IMPROVING SPECTRAL TECHNIQUES TO DETERMINE SOIL ORGANIC CARBON BY ACCOUNTING FOR SOIL MOISTURE EFFECTS

Marco Nocita
Antoine Stevens
Bas van Wesemael

Presentation outline

- Background
  - Predicting soil organic carbon (SOC) using soil spectroscopy
  - Soil moisture and spectral reflectance
  - Research objectives
- Methodology
  - Study area
  - Soil analyses
  - Spectral measurements and data pre-processing
  - Soil moisture and SOC prediction models
- Results and discussion
  - Soil moisture effect on spectral reflectance
  - SOC predictions per moisture levels
  - Soil moisture prediction model
  - SOC modeling based on moisture content prediction
- Conclusions and follow-up

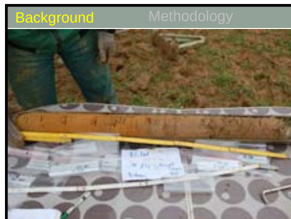
Soil spectroscopy to predict SOC

Soil attribute	Spectral region	Spectral range (nm)	Multivariate method[a]	n_{calib} | n_{valid}[b]	RMSE	R^2	Authors
OC; %	NIR	1100–2500	MLR (1744, 1870, 2052)	72|48		0.93	Dalal and Henry (1986)
OC; %	NIR	1100–2500	RBFN	140|60	0.32	0.96	Fidêncio et al. (2002)
OC; %	NIR	700–2500	PCR	121|40		0.68	Islam et al. (2003)
OC; g/kg	NIR	1100–2498	PLSR (18)	177|60		0.82	McCarty et al. (2002)
OC; mg/kg	NIR	1100–2300	PLSR (8)	180 x-val		0.94	Reeves and McCarty (2001)
OC (acidified soil); g/kg	NIR	1100–2498	PLSR (17)	177|60		0.80	McCarty et al. (2002)
OC; g/kg	VIS–NIR	400–2498	PLSR (6)	76|32	0.62	0.89	Chang and Laird (2002)
OC; g/kg	VIS–NIR	350–2500	MARS	449|225	0.31	0.80	Shepherd and Walsh (2002)
OC; dag/kg	VIS–NIR	350–1050	PLSR (5)	43|25	0.36		Viscarra Rossel et al. (2003)
OC; %	UV–VIS–NIR	250–2500	PCR	121|40		0.76	Islam et al. (2003)

Viscarra Rossel et al. (2006)

accurate in the laboratory

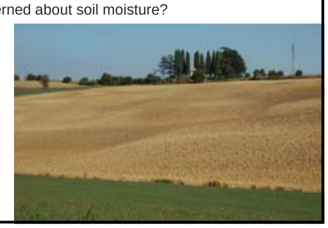
less precise for field and airborne applications

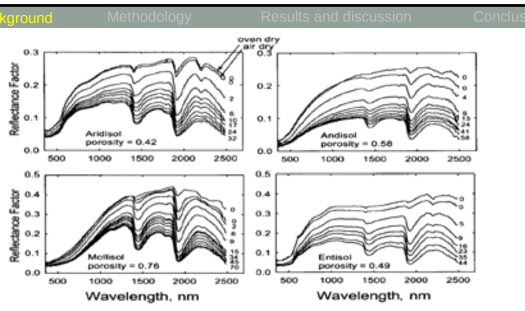


Field spectroscopy

Why should we be concerned about soil moisture?

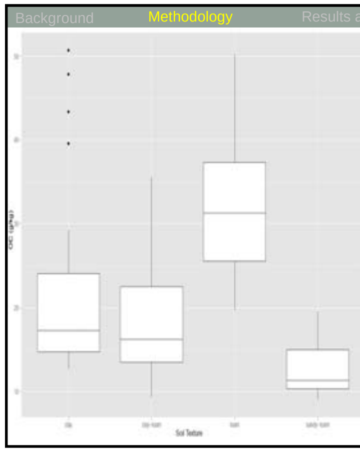
Hyperspectral remote sensing



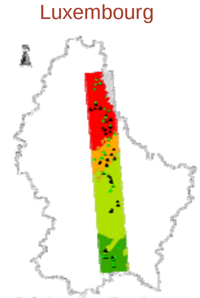


Lobell et Asner, 2002

Questions:
Can we quantify the effect of soil moisture on SOC predictions based on VNIR spectroscopy?
Can we build a tool to predict SOC for soils with no a-priori data on their moisture content?



