Aus welchen Bodentiefen beziehen Bäume ihr Wasser?

M. Beyer, M. Gerchow, F. Bossy, V. Hörmann, F. Feldmann, M.Strohbach, J. Hoppenbrock M.Bücker, M. Quambusch

CliMax

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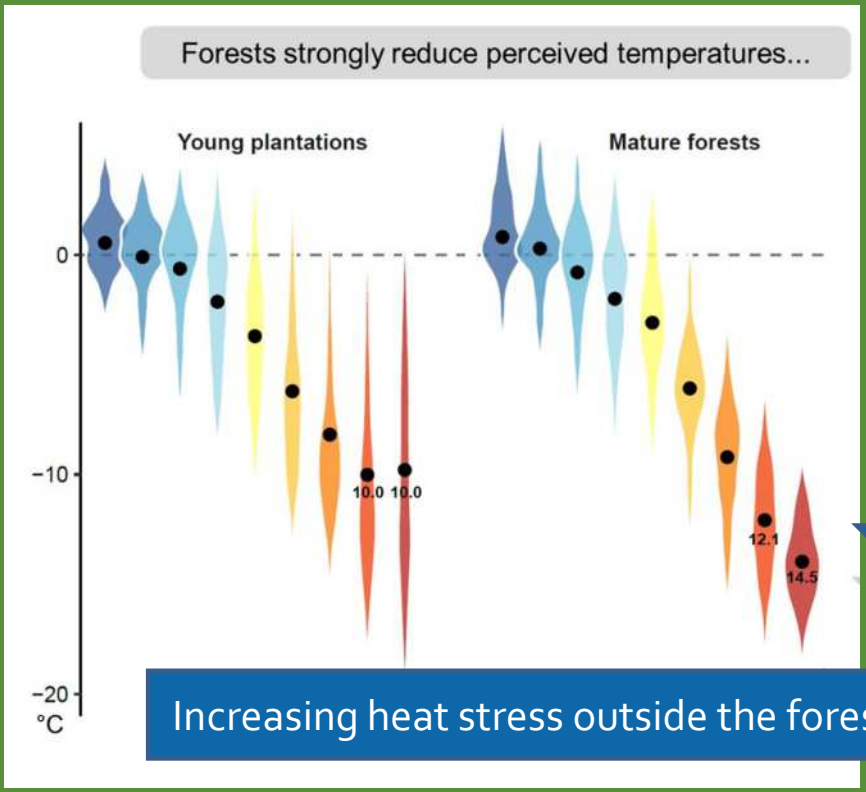
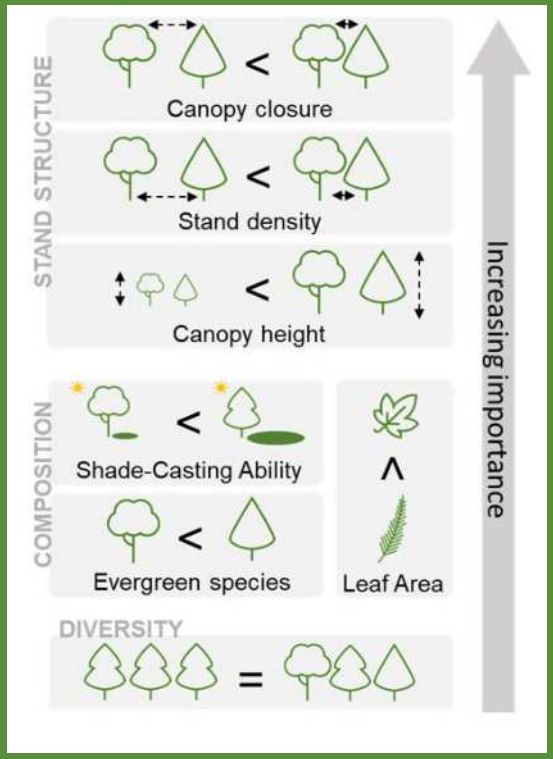
Maximizing the carbon sequestration in urban trees: Developing knowledge and tools for climate change mitigation and adaptation with multifunctional urban green infrastructure

Trees regulate our climate…



Increasing cooling effect



[Gillerot et al., 2022. Forest structure and composition alleviate human thermal stress. Global Change Biology 28, 7340–7352. https://doi.org/10.1111/gcb.16419]

…but they need sufficient water…

The climate dilemma

Temperature ↑ +

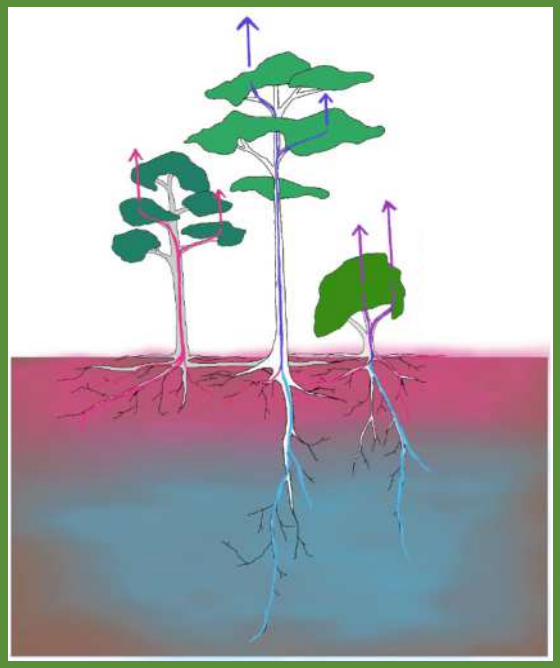
Precipitation ↓ +

Extremes ↑ +

Too many shallow rooters

The World's Roots Are Getting Shallower

Root-filled soils are hot spots of nutrient cycling and carbon storage. New research finds that the world has lost millions of cubic meters of rooted soil volume—and we're on track to lose much more.



…the shallow root zone is the most vulnerable…

Urban environments

- Water is limiting factor
- Carbon sequestration and other ecosystem services is decreasing under drought conditions

Buenos Aires, Argentina

How DO these trees survive?

How WILL these trees survive?

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Questions

Which water sources are trees using (in different settings)?

How much water is and will be available for trees?

How can we investigate this?

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ISODRONES

A research initiative dedicated to developing novel and innovative methods to investigate different aspects of the water cycle.

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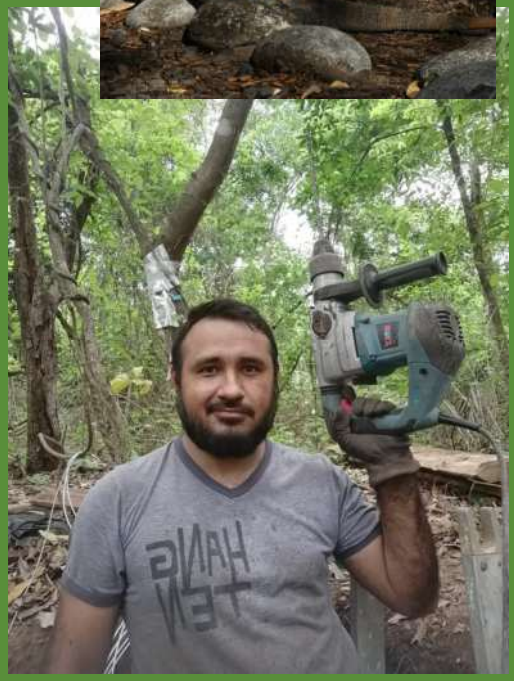
Maximizing the carbon sequestration in urban trees: Developing knowledge and tools for climate change mitigation and adaptation with multifunctional urban green infrastructure

Isodrones superheroes

Stratzlawski
El verdadero cerebro de los Isodrones

Kathrin Kühnhammer (‘Deuteria’):
Dinámica a corto plazo de la absorción de agua por las plantas.

Malkin Gerchow (‘Superfly’)
Imágenes UAV para la estimación de la transpiración y los parámetros del dosel.



Alberto Iraheta
(‘La maquina’)
Recarga de aguas subterráneas

Methods

How to study root water uptake depths?

- Root excavation: measures root presence, destructive, laborious, not always possible
- Root length density: measures root presence, destructive, not species-/tree – specific, error-prone

Root presence does not equal root water uptake depth!

- Monitoring of soil moisture: measures root water uptake, quantitative, installation not always possible, not species-/tree-specific

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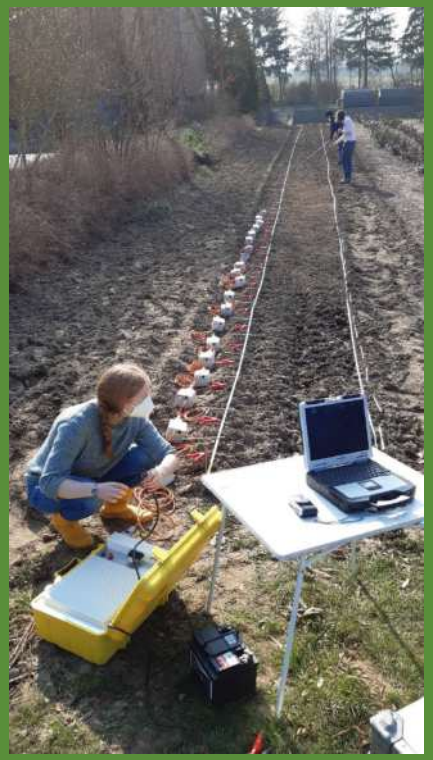
Methods How to study root water uptake depths?



- Geophysical methods: non-destructive, spatially integrated, species-/tree – specific
- **Water stable isotopes: semi-destructive, species-/tree – specific, measures root water uptake (not presence), quantitative if combined**

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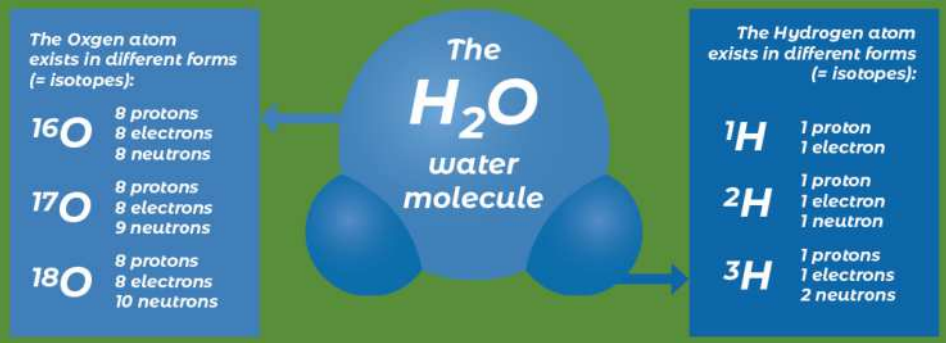
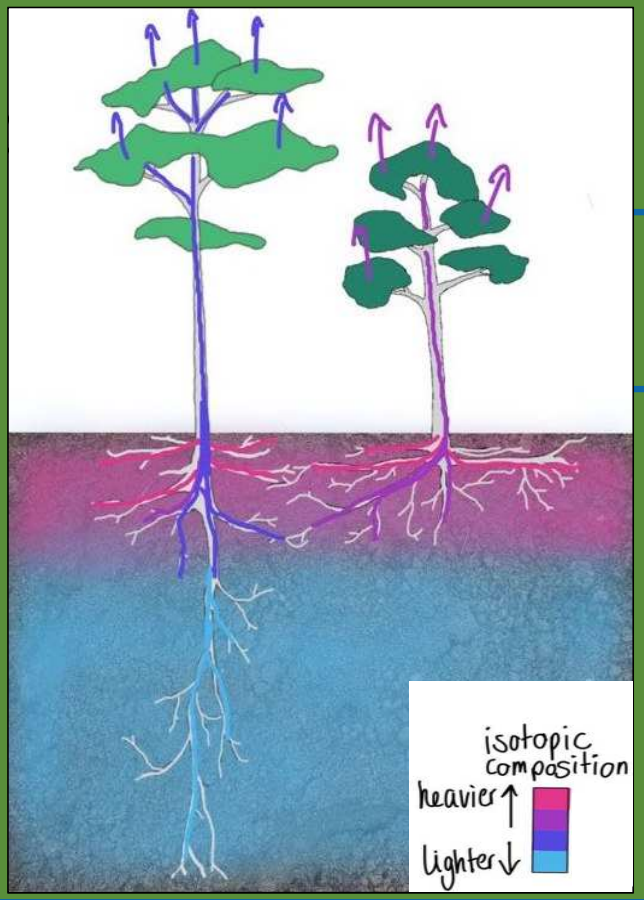
Methods Water Stable Isotopes

- Water molecules are not all the same….



