Arwed Schwark, Kiel

Measuring Conductivity as a Dimension for Soil Density

To analyse soil compaction there are both selective and large area measuring methods available. Among the selective methods especially soil core sampler measurements are noteworthy, and for large-areas the horizontal penetrometer. Measurements with the soil core sampler are laborious, costly and respond only moderately to changes in soil structure and with great variations. The penetrometer can be applied to large areas, but not on overgrown surfaces. Furthermore, stony soils cause problems. A non-destructive measuring method for large-areas with sensitive reactions to soil changes would be optimal. One such method, geoelectricity, was tested for its suitability.

Dr. agr. Arwed Schwark is scientific assistant at the Institute of Agricultural Process Engineering at the Christian-Albrechts-University of Kiel, Olshausenstraße 40, 24098 Kiel;
e-mail: *aschwark@ilv.unikiel.de*

Keywords

Soil, conductivity, compaction

Geoelectricity belongs to the Applied Geophysics and includes methods for the examination of the earth's crust by measuring conductivity and voltage at the earth's surface. The measuring methods are suitable as well for the investigation of the layered subsurface construction as for the boundary of lateral rock changes. The Geoelectricity is used for the deposit prospection on clay, gravel, ore and water, for the soil exploration, for the monitoring of contamination fields, embankments, reservoirs, for the locating of tunnels, pits, leakages and so on. [1]

A well-established measuring method that already is in use in agriculture is the measurement of the conductivity using the EM 38, tightly correlating with the clay concentration. The method is used in conjunction with GPS, to prepare digital soil maps fast and effectively. The EM 38 method is based on electromagnetic induction and provides a signal from a depth of up to 1.5 m [2].

Geoelectric direct current resistance measurement systems depend as well on the principle of resistance measurement. Unlike the EM 38 method, no measurement of electromagnetic induction is done, but current is directly supplied to the soil. Such a system consists of two electrodes for the current entry and the measuring electrode, respectively. According to the distance of the current electrodes to each other, a different region of the underground of the current system is detected. If the distance between the electrodes is changed, different ranges of depths are getting scanned. This is not possible with the EM 38 method (*Fig. 1*).

The disadvantage of measurement in only one depth with the EM 38 should be met by this method. In cooperation with the company „Geoserve Kiel“ and Prof. Dr. Jürgen Lamp from the Institute of Plant Nutrition and Soil Science of the Christians-Albrecht-University, Kiel, the measuring system „Pluripol“ has been constructed, in order to facilitate the partial area specific mapping of soils with information from different depths. With „Pluripol“ it is possible to supply the soil with direct current of 12 to 120 V over two isolated rolling electrodes, and to measure the apparent electric resistance of the soil simultaneously with three more pairs of electrodes (*Fig. 2*). The „Pluripol“ is pulled by a Landrover Defender. The measuring system records the resistance as well as the GPS position every second.

Since for these measurements an integral, i.e. an over a range of depths averaged electric resistance is assessed, the inversion of the measuring data is in fact necessary. Because of lacking inversion routines for three-dimensional data recording, the inversion was not feasible at present.

It is well-known that besides the texture other attributes influence the soil conductivity. The most important are the moisture content, the nutrient concentration and the soil density. For the following experiment,

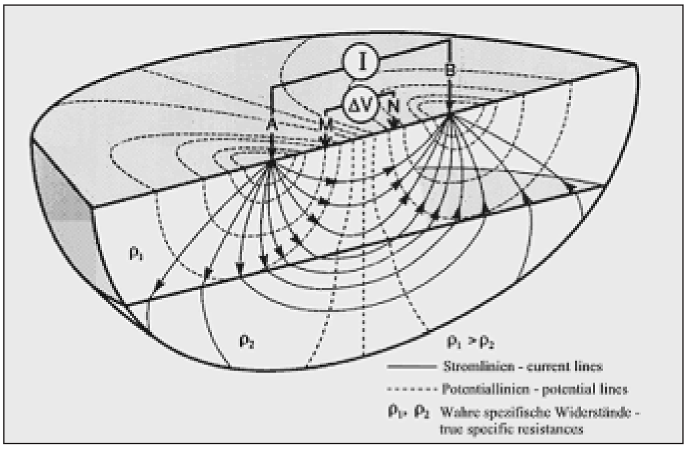

Fig. 1: Propagation of current and potential lines [3]

