Measuring and modeling spatial variability of soil C

Sasha Kravchenko

Crop & Soil Sciences

Michigan State University

- Soil C is spatially variable at a variety of scales reflecting variability in soil forming factors (topography, parent materials, vegetation, etc.)
- Changes in land use or land management conducted across diverse landscapes result in spatially variable soil C responses

Example:

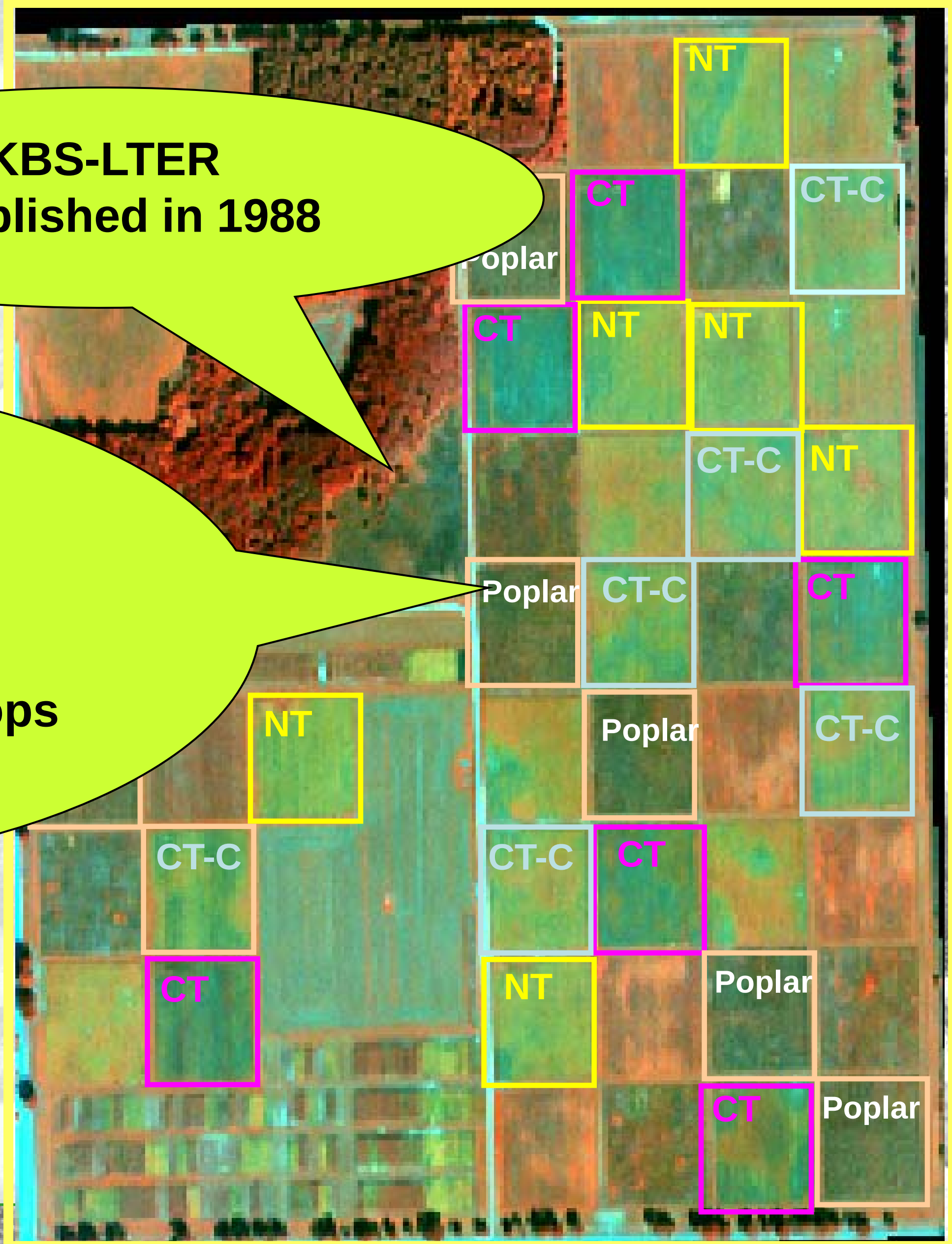
KBS-LTER
Established in 1988

Treatments

Tillage + chemical inputs **(CT)**

No-till + chemical inputs **(NT)**

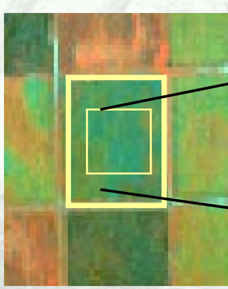
Tillage + organic with cover crops **(CT-cover)**

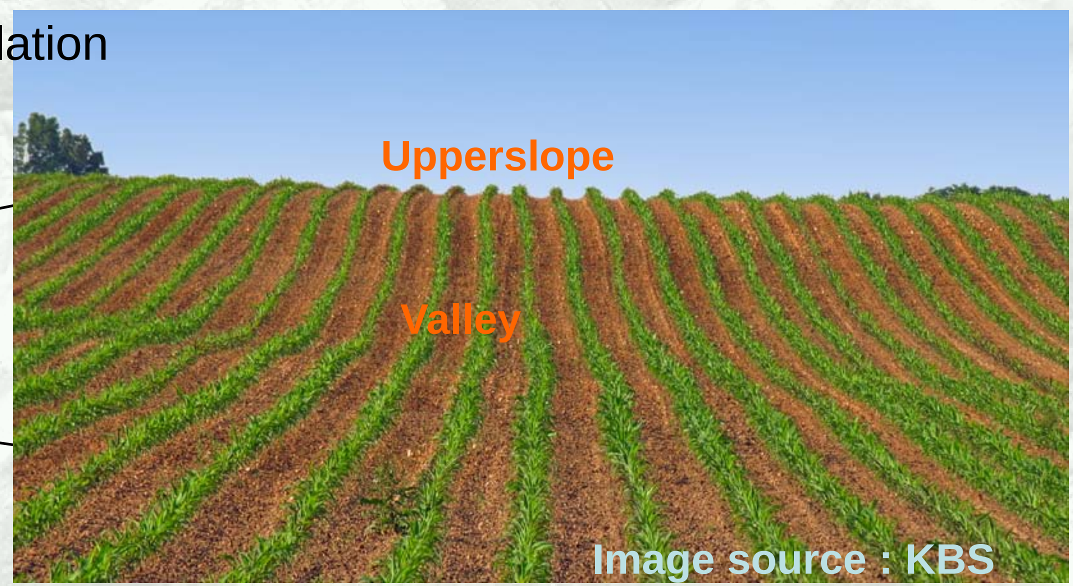


site-specific (e.g.,**topography**-specific) changes in soil C

- Outcome variable: Landform
- Potential explanatory variables
  - Elevation
  - Slope
  - Wetness index
  - Curvature
  - Flow accumulation

