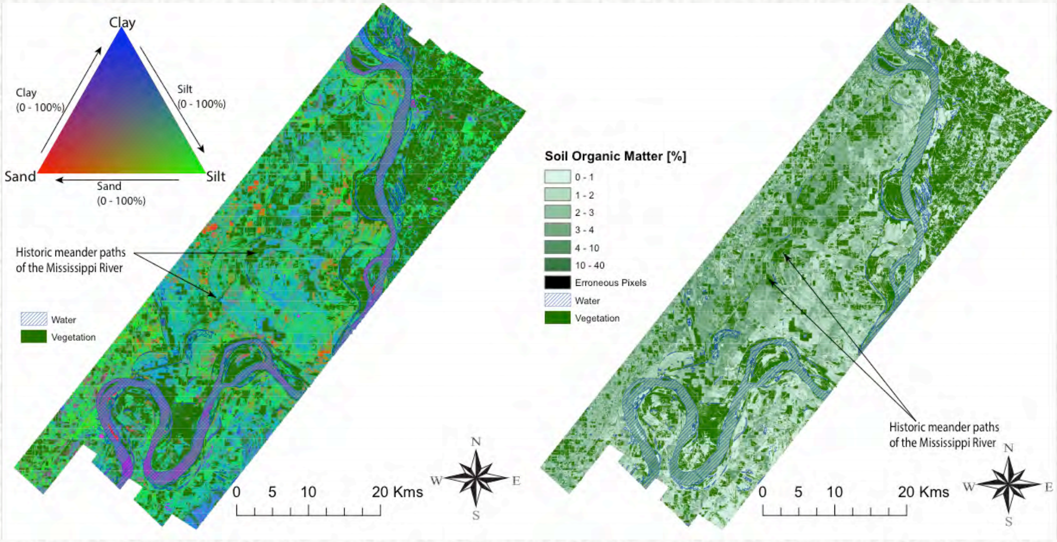
Effect of Spatial Resolution on Characterizing Soil Properties from Imaging Spectrometer Data



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Presented at

HyspIRI Science and Applications Workshop - Caltech

October 2015

Problem Statement and Research Questions

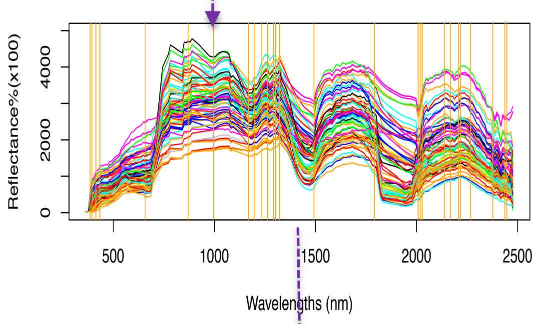
1. *What is the feasibility of quantification of the soil properties/constituents using airborne imaging spectroscopy data ?*

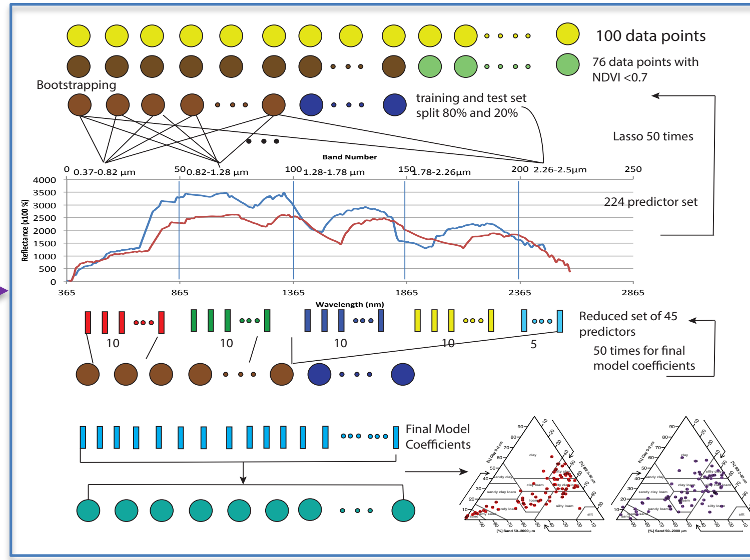
2. *What is the Effect of Spatial Resolution (Scaling Up) on the Characterization of Soil Constituents?*

Approach – Feasibility of Characterizing Soil Constituents over Large Areas

Soils are complex Heterogeneous system

Take advantage of the AVIRIS spectra (224 bands @10 nm) covering the full Vis-NIR and SWIR region of the spectra





