Новые методы и результаты исследований ландшафтов в Европе, Центральной Азии и Сибири

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This monograph shall inform you about up to date methodologies and recent results in landscape research. It is intended as a guide for researchers, teachers, students, decision makers, stakeholders interested in the topic of landscape science and related disciplines. It provides information basis for decision makers at various levels, from local up to international decision bodies, representing the top level of landscape science in a very short form.

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Chapter III/40: SOIL MAPPING WITH GEOPHILUS ELECTRICUS

Глава III/40: Картирование почв с помощью GEOPHILUS ELECTRICUS

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ABSTRACT. Near-surface geophysical techniques such as the developed Geophilus Electricus system have the potential to map important soil parameters. The Geophilus sensor uses an equatorial dipole-dipole array of rolling electrodes and allows for measuring the apparent electrical resistivity at five depth levels. Therefore, in addition to conductivity maps illustrating lateral variations of apparent conductivity, sounding curves are available at each measurement point. These contain information about vertical changes in electrical conductivity up to a depth of about 1.5 m. Using an appropriate inversion procedure, allows us to transform the measured data into resistivity-depth-functions. However, due to the complex parameter relationships usually observed between electrical conductivity and different soil properties, we typically can not translate our geophysical result into a single soil attribute like soil moisture or clay content. To overcome some of such limitations in interpretation, we combine our electrical data with measurements of the natural gamma radiation, which may be a good indicator for soil clay content.

Резюме. Приповерхностные геофизические методы, такие как разработанная система Geophilus Electricus, могут отображать важные параметры почвы. Датчик Geophilus использует экваториальную диполь-дипольную решетку прокатных электродов и позволяет измерять кажущееся электрическое сопротивление на пяти уровнях глубины. Поэтому в дополнение к картам проводимости, иллюстрирующим боковые вариации кажущейся проводимости, кривые зондирования доступны в каждой точке измерения. Они содержат информацию о вертикальных изменениях электропроводности на глубине около 1,5 м. Используя соответствующую процедуру инверсии, мы можем преобразовать измеренные данные в функции глубины удельного сопротивления. Однако из-за сложных отношений параметров, которые обычно наблюдаются между электропроводностью и различными свойствами почвы, мы, как правило, не можем перевести наш геофизический результат в единую почвенную характеристику, такую как влажность почвы или содержание глины. Чтобы преодолеть некоторые из таких ограничений в интерпретации, мы объединяем наши электрические данные с измерениями естественного гамма-излучения, что может быть хорошим показателем содержания глины в почве.
INTRODUCTION
Soil plays a central role in landscape modeling because of its multifunctional properties. Since traditional soil mapping cannot satisfy the obvious need for high-resolution and accurate soil maps, proximal soil sensing is used as an effective approach for measuring soil properties [14]. Among all techniques, electrical conductivity (EC) and resistivity mapping are well established geophysical methods having the potential to provide information about important soil properties. The most promising and popular techniques are frequency domain electromagnetics and direct current (DC) electrical methods [3, 1]. Because the parameter of EC is better known in soil sciences, measured resistivities are often converted into EC data. Although conductivity readings are affected by soil stratification, so far farmers do not consider this information about layering. Conductivity mapping can, for example, be applied for prediction of soil salinity [7], in environmental geophysics, for archaeological prospection and in precision agriculture [1]. Additionally, multi-sensor-platforms are used to reduce the ambiguity in the interpretation of EC data. For example, collocated data of EC and gamma measurements might help to distinguish whether high conductivity values are caused by clay or by peat.

ELECTRICAL CONDUCTIVITY MAPPING ON FARMLAND
In precision farming, maps of apparent electrical conductivity (ECa) are used for studying the in-field heterogeneity, for delineating management zones and for guiding direct soil sampling. In combination with a site specific calibration, electrical conductivity can also be used as a proxy for many other soil properties. Owing to the often observed stability of the conductivity patterns [2, 9, 12], a single mapping is sufficient. From their studies, Vitharana et al. [15] and Van Meirvenne et al. [11] concluded that electrical conductivity is one of the key properties in precision agriculture. Although, soil electrical conductivity might be indicative for many soil properties affecting yield, there is often no direct correlation observed.