- Different number of neutrons = different molecular weight and properties → different behaviour in natural processes (e.g. evaporation, rainout from clouds)
- We can measure the ratio of ‚heavy' and ‚light' molecules in waters



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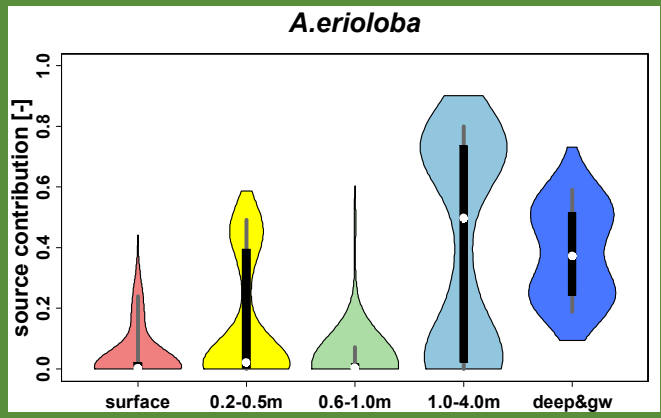
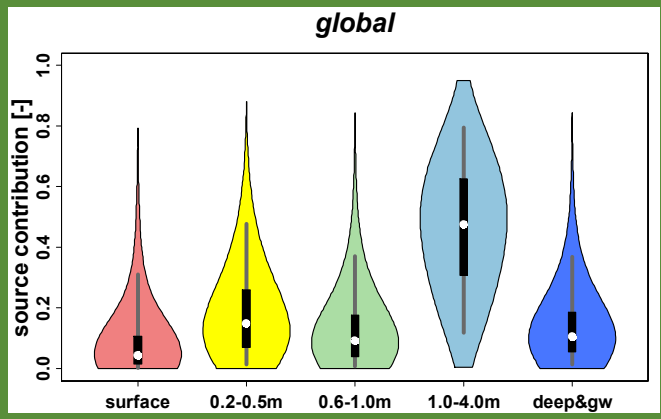
Methods Water Stable Isotopes

Plant water isotope composition + soil water isotope profile

(EMMA-end-member mixin analysis)

Contribution of different soil depths to transpiration





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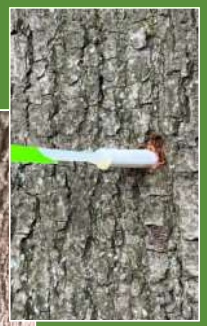
Methods

Novel In Situ Methods



- Less destructive = less tree damage
- Continuous monitoring possible
- Combined with soil moisture sensors & sap flow: **qualitative AND quantitative**

Kühnhammer, K., Dahlmann, A., Iraheta, A., Gerchow, M., Birkel, C., Marshall, J. D. and Beyer, M.: Continuous in situ measurements of water stable isotopes in soils, tree trunk and root xylem: field approval, Rapid Commun. Mass Spectrom., e9232, doi:10.1002/RCM.9232, 2021.

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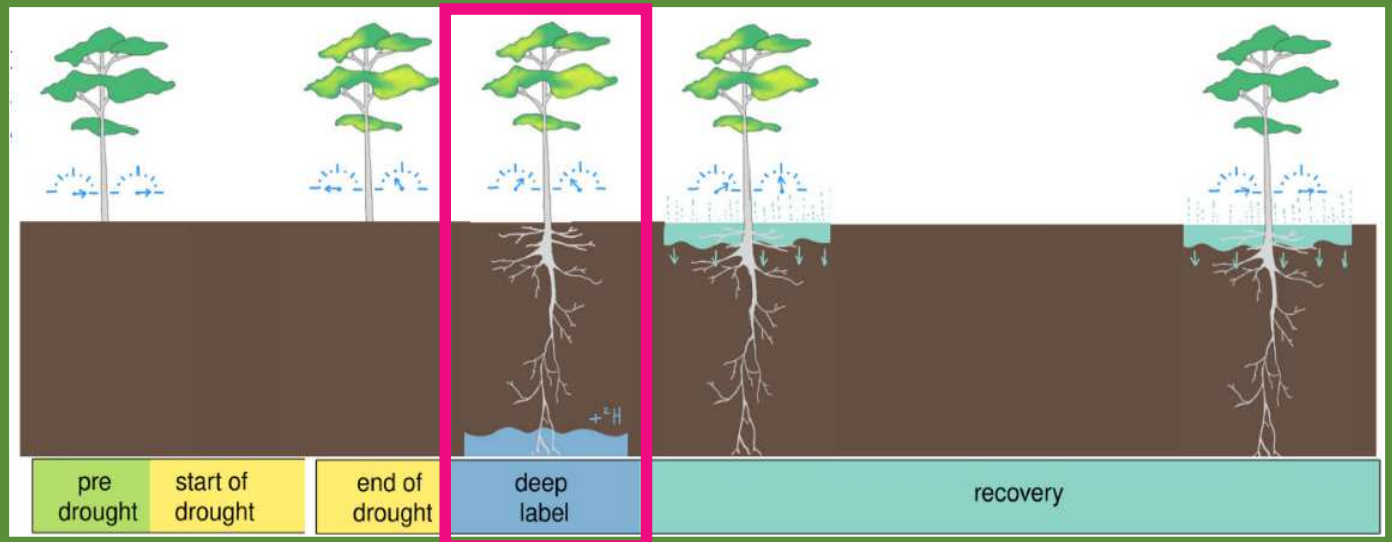
B2WALD: A tropical rainforest under drought



~3000 L of deuterium-enriched water injected via drainage

Werner et al., 2021: Ecosystem fluxes during drought and recovery in an experimental forest, Science (80-.)., 374(6574), 1514–1518, doi:10.1126/SCIENCE.ABJ6789

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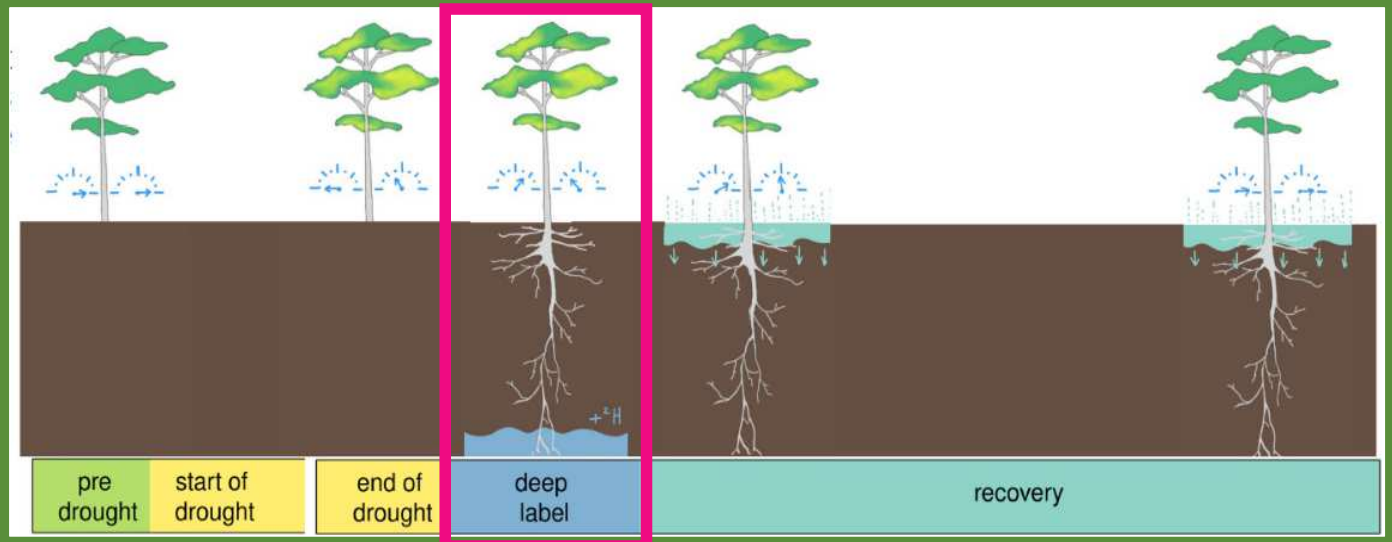
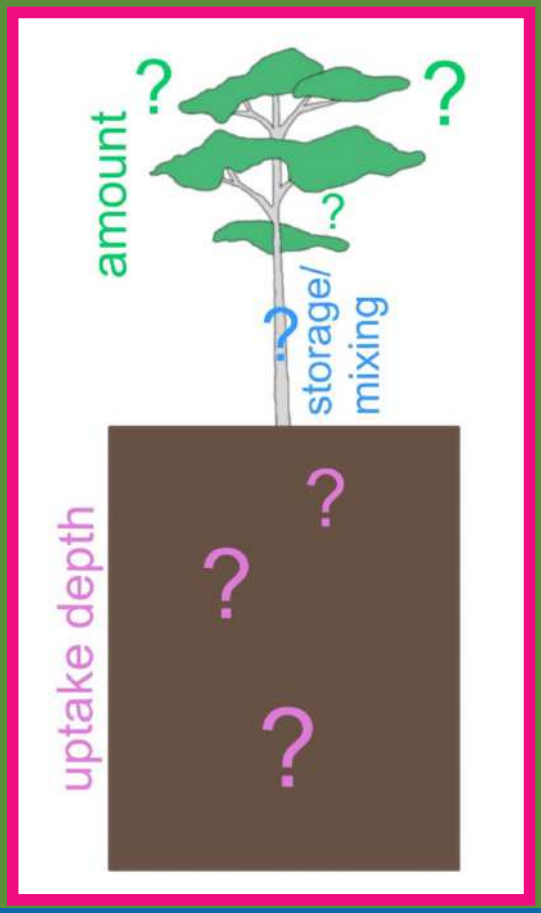