Very few field observations

Characterizing soil attributes over large areas

Develop a modeling framework applicable over large areas

Evaluate the consistency of results over the landscape

Generally an over-determined problem with p >>n

-"lasso" method suited for p >>n

-sparse "narrow band" models will be able to capture soil attributes

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n$$

Application of models spatially over large areas

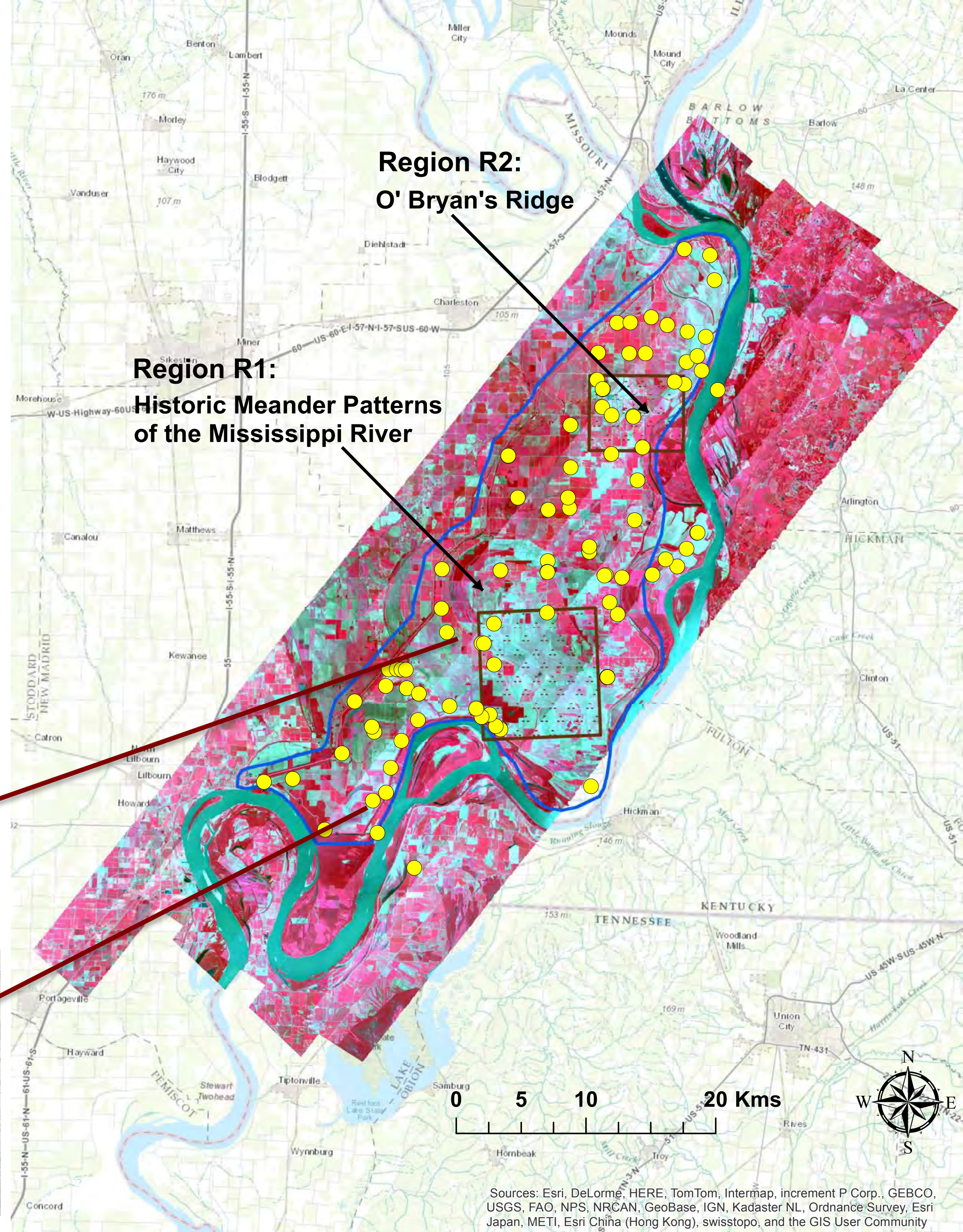
Gain insights into the model structure

Captures variability in attributes spatially ?

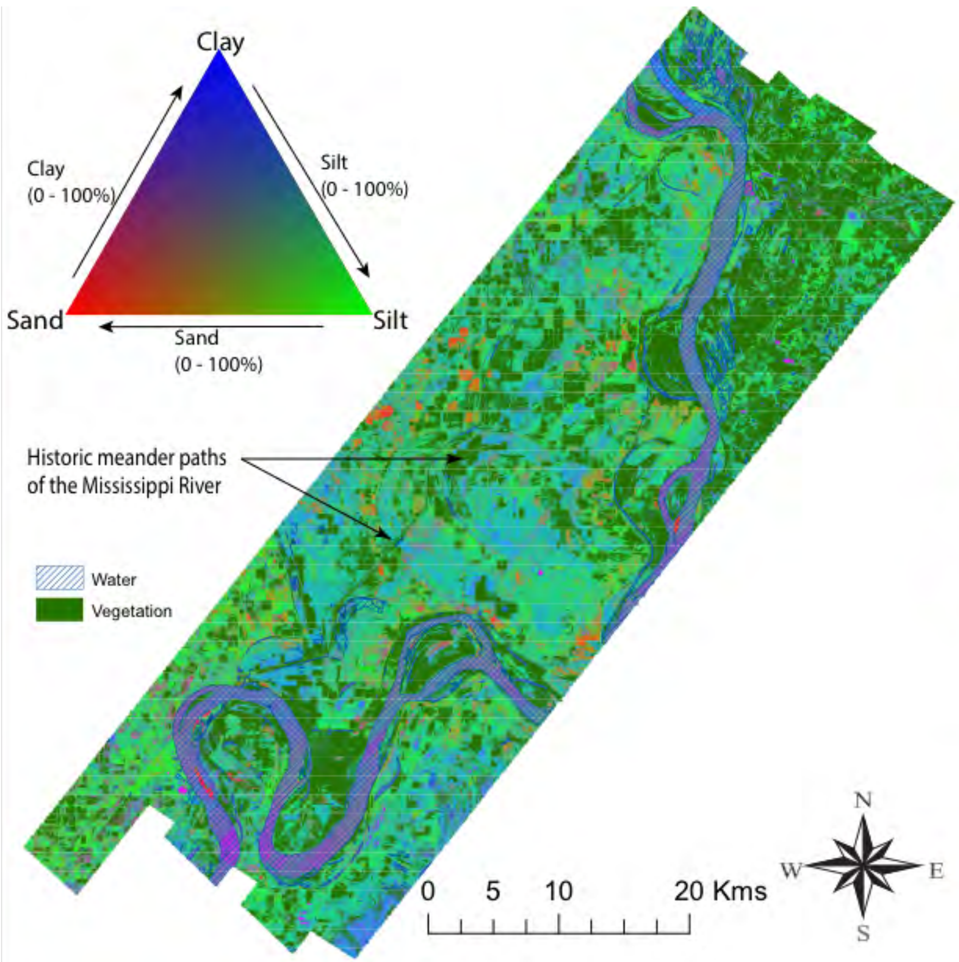
Dutta et. al., On the Feasibility of Characterizing Soil Properties From AVIRIS Data, IEEE TGRS, Sept 2015: doi: 10.1109/TGRS.2015.2417547

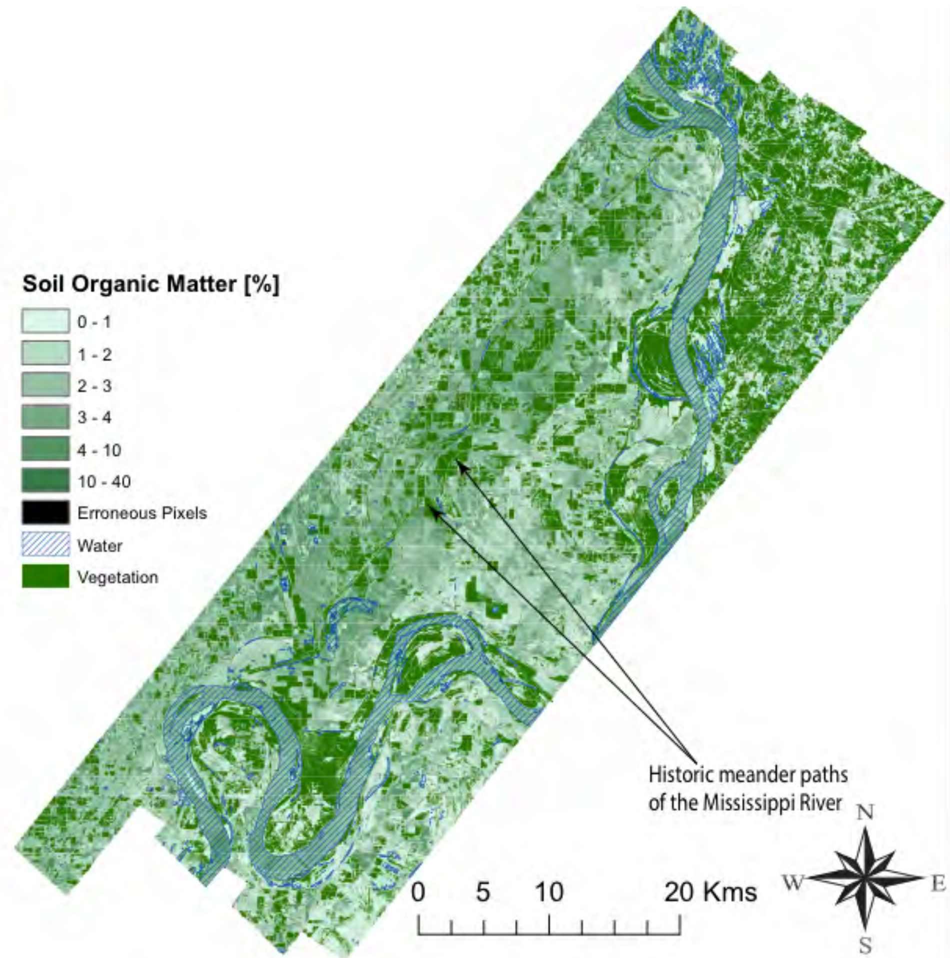
Data and Study Region

- 27^{th} July 2011 between 14:04 and 15:00 local time (19:04 – 20:00 GMT).
- Altitude 9.0 – 9.1 km resulting in pixel resolution of 7.6m.
- Grab samples at 100 different locations.
- Lab analysis of texture and chemical constituents, Organic matter, Ca, Mg, K, Al, B, S, Fe, Zn, Cu, P and Mn

