Using Spectral Sensors to Determine Soil Organic Carbon for Monitoring

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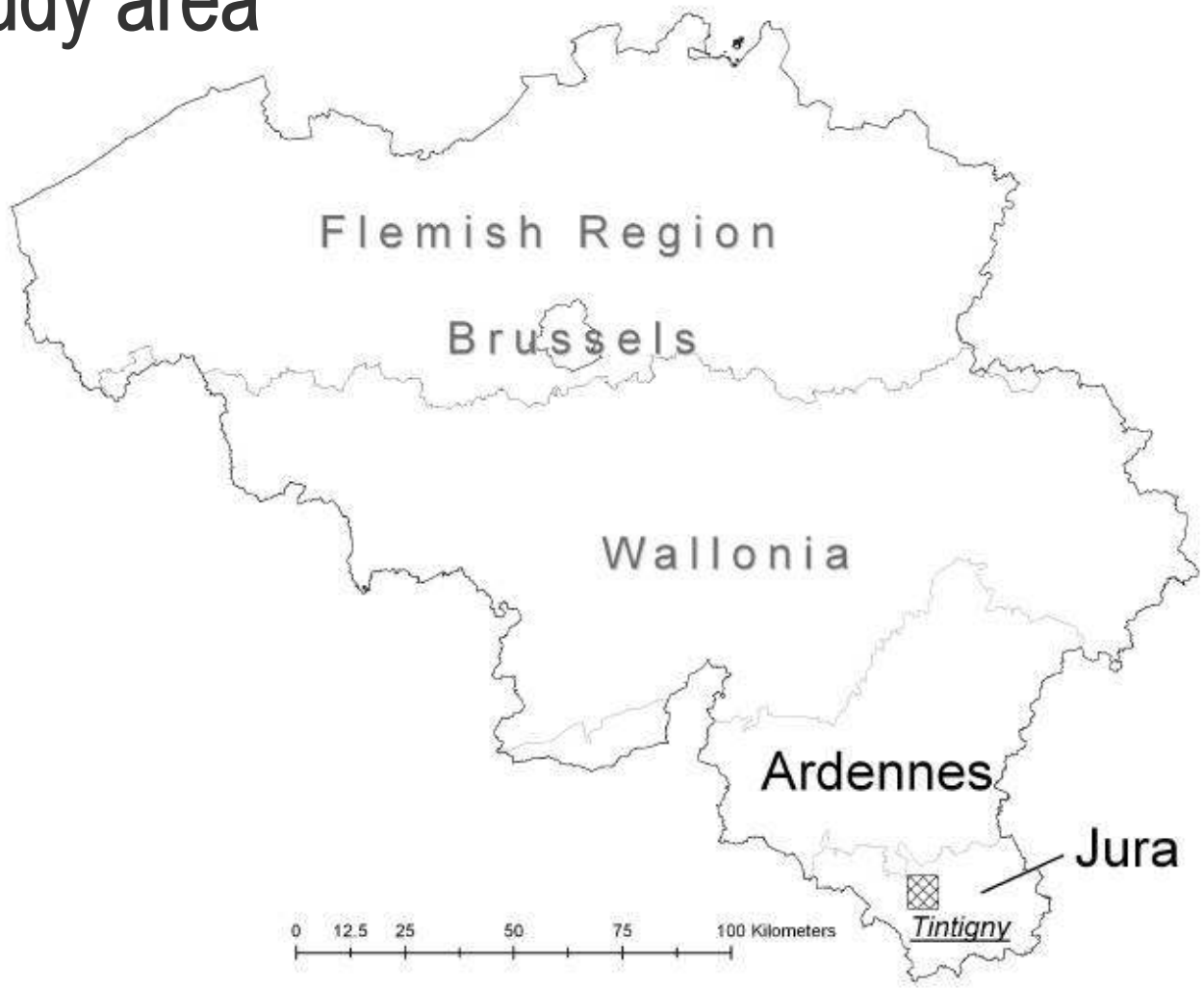
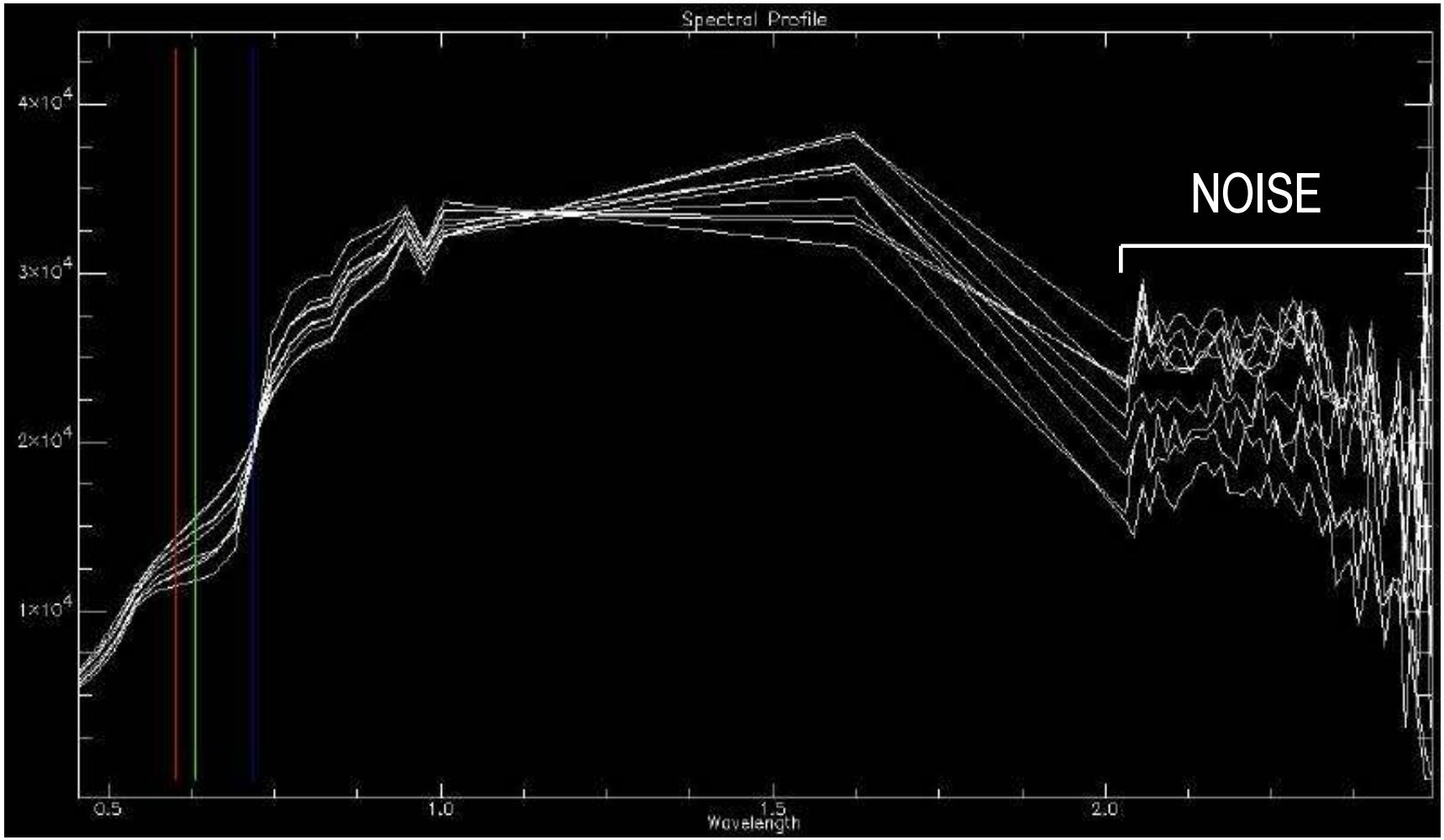
- Introduction
  - Why Soil Organic Carbon (SOC) Monitoring ?
    - To study carbon fluxes between soils and the atmosphere
    - As a measure of soil quality and fertility in croplands
  - Why using spectroscopic techniques ?
    - High spatial variability of SOC → high sampling density required
    - Traditional sampling techniques are time consuming
    - High potential for rapid in situ measurements and SOC mapping

