

Playing in the sandbox: An experimental set-up for comparison of soil moisture profile sensors

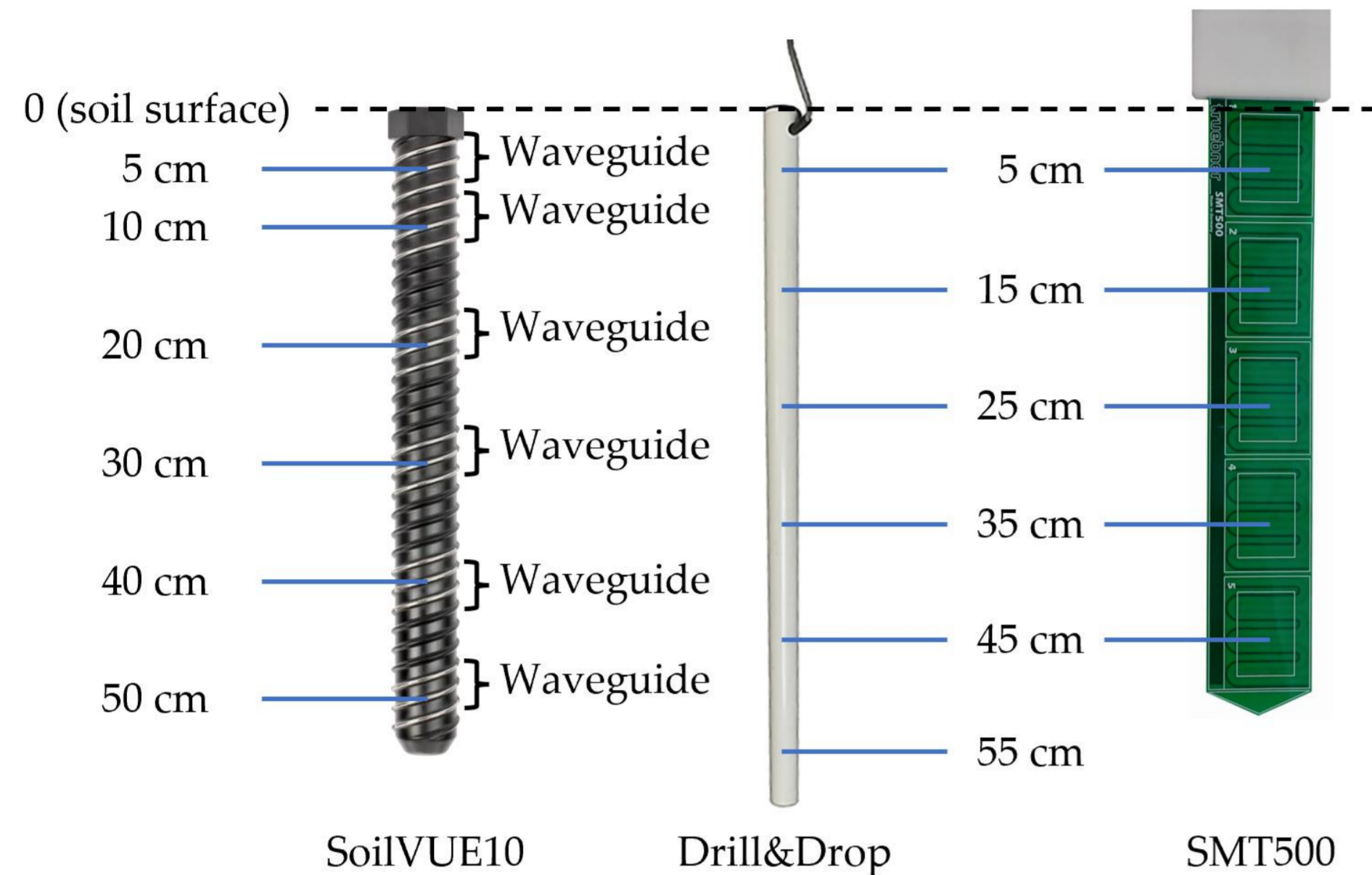
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High potential for Agriculture 4.0

