Moving visNIR Measurement of Soil Properties from the Laboratory to the Field

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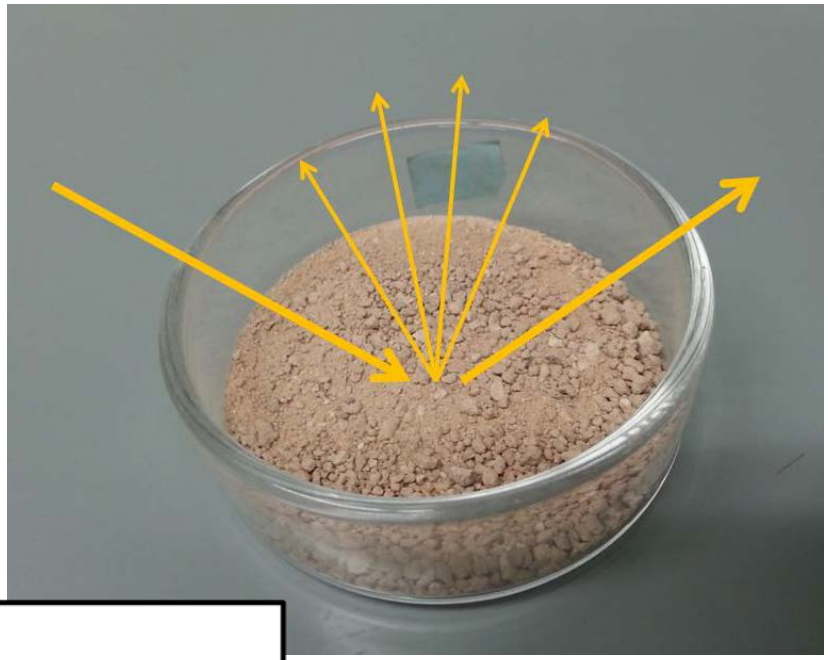
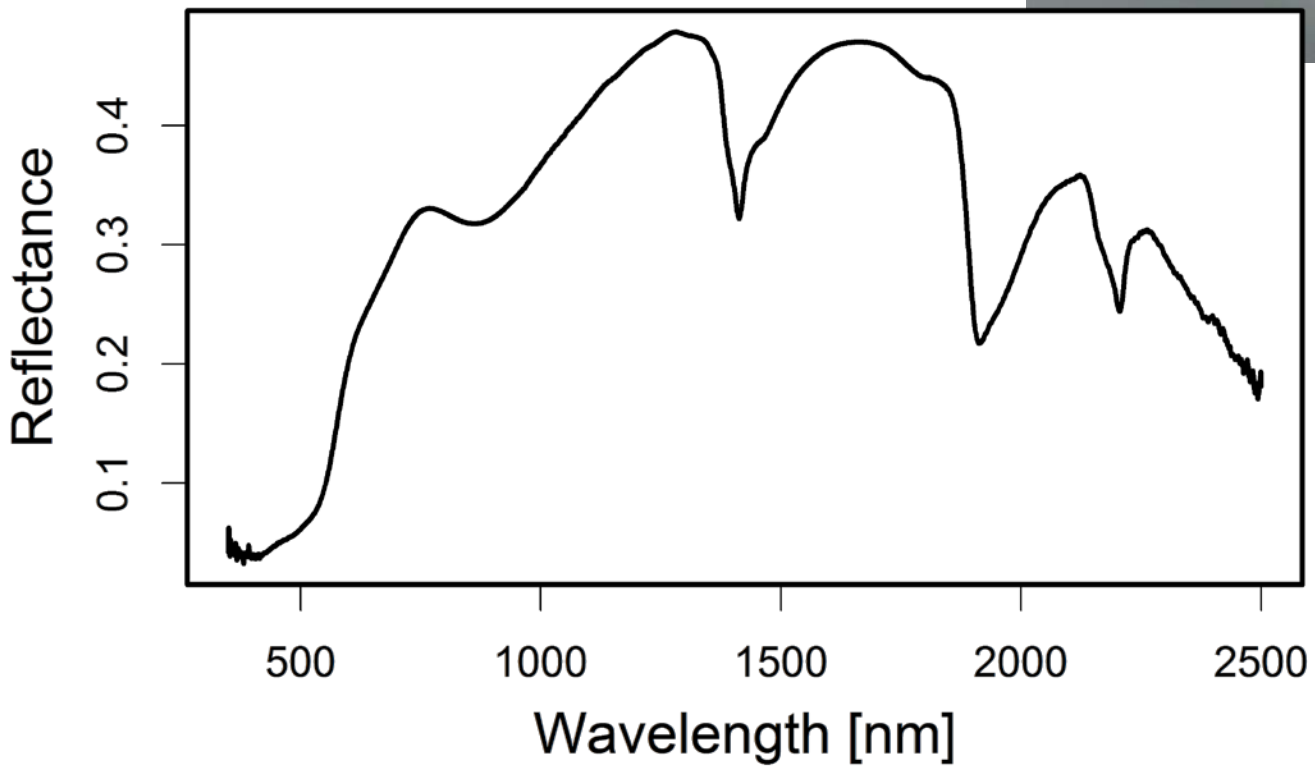
Proximal Soil Sensing

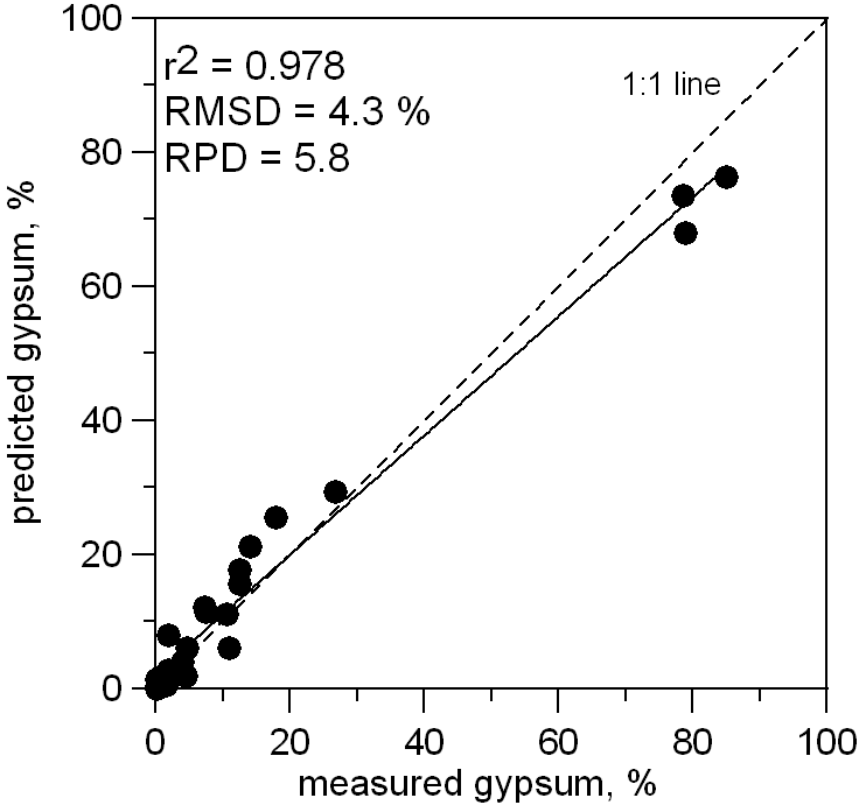
Visible Near-Infrared Spectroscopy: VisNIR



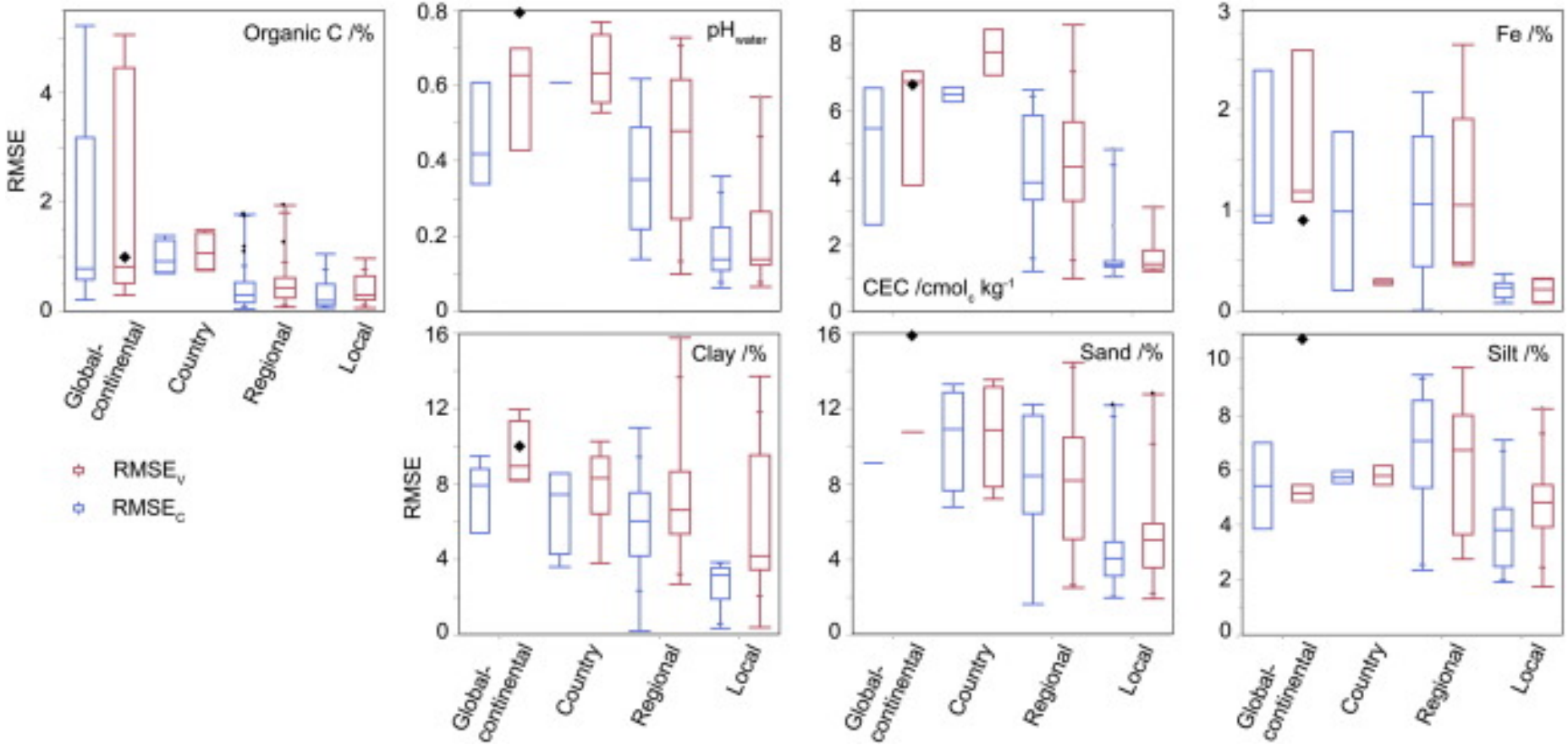


What can VisNIR Spectroscopy predict?

Clay Content (texture)
Clay Mineralogy (categorically)
Organic Carbon
Inorganic Carbon
CEC
Fe



Global Spectral Soil Library

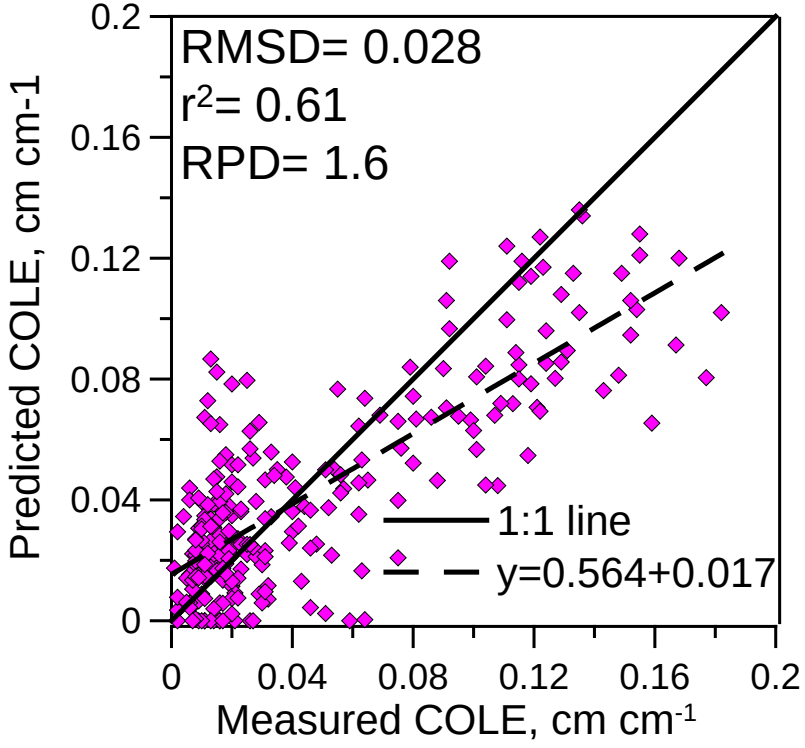


Viscarra Rossel et al., 2016 A Global Spectral Library to Characterize the World's Soils. Earth Science Reviews. Accepted.

