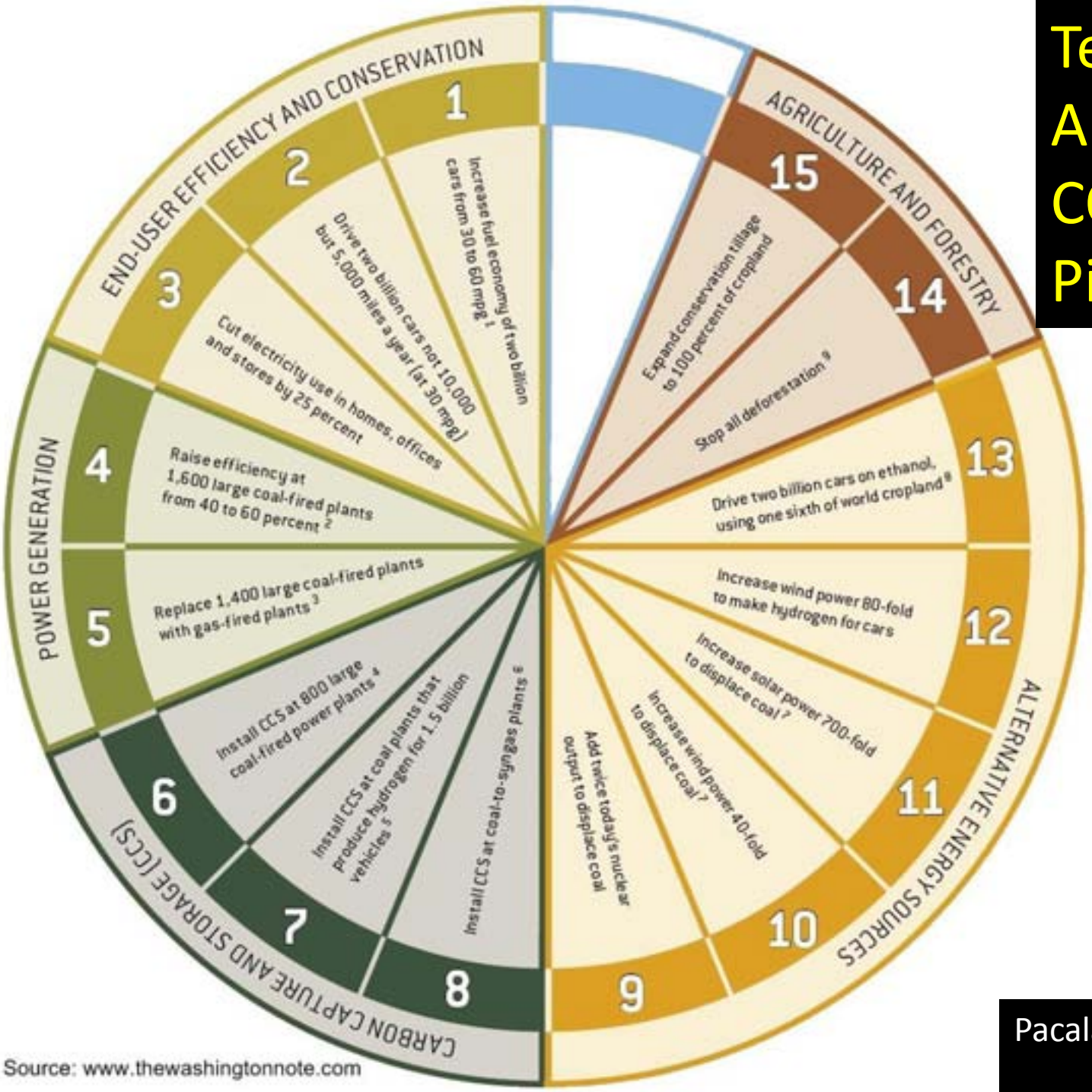
Big Sky Carbon Sequestration Partnership

Terrestrial Sequestration

David J. Brown (et al.)
Washington State University

DOE Fossil Energy Partnerships Meeting
16 November 2009, Pittsburgh, PA

Terrestrial: A slice of the CO_2 reduction Pie



Source: www.thewashingtonnote.com

Pacala and Socolow, 2004

Terrestrial Sequestration Potential

Cropland technical potential (20-30 yr):

- 200 Tg CO_2/yr in the US (~15% of US emissions)
- 5000 Tg CO_2/yr globally (~17% of global emissions)
- *Positive externalities*

Forestry technical potential??

