

Background

In-situ soil moisture sensors provide continuous information on soil water status for irrigation planning and the evaluation of irrigation systems. Wireless sensors minimize field interventions and enable spatially explicit monitoring of actual wetting patterns—something that rain gauges placed above the canopy cannot capture due to interception and microdistribution. Reliable irrigation decisions require precise and accurate measurements. Therefore, we assess both attributes and show how calibration aligns sensor readings with reference values. However, the performance and practical applicability of the sensors depend on soil properties, the moisture range, and operating conditions.

Objectives

- Assess the precision and accuracy of wireless dielectric soil moisture sensors under controlled laboratory dry-down conditions
- Compare sensor performance between lab and field settings
- Evaluate sensor data utility for assessing sprinkler uniformity and application efficiency

Methods

Lab experiment: Soil Physic Laboratory, BOKU University

Field experiment: Agricultural School (LFS) Obersiebenbrunn, Lower Austria

Weather: Mean temperature 10.5 °C and mean annual precipitation 550 mm

Soil type: Sand & Loam

Irrigation: Sprinkler

Crop: Potato & Carrot

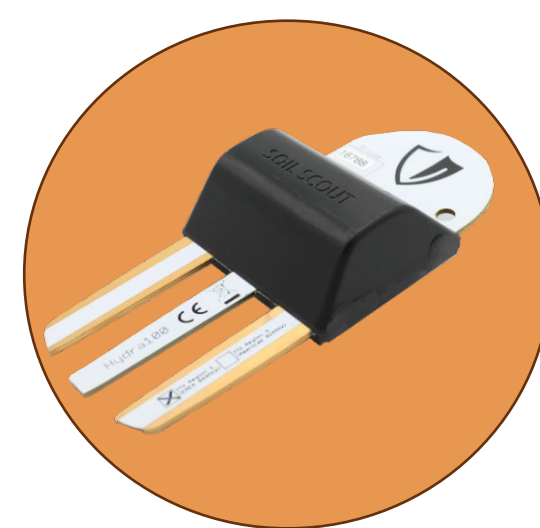


Fig 1. Wireless dielectric soil moisture (capacitive) sensor (Hydra100 by SoilScout Oy, FIN)