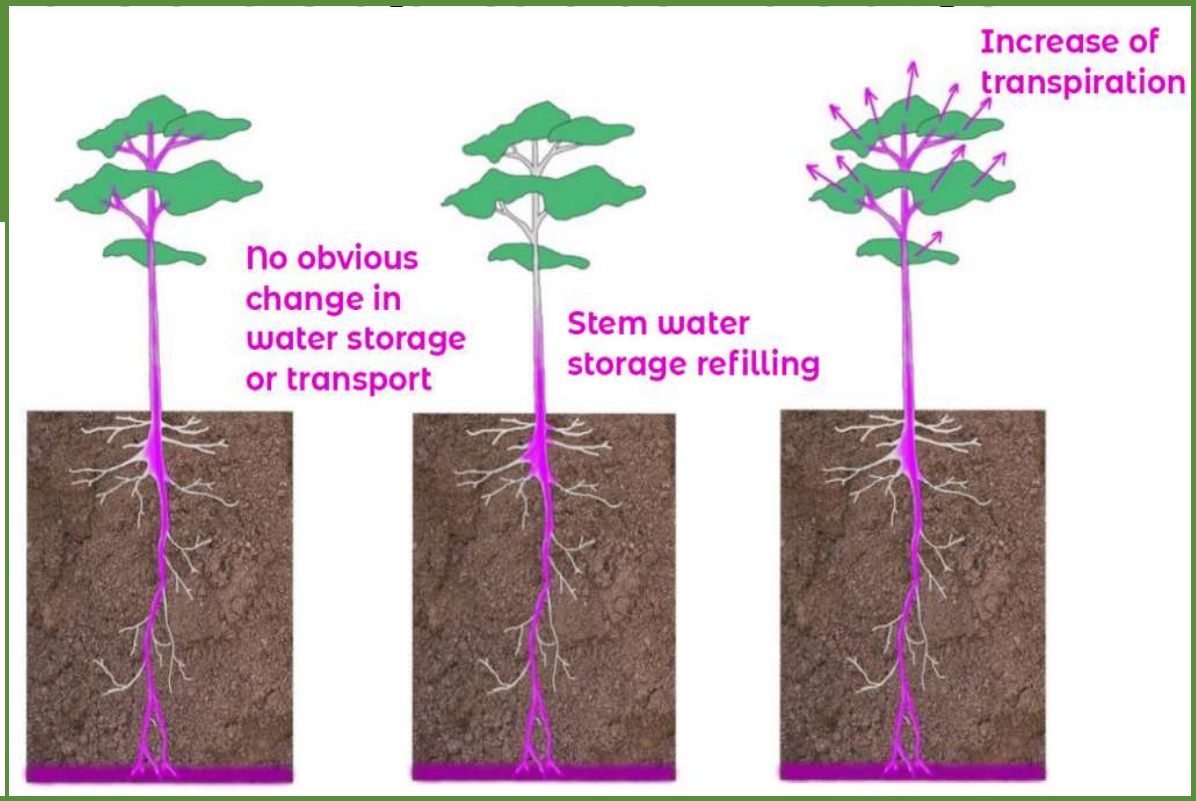
~3000 L of deuterium-enriched water injected via drainage

- Uptake depths/amounts?
- How do they change with drought/rewetting?
- Usage of water (storage refill / mixing?)

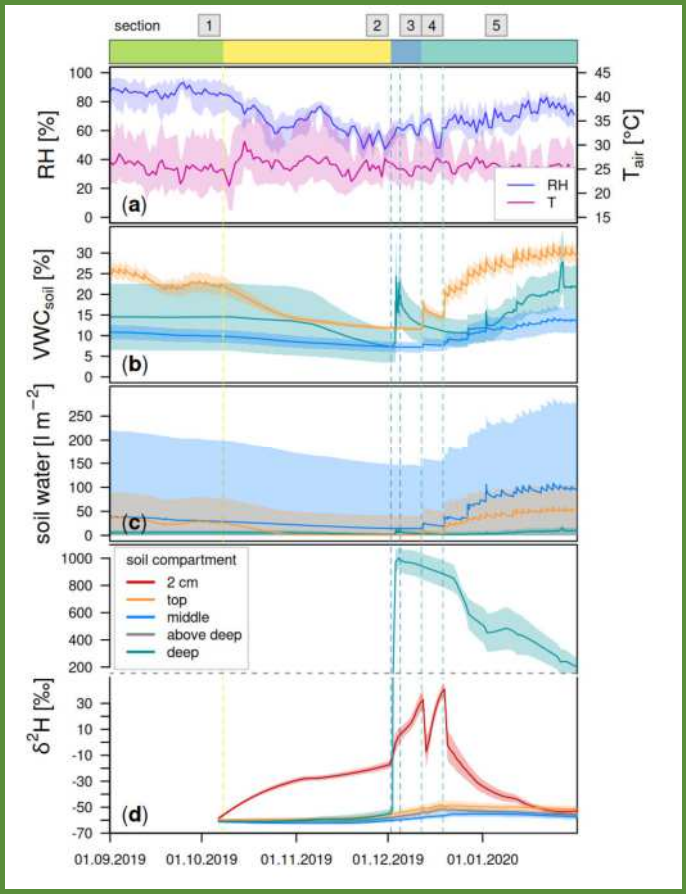
Werner et al., 2021: Ecosystem fluxes during drought and recovery in an experimental forest, Science (80-.)., 374(6574), 1514–1518, doi:10.1126/SCIENCE.ABJ6789

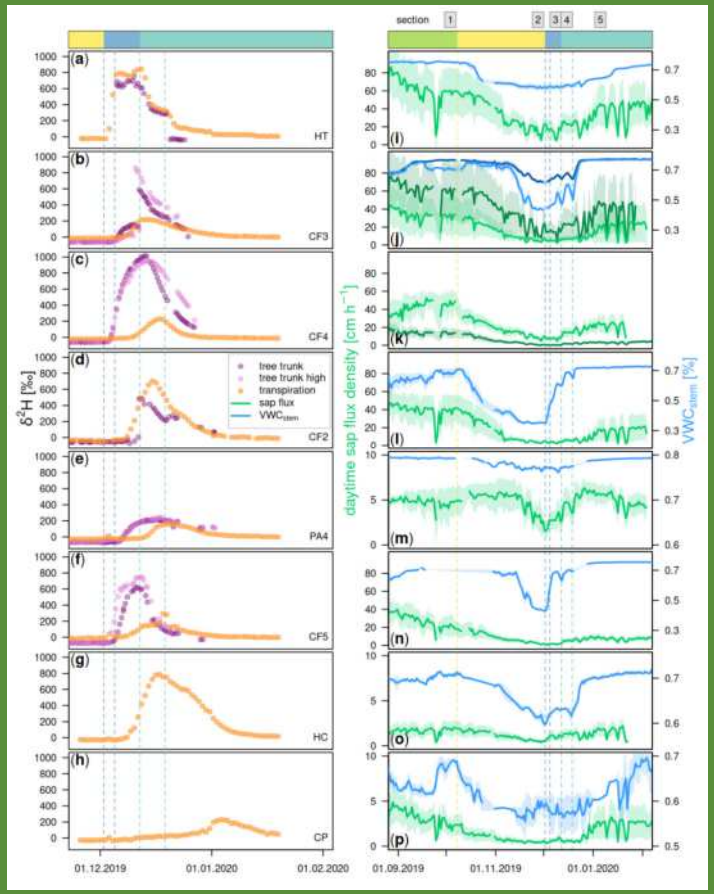
B2WALD: A tropical rainforest under drought





B2WALD: A tropical rainforest under drought





All studied large tropical trees access water at soil depths up to 3.3 m!

Kühnhammer, K., van Haren, J., Kübert, A., Bailey, K. Dubbert, M., Hu, J., Ladd, S.N., Meredith, L.K., Werner, C., Beyer, M., 2023. Deep roots mitigate drought impacts on tropical trees despite limited quantitative contribution to transpiration. Science of The Total Environment 893, 164763. https://doi.org/10.1016/j.scitotenv.2023.164763

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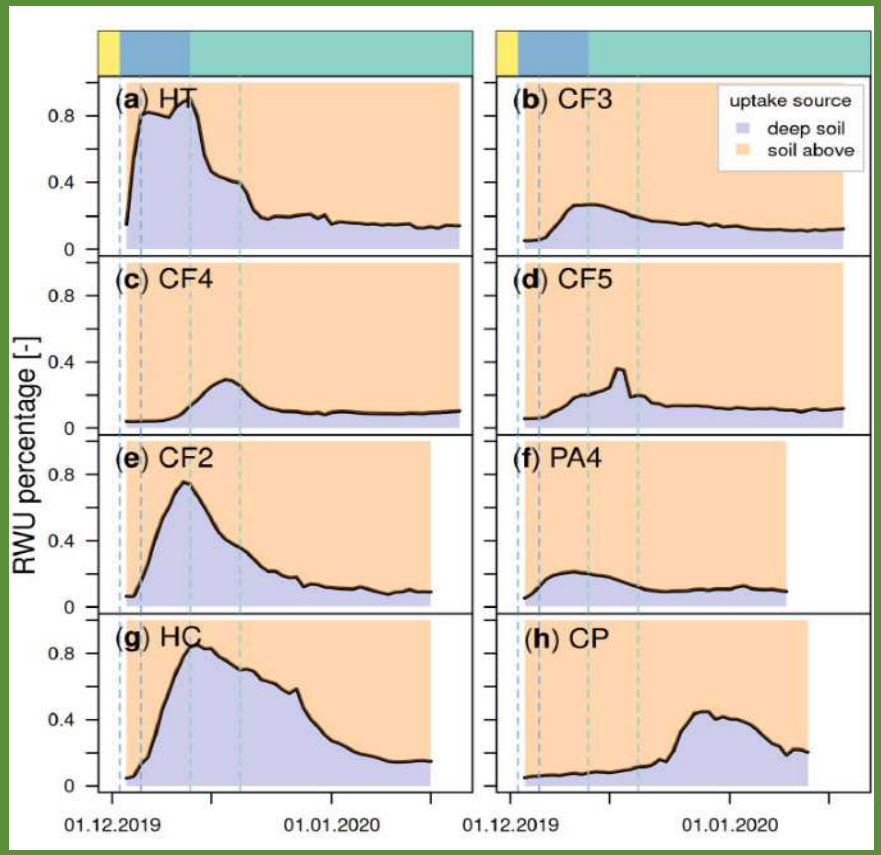


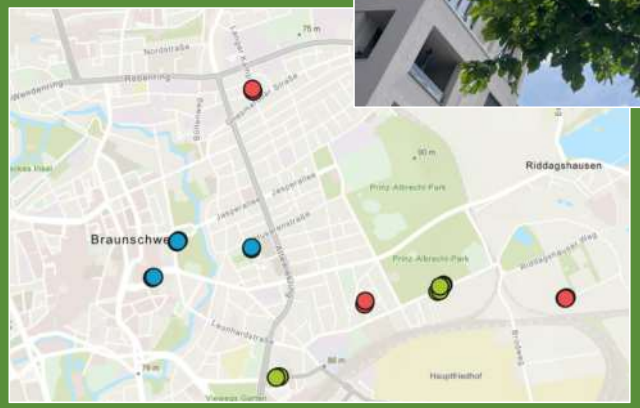
Deep roots help tropical trees endure droughts but total transpiration fluxes are driven by precipitation.

Kühnhammer, K., van Haren, J., Kübert, A., Bailey, K., Dubbert, M., Hu, J., Ladd, S.N., Meredith, L.K., Werner, C., Beyer, M., 2023. Deep roots mitigate drought impacts on tropical trees despite limited quantitative contribution to transpiration. Science of The Total Environment 893, 164763. https://doi.org/10.1016/j.scitotenv.2023.164763

Deep roots are extremely important under natural conditions – but how about urban trees?

Braunschweig

- 3 species: **Baumhasel, Winterlinde, Pyramideneiche**
- 3 levels of sealing: unsealed, partly sealed, fully sealed
- 9 soil plots, 27 trees monitored
- Sap flow sensors
- Soil moisture sensors at each plot down to 2m soil depth



Deep roots are extremely important under natural conditions – but how about urban trees?

