SOIL COMPOSITION, SOIL VARIABILITY, AND PROXIMAL SOIL SENSING OF SOILS

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Novel Methods for
Phytosequestration
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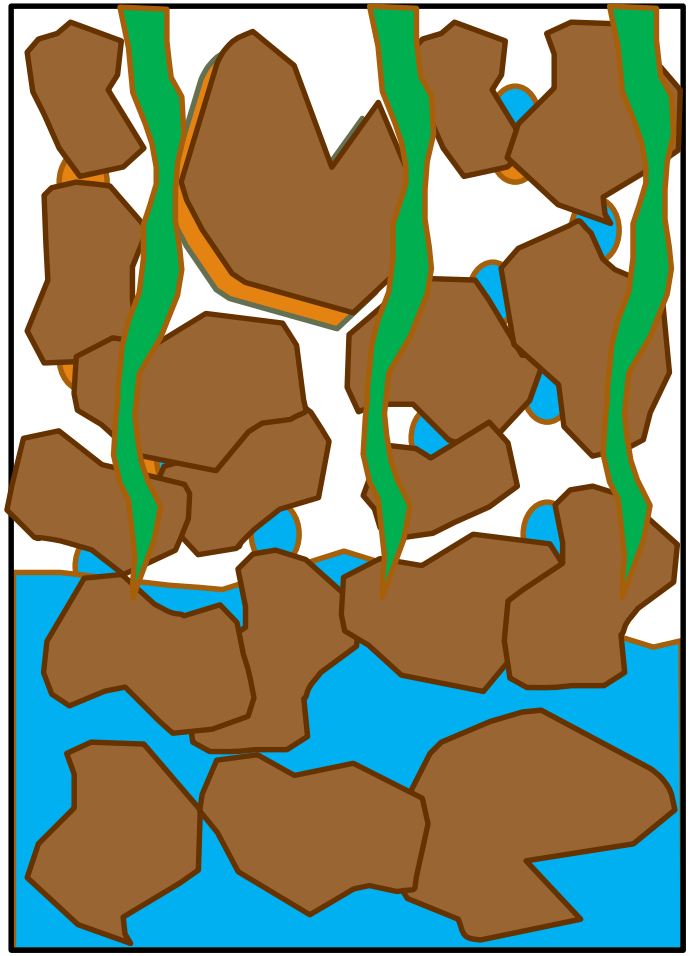
Outline

- Introduction to soil properties & composition
- Current tools for proximal sensing
- Spatial Variability, Precision/Accuracy

Soil as a 3 + 1 phase system



Solids

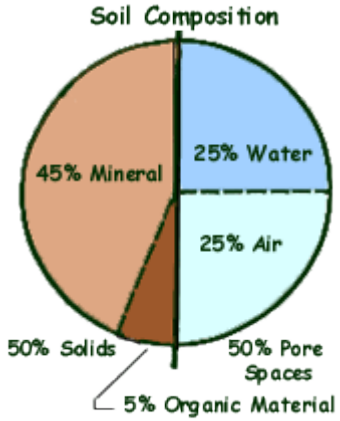
Liquids

Gas

+ Roots

Imaging the soil requires discrimination between the soil phases

Fundamental soil properties



Solids
Bulk Density/Porosity

Soil Minerals (Physical)
- Particle Size Distribution
- Mineralogy of silicate clays
- Mineralogy of size-fractions

Soil Minerals (Chemical)
- Cation Exchange Capacity
- Exchangeable Cations and Ions
- pH

Organic Carbon

Liquids
Water-filled pore space

Water-filled pore space as a function of matric potential

Extractable water chemistry

Gasses

Air-filled pore space as a function of water content or potential

Gas Composition

Fundamental soil properties

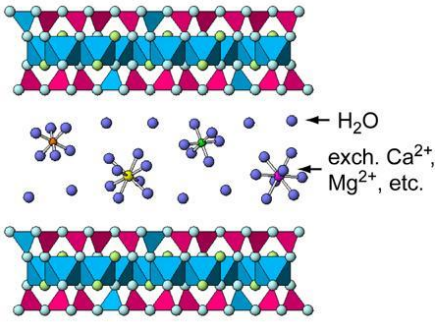
Soil Minerals (Physical)

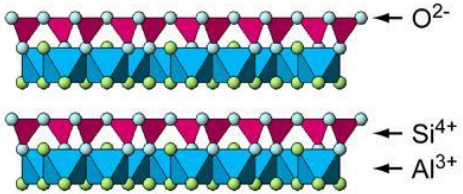
Particle Size Distribution

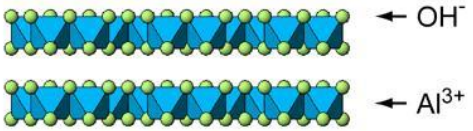
sand	2.0 to 0.05 mm
silt	0.05 to 0.002 mm
clay	< 0.002 m

Any Fraction: Carbonates, Gypsum, Salts

Clay Fraction: Silicate clays (2:1 and 1:1 clay silicates)





