CENTRE OF EXCELLENCE
FOR APPLIED PHYSICS IN SUSTAINABLE AGRICULTURE
"AGROPHYSICS"

International Conference
"Method and methodology for determination of basic physical characteristics of porous media with application of TDR technology"

Institute of Agrophysics, Polish Academy of Sciences
Doświadczalna 4, Lublin, Poland
1-4 February 2004

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BOOK OF ABSTRACTS

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THE INITIATIVE OF ELABORATION OF INTERNATIONAL STANDARD (ISO OR EN) CONCERNING THE REFLECTOMETRIC MEASUREMENT OF SOIL WATER CONTENT - TDR

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Abstract

The aim of this presentation is to show problems connected with normalization of soil water content measurement with reflectometric technique (TDR).

To summarize this issue it can be stated that:

1. This problem has been admitted as important and it has been the subject of work, undertaken in the frame of International Normalizing Organization;
2. This work had been done till the moment when ISO were enforced to suspend it because of the lack in personnel.
3. A group, gathered at this conference, seems to be a natural supplier of personnel to reactivate the work connected with elaboration of a standard; This led to the initiative of a renewal of the procedure of elaboration of an international standard;
4. We are open to any forms of cooperation and support; We are very particular about your joining this process which can be one of the aims of the international experts group.

The International Organization for Standardization (ISO) is engaged in elaboration of international standards which in practice refer to all the areas of human activity. Therefore, in its organization structure it is divided into committees and subcommittees dealing with particular areas as well as working groups which elaborate specific standards.

The technical committee with the number TC 190 deals with the problems of soil physics. One of its subcommittees - SC 5 which restricts these problems to the physical methods appointed a working group WG 3 "Water content", which undertook the work on the standard „*Soil Quality – Determination of soil water content volume fraction – Time Domain Reflectometry (TDS) and Time Domain Transmissometry (TDT) Methods*" in the second half of the 90-ies This standard was given a working number 12229.

Before the international standard is finally accepted, the procedure of standards elaboration provides several intermediate stages. Particular projects of a given standard, which are the effect of the work performed in a stage, are accordingly denoted at the standard's number.

For instance:

ISO/CD denotes *Committee Draft* and is the result of work done in a working group. This is the first proposition to formulate this problem in the form of a standard.

ISO/DIS denotes *Draft International Standard* and is the effect of consultation and discussion which took place outside the working group.

ISO/FDIS denotes *Final Draft International Standard* and is the last version of the document, proceeding an official publication.

The procedure of standard's elaboration is a little bit arduous and prolonged in time. It requires that the experts from various countries were engaged in the working group. Therefore, particular persons can resign of different motives from participation in a working group and the quorum is not preserved. In such case the work on a given standard are suspended.

Such situation took place in case of the standard ISO/CD 12229. The decision of ISO/TC 190/SC 5 WG 3 "Water content" from 7/11/2000, taken during the meeting in Gold Coast in Australia reads as follows:

"The Working Group discussed how to proceed with ISO/CD 12229 "Soil quality - Determination of soil water content volume fraction - TDR method" (document N 74). It was decided to cancel this work item because nobody is available to process the document. The Working Group regrets the decision because this TDR method is considered to be the most up to date and widely used method."

Taking into consideration that the normalization of the soil water content measurement with application of TDR technology is really needed by the users, the Institute of Agrophysics PAS in Lublin has made a trial to reactivate the works on that standard.

It results from the discussion made recently that reactivation of the work in the frame of the subcommittee ISO/TC 190/SC 5 is practically impossible due to the lack of a representative number of interested persons. However, a chance exists that this work can be taken over by the technical committee 345 European Committee for Standardization (CEN).

To strengthen our efforts we would like to prompt the participants of this conference to support this work. This support could be realized twofold:

1. making the national standardization committees in particular countries acknowledged and interested with this topic;
2. by direct declaration of cooperation in the process of elaboration of the standard.

