-situ* trees measured

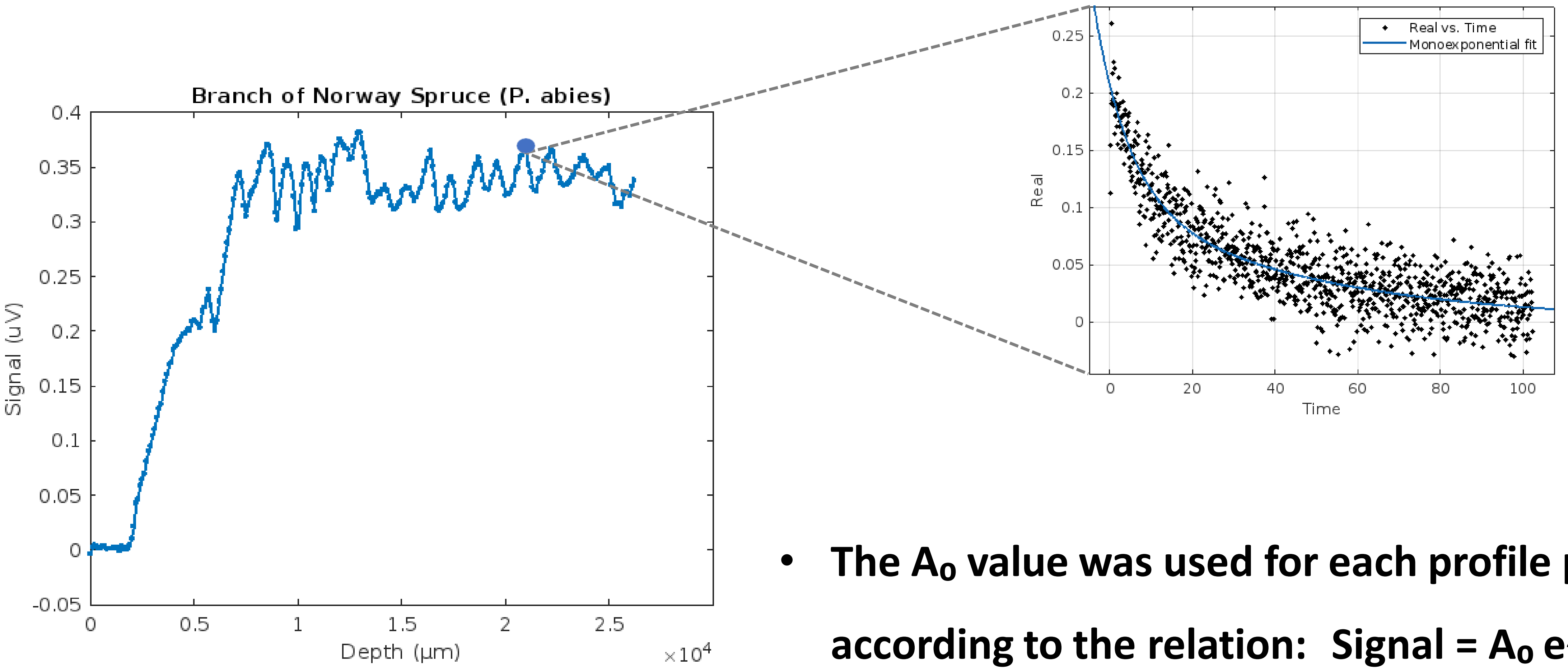


Constructing the profiles



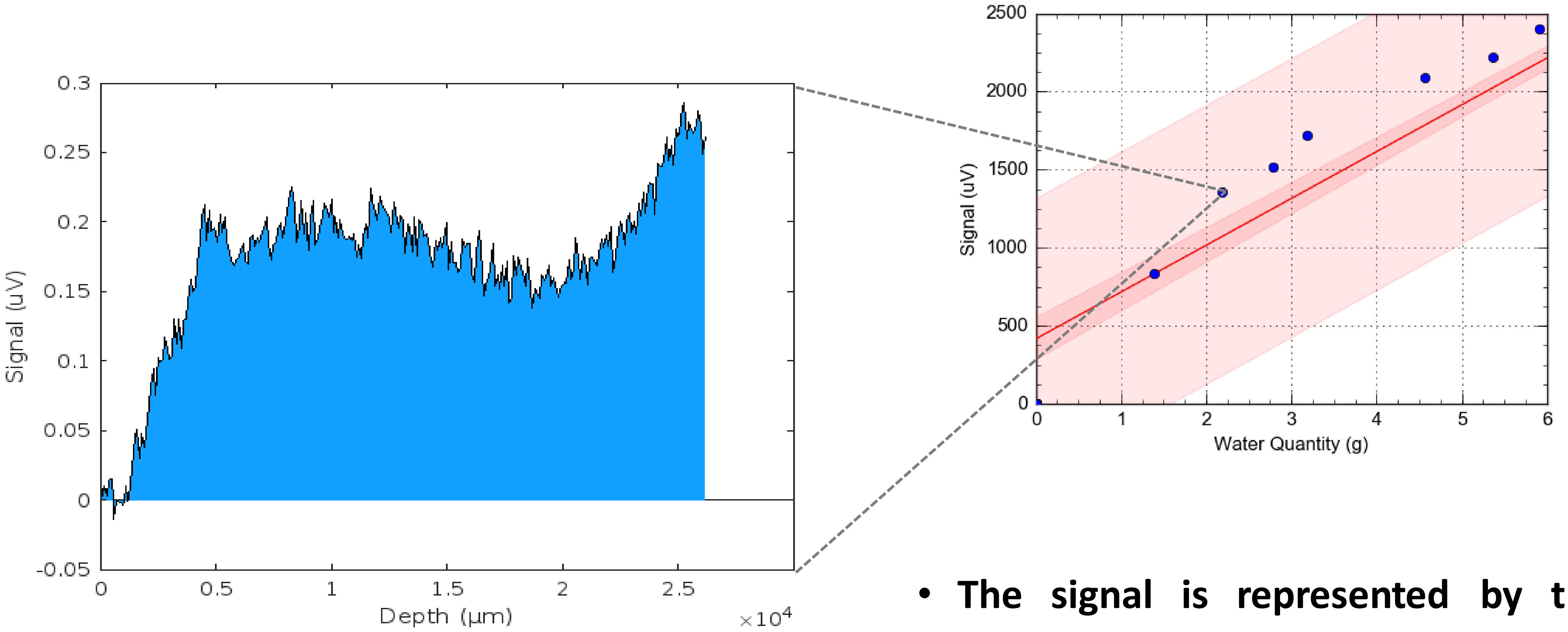
- **CPMG sequence at each depth, with parameters: TE=102, TR=3000, scans = 4, NrEchoes = 128, resolution 100 µm**

Constructing the profiles



- **The A_0 value was used for each profile point, according to the relation: Signal = A_0 e^-t/T2**

Making the model



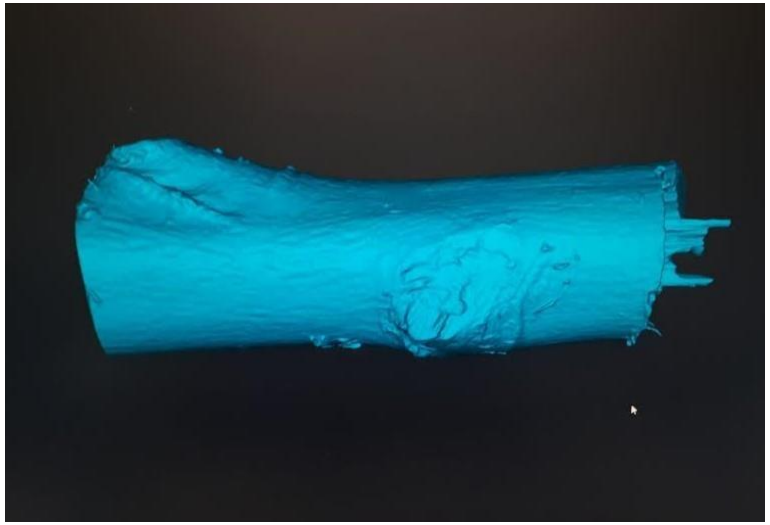
- **The signal is represented by the integral of A_0 profiles**

Making the model

Calculating Water Quantity in the NMR sensitive zone:

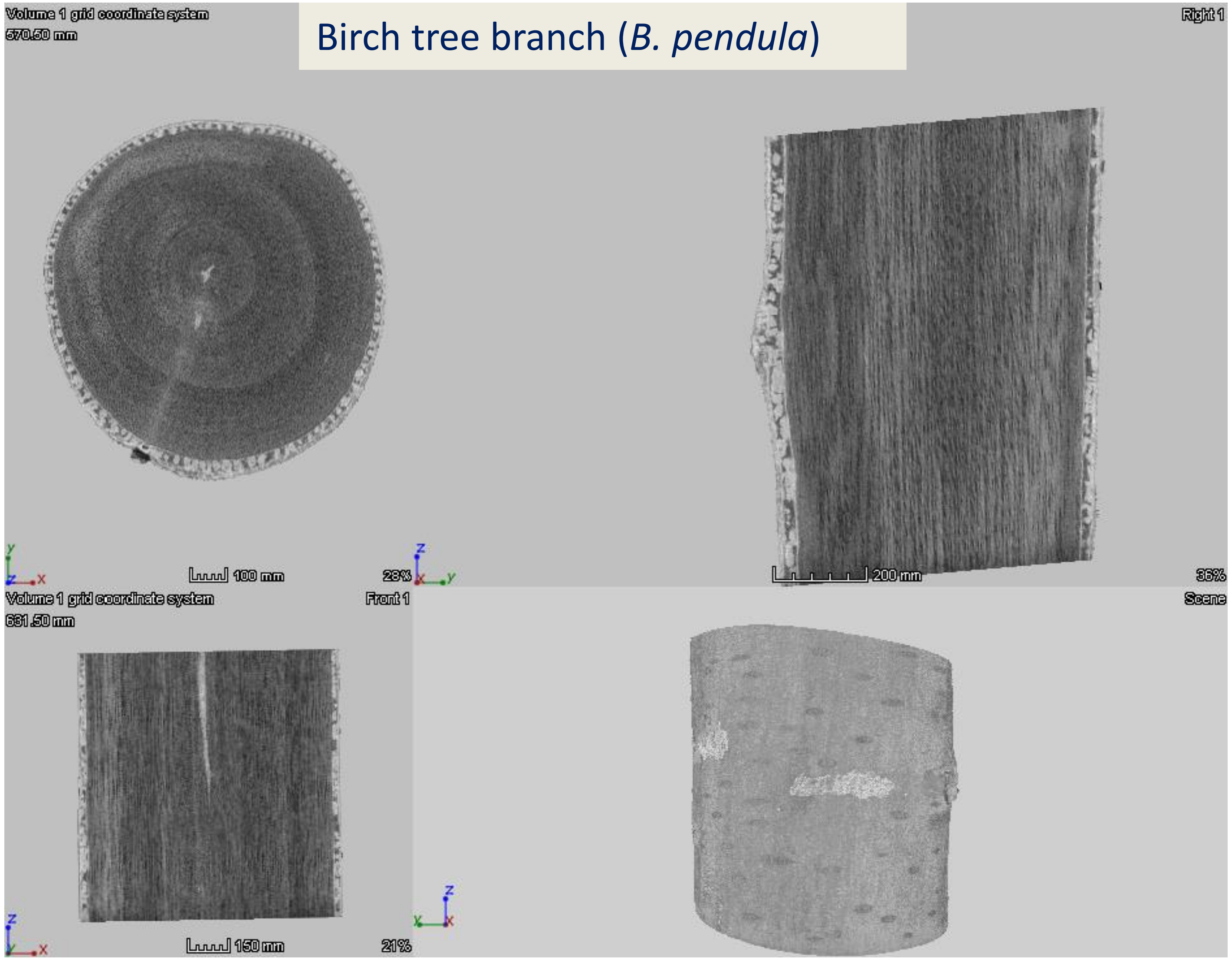
Water quantity (g) = Branch water content (g/cm³) X Volume of branch in sensor (cm³)

- Water content (g) was calculated by taking fresh and dry weights
- Volume (cm³) determined by taking 3D scans



Results

Determing the actual depth of different tissues



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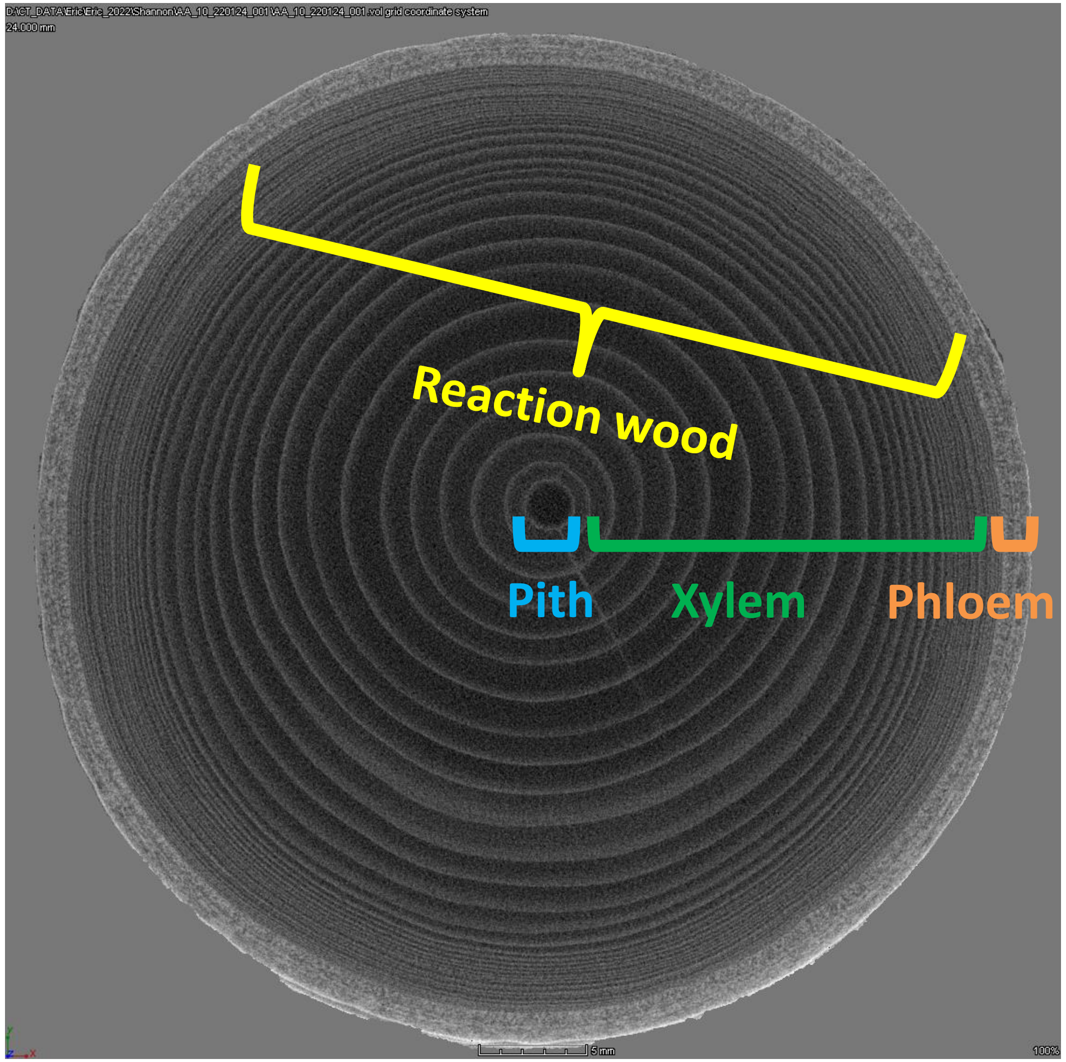
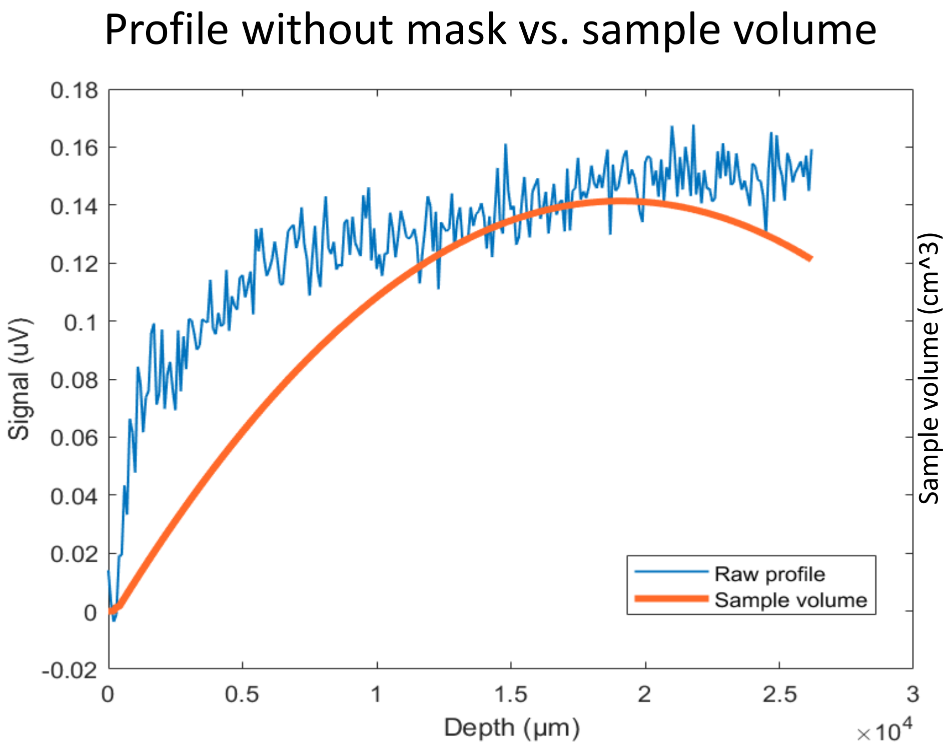