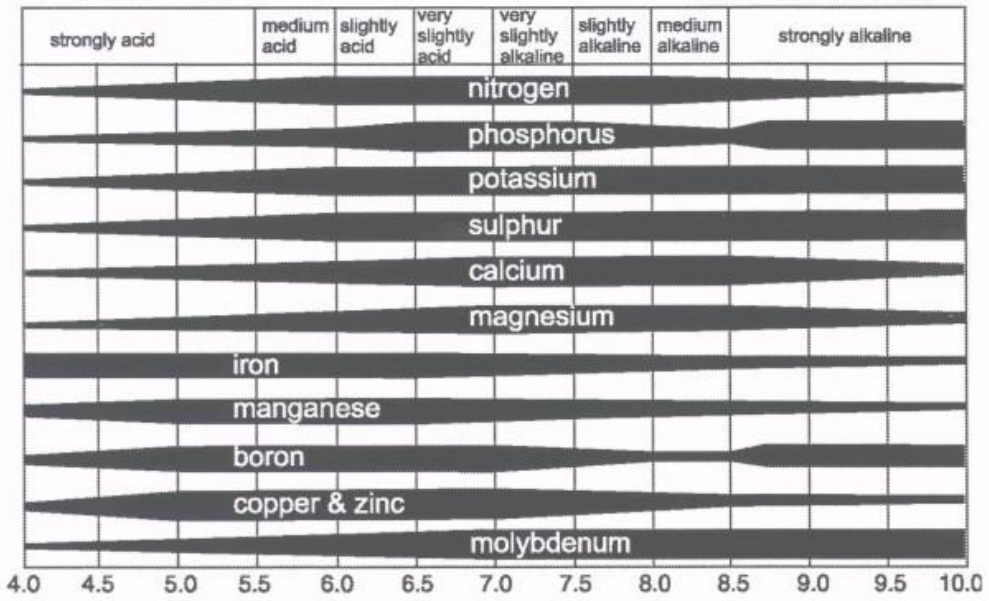


Fundamental soil properties

Soil Minerals (Chemical)

- Cation Exchange Capacity
  - Sandy Soil 3 to 5 meq $100g^{-1}$
  - Clayey Soil 30 to 40 meq $100\ g^{-1}$
- pH

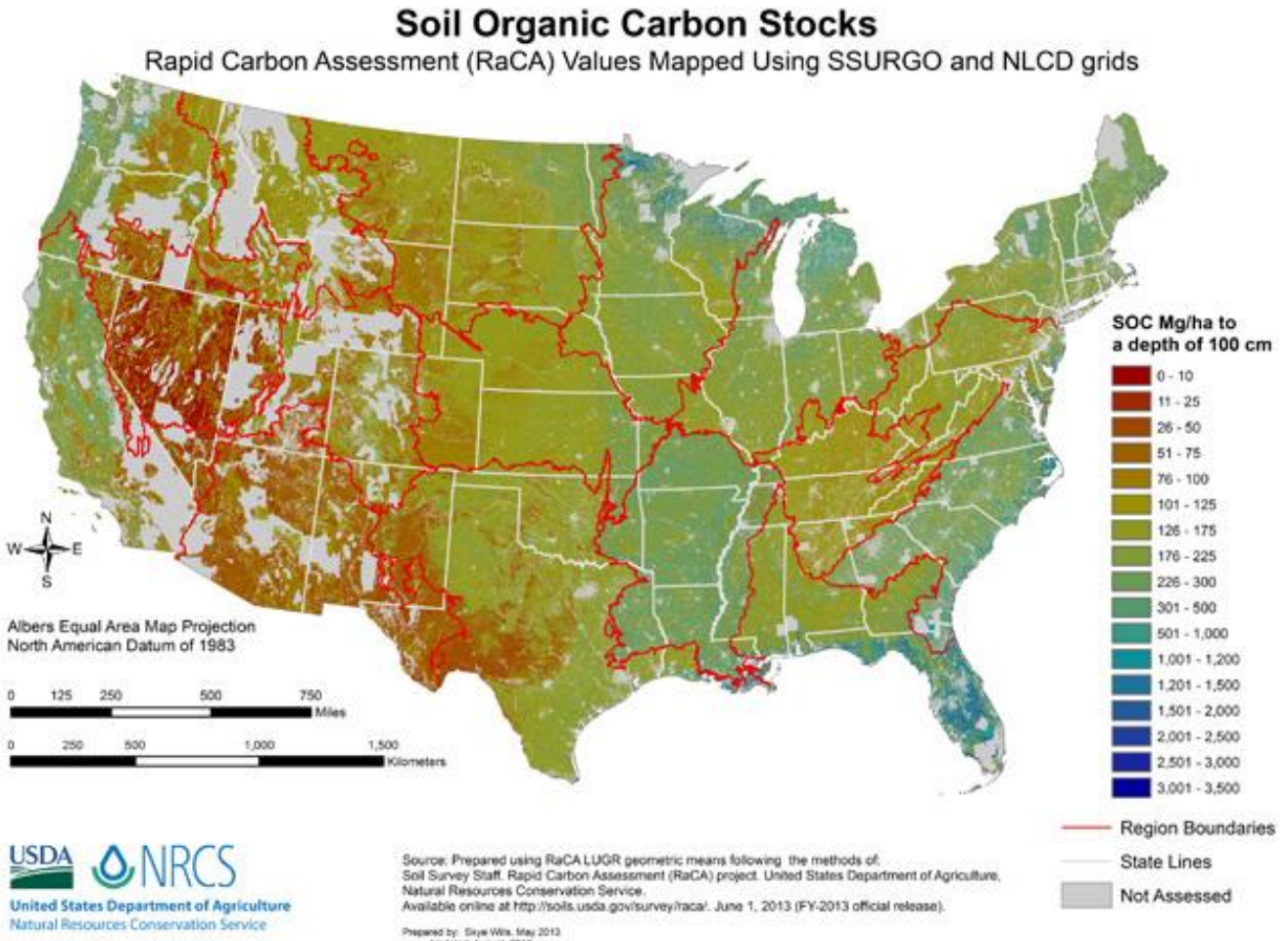
  5.5 to 8.5 (Temperate Agricultural Soil)