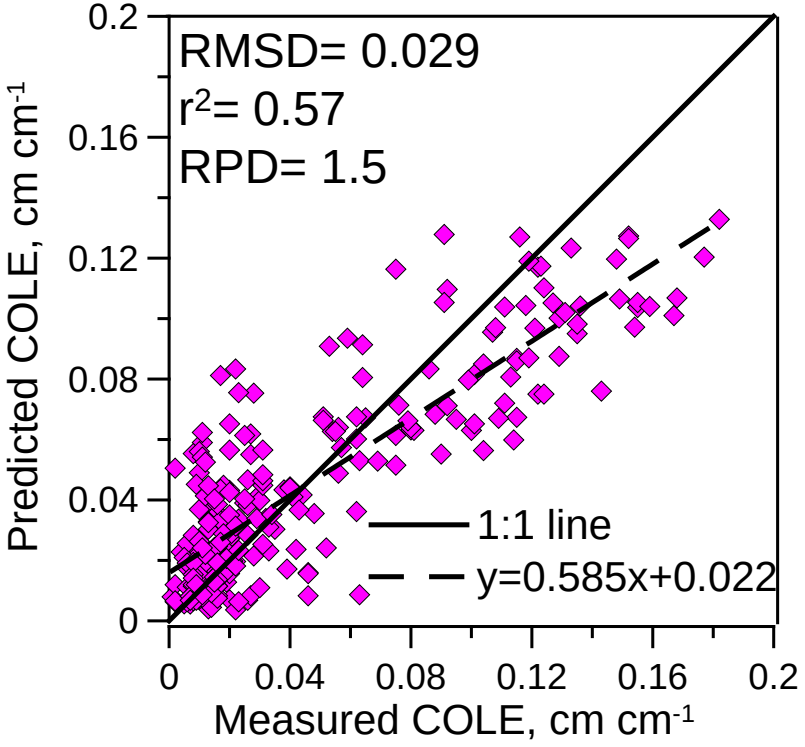
http://dx.doi.org/10.1016/j.earscirev.2016.01.012

Coefficient of Linear Extensibility

VNIR Spectroscopy

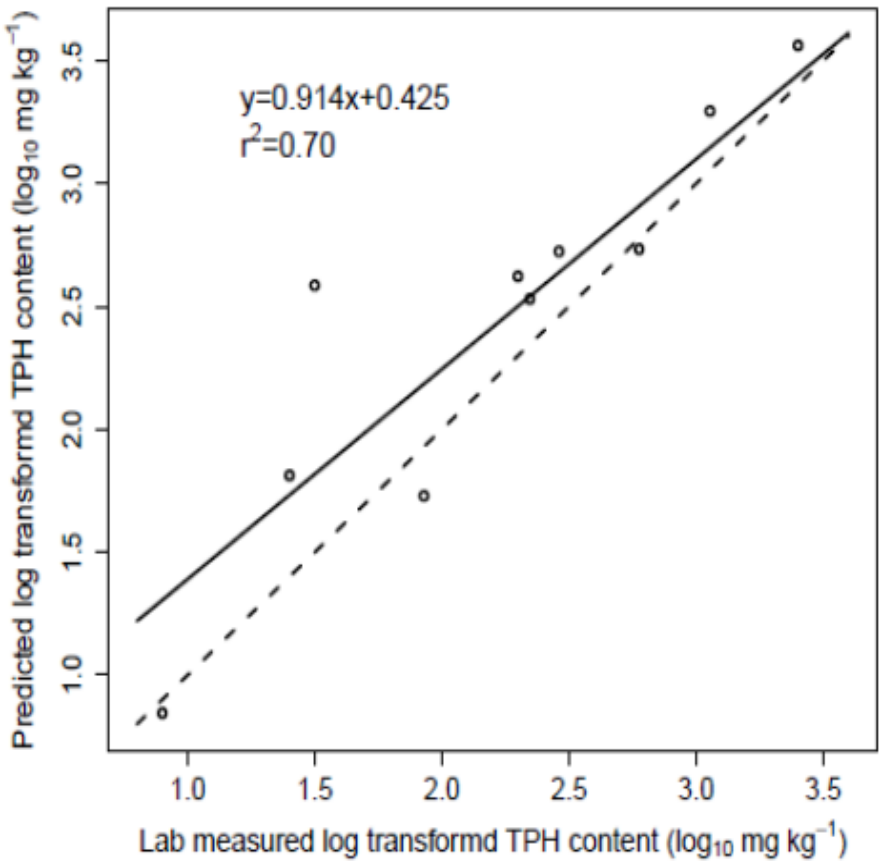


Pedotransfer



Wilke, 2008

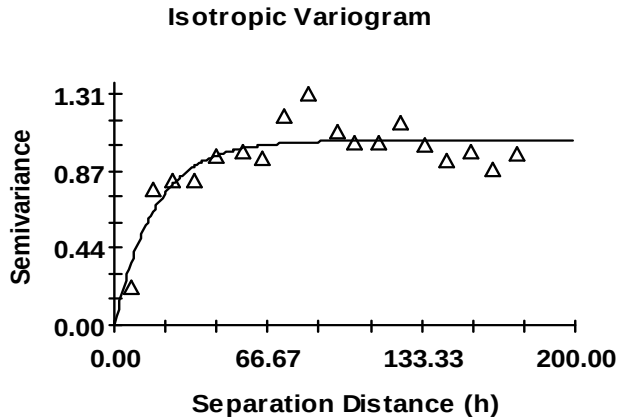
Total Petroleum Hydrocarbons



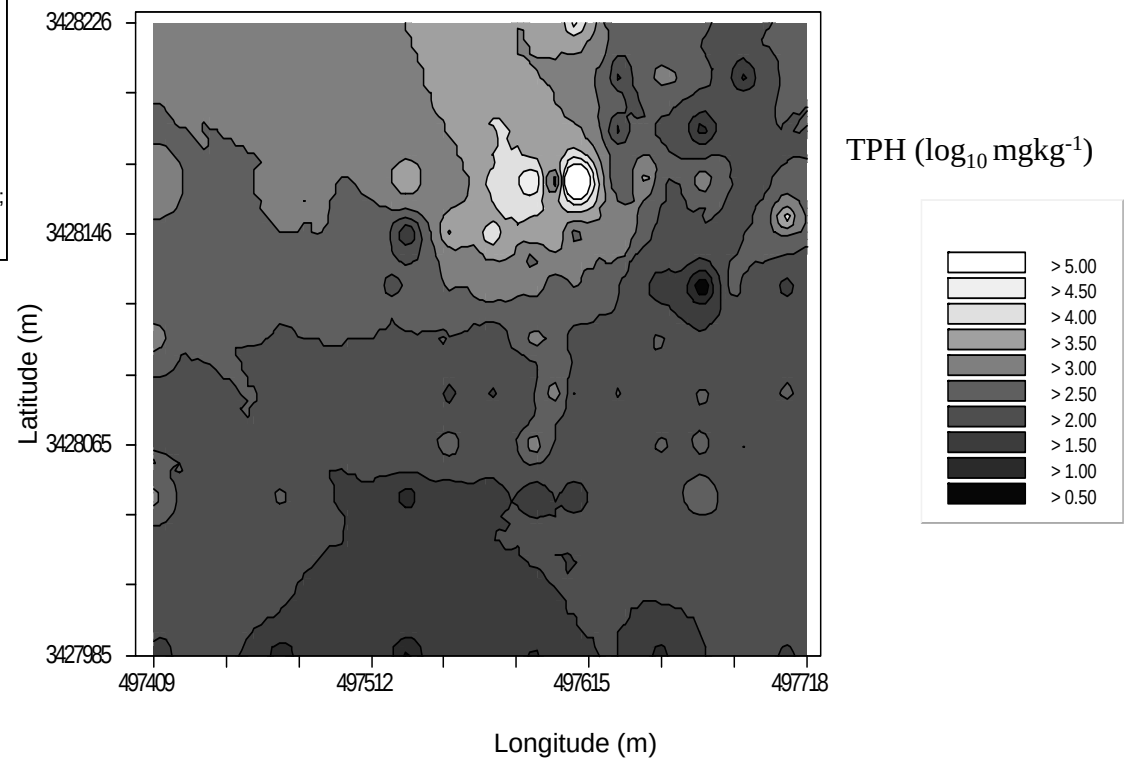
r^2=0.70 RPD= 2.0
RMSE= 0.409 $\log_{10}$ mg kg^{-1}
bias= 0.235 $\log_{10}$ mg kg^{-1}

Chakraborty, S., D.C. Weindorf, Y. Zhu, B. Li, C.L.S. Morgan, Y. Ge, J. Galbraith. 2012. Spectral reflectance variability from soil physicochemical properties in oil contaminated soils. Geoderma. 177-178:80–89.

Kriged Map of TPH at a Contamination Site



Exponential model (Co = 0.001; Co + C = 1.044; Ao = 17.70; r2 = 0.764; RSS = 0.209)



Chakraborty, S., D.C. Weindorf, Y. Zhu, B. Li, C.L.S. Morgan, Y. Ge, J. Galbraith. 2012. Assessing spatial variability of soil petroleum contamination using visible near-infrared diffuse reflectance spectroscopy. Journal of Environmental Monitoring. 14: 2886-2892.

VisNIR for Proximal Sensing

Surfing

High resolution surface (x,y) mapping

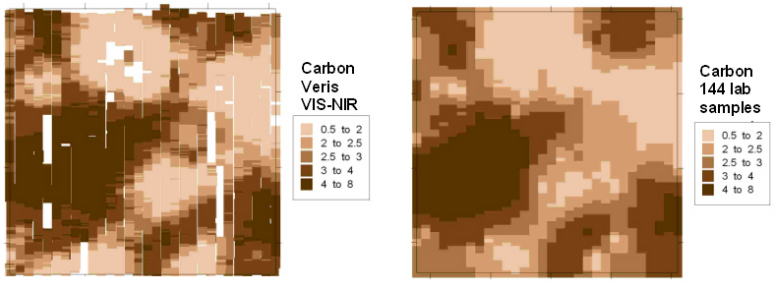
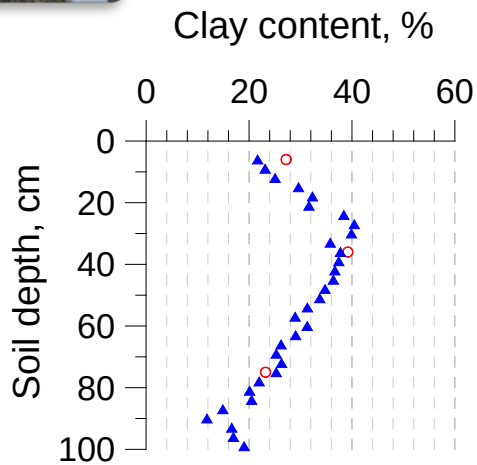


Image from Veris Technologies
e.g. Christy, 2008; Bricklemyer and Brown 2010

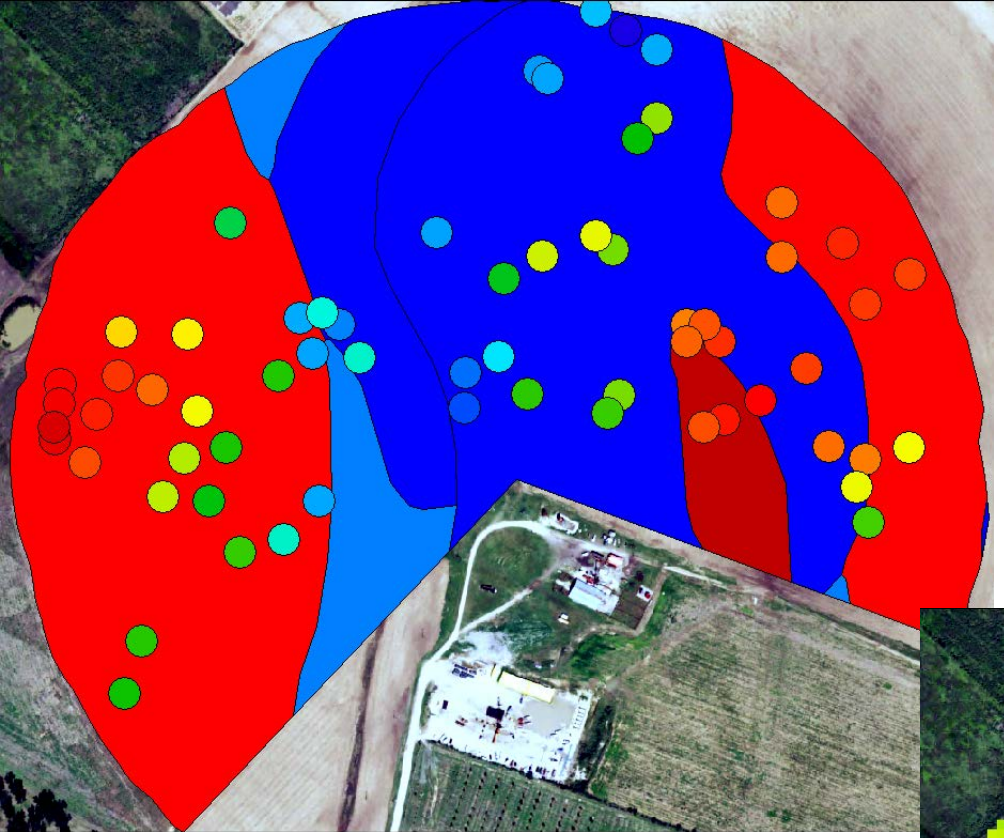
Diving

High resolution profile mapping (z)