Locating water peaks



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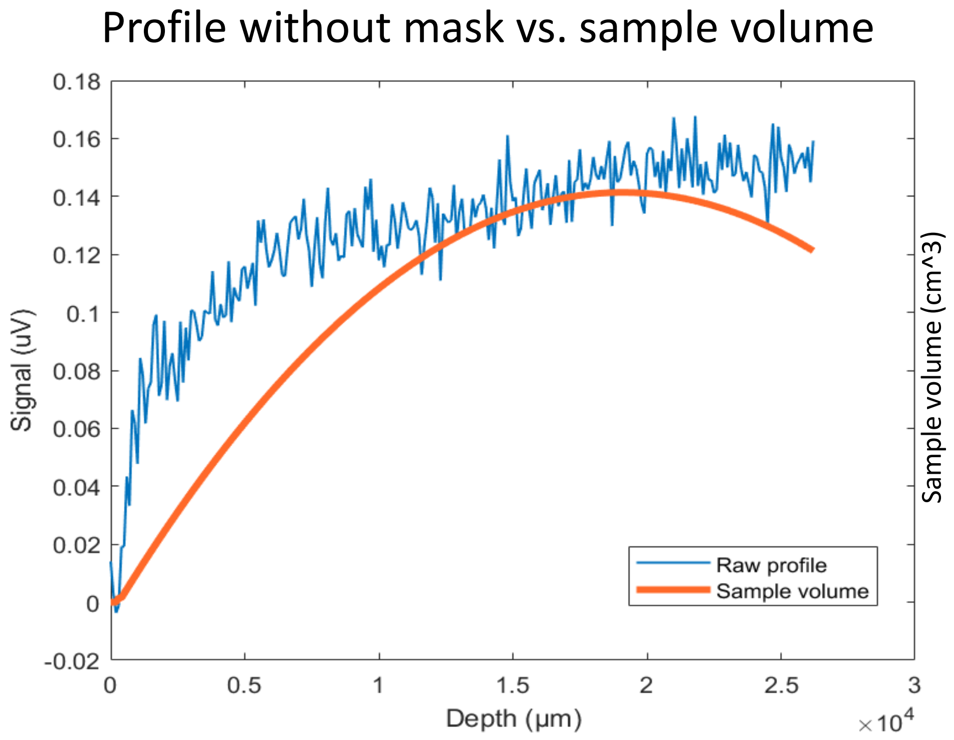
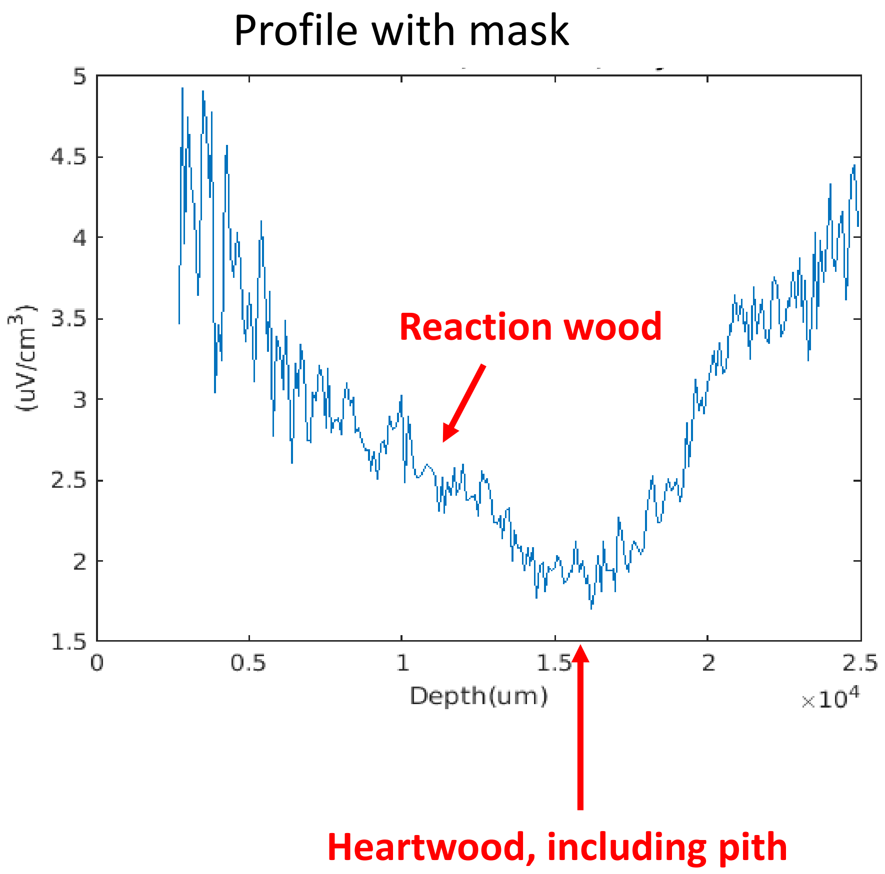
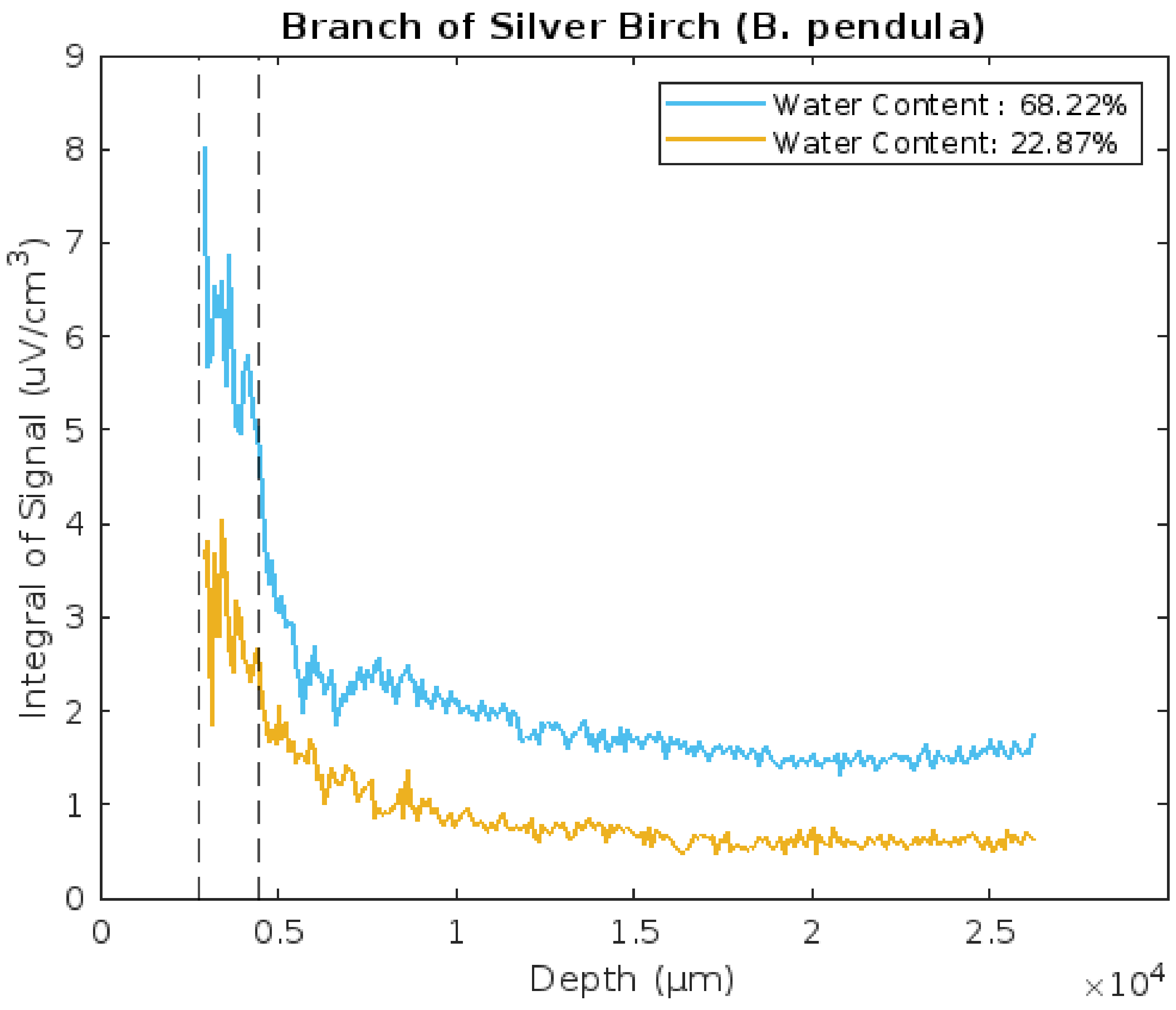




Can we locate conductive tissues from profile peaks ?



