Peter Schulze Lammers, Bonn, as well as Yurui Sun and Daokun Ma, Beijing/China

Using a Combined Sensor for Mapping Soil Resistance Force and Soil Water Content

Penetrometers are easy to handle measuring devices for measuring soil resistance force. As vertical penetrometers they are used to depict a compaction depth profile, as horizontal penetrometers to record the area distribution of soil compactions. When from soil resistance, measured as a force, conclusions are drawn on compactions, a strong non-linear relationship with the soil water content must be considered.

A continuous and simultaneous measurement of the water content is required in order to compensate its impact when using a penetrometer in experiments. The water content can be determined by the soil probes method or with instruments like TDR probes, which allow on-site data acquisition. A penetrometer facilitated with a water content sensor should provide signal acquisition of similar resolution for both sensors. Embedding the soil water sensor into a vertical penetrometer was already described by [1]. For the mapping of greater areas like fields however a horizontal penetrometer is preferable.

Method

The soil water content has been measured by a capacitance sensor, which is embedded in the horizontal-penetrometer shaft. The capacitor is consisted of two electrodes in the form of metallic rings, which are divided by insulating rings (*Fig. 1*). The measuring principle of the sensor is based on the relation of the permittivity and the water content and it requires calibration. If the permittivity is known, the equation of Topp [2] can be applied to adjust the probe.

The sensor frequency is chosen in a range where the imaginary part of the permittivity is low in order to reduce the electrical losses which are part of the apparent permittivity.

The shaft of the cone, which is used for the soil resistance measurement, has a low stability because of its length and due to a central bore for cable connection with the electrodes. For this reason the forces of the soil resistance are translated via lever to an external force sensor, i.e. load cell (*Fig. 1*). To protect the lever, which is used for the force translation, from the influence of the soil cutting, a second shaft in the form of a blade is applied. The cone tip and the shaft were designed similar to the ASABE-Standard S313.2 [3].

Experiments

Firstly, calibration tests for soil water content and soil resistance sensors were performed. The signal of the water content sensor de-

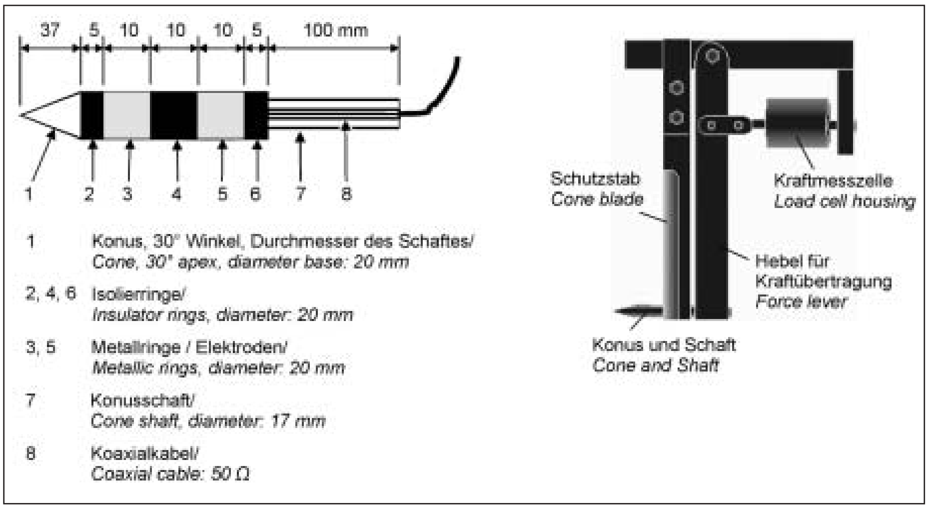

Fig. 1: Main parts of horizontal combined penetrometer and implemetation of electrodes

Prof. Dr. Peter Schulze Lammers is head of the Department Agricultural Engineering in Plant Production at the Institute of Agricultural Engineering of Bonn University, Nussallee 5, 53115 Bonn,
e-mail: *lammers@uni-bonn.de*
Prof. Dr. Yurui Sun is head of the Research Center for Precision Farming and Dr. Daokun Ma is member of the scientific staff of China Agricultural University, Quing Hua Dong Lu 17, Beijing,10083,
e-mail: *pal@cau.edu.cn*

