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Measuring soil moisture

Soil moisture measurement provides important information both for irrigation control and for other steps in arable farming. However, there is still a lack of practical techniques for measuring soil moisture, so studies were carried out on various sensors. It is not possible to recommend any of these sensors for use in irrigation control because of the large divergence of the measurements.

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Keywords

Soil moisture, irrigation management

There has been some success in improving the operating technology used in irrigation, but still practical techniques for determining soil moisture need to be developed. The question asked by the studies was whether irrigation can be controlled exactly with the help of soil moisture sensors. Following a review of the literature and initial experience with various sensors, one problem became obvious. The capability of the various types of sensors for measuring the water content at a single point in the soil differs, but is generally adequate.

However, the moisture content in the soil itself under field conditions is so heterogeneously distributed, even over short distances, that measuring at just one point is not sufficient. This makes it necessary to establish mean values over a larger area of soil or over several individual sensor measuring points in order to obtain a reading that is sufficiently reliable.

Neither the soil volume measured nor the weighting within this volume are known in practice, so the divergence of the whole measuring procedure must be observed. It appears that this kind of quantitative data on the extent of divergence of soil moisture readings is very sparse or not available for modern, inexpensive measuring methods.

Field experiments on the divergence of readings

It is known that the variability of soil moisture readings can be very high, but very little data is available on what can quantify this variability. Details on the influence of the soil sample volume on the statistical properties of a random sample are given in [1]. The statistical distribution of readings of soil water tension taken with a tensiometer in a field equipped with drip irrigation is described in [2].

Using three selected procedures as examples, test results are given here to illustrate the statistical properties. The experiments are designed to give an impression of how great the reading divergence can be using methods which are technically completely different from soil sample taking. Additionally we wanted to examine whether the divergence ranges of various methods differ so widely that it is advisable to look for methods with a much smaller divergence.

Experiment method

A total of 75 soil moisture sensors was installed under two-year grass on loamy sand soil. They consisted of 25 Time Domain Reflectometry (TDR) sensors, 25 Granular Matrix Sensors (GMS) and 25 EC sensors, placed in a square grid with spaces of around 75 cm. The centre of each sensor was placed at a depth of 15 cm in the main root area of the grass.

This arrangement should have supplied the same readings if the soil was completely homogeneous and identical sensors were used in each group. The expected deviations within the groups should have provided qua-