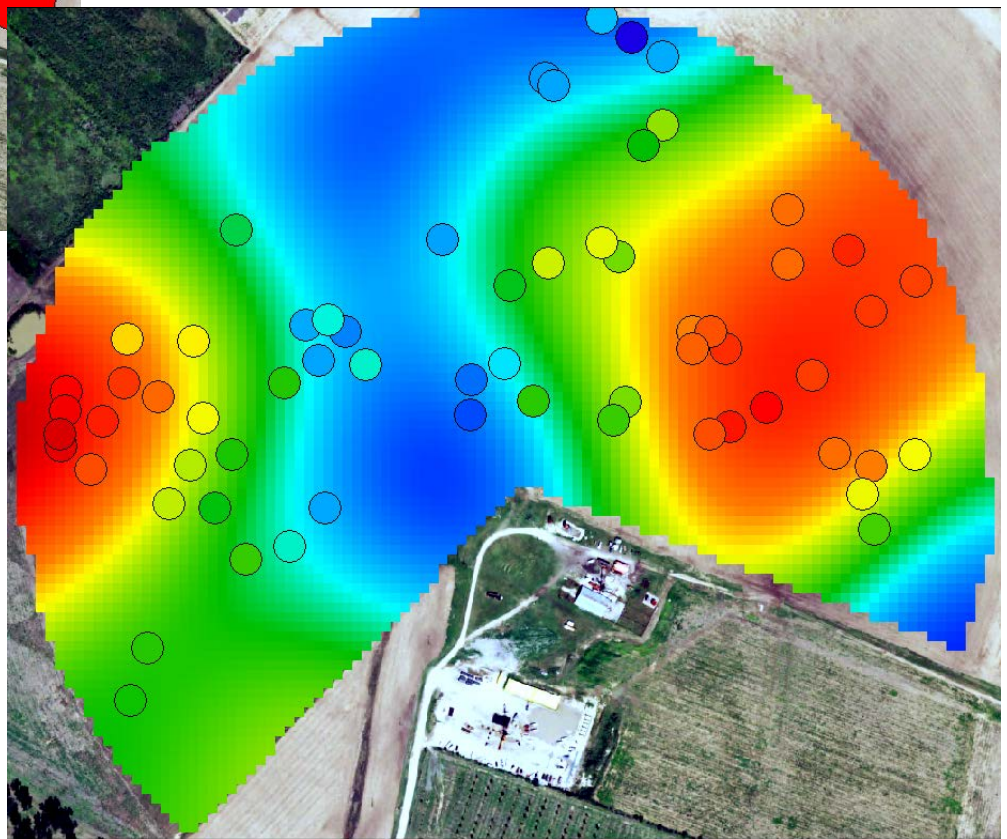
e.g. Waiser et al. 2007

SSURGO: Clay 0-50 cm

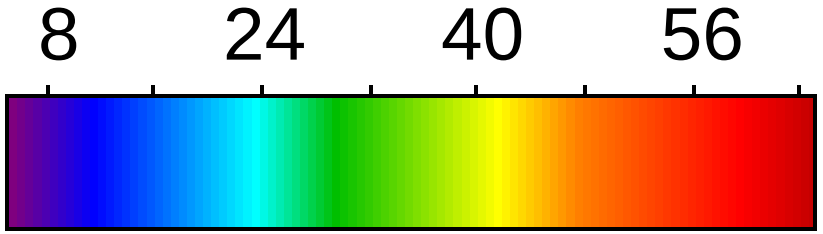


SSURGO

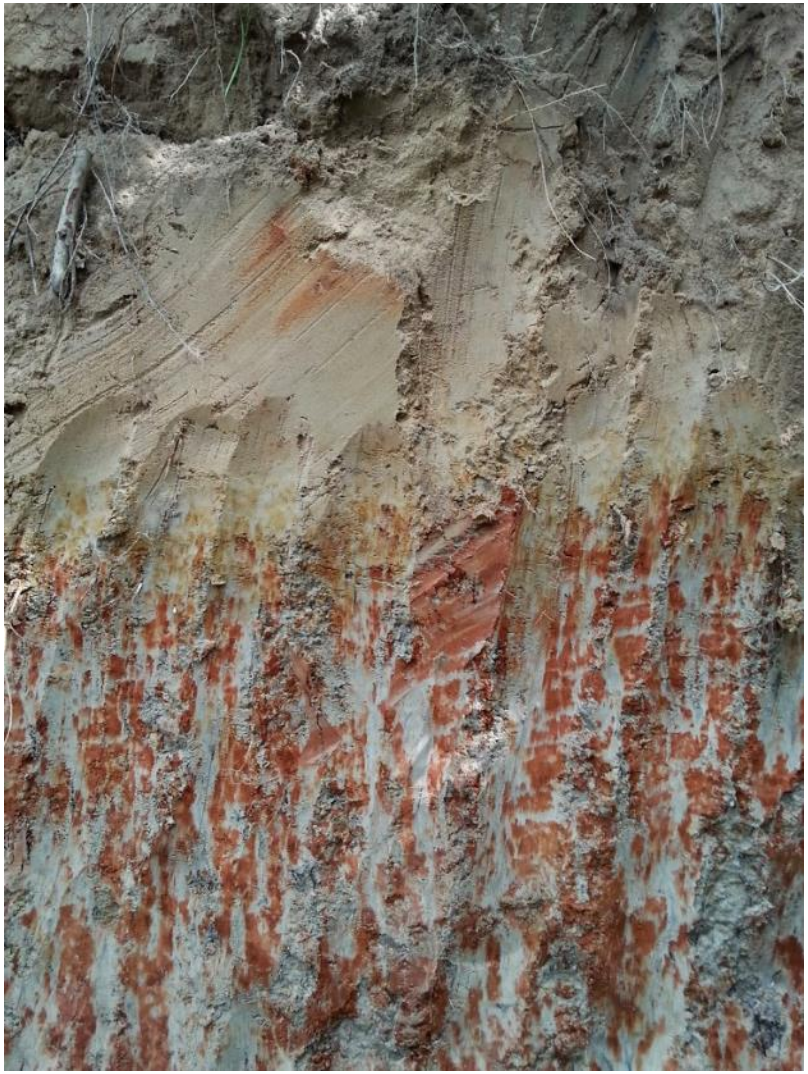
Measured

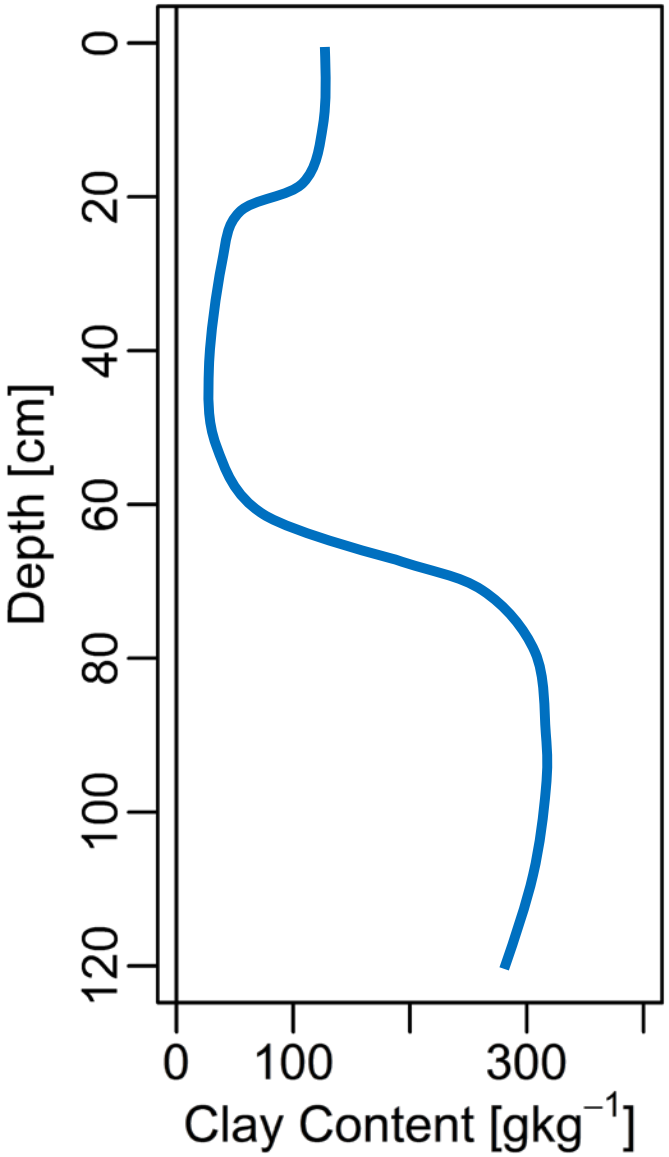


Clay Content (%)

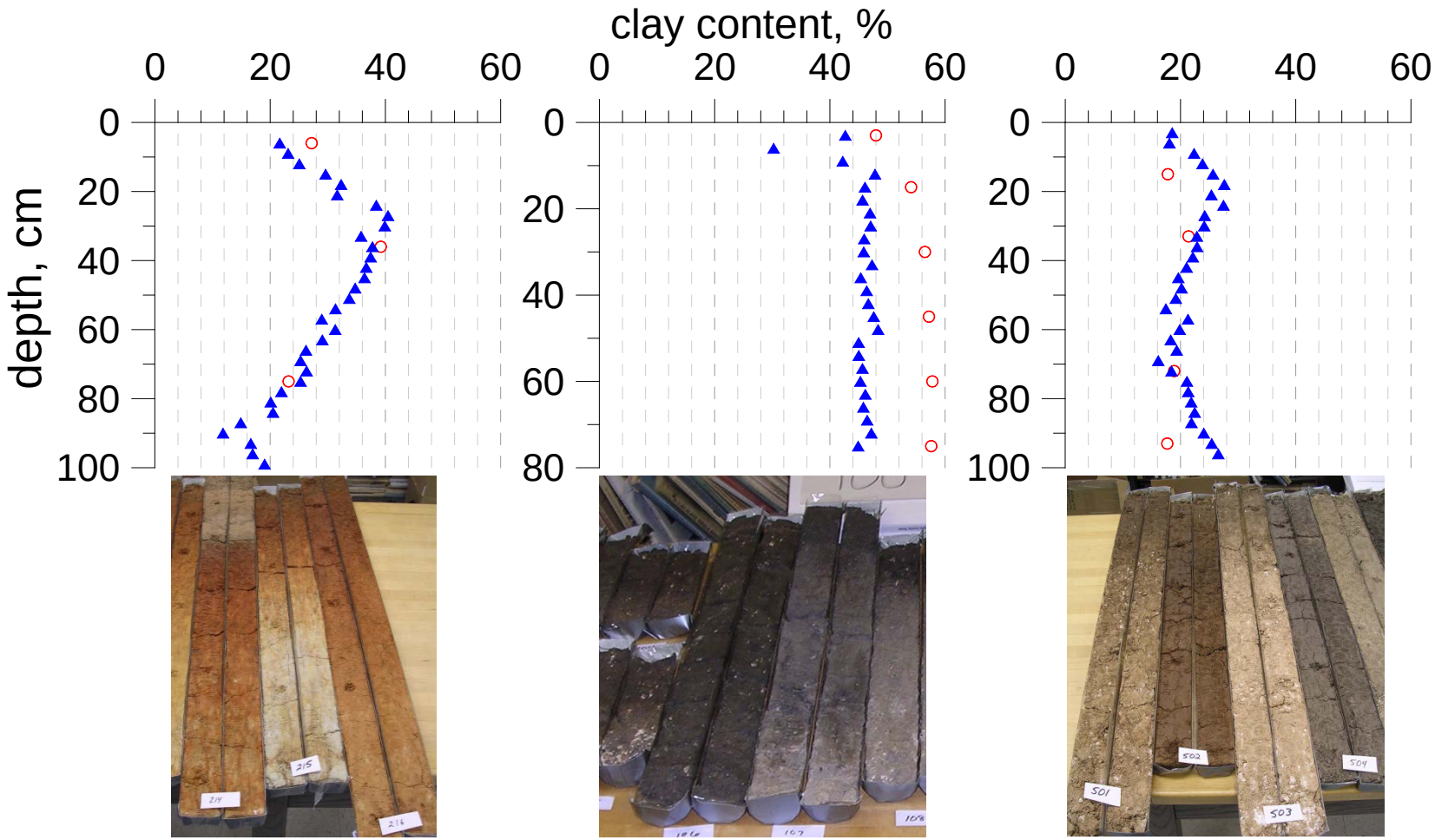


Motivation





Profile Scans



Fine, mixed, active, thermic Udic Paleustalfs

Very-fine, smectitic, thermic Oxyaquic Hapluderts

Fine-loamy, mixed, thermic Udic Calciustolls

Data need -> limited soil measurements

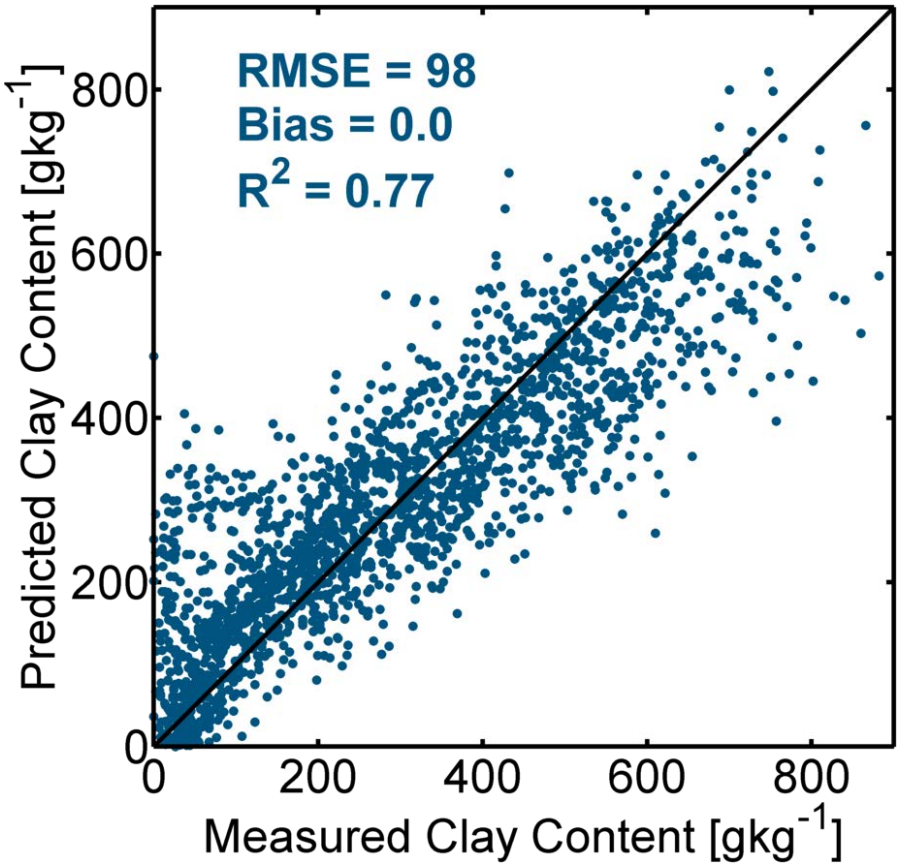
- Limited spatial coverage
- Limited depth resolution