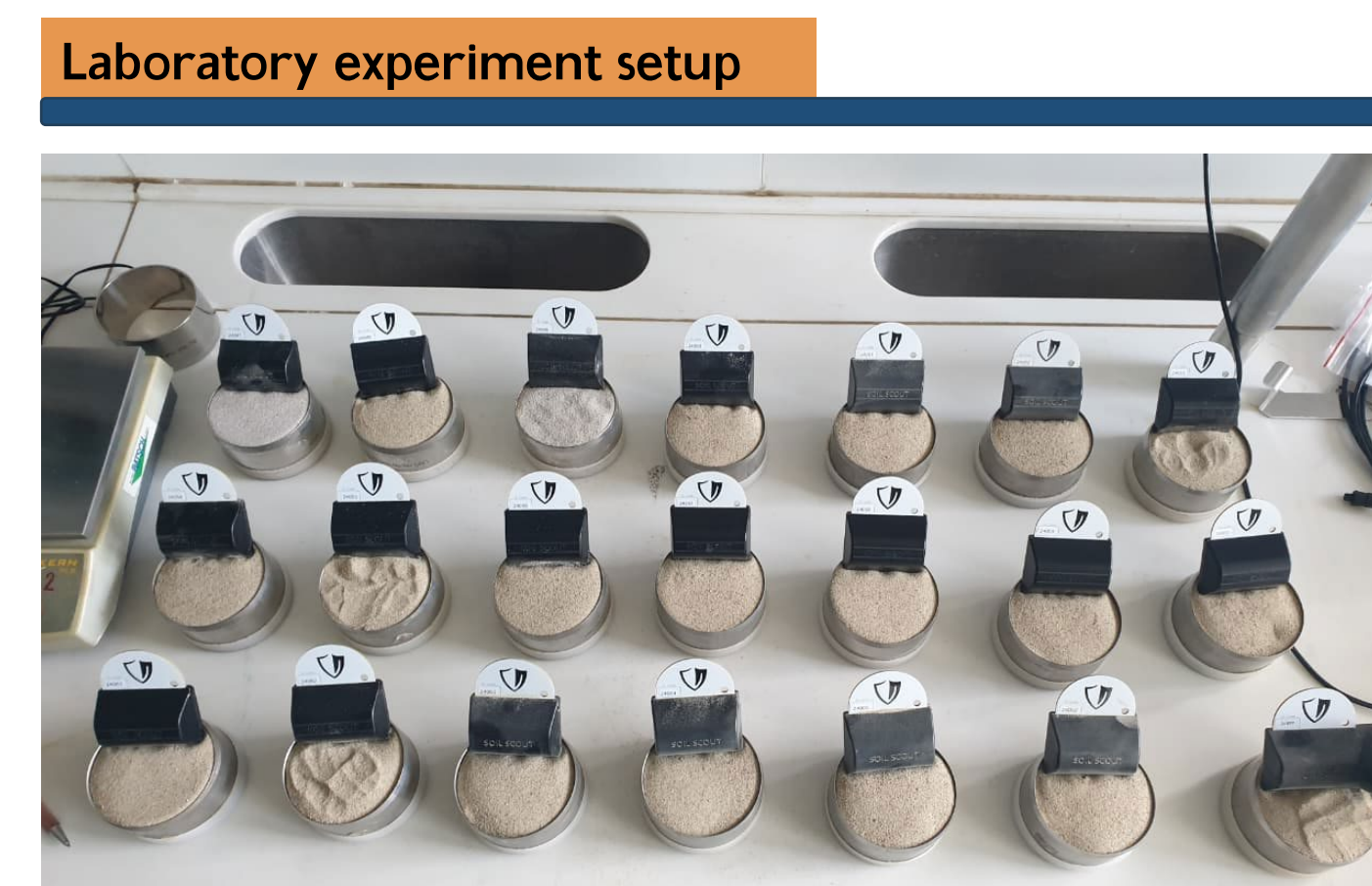


Fig 2. Lab test: gravimetric water content of sandy soil cylinders used as reference

