

FUNCTIONAL EVALUATION OF TMS-4 SOIL MOISTURE AND TEMPERATURE SENSOR

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SOIL MOISTURE CONTENT DETERMINATION - ACCURACY

There are many factors affecting soil moisture content measurement accuracy

- Sensor (type, **calibration**, aging of the sensor, measurement volume)
- Soil properties (texture, structure, ρ_d , OM, EC, rock presence, air gaps)
- Environment (**temperature**, freezing/thawing, shrinking/swelling)
- Operational factors (logging frequency, INSTALLATION QUALITY)



AIM OF THE STUDY

To test the performance of a relatively cheap soil moisture sensor TMS-4 (TOMST, Czech Republic) under variable temperature and soil moisture conditions when using factory and own soil-specific calibration.

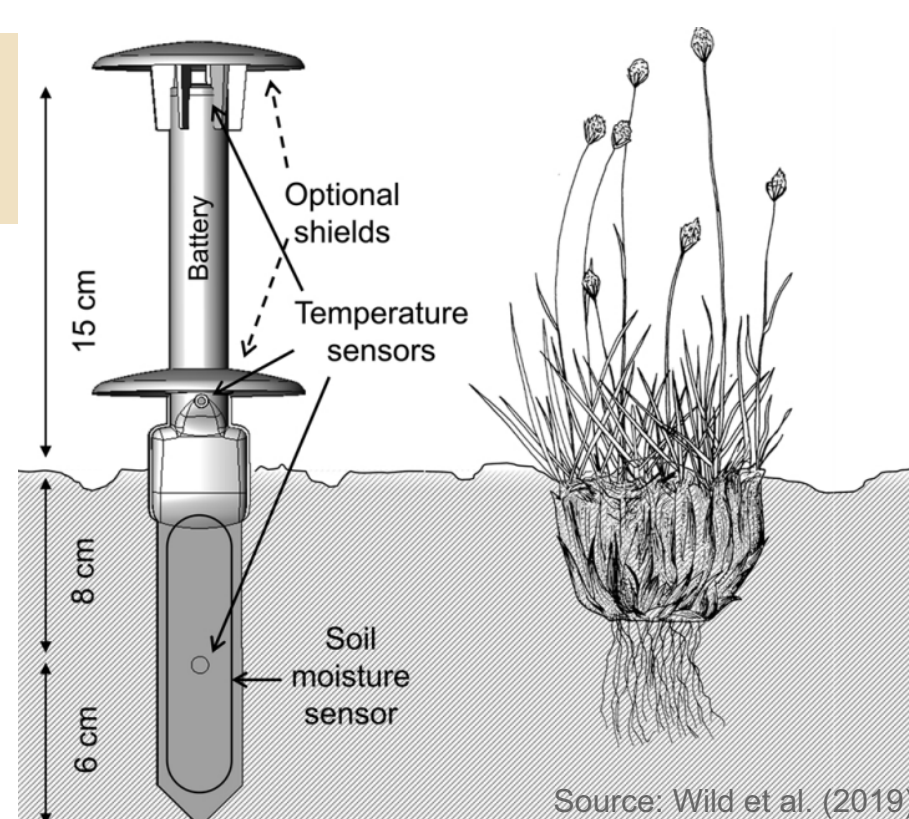
SENSOR DESCRIPTION

TMS-4 (TOMST, Czech Republic) - 100 € /pc.

Working principle: Time Domain Transmission

Measurement error of VWC: < 1 % (by vol.) ... ?