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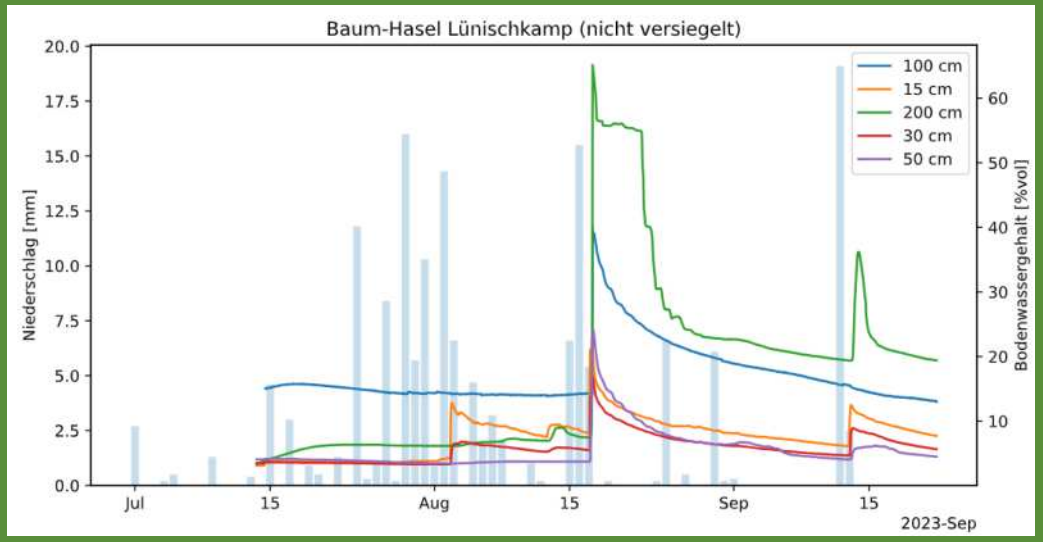
VolkswagenStiftung
Technische Universität Braunschweig

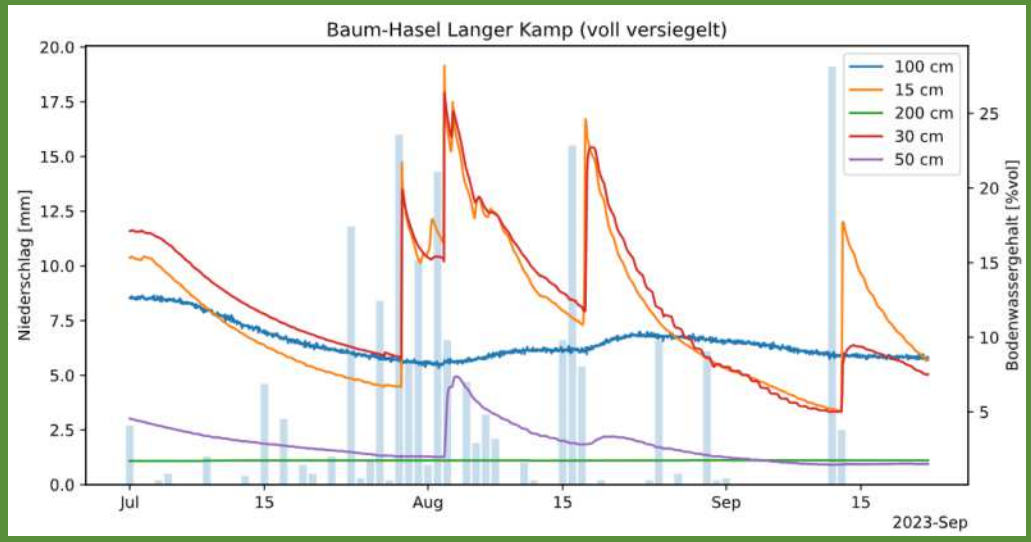
Soil water content

Baumhasel

Baumhasel - unsealed

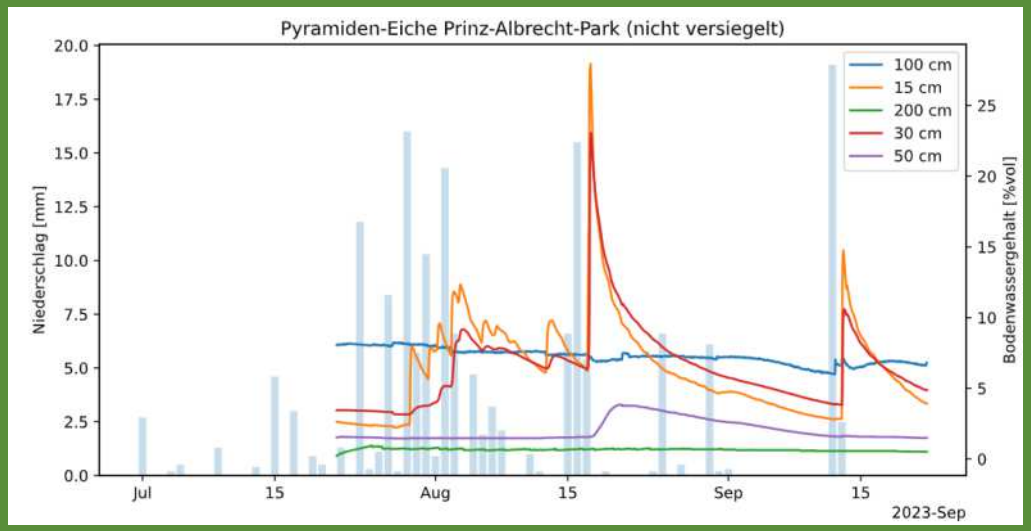


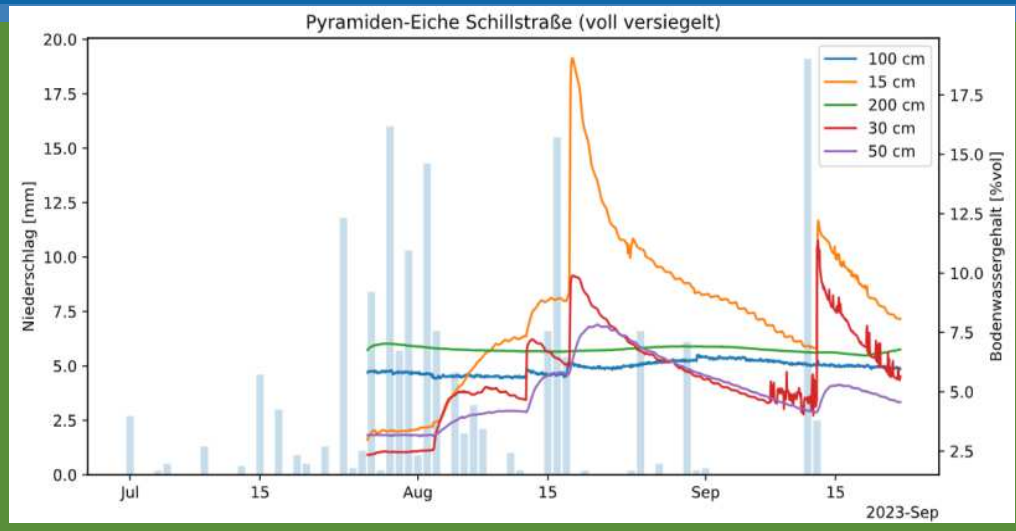
Baumhasel - sealed

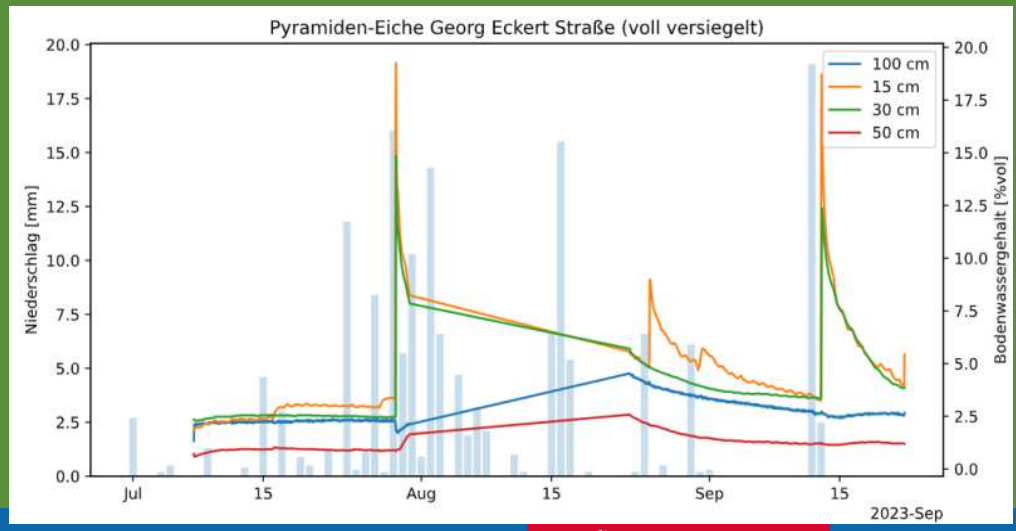


- Unsealed: lateral water inflow from drainage channel, no deep soil reaction during July/August rains
- Sealed: fast shallow surface reactions, dry deep&intermediate soil

Soil water content







- Generally low water availability deeper 50 cm

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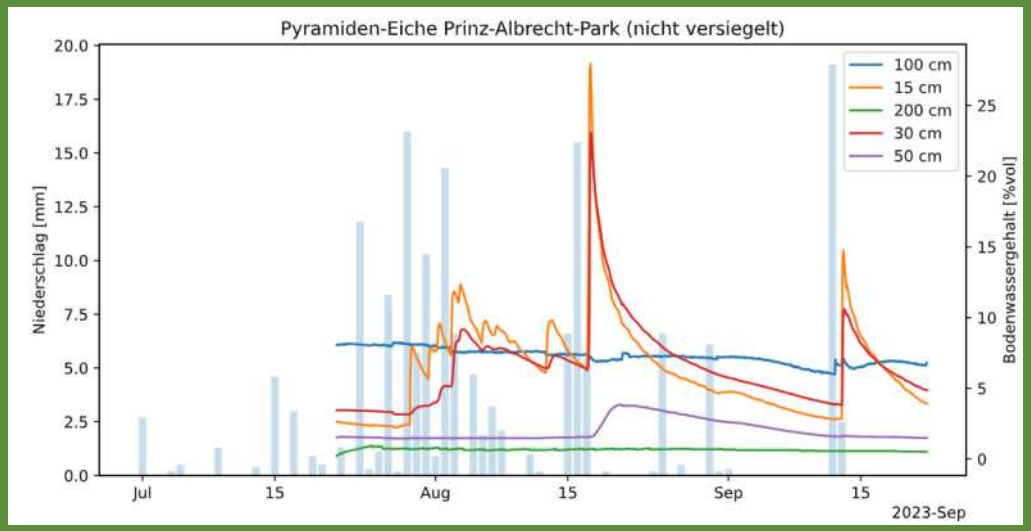
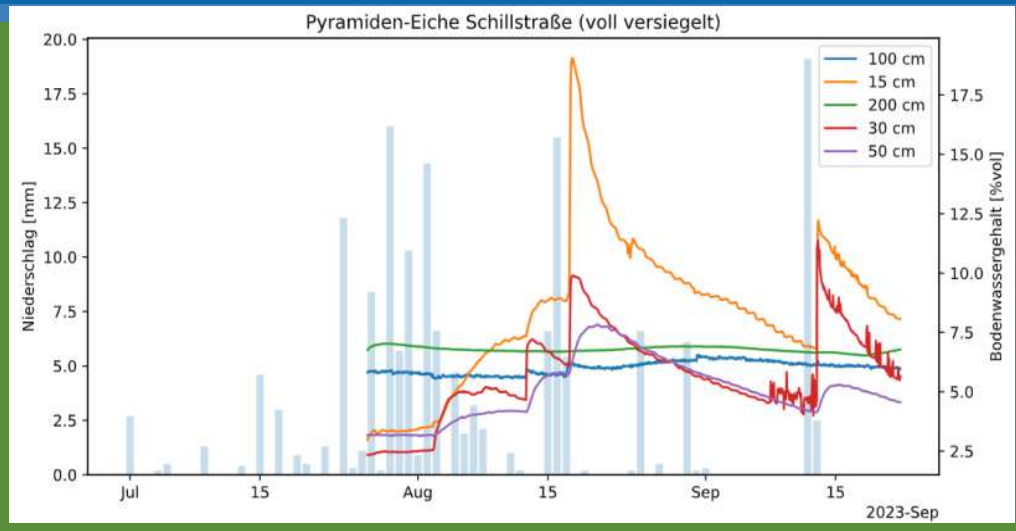
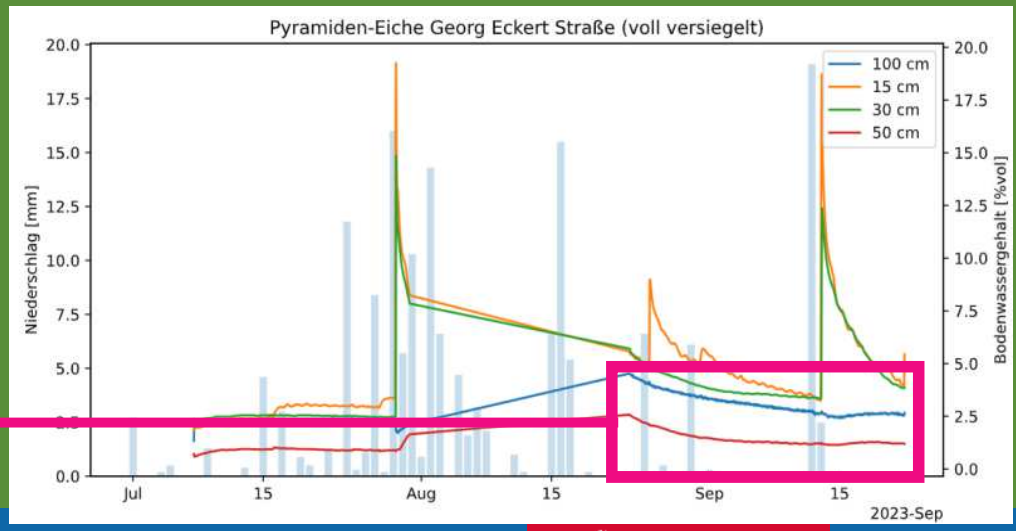
Soil water content





