Hyperspectral assessment of the three-dimensional variability of various soil properties in a stagnic luvisol

Markus Steffens (1) and Henning Buddenbaum (2)

(1) Lehrstuhl für Bodenkunde, TU München, Freising, Germany (steffens@wzw.tum.de), (2) Remote Sensing Department, Trier University, Trier, Germany

Most studies in soil science assume diagnostic horizons to be homogeneous and consequently take a low number of replications. But many horizons are obviously heterogeneous and show clear patterns with widely varying physical and chemical properties on small spatial scales, e.g oxidised and reduced areas in the temporarily water-logged stagnic horizon. An associated problem is that most analytical techniques in soil science are destructive and the sample is lost when one parameter is measured. So even if we have enough replications and patterns are sampled accurately, only one or few properties can be measured before the sample is lost. A solution to this problem can be the bi-directional reflectance of a sample as it contains much information on a wide variety of a sample's properties which can be measured fast and simultaneously. The problem is that most of these devices measure disturbed samples that were milled to powder size - again, no information on the small-scale variability of the parameters is provided. We are looking for a fast, non-invasive tool to estimate the horizontal and vertical heterogeneity of an undisturbed soil and quantify important physical and chemical properties with high statistical significance.

We sampled a stagnic Luvisol (siltic) under a Norway spruce monoculture in Southern Germany (Freising, Bavaria) using a stainless steel box (100x100x300 mm). A hyperspectral camera (400 to 1000 nm in 160 bands) equipped with a translation stage (moves the sample under the detector) was used. The spatial resolution was 62x62 μm per pixel and 1600 pixels were recorded in each row. Up to 5000 rows were recorded for the complete sample length. After recording the image, representative patterns (e.g. high and low oxide concentration) were sampled for further analyses (66 areas). Then 15 mm of the soil core were carefully removed and the surface smoothened prior to the next image (seven images). Organic carbon, total iron and total manganese concentrations were determined with standard laboratory measurements for quantification and correlation with the measured spectra.

The spatial heterogeneity of the soil profile was analysed with semivariograms after data reduction and showed clear differences between the major horizons. Classification analyses were used to separate and identify homogeneous regions in the profile and in the homogeneous horizons and to quantify the contribution of the oxidised and reduced areas to the total area. Narrow band indices, partial least square regressions and support vector regressions were used to calculate maps of organic carbon, total iron and total manganese concentrations out of the bidirectional reflectance and the elemental concentrations determined with standard laboratory methods. We show that this technique is a powerful new tool to accurately quantify important soil properties on the aggregate scale in an undisturbed soil system.