We welcome all the interested people to cooperation. The detail information can be obtained from dr. Wojciech Skierucha and dr. Andrzej Bieganowski.

TEMPERATURE EFFECT OF SOIL DIELETRIC CONSTANT

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Abstract

Introduction of TDR meters to monitor soil moisture in long time periods, including soil temperature, *T*, differences between day and night revealed significant fluctuations of moisture readouts correlated with the soil temperature.

The aim of the study was to determine the influence of temperature on soil dielectric constant. The end result is the development and verification of a physical model describing the change of soil dielectric constant with temperature for soils having different type, moisture and salinity. The presented model will help to interpret the influence of selected soil physical parameters on its electromagnetic properties and will improve the calibration procedure of reflectometric moisture and electrical conductivity meters.

The measurements performed by specially constructed original setup confirmed the temperature effect $\varepsilon(T)$, causing the TDR soil moisture measurement error.

Significant agreement between experimental data and the physical *de Loor* model of dielectric constant of porous materials has been reported. This model assumes that the amount of water bound to soil solid phase depends on the value of soil specific surface and indirectly on the soil clay content. The presented temperature correction formula of TDR moisture readout developed after analyzing of small part of experimental data needs further development.

CALIBRATION OF TDR FOR MOISTURE DETERMINATION IN PEAT DEPOSITS

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Abstract

Determination of soil water content using Time Domain Reflectometry (TDR) method is recently modern and widely used. The practical application of TDR requires its calibration i.e. determination of the relationship between dielectric constant and volumetric moisture content of the soil. The paper presents the development of calibration equations for the range of different peat types (willow peat, sedge-moss, reed and sedge-reed) from Biebrza river valley. The undisturbed soil samples were used in the calibration procedure. The volumetric moisture content and dielectric constant were measured simultaneously during the calibration. The measurements performed on undisturbed peat samples from Biebrza river valley showed that bulk density of peat soils substantially affects the relation between dielectric constant and moisture content. The relationship between dielectric constant and moisture content in peat deposits can be represented by square-root equation and it was proven, that the values of intercept *a* and slope *b* in this equation are strongly depended on bulk density. The proposed calibration equation relating moisture content with dielectric constant and bulk density for TDR moisture measurements in peat deposits from Biebrza river valley is statistically significant and can be applied for peat soils with the bulk density values ranging from 0.08 g cm^{-3} to 0.25 g cm^{-3}. The peat bulk density significantly influences on the dielectric constant values for the volumetric soil moisture content lower than 70%. Increasing values of soil bulk density lead to higher values of dielectric constant for given moisture content.

APPLICATION OF TDR MEASURING TECHNOLOGY FOR BUILDING MATERIALS IN SEMI-SCALE EXPERIMENTS

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Abstract

There are two basic approaches in the investigation of hygrothermal function of a building envelope representing a multi-layered system of porous building materials. The first possibility is to experimentally determine thermal and hygric parameters of particular materials applied in the tested building structure in laboratory conditions. These material parameters should be determined in dependence on moisture content and temperature in the whole range of their usage in the technical practice. From these basic material tests we obtain necessary data for the subsequent process of computational analysis of the tested building structure, where it can be exposed to real climatic conditions. The second way how to describe the hygrothermal behaviour of the whole building structure is to measure thermal and hygric field variables directly in the tested construction. The measurements can be applied directly on a real building or on so-called test houses. Field measurements on building site make it possible to monitor the hygrothermal performance of a particular envelope, to test the effectiveness of hygric and thermal insulation systems in real conditions, and to validate and calibrate physical models of moisture and heat transport in building materials and components.