- Real time soil moisture monitoring using IoT technologies for irrigation, fertilization and accessibility scheduling
- Use limited water resources in an efficient, economical and responsible manner
- Soil moisture profile sensors (SMPS) are easy to deploy and measure in different depths

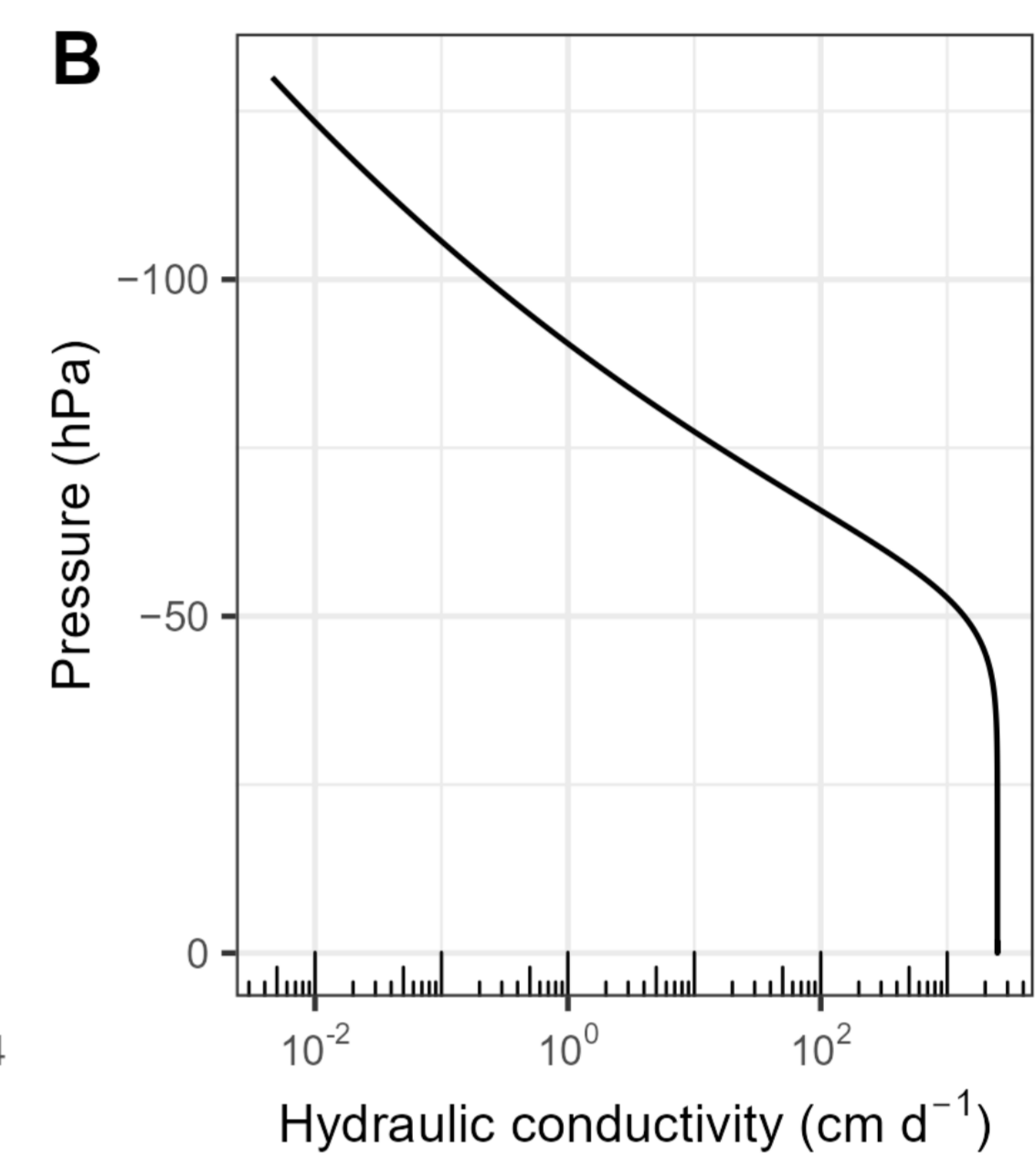
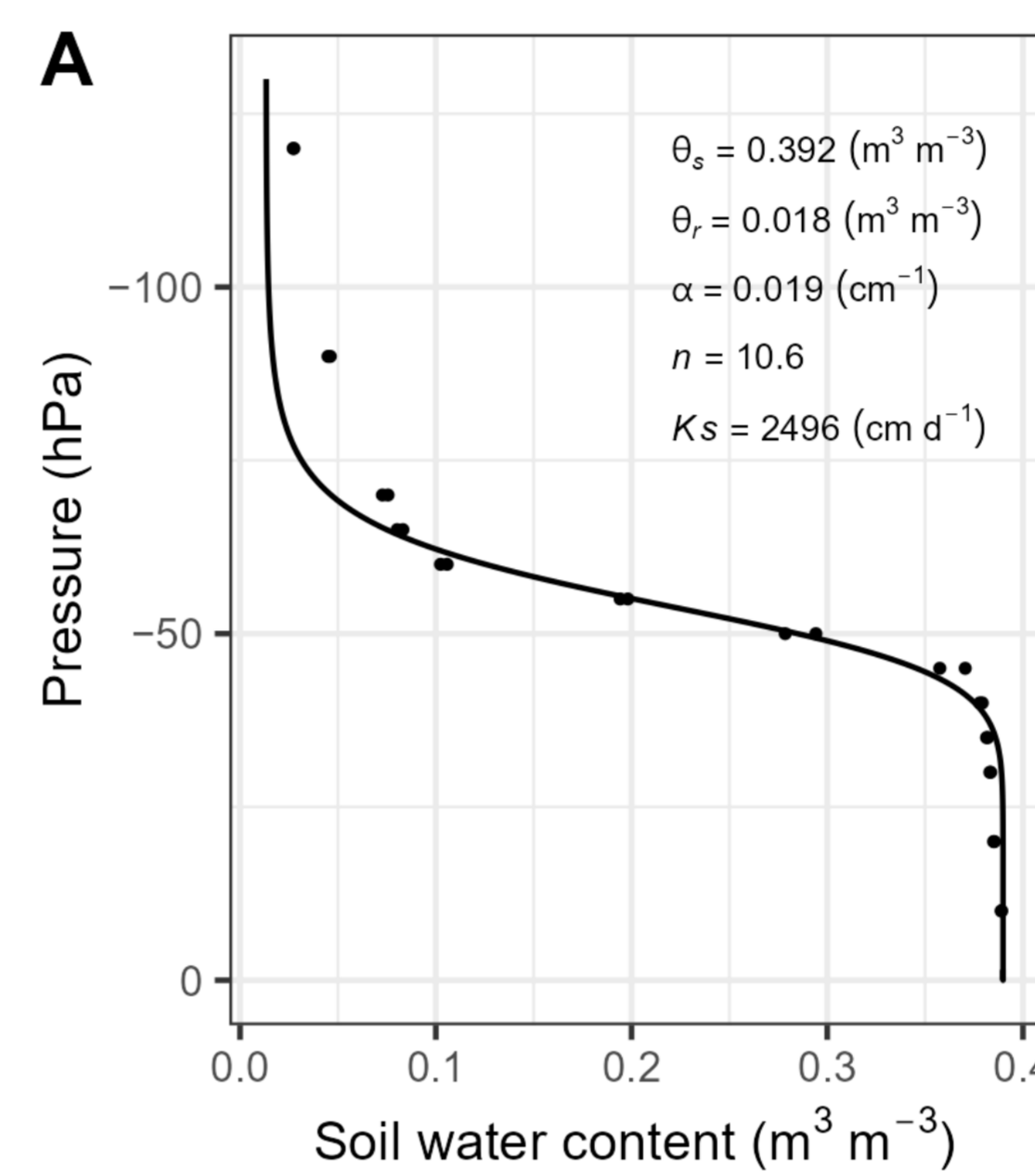


