Methods for Measuring and Monitoring Soil Carbon Sequestration

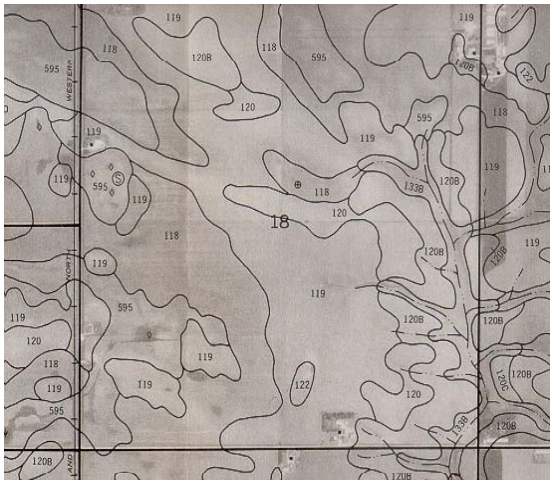
R. César Izaurralde
PNNL, Joint Global Change Research Institute
www.globalchange.umd.edu

US Senate Agriculture Committee Briefing
Washington, DC
March 20, 2009

Pacific Northwest
NATIONAL LABORATORY

Measuring and monitoring soil C sequestration: a new challenge?

Soil scientists have been measuring and monitoring soil carbon in long-term experiments for many decades

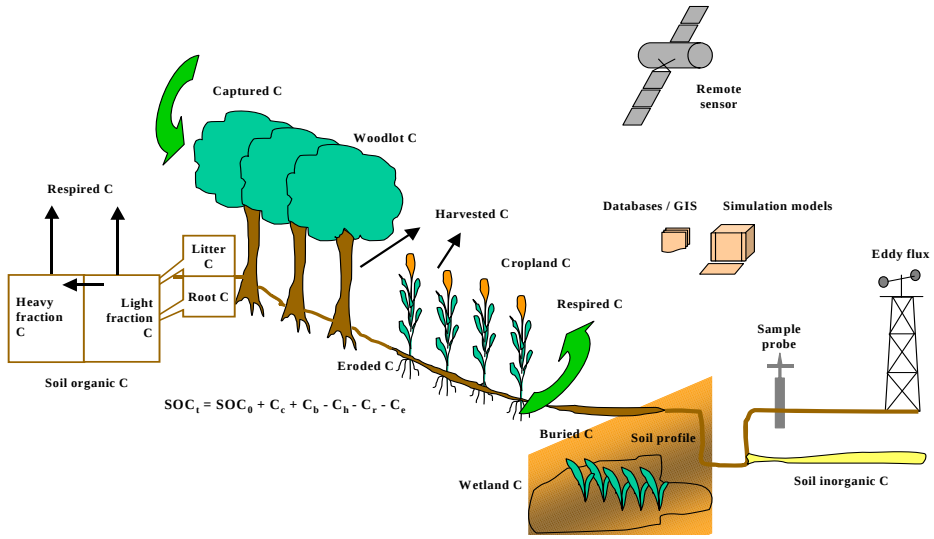


Soil survey maps can be used to estimate the spatial distribution of soil organic C stocks

The challenge consists in developing cost-effective methods for detecting changes in soil organic C that occur in fields as a result of changes in management

Detecting, measuring and scaling soil carbon sequestration

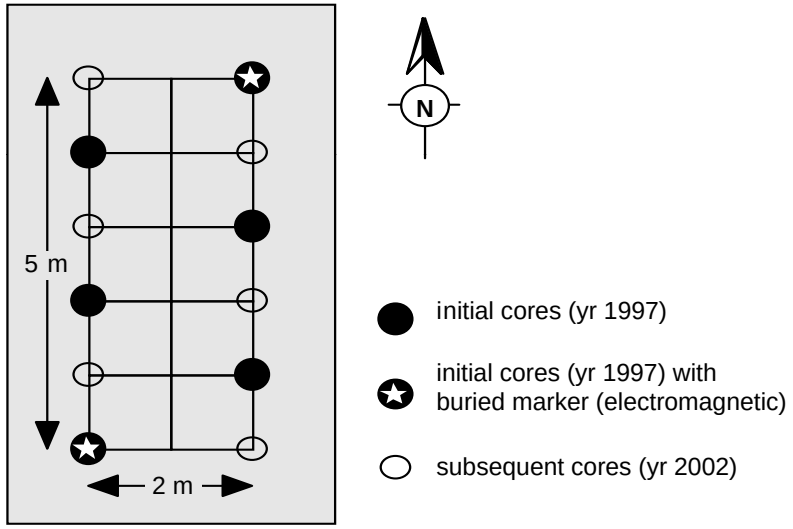
- Detecting changes in soil C stocks
  - Difficult in the short term
  - Changes to be detected small compared to total C stocks
- Methods for detecting and scaling soil C sequestration
  - Direct methods
    - Field and laboratory measurements
      - Soil sampling
      - Wet and dry combustion
    - Eddy covariance
  - Indirect methods
    - Accounting
      - Stratified accounting with databases
      - Remote sensing
    - Simulation modeling
      - Century, DayCent
      - RothC
      - EPIC, APEX
      - DNDC
      - DSSAT