However, both the given approaches have some substantial disadvantages, which have to be taken into account in a practical application. Application of computational

simulations is limited by the exact determination of material parameters in dependence on moisture content and temperature, what is not an always practicable task. The next limitation consists in the faintnesses of computer codes, especially in the assessment of empiric parameters, e.g. in the determination of interface transport resistances. Therefore, computer simulations should be employed only in the first step of designing new building systems for estimation of demanded properties of particular materials involved in the designed structure. Application of temperature and moisture fields monitoring on building site will certainly always remain the final and decisive stage of testing the performance of building envelopes. Nevertheless, this solution should be considered as a final step, when all principal problems are already solved and the risk of failure is minimal, because the costs of building a special test house are quite high and using private buildings for testing purposes might result in the difficult problems if the designed solutions do not work as expected.

In this work, specially designed semi-scale device for the assessment of hygrothermal performance of building envelopes is described. Design of a semi-scale experiment presents a logical bridge filling the gap between the laboratory measurements of hygrothermal properties and full-scale test house measurements of field variables of heat and moisture transport. A semi-scale measuring system for determination of temperature and moisture fields was designed in such a way that it simulates conditions, which are as close as possible to the real conditions on building site, but it still maintains its laboratory character, so that the expenses can be kept considerably lower compared to a real test house.

PRACTICAL EXPERIENCES WITH THE EASY TEST FOM MOISTURE METER IN ASSESSING THE SOIL WATER BALANCE OF A MAIZE FIELD

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Abstract

Simulation of water movement in agricultural soils has become a very valuable tool in estimating the amount of natural ground water recharge, which must be known for effective ground water us as well as for the quantification of ground water pollution by fertilisers and pesticides. Long lasting and intensive field measurements of the soil water balance at different places are needed for model calibration and verification. In the present paper the performance of such soil water monitoring with the EASY TEST FOM moisture meter and the results of the calibration of the SIMWASER soil water balance and plant growth model are described and some problems and shortcomings during the practical work are discussed.

The measurements were taken in an experimental maize field where soil water samplers were installed by which deep percolation was measured. The soil moisture monitoring station consisted of EASY TEST FP/m moisture field probes which were modified to be horizontally inserted at 10, 20, 30, 40, 60, 80, 100 and 150 cm depth into a pit wall together with gypsum blocks and granular matrix sensors, which had been calibrated in the laboratory to yield matrix potential after having been corrected to the ambient soil temperature, which also was measured at the same depths. The deterministic simulation model SIMWASER was used to calculate the water balance at this site after having been calibrated by comparing measured and simulated soil moisture. Depending on the tillage practice at the continuous maize plot the sensors

in the upper soil layers had to be excavated each spring to enable ploughing without destroying the sensors. Due to the loosened soil, water content measurements were now distinctive lower than before and the upper four sensors - that were excavated and re-installed once each year - had to be corrected. The measurements were taken at more or less regular intervals during the period of 1997 to 2001 without any larger problems. Sufficient data on soil water content and on soil water suction were available for creation of so called Field-pF-Curves in order to deduce the needed soil physical soil parameters as well as for calibration of the SIMWASER model.

The simulated and measured water content at the different measuring depths as well as the simulated and measured soil water storage were in very good agreement, so one may conclude that SIMWASER was able to assess the soil water balance of the maize crop at this place in a realistic manner. However, there still was a difference between simulated and measured ground water recharge, the amount of which was 1800 mm according to the simulation, but was 1500 mm according to measurements. Thus the difference of 300 mm was only about 7% of total rainfall of 4500 mm during the five years period. The most likely reason for this fact may be the difference between the soil profiles found at the soil moisture monitoring site and at the percolation measuring site. The EASY TEST FOM TDR Moisture meter provided reliable data and proved to be robust and simple to operate.

TDR DETECTED AND SIMULATED SOIL WATER CONTENT DYNAMICS OF MANAGED FOREST STANDS

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Abstract

The soil water content of the root zone under two different forest's sites was monitored with TDR-like moisture probes in order to establish the characteristic water balance of the forest stands. To validate the water content readings the moisture probes were calibrated and reference samplings and measurements were applied. The measured soil water content dynamics was simulated using a soil water and heat model. The water balance of the forest stand and its forest management aspects are discussed.