Objective: Develop technique for soil measurement

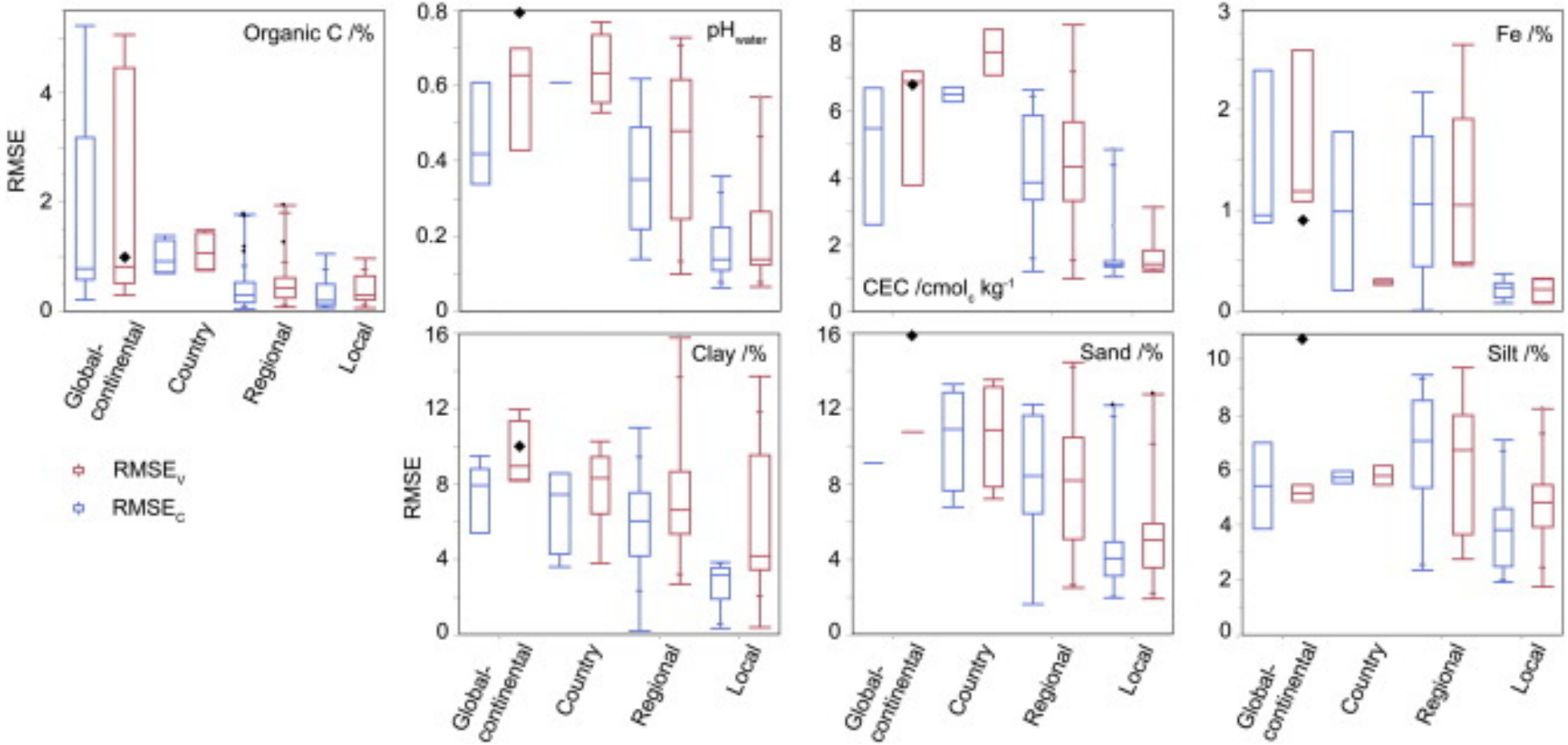
- Rapid, low cost, accurate
- Usable in the field
- Increased spatial coverage
- Finer depth resolution

Texas Spectral Soil Library

- 2094 Air-dry and ground VisNIR spectra
- 284 pedons
- 44 counties



Global Spectral Soil Library



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http://dx.doi.org/10.1016/j.earscirev.2016.01.012

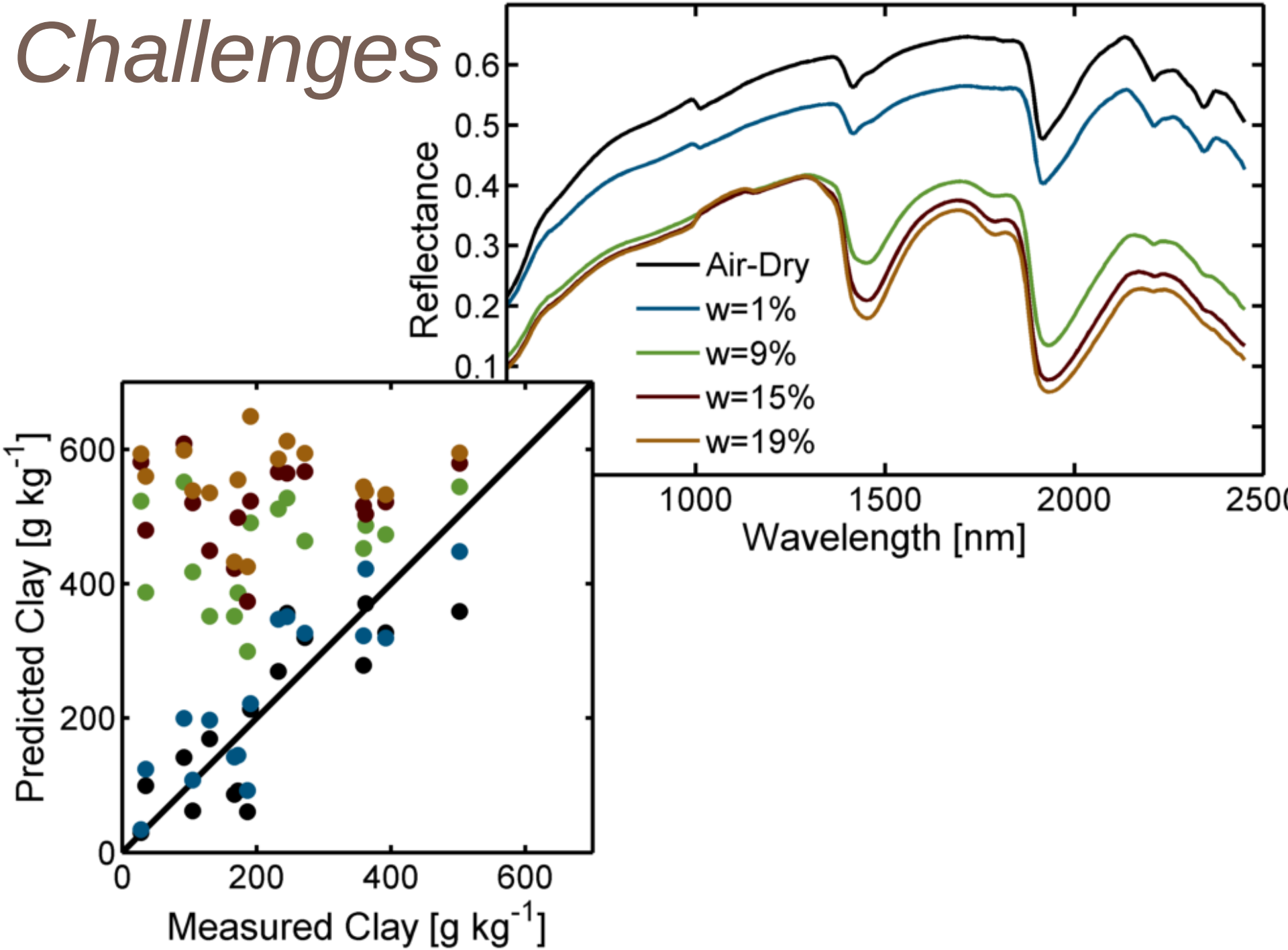
Components of Field Spectroscopy

Use dried-ground soil spectral libraries for field-moist in situ spectral scans

Equipment – small penetrometer design that is plug-and-play with any spectrometer

Field Methodology

Challenges


Reflectance
0.6
0.5
0.4
0.3
0.2
0.1
Air-Dry
w=1%
w=9%
w=15%
w=19%
1000
1500
2000
2500
Wavelength [nm]
Predicted Clay [g kg^{-1}]
600
400
200
0
0
200
400
600
Measured Clay [g kg^{-1}]

External Parameter Orthogonalization

$$\mathbf{X} = \mathbf{XP} + \mathbf{XQ}$$

Useful Component

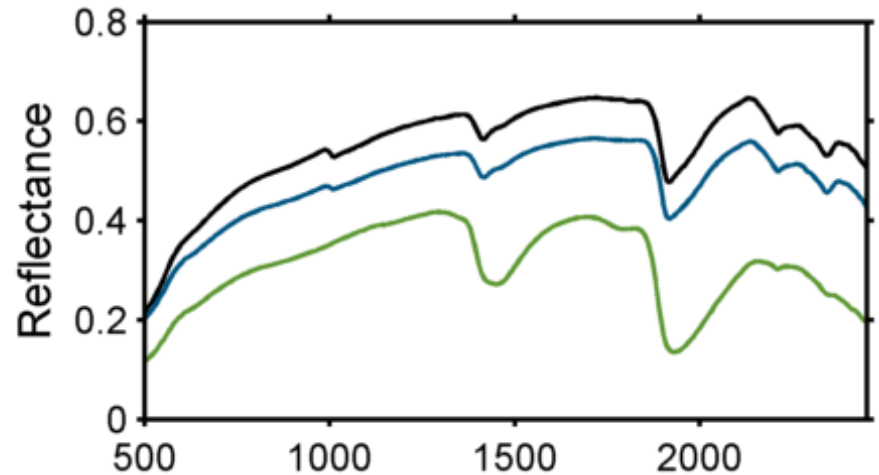
Raw VisNIR Spectra

Parasitic Component

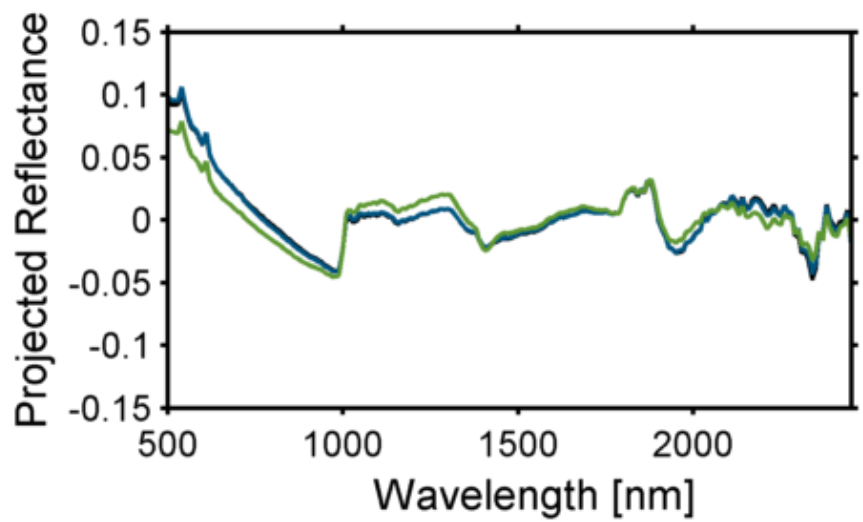
- Estimate **P**
- Project spectra *and* library

Ge, Y., C.L.S. Morgan, J.A. Ackerson. 2014. VisNIR spectra of dried ground soils predict properties of soils scanned moist and intact. Geoderma. 221-222:61-69.