Field experiment setup

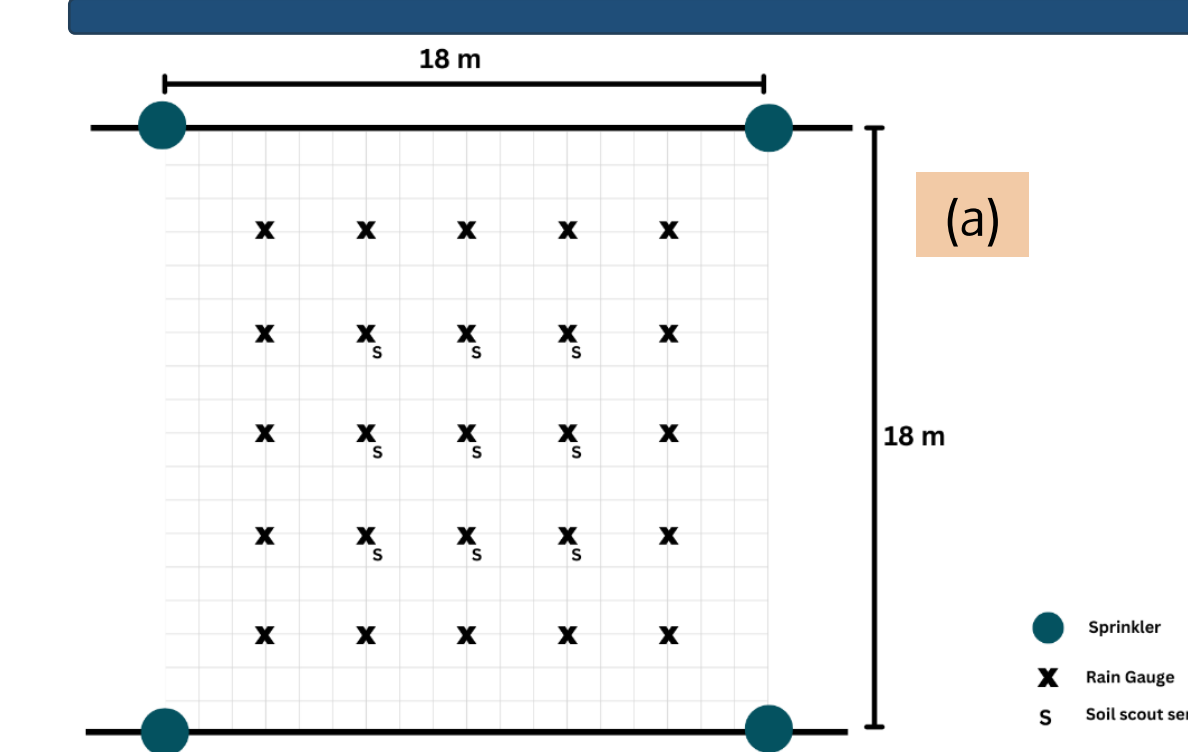


Fig 3. Potato (a) and Carrot (b) field experiment

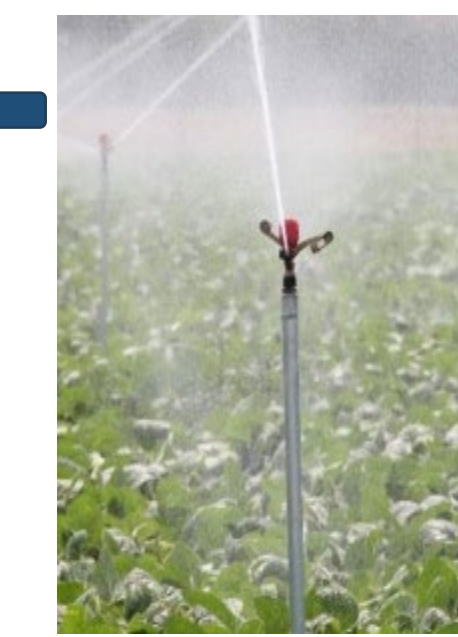


Fig 4. Sprinkler systems

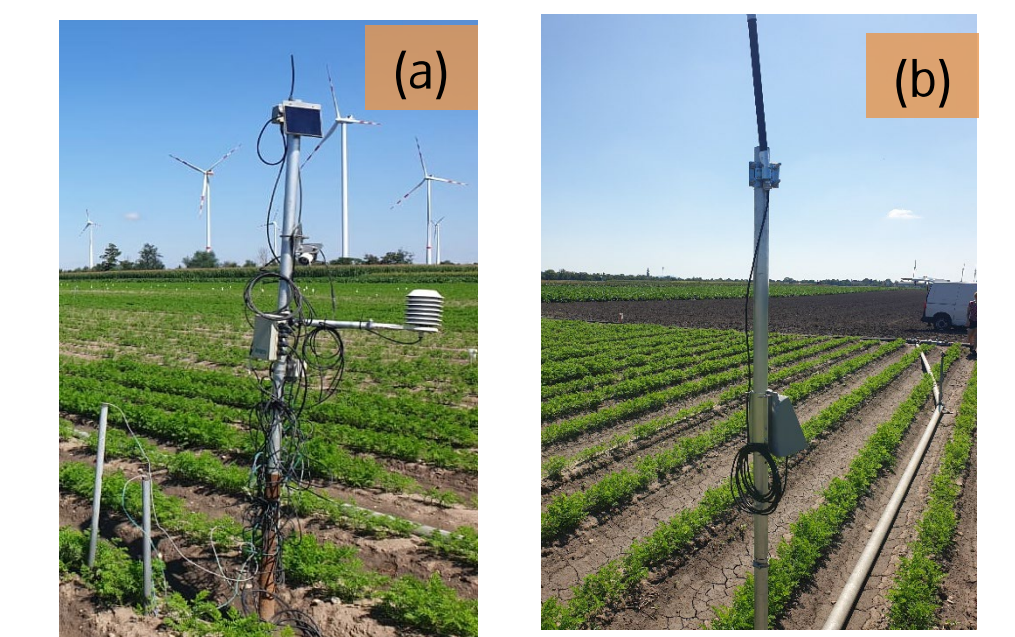


Fig 5. Field monitoring station (a) and wireless sensor receiver (b)

