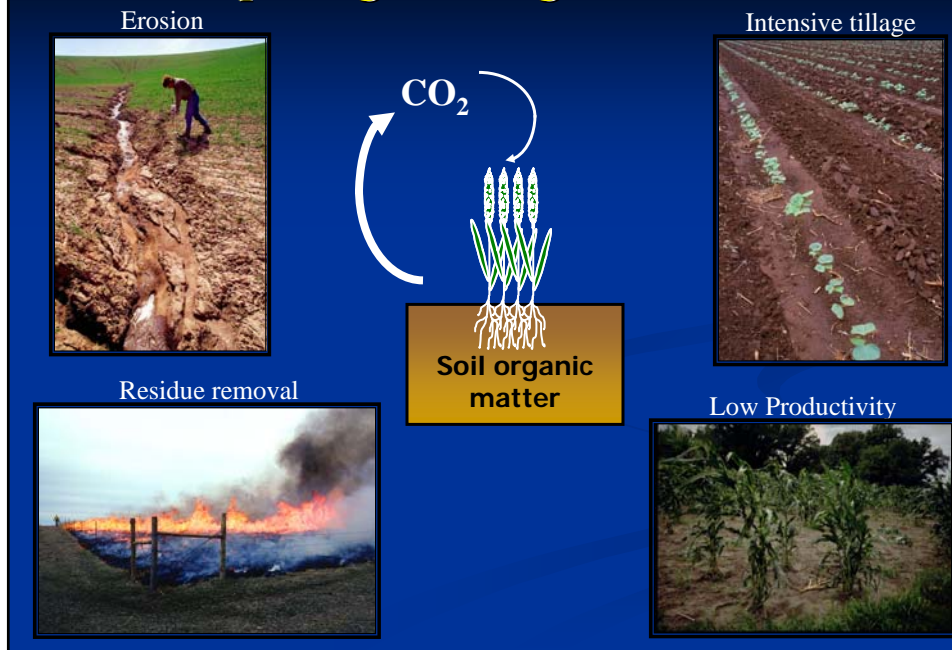


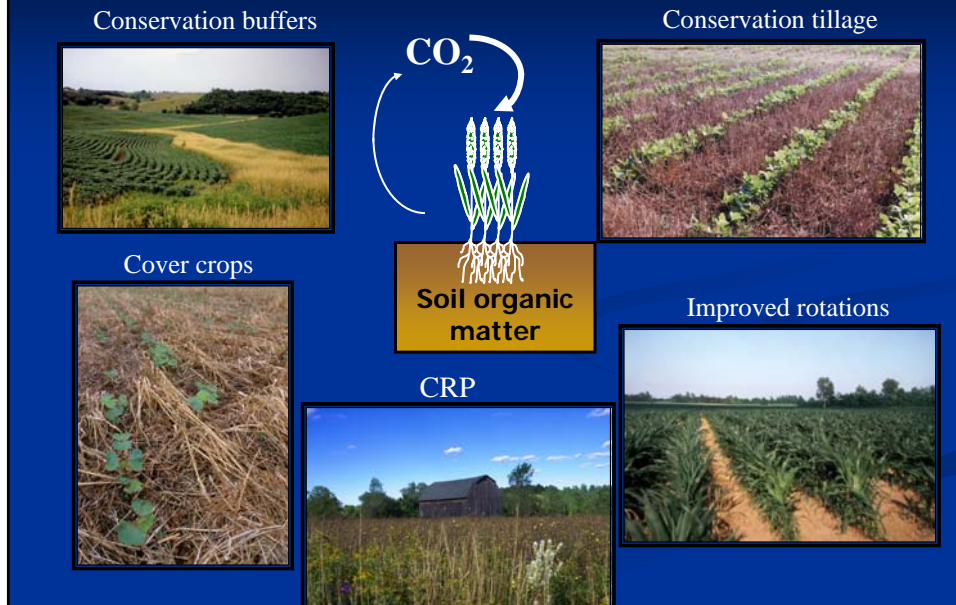
Recap of Soil Carbon Sequestration

- Organic carbon in biomass and soils is derived from carbon dioxide (CO_2) taken up from the atmosphere by plants.
- Organic matter in soils is formed from the decomposition of plant biomass – some of which resides in soils for 10's-1000's of years.
- Increasing the storage or **stock** of carbon in soil represents a net removal of CO_2 from the atmosphere.

