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The OhmMapper

Geoelectrical Mapping with a Capacitive Resistivity Technique

The OhmMapper implements geoelectrical mapping with a capacitive resistivity technique which provides an alternative to other methods currently used in agriculture. The capacitive resistivity technique combines the advantages of the electromagnetic induction method, regarding the ease of coupling and small dimensions of the implement, with the benefits of the interpretation schemes of the galvanic coupled method. Nevertheless, experimental results show that the instrument is less suited for agricultural purposes due to its mechanical properties and the incidental occurrence of measurement errors.

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Mapping of apparent electrical conductivity (ECa) or electrical resistivity (ERa) of the soil by geoelectrical methods is generally accepted by researchers as well as by farmers as means to characterize soil spatial variability for precision agriculture. The ECa [mS/m] or its inverse, the ERa [Ωm] is influenced by several soil properties, of which many are relevant for crop growth [1].

To produce ECa maps for agricultural purposes we need a mobile sensor with continuous data acquisition capability, which is pulled by a vehicle. Additionally a GPS has to provide geographical positions. The most popular geoelectrical sensor is the EM38 (Geonics Ltd.), which is based on electromagnetic induction. Another well-known sensor is the Veris 3100 (Veris Technologies), which is based on galvanic coupled resistivity measurement. Compared to these sensors the OhmMapper of Geometrics Inc., CA/USA is largely unknown in agriculture. The OhmMapper is measuring soil ERa by capacitive coupling (*Fig. 1 a*). Capacitive coupling avoids the notorious difficulties of galvanic coupling on hard rock, dry soil or frozen ground. At the same time capacitive ERa measurements are equivalent to those obtained with the classical galvanic coupled technique. Thus a large number of well established interpretation schemes are available.

Measuring principle and construction of the instrument

The OhmMapper implements a four-point arrangement of capacitor plates which is analogous to the four-point arrangement of electrodes of the direct current technique (*Fig. 1 b*). The four-point arrangement consists of a current dipole, which is coupling the current to the soil and a potential dipole, which is used to measure the voltage drop. The four capacitor "plates" of the OhmMapper are made of coaxial cables. Two of them are forming the current dipole (transmitter) and the second pair is forming the potential dipole (receiver). The electronics and the batteries of the transmitter and receiver are

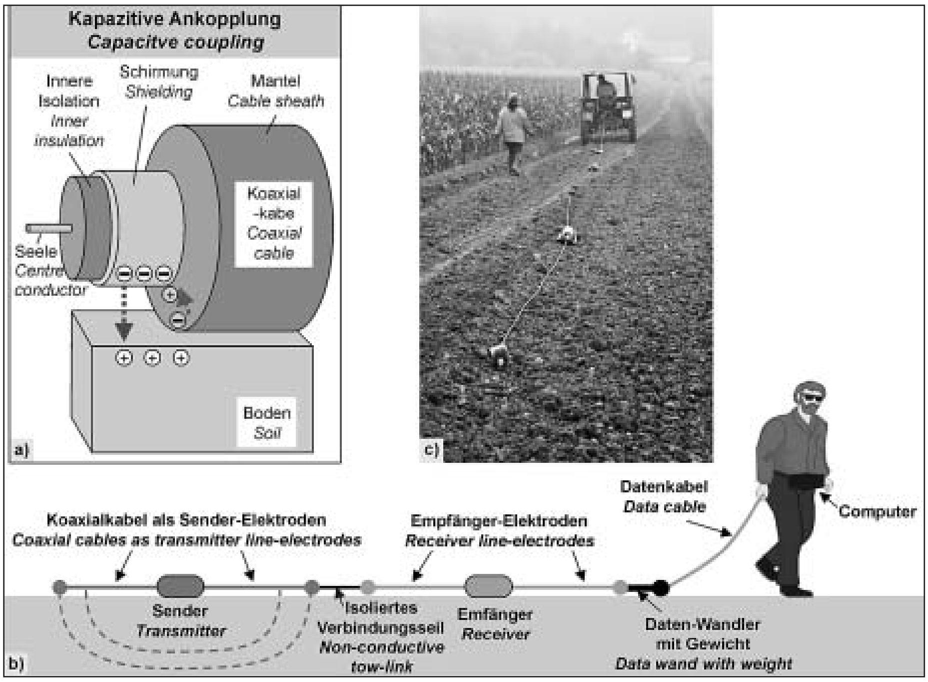

Fig. 1: Measuring principle and construction of the OhmMapper, Geometrics Inc., CA/USA

placed in the middle of the respective dipole. The copper braid shielding of the coaxial cables actually constitutes the capacitor plates. This shielding is protected by a tough outer isolation. Since the cables are coupling over their entire length, they are called line electrodes. Capacitive coupling is based on displacement currents. Current transmission by displacement currents increases with frequency. To supply sufficient high currents, a minimum frequency of 1.6 kHz is needed. The upper frequency limit of 25 kHz is given by the condition to fulfil the low-induction-number regime. The OhmMapper's operating frequency of 16.5 kHz is within these limiting frequencies. Depending on ground conductivity, the current output of the transmitter has to be adapted. This is done automatically within a range of 0.125 and 16 mA. The selected current setting is signalled to the receiver by a 4 Hz modulation of the injected current. The phases of the receiver and the transmitter are synchronized by another 2 Hz signal. At operating frequency the input to the receivers has an impedance of greater than 10 MΩ. At other frequencies its input impedance is lower. This reduces effects of cultural noise such as the 50 Hz mains frequency. Regarding the measuring principle further details can be found in [2].