- Introduction
  - Instruments available:
    - Laboratory sensors
    - Field Portable sensors
    - Airborne or spaceborne sensors
  - Aim of the study
    - Compare the predictive ability of these three types of sensors for SOC determination
    - Evaluate the spatio-temporal stability of calibrations obtained by PLSR
    - Evaluate the potentialities for SOC monitoring

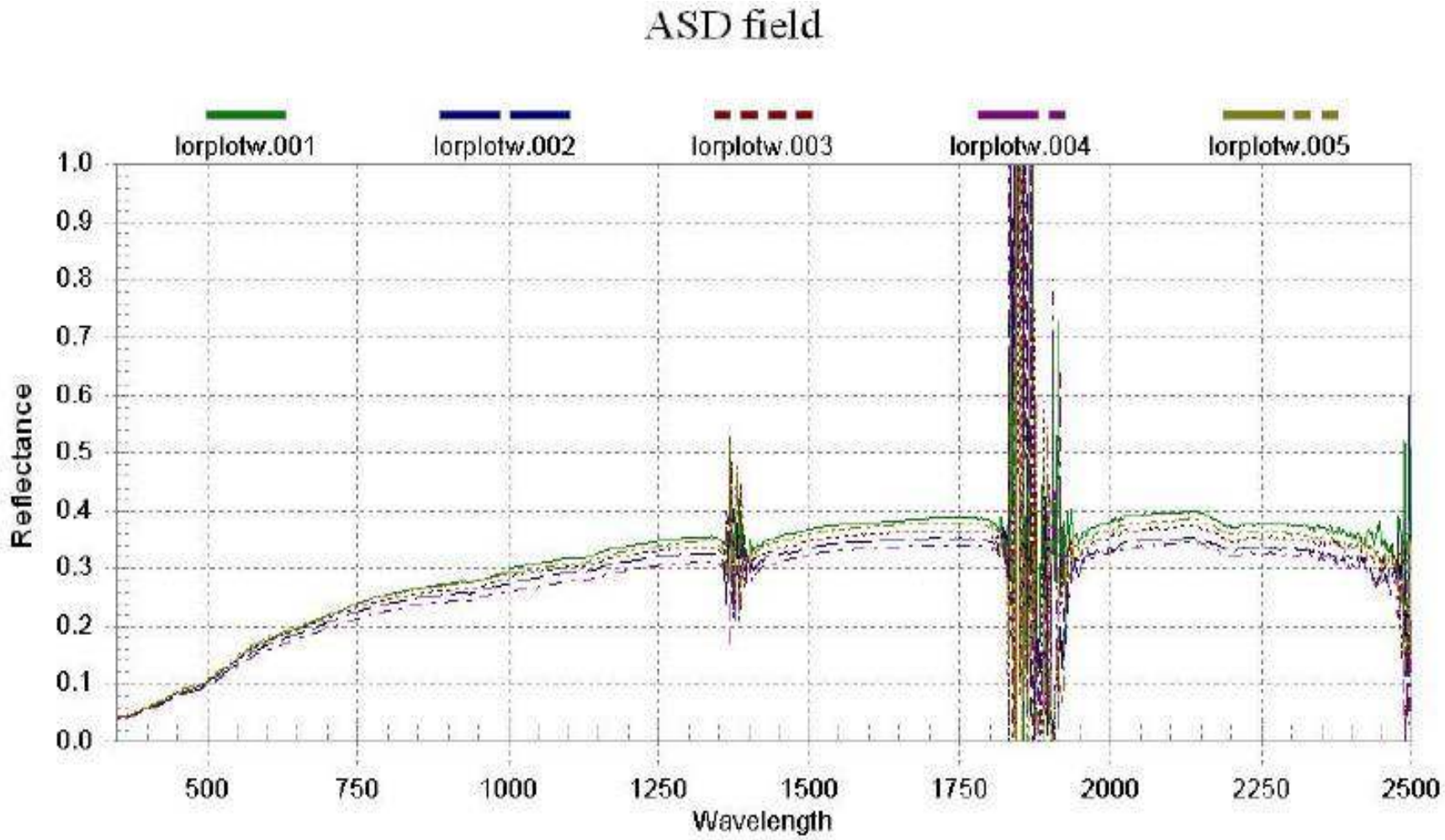
- Introduction
- Methodology
- Study area



- Flight campaign:
  - During spring = non-optimal time window, bare soils are required
  - More than 110 experimental plots (7.5*7.5 m) were cleared in maize fields


Spectral Profile
4x10^4
3x10^4
2x10^4
1x10^4
NOISE
0.5
1.0
1.5
2.0
Wavelength

- Flight campaign:
  - During spring = non-optimal time window, bare soils are required
  - More than 110 experimental plots (7.5*7.5 m) were cleared in maize fields
- Field measurements :
  - One bulk soil samples per plot (depth of 5 cm)
  - Plots geo-referenced by DGPS
  - ASD field spectral measurements