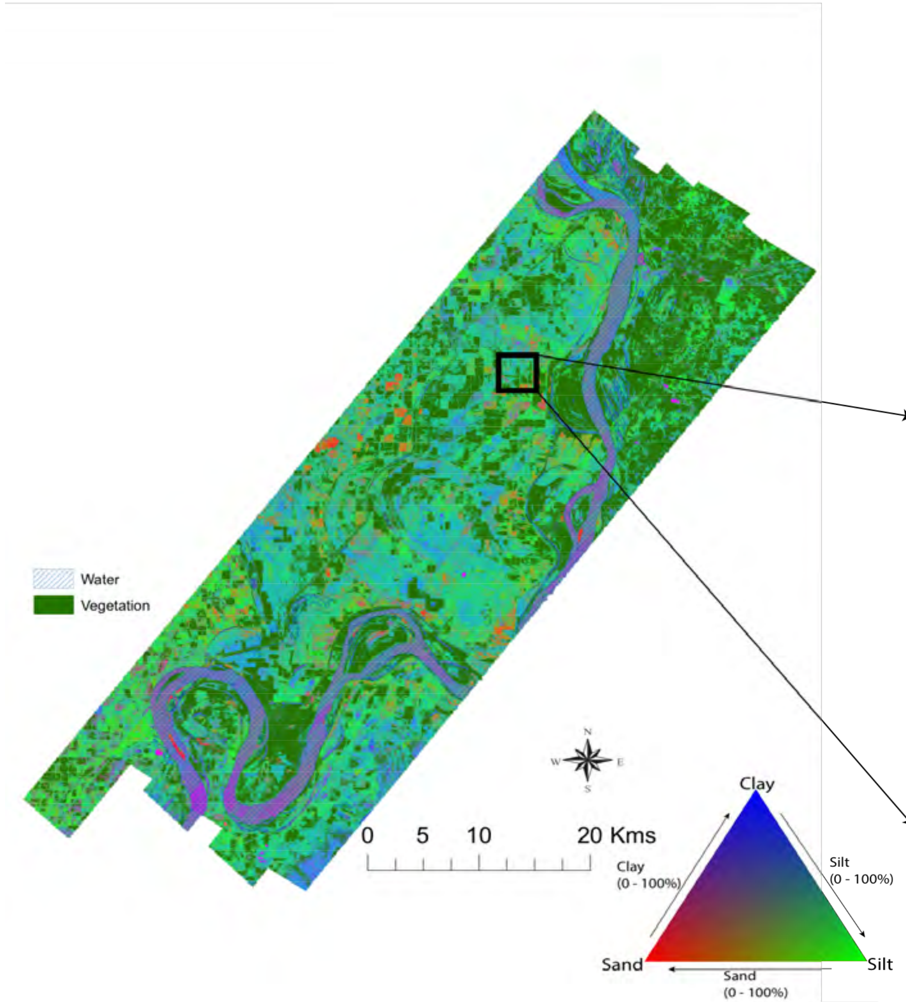


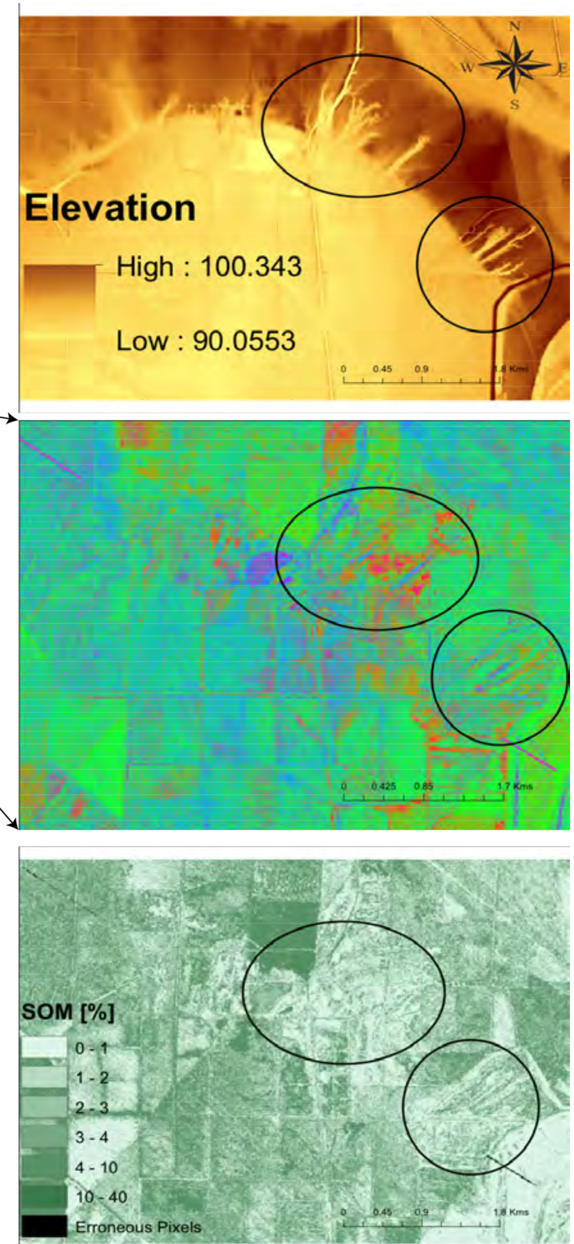
Results – Spatial Maps of Texture and Organic Matter





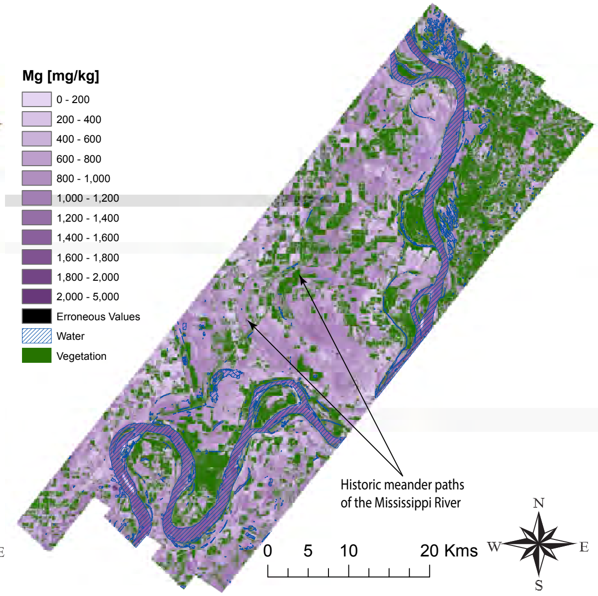
Results – Spatial Organization and Landscape Features