Fundamental soil properties

Soil Organic Carbon

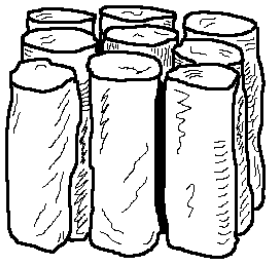
0.5 to 4 % Soil Organic C in topsoil of majority of temperate agricultural soil



Organization of Soil in the Field

Bulk Soil

Bulk Density — 1.0 to 1.62 g cm^{-3}
root limiting ~ 1.3/1.5 1.7-for sure!



Porosity — 0.62 to 0.38 % pores by vol.
root limiting ~ 0.38-0.35

Soil Structure: Related to the arrangement and organization of the soil phases

Affects: Pore-network connectivity, tortuosity

Courtesy of the NCSU Soil Science Flickr Stream

Proximal Sensing

Proximal Sensing: non destructive, field-located sensing of soil properties

Surfing

High resolution surface (x,y) mapping

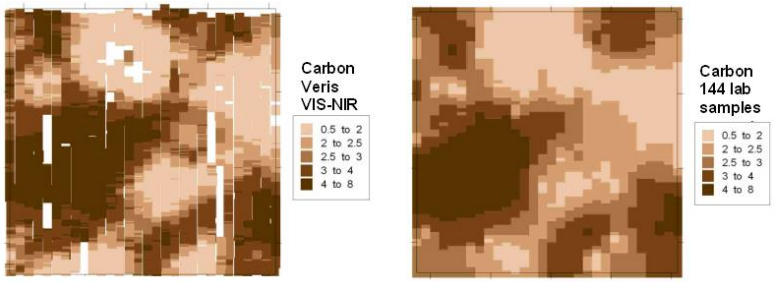
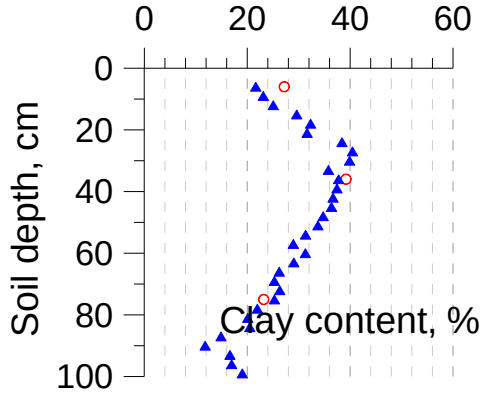


Image from Veris Technologies

e.g. Christy, 2008; Bricklemyer and Brown 2010

Diving

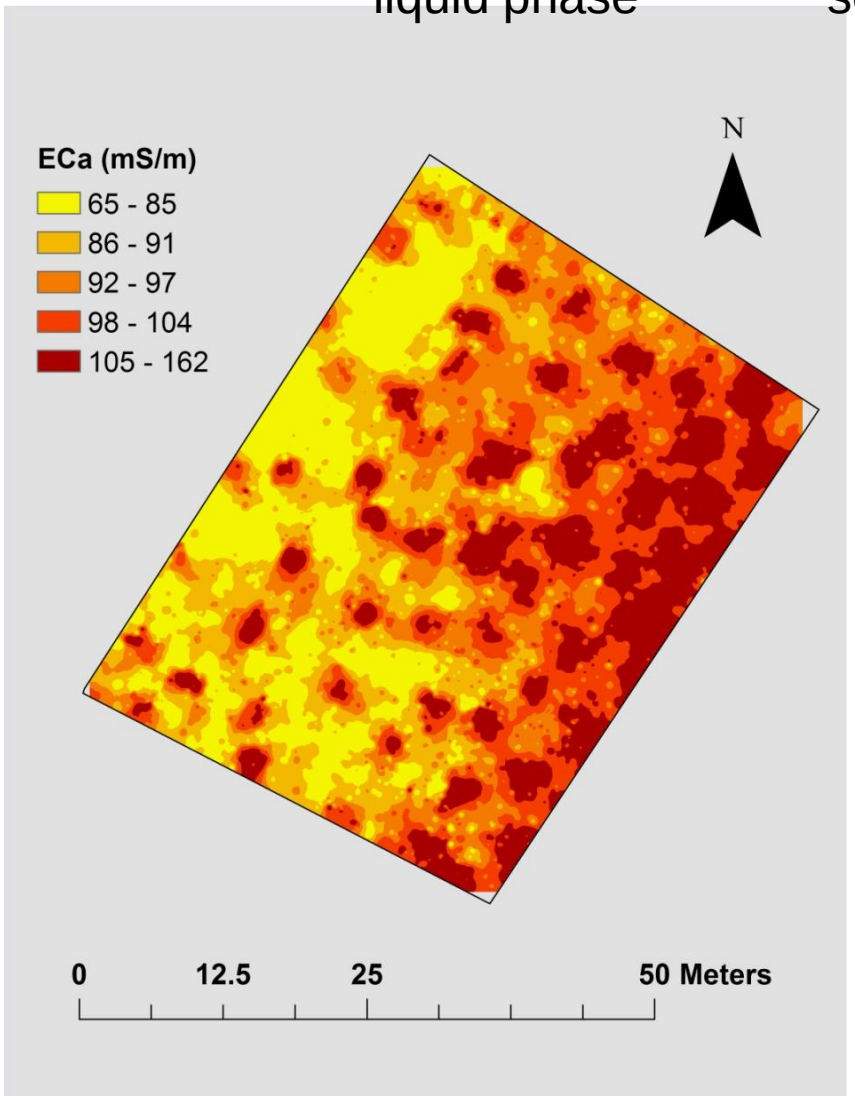
High resolution profile mapping (z)