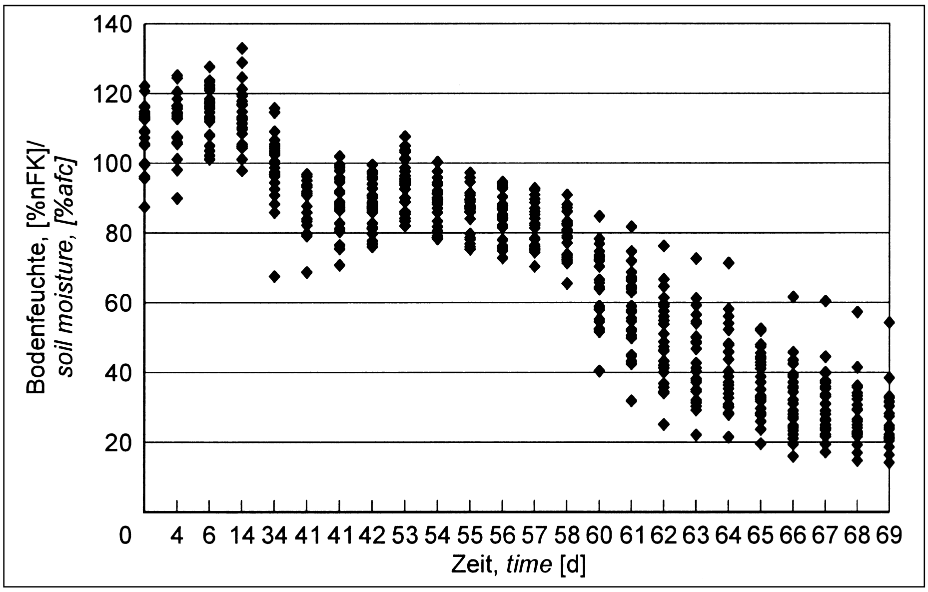

Fig. 1: Readings of TDR-sensors

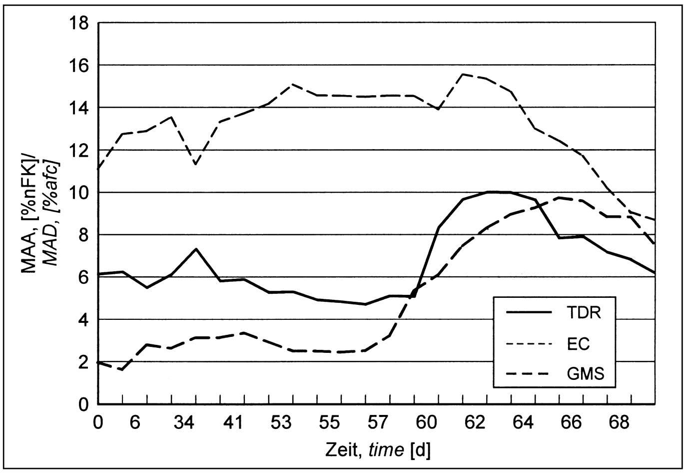

Fig. 2: Mean absolute deviation of TDR-, EC and GMS-readings

litative and – due to the relatively large number of sensors – also quantitative information on the divergence of the readings from each of the three measuring methods. The field moisture capacity of the soil at a depth of 15 cm was 21.9 % by volume and the wilting point was 5.6 % by volume.

During the vegetation period prior to the beginning of the experiment, no irrigation took place, so that it can be assumed that there was no influence of irrigation technology on the distribution of the soil moisture. Readings were taken as a rule daily at about 09.00 h. The readings were evaluated on the basis of the volumetric water content.

Findings

Figure 1 shows the pattern of the soil moisture values over time for each group of 25 sensors, converted into % nFK. The height of the resulting vertical point accumulations gives an optical impression of the range of divergence. *Figure 2* shows the course over time of the mean absolute deviation for the three groups.

The three methods reveal considerable differences in the range of divergence. It is noticeable that this increases as the soil dries out, so the most unreliable values are given just shortly before any irrigation would start. It can be assumed that the relative change in readings relating to a starting time would display a narrower range of divergence than the absolute values.

Figure 3 shows the course over time of the TDR readings, from each of which the reading for day 1 has been subtracted. This gives the water balance since the beginning of the experiment. As can be seen from the curve of the mean absolute deviation (solid line), the variability is only insignificantly below that of the absolute values.

The courses of the relative values of the other two methods are not shown here because they are very similar to those for the TDR sensors. Here too the confidence limits for various extents of random sampling were calculated according to mean absolute deviation and according to the standard deviation. Similarly, there was no significant difference between the two methods.

Discussion and conclusions

Assuming that these findings are representative for the entire rooting depth and for other crops, the possible limitation of the irrigation level can be determined.

If the requirement is to fill up the soil from 40 %nFK to 80 %nFK, a limitation by a quarter, or 10 %nFK, can be assumed to be acceptable. This would mean that, depending on the statistical reliability (details on confidence level, extent of random sampling [3]), nine TDR or GMS sensors and 20 EC sensors would have to be installed at each depth.

This appears at first sight to be far too many. The number of depths at which measurements must be taken depends on the course of the vertical soil moisture gradient towards the end of a dry interval (!). Assuming the number is four (a reasonable number, although not backed up by studies), that would mean for instance that 40 GMS sensors, at a unit cost of DM 40, or altogether DM 1,600 would be necessary on an area of 10 m^2 to determine the mean soil moisture with an adequate degree of accuracy.

At any rate, the number of sensors per depth necessary with this method is much higher than generally usual, which could explain the problems often experienced with irrigation control according to soil moisture measurements. However, even just halving the range of divergence, which appears not unrealistic considering the huge differences between the ranges of divergence of the three methods, could reduce the number of sensors required to an acceptable quantity.

For direct measurement of soil moisture it is appropriate to concentrate first of all on achieving a better determination of the spatial mean value. The studies have shown that this is feasible. Moreover, as costs for the equipment fall (GMS as opposed to dielectric tensiometers), the use of larger numbers of sensors may become reasonable. However, it is important to take labour costs into account too here.

Literature

Books are signed with •

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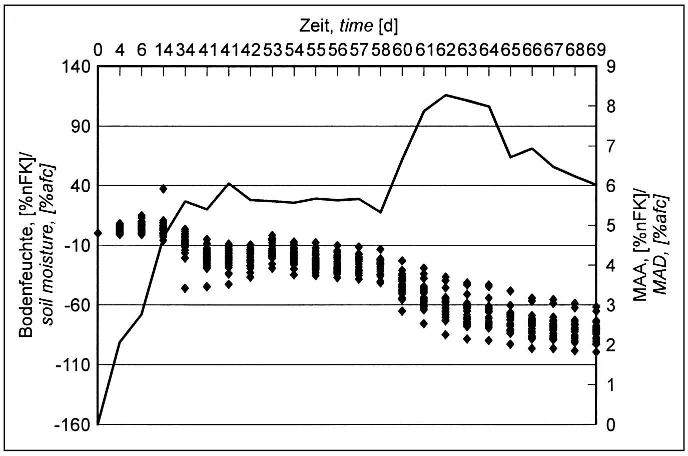

Fig. 3: TDR-readings relative to day 1