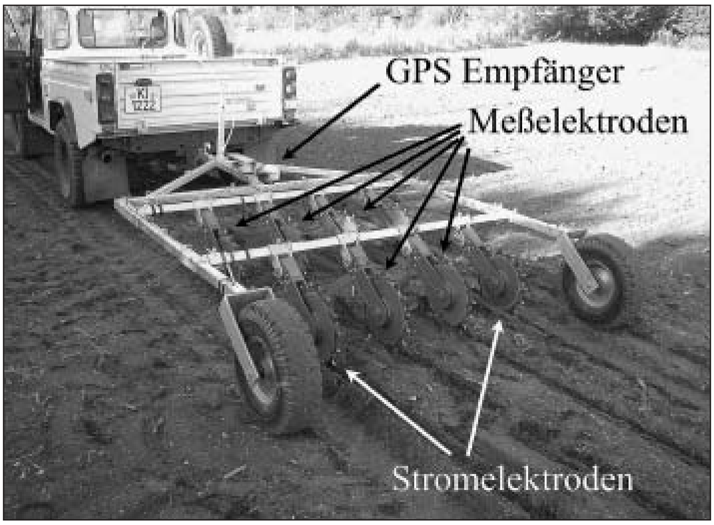

Fig. 2: Measuring system device with rolling electrodes and GPS receiver

the circumstances were put into the question, how the change of the soil density influences the measuring data and whether the conductivity is a suitable parameter for mapping of compressed areas. The advantage would being able to map a bigger area with less effort.

Material and Methods

On March 19th 2004 an experiment was carried out on a field of winter wheat of the Institute of Agricultural Process Engineering. The field was cultivated with winter wheat, with mulch tillage after rapeseed and the soil moisture was near the field capacity. The soil texture was sandy loam. On the field, three partial areas of land were built with a distance of 50 meters to each other. The parcels were 20 meters long and 5 meters wide. The resistance in the parcels was measured twice before the stress with the measurement system was set to them. After the measurement the parcels were compacted using a tractor (weight: 7,5 t, rear tyre equipment: 520/70 R 38, 1,5 bar) in more than 30 crossings. After the compaction the resistance was measured again and the variance of data was analysed.

Results

Figure 3 shows the resistance of the rear row of electrodes in Schlumberger-configuration. It has the least penetration depth and measures basically only the topsoil. The precise determination of the penetration depth is not possible without data inversion. During the data inversion the apparent electric resistances of several electrode configurations get converted iteratively into the true specific resistances in the particular depth.

The results of the measurements of the resistances of the partial areas show that the crossing of the field with the tractors has a significant influence on the extent of the resistances. On all partial areas the resistance decreases. The variation between the measuring values is marginal within the respective partial areas, therefore the reproducibility of the measurements seems to be good. There are significant differences in the absolute extent of the resistance between the partial areas, which exceed the changes by the stress of the crossings. The measuring values of partial area 2 are 40% below those of partial area 1, while the decrease of the resistance after the treatment is only 13%. The distance between all partial areas is only about 50 meters and assigned to the soil texture sandy loam. The measurements with the EM 38 showed a conductivity between 16 to 18 mS/m. Because of the total measuring spectrum of 1 to 50 mS/m between sand and clay, these measurements values have to be estimated as being the same. Obviously the measuring system reacts more sensitively to relatively low changes of the soil conditions than to changes in the soil density.

From this it can be concluded that this method is not applicable for the display of compacted areas in the GIS, because it is not possible to see on the map whether the high resistance or the low resistance of an area is caused by the soil density or by other factors. For experiments working with directly comparing lanes and unstressed soil, the measuring method could be applicable. The method bears the problem that the measured resistances are apparent electric resistances, not the real resistances. Therefore it would be better to use fixed electrodes instead of rolling electrodes at this moment, because it is easier to generate a two-dimensional inversion.

Conclusion

The geoelectric direct current measuring method reacts in a direct comparison reliably to differences in soil density, but other differences in soil texture can superpose these results. Therefore the geoelectricity is not suitable for extensive display of compactions in the GIS. It can possibly be used for defined stress experiments.

Literature

Books are identified by •
[1] www.geoserve.de
[2] *Lück, E., M. Eisenreich und H. Domsch*: Innovative Kartiermethoden für die teilflächenspezifische Landwirtschaft. Stoffdynamik in Geosystemen. Universität Potsdam, 2002
[3] • *Knödel, K., H. Krummel und G. Lange*: Geophysik - Handbuch zur Erkundung des Untergrundes von Deponien und Altlasten. Springer Verlag, Heidelberg, 1997

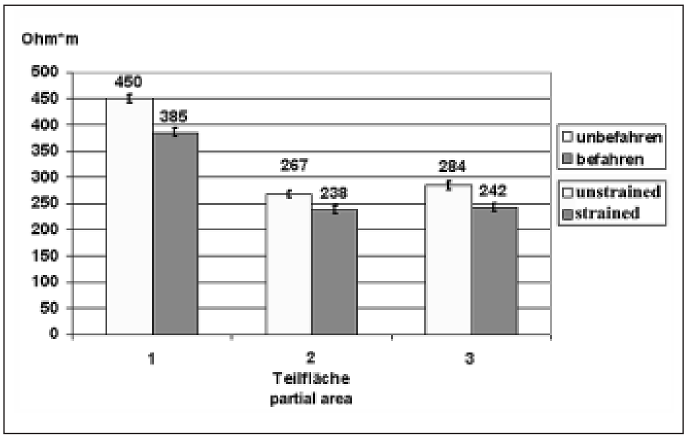

Fig. 3: Influence of partial areas on the extent of the measuring value