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

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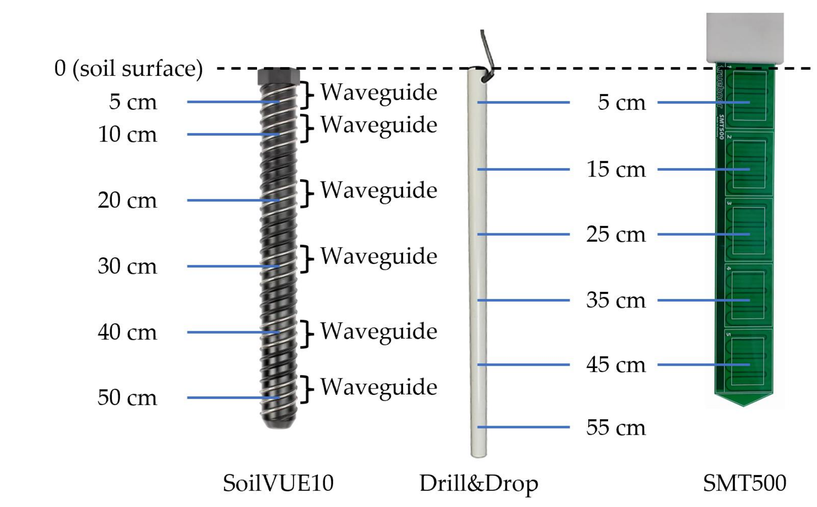
High potential for Agriculture 4.0

- 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 from above ground and measure in different depths

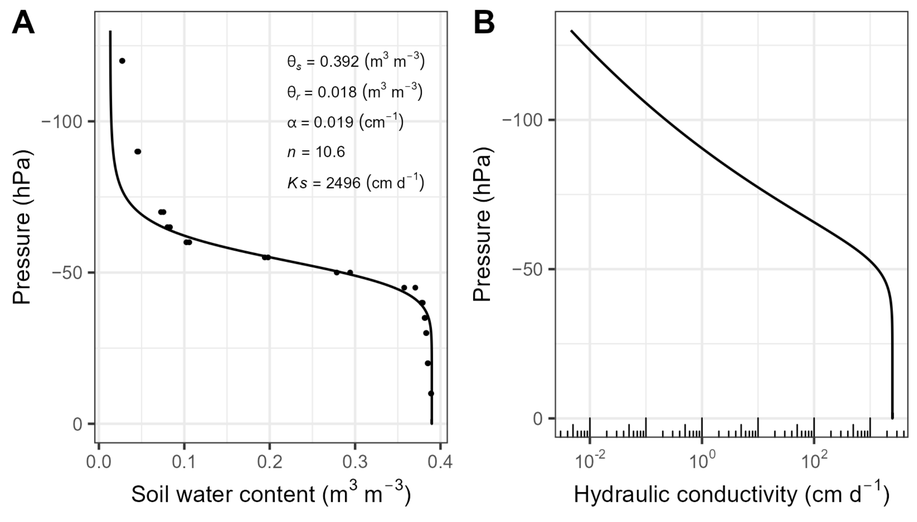


The three SMPSs evaluated in this study. From left to right: SoilVUE10 (Campbell Scientific), Drill&Drop (Sentek) and SMT500 (TRUEBNER, early prototype)

- How do the individual segments of the sensors react to changes in temperature at saturation water content?
- Compare soil moisture profile sensors against reference measurements under controlled moisture regimes

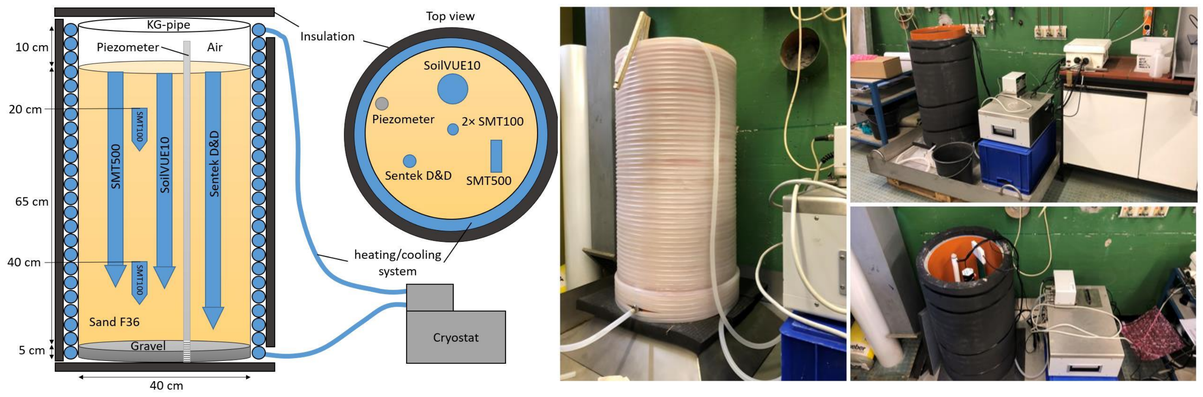
The substrate – Sand F36

- 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 [4]. For comparability with the sandbox, the data and curves are only shown up to a pressure of 130 hPa.