Depleting Soil Organic Matter



Rebuilding Soil Organic Matter



Will agriculture be able to participate in a future cap-and-trade system?

- Significant mitigation potential for agriculture.
 - US – 440-670 Tg CO₂ eq. yr⁻¹ (CAST, 2004).
- Agriculture is not likely to be included as a 'capped' sector, but may be allowed to produce 'offsets'.
 - Ca. 10 pending bills in Congress that could include potential for agricultural offsets.
- Agriculture (and forestry) offsets could add flexibility and low cost options to a C&T, with ancillary environmental benefits, while achieving emission reduction targets.
- However, 'opposition' to Ag/forestry offsets is based on whether offsets will have 'environmental integrity'?

What is meant by 'environmental integrity' of carbon sequestration offsets under C&T?

'RSVP'

- **Real** – Is CO₂ in the atmosphere actually reduced?
- **Surplus (Additional)** – Are offsets 'in addition' to BAU?
- **Verifiable** – Can we measure and monitor?
- **'Permanent'** – Ensure that sequestered C is not re-emitted (within a specified duration of time)?

What is meant by 'environmental integrity' of carbon sequestration offsets under C&T?

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 - **Verifiable** – Can we measure and monitor?
 - **'Permanent'** – Ensure that sequestered C is not re-emitted (within a specified duration of time)?
- ∴ Measurement and monitoring is **the** linchpin for the success of agricultural offsets!

Soil C measurement – some facts

- The carbon (C) content of soil is routinely measured with a high degree of accuracy and precision.
 - Instrument error < 0.1%
 - Overall laboratory measurement error < 1-2%
- Field equipment and protocols for soil sampling have been well documented and applied throughout the US for decades.

Soil C measurement – some facts

- The general response of soil carbon stocks to environmental variables and agricultural practices is well known.
 - > 50 long-term field experiments ongoing in US
- Sophisticated models of soil carbon dynamics have existed for > 20 years and are increasingly deployed for research, management and policy applications.

But, there are challenges

- Soil carbon contents can be highly variable within an individual field.
- Annual changes are usually small relative to existing C stocks, e.g.,
 - Typical C stocks 20-80 tonnes/ha
 - Typical C changes 0.1-1 tonnes/ha/yr
- Multiple factors (e.g. soil type, climate, previous land use) influence soil responses at a specific location.

The way forward

- ~~Direct measurements on each farm~~
- Need 'practiced-based' approaches that:
 - integrate effects of multiple practices (e.g. rotation, tillage, N management) and land use history
 - are soil- and climate-specific
 - provide unbiased estimates with known uncertainty
- Model-based systems supported by a coordinated measurement system

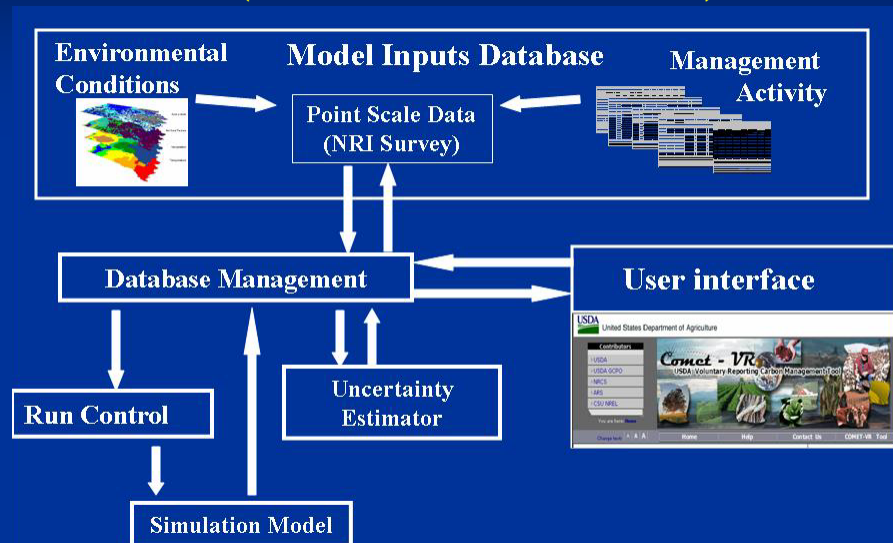
The way forward

Combined measurement/model-based estimations

- Leverage existing model-based decision-support systems
 - COMET-VR used by USDA for 1605B voluntary registry
 - Incorporates county- and ecoregion databases **with field-specific** information on soils and management practices