THE GEOPHILUS SYSTEM
Geophilus Electricus is a soil mapping system which has been developed within different projects over the past years in cooperation between the University of Potsdam and the Leibniz-Institute of Vegetable and Ornamental Crops [8]. Working with the first multi-receiver dipole prototype configuration, data are generated with the SIP Rabbit system (SIP – spectral induced polarization) developed by Radic Research (Germany) [6] in combination with a laptop and a GPS receiver for positioning. Its design and technical specifications allow for measuring apparent complex electrical resistivity data at different depth levels up to about 1.5 m using an array of galvanic coupled electrodes. A Geophilus sounding is composed of five equatorial dipole-dipole measurements with a constant dipole length of a = 1 m and a varying offset b between the source dipole and the receiver dipoles (Figure 1). The Geophilus measurement system will be continuously developed. So, the current rolling electrode system was enlarged by a sixth receiver dipole and the presently used electronic unit (Delphin Technology) optimizes the voltage input automatically. The electrical measurements of the Geophilus were recently combined with a gamma probe built by the company BLM Storkow (Germany). This gamma sensor consists of polystyrene and measures total counts of natural gamma radiation [10]. Because of its relative large volume of about 10 liters, the sensor can scan relatively quickly the gamma activity in mobile mode.

INFORMATION ABOUT SOIL STRATIFICATION
The depth of investigation depends on the used electrode configuration [13, 4]. By using multi-array systems with several electrode configurations, it is possible to measure simultaneously the ECa data for more than one depth level. Therefore, at each position a dataset known as a vertical electrical sounding (VES) can be recorded. Such data can be interpreted as a sounding curve (ECa as a function of the spacing between the electrodes) or after inversion as a resistivity-depth-function. We have developed an algorithm which performs the one-dimensional inversion of large multi-offset equatorial dipole-dipole data sets [5] as recorded with the Geophilus system. This efficient one-dimensional inversion approach allows us to
put special attention on modeling the effects of noise of mobile electrodes, which are much stronger than for data collected with fixed electrodes.

FIELD DATA EXAMPLE
In the past, the applicability of the Geophilus system has been demonstrated at several sites on soils with various electrical characteristics (ECa ranging from 0.3 up to 150 mS/m). Here we present one typical data set collected on an 18 ha field in the south of Berlin where a transition zone between peat and sand is present. The thickness of the peat layer varies between 10 cm and about 1 m. Instead of the GPS receiver, a tachymeter was used for positioning. Therefore, a precise elevation model could be determined in addition to the geophysical data. The test site is a flat area with elevation differences of a maximum of 1 m. Figure 2 shows all measured raw data. The correlation between topography and soil properties is obvious. The lowland is a high conductive area with low gamma activity caused by peat. Because of the good resolution, small linear sand ribs are visible in all top soil data. To illustrate also the vertical tendency of ECa (i.e., soil layering), all ECa maps are with the same color scale. While shown channel 1 is mostly influenced by the top layer, the ECa values of channel 5 are also affected by the subsoil. Especially for the peat regions, the ECa maps indicate a decrease of conductivity with depth, which is caused by the sand layer underlying the peat. We have inverted the data to study the stratigraphy more precisely. In Figure 3, we present two of the conductivity depth models that reflect the stratification of the test site. While the eastern part of the field can be characterized by a high conductive upper layer, the western part has a low conductive top layer. This corresponds well with the soil probing.

CONCLUSIONS
1. We developed a mobile system for mapping the electrical resistivity/conductivity within several depth levels.
2. The data deliver not only information about the lateral but also about the vertical changes of electrical properties.
3. An algorithm was developed to perform the one-dimensional inversion of large multi-offset equatorial dipole-dipole data sets.
4. A gamma sensor provides complementary data for digital soil mapping.
Figure 2 – Typical dataset for a Geophilus measurement consisting of an elevation map, five ECa-maps corresponding to the 5 receiver dipoles and the map of the total count of gamma radiation. I and II indicate the position of two transect for which conductivity depth models are shown in Fig. 3

Figure 3 – Conductivity depth models for the transects I and II, the position of which is given in Fig. 2. Note that different scales have been used for distance and elevation.

REFERENCES