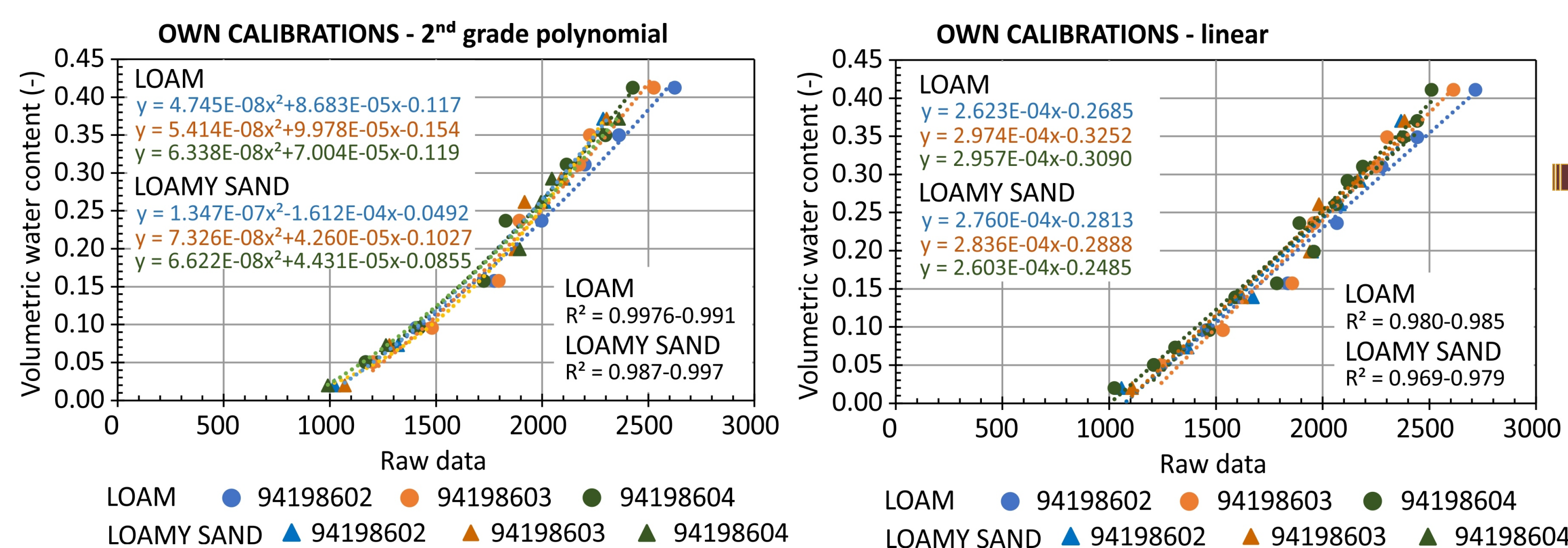
Storage capacity: 500 000 values ~ corresponding to measurements every 15 min for 14 years



RESULTS AND DISCUSSION

CALIBRATION and TEMPERATURE EFFECT - Comparison of calibrations types

Factory calibration equations: $y = -5.10 \cdot 10^{-8} \cdot \text{RAW}^2 + 3.98 \cdot 10^{-4} \cdot \text{RAW} - 0.291$
 $y = -2.30 \cdot 10^{-8} \cdot \text{RAW}^2 + 2.82 \cdot 10^{-4} \cdot \text{RAW} - 0.167$