COMET-VR model

(www.cometvr.colostate.edu)



The way forward

Combined measurement/model-based estimations

- Leverage existing model-based decision-support systems
 - COMET-VR used by USDA for 1605B voluntary registry
 - Incorporates county- and ecoregion databases with **field-specific** information on soils and management practices
 - Provides statistical estimates of uncertainty based on measurements from existing long-term field experiments (ca. 800 management treatments)

The image displays four sequential screenshots of the 'Online Tool for Agriculture & Range' interface, illustrating the user workflow:

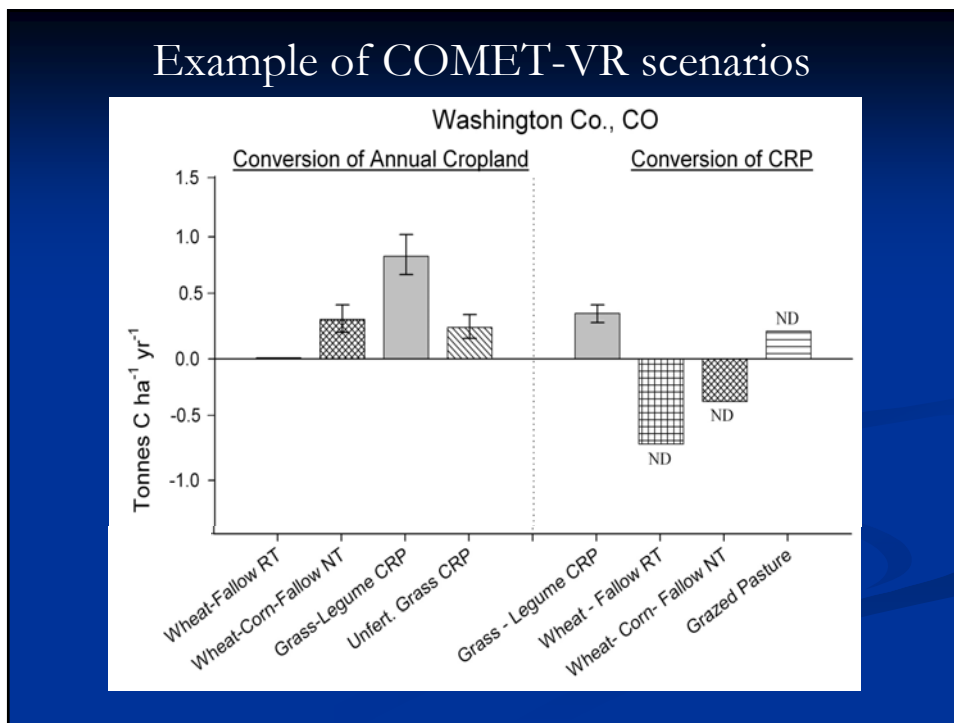
- Top Left Screenshot:** Shows the 'Step 1. Enter the State Information' screen. A dropdown menu for 'Select a State' is open, listing various states. A white arrow points from the text 'Select state and county' to this dropdown.
- Top Right Screenshot:** Shows the 'Step 2. Enter the County Information' screen. A dropdown menu for 'Select a County' is open, listing counties within the selected state. A white arrow points from the text 'Select state and county' to this dropdown.
- Bottom Left Screenshot:** Shows the 'Step 4. Enter the Soil Information' screen. A dropdown menu for 'Select the surface soil' is open, listing various soil types. A white arrow points from the text 'Select soil type and drainage condition' to this dropdown.
- Bottom Right Screenshot:** Shows the 'Step 3. Enter the Drainage Condition' screen. A dropdown menu for 'Select a Drainage Condition' is open, listing various drainage conditions. A white arrow points from the text 'Select soil type and drainage condition' to this dropdown.

