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Disturbances in Soil Moisture

Detection with Time Domain Reflectometry

Soil moisture detection is an essential parameter in assessing measures for plant production. It can serve as a decisive data base for irrigation management or for cultivation-, process- and trafficability-decisions and is simultaneously the feedback signal and the control variable.

However, difficulties with measurement accuracy when using TDR are being discussed, which are mainly caused by the presence of large pores or stones within the high frequency measuring field of probes.

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Keywords

Soil moisture, dynamic, real time, Time Domain Reflectometry (TDR)

The measurement of soil moisture by the use of the TDR method relies on the differing permittivity of soil (dry and porous material), water and air. To avoid faulty measurements, it is imperative, to care for a tight contact of sensor and measurand. The permittivity of air (ε_r=1) and soil (ε_r < 5) is significantly lower than the permittivity of water (ε_r = 81). The interdependence of the specific runtime of an electromagnetic pulse at the sensor and the permittivity of the measurand therefore gives a determination of the actual moisture of the measurand. Disturbances within the high frequency field cause faulty measurements. So far the electronic detection of soil moisture is run stationary. For that, different expressive spots have to be selected at site. To avoid a failure data interpretation, usually soil scientific maps are consulted. The widespread shape of the sensors is a two or three prong fork, whose prongs are set-up parallel. The size of the field is dependent on substrate and surrounding moisture, typically it has a size of 2/3 of the prong spacing (*Fig. 1*). The longer the prongs are realized, the more accurate the measurement gets. Using TRIME (Time Domain Reflectometry with Intelligent Microelememts, manufacturer: IMKO), the observed value [Vol.%] is displayed on a handheld device. Using regular TDR probes requires to read the value on an oscilloscopes characteristic TDR curve (e.g. Tektronix Cabletester, manufacturer). The visually quoted value has to be translated to the respective volumetric water content of soil. ROTH [3] gives an equation, regarding soil physical properties (porosity and bulk density), TOPP [4] formulates an empirical equation in order to derive the volumetric water content. The TRIME system implies these calculations within the handheld instrument. The TRIME measurement results in accurate readings for soils within the normal range of electrical permittivity [5]. Further soils have to be tested by determining the soil moisture by means of DIN 18121-1 (oven drying: 24 h 105°C) and save a calibration value in the handheld gauge. For a dynamic application it is necessary, to reduce the previous measuring time from 10 seconds to the system edge in order to gain a high resolution pattern of test points on site. Moreover a tight sensor soil contact is essential as the aforementioned difference of permittivity might cause a failure interpretation of the test values [6]. On top of that, a mobile probe has been designed, which is capable of keeping a close contact to the surrounding soil. However there are process immanent limits, which could be named as

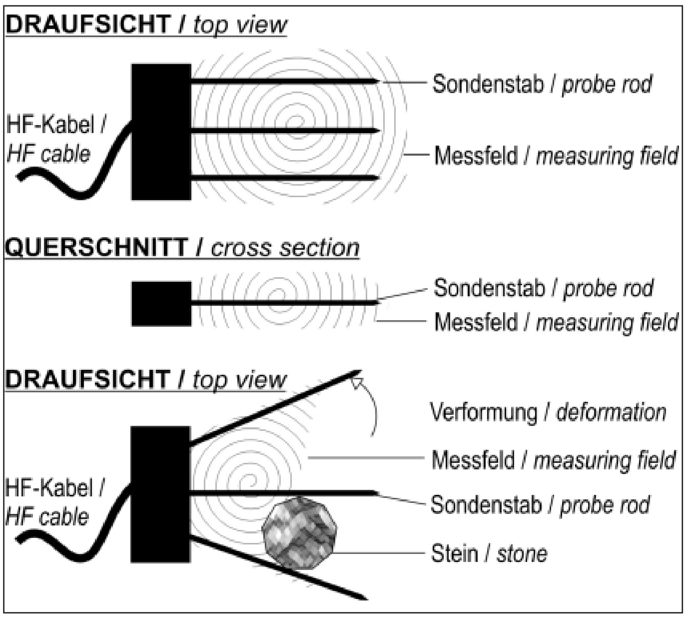

Fig. 1: Probe deformation at a 3-prong sensor

mechanical feasibility of soil sensor contact during drought and concurrent formation of clods on site.

Effects on TDR detection

In practice, there are three kinds of failure to appear using fork probes: air filled gaps, water filled gaps and stones bending the prongs. These disturbances of test values are not represented with soils average porosity. The appearance of large pores might be explained by root tracks and earth worm tracks. The piercing of the probe causes a volume of disturbance surrounding the probe, mainly it is caused by stones within the soil layers. The probe prong hits the stone while it is plugged into the soil. The prong is deformed while the probe is pressed steady about the disturbing stone. This causes a volume of disturbance. Besides that, it is possible, that the stone stays in between the prongs, whereby the measurement might also be interfered.

