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Soil water content sensors from laboratory calibration to field monitoring: discrepancies and uncertainties

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Monitoring soil water status is one key option to optimise water use in agriculture. Soil moisture sensors are widely used for investigating available soil water to optimally adapt irrigation scheduling to crop water requirements. Although reliable measurements are subject to proper soil-specific calibration of sensors, meaningful calibration functions are not always available. Another question is the plausibility of soil water monitoring under field conditions. The objective of this study was to calibrate four multi-sensor capacitance probes in the laboratory and to evaluate the calibrated water content readings under natural conditions in an irrigated field by means of a modelling approach.

The multi-sensor capacitance probes (SM1 by ADCON Telemetry) were of 90 cm length and contained nine sensors (S1 to S9) at 10 cm spacing. The digital output values were given in scaled frequency units (SFU). The laboratory calibration was carried out on sandy loam and sand. Measurements were undertaken by placing the probes inside a PVC tube backfilled with soil at different water contents. Soil samples were collected using metallic cylinders of 250 cm^3, from which volumetric water content (θ) was determined gravimetrically. The sensor readings in soil were normalised by using sensor readings in air and water as lower and upper limit, respectively. The pairs of measured θ and normalised SFU were related to each other by curve fitting. For each soil type, eight sensor-specific calibration functions were developed that allowed the calculation of θ in $cm^3\ cm^{-3}$ from SM1 readings.

After calibration, the SM1 probes were installed in a field in Obersiebenbrunn, Lower Austria, where sandy loam is the main soil. Three of the probes monitored irrigated plots and the fourth a rainfed plot. To obtain reference values, one HydraProbe soil moisture sensor (Stevens Water Monitoring Systems) was installed in 20 cm depth, near each SM1. The average daily θ-values from the S2 (20 cm depth) contained in each SM1 probe were compared to the water fraction collected with the corresponding HydraProbe. Moreover, the SM1 θ-values were used to determine the daily soil water depletion in the root zone (Dr) for a rooting depth of 1 m. The obtained Dr datasets were compared to Dr simulated using CROPWAT 8.0 by FAO.

The field results showed that the SM1 probes were able to reproduce the HydraProbe dynamics of wetting and drying periods during the crop season. Nevertheless, a considerable difference was noted between the sensor measurements. The SM1 overestimated θ in the irrigated plots,

whereas it underestimated θ in the rainfed plot. The discrepancies can be attributed mainly to the different physical mechanisms behind the sensors and to the unfeasible reproduction of field bulk density and soil structure in the laboratory. Furthermore, the operational frequency and permittivity response of the SM1 probes should be revised for future versions. The simulation results showed that the observed Dr values were more consistent with CROPWAT Dr results at the end of the simulation period, suggesting that the SM1 required several weeks to consolidate and give representative θ-values for the soil profile.