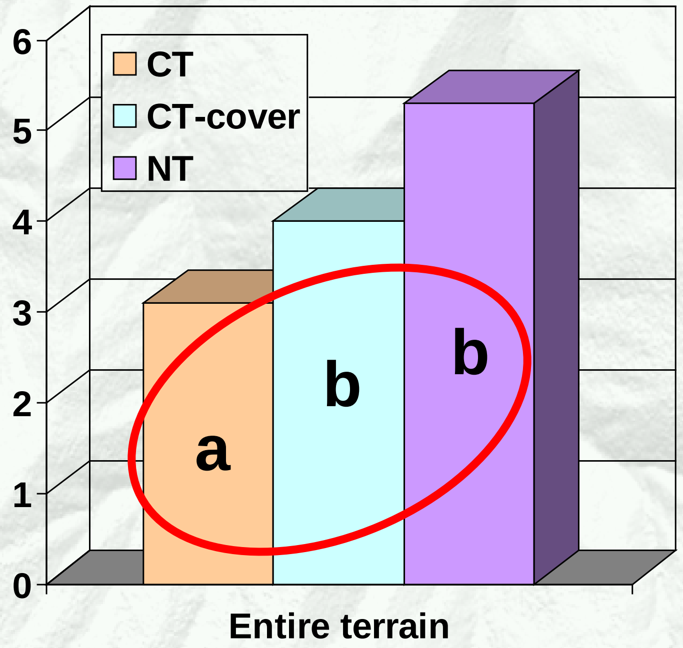
{ **Upperslope**
Valley

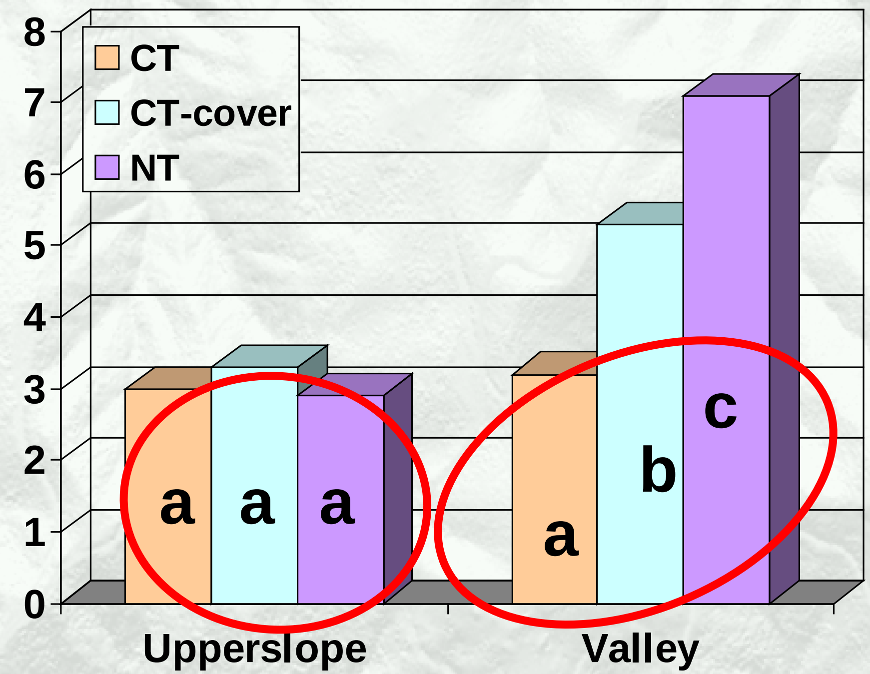




Differences in C content

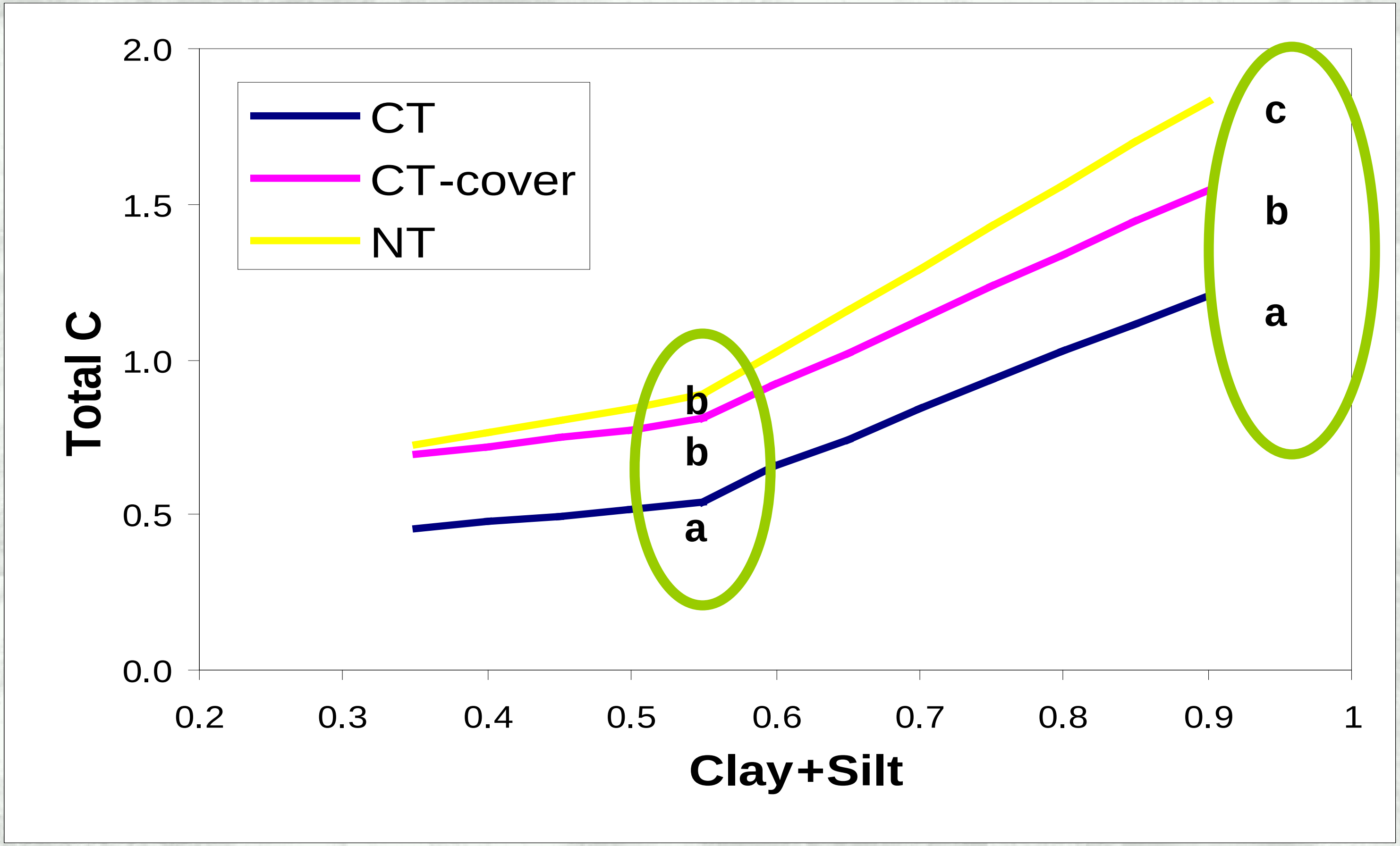
- 20-30 cm depth





Senthilkumar, S., A. N. Kravchenko, and G.P. Robertson. 2009. Topography influences management system effects on total soil carbon and nitrogen. Soil Sci. Soc. Am. J 73: 2059–2067

site-specific (e.g.,**texture**-specific) changes in soil C



Hao, X. and A.N. Kravchenko. 2007. Management practice effects on surface total carbon: Differences along a textural gradient. Agronomy J. 99:18-26

- **Land use/land management changes that reduce soil disturbance lead to formation of stronger spatial patterns in soil C distribution across diverse terrain**

photo credit J.E. Doll/KBS-MSU

Characterization of spatial variability patterns with geostatistical tools

Data

↓

Sample Variogram

$$\gamma(h) = \frac{1}{2N(h)} \sum_{\alpha=1}^{n} \left(z_i(\alpha) - z_i(\alpha + h) \right)^2$$

↓

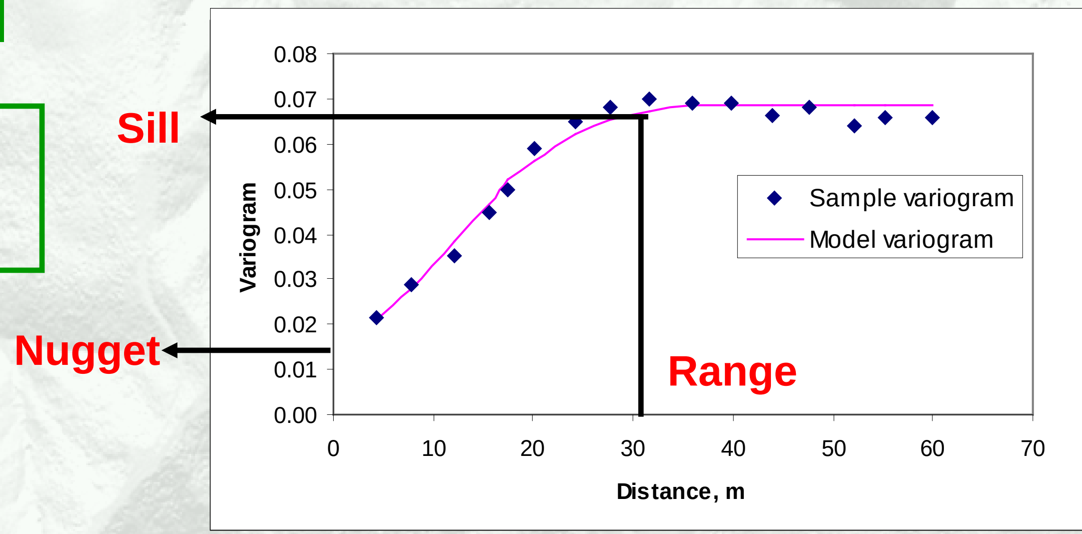
Variogram model fitting
(sph, exp, Gau)

↓

Testing model fit
(MSE, AIC)