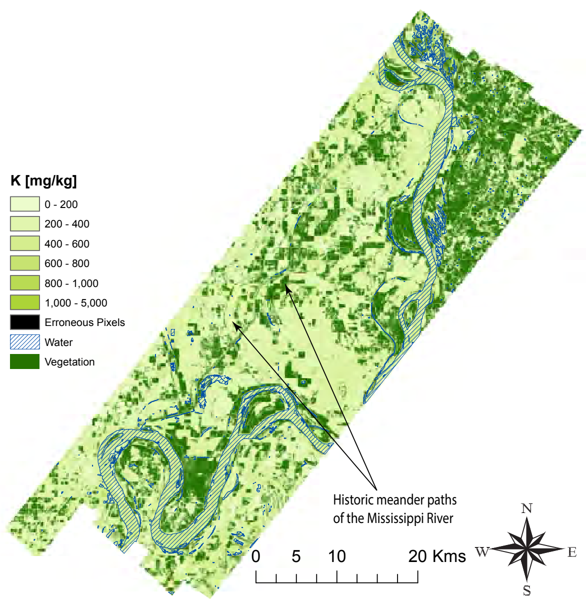


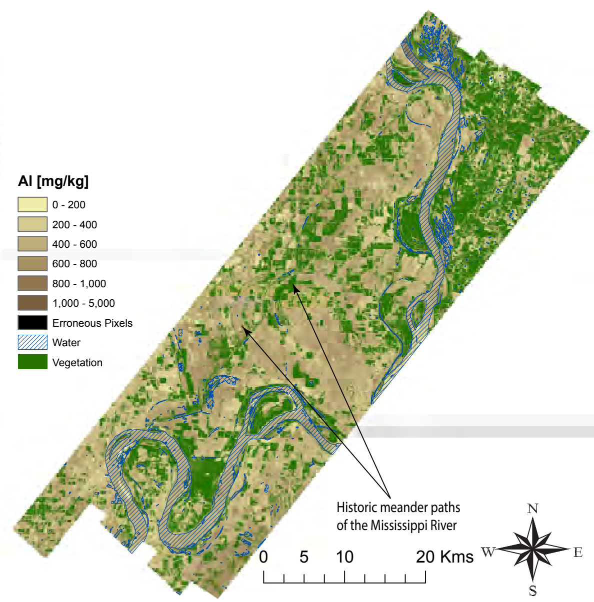


The spatial maps which reveals consistent spatial organization including legacy landscape features and immediate fine scale disturbances on the landscape.

Results – Spatial Maps of Chemical Constituents







Guiding Research Questions

1. *What is the feasibility of quantification of the soil properties/constituents using airborne hyperspectral data ?*

   – "Lasso" algorithm based framework found to be feasible to quantify soil constituents over large areas with limited soil sample data and field spectroscopy.

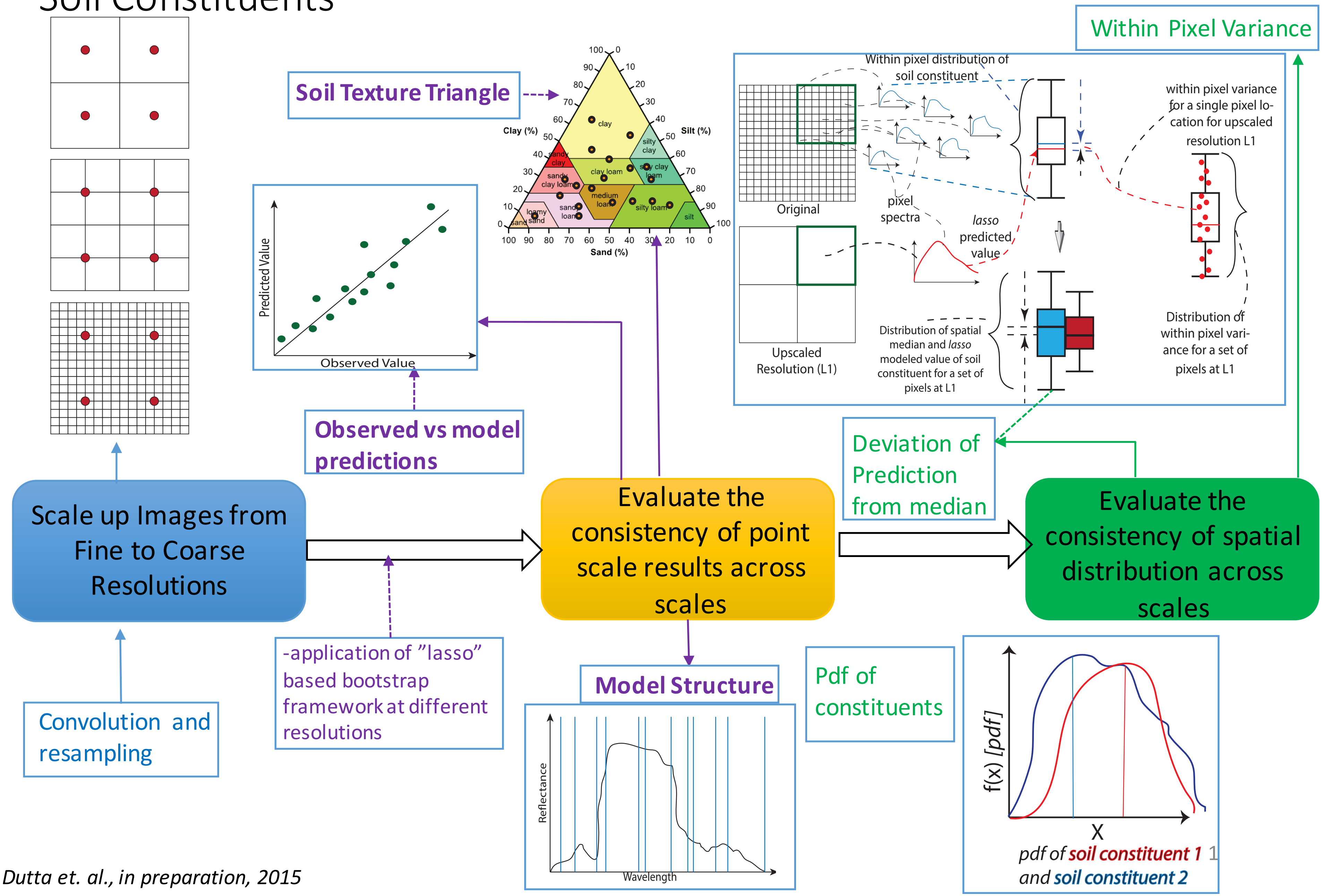
   – Method is applicable equally well for soil texture and chemical constituents and provides spatial maps which reveals consistent spatial organization including legacy landscape features and immediate disturbances on the landscape.