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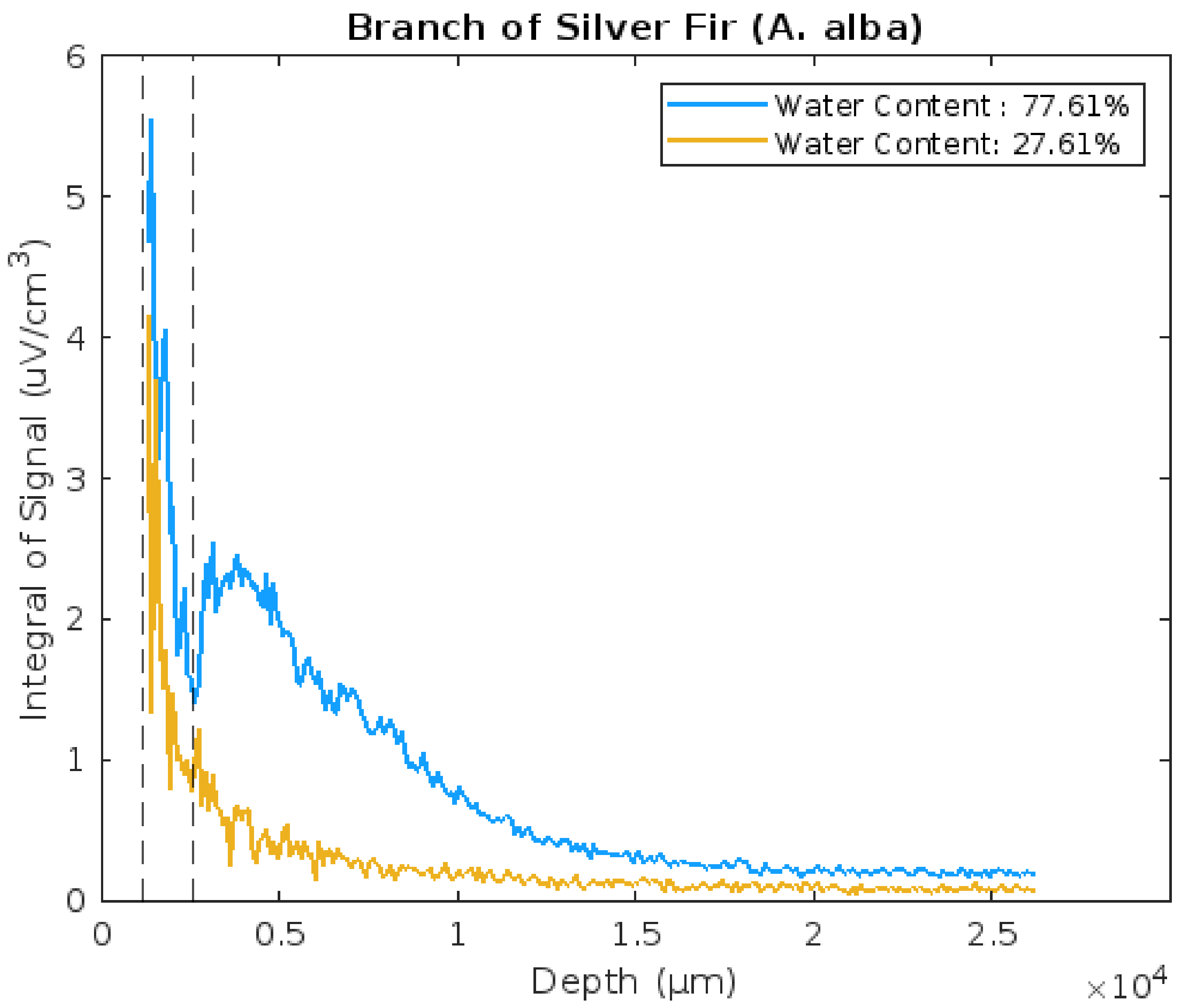
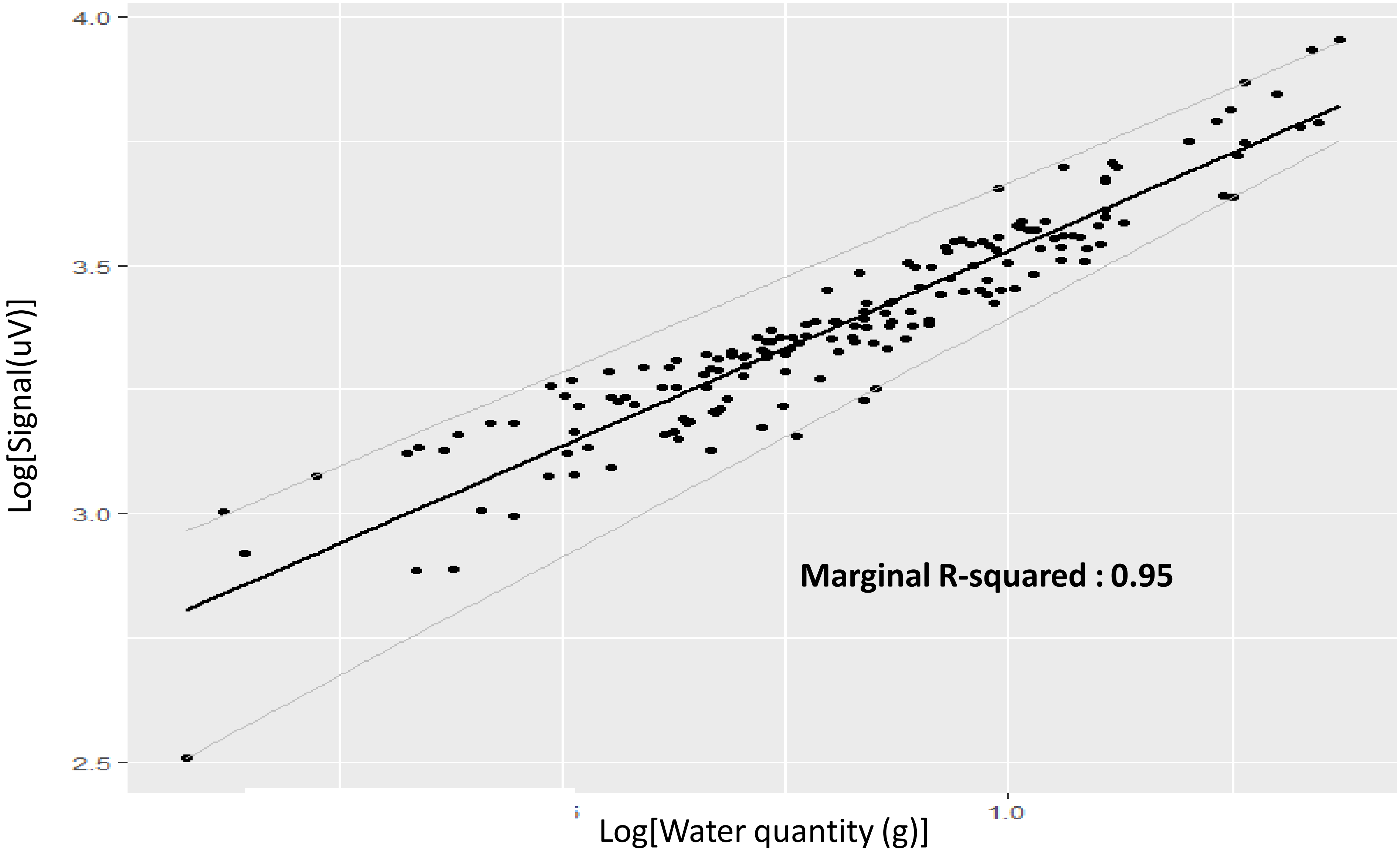


But is quantitative ?