The three SMPSs evaluated in this study. From left to right: SoilVUE10 (Campbell Scientific), Drill&Drop (Sentek) and SMT500 (TRUEBNER, early prototype)

- How do the individual segments of the sensors react to changes in temperature for a saturated sand sample?
- Compare soil moisture profile sensors against reference measurements under controlled moisture regimes

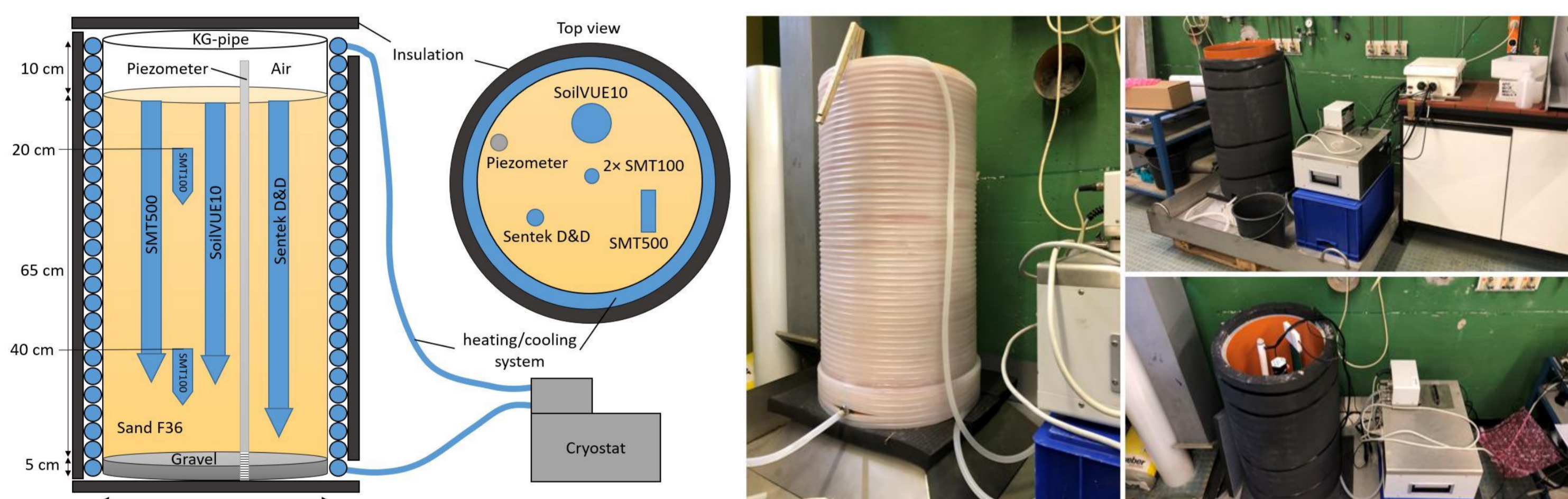
The substrate – Sand F36

- Well sieved fine sand
 - Average grain size: 0.16 mm, > 99 % SiO₂ content
 - Saturated hydraulic conductivity: 2496 cm d⁻¹ [3]
- High permeability and absence of organic matter
 - easy to create a homogeneous testbed
 - uniform bulk density and water content
 - limited wetting / drying hysteresis



(A) Soil water retention curve and fitting parameters and (B) unsaturated hydraulic conductivity curve of F36 sand estimated with the van Genuchten–Mualem model [2]. For comparability with the sandbox, the data and curves are only shown up to a pressure of -130 hPa