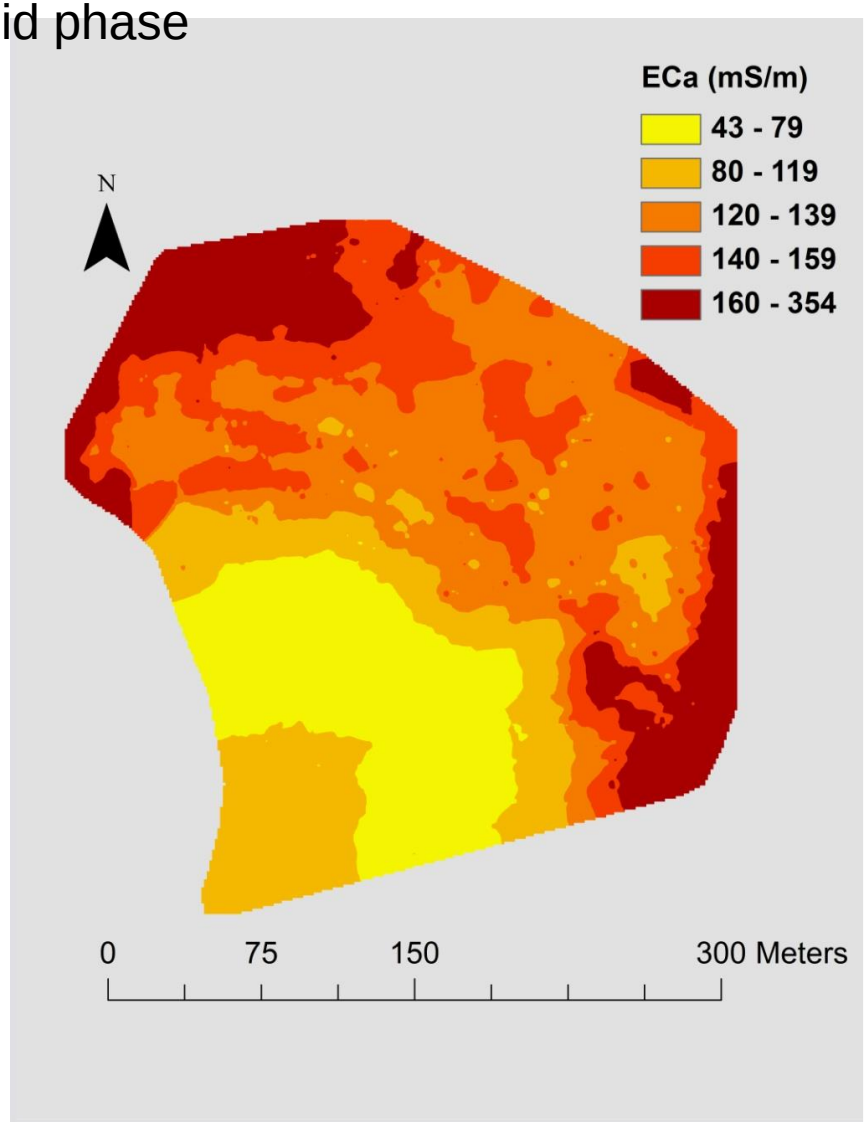


e.g. Waiser et al. 2007; Ackerson et al. 2015

Field Measurements: Electromagnetic Induction

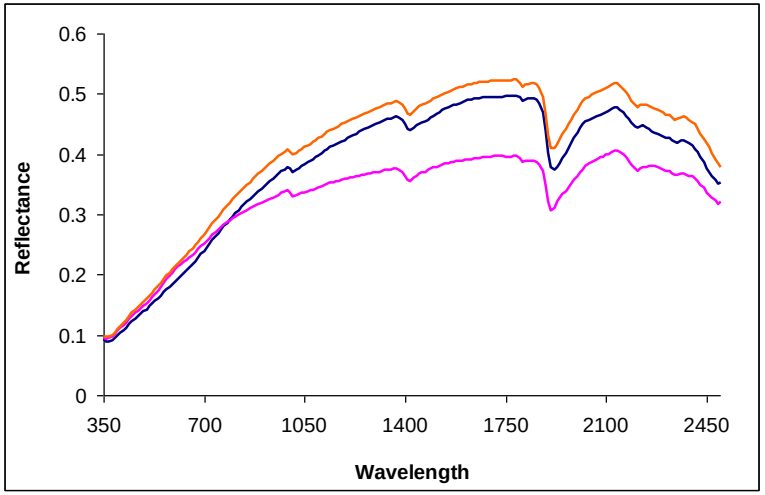
$$ECa = EC_{liquid\ phase} + EC_{solid\ phase}$$