The linear relationship between water quantity and signal

Statistical Treatment :

- ANCOVA
- Collinearity between species and functional type as variables are nested
- Mixed model used :

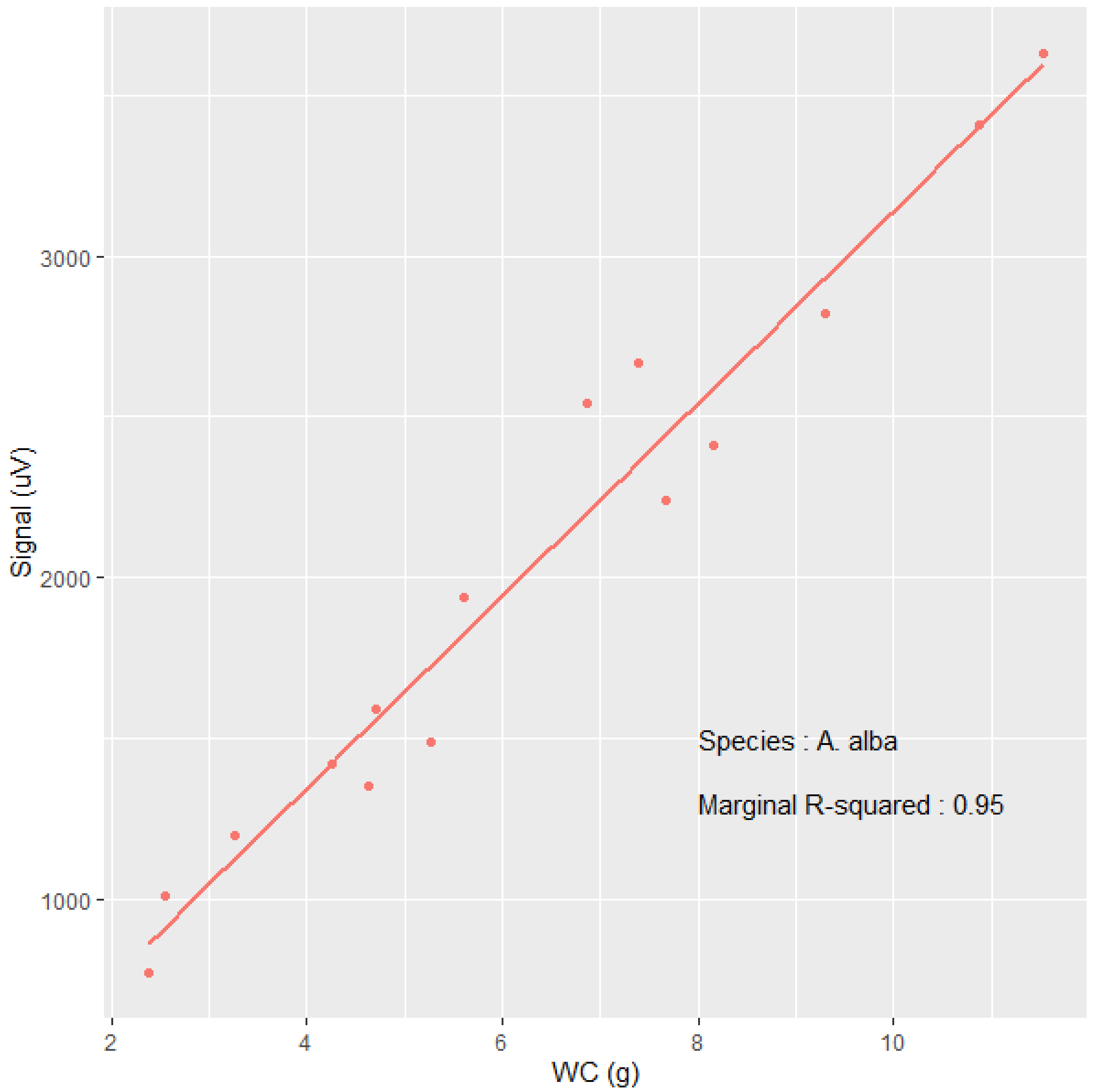
Signal ~ Water Quantity * Species + (1|Branch)

The linear relationship between water quantity and signal

Results of ANOVA :

	Df	Sum Sq	Mean Sq	F value	P-value
Water quantity	1	2.380	3.438	273.310	**< 2e-16 *****
Species	5	0.145	0.039	3.127	**9.323e-05 *****
Water quantity : Species	5	0.187	0.011	0.895	**< 2e-16 *****

The linear relationship between water quantity and signal



Species	Intercept	Slope
A. alba	101.732	309.724 ***

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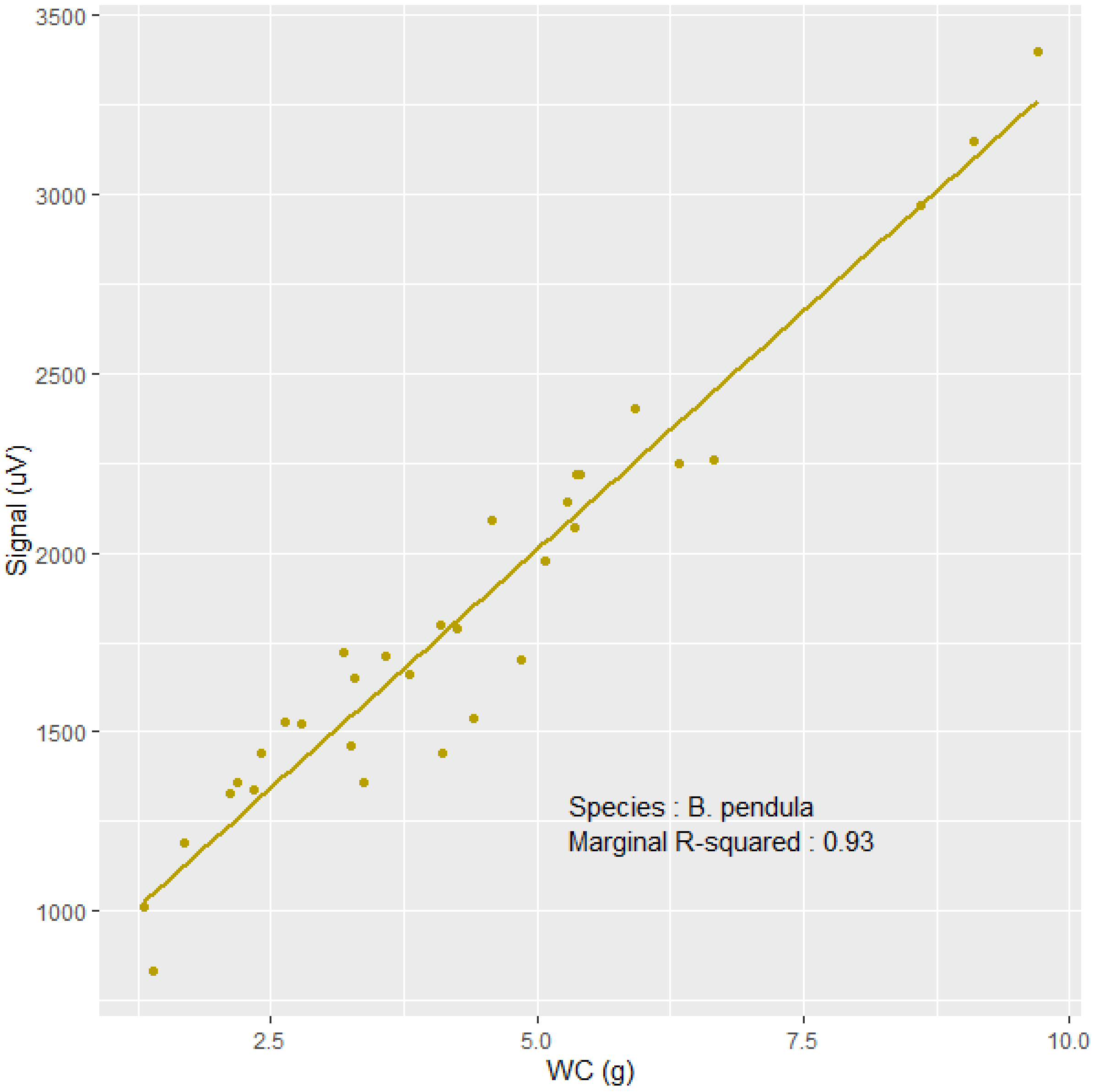

Species	Intercept	Slope
A. Alba	101.732	309.724 ***
B. pendula	594.149 ***	284.809 ***