Methods

Large pores effect on the accuracy of the measurement was investigated at the soil laboratory.

The trials were carried out, using screened silt (0.5 mm) with an appearing field capacity of 50%. Starting moisture for the experiments was set to 25% and raised by steps of 5% until field capacity was reached. The applied probe was a self made 3 prong sensor (prong length: 8 cm), which was used in context with a Tektronix cable tester (manufacturer). The measured volume showed 0.92 litre. The impact of deformation on measurements accuracy was investigated simultaneously. Therefore different grades of moisture were established on sandy clay [7]. Three blends of gravel were set up complementary (25, 50, 75 % of gravel within sandy clay substrate). Reference values were gained, determining the effect of deformed probes (TDR and TRIME) within a solution of water saturated bead (Dragonit bead 0,45 mm and a reference value of 44% vol. water content) in order to avoid further negative effects on measurements quality. The measured volume had 8 - 10 litres.

Results

The first trial was set up, dealing with up to three artificial large pores (3 mm) within the range of the measured volume. This case showed no significance. Neither while saturating, nor at attained water contents. Therefore it might be concluded, that large pores do not interfere the TDR measurement, regarding a field measurement set up. A different picture could be drawn regarding an incomplete contact of the sensor with the substrate. If the sensor is moved back and forth, causing a cavity of about 1 mm, it led to an underrating of 5 to 7% water content. While saturating, a readable curve could just be detected after the water completed seeping. During seepage disturbances of the signal were observed, which made a visual reading of the signal impossible. Stationary measurements are not affected by this observation, though the effects appear only for a short while after precipitation or irrigation. A second series of experiments with a larger measurand was to show effects of probe deformation on the accuracy of the measurement. The grade of deformation reached from 0° to 90° with TDR probes, 0° to 20° with TRIME probes. Deformation was carried out both, lengthways and crosswise (*Fig. 1*) at all three prongs. TDR readings showed decent values despite an enormous deformation. But straddling the two outer prongs led to a >5 % underestimation of the reference value. The contradictory effect could be reported by using TRIME. It results in overestimating the value about 10 %. The other kinds of deformation lead to an even distribution of the measured values (+/- 5%) around the reference value (*Fig. 2*). An explanation could be the software based calibration of TRIME sensors, which is of limited capability interpreting deformations of the used probe. Therefore it is indispensable to care for the sensors integrity. For a dynamic application of the TRIME system, a solid probe body was designed [8] in order to guarantee the aforementioned.

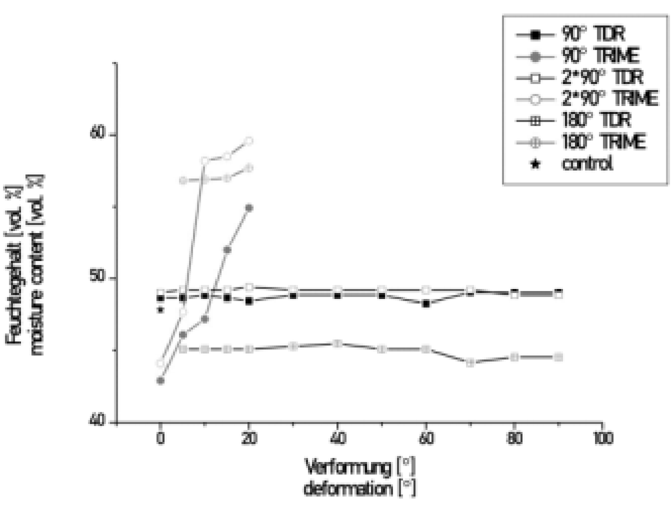

Fig. 2: Straddling of the probe: top: one side to the outside (90°); middle: two-sided: to the front and to the outside (2•90°); Below: both to the outside (180°)

Outlook

Despite expected deformation of sensor prongs , the TDR measurement represents a first-class standard method determining the actual water content on site. Underestimation of soil moisture could be avoided with a proper sensor soil contact. Tremendous deformations in these investigations are not shown in real field measurements. A „normal“ deformation of up to 20° gives no significant diminution of the measurements accuracy. To avoid negative effects in stationary measurements, the use of a dummy driller for probes is recommended. The dynamic measurement in particular requires a tight soil contact. The probability of failure measurements, caused by air gaps, is likely to be incomparably higher in the field than in stationary measuring. The accuracy of the dynamic detection of soil moisture therefore remains highly dependent on top soil structure. Large clods, not to be evened by a blade angle limit the devices range.

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