COMPARISON EFFLUENT AND TDR BREAKTHROUGH CURVES OF A LABORATORY COLUMN EXPERIMENT

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Abstract

Steady state downward flux was carried out in laboratory for 2 soil columns containing sand and aggregated loam. The bulk EC was measured at the bottom of the column by horizontally installed TDR probes. The bulk EC data were evaluated by continuous flow and convolution method, and they were converted to relative concentrations as well as the effluent EC data.

For sand relative concentrations obtained from the effluent were similar to that for TDR while for aggregated loam there were significant discrepancies. The results were explained with the different pore distribution of the soils.

EXPERIENCES WITH A TDR-MOISTURE-METER IN LABORATORY INVESTIGATIONS

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Abstract

Within laboratory investigations soil moisture has been measured by means of a TDR-moisture-meter. Corresponding water contents are available from measurements of the gravimetric water content and the bulk density of the soils. Results for the period 1995-2000 approve the factory installed calibration functions and indicate that there is no time dependent shift of the used TDR-system.

Introduction

For the assessment of soil water dynamics and in case of many hydrological and environmental questions the water retention characteristic and the hydraulic conductivity function of soils have to be known. These soil parameters can be estimated in the field as well as in the laboratory. Since TDR (Time-Domain Reflectometry) technology became a common method for the estimation of the soil moisture, it was also applied to laboratory investigations (Plagge 1991, Sobczuk 1992, Hudson et al. 1996). In the laboratory of the Institute for Soil and Water Management at Petzenkirchen such measurements have been in progress since 1995 and the soil moisture of the samples has been estimated with the EASY TEST LOM/RS system all the time. Based on the results of these investigations some experiences are summarised in the present paper.

TIME DOMAIN REFLECTOMETRY AS A TOOL FOR THE ESTIMATION OF QUALITY IN FOODS

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Abstract

The EU 5th Framework project "SEQUID" aims, by measuring and analysing different seafoods during different storage conditions, to develop an instrument which will allow the determination of quality or freshness of fish and fish products. This is achieved by first measuring the time domain response of the samples to an input step pulse (rise time 60 psec) delivered to the surface of the samples by an open ended coaxial probe.

The time domain data are then transformed, along with any other relevant variables such as temperature or artificial nose responses, using multivariate analysis,

for example principal component analysis (PCA). The PC scores can then be used in regression equations or discriminant analysis.

Results are presented which show how different quality aspects such as time of storage (chilled or frozen), temperature of storage, or sensory attributes can be predicted. It is also shown how the data can be used to categorise samples into different quality groups (e.g. once or twice frozen).

Keywords: TDR, microwave, multivariate, fish quality

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Keywords: TDR, microwave, multivariate, fish quality

SOIL WATER BALANCE OF AN ARID LINEAR SAND DUNE, NIZZANA, NW NEGEV DESERT, ISRAEL

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Abstract

The soil characteristics and water balance of an arid sand dune ecosystem were investigated in Nizzana, NW Negev desert. The main emphasis was placed on the relations between atmosphere, vegetation and soil moisture. Soil moisture was carried out using time domain reflectometry (Easy Test Co.). The soil investigations were required transect- and area mapping, soil characterization and time flow analyses.

In addition to abiotic factors biotic factors affect the water dynamics in the ecosystem through redistribution and accumulation processes. Input and output paths and components of the water balance were identified and then quantified.

Keywords: Soil water balance, TDR-Technology, arid ecosystems, Negev desert

COMPARISON OF DEEP SEEPAGE ESTIMATIONS OF A VIRTUAL WITH A REAL LYSIMETER BY MEANS OF TDR-MEASUREMENTS

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Abstract

The virtual lysimeter concept was tested in comparison with a real lysimeter and found to be suitable for quantifying effective deep seepage dynamics in sandy soils. Discharge measurements and calculation results agreed well. Preconditions are accurate water content and tension measurements with high temporal resolution below the zero flux plane and an error free water balance of the calibration period. The calibration procedure has resulted in an effective unsaturated hydraulic conductivity function which allows to perform deep-seepage calculations based on the measured water content dynamics only. The assumption of the unit gradient produced adequate results in sandy soils. The calculation results are exponentially sensitive to errors of water content measurements and linearly sensitive to water balance errors. However, a single incorrect water content produces only a single incorrect deep seepage value, whereas the water balance error sums up. Therefore, the quality of the water balance estimation is of crucial importance.