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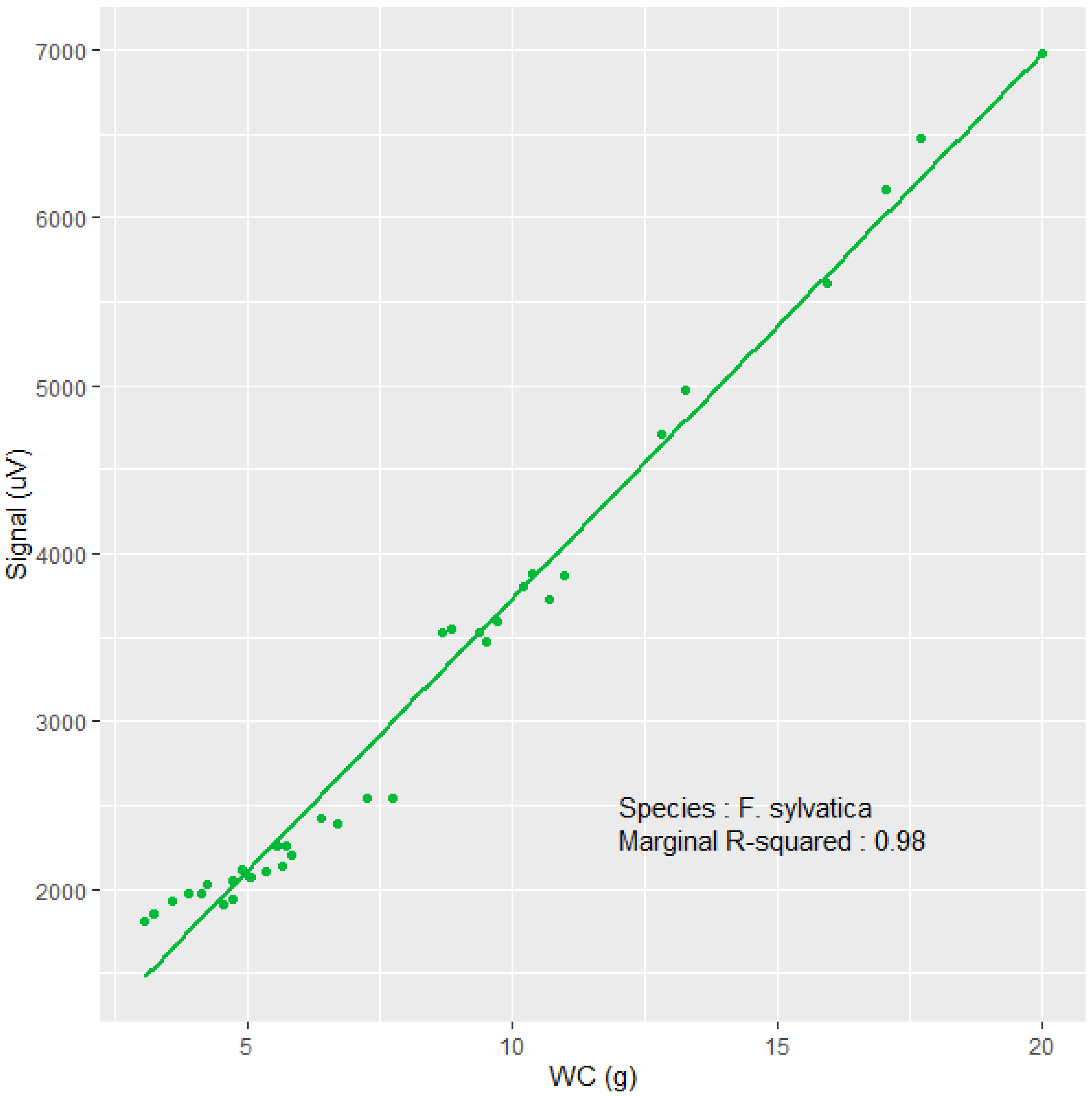

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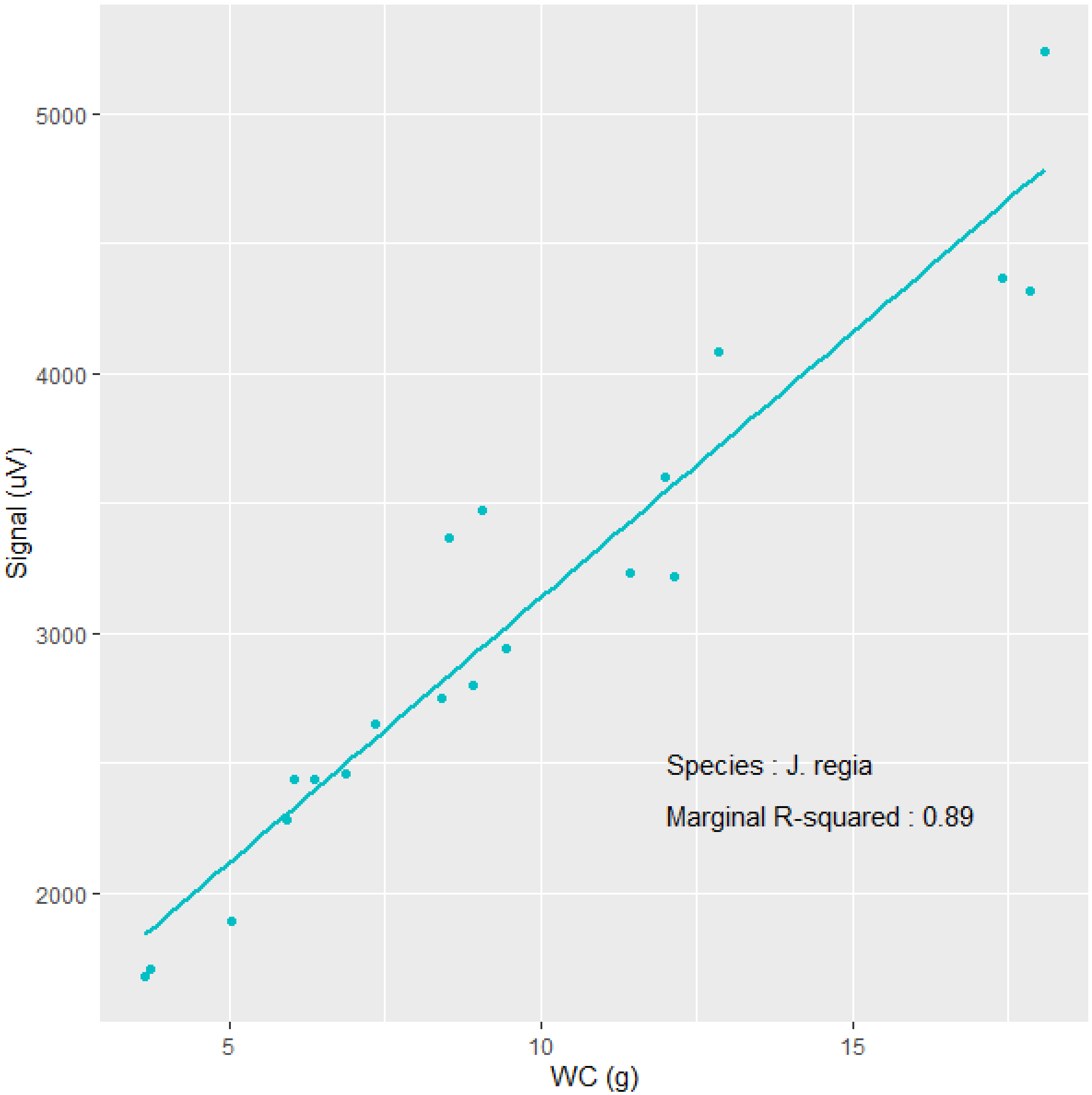