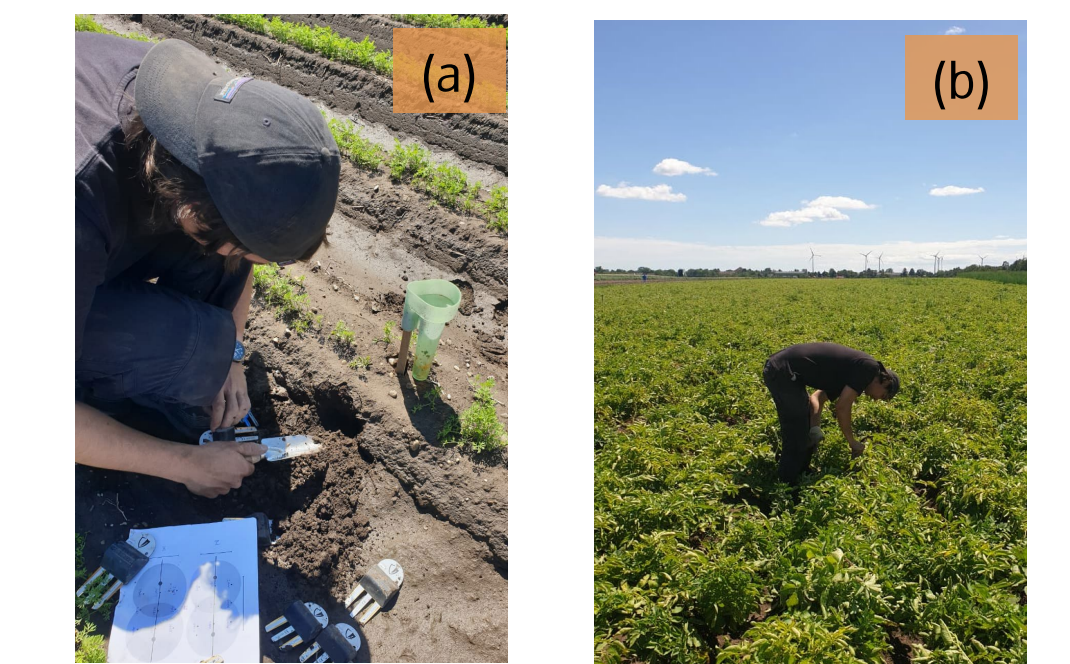


Fig 6. Sensor Installation (a) & Retrieval (b)