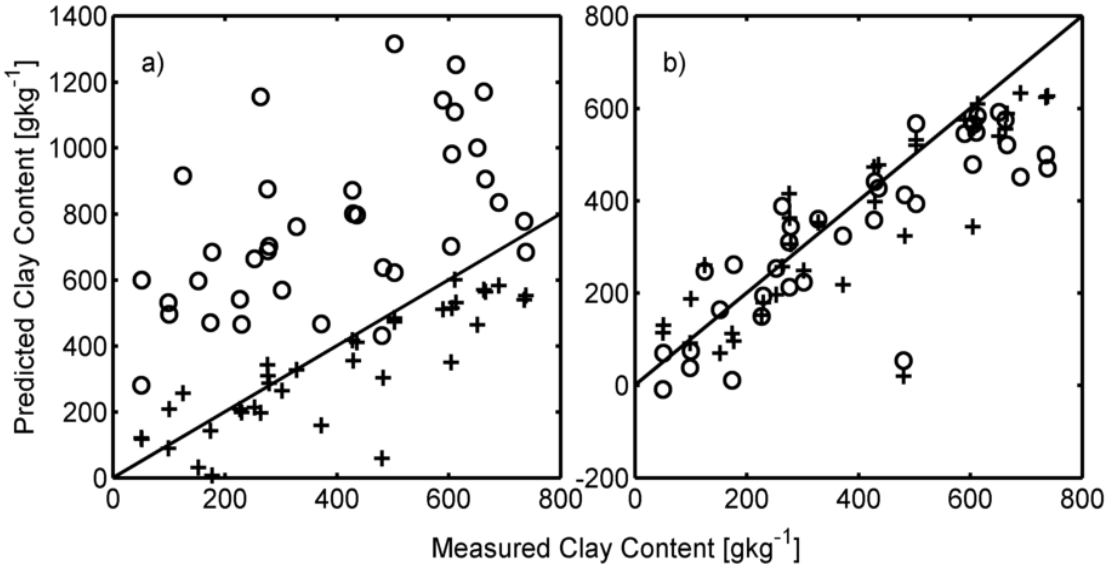
Before EPO

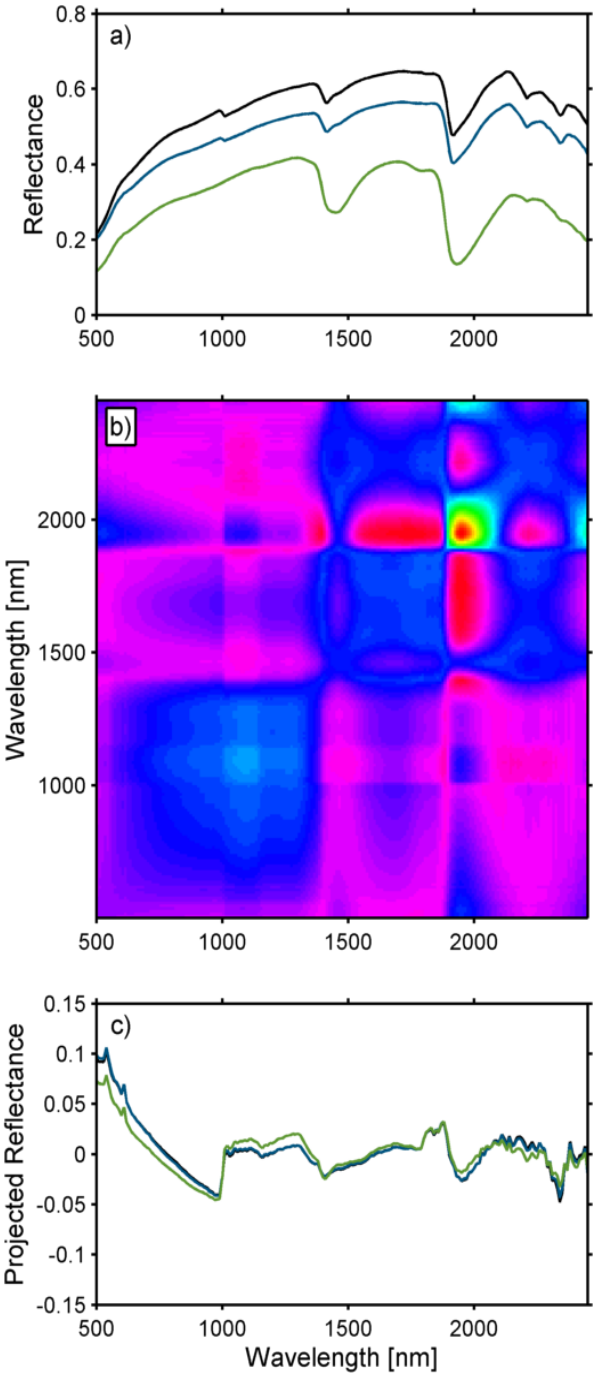


After EPO



EPO of Spectral Libraries





- EPO – removes effect of water content
- Tested on tropical and temperate soils

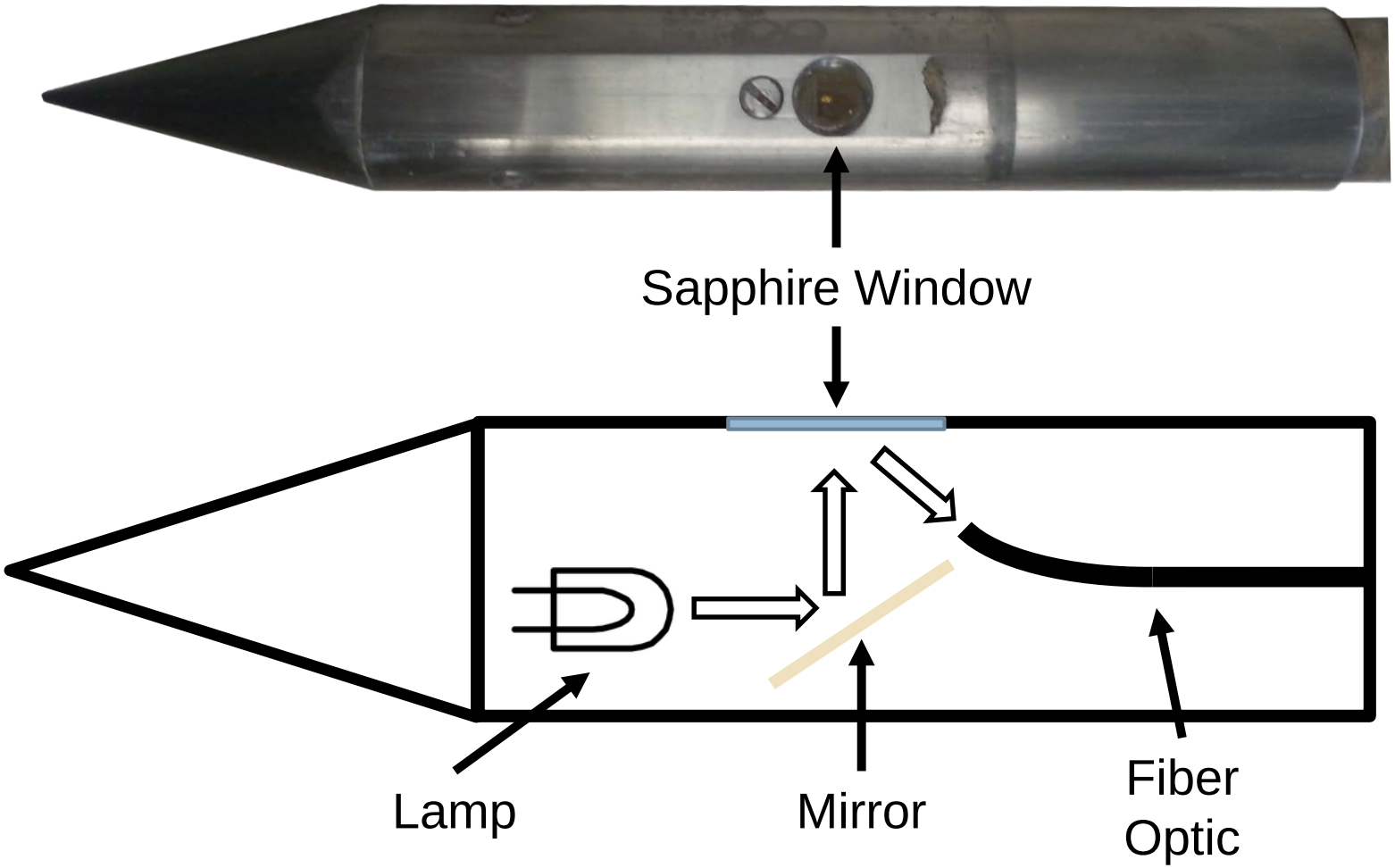
Ackerson, J.P., J.A.M. Demattê, C.L.S. Morgan. 2015. Predicting clay content on field-moist intact tropical soils using a dried, ground VisNIR library with external parameter orthogonalization. Geoderma. 259:196-204.

Wijewardane, N. Ge, Yufeng, C.LS. Morgan. 2016. Moisture insensitive prediction of soil properties from VNIR reflectance spectra based on external parameter orthogonalization. Geoderma 267:92-101.

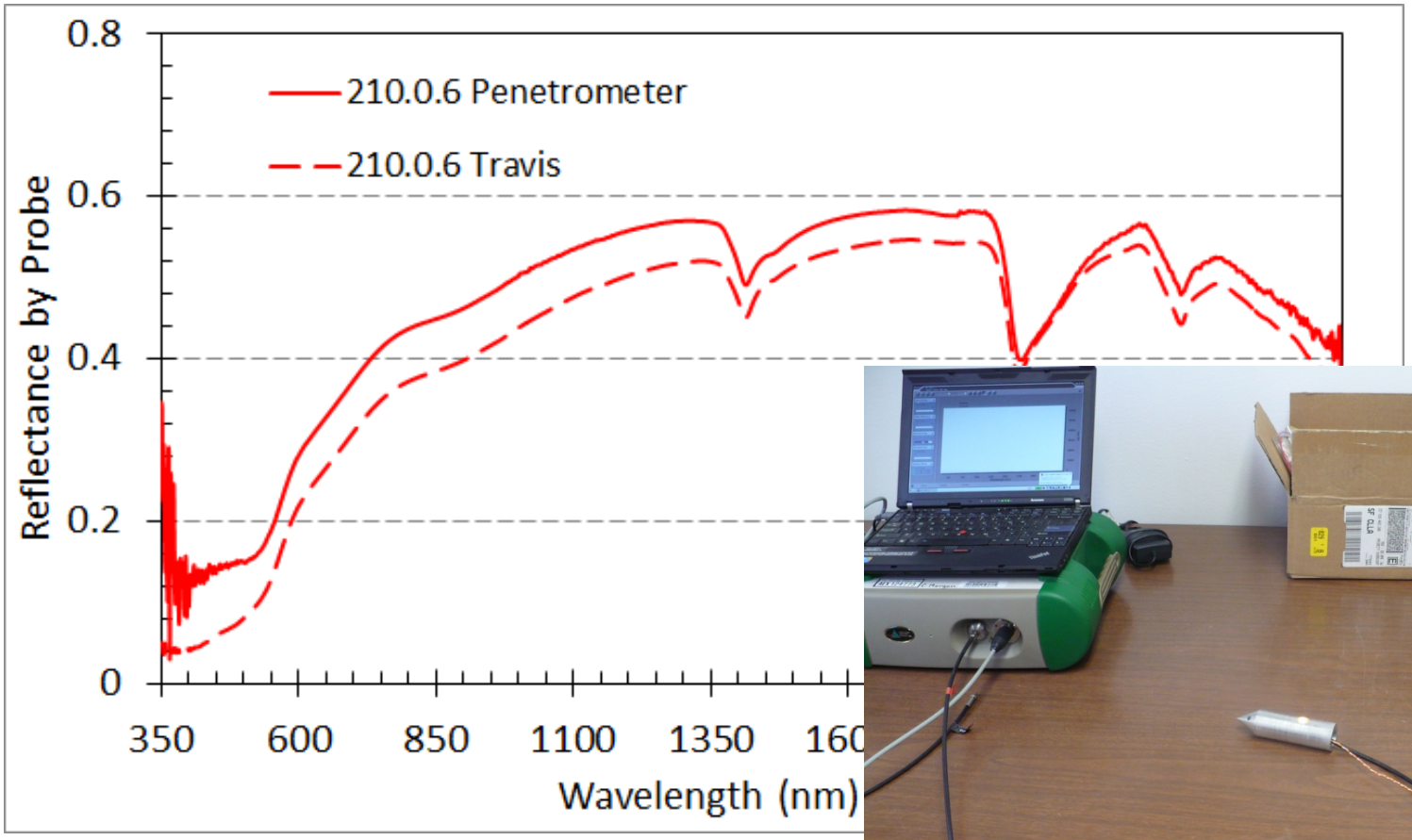
Equipment

1. Plug and play VisNIR equipped penetrometer with multi sensor platform (TDR, penetration resistance, displacement sensor)
2. Replica of ASDI handheld probe, 1.25 inch diameter (<3.2 cm)

In-situ VisNIR

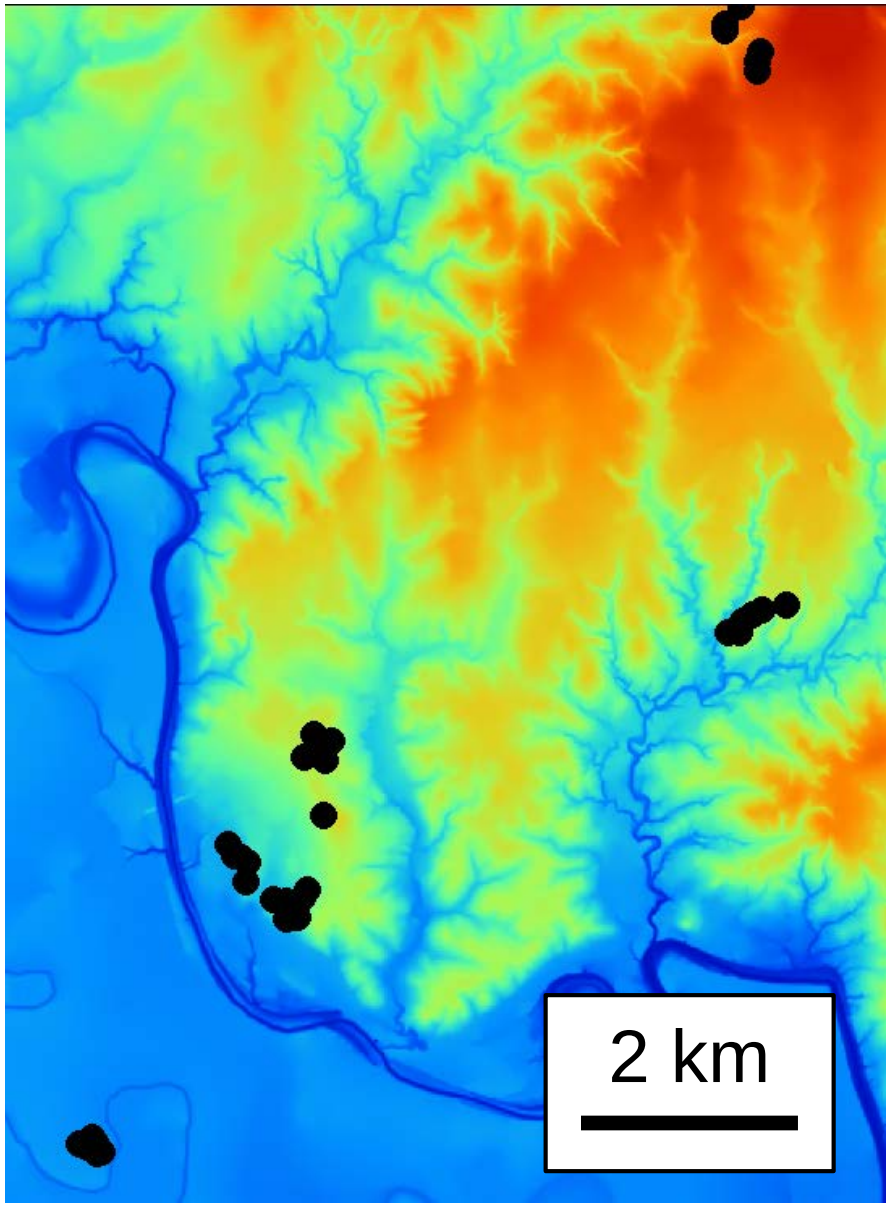


Plug and Play Probe

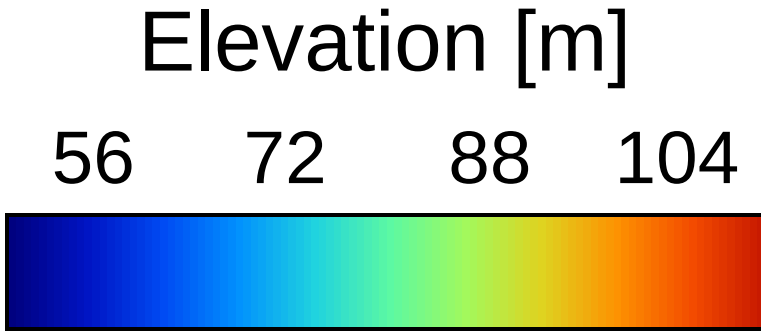


In-situ VisNIR

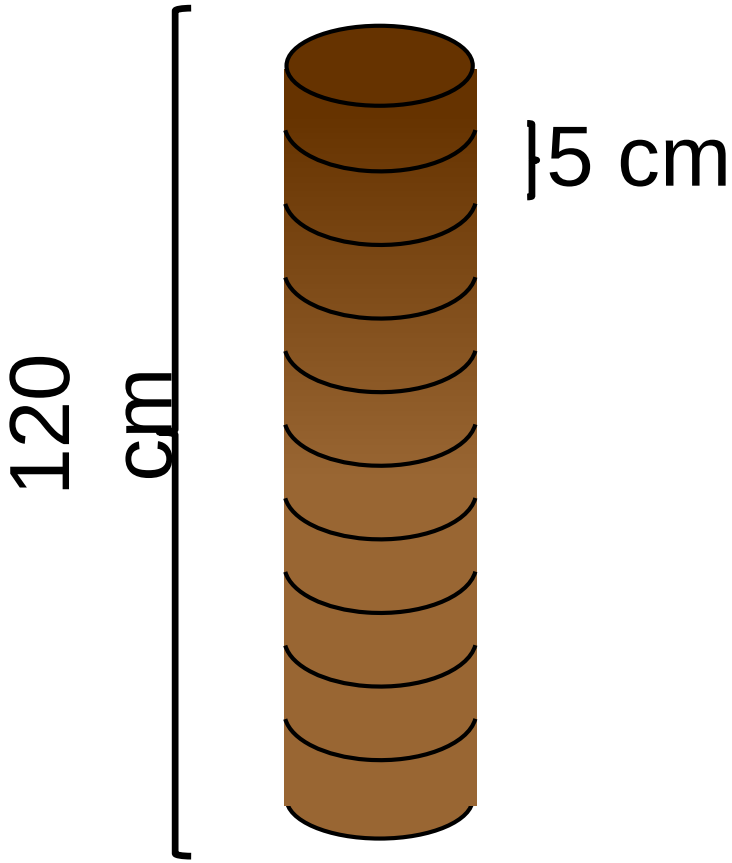
Study Area in Texas



Site	Soils
Floodplain	Inceptisols, Entisols
Stream Terrace	Alfisols, Vertisols
Upland	Alfisols, Vertisols