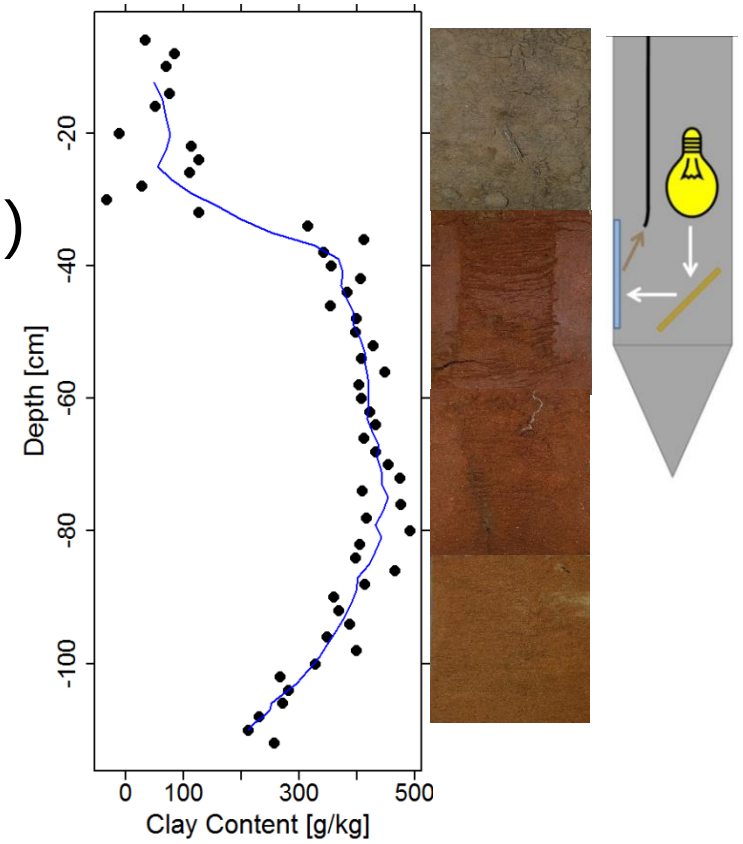




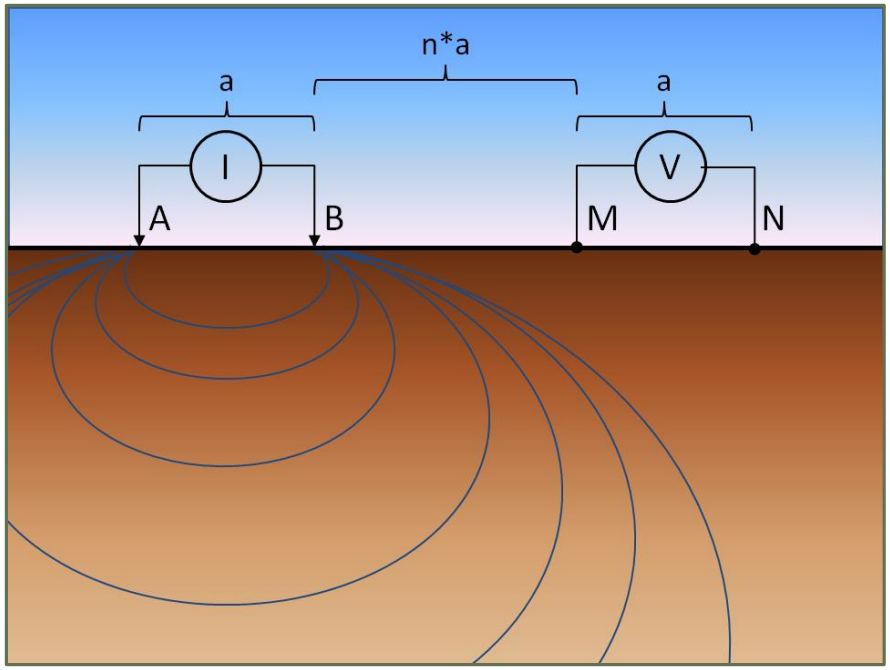
Field Measurements: Penetrometer Mounted VisNIR DRS

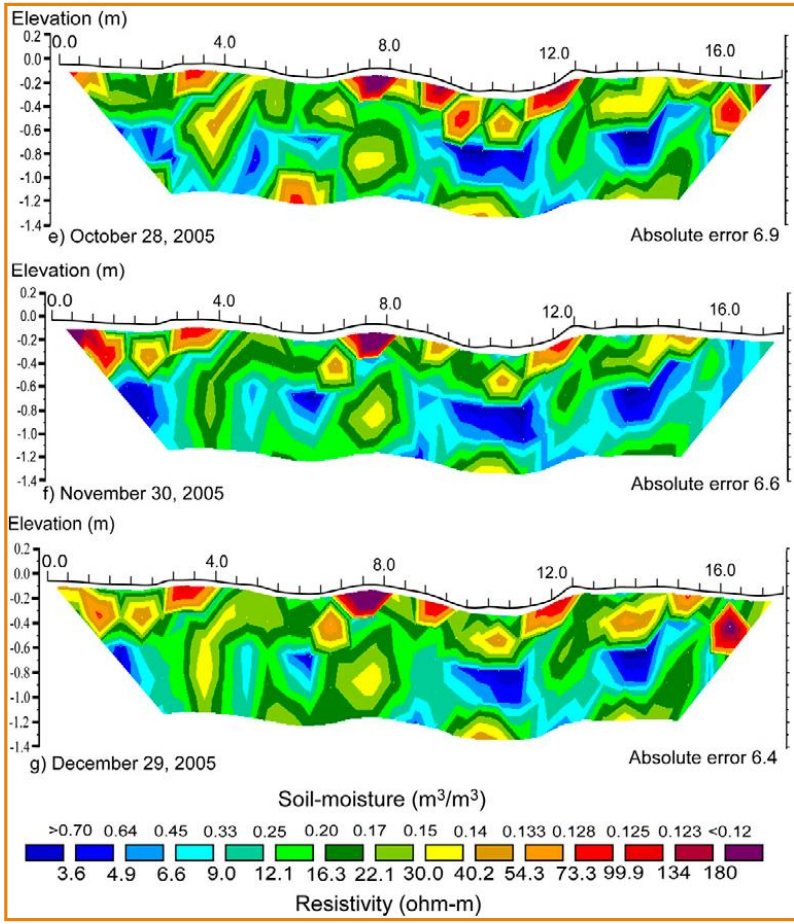
Clay Content (RMSE 5 %)
Organic Carbon (RMSE 0.5 %)
Inorganic Carbon (RMSE 0.8 %)