TDR AND LOW-FREQUENCY MEASUREMENTS FOR CONTINUOUS MONITORING OF MOISTURE AND DENSITY IN A SNOW PACK

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Abstract

An in-situ sensor for the simultaneous measurement of density and liquid water content of snow is presented in this paper. The system consists of radio frequency transmission lines of up to 25 m length cast in a flat PVC-band, which can either be set up horizontally to monitor single snow layer properties or sloping from a mast to the soil surface to determine vertical snow pack properties. The dielectric coefficient along the flat-band cable is measured with a time domain reflectometer (TDR) at high frequencies, and with a low frequency impedance analyzer. The performance of the sensor system has been tested during two winter seasons (2001-2003) at a high alpine test site in Switzerland. Overall, the sensing system proved to be quite robust and produced results in agreement with manual snow pack observations.

Keywords: snow density, snow moisture, time domain reflectometry

WATER STORAGE IN THE VADOSE ZONE EVALUATED FROM THE TDR SOIL MOISTURE MEASUREMENTS

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Abstract

This study focuses on dynamic soil water resources evaluated by the TDR soil moisture meter in selected experimental sites in central Poland. The analysis is based on the field measurements of volumetric soil moisture conducted since 1995 till present. The portable Time Domain Reflectometry meter (Easy Test) is applied to track the characteristic stages of the soil water storage of shallow soil layers. Evolution of the soil moisture vertical profiles has been highlighted on seasonal and interannual time scale. Range of natural variability of soil water storage was derived from the soil moisture profiles detected under extreme atmospheric conditions.

EFFECT OF AGGREGATE SIZE ON THE WATER CONTENT ESTIMATED WITH TIME DOMAIN REFLECTANCE (TDR)

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Abstract

Time domain reflectance (TDR) gives reliable estimates of the water content of structure-less soil. The effect of soil structure on the performance of TDR has received relatively little attention in comparison with the development of new calibration models and also the use of TDR for simultaneously measuring water content and the electrical conductivity of the pore water. In this paper we report on the effect of aggregate size on the reliability of water content determined from TDR measurements. The experiments that we report are relevant to loose seed-beds. We show that as aggregate size increases TDR progressively underestimates the volumetric water content when a standard calibration function is used. We suggest a simple rule of thumb to avoid large errors in the TDR estimated water content.

Keywords: TDR calibration, aggregated soil

MONITORING OF WATER CHARACTERISTICS FOR POLISH SOILS WITH TDR METHOD APPLICATION

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Abstract

The water retention, saturated and unsaturated hydraulic conductivity coefficients are the basic hydrophysical characteristics of the soil. The correct determination of those characteristics is indispensable to obtain the required accuracy of the used models of water transport in soil profile. Therefore, the methods of measurement and estimation of these characteristics are extensively developed.

Unsaturated hydraulic conductivity is one of the most important physical soil characteristics. Applying TDR techniques and the instantaneous profile method (IPM) the measurement of hydraulic conductivity coefficient $k(\psi)$ and also dynamic retention curve $\theta(\psi)$ has become much faster and effective. It was demonstrated, that this method gives accurate results for various initial and boundary conditions applied to the soil sample. The instantaneous profile method (IPM) rest on simultaneously measurements of water content and water potential dynamic in the process of drying or wetting the soil column (see fig. 1, 2).