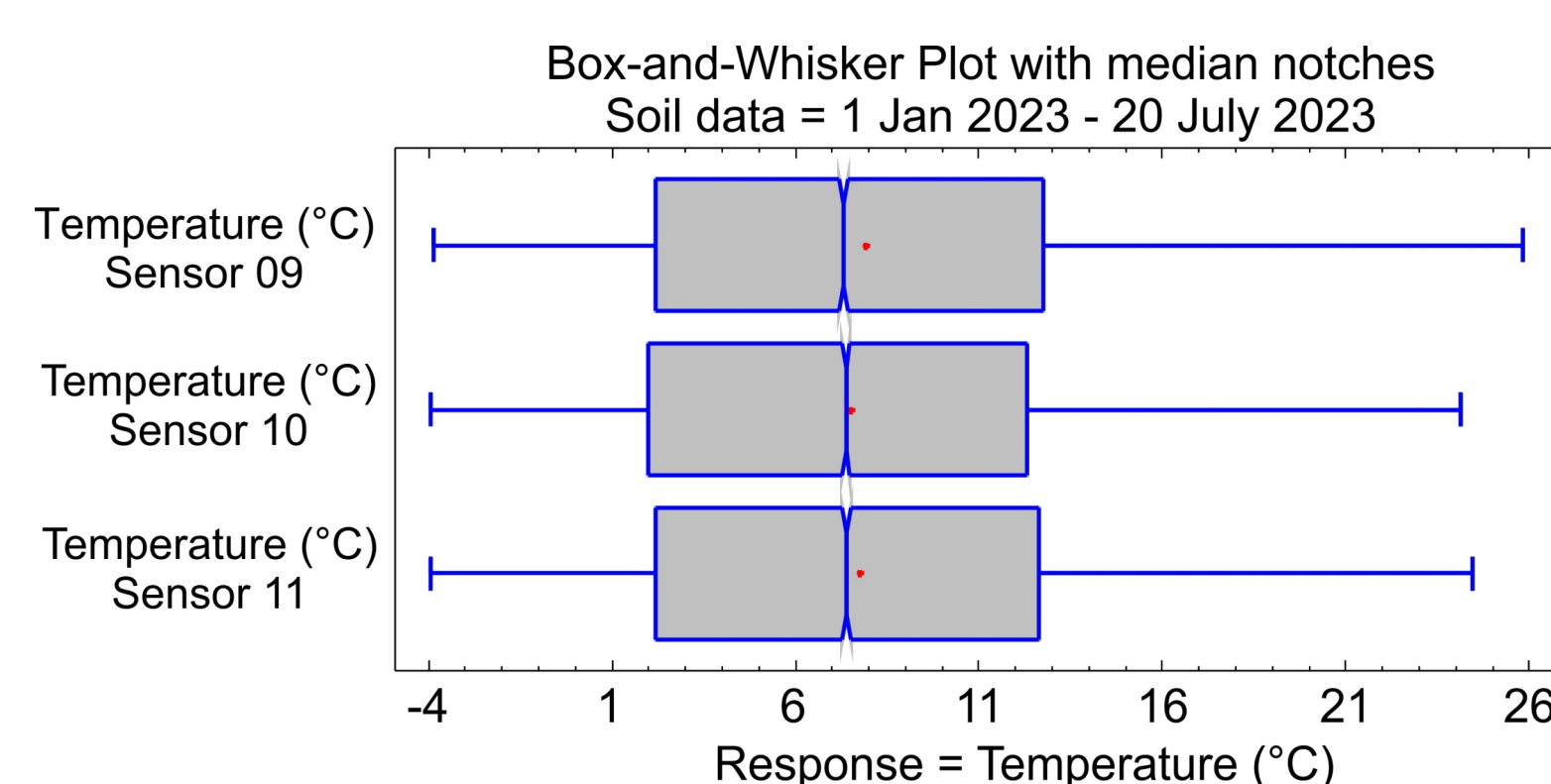
Application of own calibration equations significantly increased the measurement accuracy. Relatively good performance of linear calibration.

FIELD TESTING OF THE SENSORS

Statistically insignificant differences in measured air temperature (15 cm above surface).