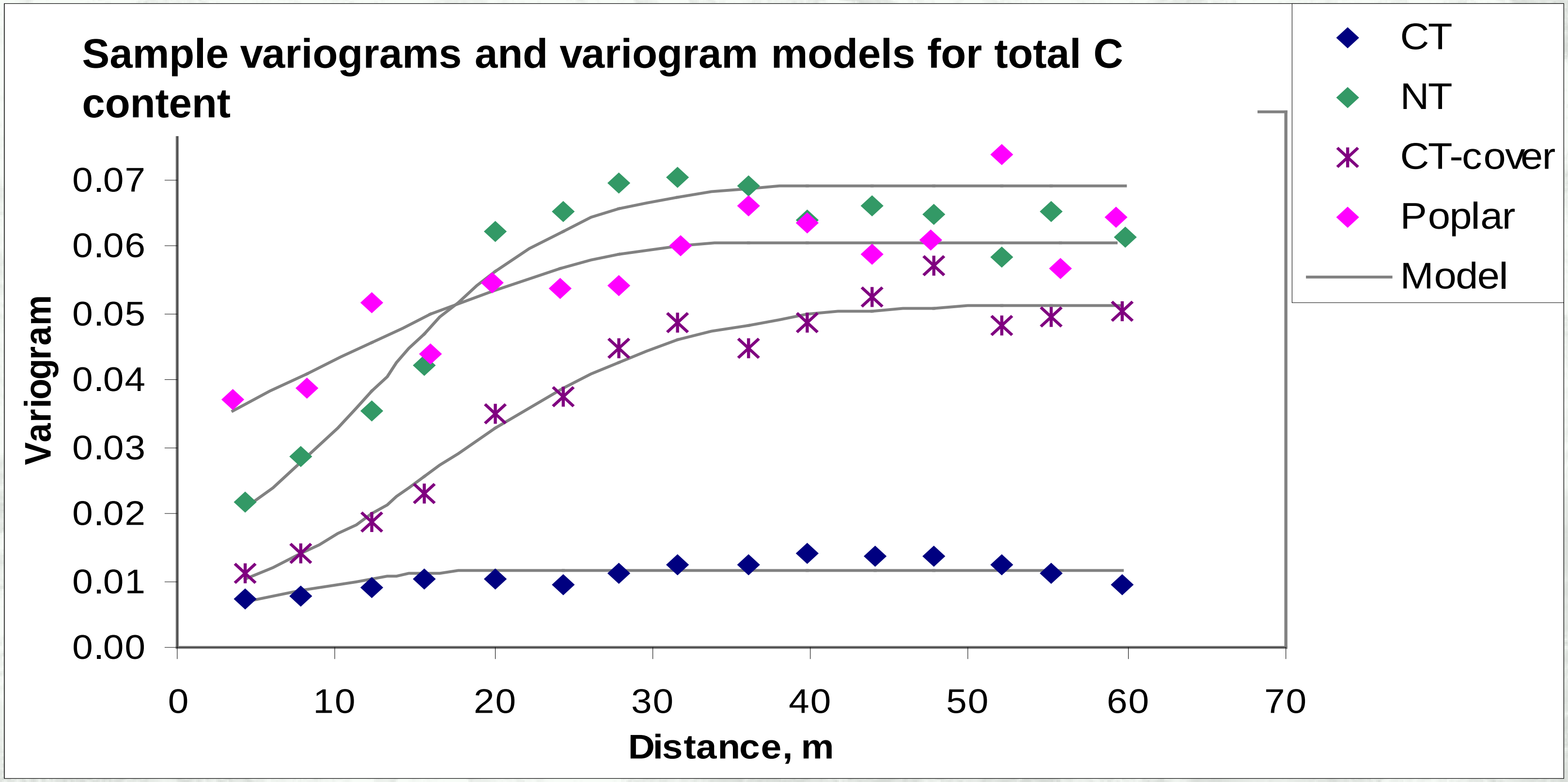
↓

Spatial Variability parameters
(nugget, sill, range, nugget: sill)



Comparing spatial variability patterns

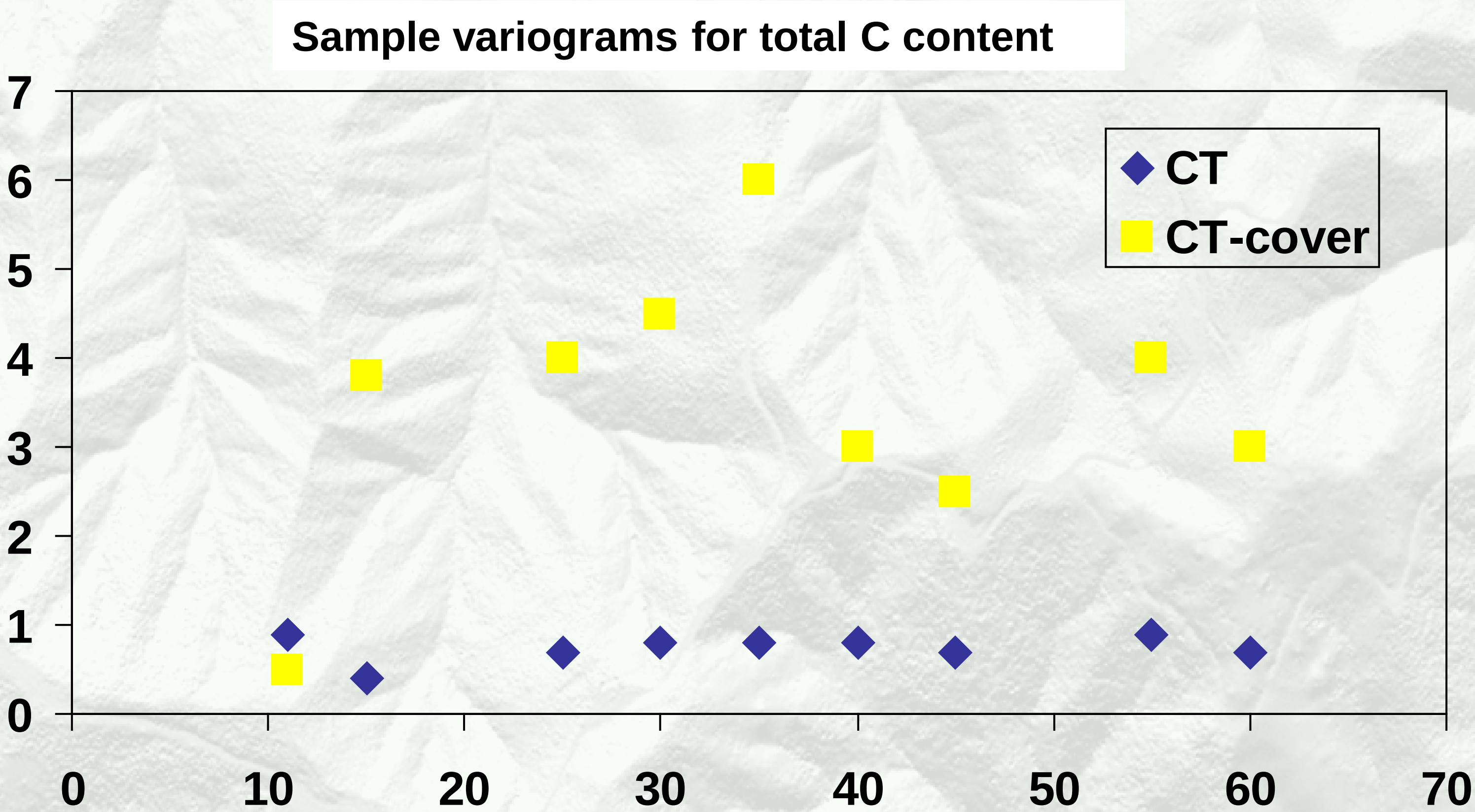
- 0-5 cm depth



Kravchenko, A.N., G.P. Robertson, X.Hao, and D.G. Bullock. 2006. Management practice effects on surface total carbon: Differences in spatial variability patterns. Agronomy J. 98: 1559-1568

Comparing spatial variability patterns

- 20-30 cm depth



Senthilkumar, S., A. N. Kravchenko, and G.P. Robertson. 2009. Topography influences management system effects on total soil carbon and nitrogen. Soil Sci. Soc. Am. J 73: 2059–2067

- Results obtained from a small plot experiment located at a carefully selected uniform experimental site
- How applicable can they be for a large scale assesment?