Assuming that the process of water transport takes place under isothermal conditions and is one-dimensional, the Darcy's low is valid for the proposed experimental conditions. The water flow can be described with the use of the following equation:

$$q(z,t) = -k(\psi)\left(\frac{\partial\psi(z,t)}{\partial z} - 1\right) \qquad (1)$$

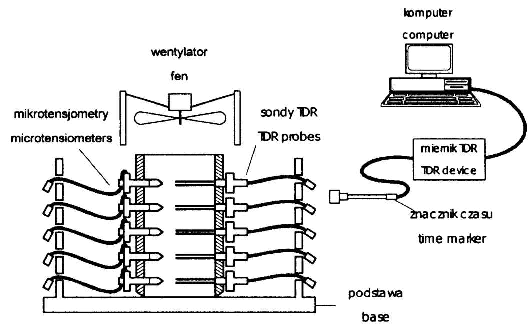

Fig. 1. *TDR set-up for water content and water potential dynamic measurements*

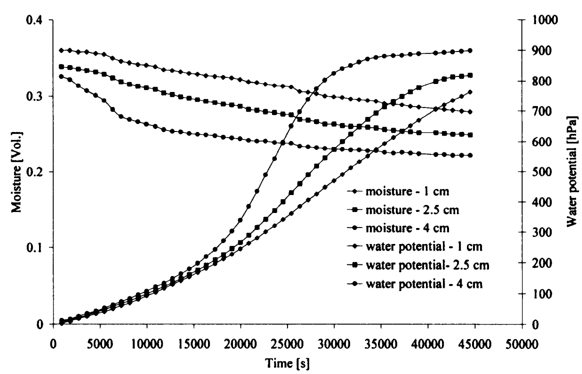

Fig. 2. *Water content and water potential dynamic in soil column evaporation process*

Alternatively the flux can be calculated from the equation:

$$q(z,t) = -\int_{z=z_0}^{z} \frac{\partial \theta(z,t)}{\partial t} dz \qquad (2)$$

Comparing these equations it is possible to calculate the hydraulic conductivity $k(\psi)$ from the equation:

$$k(\psi) = \frac{\int\limits_{z=z_0}^{z} \frac{\partial \theta(z,t)}{\partial t} dz}{\left(\frac{\partial \psi(z,t)}{\partial z} - 1 \right)} \qquad (3)$$

Using this method it is possible to determine relationship between hydraulic conductivity coefficient and water potential (see fig. 3) and so called dynamic retention curve (see fig. 4).

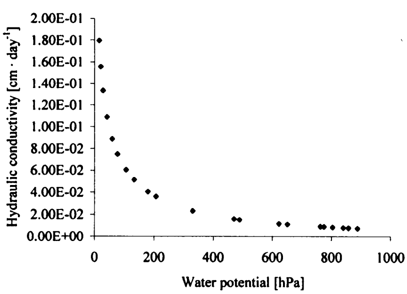

Fig.3 Hydraulic conductivity coefficient as a function of water potential

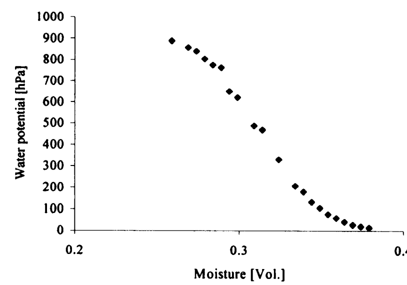

Fig. 4 Dynamic retention curve

Using TDR laboratory set-up and applying instantaneous profile methods (IPM) the hydraulic conductivity coefficients as a function of water potential and dynamic retention curve for minerals soil of Poland were determinated. Also using Richard's chambers the static retention curves were measured. Results of mentioned investigations are documented by two qualities:

- average numerical values of choosen soil hydrophysical characteristics set in tabular form,
- cartographic presentation of the variability and differentiation of soil cover of arable lands according to the values of these characteristics.