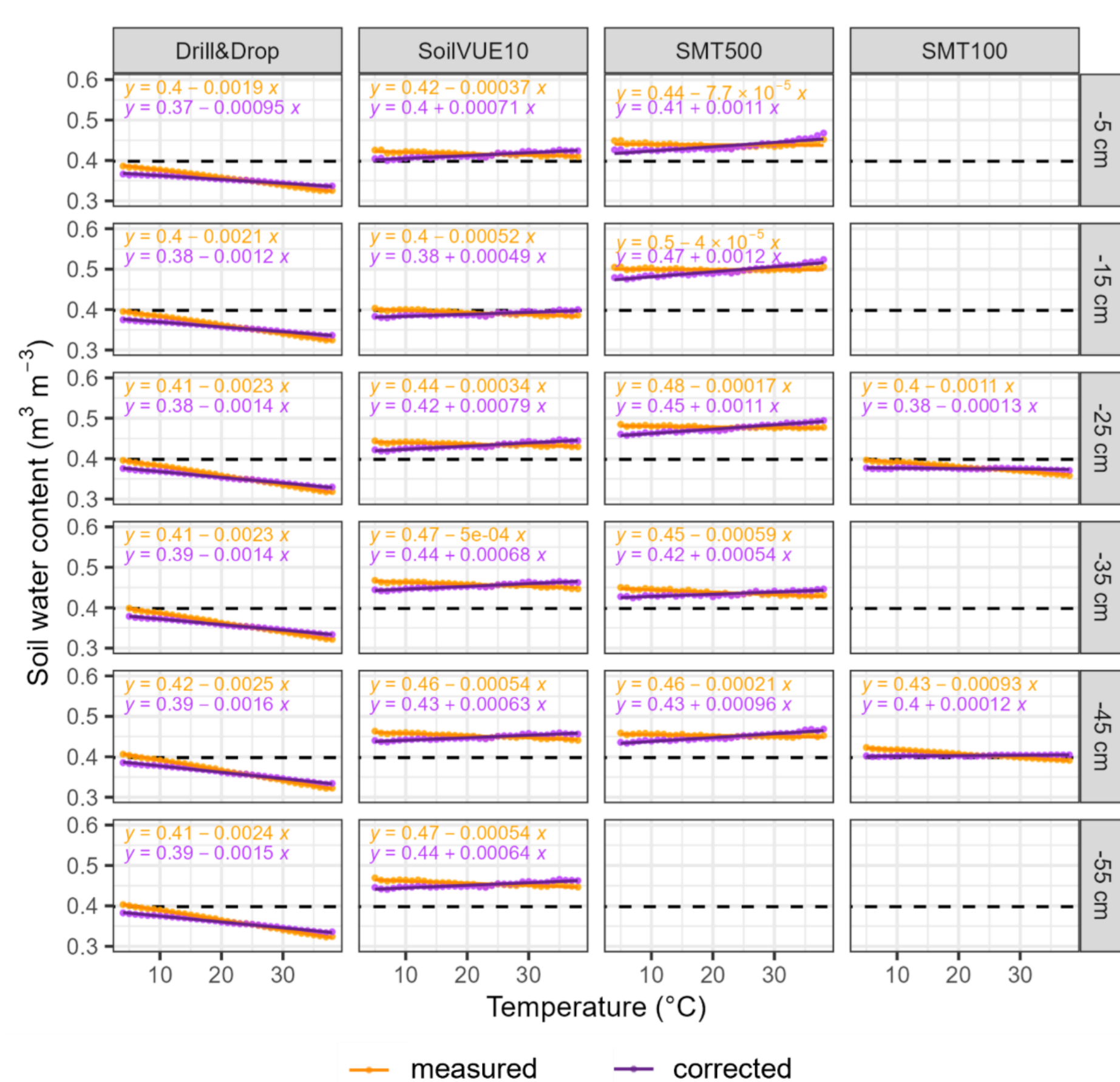
Laboratory experiment



Schematic view of the laboratory experiment

Photos of the laboratory experiment

- A 40 cm PVC column was equipped with a water cooling/heating system
- The SMPS were installed in a water saturated sand body and the temperature was stepwise increased from 5 to 40 °C
- The effect of temperature on the apparent dielectric permittivity of water was corrected for using CRIM [1]