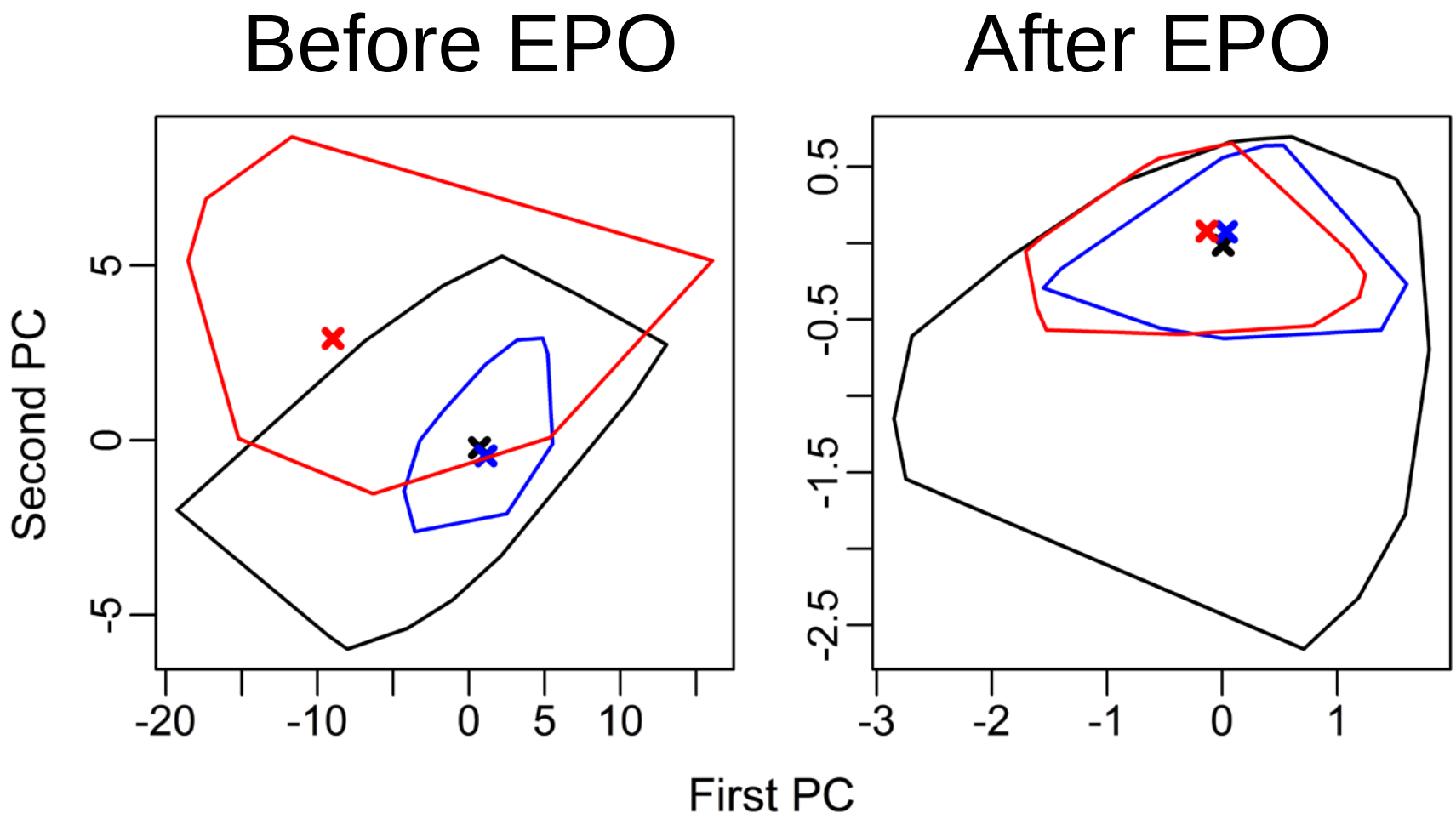


Methodology



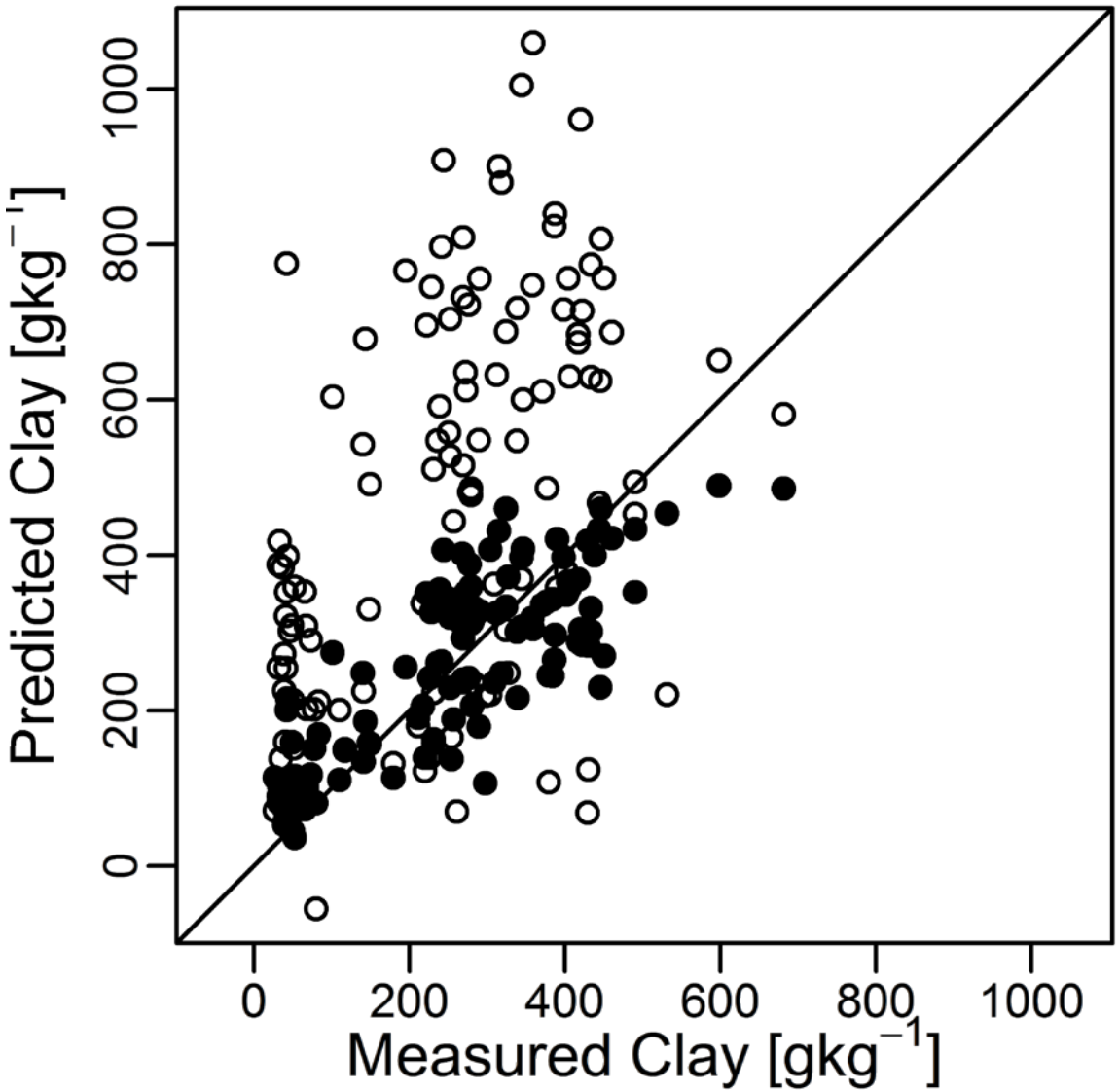
- Two *in situ* VisNIR profiles
- Spectra every 5 cm
- One core
  - Clay content
  - Dry-ground VisNIR