References:

[1] Walczak R., Ostrowski J., Witkowska-Walczak B., Sławiński C., 2002, Hydrophysical characteristics of Polish mineral soils, Acta Agrophysica, 79, 2003 (in Polish)

CONSERVATION TILLAGE PRACTICES ON A DRYLAND WINTER WHEAT FIELD IN NORTHERN CHINA: A SOIL-WATER BALANCE STUDY USING A TRIME® TUBE PROBE

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Abstract

Soil erosion by water is a severe problem in the eastern loess belt of northern China and is to a large extent associated with improper soil tillage practices. Changing the current tillage practices could therefore reduce soil loss. However, this will also affect the water balance and hence the available water for crop growth, particularly in dryland farming systems. A field study was carried out on five plots on a slope field near Luoyang, Henan province, P.R. China, in order to evaluate the water balance under different soil tillage practices on a winter wheat field with a silty loam soil texture. Five tillage practices were applied: conventional tillage, no tillage, subsoiling, reduced tillage, and cultivation of an additional summer crop. The difference in water storage was determined using a Trime® Tube Probe. From data from two consecutive agricultural years between 1999 and 2001, it was concluded that subsoiling resulted in the highest increase in water storage and in the lowest evaporation during the fallow period between harvesting and sowing of the winter wheat. A two-crop rotation with peanuts also showed promising results. The no-tillage and conventional tillage gave intermediate results, whereas the reduced tillage was the worst alternative.

THE DIELECTRIC PERMITTIVITY OF POROUS MEDIA THE COMPARISON OF MEASURED RESULTS AND ESTIMATION METHODS

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Abstract

In this paper a theoretical relationship between the apparent dielectric permittivity (dielectric constant) and mineralogical composition, organic matter content, bulk density of soil, temperature, bound and free water content of porous media is presented. Also, several estimation methods of dielectric permittivity of porous media are tested with measured results of different authors are presented. The calculations based on this theoretical relationship and comparison of the calculated results with measured data as well as statistical analysis can lead to the statement that the theoretical model predicts the soil dielectric constant with good accuracy. A comparison of the estimation methods reveals that theoretical model is the most reliable.

SOIL WATER CONTENT VARIABILITY ANALYSIS FOR FIELD AND COMMUNE SCALES BASED ON TDR AND GRAVIMETRIC MEASUREMENTS

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Abstract

The paper presents results of soil water variability analysis, and estimation of spatial distribution of water content in the area of cultivated fields and in the area of the Trzebieszów commune (Lublin Province). Soil water content in topsoil (1-6 cm) was measured with Time Domain Reflectometry (TDR) and gravimetric methods. The soil samples (about 1240 pairs of gravimetric and TDR data) were collected in points located either in regular (field) or in random networks (commune). Mean values of the topsoil water content in the individual fields as measured by means of the TDR method differed from the measurement by the gravimetric method from 2 to 22 %. Differences in the coefficients of variability were up to 42 %. The correlation coefficient for all the results of the two methods was 0.934 and the mean square error - 2.54×10^{-2} m^3 m^{-3}. Spatial distribution of soil water content obtained from the two methods were similar in general, however significant differences appeared locally as well.

RANGE OF SENSITIVITY OF SURFACE TDR PROBE

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Abstract

The presentation describes the status of work on surface TDR probe and the control program for application in building industry.

The presented surface TDR probe is a novel construction allowing determination of dielectric permittivity of building materials in non-destructive manner. Usually applied probes need to be immersed into the measured material. For solid materials it is difficult and sometimes impossible. When applied to existing building construction it destroys the surface and often is not acceptable. Application of surface probe is much more convenient but readout value is confined to the surface layer due to shallow range of TDR pulse penetration.

The construction of the probe allows to apply it to flat building surfaces. Three prototypes were tested. Each with different distance between rods.

Measurement of dielectrical permittivity of layered material has been performed in order to check how deep is a range of sensitivity of different probes. Results show that this range is about 20mm for each tested probe, but with differences in readout for each probe for lower depths.

The presented device can be applied in building industry to determine building material electrical permittivity change in time. For layered constructions there is a difficulty to measure moisture content itself, but the change of measured value in time caused by the moisture variability may be detected easily.

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