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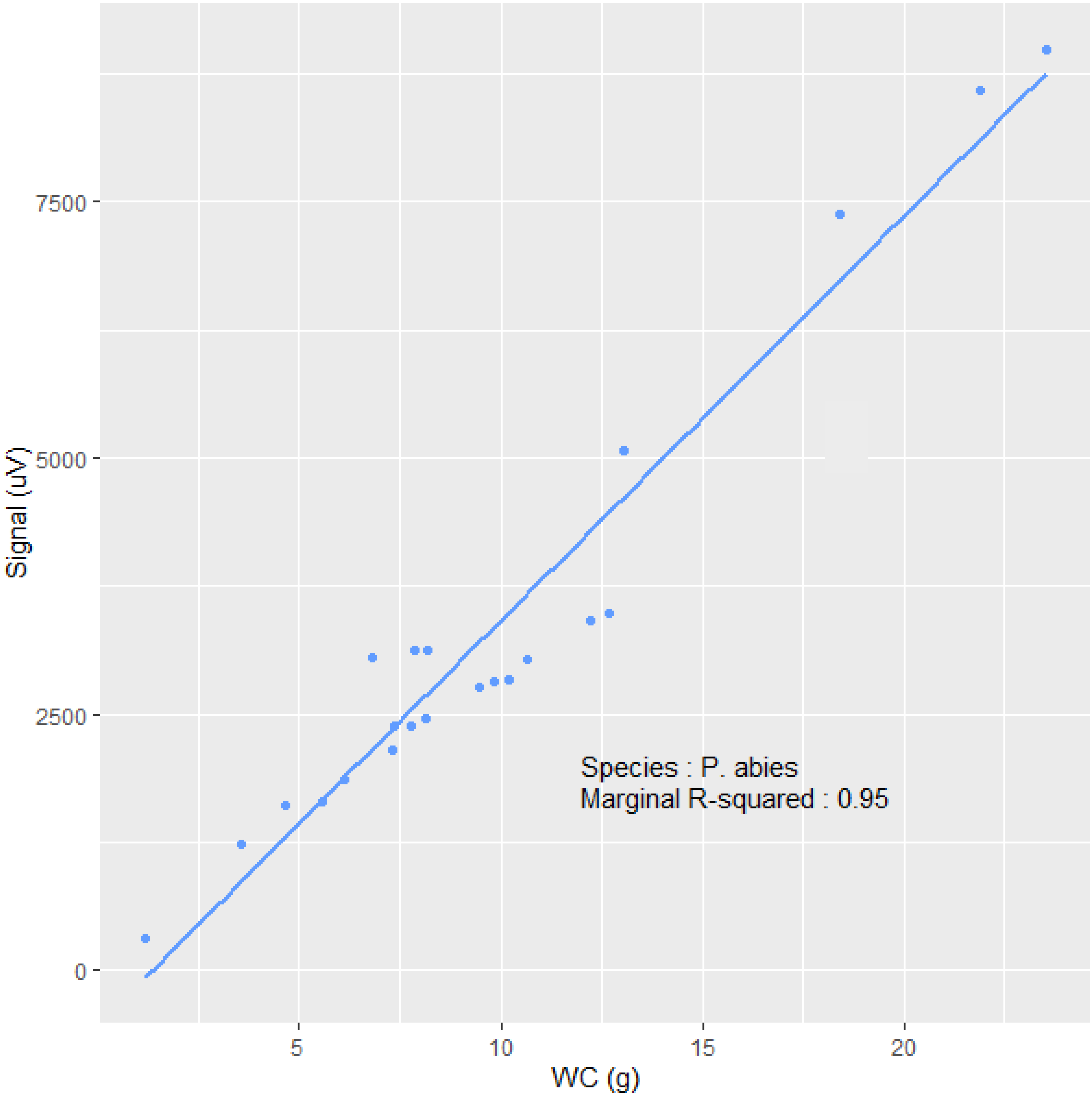

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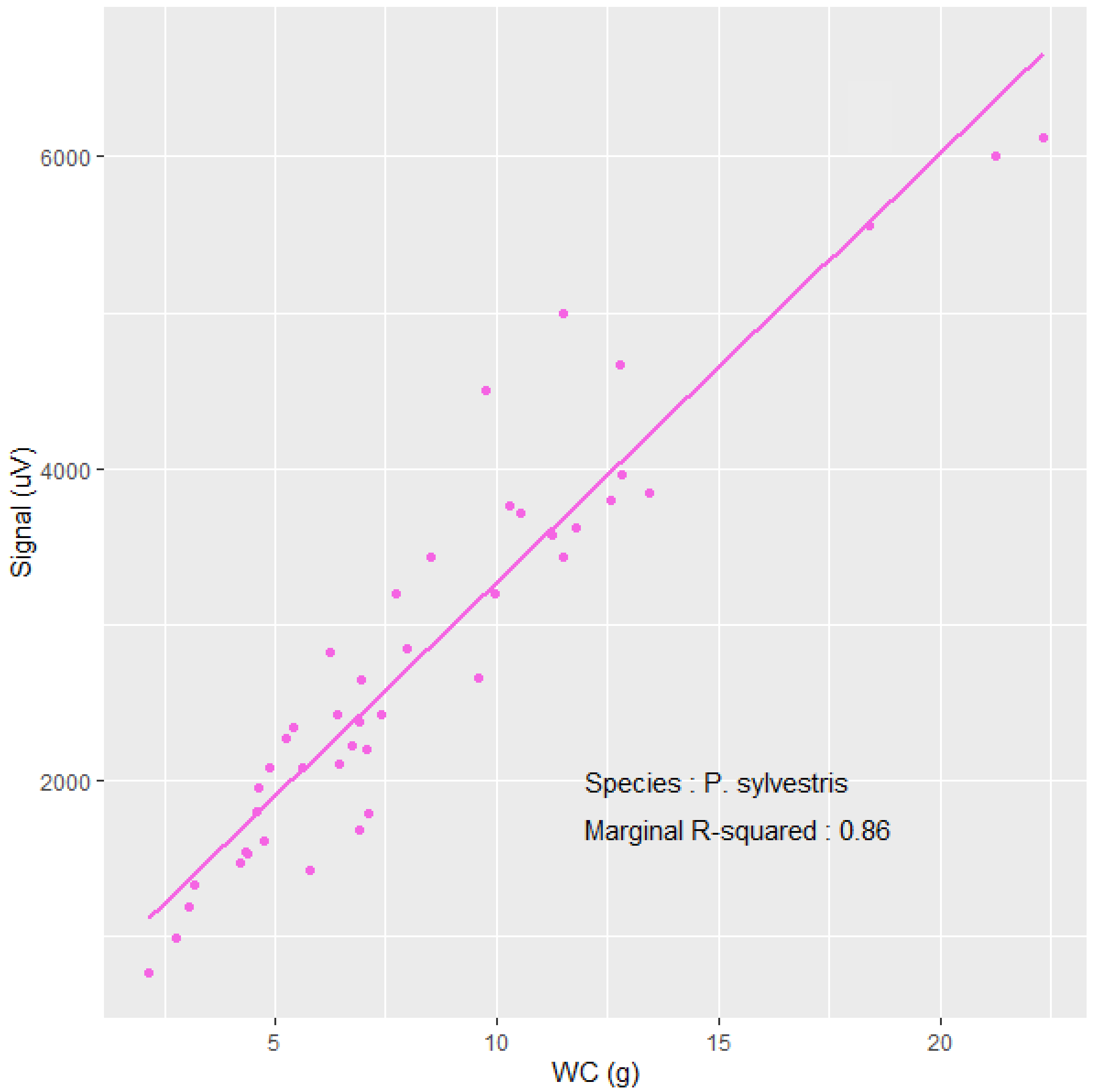

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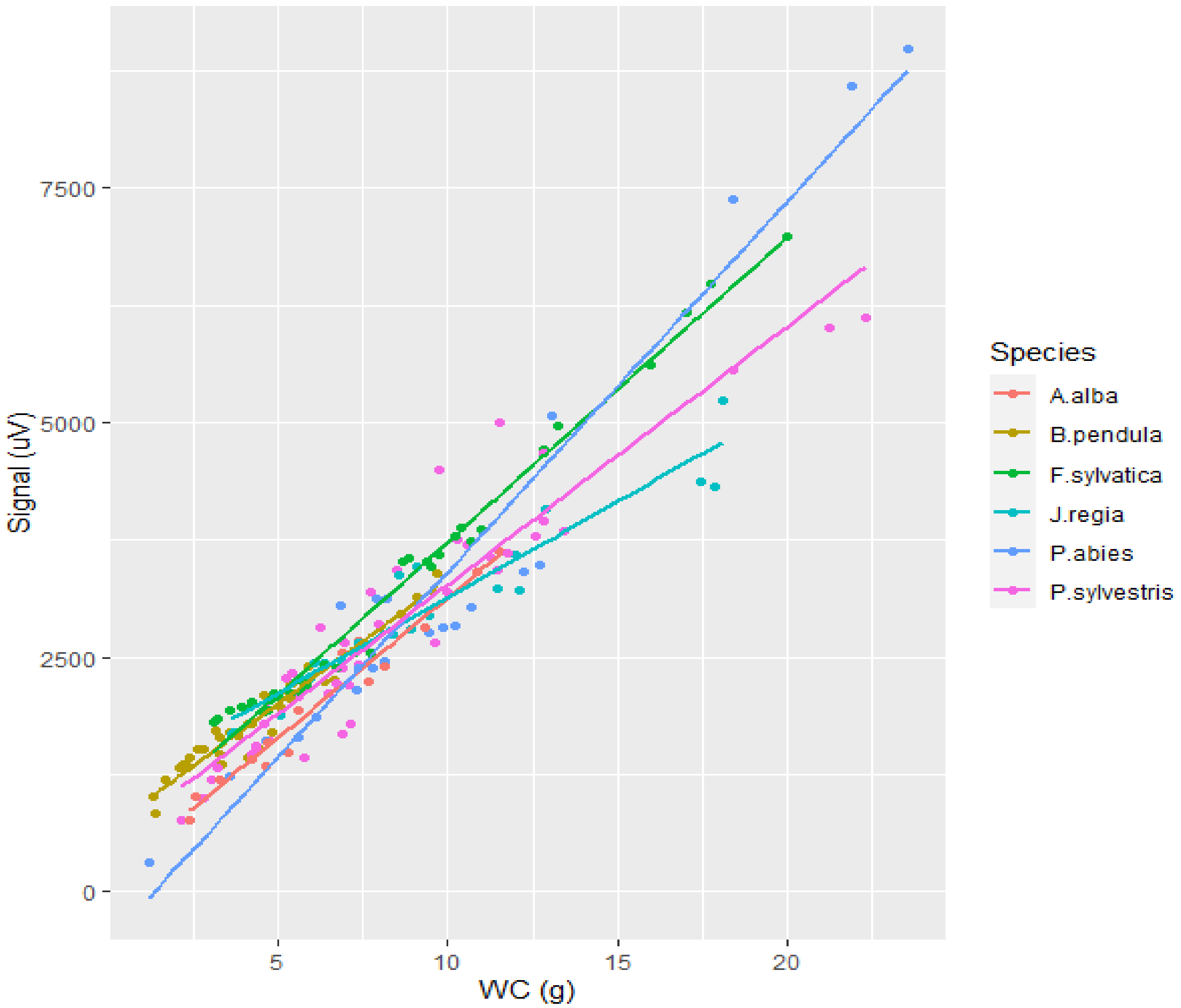

