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Geo-Physical Properties of Topsoils Retrieved from Field-Spectroscopic Data

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Introduction

Topsoils of arable farmland frequently show significant heterogeneity across fields. For precision farming applications it is important to delineate areas of different topsoil quality. Knowledge of topsoil quality is important for tillage, seed bed preparation, plant emergence, weed incidence, mineralisation of nutrients, resistance to erosion risk, water infiltration, heat balance. Important topsoil characteristics are total nitrogen content (N_t), organic matter content (C_{org}), particle size distribution, pH value, and $CaCO_3$ content. The topsoil color is additionally depending on iron oxides.

Material and Methods

The area of the investigated topsoil is located in Sachsen-Anhalt, Germany. The area is characterised as a sligthly undulated tertiary plain at 70 m altitude with an intensive arable farming and the alluvial plain of the river Elbe at 50 m altitude. With 450 mm annual precipitation and 9 °C annual temperature, the region has a negative water balance during the vegetation period. The tertiary plain is covered by Aeolian sediments mixed with different portions of tertiary sands and clays. The predominant soil type is Chernozem in conjunction with Cambisols. The alluvial plain is characterised by coarse sand to fine sand, loam and clay sediments. The predominant soil types are Mollic Gleysols and Fluvisols. The samples of the 29 collected topsoils are representing the spectrum of the occurring soil types.
The samples were passed through a 2 mm sieve and were air dried. The soils were analysed for total amount of C_{org} and N_t. The pH value and the $CaCO_3$ content was measured. The particle size distribution was analysed using the sieve analysis for the sand fractions (630 µm, 200 µm, 125 µm, 63 µm) and the coarse silt fraction (> 20µm) and the pipette analysis for the fine fractions of silt and clay (6.3 µm, 2 µm, >0.2 µm). The compounds of different iron oxides were determinated measuring the ditionite solubility (Fe_d) and the oxalate solubility (Fe_o).
The spectral properties of the 29 topsoils were measured using the GER 3700 hyper-spectral field-spectroradiometer (Geophysical & Environmental research Corp., Millbrook, USA) ranging from 330 to 2500 nm. Fiber optic was used for all measurements. Reference measurements were done using a spectralon white standard panel. The measurements were calculated in relation to the standard reference panel as reflection percentage. The spectral signatures of the topsoil samples are given in Figure 1.

Results

The min-max range of the soil data is given in Table 1. Most of the soil parameters are not independent. Different soil parameter relationships with significant correlation were found. Clay and the oxalate soluble iron oxides Fe_o show a linear correlation (r=0.90***). Clay and the ditionite soluble iron oxides Fe_d are also linear correlated (r=0.94***). Silt and sand, especially silt and the sand fraction >200 µm are non-linear correlated (r=0.91***). In this relationship it was possible to distinguish the soil samples from the tertiary plain and the alluvial plain. The C_{org} content is closely correlated with the N_t content (r=0.97***)

A spectral response was found for the clay content of the topsoils. This relation was independent of the organic matter content (C_{org}, N_t) but correlated with the amount of iron oxides which are closely correlated with clay. Only the wavebands > 2300 nm are correlating significant with the clay content. The best relationship for clay was found as non-linear regression with the wavebands at 2427-2436 nm (R^2=0.78***). Multiple regressions with clay and iron oxide fractions were not significant.

The amount of organic matter (C_{org}, N_t) correlates best in the range of short wavebands. The best non-linear regression was found for the wavebands 344-357 nm (R^2=68***). The scattering of the data was compared with the visible soil color. It became obvious, that the type of the organic matter plays a significant role for the absorption. Also the genesis of the organic matter in relation to the site specific transformation processes has to be considered for a more precise characterisation of the organic matter and for a better understanding of the spectral response.

Conclusion

The two most important topsoil parameters for precision farming applications, the organic matter and the clay content are correlating with spectral properties. It is necessary to consider the middle Infrared wavebands > 2300 nm for these applications. The organic matter can not be described only by the amount of C_{org} and N_t in relation to the spectral properties. The quality of the organic matter has to be integrated into the analysis.

The spectral signatures from 400 to 1300 nm show typical curves. In future we will apply a polynominal curve fitting procedure to this spectral range and use the curve parameter for the regression analysis too. It is intended to enlarge the data set with topsoils fron three additional fields to improve the validity of the results.

Tab 1: The min-max ranges of soil parameters

	Sand (%)	Silt (%)	Clay (%)	C_{org} (%)	N_t (%)	Fe_o (%)	Fe_d (%)
Min	16	5	7	0.5	0.05	0.06	0.14
Max	88	72	35	2.6	0.26	0.48	0.98

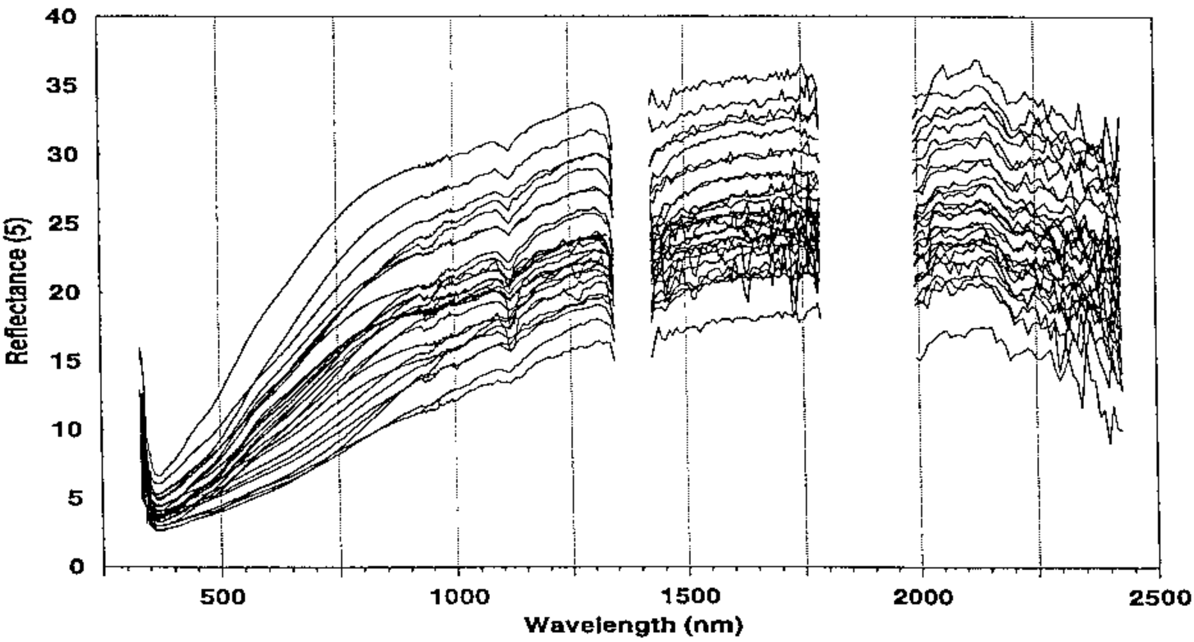

Fig. 1: Spectral signatures of the investigated topsoils