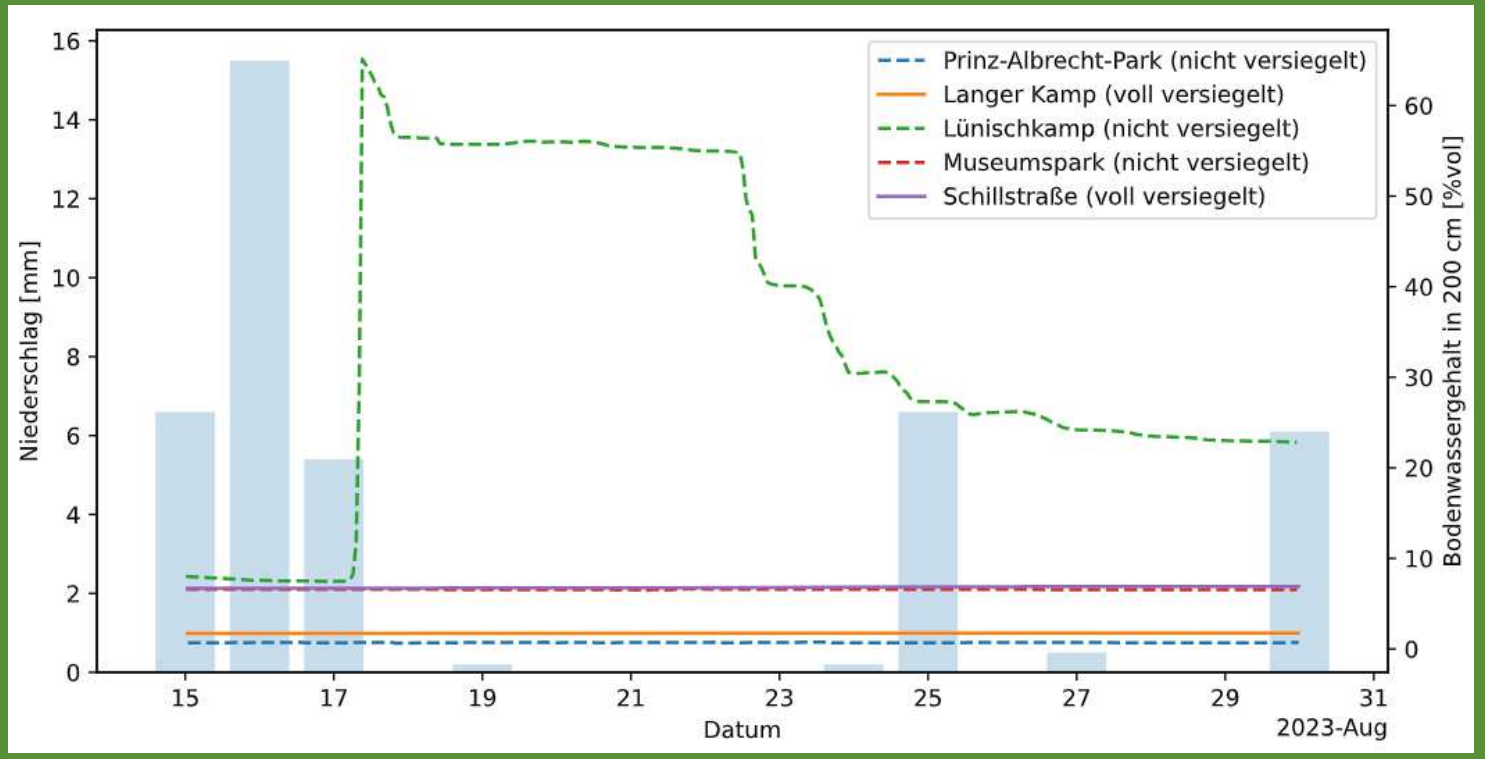


- Generally low water availability deeper 50 cm
- Could be deep water uptake

Soil water content

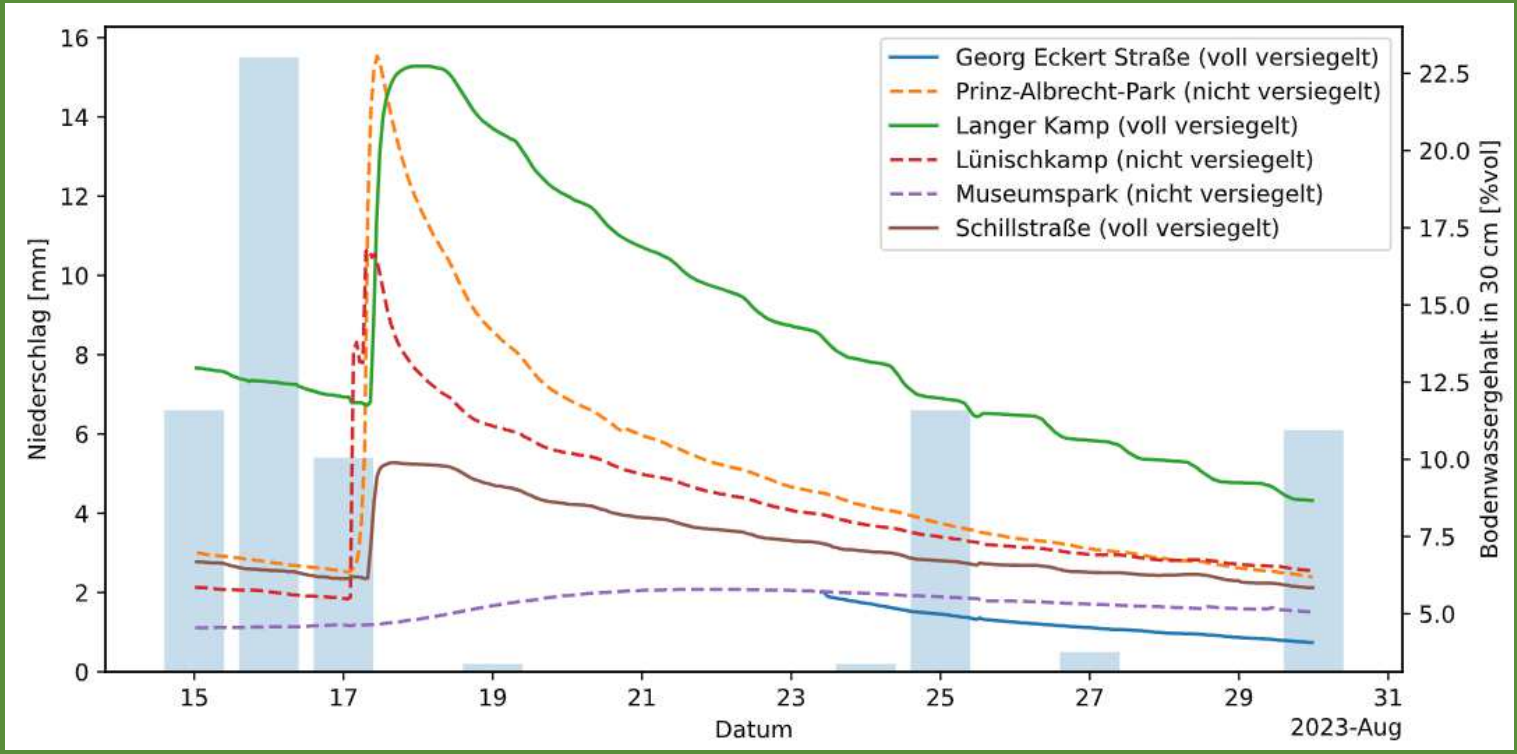
All plots

200 cm



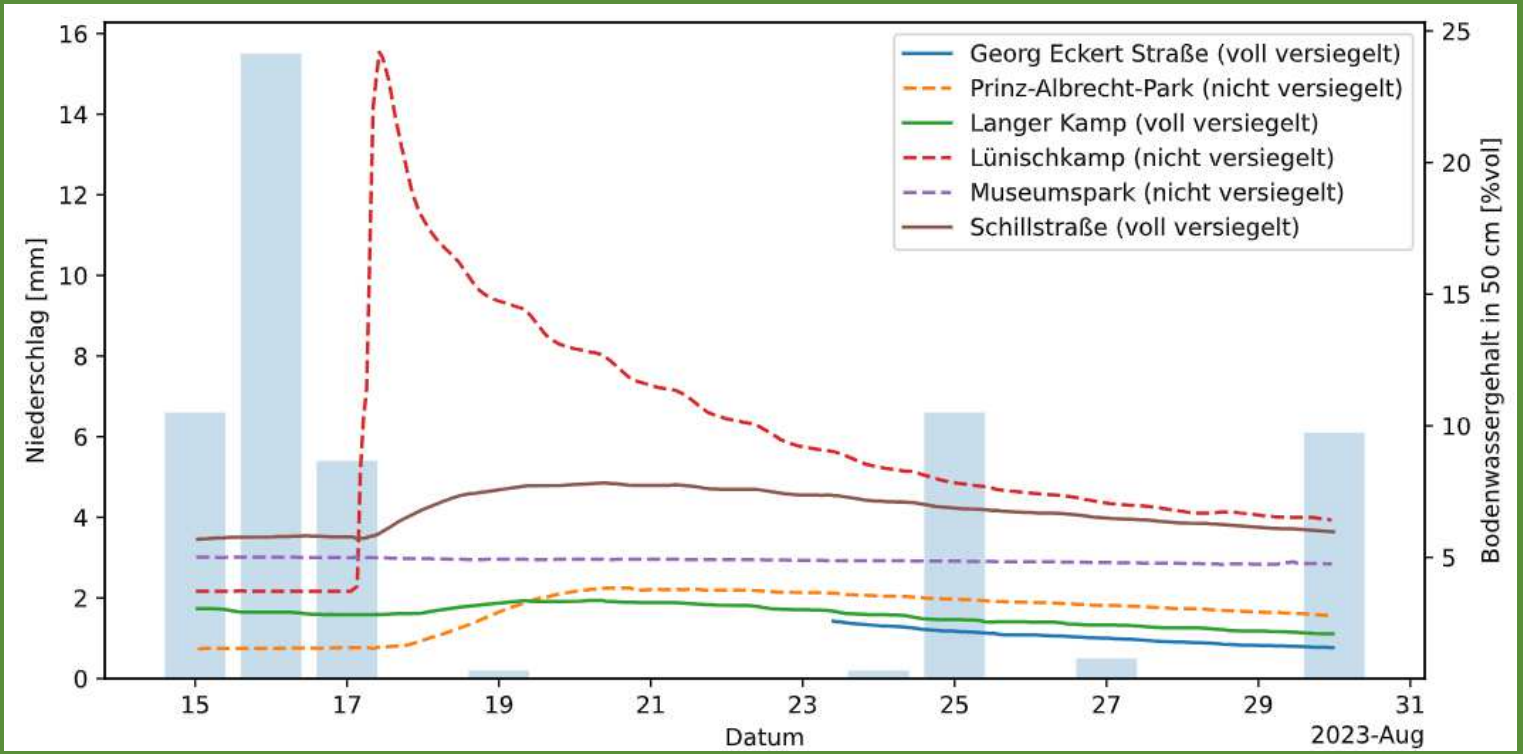
Soil water content

30 cm



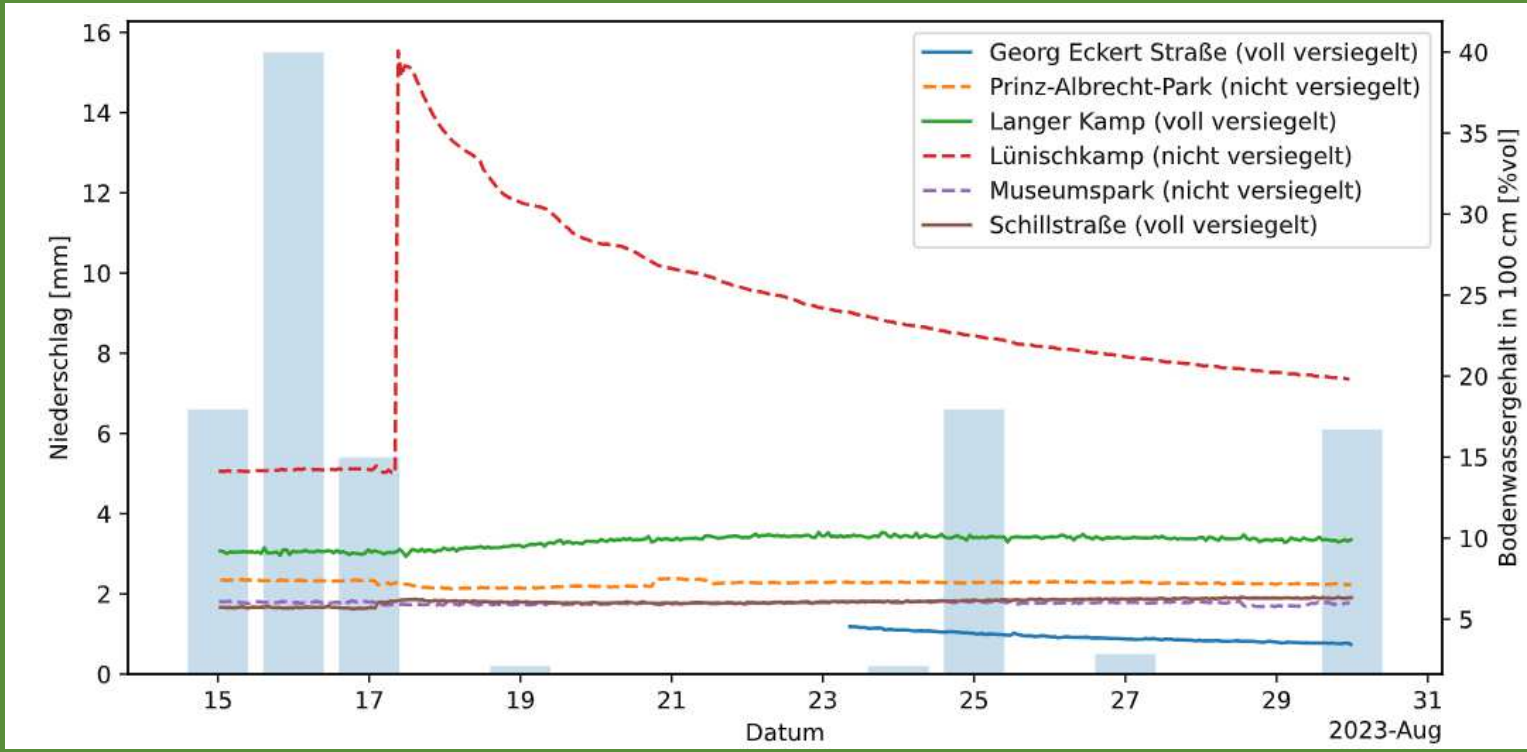
Soil water content

50 cm

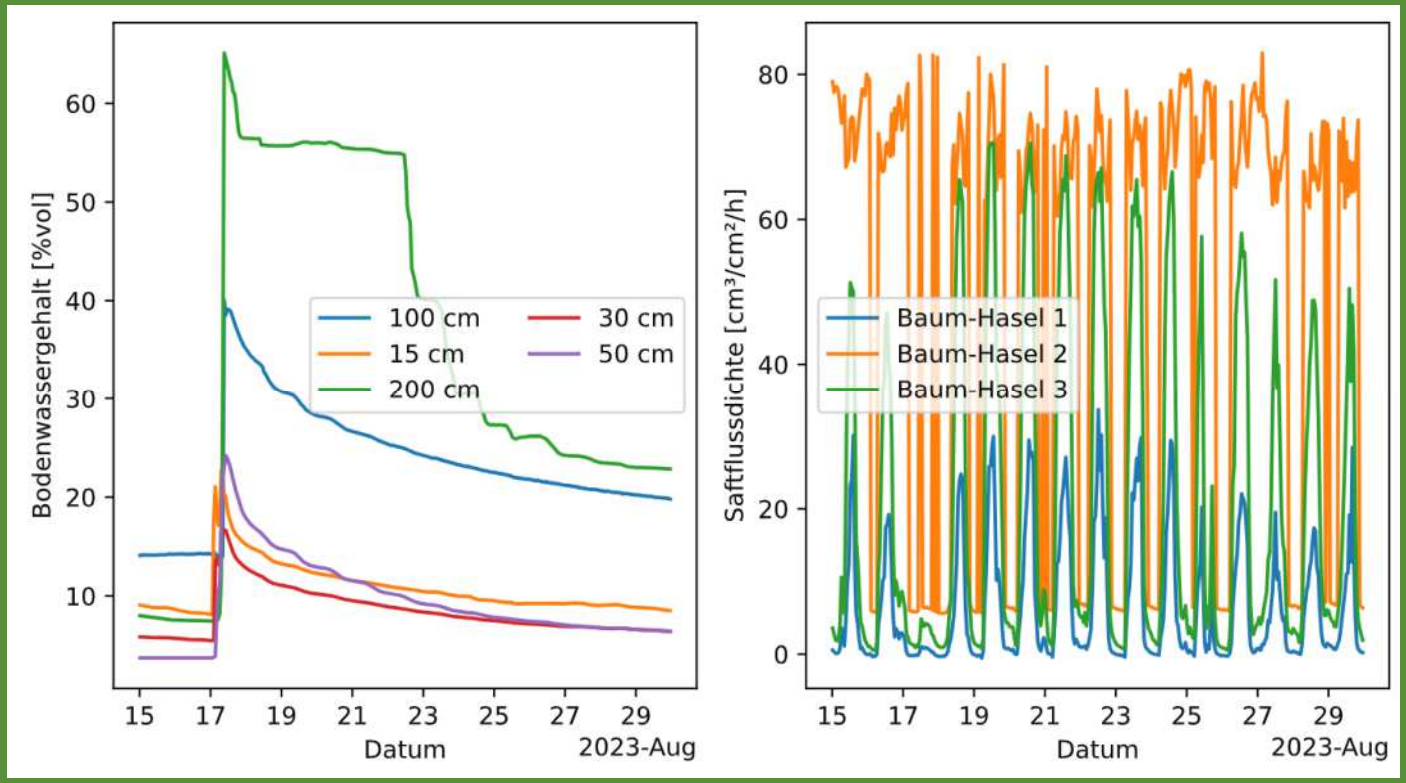


Soil water content

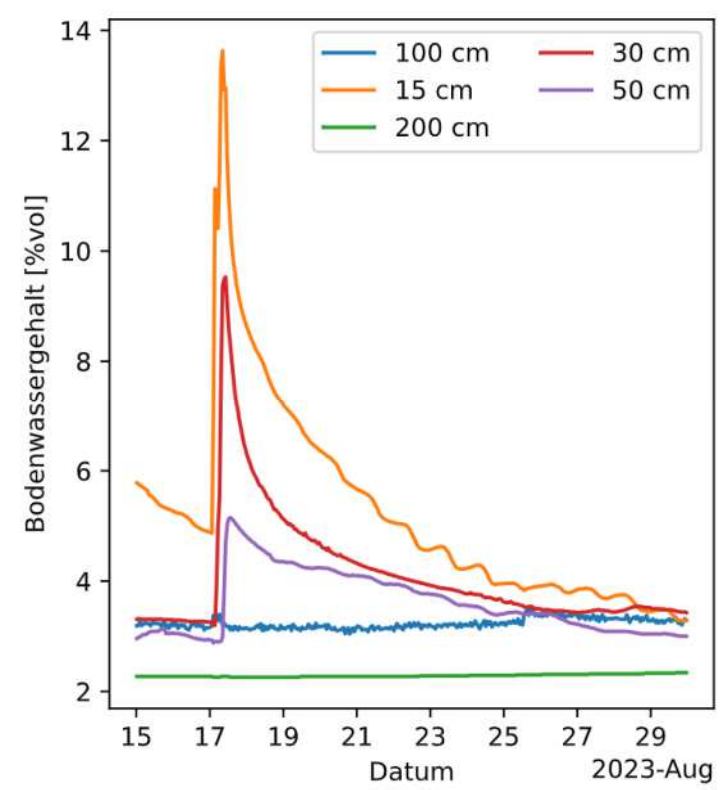
100 cm

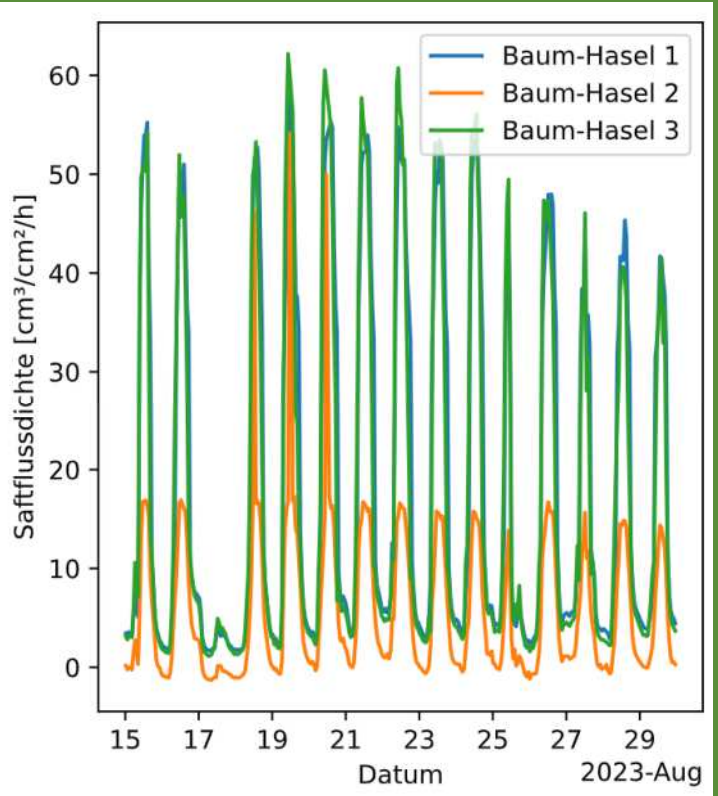


Soil water content vs. sap flow

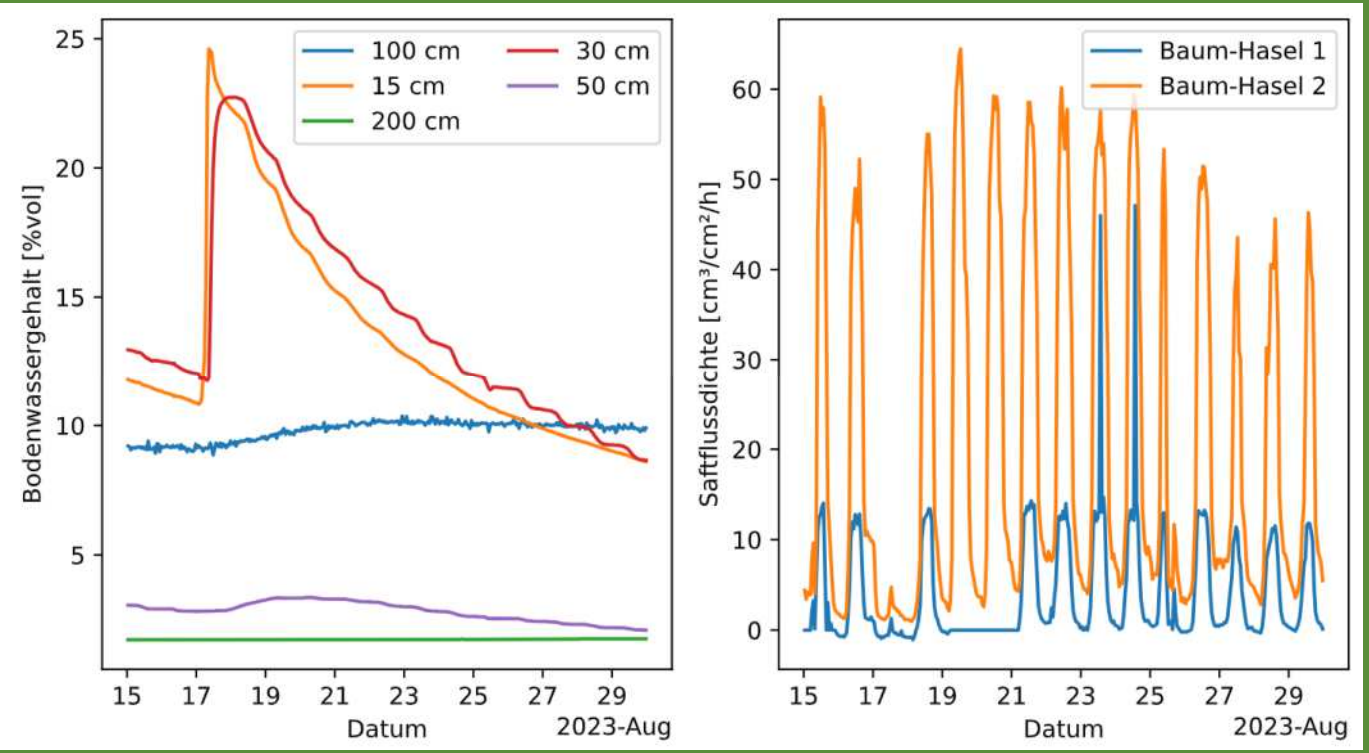


Soil water content vs. sap flow