Luxembourg



111 samples (0-5 cm), 37 fields
4 soil textures
SOC content range: 9:50 g C kg^{-1}
soil types: Cambisols, Luvisols, Arenosols, and Calcisols

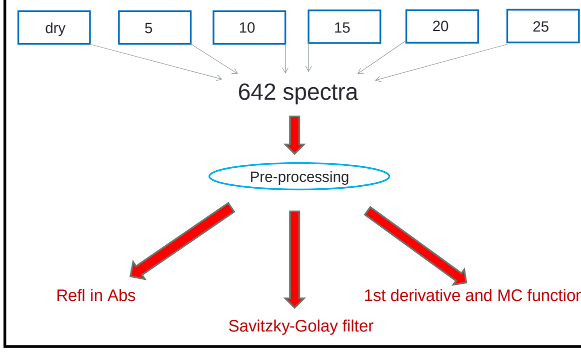
Soil analyses

- Soil samples: air dried, smashed and sieved (<2mm)
- SOC: dry-combustion with a VARIOMAX C/N analyser
- Moisture content: oven-dried at 105 ^{0}C during 24 h

…and spectral measurements

- ASD Fieldspec-Pro radiometer (350-2500 nm)
- Contact probe specific for soils (2-cm-diameter)
- Samples artificially wetted until reaching 5, 10,15, 20, and 25% MC

Data pre-processing



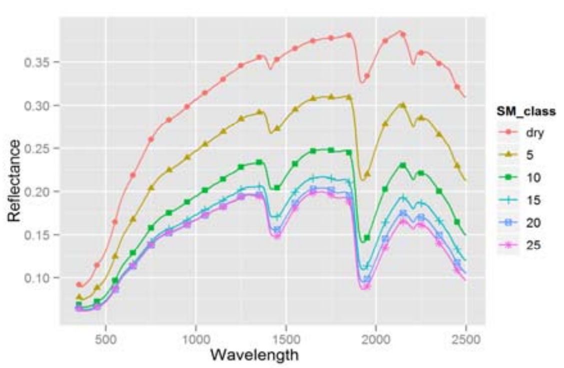
Soil moisture and SOC prediction models

- Dataset was divided in training (2/3) and test set (1/3)
- SOC prediction: Partial least square regression (PLSR)
  - leave one-out cross-validation of the training set (CV) to choose the latent factors (max=10)
  - Independent validation of the test set
- Moisture content: Normalized soil moisture index (NMSI) (Haubrock et al., 2008)
  - NSMI= [R(1800) – R(2119)] / [R(1800) + R(2119)]$^{-1}$
  - Linear regression between GSM and NSMI

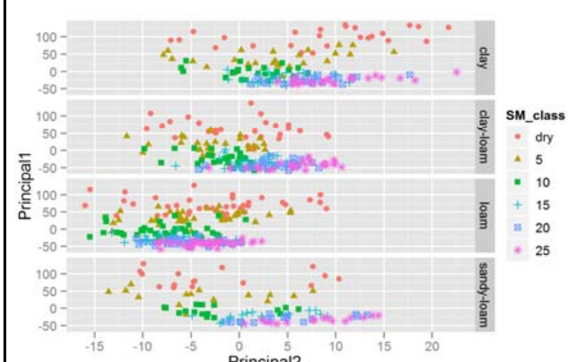
SOC content (g C kg-1)

Stats	Clay	Clay-Loam	Loam	Sandy-Loam	Global
Min	12,73	9,39	19,73	9,05	9,05
1st quartile	14,29	13,49	25,60	10,32	14,50
Median	16,43	16,26	31,24	11,35	18,05
Mean	17,43	18,31	31,59	12,60	21,97
3rd Quartile	17,68	22,51	37,29	14,99	27,82
Max	29,21	35,57	50,22	19,51	50,22

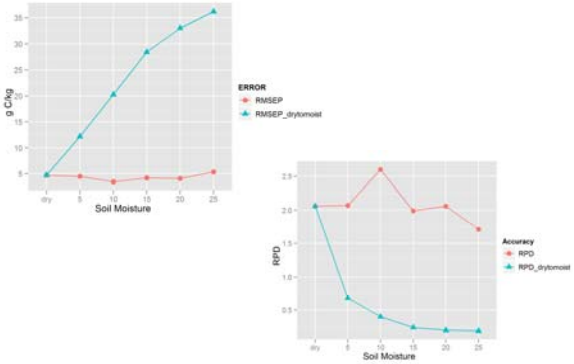
Effect of increasing soil moisture on mean spectral reflectance

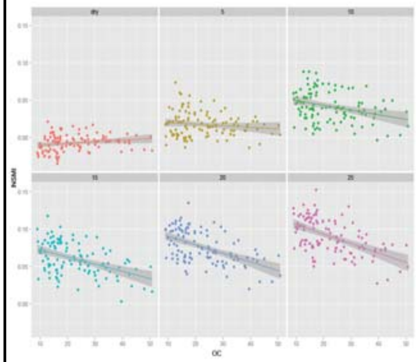


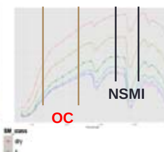
Principal components scores by soil type



