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A Framework for Standardizing Electromagnetic Water Content Sensor Assessment using Granular Porous Media

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Electromagnetic (EM)-based sensors used for water content determination are now being widely used across the globe in research, environmental monitoring networks, weather stations, irrigation management, feed and grain quality control in addition to a host of other applications. The multi-million-dollar EM sensor market continues to expand and yet lacks test standards and is generally lacking in information about sensor quality and performance. Decades of past sensor assessments have presented mixed testing approaches and a commensurate measure of mixed results. Confusion regarding EM sensor-function, -failure rate and -value, stems from testing results that often use non-standard targets including inhomogeneous (variable density and water content) and complex materials (e.g., soils) that may not be widely available for subsequent testing and verification by others. Electromagnetic sensors employ time- or frequency-domain measurements to estimate real (and sometimes including imaginary) permittivity and electrical conductivity, with different sensors measuring at varied and often unknown frequencies. Sensor output is affected by environmental impacts on circuitry (temperature) combined with effects of porous medium temperature, electrical conductivity, interfacial polarization and dielectric relaxation, all of which often combine to alter the apparent permittivity and resulting water content. Although a few attempts have been made to standardize testing, more work and research is required before an international standard can be recognized and adopted. Here we point to standardizing 1) granular porous test media, 2) media packing approaches and 3) permittivity-water content calibration functions with examples and comparison of different EM sensors.