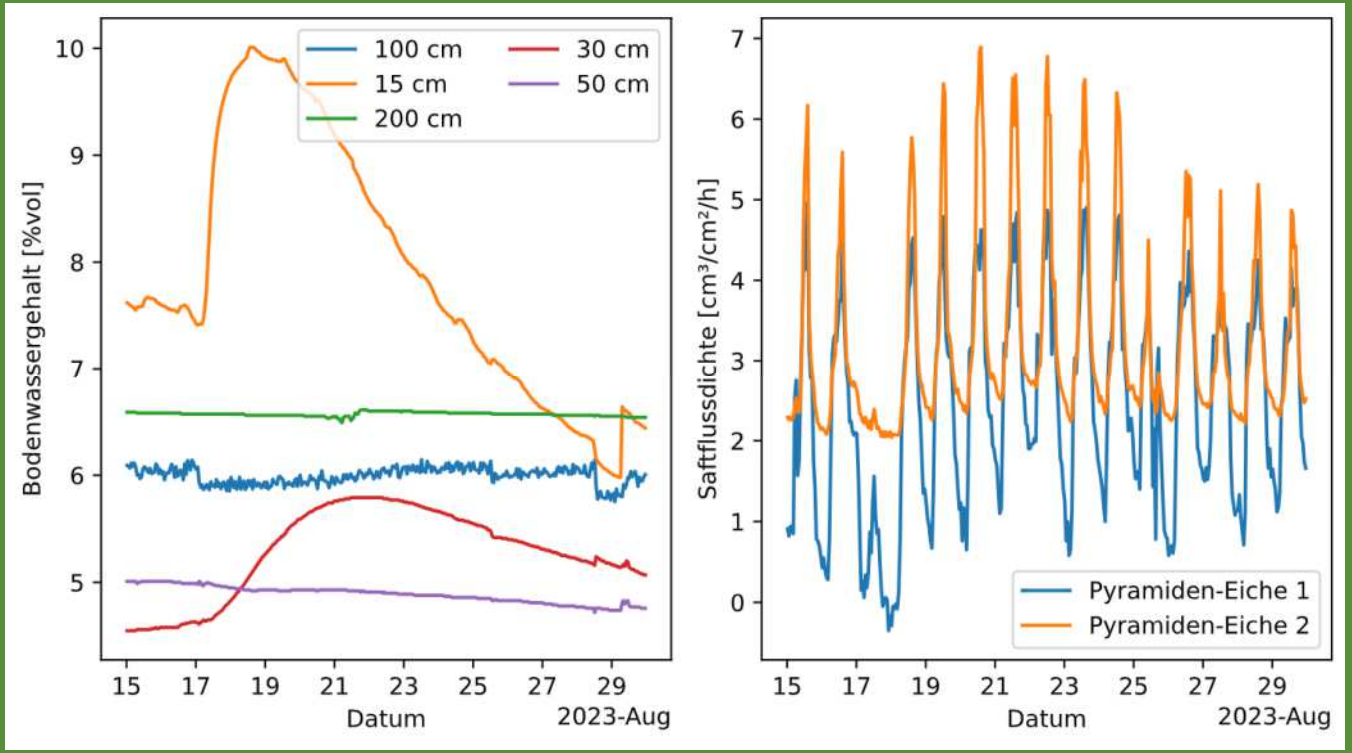




Soil water content vs. sap flow



Soil water content vs. sap flow



Take home

- IF we want to manage trees like we used to, we need to assure water availability to the upper 50 cm → irrigation is inavoidable
- BUT it would be much better to generate better retention in deeper soils and allow trees to root deeper

- Monitoring of water uptake is not simple, but important
- Very low water availability below 1m soil depth (sandy soil, no retention)
- No apparent connection to groundwater (?) → isotopes will answer