EPO performance



Library **Dry-Ground** **Penetrometer**

Penetrometer Performance



<u>Without EPO (○)</u>

RMSE: 307 gkg^{-1}

Bias: 208 gkg^{-1}

R^2: -3.2

<u>With EPO (●)</u>

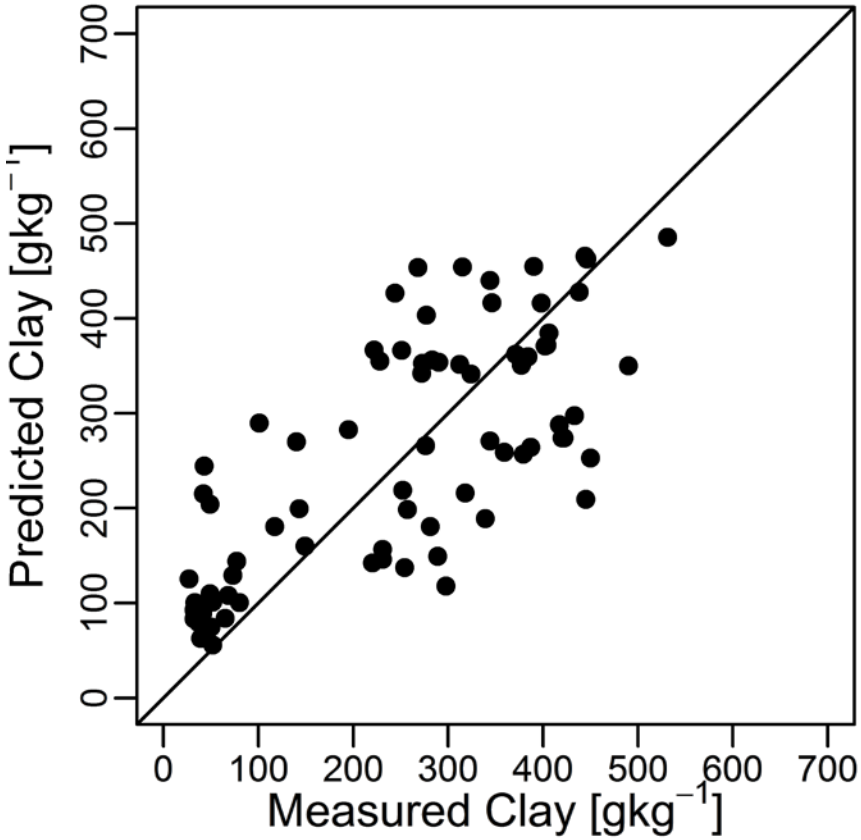
RMSE: 83 gkg^{-1}

Bias: 0 gkg^{-1}

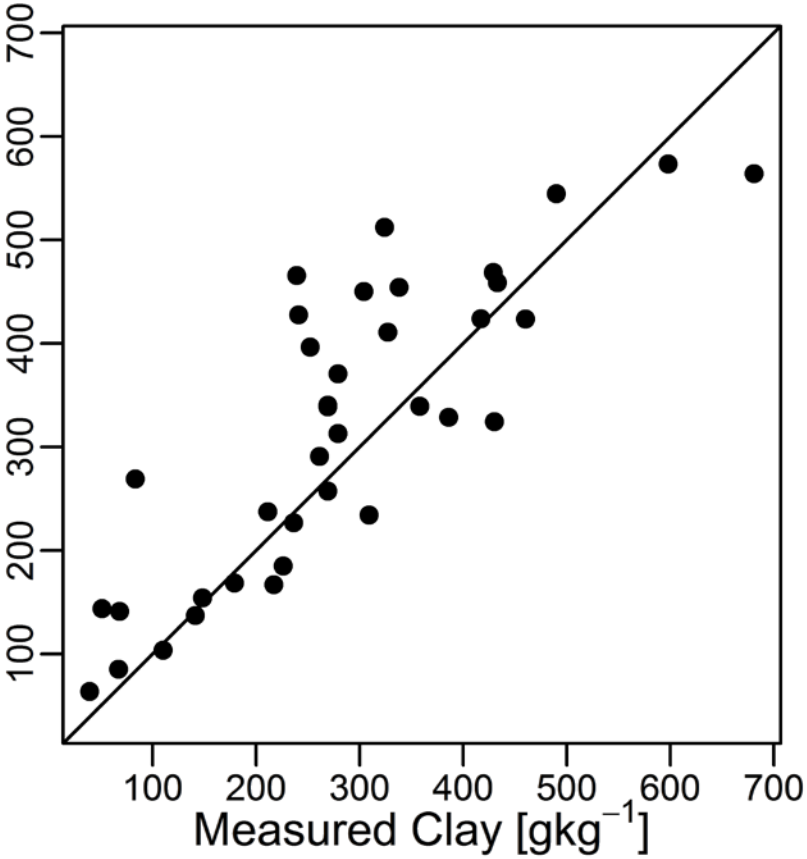
R^2: 0.69

Site-wise Performance

Stream Terraces:
RMSE = 99 gkg^{-1}
Bias = 10 gkg^{-1}

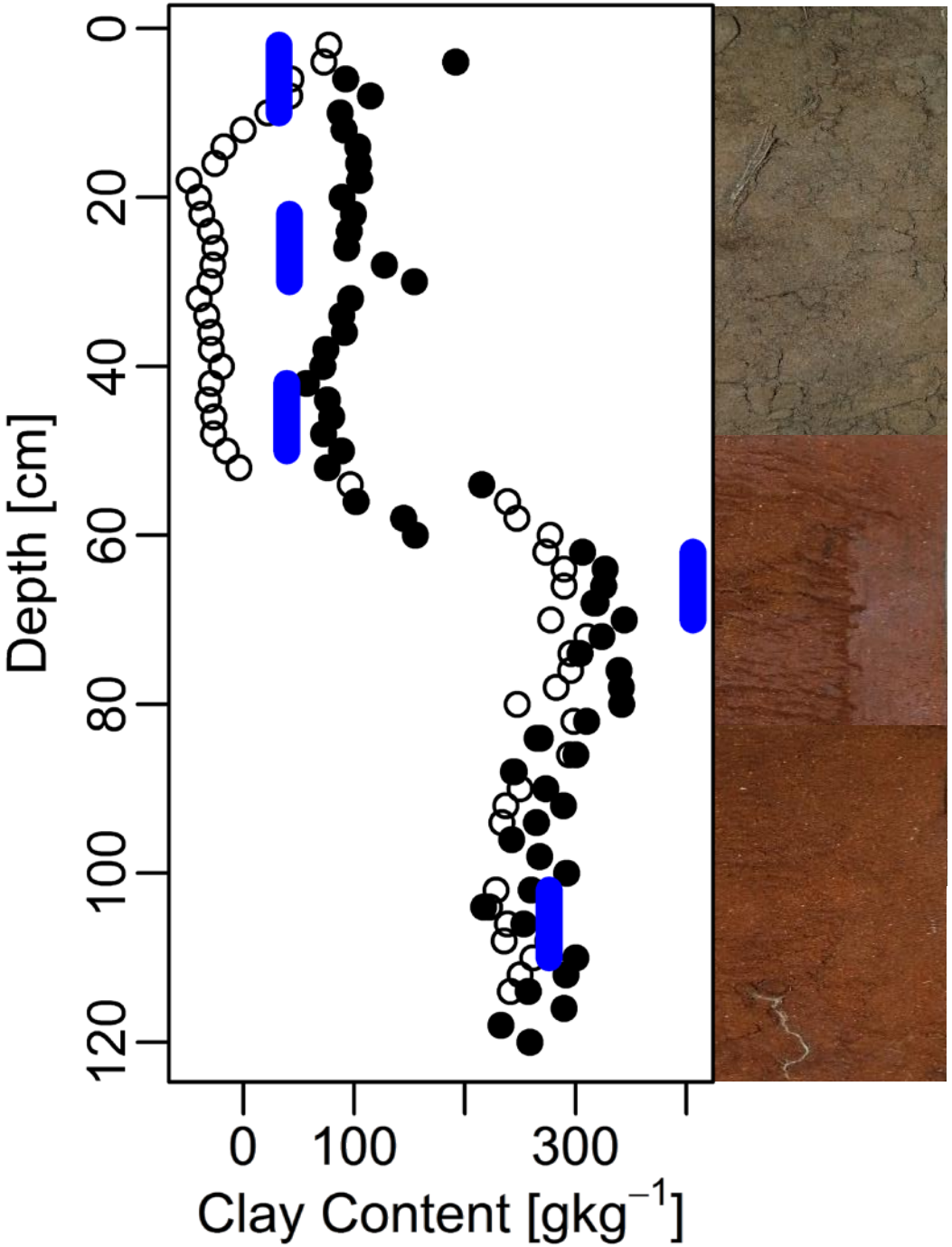


Upland/Coastal Residuum:
RMSE = 90 gkg^{-1}
Bias = 37 gkg^{-1}

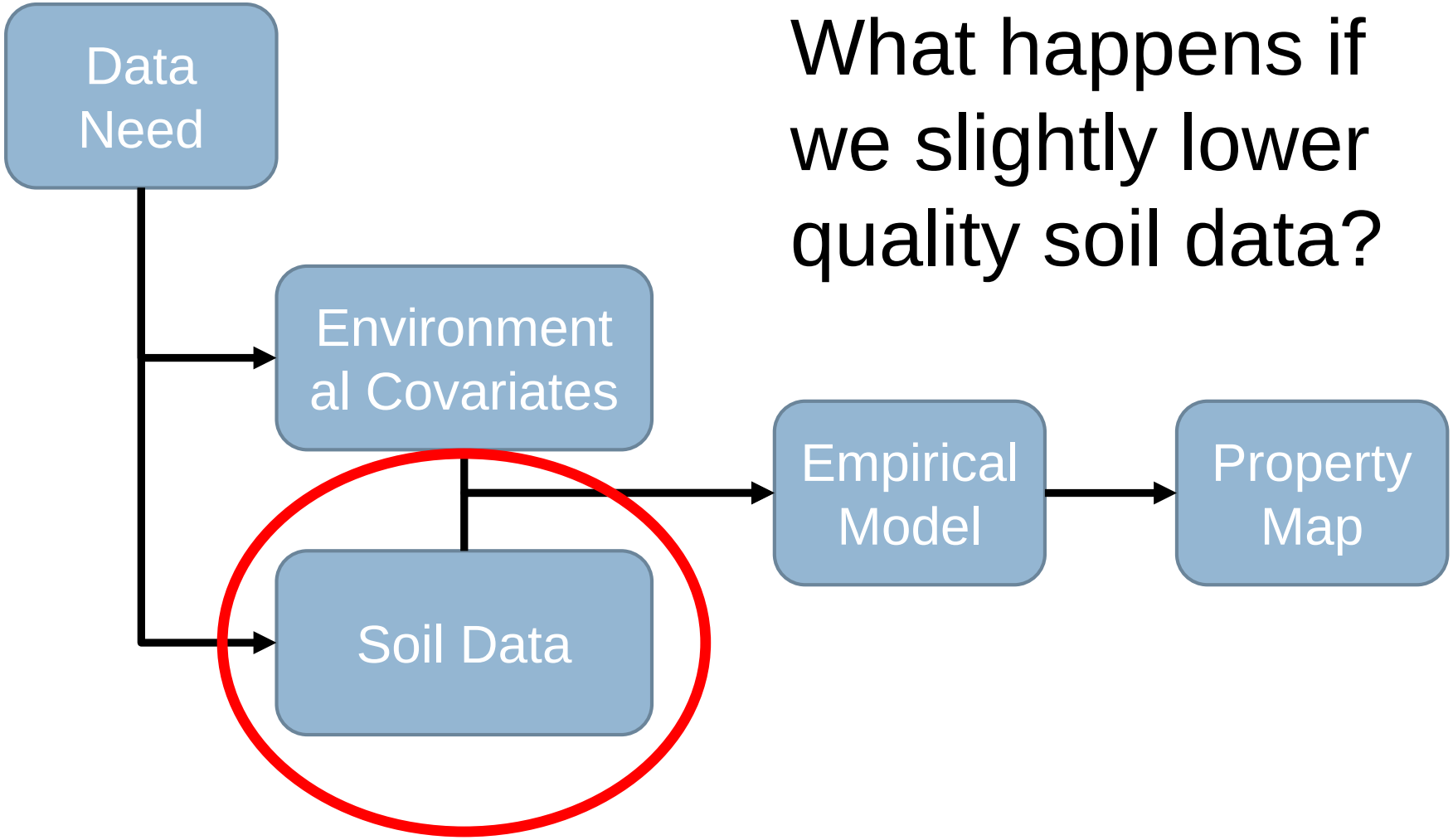


In-situ VisNIR Profiles

- ○ Dry-ground Spectra
- ● *In situ* Spectra
- ▮ Measured Clay Content



Digital Soil Mapping



What happens if we slightly lower quality soil data?

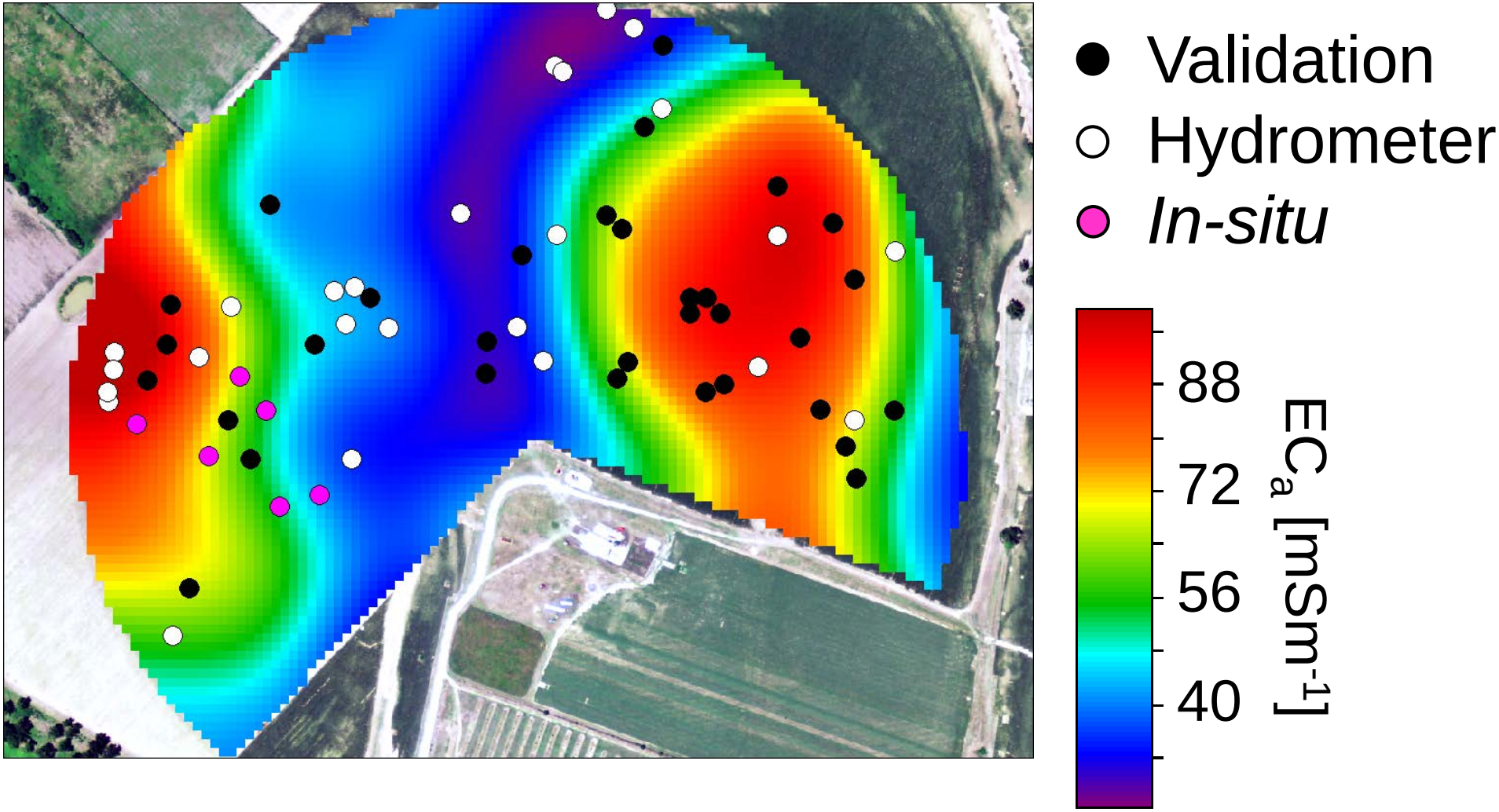
SSURGO: Clay 0-50 cm

Environmental Covariate:

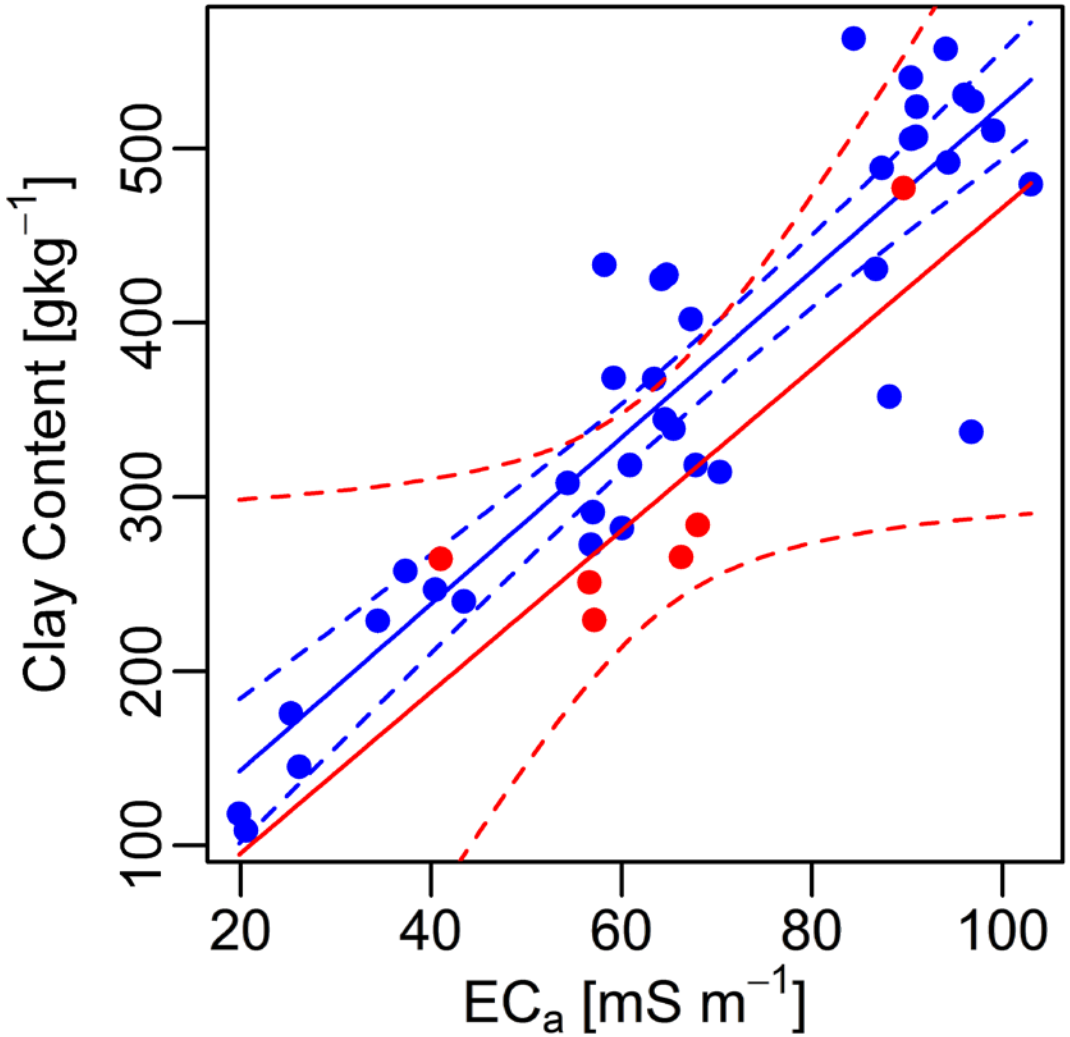
Apparent Bulk Electrical Conductivity (Ec_a)