2. *What is the Effect of Spatial Resolution (Scaling Up) on the Characterization of Soil Constituents?*

   – *Feasibility of application of the data-mining based method for quantifying soil constituents from space based satellite platforms?*

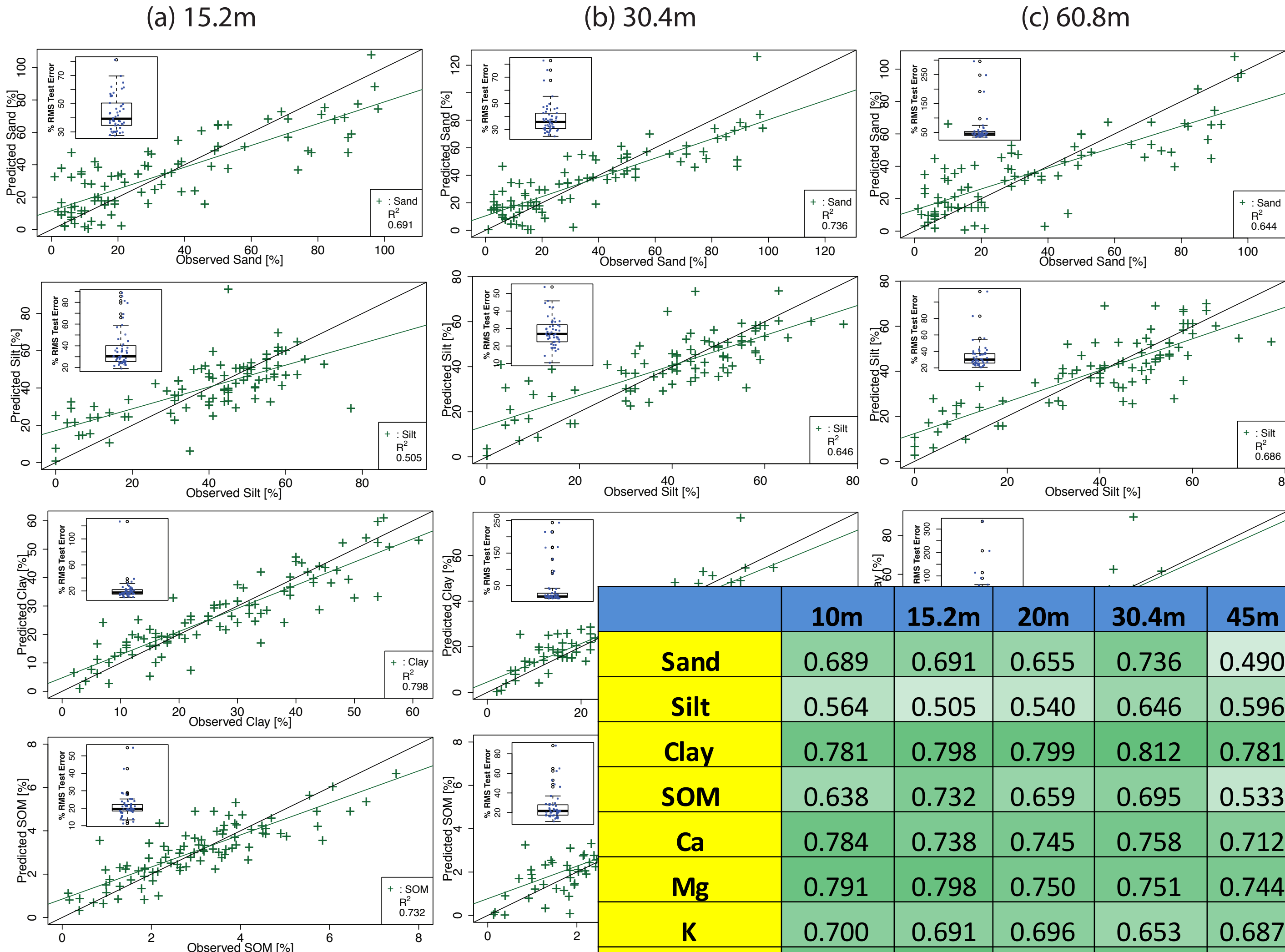
   – *Developing a suitable set of metrics for evaluation of performance and consistency of results across scales?*

Approach for Evaluating Effect of Scale on the Characterization of Soil Constituents



Dutta et. al., in preparation, 2015

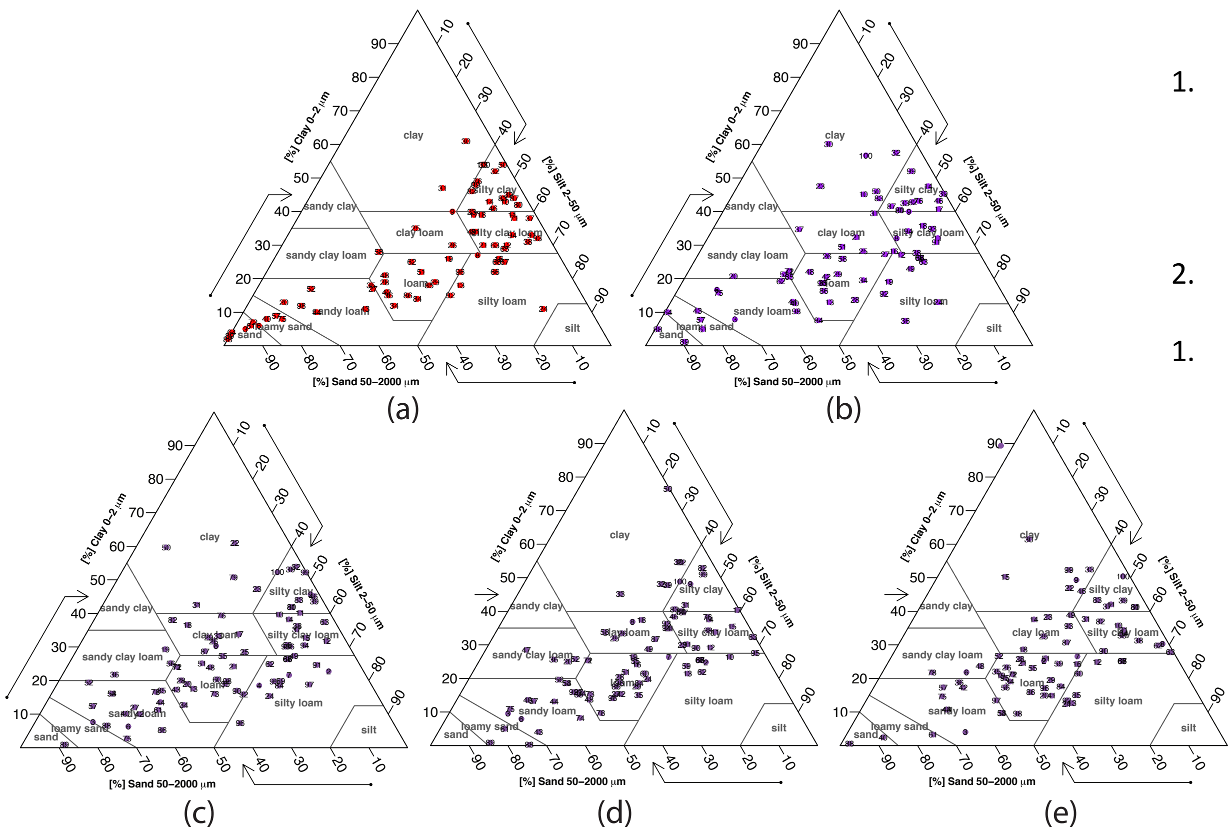
Point Scale Evaluation of Results – Observed vs Model Prediction



Summary of R^2 values for all the resolutions

	10m	15.2m	20m	30.4m	45m	60.8m	90m
Sand	0.689	0.691	0.655	0.736	0.490	0.644	0.657
Silt	0.564	0.505	0.540	0.646	0.596	0.686	0.361
Clay	0.781	0.798	0.799	0.812	0.781	0.791	0.762
SOM	0.638	0.732	0.659	0.695	0.533	0.718	0.557
Ca	0.784	0.738	0.745	0.758	0.712	0.739	0.748
Mg	0.791	0.798	0.750	0.751	0.744	0.767	0.705
K	0.700	0.691	0.696	0.653	0.687	0.698	0.658
Al	0.774	0.814	0.737	0.776	0.709	0.760	0.748
Fe	0.579	0.535	0.624	0.425	0.453	0.586	0.464

Point Scale Evaluation of Results – Soil Texture Triangles



1. If the observed and the model predicted soil properties belong to the same USDA soil texture class, we call it a coincident match or exact classification.