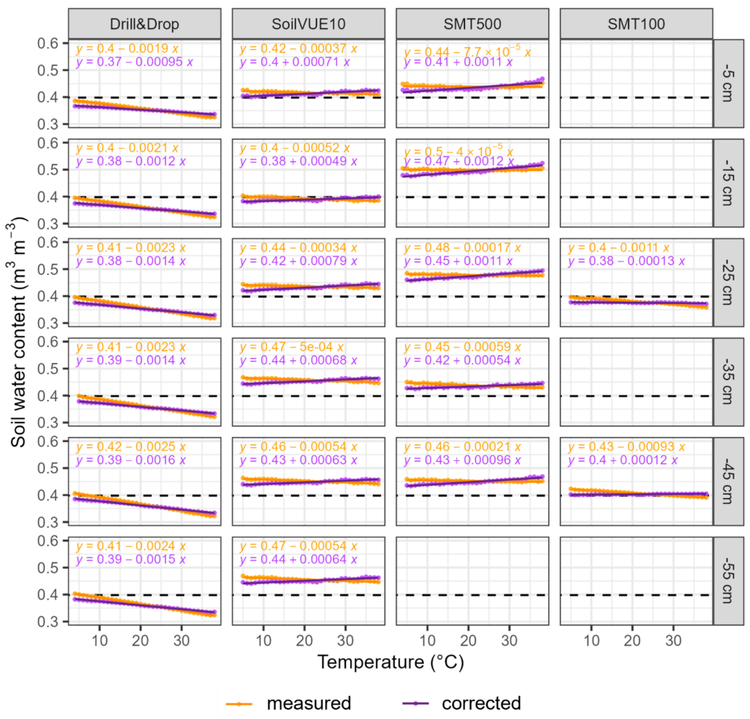
Laboratory experiment



Schematic overview of the laboratory experiment

Photos of the laboratory experiment

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



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

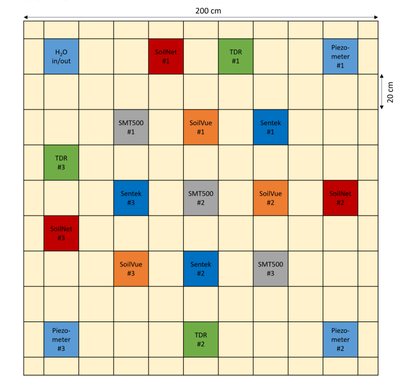
- Drill&Drop shows highest temperature sensitivity (-0.014 m^3 m^{-3} per 10 °C)
- SoilVUE10 and SMT500 show slightly positive temperature dependency
- Calibrated SMT100 exhibit negligible temperature sensitivity

Sources and links will be put here

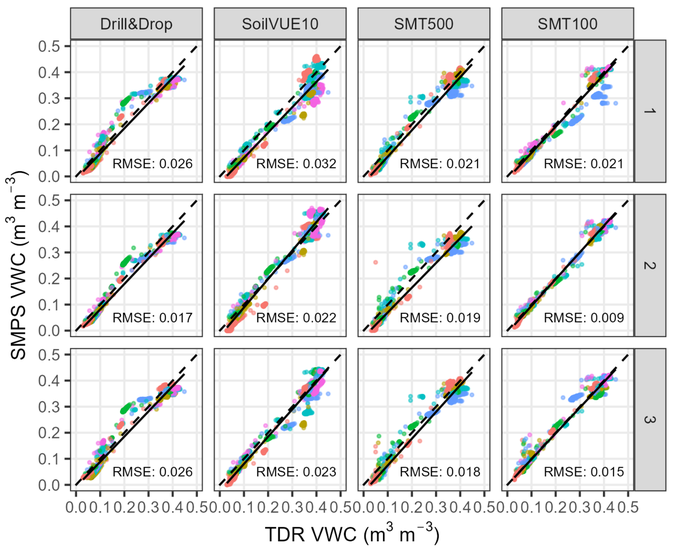
Field experiment – the sandbox

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

Photos of the sensors and piezometer arrangement in the sandbox experiment



Schematic view of the sensor arrangement in the sandbox.



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 m^3 m^{-3})
- SMT100 showed best performance (avg. RMSE: 0.015 m^3 m^{-3})

Conclusions

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