ASD field
lorplotw.001
lorplotw.002
lorplotw.003
lorplotw.004
lorplotw.005
Reflectance
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
500
750
1000
1250
1500
1750
2000
2250
2500
Wavelength

- Introduction
- Methodology

Laboratory analyses:

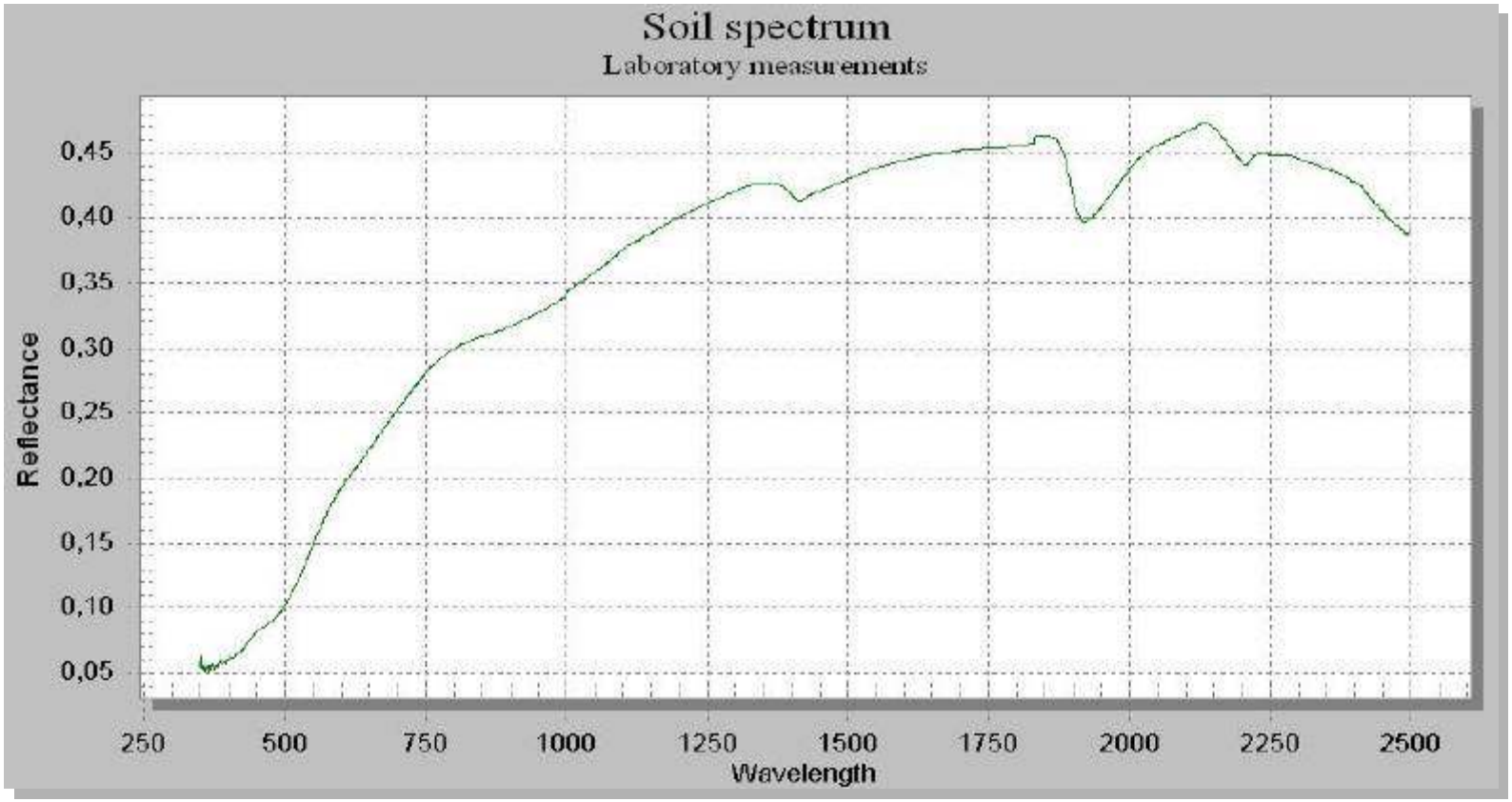
Soil Organic Carbon with Walkley-Black and moisture content

	n	Carbon content				Moisture content			
Field		Mean	SD	Min	Max	Mean	SD	Min	Max
G1	21	1.12	0.13	0.92	1.46	1.63	0.98	0.67	4.40
G2	15	1.56	0.12	1.33	1.77	0.53	0.25	0.30	1.22
P1	15	1.36	0.11	1.15	1.59	0.61	0.26	0.34	1.27
P2	15	1.66	0.23	1.30	2.21	1.74	0.65	0.87	2.83
P3	9	1.33	0.18	1.07	1.59	2.18	0.75	1.21	3.58
P4	6	0.98	0.21	0.59	1.19	2.24	0.98	0.62	3.55
P5	8	1.33	0.37	1.05	2.21	3.04	3.91	1.01	12.68
P6	9	1.56	0.21	1.33	1.98	1.97	1.08	0.55	3.89
P7	10	1.26	0.12	1.13	1.55	1.41	0.54	0.57	2.30
P8	9	1.08	0.15	0.86	1.27	1.28	0.58	0.47	2.18
TOTAL	**117**	**1.34**	**0.27**	**0.59**	**2.21**	**1.52**	**1.36**	**0.30**	**12.68**