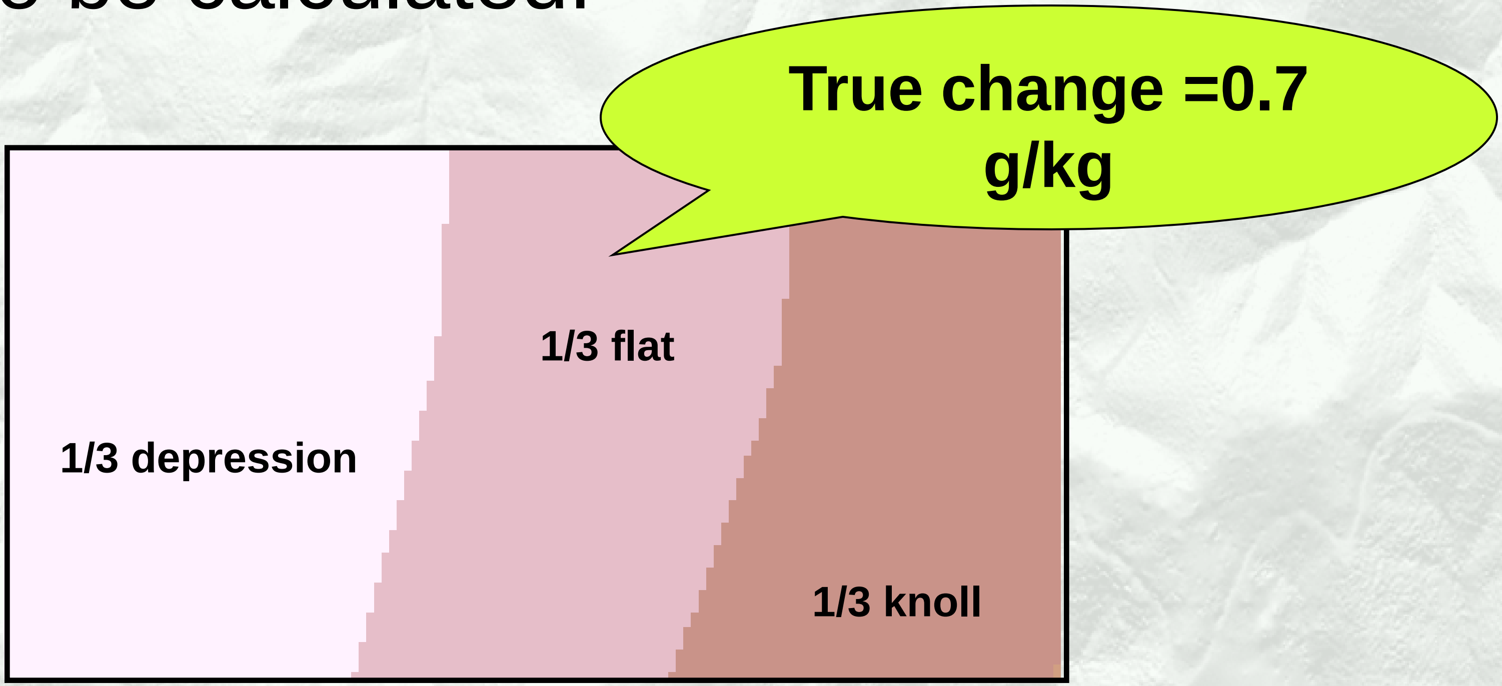
photo credit: D. Pennington/KBS-MSU

An illustration

- Compare the difference between conventional (e.g., CT) and conservational (e.g., CT-cover) managements.
- Let’s say, the true differences in C between them is:
  - 0.2 g/kg at an eroded knoll
  - 0.7 g/kg at a flat area (perfect for an experiment)
  - 1.2 g/kg at a depression

Our prediction is 0.7 g/kg change

- Field for which the average change needs to be calculated:



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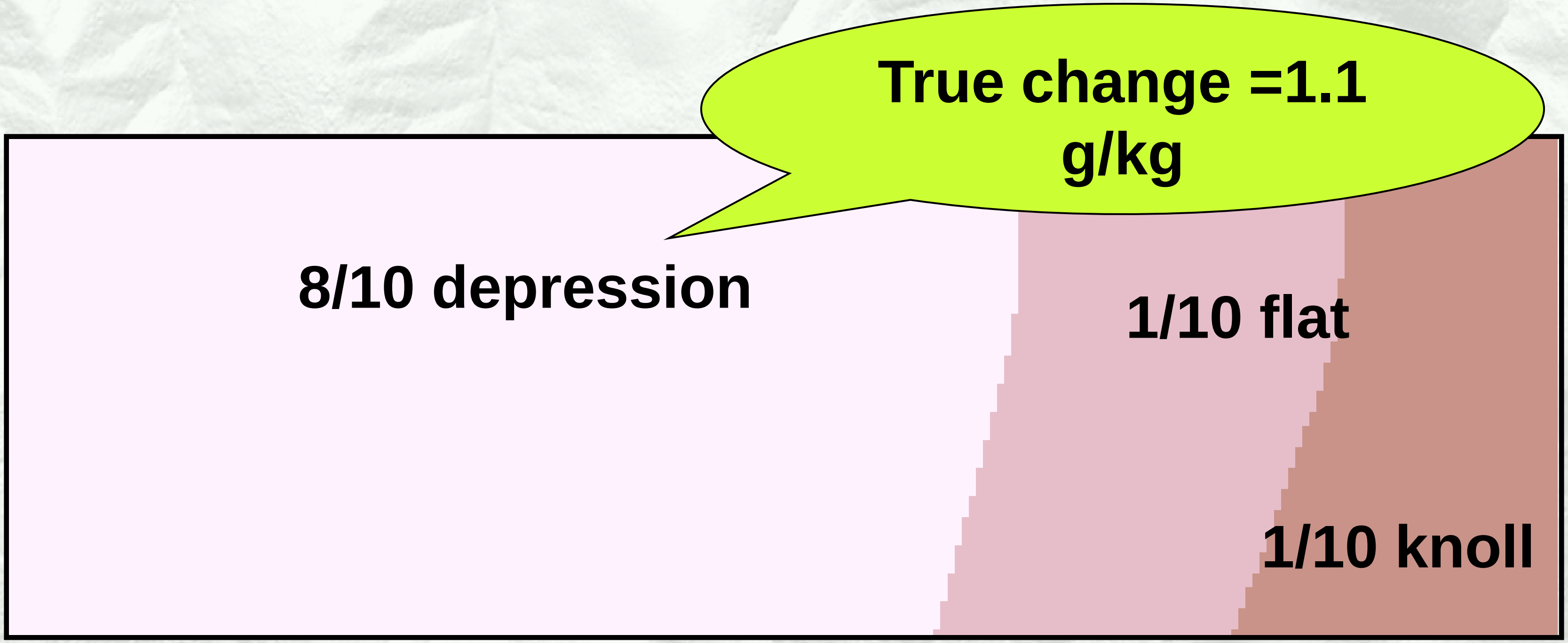
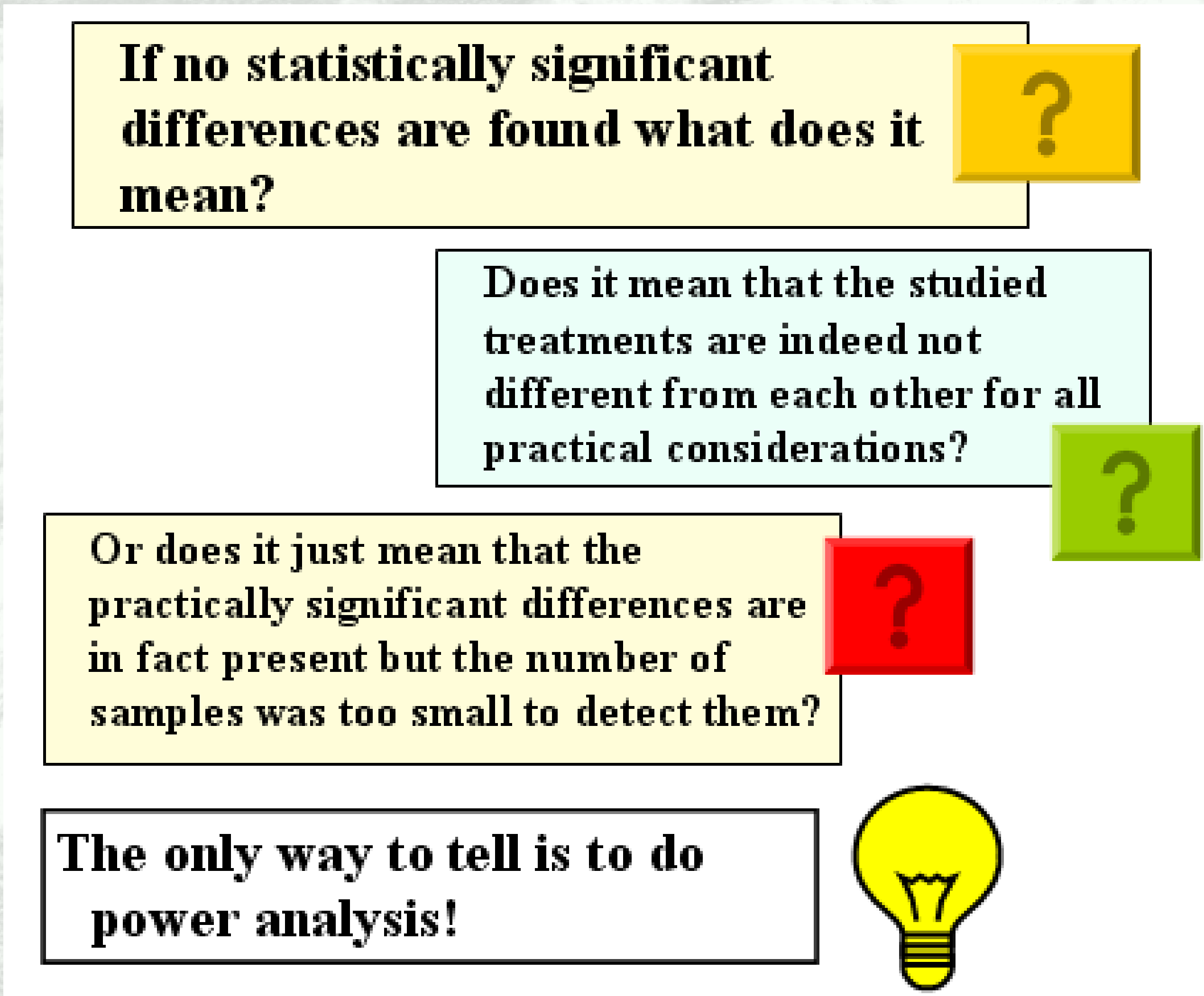