2. Otherwise we compute the total deviation.

1. If the total deviation (Δtotal%) is less than or equal to 25% we call it a 'close' classification, otherwise we call it an 'incorrect' classification.

$$\Delta_{sand\%} = |\Delta^{observed}_{sand\%} - \Delta^{predicted}_{sand\%}|$$

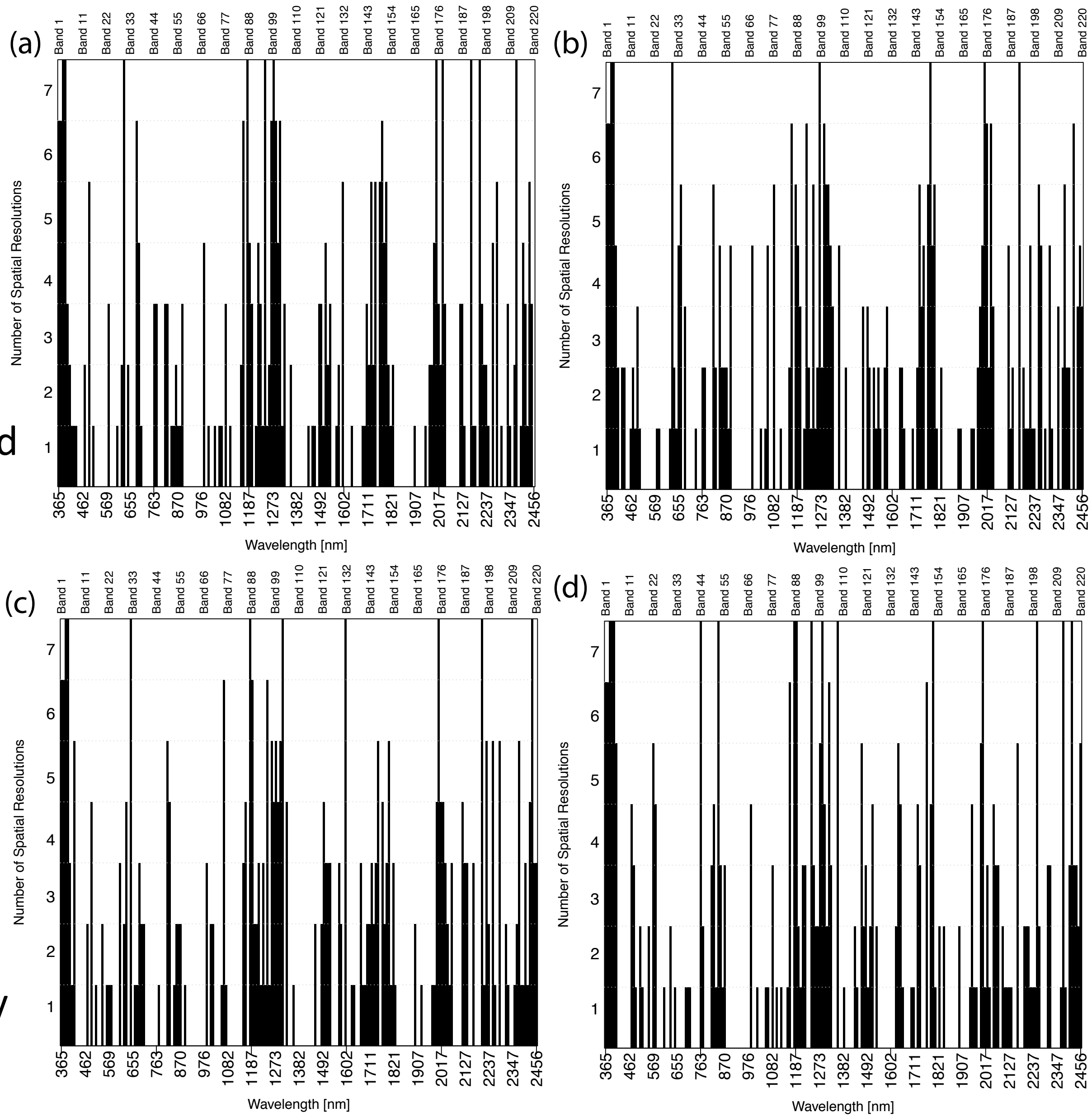
$$\Delta_{clay\%} = |\Delta^{observed}_{clay\%} - \Delta^{predicted}_{clay\%}|$$

$$\Delta_{total\%} = \Delta_{sand\%} + \Delta_{clay\%}$$

(a) The observed (b) model predicted points at 7.6 m airborne AVIRIS resolution (c) model predicted up-scaled 15.2 m (d) 30.4 m and (e) 60.8 The sample numbers are indicated on each of the dots.

Spatial Resolution	Exact Classification[%]	Close Classification[%]	Incorrect Classification[%]
10 m	46.67	28.89	24.44
15.2 m	42.86	38.46	18.68
20 m	40.22	40.22	19.57
30.4 m	43.96	43.96	12.09
45 m	43.33	36.67	20.00
60.8 m	46.51	40.70	12.79
90 m	37.35	33.73	28.92

