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Sensory recording of soil moisture during tillage near the ground level

An online data recording of soil parameters during field operation with a spring tine cultivator has been conducted on an 30 ha experimental field in Schleswig Holstein. The cultivator was equipped with an impedance sensor for recording of the soil water content, the tractor used in this experiment featured a force sensor for draft forces and sensors for velocity and depth of operation. The electric conductivity of the soil was measured by EM38 prior to the soil cultivation. As one major result of the current research the mapping of soil water content and soil conductivity are presented. In general these parameters correlate significantly. Assuming that the measured electrical conductivity of the soil represents satisfactorily the texture of the soil, it can be concluded that soil in deeper layers in general shows an increasing water content and the slip of the tractor as an indicator for the loss of force between tire and soil increases with the soil water content at all cultivating depths and with the gradient in cultivating depths.

Keywords

Specific humidity, dielectricity, soil moisture, soil moisture sensor, conductivity

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Sufficiently available soil water is a basic condition for plant growth and thus for the accumulation of crop-yield. Therefore the distribution of water in the field is a basis for measurement of optimized cultivation techniques in “Precision Farming”, which is of great importance due to growing cultivation units.

The extensive measurement of soil water content is possible by spectroscopic proceedings of near- and remote sensing. However this contactless method, which is based on the reflection of electromagnetic waves from the soil surface, can only capture the water content of soil when there is no vegetation cover.

The direct measurement of soil water content can be done with the help of Time Domain Reflectometry (TDR) as well as with the help of capacitive proceedings. However these methods are strongly influenced by conductivity of different soil types. As a third possibility the soil water content can be measured with the help of impedance sensors. This method works with the help of electromagnetic wave emission at frequencies of approx. 100 MHz.

These frequencies offer good conditions for the elimination of the imaginary part of the dielectric constant, which also contains conductivity as component depending on frequency (1;2). A major reason for unreliable values of dielectric measurements under field conditions is that the dielectricity is also depending on the soil density. In order to eliminate the influence of soil density, the volumetric water content can be applied.

Materials and Methods

During the long lasting research cooperation between the Institute of Agricultural Engineering, Bonn and the China Agricultural University, East Campus, which was funded by Deutscher Akademischer Austauschdienst (DAAD), an impedance sensor was developed which is characterized by fast reaction and low sensitivity for conductivity (1). For extensive use the measuring system was integrated in a shaft of a cone, which was fastened to a spring tine of a cultivator.

During pre-investigations on experimental fields at the University of Bonn it was checked if the instrument was fully functional. In cooperation with the Institute for Agricultural Engineering of the University of Kiel the sensor was used on a 30 ha experimental field of project „Präzise Bodenbearbeitung zur Mulchsaat“, funded by Deutsche Bundesstiftung Umwelt (DBU).

Approximately three weeks before the experiment started soil electrical conductivity was measured with an EM 38-system (Geonics, Canada). A GPS-system was attached for position-recording. During the EM 38 measurement a transmitter coil sends out an electro-magnetic field of 14,6 kHz into the soil. Secondary EM fields are induced by clay minerals and other materials with high conductivity. These secondary EM fields are registered by a receiver coil in the device. The soil conductivity of a location enables sufficiently accurate results with regard to the existing clay content and thus to the soil texture (3). Furthermore a digital map of a soil valuation of 1938 was used as source of information. The predominant soil-types on the experimental field range from sand to very loamy sand with a soil factor of 23 to 53.

The developed impedance sensor for recording of the soil water content was installed on the first tine row in-between two wheels of the support wheels of a 4 staggered tine row cultivator-disc harrow combination. For this kind of attachment the sensor was able to operate in untreated soil during the whole experiment.

