SOC3D: three dimensional soil organic carbon mapping using VNIR reflectance spectrometry

L. Ramirez-Lopez¹*, K. Knauer², B. van Wesemael¹, M. Schlerf², A. Stevens¹, T. Udelhoven² and L. Hoffmann²

¹Georges Lemaître Centre for Earth and Climate Research
Earth and Life Institute
Université catholique de Louvain

²Environment and Agro-biotechnologies (EVA)
Centre de Recherche Public – Gabriel Lippmann
Objective

Develop a methodology to represent the variation in SOC of croplands including its vertical distribution
SOC3D: three dimensional soil organic carbon monitoring using VNIR reflectance spectrometry

Proposed Methodology

Spectral Calibration

- Imaging Spectroscopy spectral data cube
- SOC calibration dataset
- Field VIS-NIR spectral profiler data

Multivariate models (PLS, SVM)

Soil Inference System

- Surface SOC maps (plough layer)
- Soil variables (texture class, ...)
- Management variables (C inputs, ...)
- Geomorphic variables (slope, curvature, ...)

SOC depth distribution (0-100 cm)

explained variable, point data

PTF

Bulk density

3D SOC stocks predictions

prediction

explained variables, continuous data
**APEX sensor** (Airborne Prism EXperiment)

Hyperspectral data in 288 channels with a 2.8 m spatial resolution

Overflight 16.09.2011, 7 flight lines, total number of 39 tiles

Weather conditions: some high altitude cirrus

Atmospheric & geometric correction by the VITO + re-analysis by Tel-Aviv University with ACORN
1. Introduction  
2. APEX data  
3. Methodology  
4. Results  
5. Concluding remarks
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Analysis of the spectral differences between bare fields in overlapping areas
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Basic strategy

APEX DATA +
(Geomorphic features)

2D

Geomorphic features

3D

Depth (m)

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**Calibration sampling:** Select a set of samples to cover properly both the VNIR and geomorphic variability.

**Validation sampling:** Select a set of independent samples to validate both the SOC models and SOC maps derived from the models.
Strategy for SOC analysis of the \textbf{calibration} samples

40 \% Conventional SOC analysis (C/N analyzer) and VNIR spectra
60 \% Only VNIR spectra

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Problem

Poor direct (univariate) correlation between each band and SOC concentration

Approach

Data mining approach to learn and exploit the multivariate relationship between SOC and VNIR features

\[ \text{SOC} = f(\text{VNIR}^*, \ldots) \]

*VNIR = \{R_{350nm}, \ldots, R_{2500nm}\}
Modeling depth distribution of soil carbon concentration...

Depth functions were used to generate SOC information (of all the profiles) at 0.01 m vertical resolution.
Spatial modeling of depth functions of soil organic carbon ...

\[
\text{SOC}_d = f\left(\text{Geomorphologic f, ...} \right) + \epsilon_0 + \epsilon
\]

Part of the error which can be modeled by using the geographical information (x and y coordinates)
Agro-pedological regions

- Oesling area
- Redange-Diekirch area
- Central area
- Minette area

SOC, %

| SOC, % | 0.88 | 4.58 |

Legend

- High: 2.37877
- Low: 1.97928

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Prediction of surface SOC

No differences between terrain and spectra + terrain

Spectra

RMSE = 0.69%
$R^2=0.30$

Terrain

RMSE = 0.55%
$R^2=0.58$

Spectra + Terrain

RMSE = 0.55%
$R^2=0.58$
Prediction of sub-surface SOC using Random Forests – kriging

RMSE = 0.37%
$R^2=0.79$
Spatial prediction of SOC

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From **SOC concentration** (g C kg\(^{-1}\) soil) to

**SOC stock** (kg m\(^{-2}\)) = **SOC** (kg kg\(^{-1}\)) × **Soil density** (kg m\(^{-3}\)) × **thickness** (m)
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Despite croplands of the northern region of Luxembourg present the highest SOC concentrations at the topsoil layer, the SOC stocks are low due fact that these soils are thin and very gravelly.

Surface data was relatively well predicted using terrain attributes, spectra did not help that much

We used completely independent validation samples (random)!

We might have been over-optimistic in the design of the experiment by selecting a too large study area and flying under not perfect weather conditions, leading to inconsistent and noisy spectral data

Vertical distribution could have been better predicted if we would have constrained predictions with better surface data....