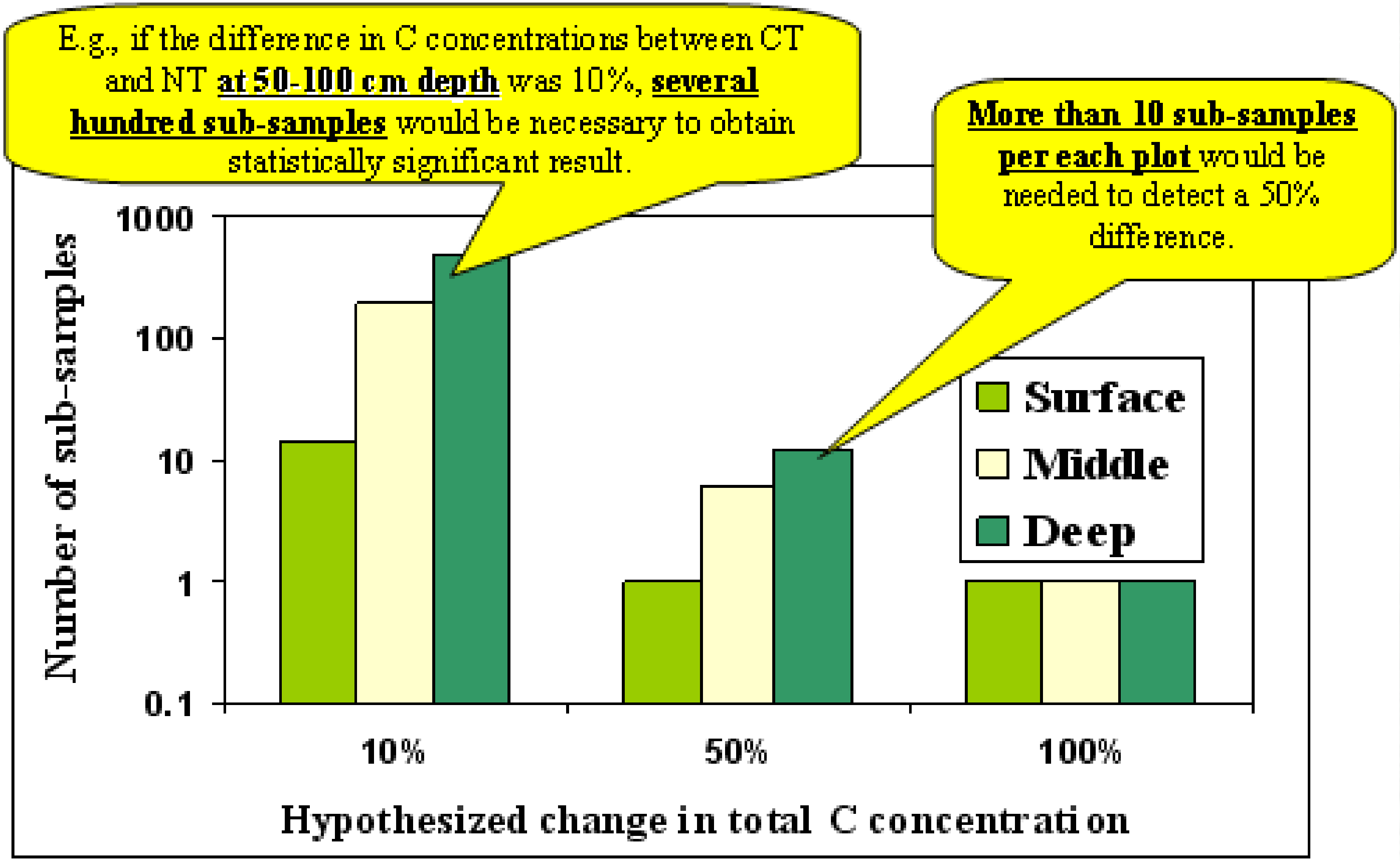
Suggestions

- Spatial variability should be accounted for in all large scale assesements.
- Important to know – what are the leading factors driving varability in a given landscape?
- Be able to quantitatively describe the relationship between them and the soil C
- Use those quantitative descriptions in large scale assesments.

How many samples are needed?