Field Measurements: Electrical Resistivity Tomography



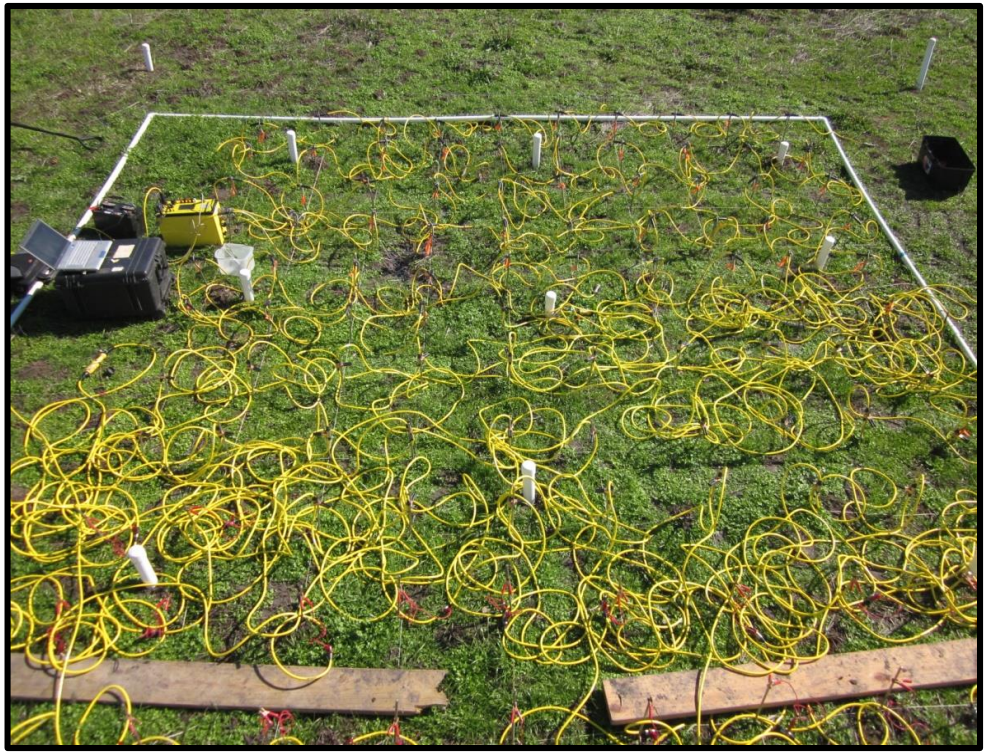


Case study: ERT in Vertisols

Cracking soils

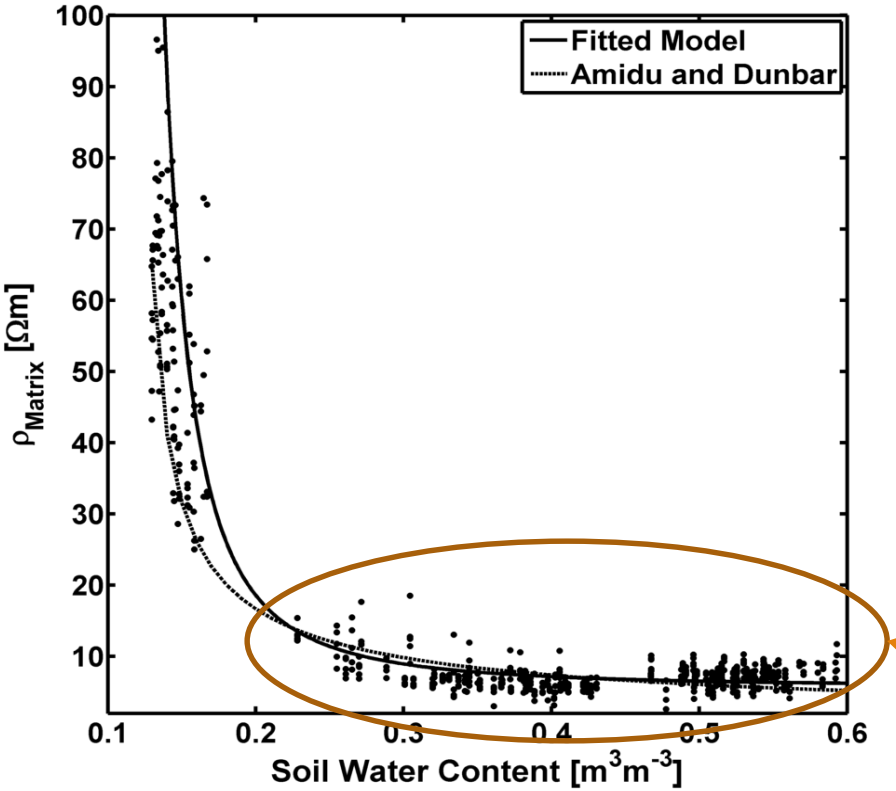
Non destructive/temporal measurements of