Post et al. (2001)

Soil sampling protocol used in the Prairie Soil Carbon Balance (PSCB) project in Canada

- Use “microsites” (4 x 7 m) to reduce spatial variability
- Three to six microsites per site
- Calculate soil C storage on a soil mass equivalence basis
- Analyze samples at the same time
- Detection of soil C changes in 3 years
  - 0.71 Mg C ha^{-1} – semiarid
  - 1.25 Mg C ha^{-1} – subhumid



Ellert et al. (2001)

McConkey et al. (2001)

Three emerging technologies to measure soil C directly in the field

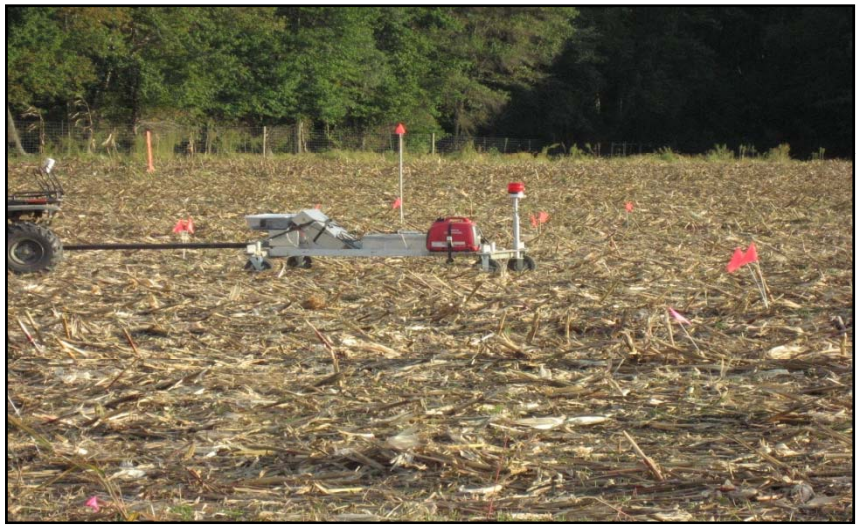
Laser Induced Breakdown Spectroscopy: LIBS

- Based on atomic emission spectroscopy
- Portable
- A laser pulse is focused on a soil sample, creating high temperatures and electric fields that break all chemical bonds and generating a white-hot plasma
- The spectrum generated contains atomic emission peaks at wavelengths characteristic of the sample's constituent elements
- A calibration curve is required to predict soil C concentration

Cremers et al. (2001) J. Environ. Qual. 30:2202-2206

Inelastic Neutron Scattering: INS

- *In situ, non-destructive* technique that consists in directing fast neutrons (14 MeV) produced by a neutron generator into the soil, where they interact with the nuclei of atoms including ^{12}C and other atoms (H, N, O, Si, K, Ca, P, etc.)
- Fast neutrons collide with C, H, and N atoms and release gamma rays with energies of 4.4, 2.2, and 10.3 MeV
- Soil mass interrogated: >200 kg
- The INS was tested in stationary and scanning modes



Wielopolski et al. (2000) IEEE Trans. Nuclear Sci. 47:914-917

Mid-Infrared Reflectance Spectroscopy: MIRS

- Unlike LIBS and INS, MIRS probes the bond identities of a sample's molecules, offering the possibility of directly distinguishing inorganic from organic C, thus eliminating the need for acid pretreatment to remove inorganic C
- Yet for the same reason, quantifying soil C must be done indirectly, by recourse of advanced data-fitting routines that require libraries of soil spectra vs. soil C data