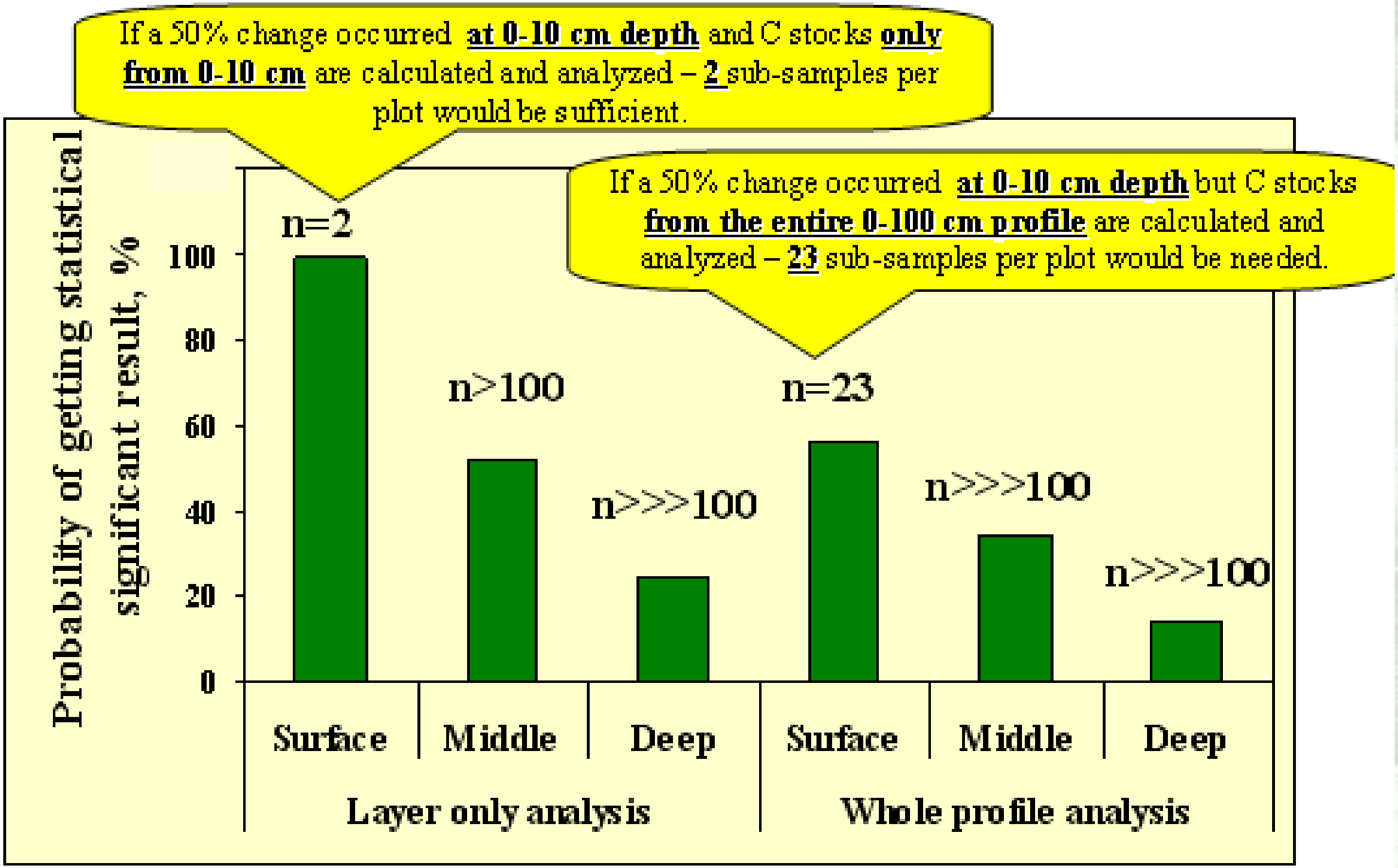


C concentration: Given variability of the studied data and experimental settings (i.e., long-term RCBD experiment with 6 replications) how many sub-samples should have been taken in order to be able to detect as statistically significant a 10% or 50% or 100% increase in C concentration with a certain probability (power) (say, 90%)?



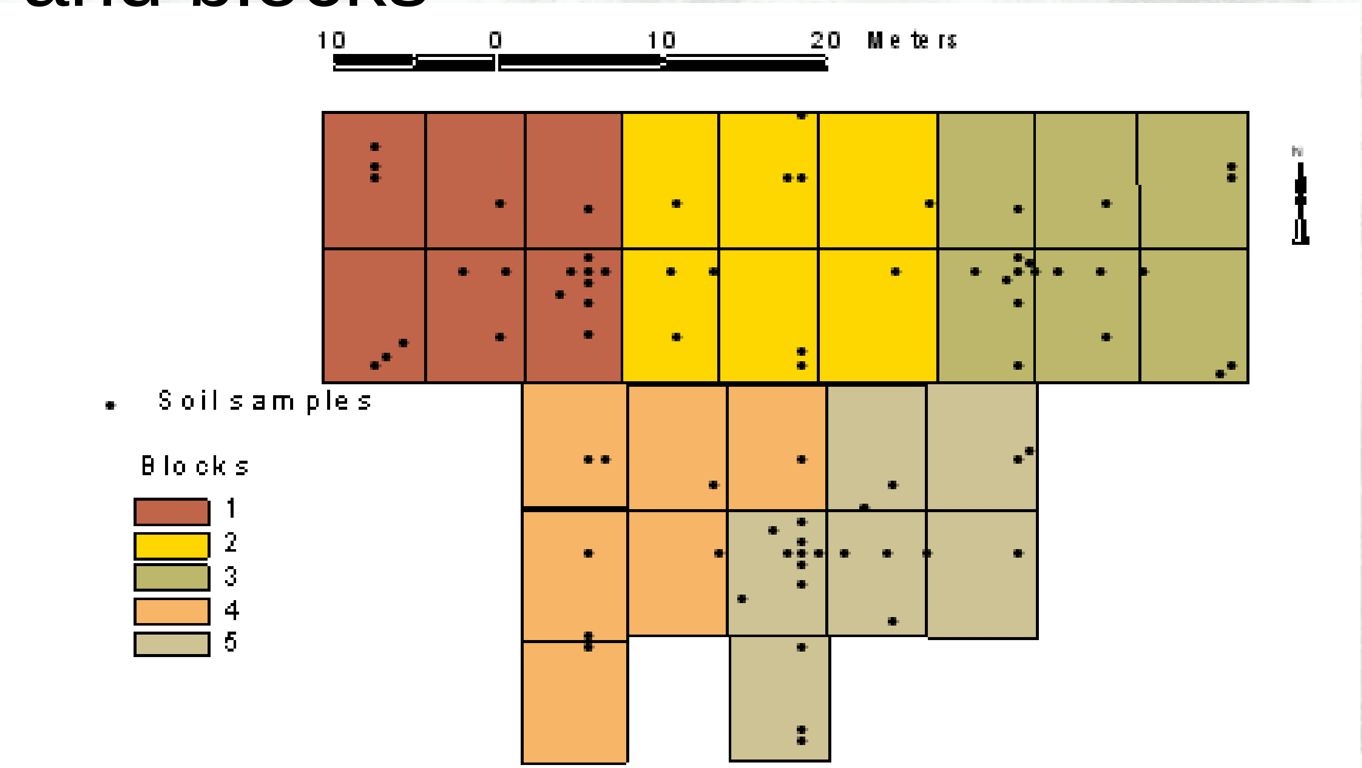
Kravchenko, A.N., and G.P. Robertson. 2009. How many replications are needed to assess deep soil C stocks? (in press Soil Sci. Soc. Am. Journal).

C stocks: Given variability of the studied data and experimental settings (i.e., long-term RCBD experiment with 6 replications) how many sub-samples should have been taken in order to be able to detect as statistically significant a 50% increase in C concentration with a certain probability (power) (say, 90%)? Or what is the probability that a 50% change will be detected in the LTER experiment (RCBD study with 6 replications and 5 subsamples)?



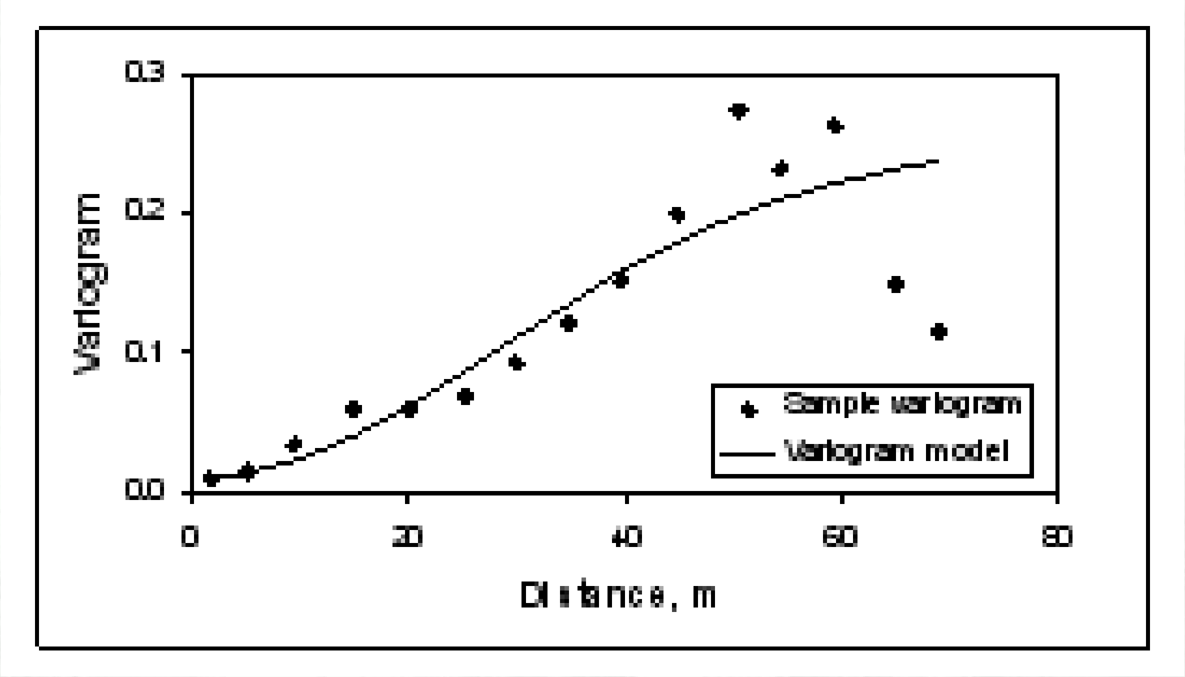
Accounting for spatial correlation will reduce the sampling costs