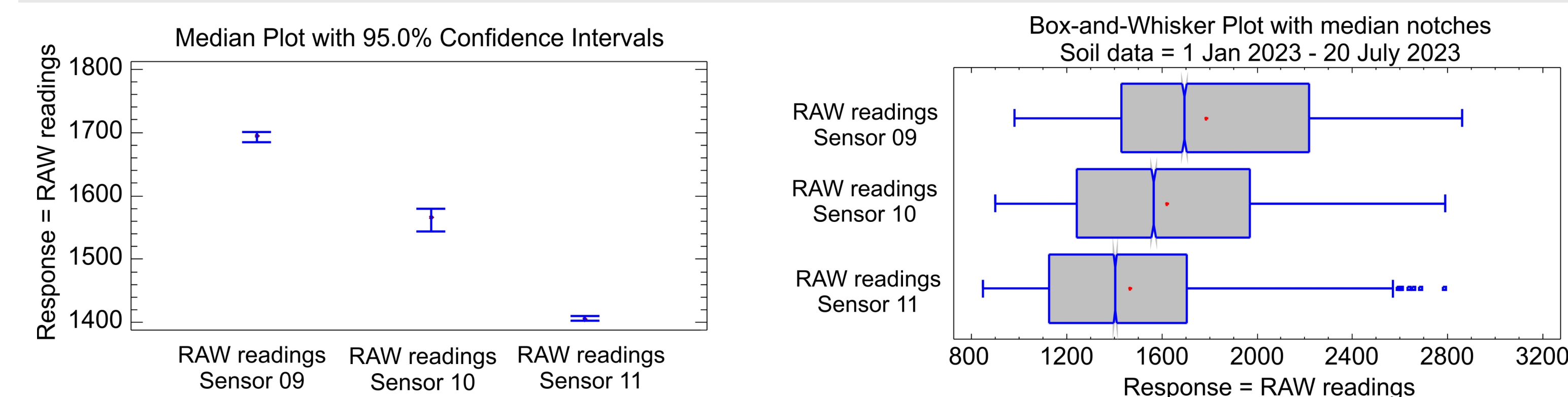
	Temperature (+15 cm)		RAW data	
	Min (°C)	Max (°C)	Min	Max
Sensor 09	-3.9	25.8	983	2860
Sensor 10	-3.9	24.1	901	2788
Sensor 11	-3.9	24.4	851	2785

Biggest measured sensor to sensor difference		
	Temperature (+15 cm) (°C)	RAW data
Sensor no. 9-10	3.8	670
Sensor no. 9-11	2.3	859
Sensor no. 10-11	2.0	438



Since the temperature and RAW data were not normally distributed, non parametric tests were performed and the medians of the data sets were compared.

Big sensor to sensor variability in RAW readings was observed.



In total, six TMS-4 sensors were tested in this study; three in the laboratory and three in the field. The sensor to sensor variability did not allow to use own calibration equations derived for sensors no. 02, 03, and 04 for the sensors applied in the field (no. 09, 10, and 11).

Large and significant differences in RAW readings (soil moisture contents) measured in the field have two possible causes; i) natural differences in soil moisture content in the field and ii) differences in the sensors readings. Further research needs to be carried out in order to quantify the extent of the sensor to sensor variability.

METHODOLOGY

Experimental setup - laboratory:

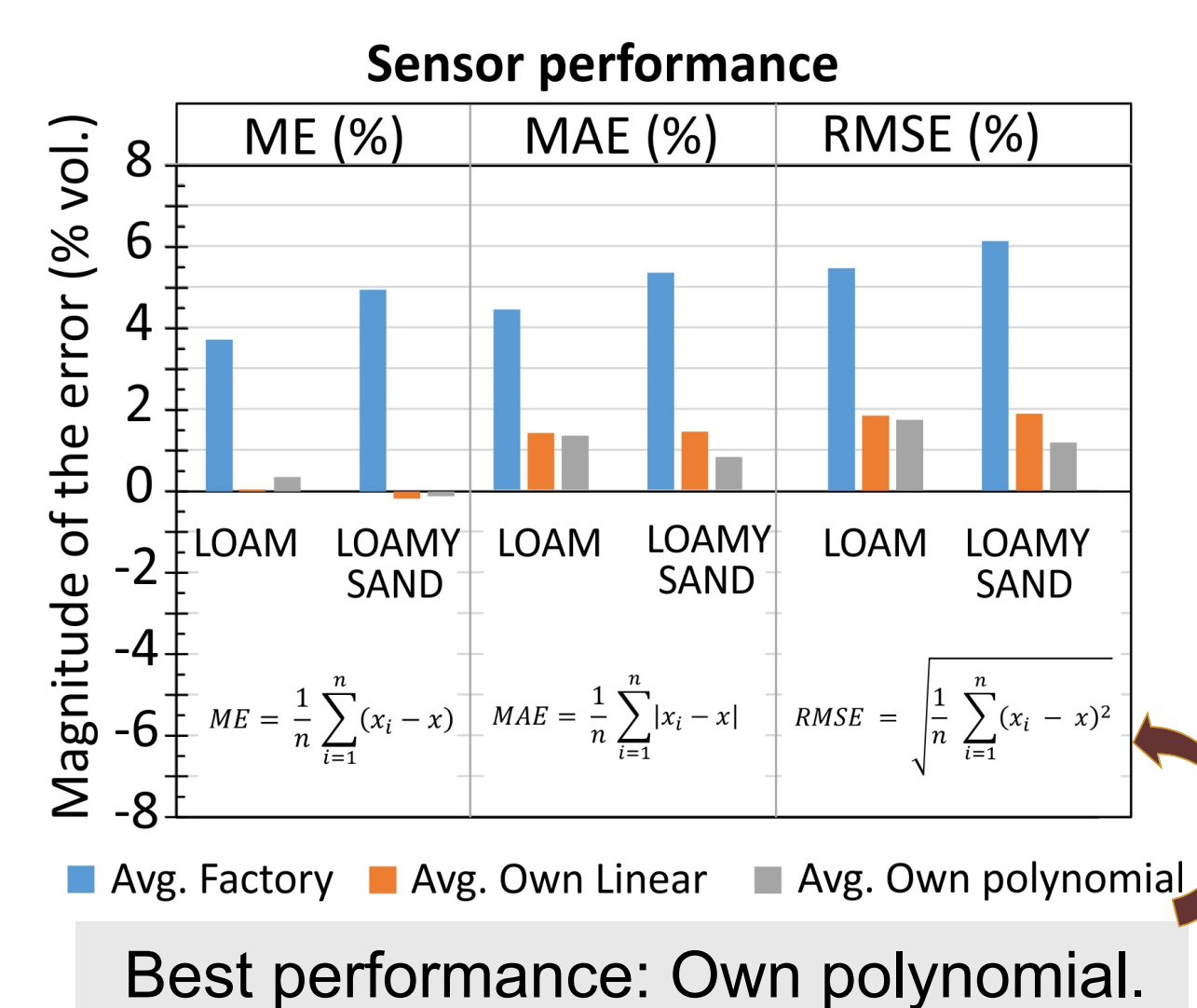
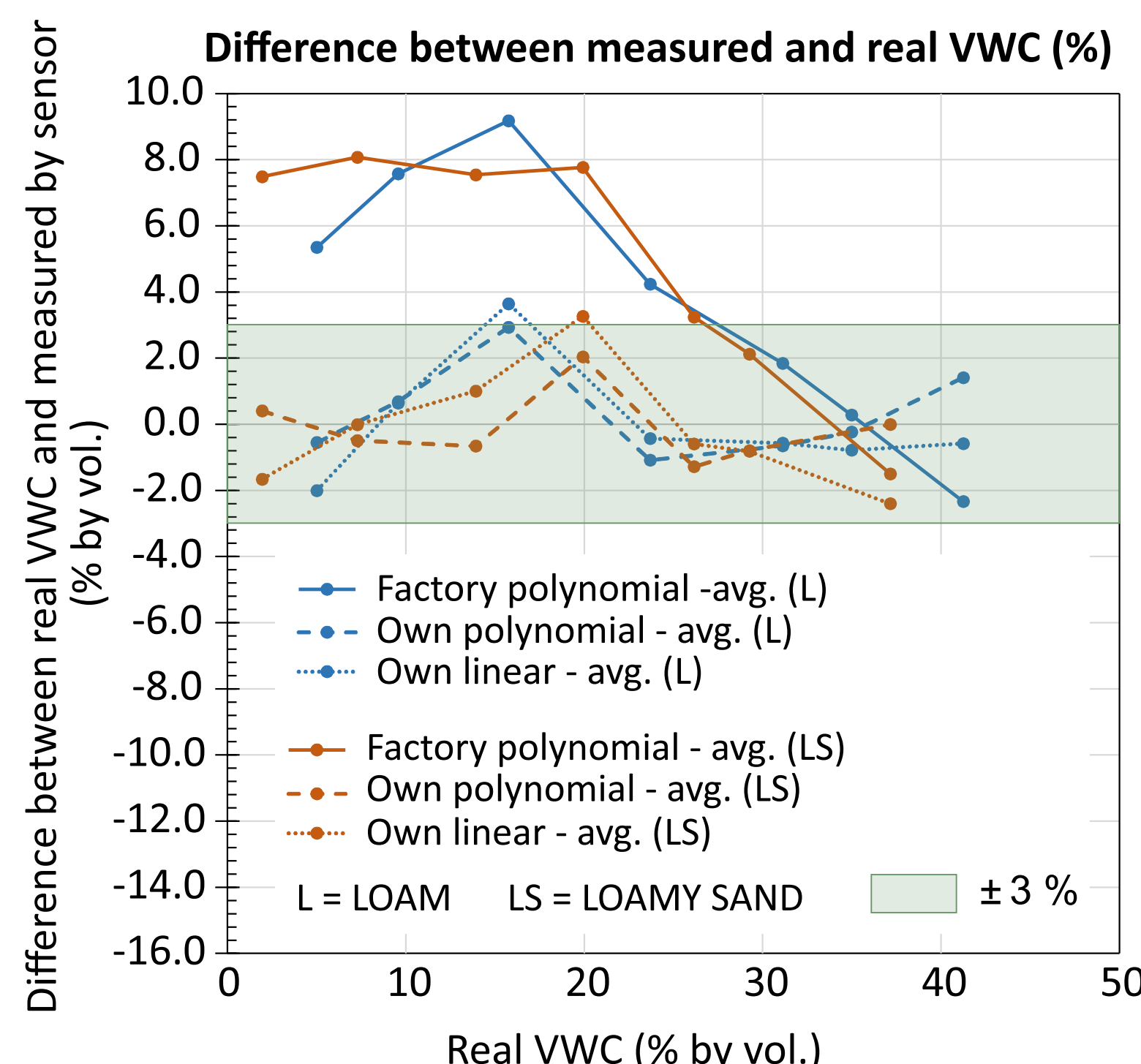
- 3 replicates of the sensor (no. 02, 03, and 04)
- 2 text. different soils (Loamy Sand, Loam)
- 3 temperature levels (4°C, 20°C, and 35°C)
- 1 calibration container (11 l, Ø 19 cm, h = 40 cm)