Result

Laboratory experiment

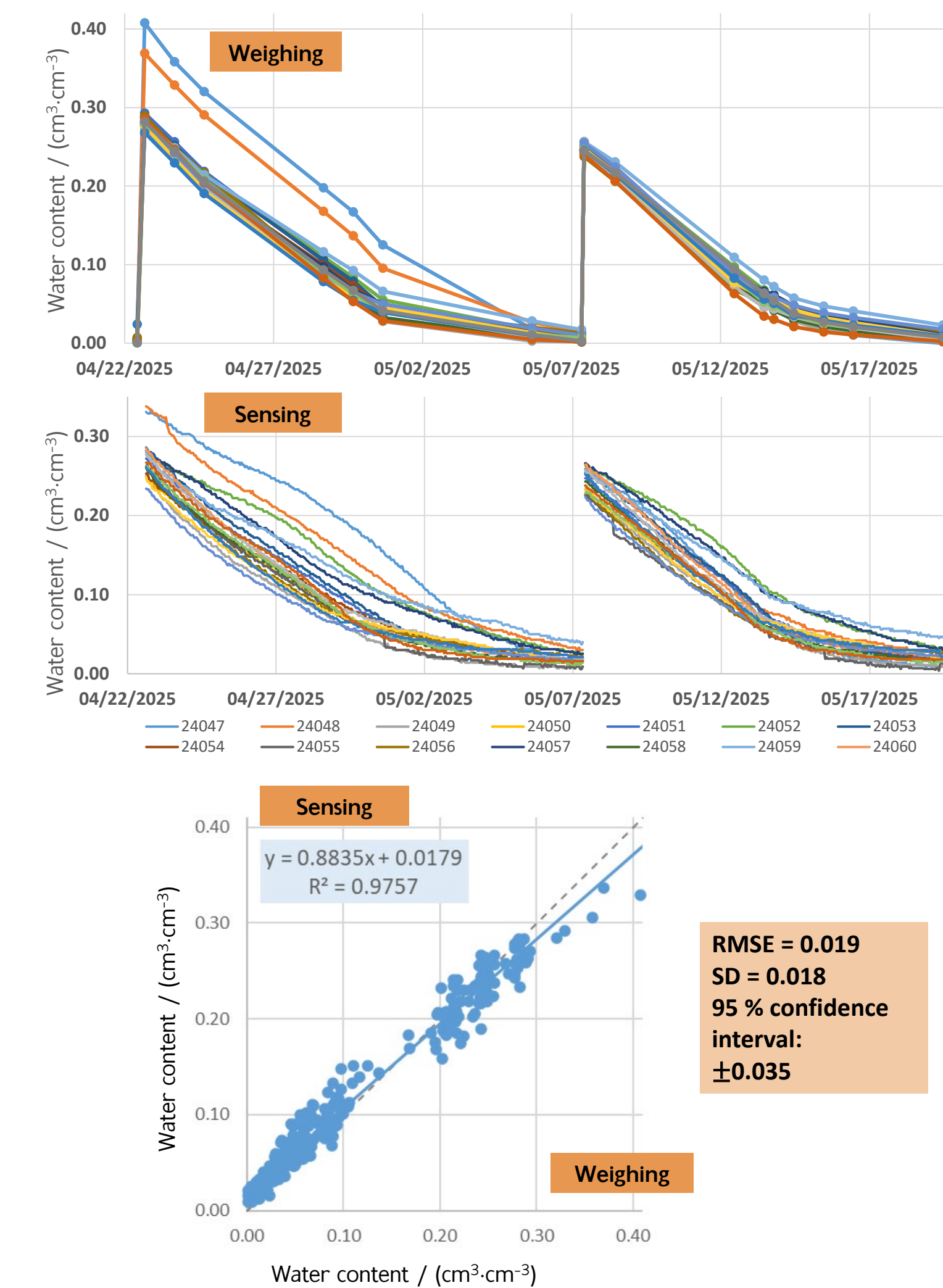


Figure 7. Lab test drying sand

In the lab:

- Residual variability was low ($SD = 0.018 \text{ m}^3 \text{ m}^{-3}$), supporting the sensor's precision and stability for threshold-based irrigation decisions after simple calibration if needed.
- Wireless sensor readings (sensing) closely matched the reference (weighing) indicating reliable tracking of dry-down in homogeneous sand.