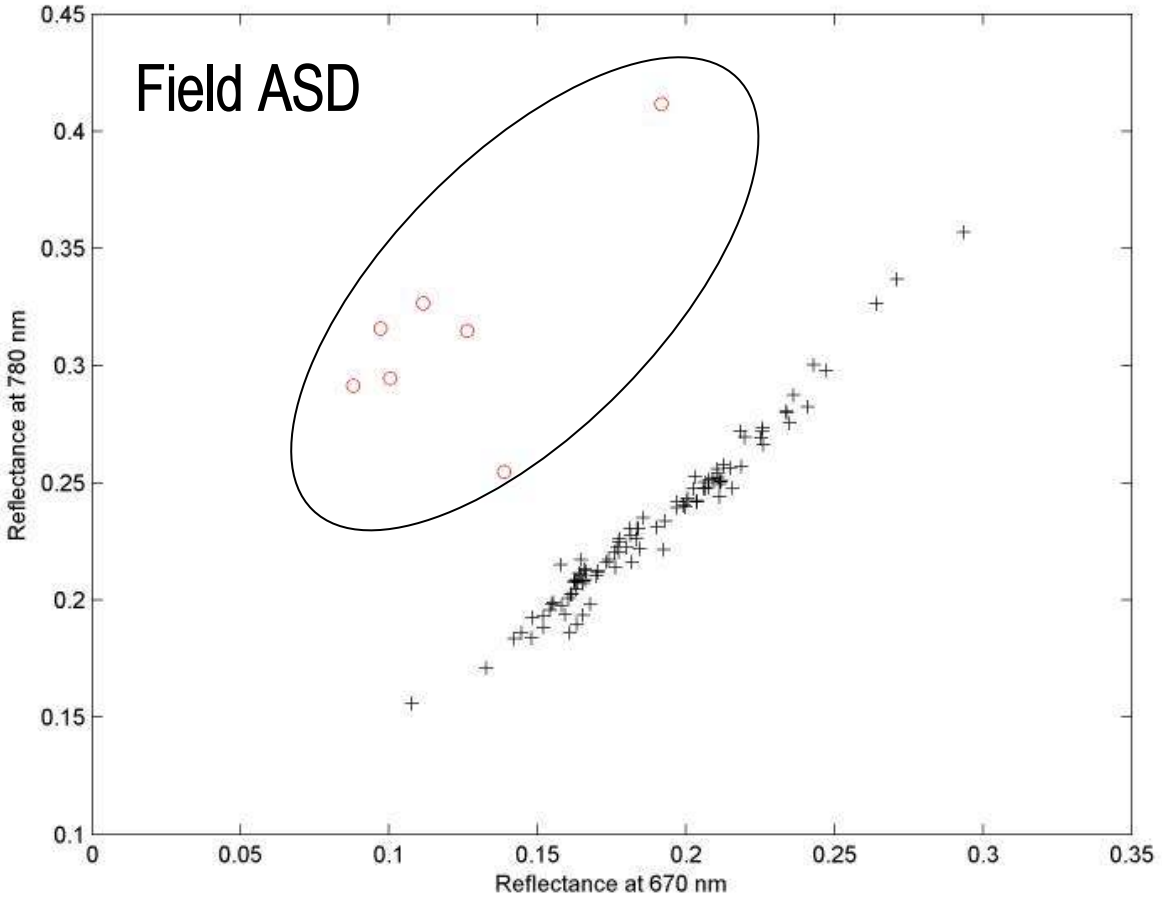
- Introduction
- Methodology

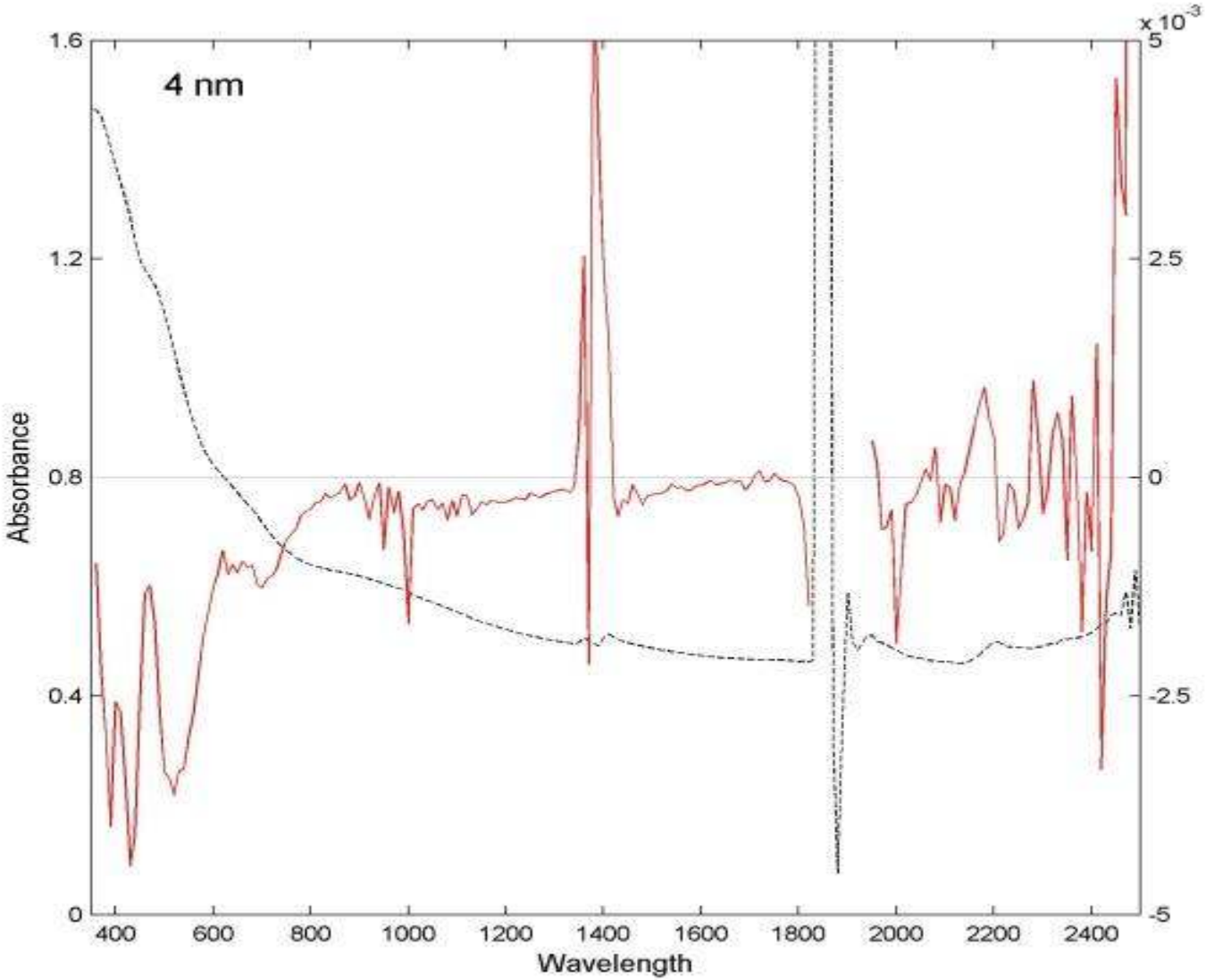
Laboratory analyses:

- Spectral measurement of sieved (2 mm) and air-dried soil samples with the ASD contact probe



- Data transformation before statistical analysis
  - Removing vegetation influence (spectra having a NDVI > 0.3)

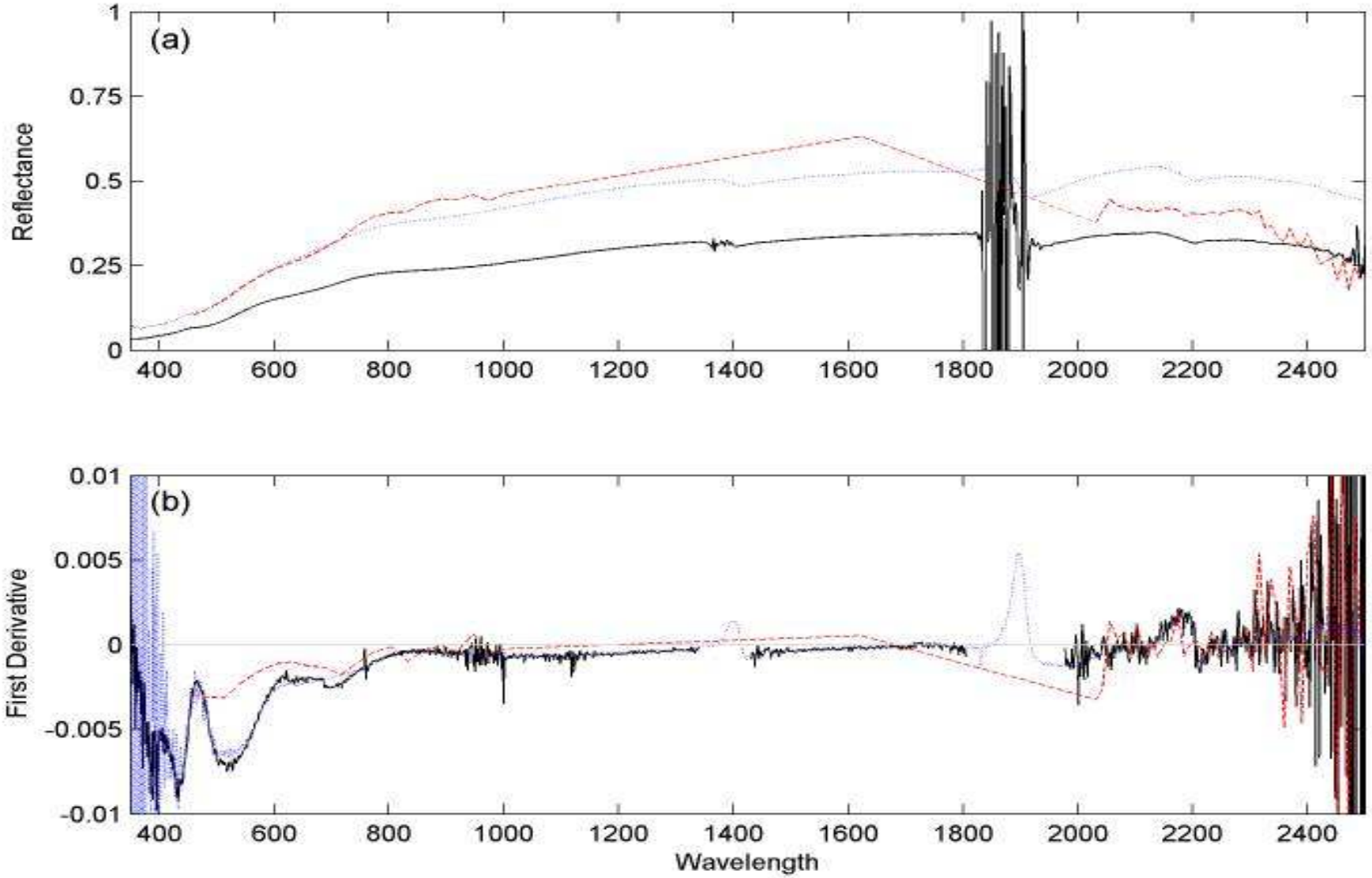



4 nm
x 10^-3
Absorbance
Wavelength
1.6
1.2
0.8
0.4
0
5
2.5
0
-2.5
-5
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400

Introduction ■ Methodology

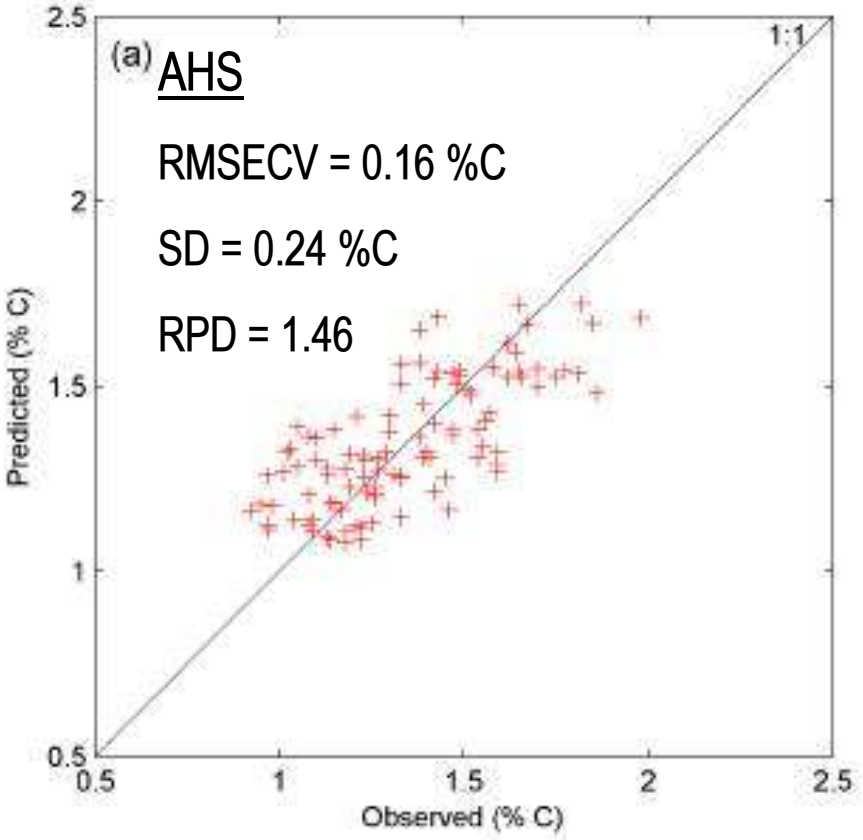
- Relate SOC and pre-treated spectra using Partial Least Square Regressions (PLSR) and an automatic outlier removal procedure
- Select the best model on the basis of their Ratio of Performance to Deviation (= RMSEP / SD)
- To test the stability of the calibrations, we joined current ASD field measurements with those of previous campaigns (CASI 2003) producing a dataset of 201 samples with varying carbon content, texture, soil surface condition and soil types