- Unsealed and sealed sites behave different, and every site is different

Thank you!

dashboard.isodrones.de

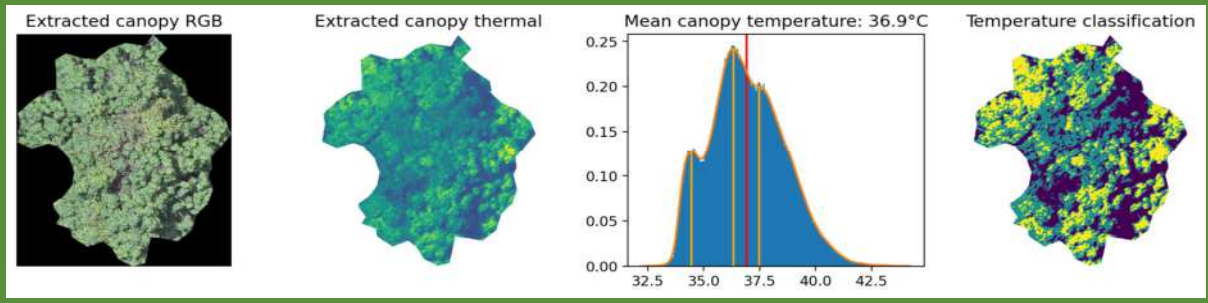
kraut&rüben
SCHÖNER. WILDER. BIOGARTEN.

Die natürliche Wasserpumpe

In der Natur gibt es einen bisher wenig erforschten, hydraulischen Effekt, der bei Dürre dazu beiträgt, dass Wasser aus tiefen Bodenschichten für Pflanzen verfügbar wird. Wie sich Gärtner das zu Nutze machen können, erklärt ein Hydrologe.

https://www.krautundrueben.de/

Please let UAV's help!



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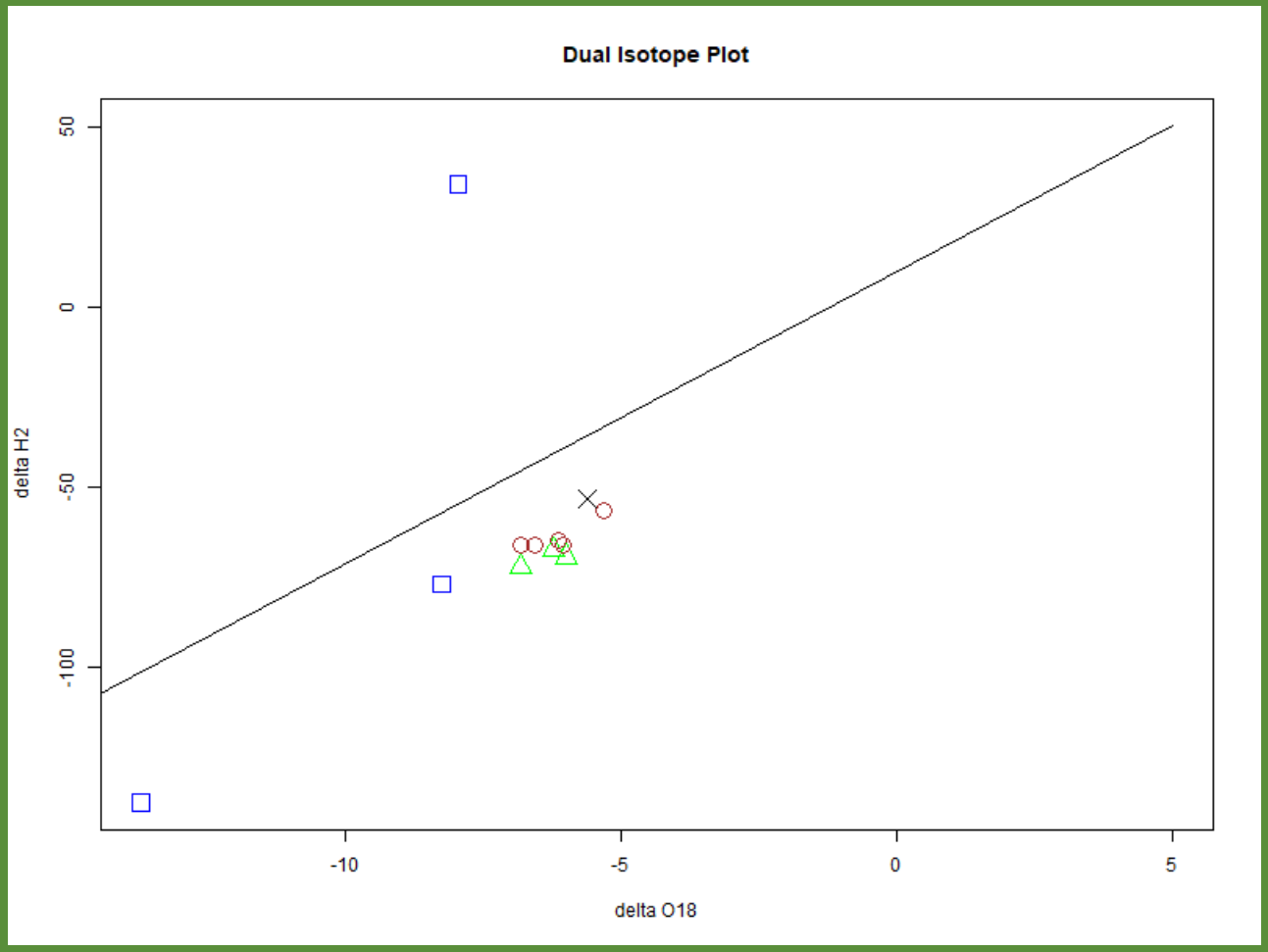