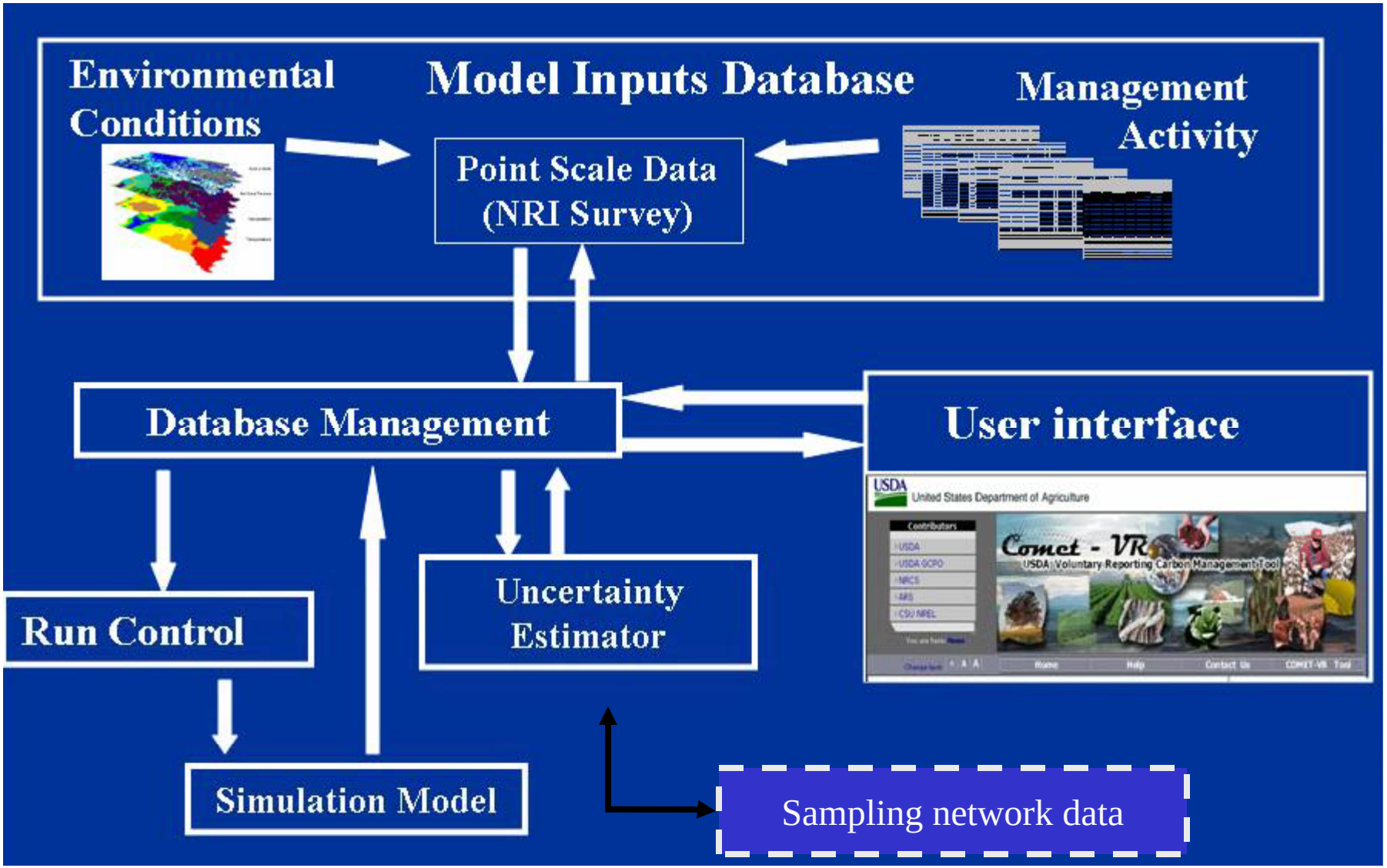
McCarty et al. (2002) Soil Sci. Soc. Am. J. 66:640-646

Detecting and scaling changes in soil C by direct methods, simulation modeling, and remote sensing interpretation

- Base data
  - Land units
  - Databases
- Sampling design and data
  - Statistical power
  - Baselines
- Sampling and processing
  - Depth and depth increments
  - Bulk density
- Reporting results
  - Equivalent soil mass
- Ancillary measurements
  - Crop and biomass yields
  - Inputs and management
  - Environmental conditions
- Modeling and remote sensing
  - Models and model complexity
  - Remote sensing
    - Crop identification
    - Crop residue cover

Izaurralde and Rice (2006)

COMET - VR: an example of an integrated soil carbon monitoring system



In summary…

- Soil carbon changes can be measured with accuracy adequate for monitoring protocols following accepted methods of soil sampling and analysis
- Several advanced technologies to measure soil carbon directly in the field appear promising for fast, accurate, and cost-effective monitoring projects
- Integrated modeling-measurement systems can provide reliable, cost-effective quantification to support agricultural GHG mitigation policies
- Efforts are needed to establish broad-scale, regional networks of soil C monitoring locations (via national/international efforts or ‘data pooling’ from pilot projects)