INTRODUCTION

The recently presented Dexter et al. (2008) threshold (ratio of clay to organic carbon (OC) of 10 kg/kg-1) is a good indicator for soil functional properties. However, the conventional analysis of OC and clay are costly and time consuming, thus an alternative method to quantify OC, clay or clay/OC ratio directly would be valuable. Visible near infrared spectroscopy (vis-NIRS) is a cost-effective method for soil analysis and was tested here for the prediction of clay/OC ratio. Soil samples from two agricultural fields in Denmark (N=115) were analyzed. Partial Least Squares regression (full cross-validation) was performed on 80% randomly selected samples to correlate soil spectra with OC, clay and clay/OC. The robustness of calibration models was tested on the remaining 20% of the samples. The soil from the two study sites vary greatly presenting clay/OC ratio between 1.20 and 10.43. Successful calibration results for OC, clay and clay/OC ratio were generated. The OC content was predicted with a RMSEP of 0.23%, $R^2$ of 0.96, whereas the prediction of clay resulted in RMSEP=0.94%, and $R^2=0.94$. The most successful predictive ability reported was of the clay/OC ratio (RMSEP=0.42, and $R^2=0.97$) with the most important absorption bands related to both clay minerals (1421, 1910 and 2206 nm – OH bonds and 429, 720 nm – Fe oxides) and organic carbon (1730, 2160 nm and 2310 nm). The results of this study show that vis-NIRS can provide very successful and direct determination of Dexter index on a field scale through its correlation to both OC and clay.

KEYWORDS: NIRS, soil quality, clay/organic carbon ratio
This method ensures a full coverage of the range of each variable by maximally stratifying the marginal distribution. It can represent the complicated nature of a landscape variation well. CLHs sampling was based on the electrical conductivity (EC) data available for this field and terrain attributes. In total 50 samples were collected at this site (Fig. 1).

![Figure 1. Location of the study sites.](image)

Collected soil samples analyzed with the conventional laboratory methods for soil texture and organic carbon (OC). Soil texture was determined by a combination of wet-sieving and hydrometer methods. Soil organic carbon was determined on a FLASH 2000 organic elemental analyzer coupled to a thermal conductivity detector (Thermo Fisher Scientific, Walthman, MA, USA).

Spectral measurements were conducted on air dried and 2 mm sieved soils using vis-NIR (400-2500 nm) spectrometer DS2500 (Foss, Hillerød, Denmark). Approximately 40 g of soil were placed in a sample holder which rotated seven times during the analysis. At each position four spectra were collected and averaged into one representative spectrum per sample.

Partial Least Squares regression (full cross-validation) was performed on 80% randomly selected samples to correlate soil spectra with OC, clay and clay/OC. The precision and robustness of calibration models was tested on the remaining 20% of the samples and evaluated using: root mean square error of prediction (RMSEP); $R^2$; and a ratio of performance to inter-quartile range (RPIQ). Analysis of regression coefficients was also performed.

**RESULTS AND DISCUSSION**

The soil from the two study sites vary from very sandy (90% sand) to clayey (24% clay) and from lower (1.5% OC) to high in OC content (>6%), giving clay/OC ratio between 1.20 and 10.43 (Table 1).
Successful calibration and validation results for OC, clay and clay/OC ratio were generated (Table 2 and Fig. 2). The prediction of clay resulted in RMSEP=0.9%, R²=0.94, and a high RPIQ (7). The highest values of the regression coefficient in the clay model were located at 541 and 640 nm (Fe oxides) and at 1412, 1910 and 2208 nm (OH bond) (Fig. 2).

The OC content was predicted with a RMSEP of 0.2%, R² of 0.96 and RPIQ of 5. The important wavebands were related to soil organic matter (780, 1727, 2311 and 2330 nm), Fe oxides (442, 490, 560 nm) and OH bonds (1908 and 2208 nm) (Fig. 2). The most successful predictive ability reported was interestingly of the clay/OC ratio (RMSEP=0.4, R²=0.97, RPIQ=11). The most important absorption bands were related to both clay minerals (1421, 1910 and 2206 nm – OH bonds and 429, 720 nm – Fe oxides) and organic carbon (1730, 2160 nm and 2310 nm) (Fig. 2).

Where: cal: calibration data set; val: validation data set; OC: organic carbon; RMSECV: root mean square error of calibration; RMSEP: root mean square of prediction; RPIQ: Q1-Q3/RMSEP; LV’s: number of latent variables

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Figure 2. Regression coefficients from clay, OC and clay/OC ratio PLSR models.

CONCLUSION

The results of this study show that vis-NIRS can provide very successful and direct determination of clay/OC ratio on a field scale through its correlation to both OC and clay. Further studies across different soil types will be conducted.

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References