Field experiment

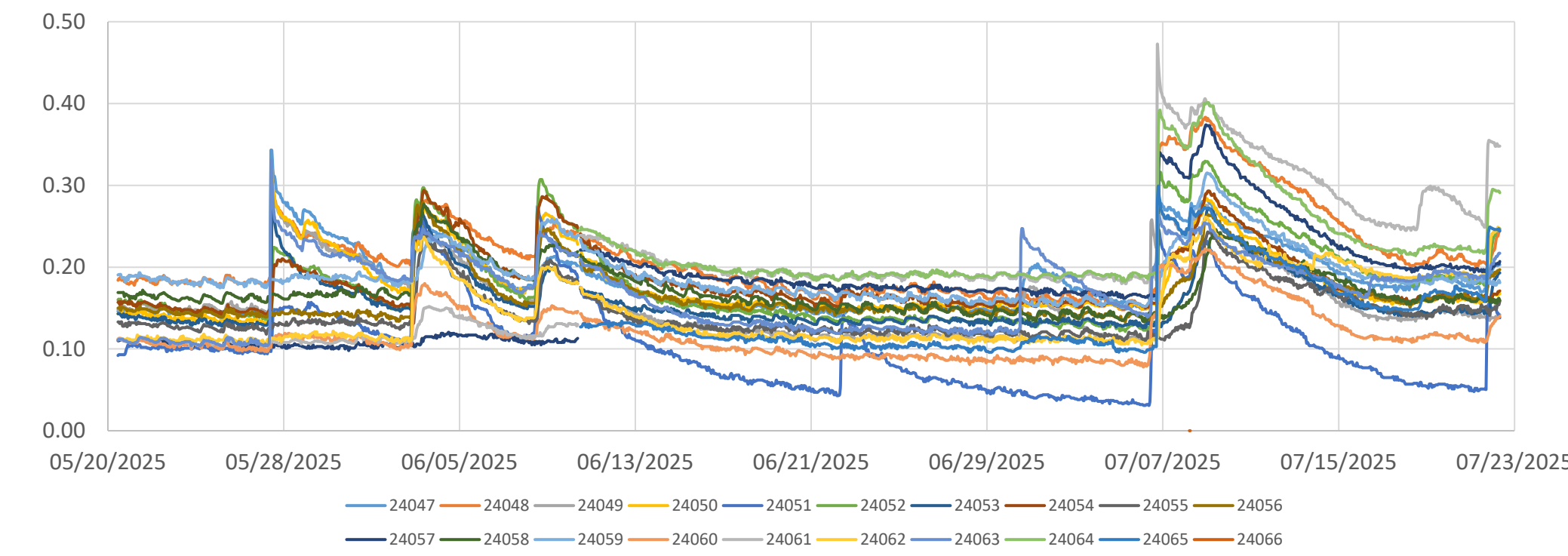


Figure 8. wireless sensor measurement during potato irrigation experiment

Irr (May 27) / mm	Irr (Jun 22) / mm	Irr (Jun 30) / mm	Irr (Jul 6) / mm
8h-12h	8h-12h	12h-15h	10h-13h
24 21 16 9 8	16 22 8 25 9	16 9 8 8 8	5 15 10 12 10
25 21 15 7 4	11 15 11 13 5	12 8 6 8 11	15 15 10 15 15
14 11 9 8 6	15 15 12 9 12	15 13 4 28 40	15 20 10 20 15
17 12 6 9 14	18 15 11 4 20	5 15 26 4 27 20	5 15 10 15 20
28 21 3 30 46	17 15 8 3 21	18 15 6 21 25	15 15 5 10 12
wc SoilScouts / %	wc SoilScouts / %	wc SoilScouts / %	wc SoilScouts / %
17 13 1 1	0 0 0 0	4 0 0 0	5 0 0 0
15 6 0 0	0 2 0 0	0 0 0 0	0 0 0 0
10 5 1 1 0	2 9 0 0 0	0 0 0 0	2 9 0 0 0
8 0 2 0	0 0 0 0	0 0 0 0	1 1 5 0
14 0 0 16	1 1 1 0	5 0 0 11	12 0 0 6

Figure 9. sprinkler uniformity performance under SoilScout application on potato experiment

Water distribution maps based on rain gauge measurements reflect applied depths & patterns. Wireless sensor measurements track changes in volumetric water content to indicate in-situ wetting under canopy during event.

Parallel rain-gauge assessment indicated generally fair uniformity, but performance depended on crop and timing. In potatoes, full canopy and afternoon evapotranspiration suppressed $\Delta\theta_v$, while in carrots pre-wet soils near field capacity yielded little pre-/post-event contrast.

Table 1. sprinkler performance on potato experiment

Parameter/Date	27/05/25	22/06/25	30/06/25	06/07/25
Water amount	22	14	15	20
Efficiency (%)	70	94	99	65
CU (%)	50	66	53	73
DU (%)	34	42	38	54
SC	3.5	3.3	3.2	2.6

CU < 70% = very poor
DU < 65% = very poor
SC < 1.8 = unsatisfactory

Reduce irrigation			Full irrigation		
Irr (07 Aug) / mm	Irr (03 Oct) / mm		Irr (07 Aug) / mm	Irr (03 Oct) / mm	
17 11 11	0 8 13		20 19 22	15 4 12	
23 19 13	19 16 16		20 16 15	10 7 8	
15 16 12	15 5 15		26 19 14	0 14 11	
wc SoilScouts / %	wc SoilScouts / %		wc SoilScouts / %	wc SoilScouts / %	
0.7 21.5 0.4	0.4 0.1 0.4		10 12 1	0.1 0.1 0.5	
0.4 8 0.7	0.5 0.3 0.7		6 9 3	0.2 0.2 0.4	
0.3 18.9 1.1	0.4 0.8 0.4		6 15 5	0.4 0.5 0.3	

Figure 10. sprinkler uniformity performance under SoilScout application on carrot experiment

Table 2. sprinkler performance on carrot experiment

Parameter/Date	Reduce Irrigation	Full Irrigation
07/08/25	03/10/25	07/08/25
03/10/25	03/10/25	03/10/25
CU (%)	79	58
DU (%)	72	16
SC	1.4	4.8