SOC predictions by moisture content levels

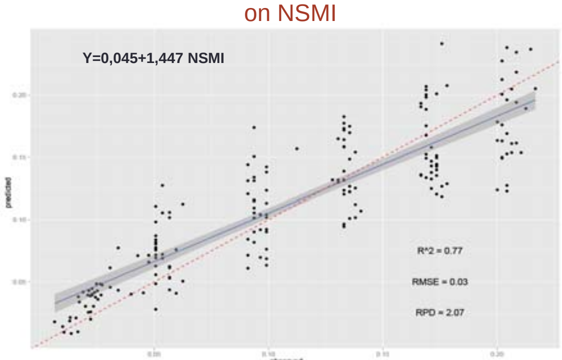




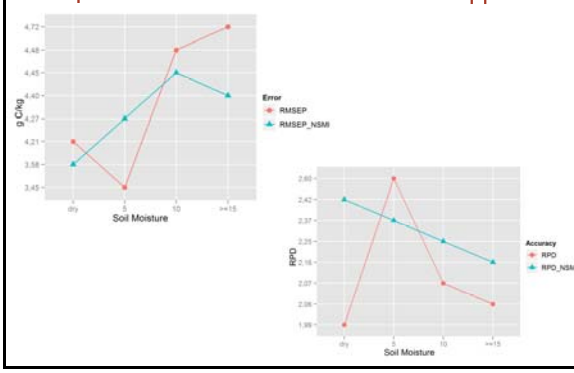


r (NSMI~OC)
dry: 0.19
5%: -0.13
10%: -0.32
15%: - 0.46
20%: -0.54
25%: -0.54

Moisture content predicted vs. observed based on NSMI



SOC predicted vs. observed after NSMI application



Belgium Loam-Belt

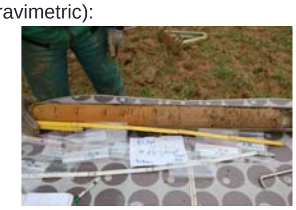
- 30 soil cores (1m depth)
- 110 soil samples (10 cm)
- 330 soil spectra (3 times at different soil moisture)
- SOC range: 0.3 to 14 g C kg^{-1}
- Moisture content ranges (gravimetric):
  - 1st scan: ~15 : 35 %
  - 2nd scan: ~ 2 : 17%
  - 3rd scan: ~ 1 : 6%

MC predictions: 10% of soil samples (random selection)

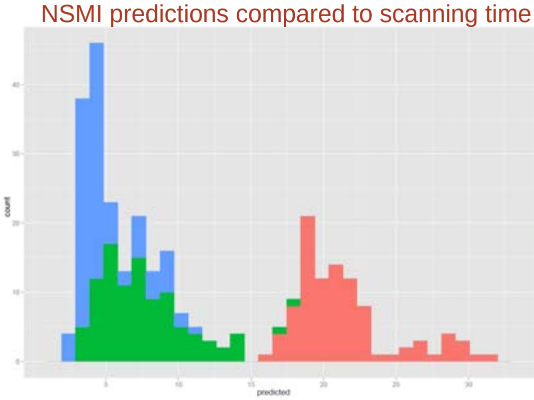
First application: profiling in a field (central Belgium)

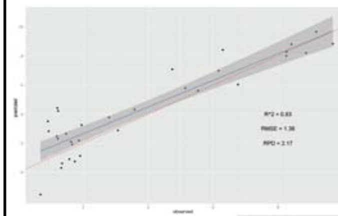
- 30 soil cores (1m depth)
- 110 soil samples (10 cm)
- 330 soil spectra (3 times at different soil moisture)
- SOC range: 0.3 to 14 g C kg^{-1}
- Moisture content ranges (gravimetric):
  - 1st scan: ~15 : 35 %
  - 2nd scan: ~ 2 : 17%
  - 3rd scan: ~ 1 : 6%
  - MC predictions:

    10% of soil samples

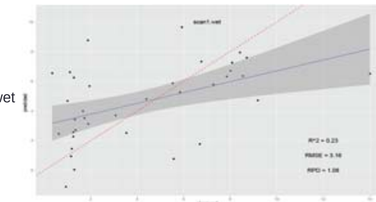


NSMI predictions compared to scanning time





NSMI-wet



scan1-wet

Soil moisture is an important factor in soil spectroscopy

- Strong influence on spectral reflectance from dry to 15% moisture content
- Accuracy decrease when dry model is applied to moist soils
- Constant error for SOC predictions at different moisture levels
- NSMI easy and fast tool to develop moisture content classified predictions
- No accuracy decrease of SOC prediction after NSMI classification

Follow-up

Test of NSMI application under uncontrolled soil moisture conditions

1. Other profiling soil spectroscopy
2. Hyperspectral remote sensing

UCL Université catholique de Louvain

DIGISOIL

Thanks for your attention

marco.nocita@uclouvain.be