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Monitoring soil organic carbon in croplands using imaging spectroscopy

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Conventional soil sampling techniques are often too expensive and time consuming to meet the amount of quantitative data required in soil monitoring or modelling studies. The emergence of portable and flexible spectrometer operating in the visible and near infrared range of the electro-magnetic spectrum could provide the large amount of spatial data needed. To this regard, the ability of airborne imaging spectroscopy to cover large surfaces in a single flight campaign and study the spatial distribution of soil properties with a high spatial resolution represents an opportunity for improving the monitoring of soils. The potential of quantitative spectral analysis has been repeatedly demonstrated in soil science either in the laboratory or with remote sensors. However, imaging spectroscopy for soil applications has been generally applied over small areas or homogeneous soil types and surface conditions. Here, five hyperspectral images acquired with the AHS-160 sensor were analysed to predict Soil Organic Carbon (SOC) in an area (350 km2) in Luxembourg characterized by different soil types and a large variation in SOC contents.

Reflectance data were related to surface SOC contents of bare cropland by means of 3 different multivariate calibration techniques: Partial Least Square Regression (PLSR), Penalized-spline Signal Regression (PSR) and Least Square Support Vector Machine (LS-SVM). The stability of the methods across different agropedological zones, soil types or soil surface conditions were tested by comparing their performance under different combinations of calibration/validation sets (global and local calibrations).

A lack of fit at high SOC content was observed under global calibrations, yielding a relatively high Root Mean Square Error in the Predictions (RMSEP) of 4.7-6.2 g C kg-1. PSR showed a greater ability to handle noisy spectral features, resulting in more robust calibrations than PLSR. Local calibrations based on soil types and agrogeological regions appeared to be more efficient than global calibrations, due to the correlation of these strata with important chromophores like soil moisture or ferrous oxide content. Specifically, these calibrations allowed increasing the prediction accuracy up to two fold. The main difference between the SVMR models and the PLSR/PSR related approaches is that the former perform better for the global data set. On the other hand, SVMR validation results are of minor quality for the soil and region related sub-models compared to the PLSR/PSR models. The analysis of field-scale SOC maps revealed strong spatial patterns of SOC related to topographic and management variables, which confirm the importance of both inter- and intra-field variability in the assessment of SOC contents at larger scale.