CU < 85% = fair
DU < 80% = good
SC < 1.5 = good

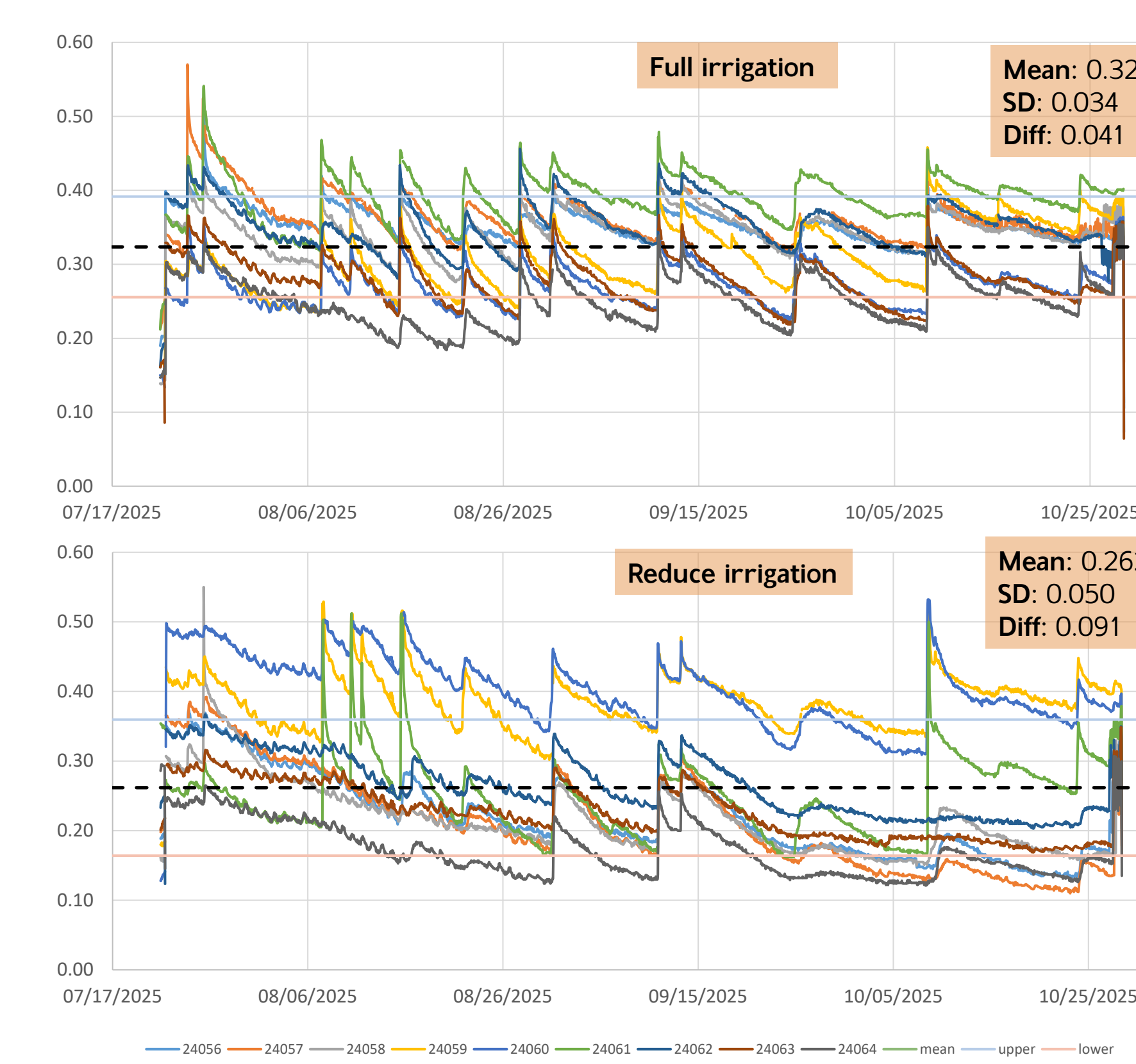
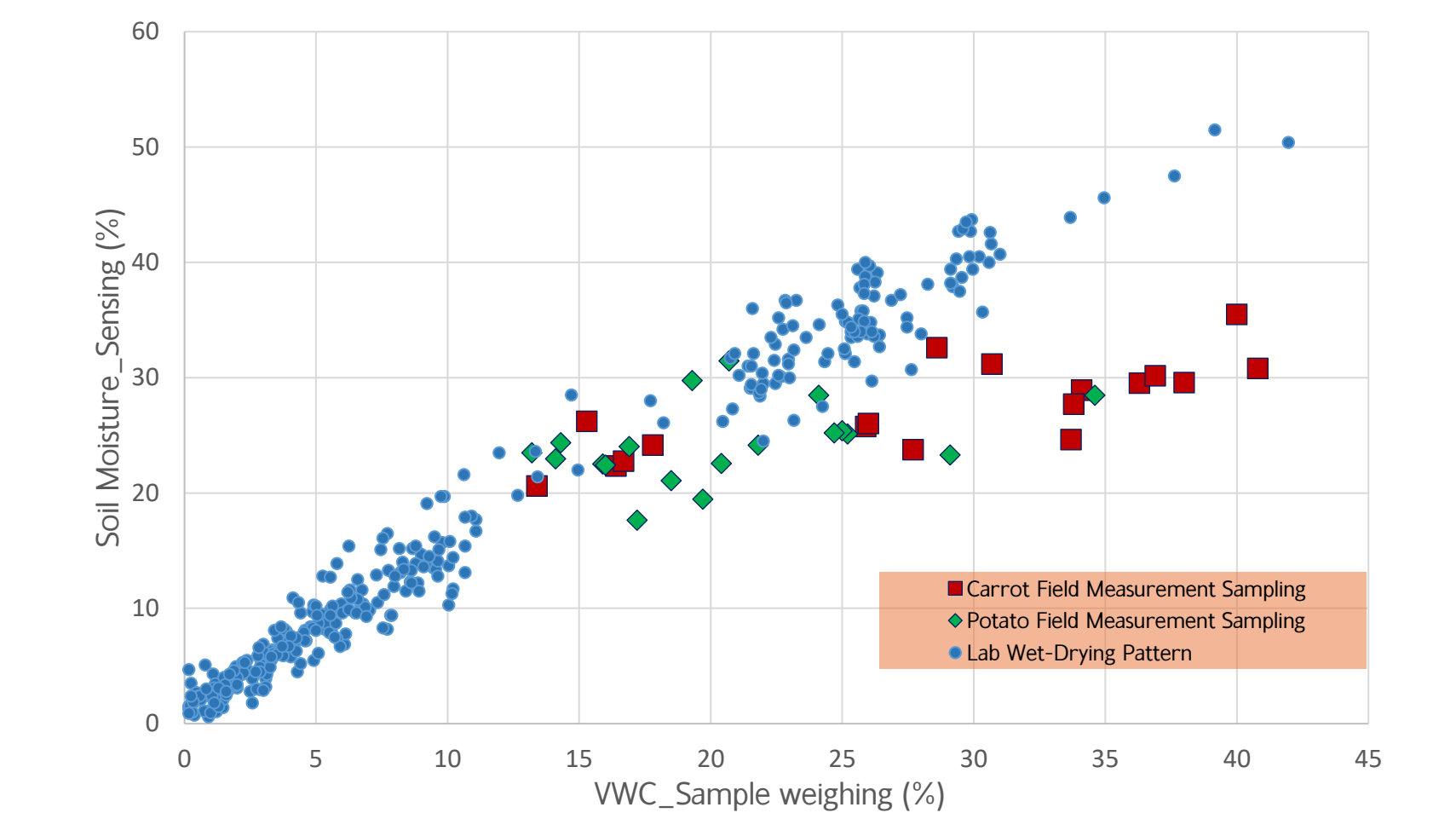


Figure 11. wireless sensor measurement during carrot irrigation experiment

Soil Moisture Sensor Field Performance



Across the potato and carrot trials, sensor readings showed a clear, monotonic response with tight clustering across replicates, indicating good precision for operational monitoring. Lab wet-dry tests confirmed a stable near-linear response; in the field the same trend held with slight compression at the wet end, yet sensors still resolved event-driven differences well enough to compare locations and summarize sprinkler uniformity.

Conclusions

- Wireless dielectric sensors demonstrated high laboratory performance and adequate field performance for operational use, especially for tracking dynamics and assessing sprinkler uniformity under canopy.
- Under-canopy sensor networks complement rain gauges by capturing the wetting that reaches the root zone, enhancing evaluation of distribution uniformity and application efficiency.
- Future work should refine absolute accuracy quantification, improve retrieval strategies (tagging/georeferencing), and assess calibration across soil conditions.

Acknowledgement

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