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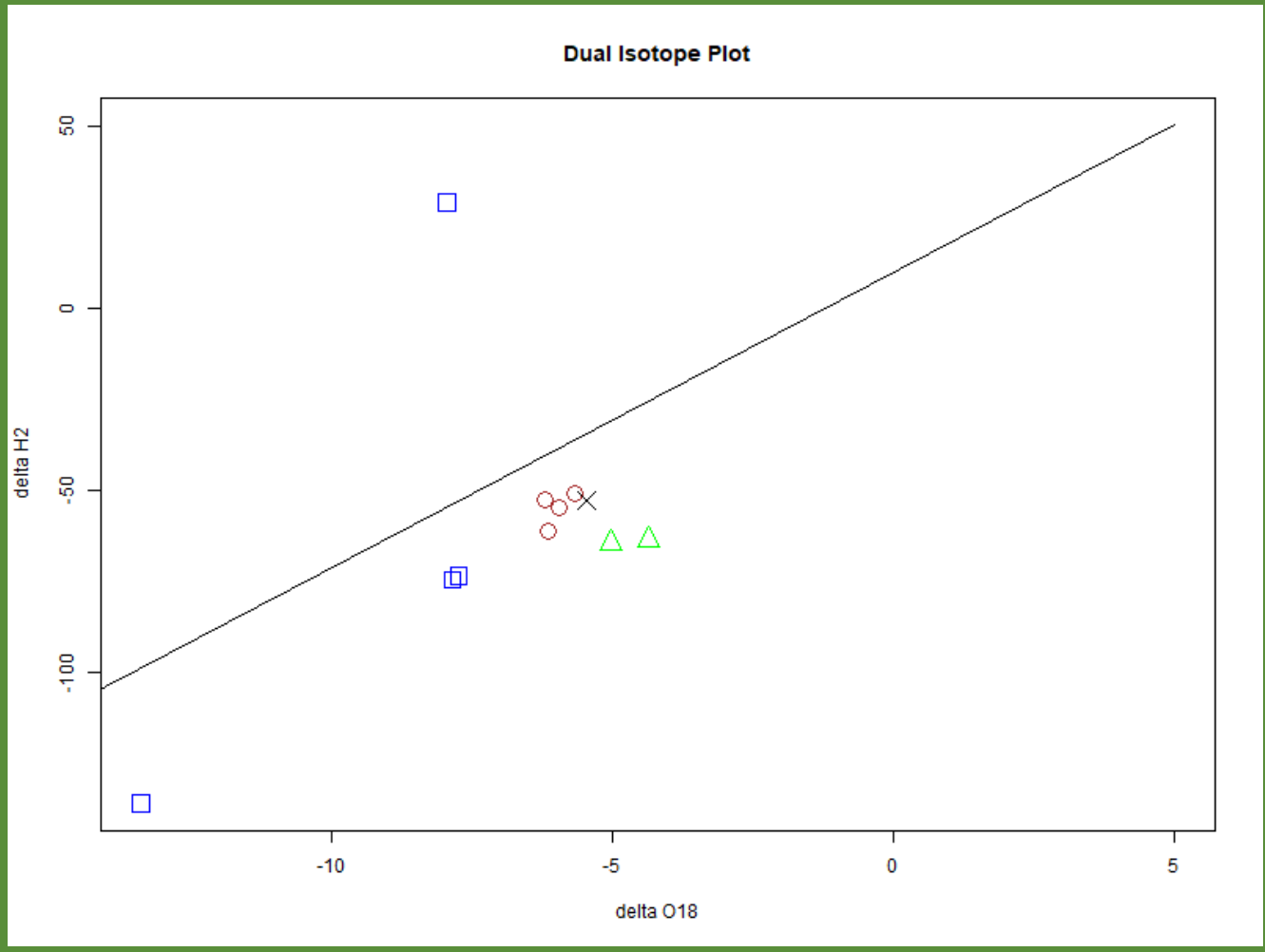

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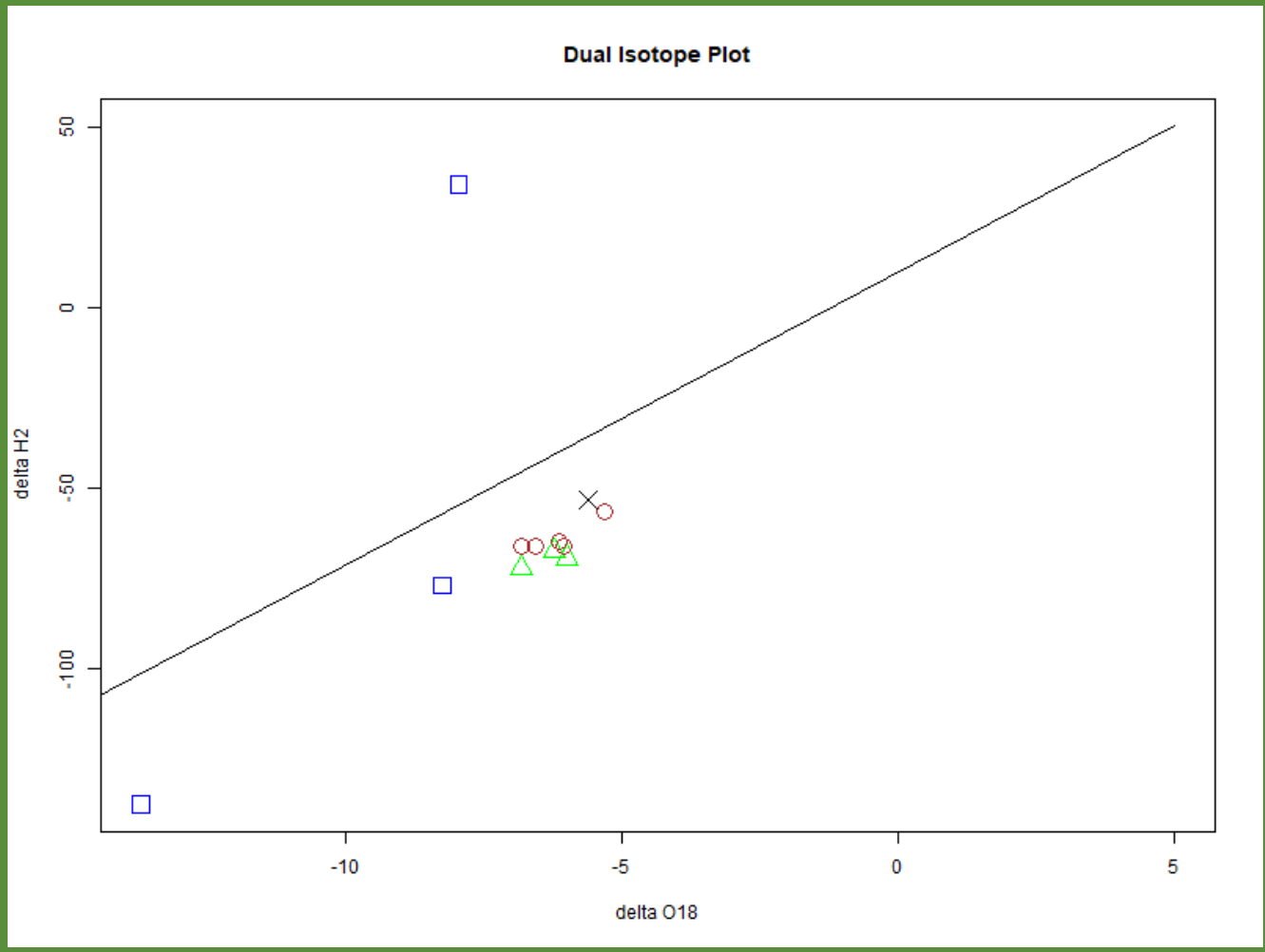

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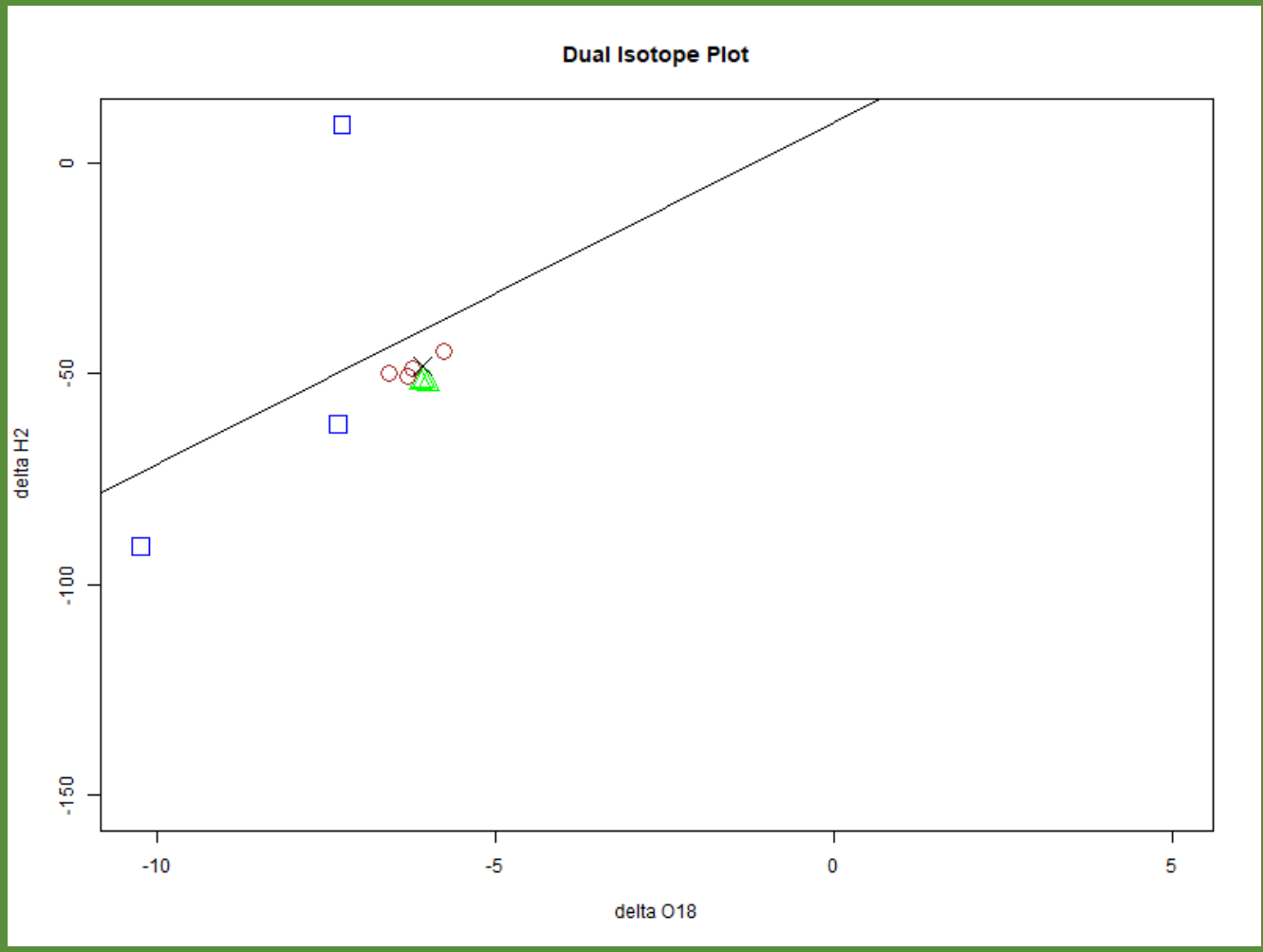

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