Point Scale Evaluation of Results – Model Structure



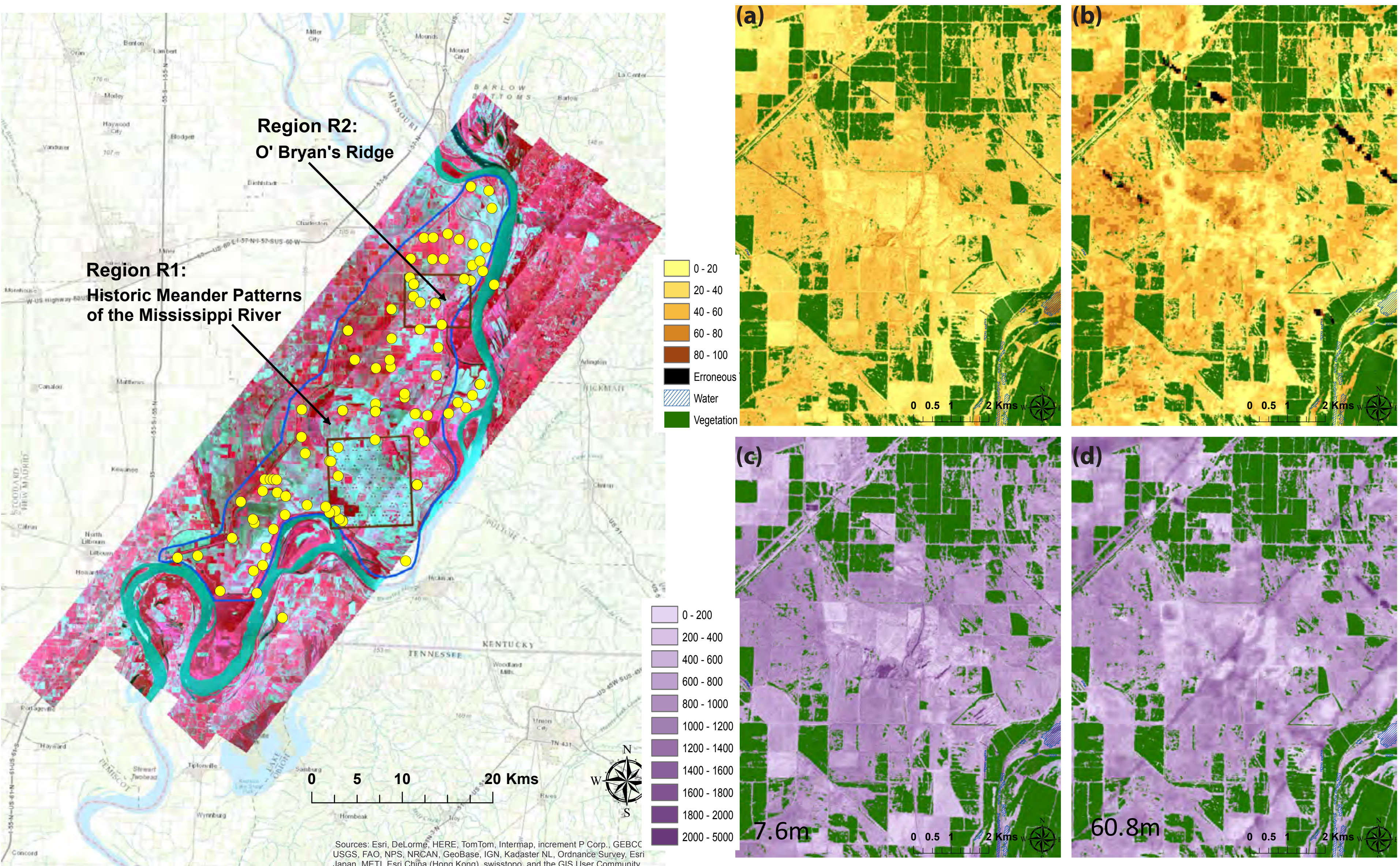
Sand

Silt

Clay

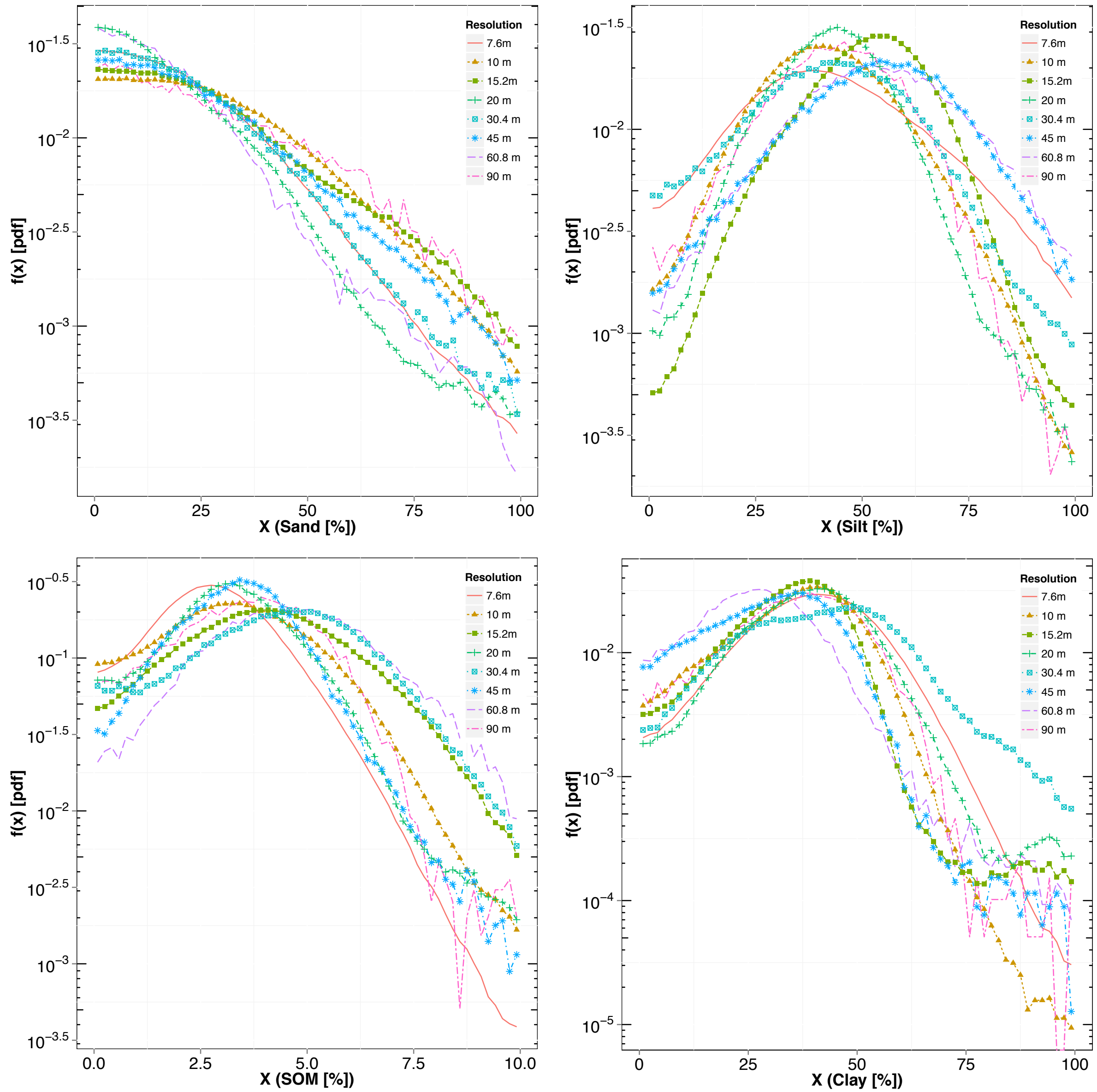
Organic Matter

Spatial Distribution of Soil Constituents Across the Landscape

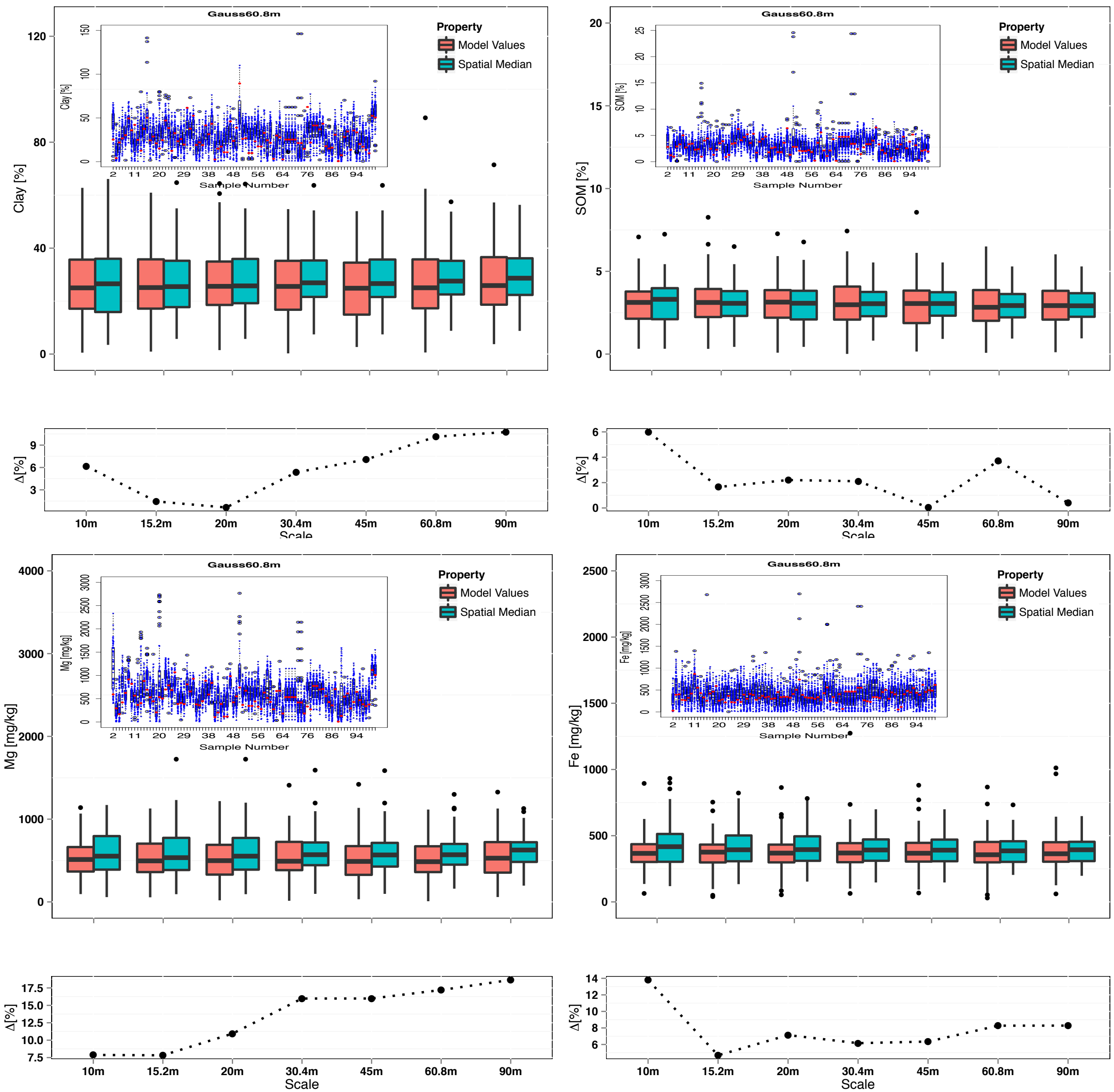


Spatial Distribution of Soil Constituents Across the Landscape - *pdfs*

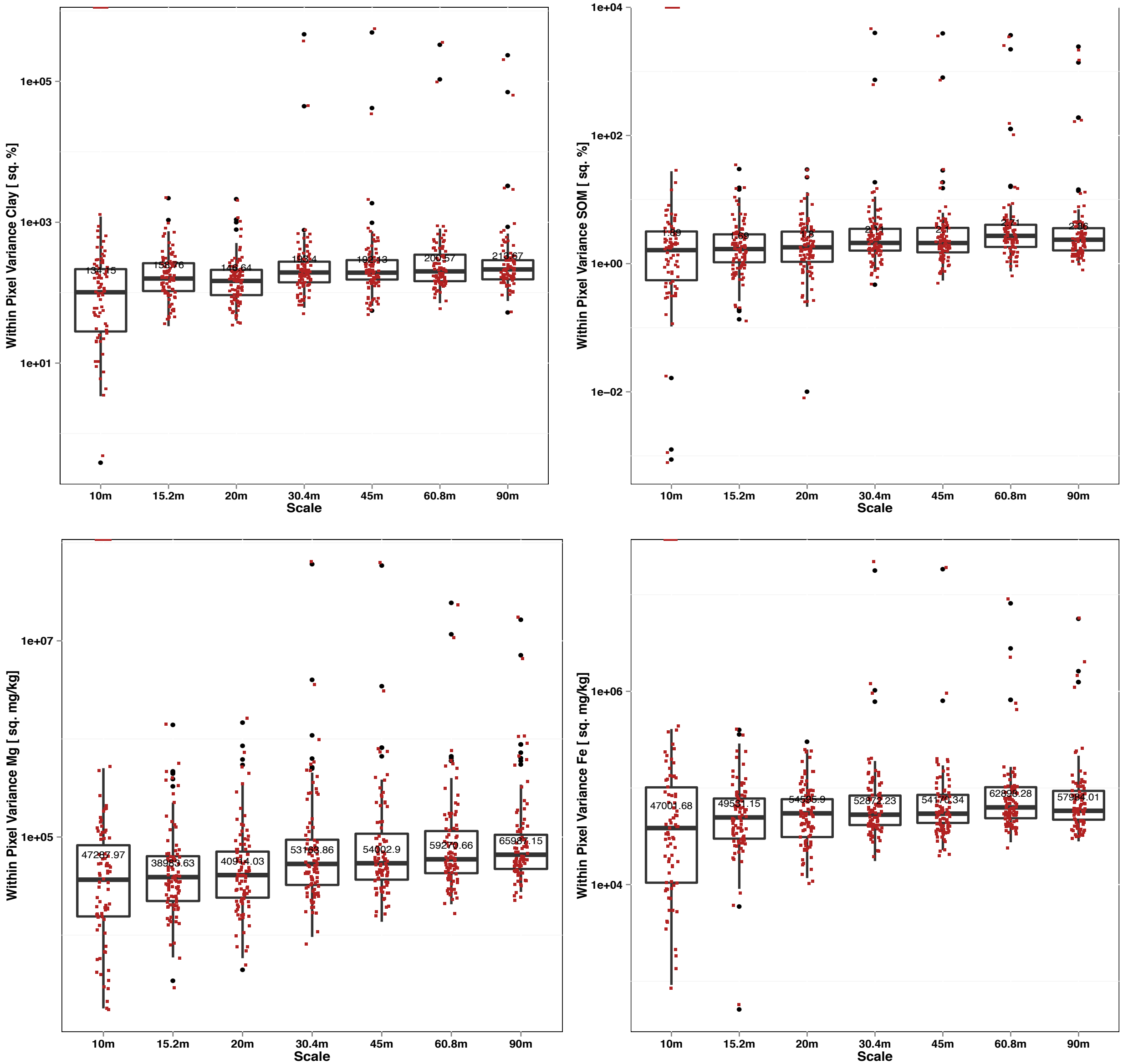
Region:R1



Spatial Distribution of Soil Constituents Across the Landscape – Deviation from Statistical Central values



Spatial Distribution of Soil Constituents Across the Landscape – Within Pixel Variances



Summary and Conclusions

- Lasso algorithm based modeling framework is applicable across multiple scales from fine to coarse spatial resolutions.

- The model structure across multiple resolutions reveals that important spectral features such as water absorption, minerals (clay, OH-, CO3-)are represented across multiple resolutions.

- The point scale results and the within pixel variance of constituents are found to be consistent across scales.

- The pdf of the constituents are also found to be similar across scales with slight shift in the modes for some constituents.

- The lasso based quantification method has the potential to be applicable from space-based sensors such as HyspIRI.

Thank you!