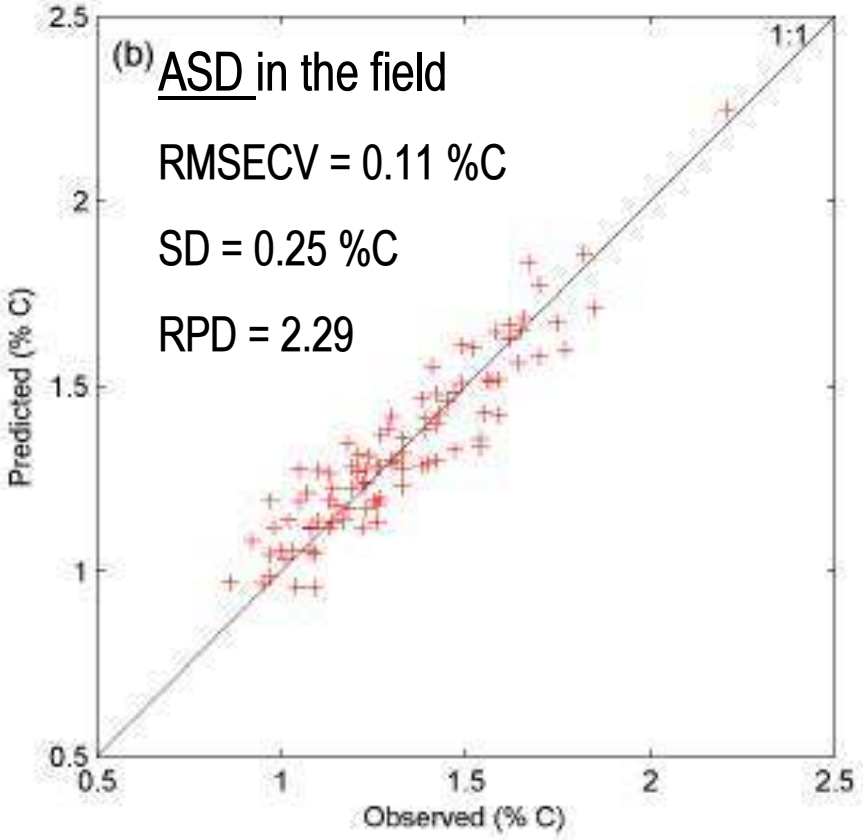
Introduction Methodology Results



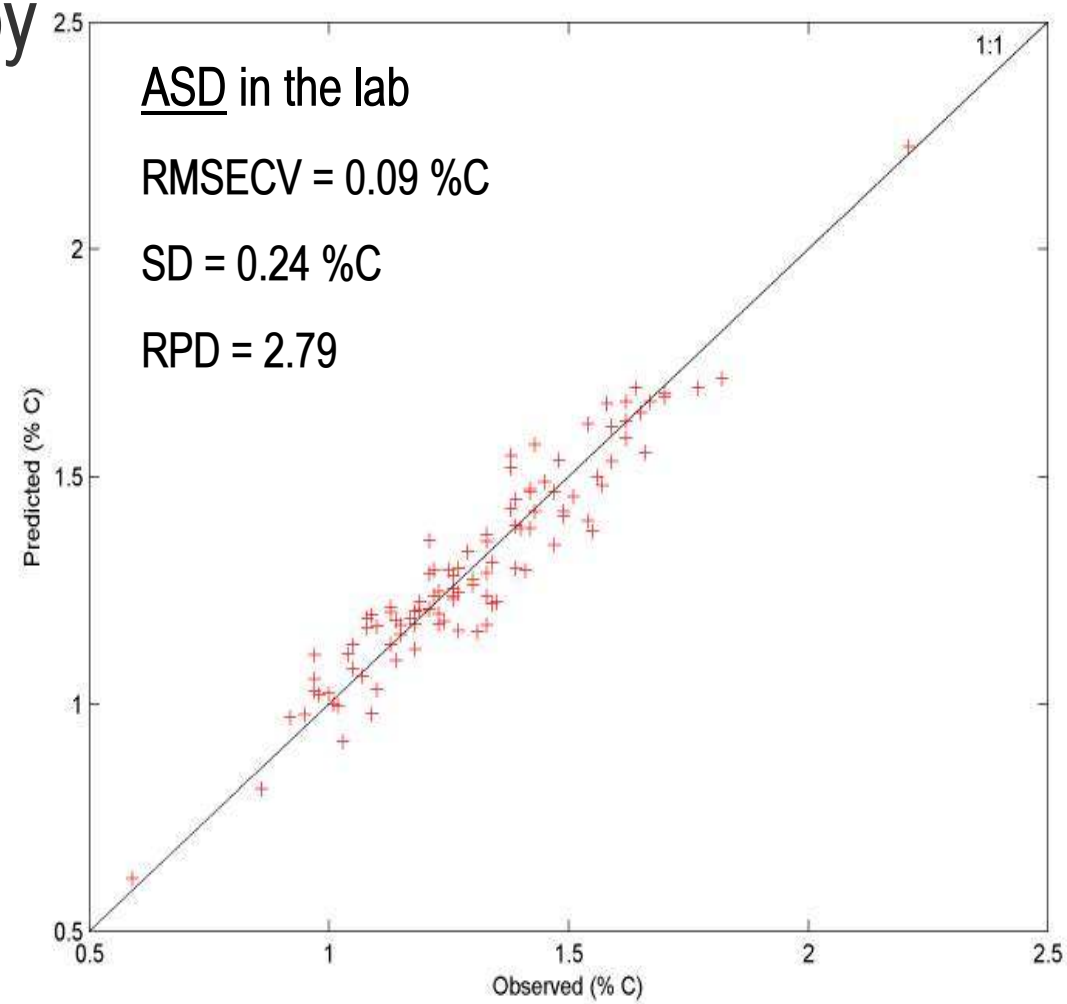
Introduction Methodology Results

Predictive ability of ground- and