- A simulated RCBD experiemnt –sampling points and blocks

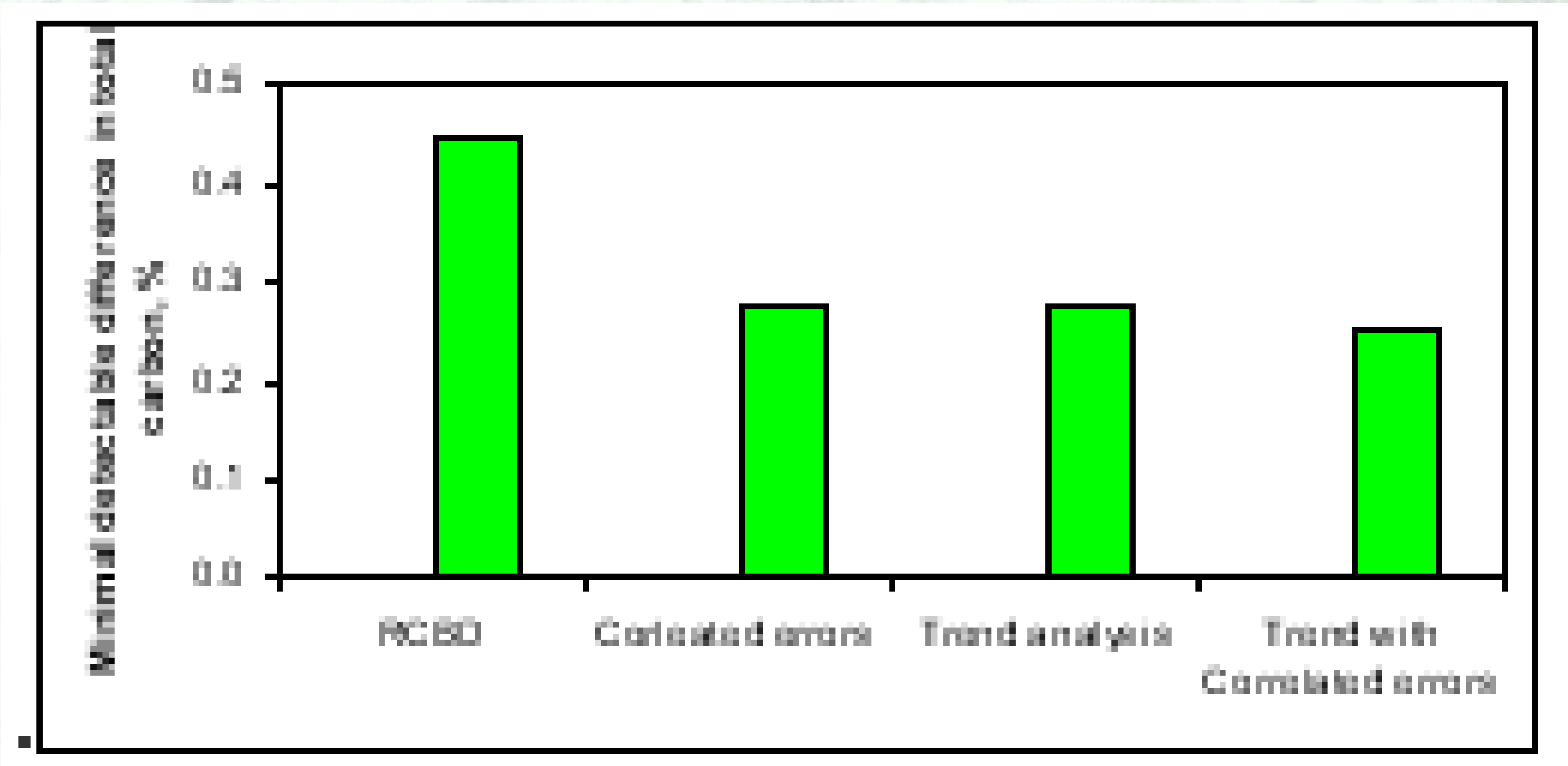


Kravchenko, A.N., G. P. Robertson, S.S. Snapp, and A.J.M. Smucker. 2006. Using spatial variability information for improved estimates of soil carbon. Agronomy J. 98:823-829

- Sample variogram and variogram model for the C data – typically observed strong spatial correlation

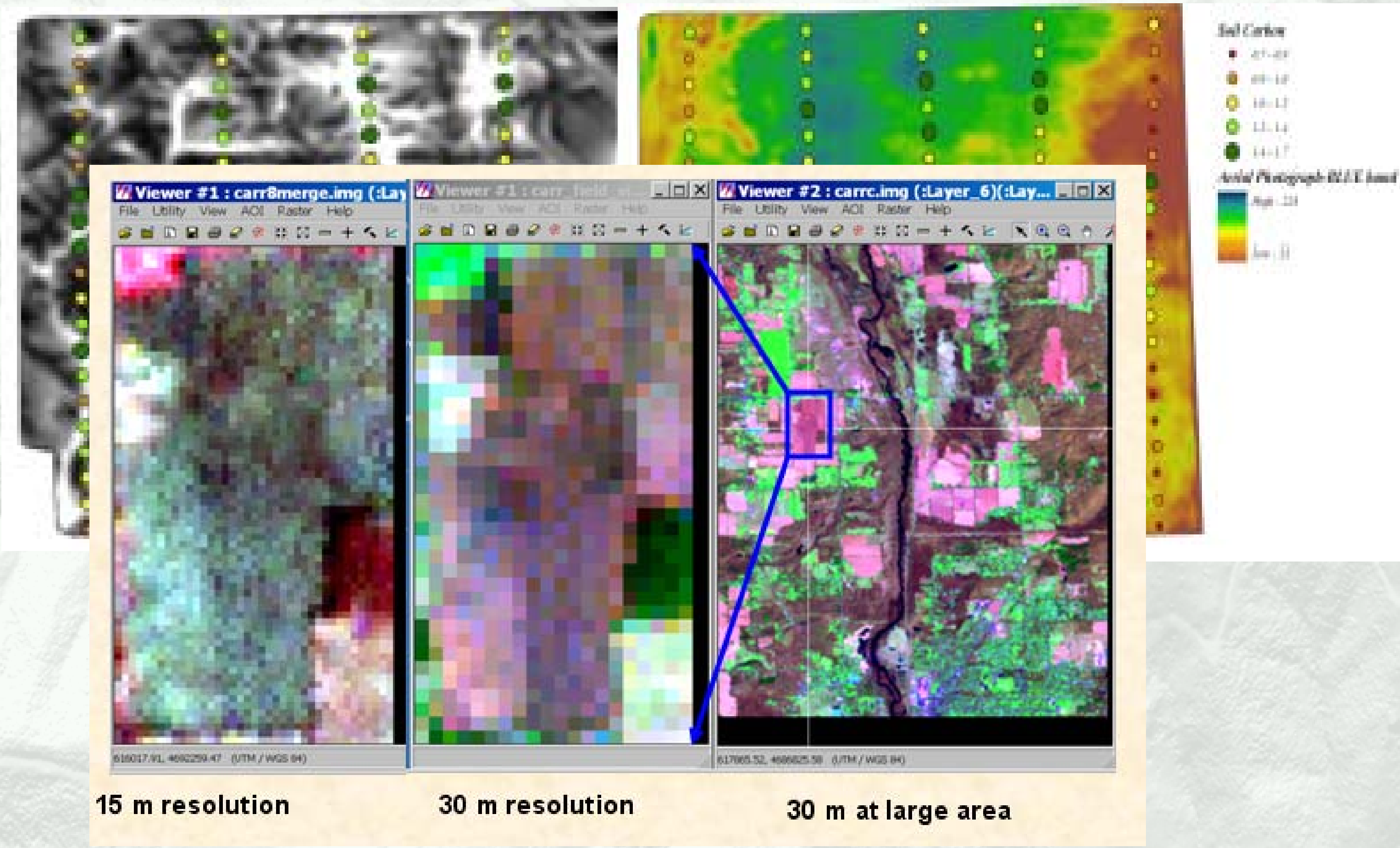


- Minimal statistically significant difference that can be detected using classical and spatially corelated data analyses



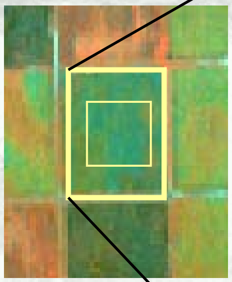
- How to account for spatial variability with a reasonable effort?
- What are the feasible options for obtaining them?
  - Digital elevation models
  - Areal photographs
  - Sattelite images
  - NIR on-the-go systems