Procedure:

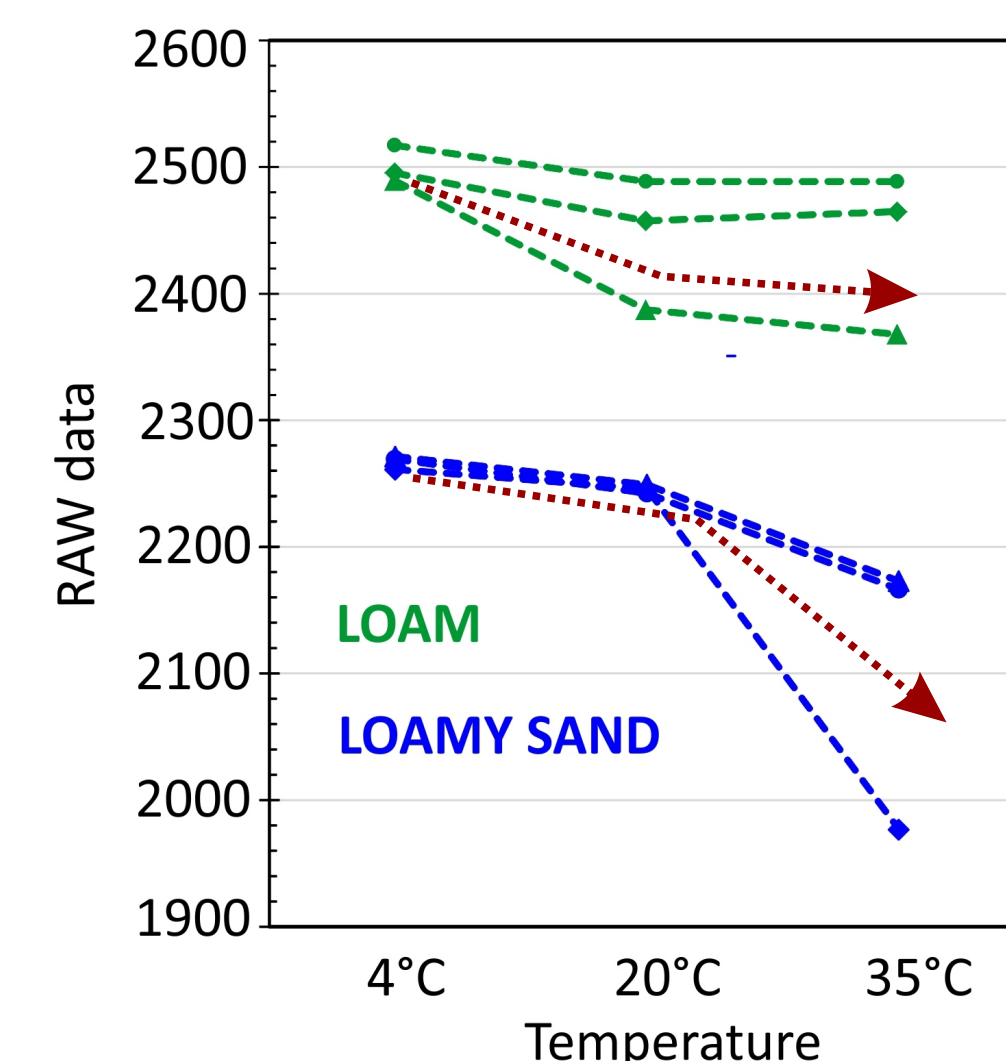
- Sensing volume of the sensors
- Own soil-specific calibrations (7 steps; 0 - 35 % vol.)
- SWC at different temperature levels – Climabox
- Statistical evaluation (ME, MAE, RMSE)
- Evaluation of temperature effect for real field conditions

Experimental setup - field:

- 3 replicates of the sensor (no. 09, 10 and 11)
- 1 soil (Loam, the same as used for the laboratory)
- Natural temperature fluctuation (from -3.9 to 25.8°C)
- Exp. period: 1 Jan 2023 - 20 July 2023, crop: winter wheat
- Measurement frequency: every 15 minutes



Sensor performance - temperature effect



Different pattern observed for Loam and Loamy Sand.

CONCLUSIONS

- Own calibration is necessary for accurate results.
- Although the polynomial type of calibration performed better, linear calibration might be more relevant due to relatively large sensor to sensor variability.
- Linear calibration in-situ would reflect field conditions and fewer points are needed for its construction.
- Temperature variations did not have significant impact on sensor accuracy in tested soil.
- RAW readings observed in the field differed significantly between the sensors; relatively large sensor to sensor variability has been confirmed, but some part of the differences can be attributed to soil heterogeneity.