remote- sensing VNIR spectrosopy

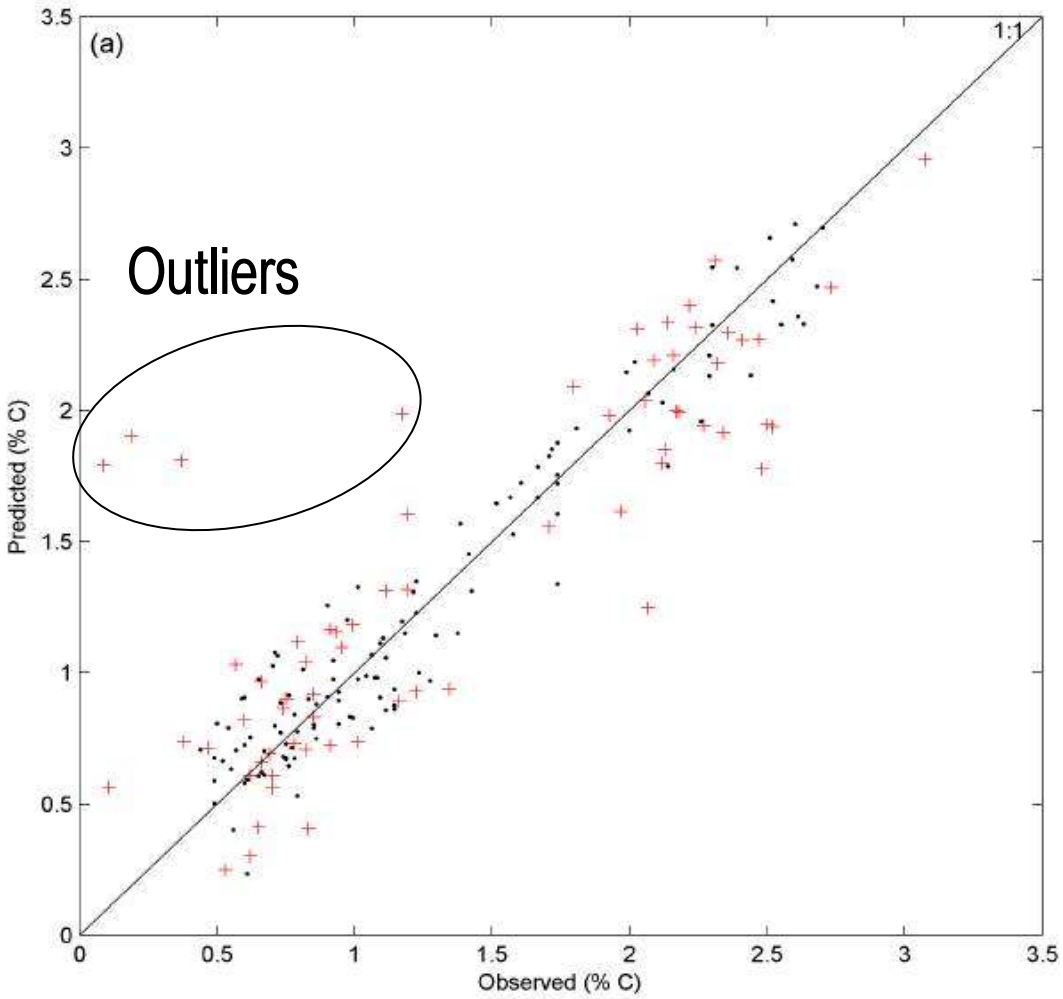




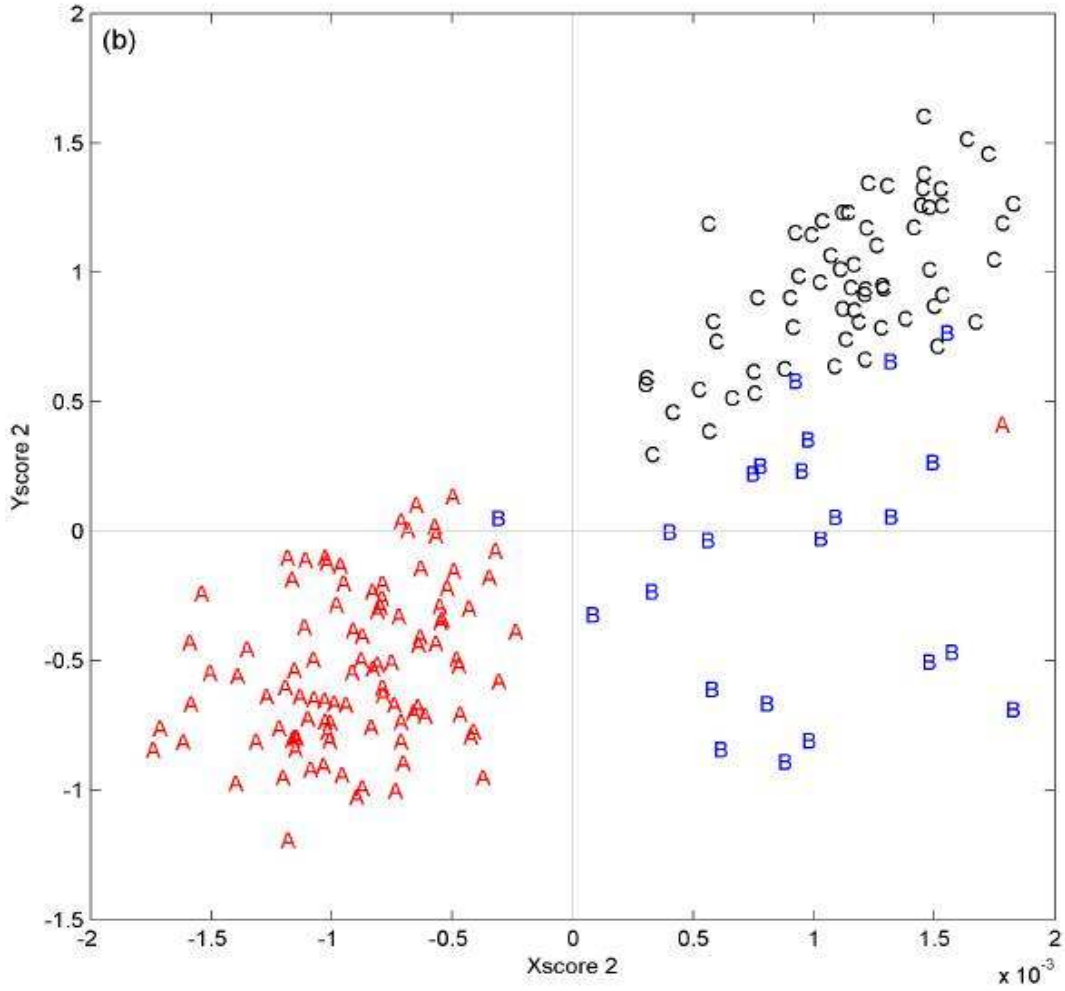
- Predictive ability of ground- and remote- sensing VNIR spectrosopy