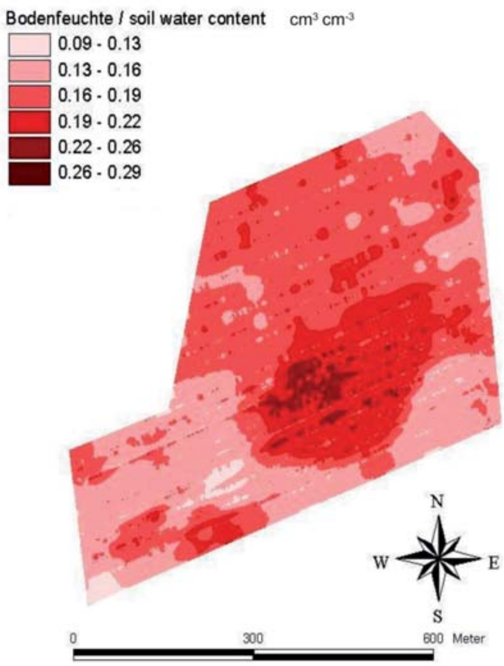
The tractor, which was used for the field research, was equipped with a measurement technique which could capture important data such as fuel consumption; relative und absolute speed, draught force and engine rev. The respective soil depth of the soil cultivator could be automatically defined, adapted and documented. The captured data was saved with GPS coordinates every second.

The field, a rape stubble, was divided into a total of 42 plots, which were cultivated at depths of 10, 12, 14, 16, 18 and 20cm repeated 7 times shortly before the seeding of wheat on Sept. 10th and 11th 2008. First tillage of the stubbles to a depth of approximately 2cm was already done after the harvest of the rape.

Results

The georeferenced values of soil water content and electrical conductivity, detected with our soil moisture sensor and the EM38 on the experimental field are shown in **figures 2** and **3**.

Fig. 2



Mapping of the volumetric soil water content in a depth of 10 to 20 cm

Fig. 1

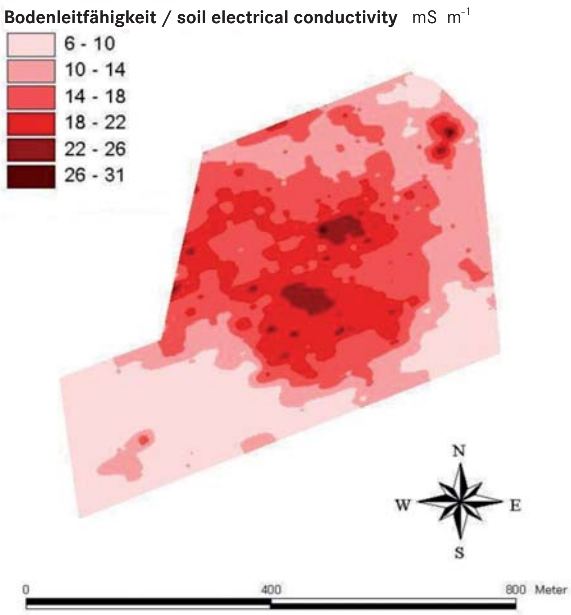
Impendance sensor for soil water mounted to the front bar of the cultivator

The soil water content in the experimental field was in the range of 0.12 and 0.25 cm^3cm^{-3} and the electrical conductivity in the range of 6 and 30 mSm^{-1}.

The relationship between the measured conductivity and the specific water content is shown in **figure 4**; a linear increase of the soil conductivity with increasing water content of the soil is clearly distinguishable.

In **figure 5** the average values of soil moistures at different depths are described. To exclude influence of soil texture or soil conductivity only data of identical soil conductivity classes was used to represent soil moisture at the respective working depths in **figure 5**. Therefore six soil conductivity classes were

Fig. 3



Mapping of the electrical conductivity measured by EM38 formed. For each of these classes soil moisture was determined using the impedance sensor at different depths on the experimental field.

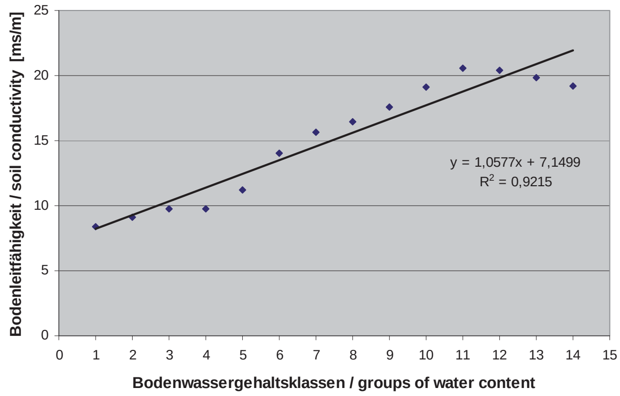
Figure 5 shows that soil moisture is higher at higher soil conductivities. In the soil horizon between 0.1 and 0.2 m depth a slight increase of soil moisture with increasing depth tends to be apparent. However it is not continuous over all depth gradients.