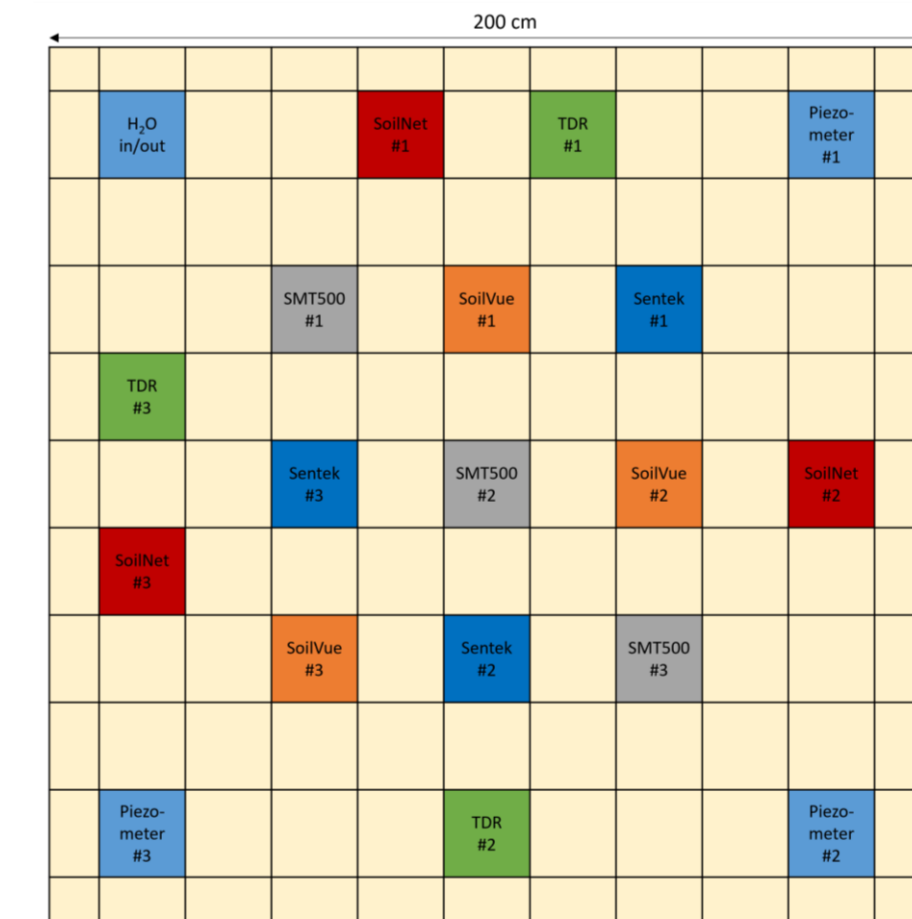
— measured — corrected

Soil moisture as a function of temperature before and after correction for the temperature effect on the dielectric permittivity of water

- Drill&Drop shows highest temperature sensitivity (-0.014 m³ m⁻³ per 10 °C)
- SoilVUE10 and SMT500 show slightly positive temperature dependency
- Calibrated SMT100 exhibits negligible temperature sensitivity