1. Soil water content
2. Crack volume and location

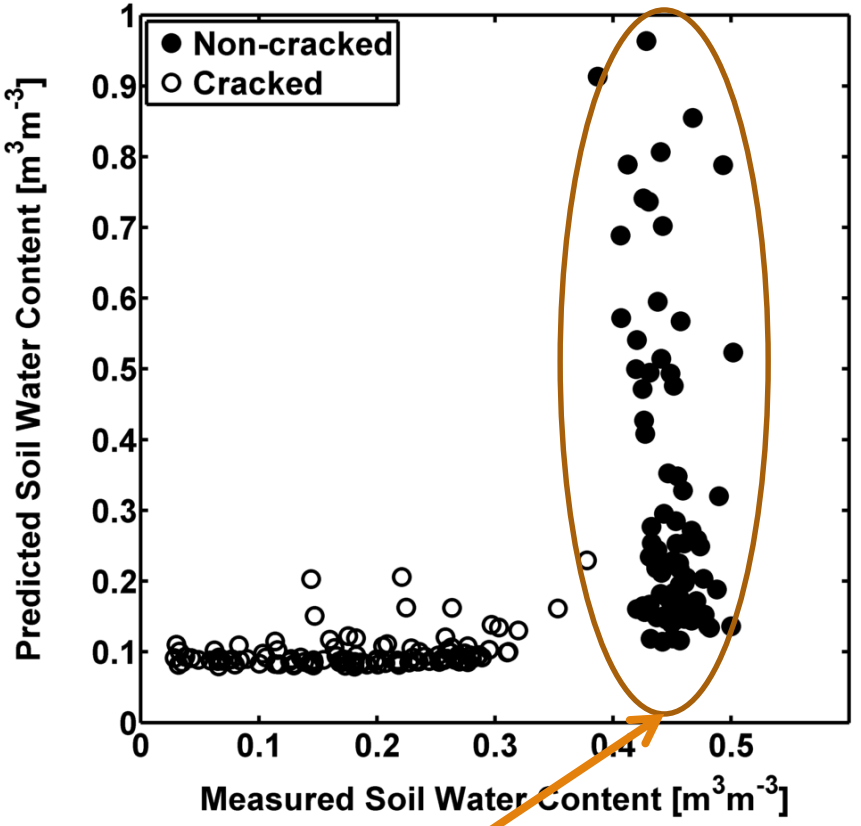


ERT and Soil Water Content

Laboratory Data



Field Data

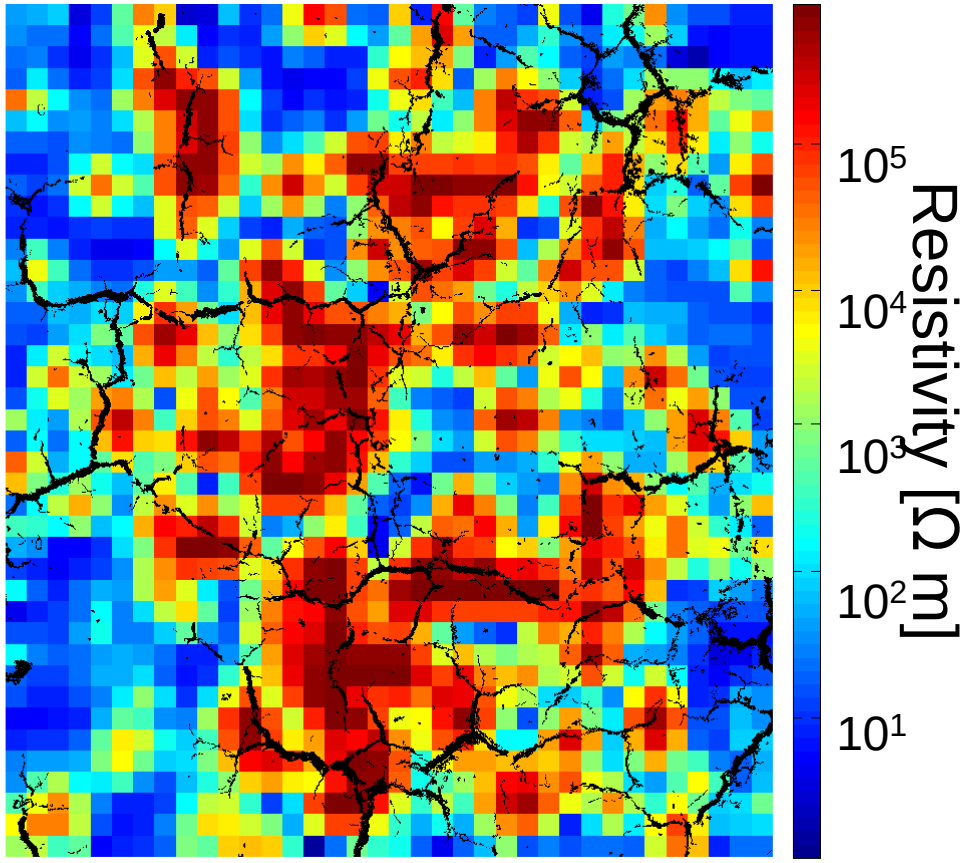


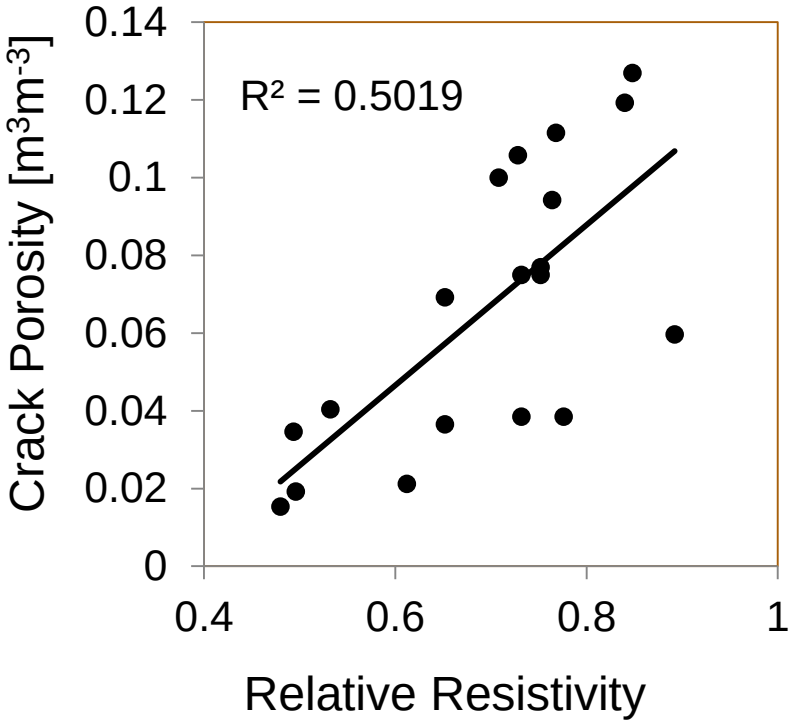
Poor contrasts between soils at different water content

Ackerson et al., 2014

ERT and Cracking

Strong contrast
between cracks & soil





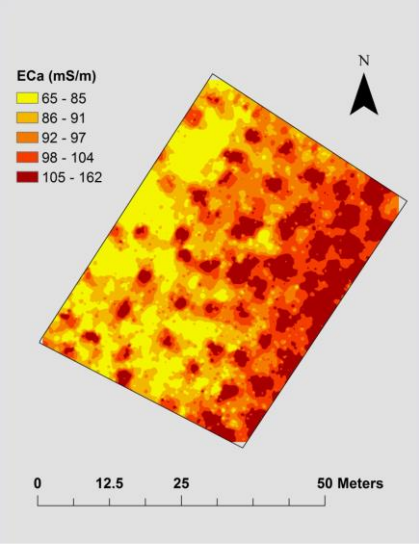
Ackerson, 2014

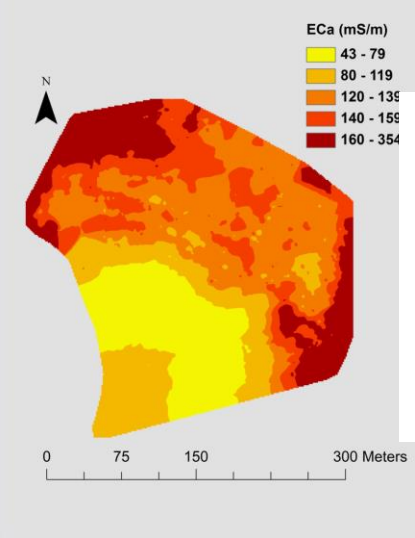
Spatial Variability

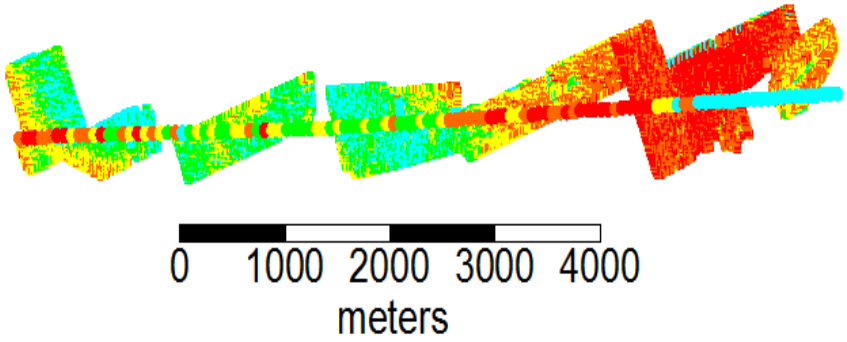
Soil properties vary at all spatial scales

Soil properties that affect soil organic C at the watershed (km) and field (m) scale include

- Texture (particle Size distribution)
- Topography characteristics (wetness index/drainage)
- Soil condition







Summary

The efficacy of imaging or sensor technology is soil dependent

Electromagnetic Induction: good for spatial structure of soil change

VisNIR: good for point-profile measurements e.g. soil organic C spatial variability and stock (precision is 0.5 % SOC)

ERT: good for monitoring change over time

Soil function in the field determines the efficacy of ERT

- Poor measurement of water content
- Good measurement of cracking