Keywords

Soil compaction, water content, penetrometer, on-the-go measurement

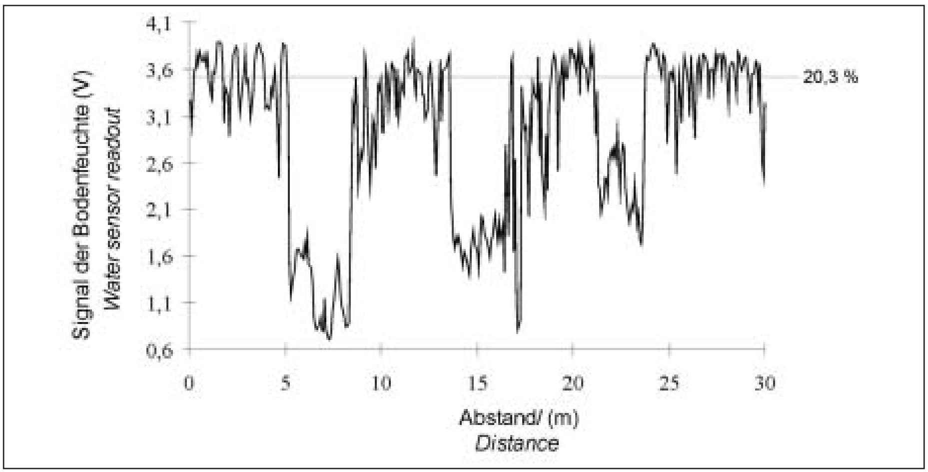

Fig. 2: Response of the water content sensor when going through soil sections with three different moisture profiles

scribes the water content by the quadratic function on below:

$$\Theta = 0.0259x^2 - 0.0087x + 0.0143 \qquad (1)$$

with $R^2 = 0.978$. The force signal has a linear relation to the soil resistant forces at the tip of the cone.

Two experiments have been performed in order to test the suitability of the horizontal penetrometer:

a) time response of the soil water content sensor
b) test of different velocity effects

For preparation of the experiments distinct soil areas were compacted on three depth levels and in other areas three different soil water content levels were produced in the working depth of the penetrometer (15 cm). *Figure 2* displays the course of the soil water content (6, 9 and 12 %) signals. Immediately after passing the zones of predefined water content the signals move back to the natural level (20.3 %). The results of the velocity test were applied to a Kruskill-Wallis variant analysis. There was no significant impact of the velocity in the range from 0 to 1.5 m/s to the soil water content signal in the working depth of 15 cm. In the same velocity range the signal of the force transducer as designed for the horizontal penetrometer (diameter 20 mm and 30° apex) increased by 14 %.

After the pre-tests a plot of the experimental farm Dikopshof of the University of Bonn (2 ha) was used for mapping of soil water content and resistant force. This field was chosen due to its high heterogeneity in texture. The results are presented in *Figure 3a* for the soil resistance and *Figure 3b* for the soil water content.

Conclusion

The visual analysis of the mapped plot indicates that the areas with high soil water content match to the areas of low soil resistance. This can be accepted as a plausible result and confirms that the penetrometer signals are of low significance without information about the soil water content. The question can be raised whether a horizontal penetrometer is more appropriate for determination of the heterogeneity of the soil water content than for the soil compaction. Thereby it is not questioned that the vertical penetrometer is a valuable instrument for evaluation of the soil trafficability, which is its original purpose.

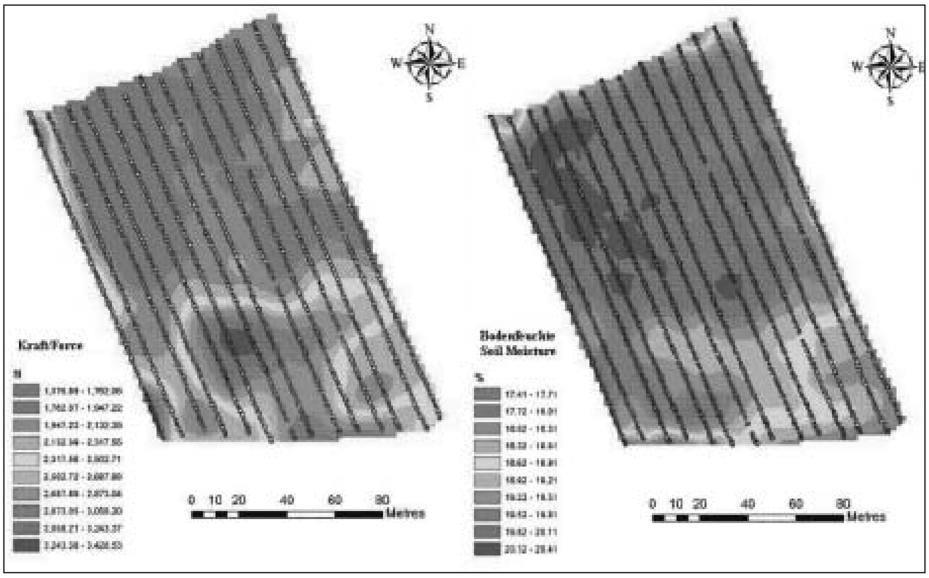

Fig. 3: Maps of the resistance force (a) and soil water content (b)

Literature

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