White text labels and arrows are overlaid on the screenshots to guide the user through the selection process:

- 'Select state and county' with arrows pointing to the state and county selection dropdowns.
- 'Select soil type and drainage condition' with arrows pointing to the soil type and drainage condition selection dropdowns.

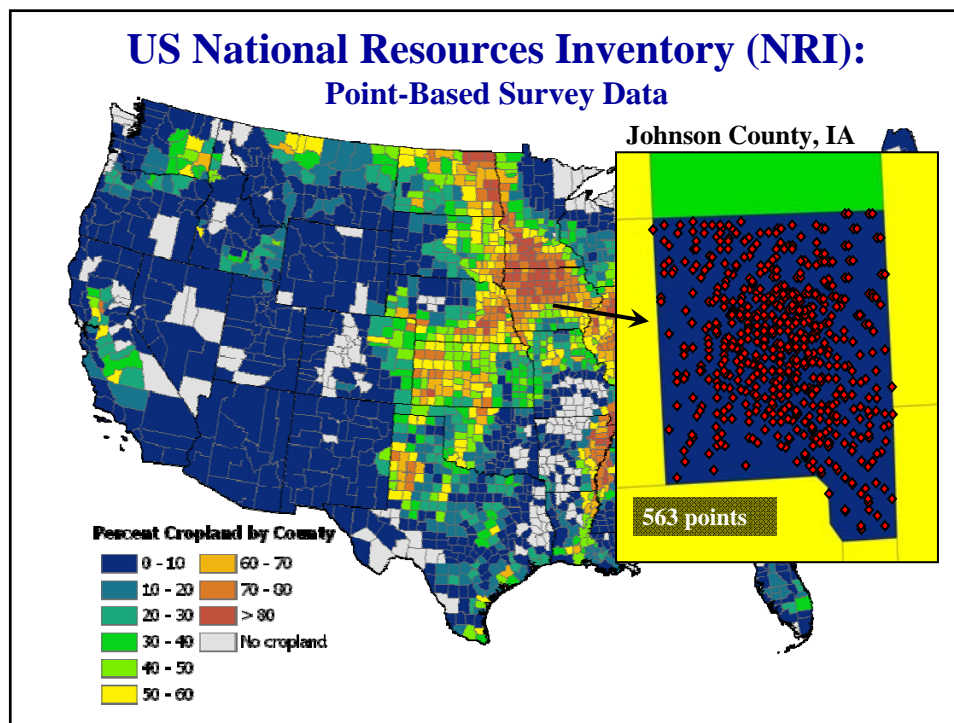
Select management sequences

Select tillage management sequence



The way forward

- Repeated measurements at permanent locations in farmer fields
 - 5 yr sampling intervals provides sufficient time for detectable changes
 - Remeasurement at permanent inventory plots reduces effects of spatial variability (~2-4% resampling error – Conant and Paustian, 2002)
 - Most of the variability in soil C is expressed at small scales – hence there are huge advantages to regional/national scale sampling designs.
 - Leverage existing land use inventory data where management practices are recorded.



A National Soil Inventory Network

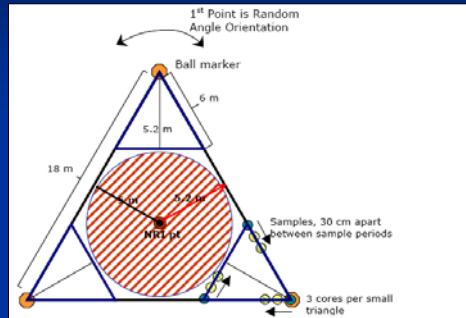


Figure 4. Layout of a monitoring site in proximity to a NRI point location.

- Establish ~ 5000 locations at existing NRI inventory points
- ~1000 locations measured each year
- Prototype network of 50 locations est. with USDA/NASA research funding



The way forward

Combined measurement/model-based estimations

- Models provides an efficient means to integrate climate, soil, management interactions to provide site-specific estimates.
- Data from inventory network observations will greatly reduce uncertainty in estimates.
- Verification for individual producers can largely rest on observation of practices.

Questions ?