Field experiment – the sandbox

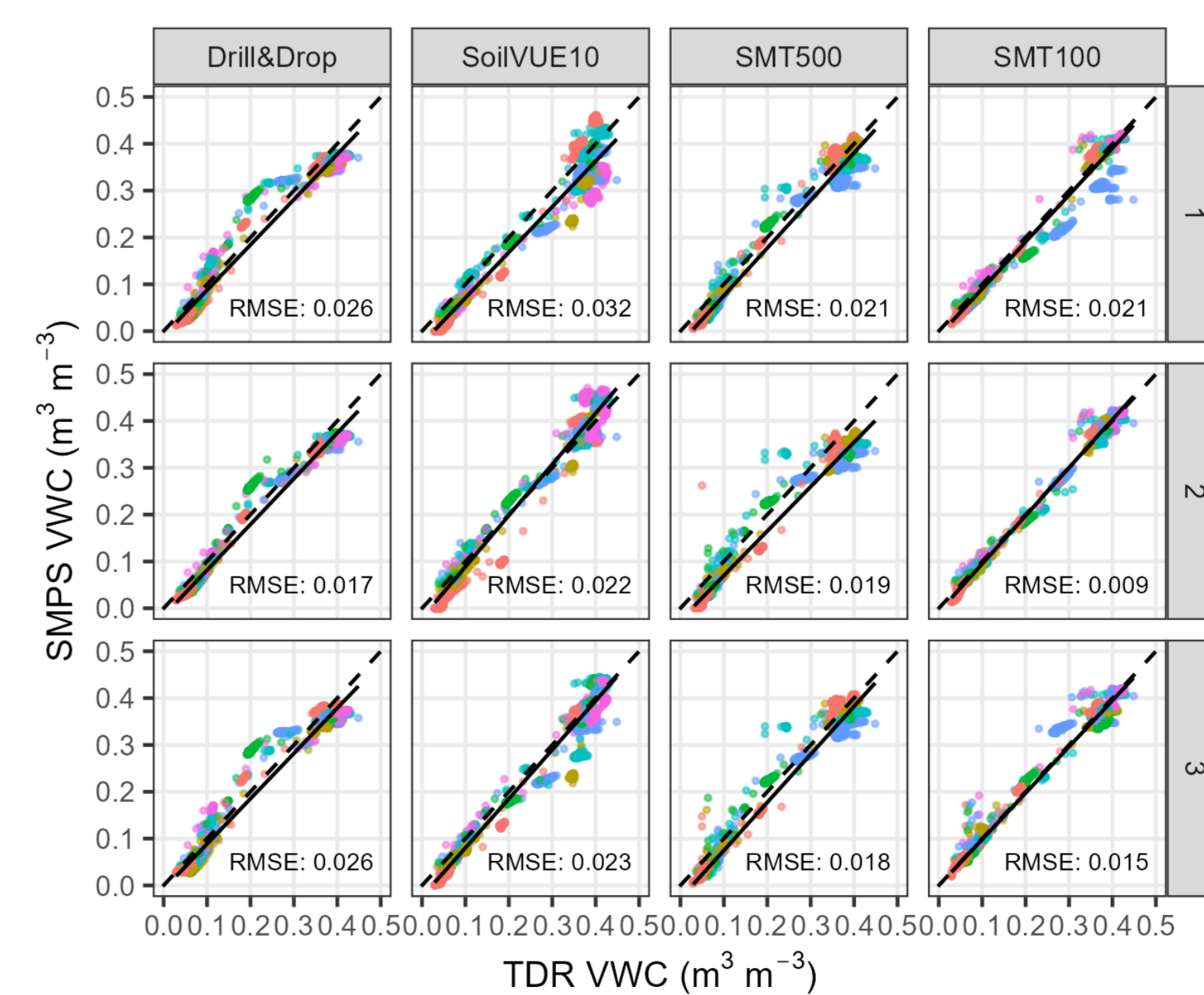
- Sensors were installed with triple replication in 2 x 2 x 1.5 m sand body
- Sandbox is equipped with TDR100 and SMT100 reference measurements
- Water table can be controlled through piezometers



Schematic view of the sensor arrangement in the sandbox



Photos of the sensors and piezometer arrangement in the sandbox experiment



Scatter plot of soil moisture measured by all SMPSs and SMT100 sensors versus soil moisture measured by TDR

- Drill&Drop, SoilVUE10 and SMT500 exhibit comparable correlations with TDR reference measurements (avg. RMSE: 0.020 to 0.026 m³ m⁻³)
- SMT100 showed best performance (avg. RMSE: 0.015 m³ m⁻³)

Conclusions

- Drill&Drop: economic sensor but potentially needs soil specific calibration
- SoilVUE10: relatively accurate, but installation can be difficult
- SMT500: accurate but calibration and calculations need improvement
- SMT100: good reference sensor with high accuracy and low temperature sensitivity



[1] Roth, K., Schulin, R., Flüher, H., and Attinger, W.: Calibration of time domain reflectometry for water content measurement using a composite dielectric approach, Water Resour. Res., 26, 2267–2273, doi:10.1029/WR026i010p02267, 1990.
[2] van Genuchten, M. T.: A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils, Soil Science Society of America Journal, 44, 892–898, doi:10.2136/sssaj1980.03615995004400050002x, 1980.