Figure 6 shows the influence of soil moisture on the measured slip of the tractor used. In order to minimise the influence of different soil types on the extent of slip at different working depths only the data from subareas with a defined soil conductivity from 10.5 to 17.4 mSm^{-1} are considered in **figure 6**. As expected, the slip tends to increase with both soil moisture and working depth. Increasing soil moisture and working depth exponentially increase the slip. Within the 0.1 m horizon of soil, moisture increases the slip by 0.7%, whereas in the 0.2 m horizon slip increases by 2.4% when soil moisture is raised from 0.15 to 0.3 cm^3cm^{-3}.

Conclusions

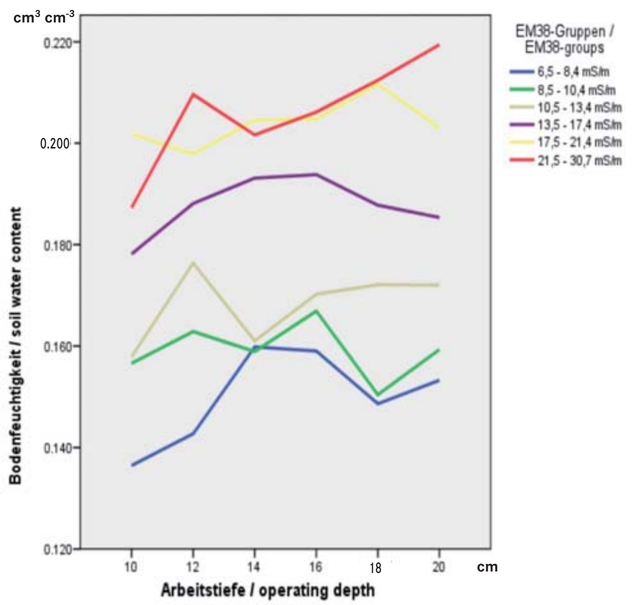
Using a newly developed measurement system for georeferenced identification of soil moisture distribution shows, that there are significant differences in the experiment which are related to soil conductivity and thus to the distribution of soil types. As expected, deeper soil layers show highest soil moisture respectively. The slip was used as an indicator of transmission loss between tire and ground. However slip increases with increasing soil moisture in almost all depths horizons, processed in the experiment. The measured differences in soil moisture during the cultivation can be used for estimation of soil-productivity as well as for interpretation of yield maps. Furthermore, the current site-specific information of soil moisture can be used as an important criterion for site specific variation of techniques such as tillage or sowing.

Fig. 4



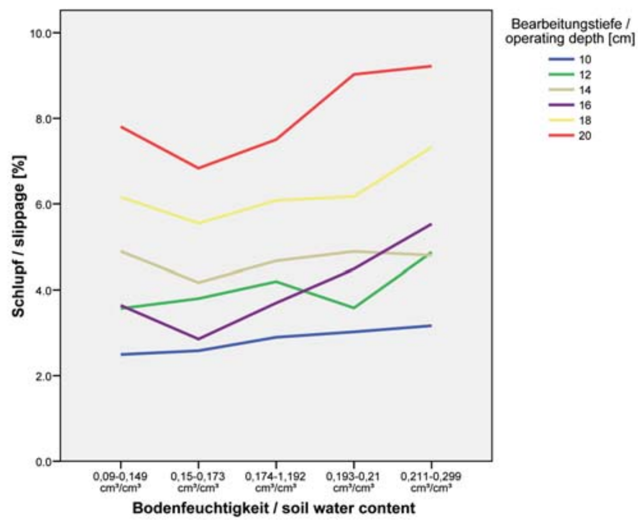
Electrical conductivity versus soil water content and correlation among these units

Fig. 5



Relationship between soil water content and soil electrical conductivity and cultivating depth

Fig. 6



Impact of soil water content on slip for different operations depths related to subareas with conductivity of 10.5 to 17.4 mSm^{-1}

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