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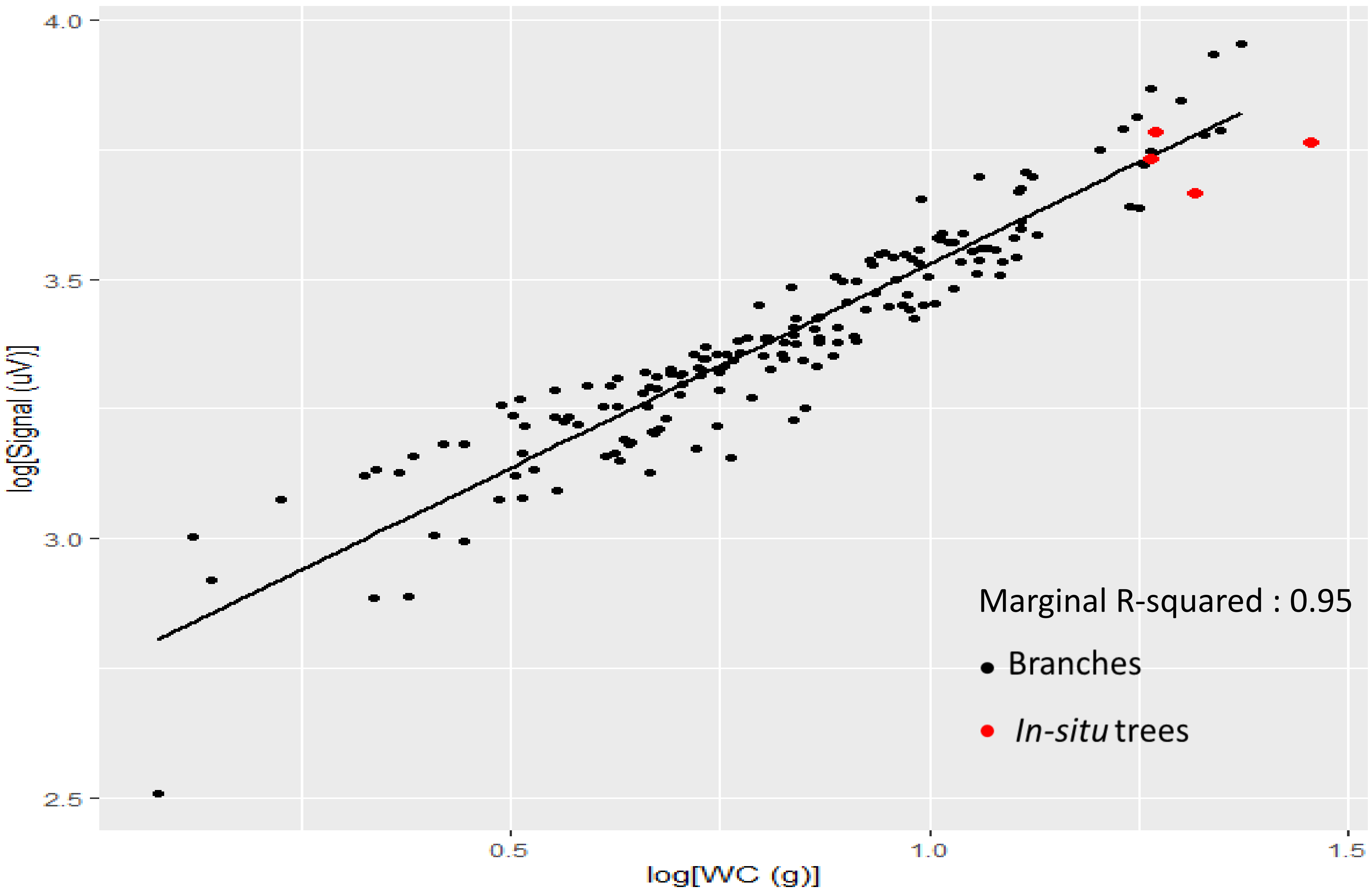
Effects of species and functional type

- Spectrum of wood density between functional types

- The persian walnut, *J. regia*, is the most dense wood amongst the species, and it has the thickest bark zone (varying water content)

In-situ trees added to the model



Conclusions and perspectives

- Tree water content can be reliably measured with the NMR-MOUSE at the level of the species
- Conductive tissues can be detected as distinct water peaks on the NMR profile
- Additional *in-situ* measurements will help to validate these conclusions

Acknowledgements

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Join the project

- We are looking for a postdoctoral researcher to work on this project
- The candidate will work on *in-situ* flow NMR with the goal of measuring xylem and phloem fluxes

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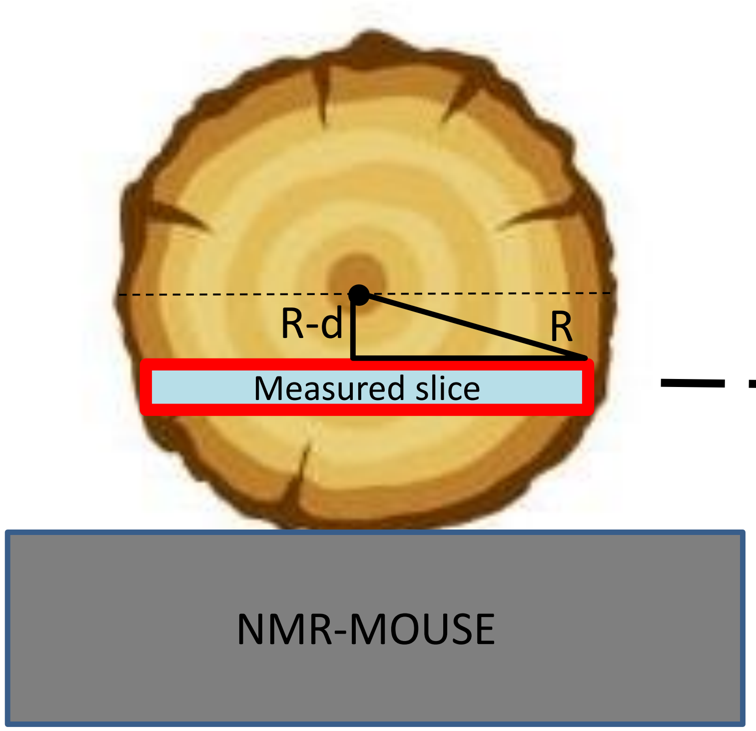
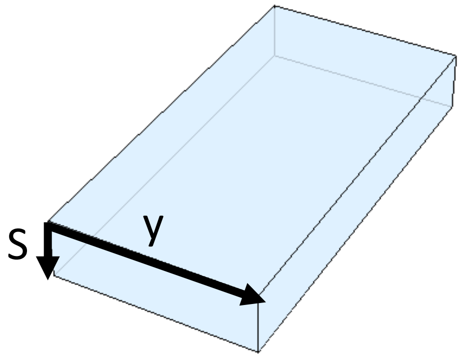
Normalizing for the volume of the measured slice

Treatment of Signal:

At each depth: slice amplitude/volume, where the volume is calculated:

$$v = 2\sqrt{R^2 - (R-d)^2}\, Sy$$





S = 100 µm slice thickness
y = 4 cm length of NMR sensitive zone