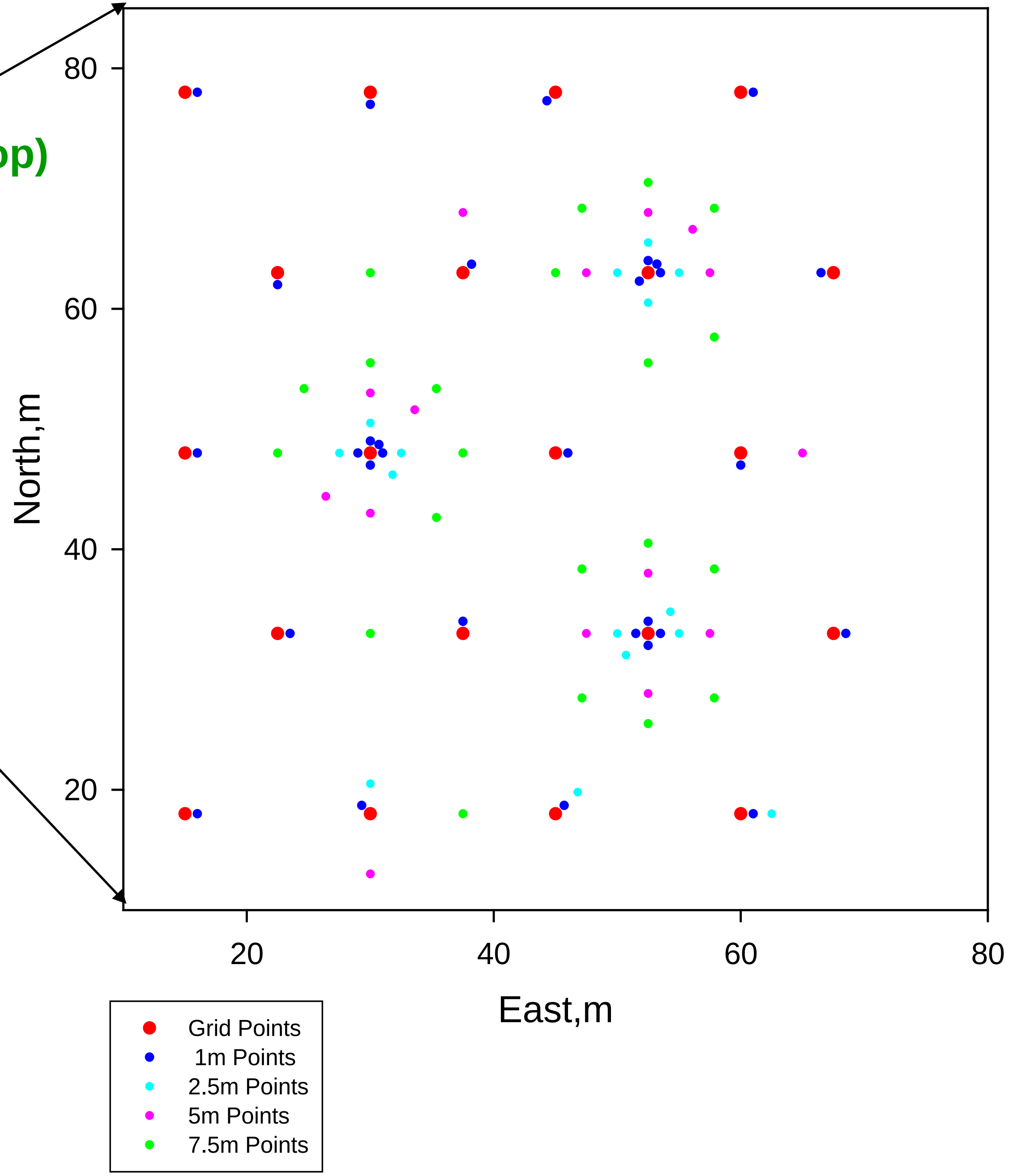
Soil C map for Great Lakes Bioenergy Research experimental site – KBS, MI



Huang, X., S. Senthilkumar, A. Kravchenko, K. Thelen, and J. Qi. 2007. Total carbon mapping in glacial till soils using Near Infrared Spectroscopy, Landsat Imagery, and topographical information. Geoderma 141:34-42

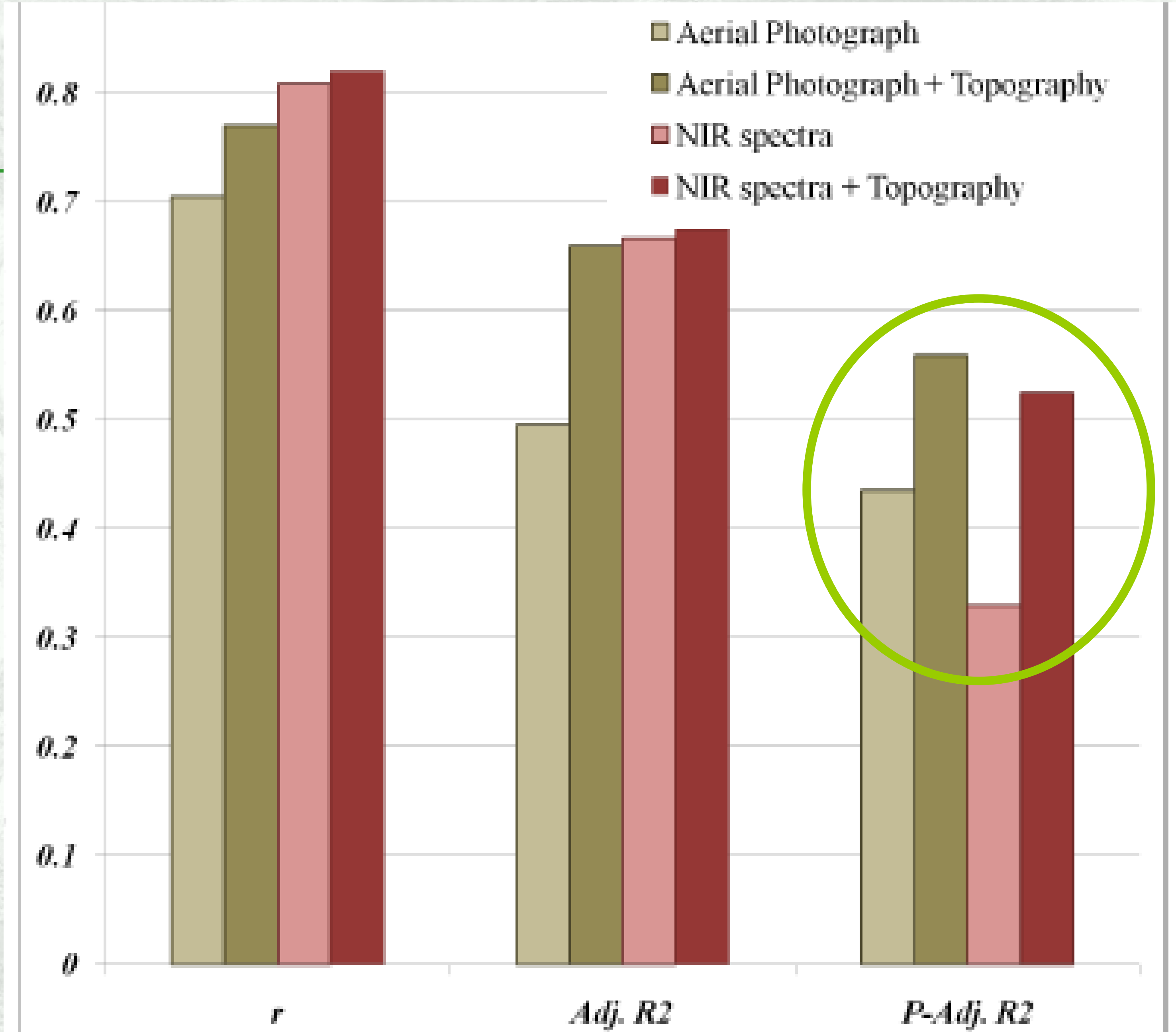
Sampling Layout
(CT, NT, CT+Cover crop)





-100 samples /repln
using core sampler
(6repln/trt =1800 samples in total)

-GPS measurements


Aerial Photograph
Aerial Photograph + Topography
NIR spectra
NIR spectra + Topography
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
r
Adj. R2
P-Adj. R2

Suggestions

- Systematic/stratified sampling with random components for short distance variations – optimal configurations can be obtained in advance
- Re-sampling is strongly recommended
- Sampling requirements calculated based on the ad-hoc power analysis – optimal numbers of samples for a variety of scenarios
- Spatial information should be used in the data analyses (and in sample size calculations) – potential big reduction in sample numbers

Thank you…

Sampling Layout (Poplar)