The OhmMapper comes with a handheld computer, which provides storage space and survey-monitoring functions. A GPS interface is included. The Geometrics DataMapper software for PC can be used for visualization, post-processing (filtering), and export into other applications.

Depth of investigation can be increased by increasing the dipole cable length and/or the distance between the receiver and the transmitter. We have used cables of 2.5 and 5 m length. For mobile mapping one transmitter cable has to be linked to one receiver cable by a non-conductive tow. This results in a linear co-axial arrangement of the transmitter and receiver dipoles also known as the "dipole-dipole" array. One can survey several depths simultaneously by linking additional receivers.

Methods

The OhmMapper was tested on soils of different geological origins in Germany [3]. Parts of the measurement were conducted on specific transects, which have been surveyed by a GeoTom multi-electrode array beforehand [3]. The GeoTom multi-electrode array is used as a reference. It is based on the direct current galvanic coupled resistivity method. Up to 100 stationary electrodes can be switched automatically. The electrodes were placed in 50 cm intervals. To obtain readings from different depths, electrodes are successively switched to increase separations. Separations between adjacent electrodes involved in the measurement were equal. This configuration is called Wenner array. Measuring positions were shifted along the transect. In the end, at every position, readings from up to 8 depths (up to 4 m spacing accordingly) were available. The internal error correction of the GeoTom guarantees the recording of high-accuracy ERa values. GeoTom and OhmMapper data were compared regarding similar investigation depths. Certain electrode spacings of the GeoTom have approximately the same depth of investigation as certain OhmMapper configurations. In *Figure 2* we are comparing shallow and deep measurements of the GeoTom at 0.5 and 4 m spacing with OhmMapper measurements with a distances of 0.5 and 4 m between 10 m dipoles, respectively. The OhmMapper was pulled over the transects by a single person while positions were acquired by tape measure. Additionally, field extent mapping was carried out with the OhmMapper attached to a vehicle and combined with a dGPS (*Fig. 1 c*).

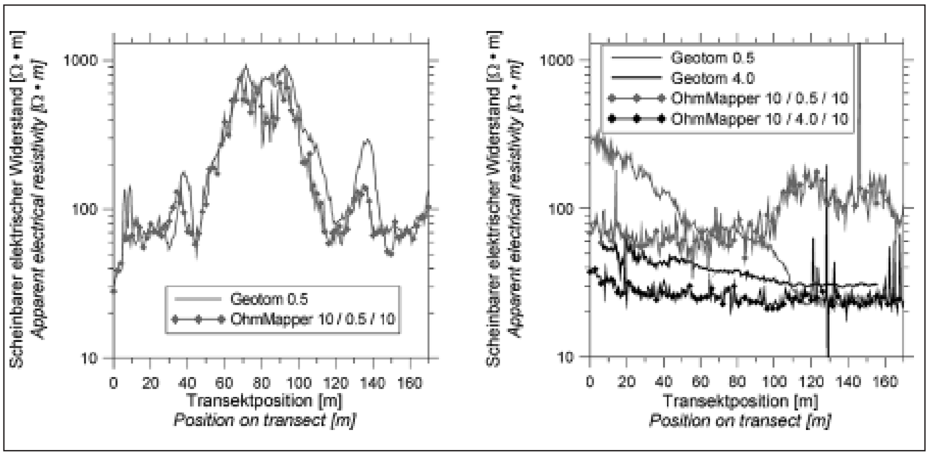

Fig. 2: Comparing the GeoTom (reference) and the OhmMapper in a ground moraine location with sandy to loamy soils (left) and in a mudstone area (right) with a sandy top layer decreasing from left to right

Results

As an important prerequisite for capacitive coupled measurements the height of the capacitor plates above the soil has to be constant. It is assumed that this applies to the OhmMapper due to the flexibility of its cables. During our test with cables of 2.5 m we observed considerable noise. Similar results are reported by [4]. Even with longer cables, outliers were obvious regardless of the roughness of the soil surface. On soils with higher conductivities the OhmMapper exhibited pronounced deviations from the reference values (*Fig. 2 right*). Pulling the OhmMapper with a vehicle turned out to be difficult. The array tended to get stuck which caused the overload clutch to get released. Consequently the mapping was interrupted. During curves, measurements are disturbed due to the modification of the array geometry and due to the lateral skips of the cables.

Conclusions

The OhmMapper implements a promising measuring technique. Because of its sensibility to mechanical stresses it seems to be unlikely that the instrument will be widely used for agricultural soil mapping.

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