- Non-invasive
- Rapid
- Sensitive to:
  - Water Content
  - Clay Content

Electrical Conductivity (Ec_a)



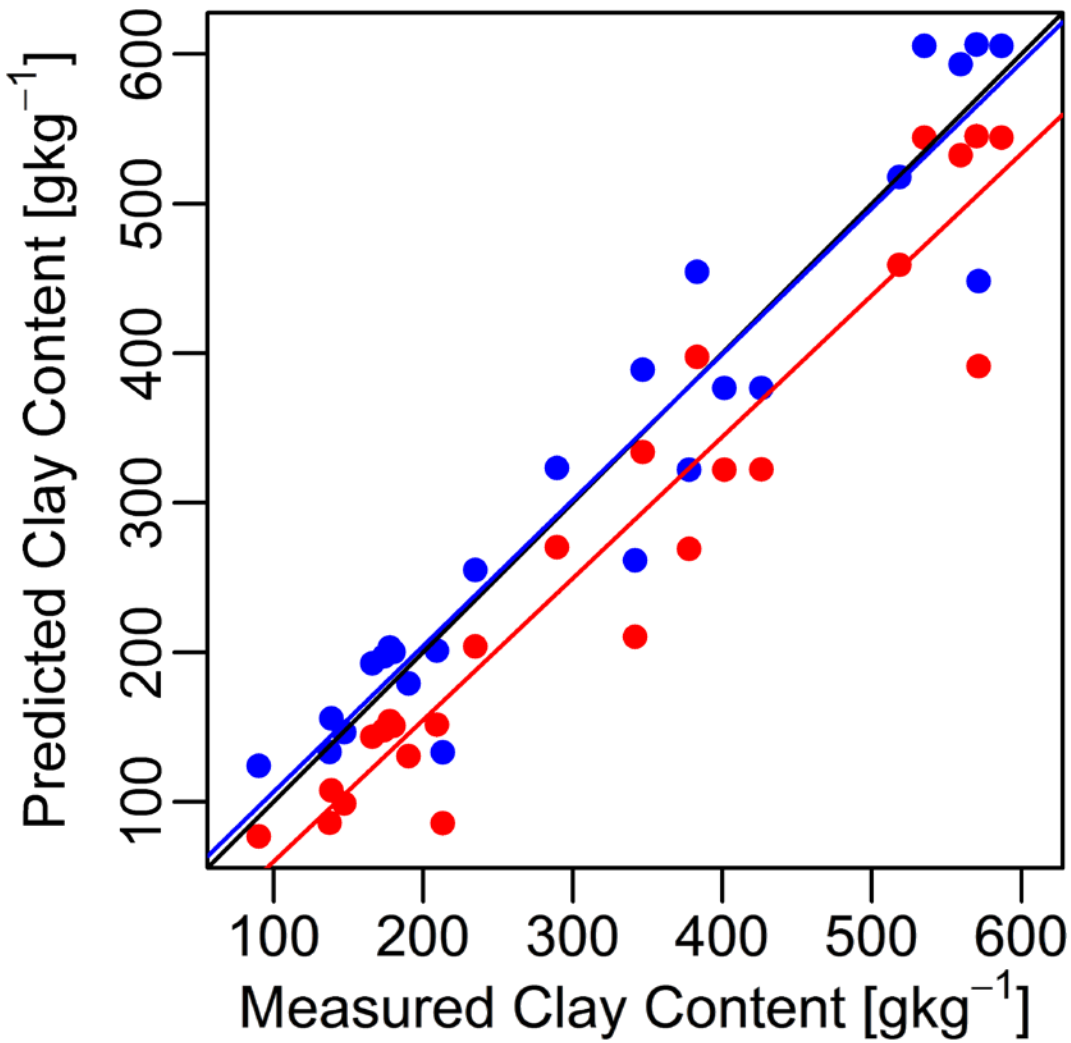
Empirical Model – Clay vs EC_a



Hydrometer
$R^2 = 0.81$
P-value < 0.001

In situ
$R^2 = 0.59$
P-value = 0.04

Empirical Model Performance

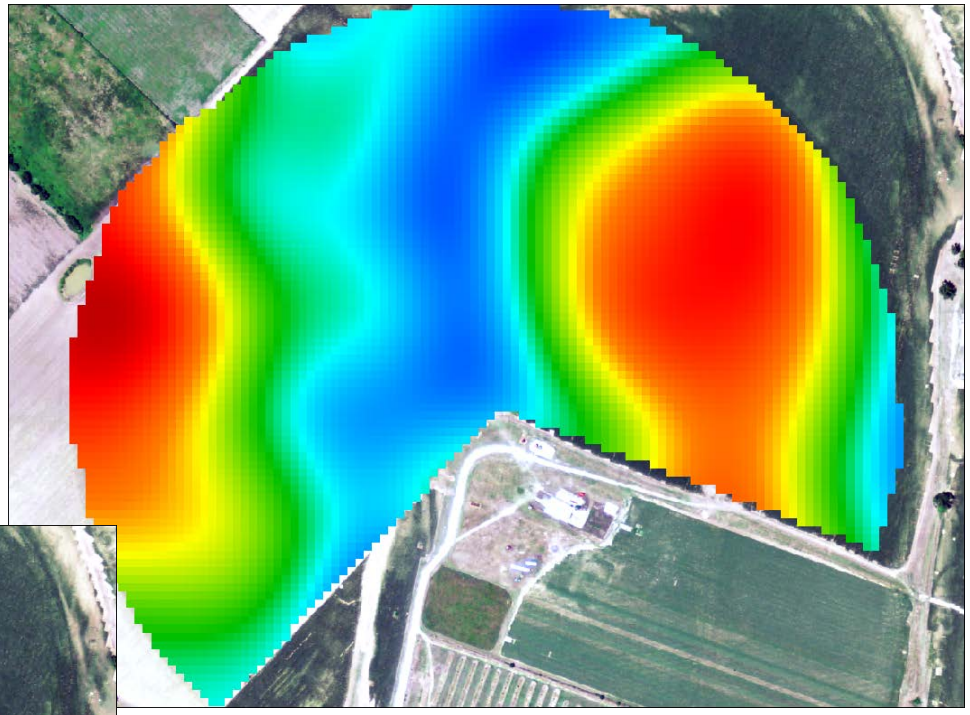


Hydrometer
$R^2 = 0.92$
RMSE = 46 gkg^{-1}
Bias = 1 gkg-1

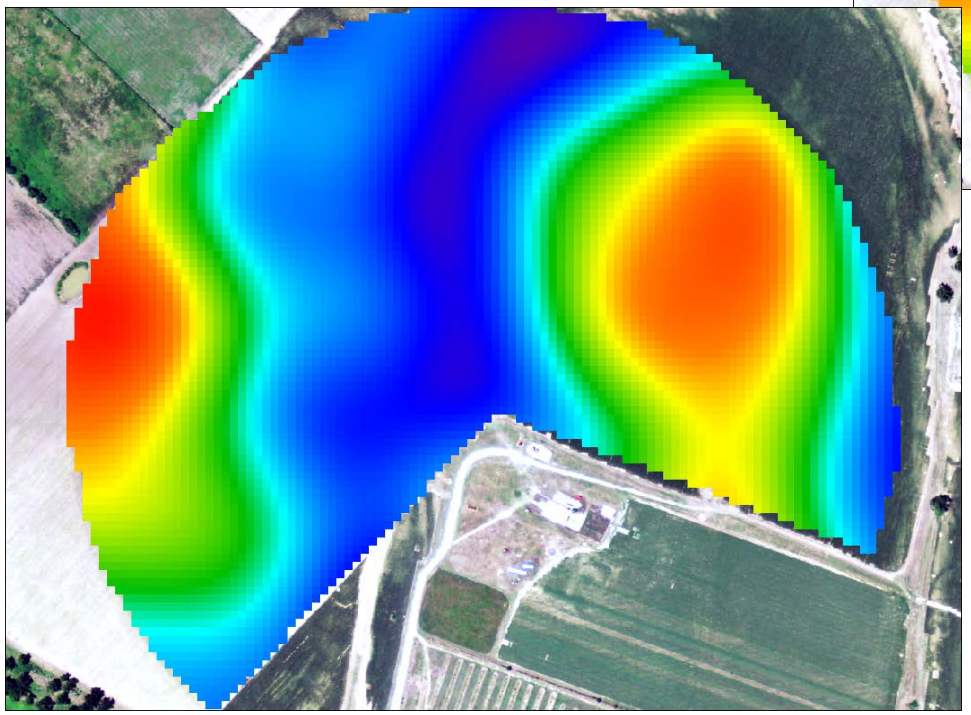
In situ
$R^2 = 0.82$
RMSE = 67 gkg^{-1}
Bias = -51 gkg^{-1}

Soil Property Maps

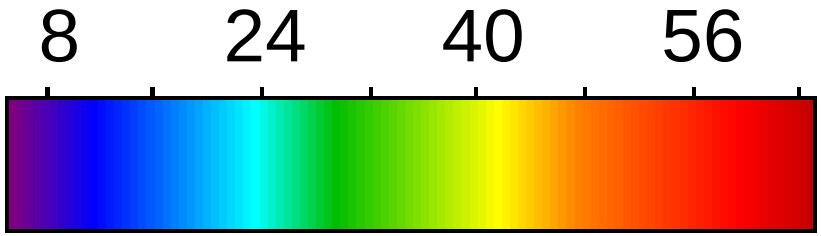
Hydrometer



In situ

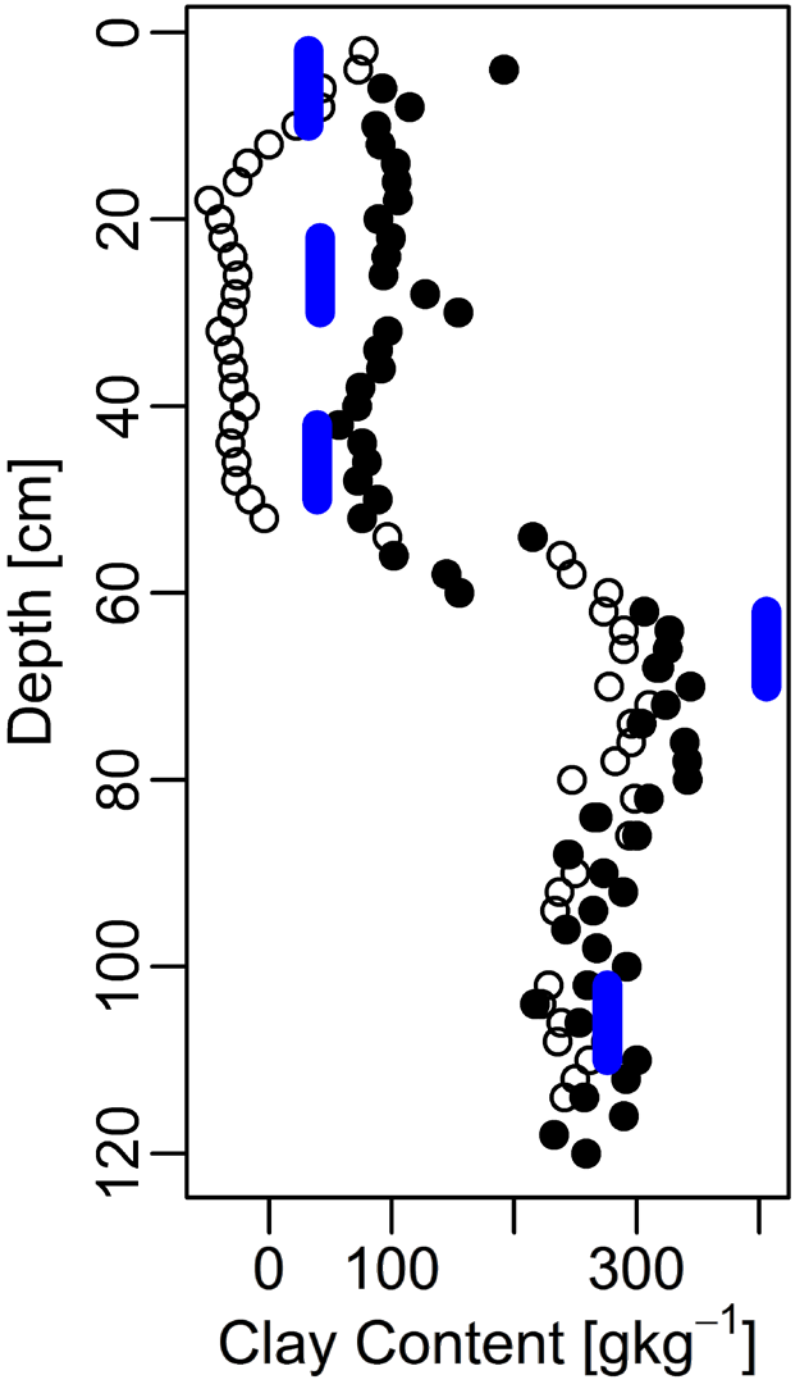


Clay Content (%)



Conclusions

- VisNIR-equipped penetrometer can accurately measure *in situ* clay content
- High-depth resolution measurements
- Effective tool for digital soil mapping



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Ross Bricklemyer

Other Primary Collaborators:
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Katrina Wilke, NRCS
Travis Waiser, NRCS

Thank you for your attention