Stability across time and space: validation



Stability across time and space: cross validation



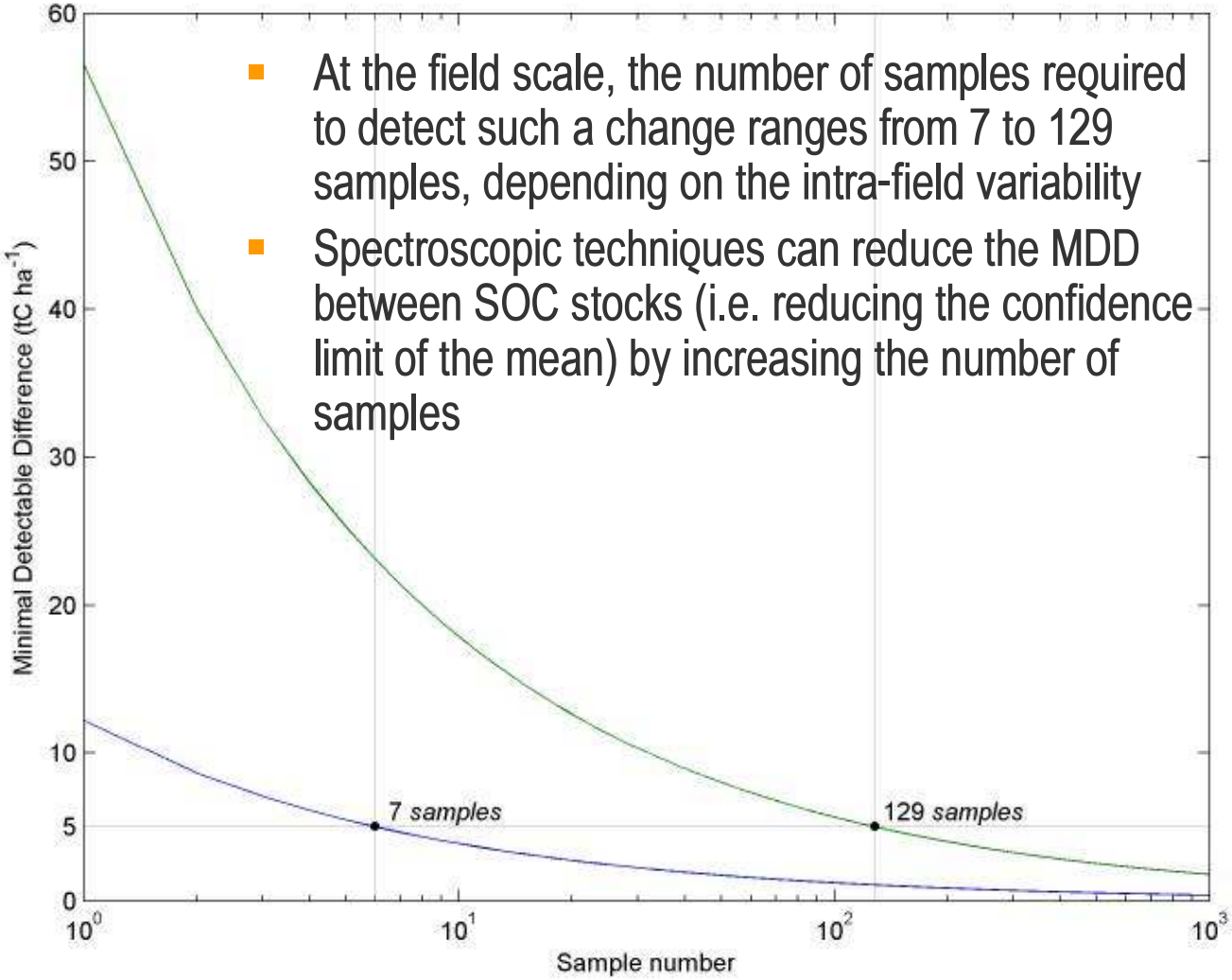
Summary of results

- There is a decrease in predictive ability from laboratory spectroscopy to remote-sensing due to :
  - Difference in sensor characteristics (number of spectral bands);
  - An increase in environment-induced variability (soil surface conditions);
  - Uncontrolled measuring conditions (light source quality, SNR)
- The ASD gives accuracies (± 0.1%C) that are similar to a routine analytical method (Walkley&Black)
- Calibrations are currently site-specific and partly fail to predict, under a proper independent validation, samples belonging to another study area

- Summary of results
  - PLSR are able to take into account a double variability :
    - in spectral shape (2 different campaigns) ;
    - in carbon content (range: 0.5-4%C)
  - Further needs:
    - More measurements !
    - Standard spectral measurement protocols in the field (surface conditions required,etc.)

- Monitoring of soil carbon
  - Evaluate potential of VNIR spectroscopy for soil monitoring
  - Minimal Detectable Difference (MDD) : How many samples are required to demonstrate a given change in SOC stocks?
    - SOC stock change after management change are <= 2tC $ha^{-1}y^{-1}$ (Freibauer et al., 2004)
    - After 3-5 year, it corresponds to 5 tC ha^{-1}

- At the field scale, the number of samples required to detect such a change ranges from 7 to 129 samples, depending on the intra-field variability
- Spectroscopic techniques can reduce the MDD between SOC stocks (i.e. reducing the confidence limit of the mean) by increasing the number of samples



Conclusion

- Accuracies achieved by the ASD are comparable to the one of a standard analytical method (Walkley-Black) and they can thus be used for monitoring studies where their speed is a valuable advantage.
- Imaging spectroscopy, appears, for the time being, not able to predict SOC with an acceptable accuracy due to its low SNR and problem to achieve true spectral information. Nevertheless, the greater potential lies in this technique and more efforts have to be put in spectrum calibration

Thank you !