(CAST, 2004; IPCC, 2007b)

Terrestrial Carbon Sequestration MMV

Δ Land Management

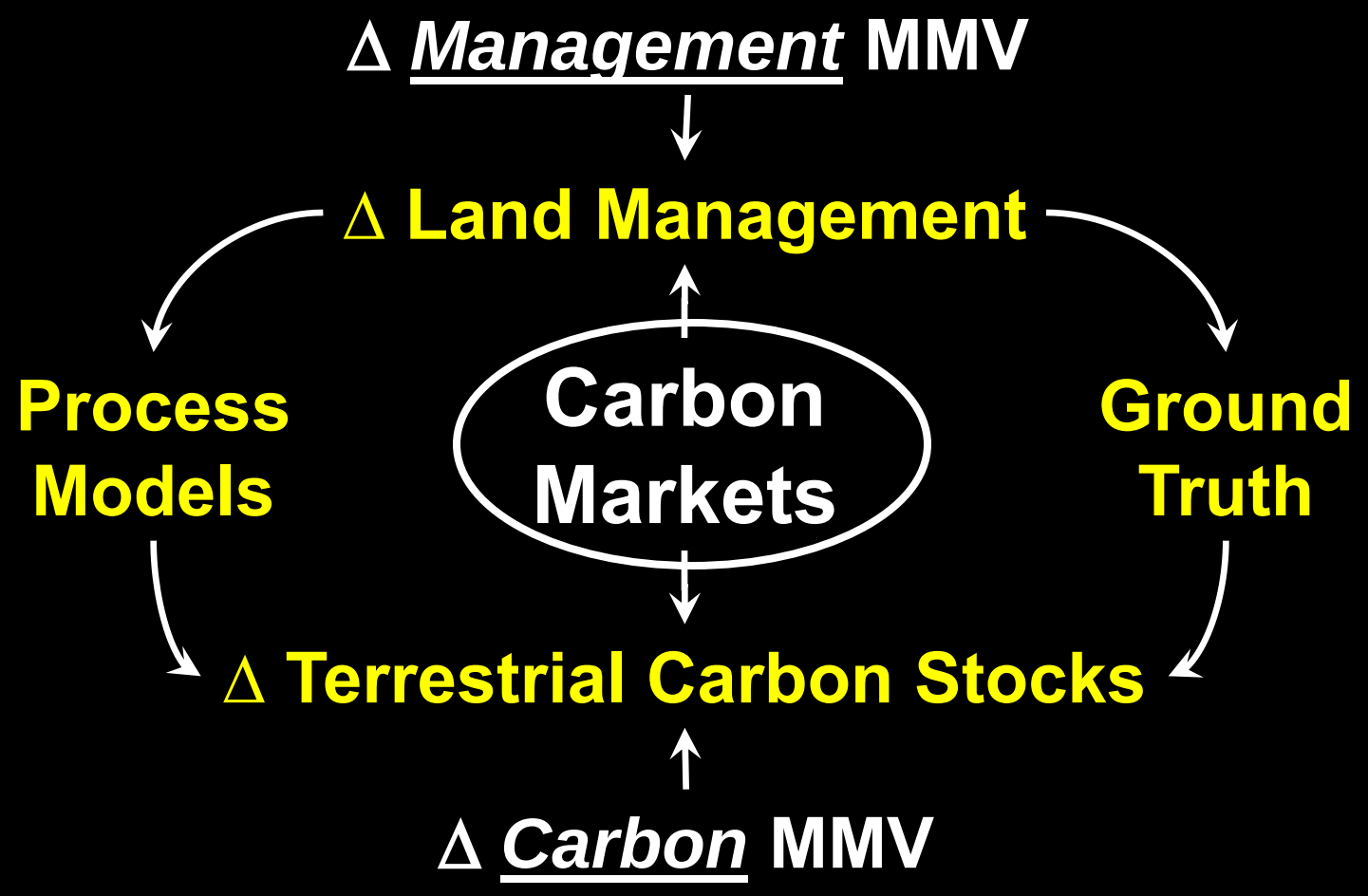
↑

Amount – Certainty – Cost – Value

↓

Δ Terrestrial Carbon Stocks

Terrestrial Carbon Sequestration MMV



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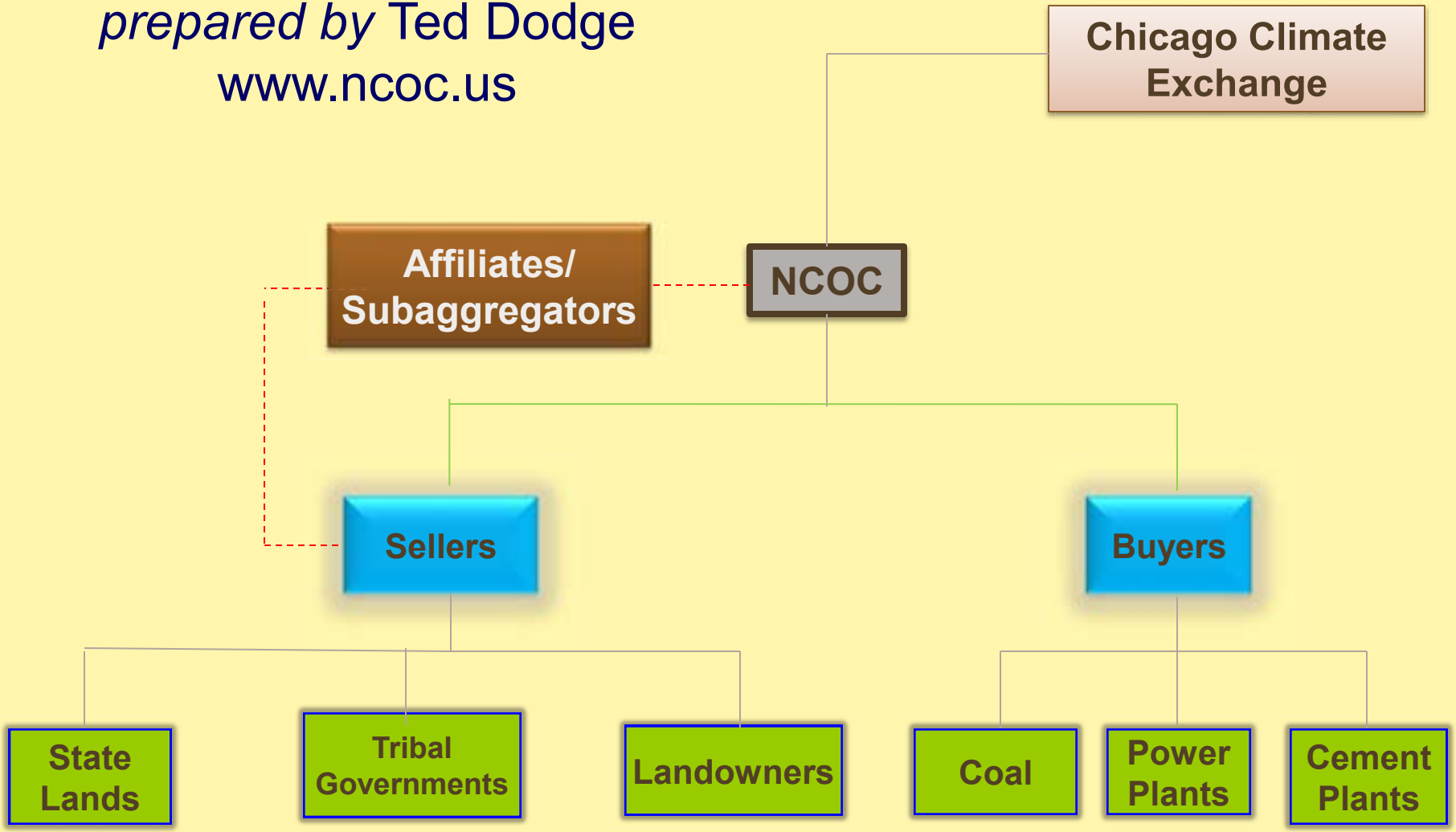
- Carbon Market Development
- Controlled Cropland Sites – *model calibration*
  - ✓Cropping System Effect on C sequestration
  - ✓Stable carbon isotope tracers
- Enrolled Cropland Sites MMV
  - ✓Remote Sensing *(Δ management)*
  - ✓LIBS and VisNIR *(Δ carbon)*
- Forestry MMV *(Δ carbon)*

National Carbon Offset Coalition

prepared by Ted Dodge
www.ncoc.us



Benefits of Terrestrial Offsets

GHG Reductions Now

↓

Local Conservation & Environmental Benefits

↓

Revenue Source for Landowners, Tribal & State Governments

What Terrestrial Practices Sequester Carbon?

- No-till or reduced tillage
- Winter cover crops
- Increased crop productivity
- Intensified crop rotations (double crop)
- Conservation buffers

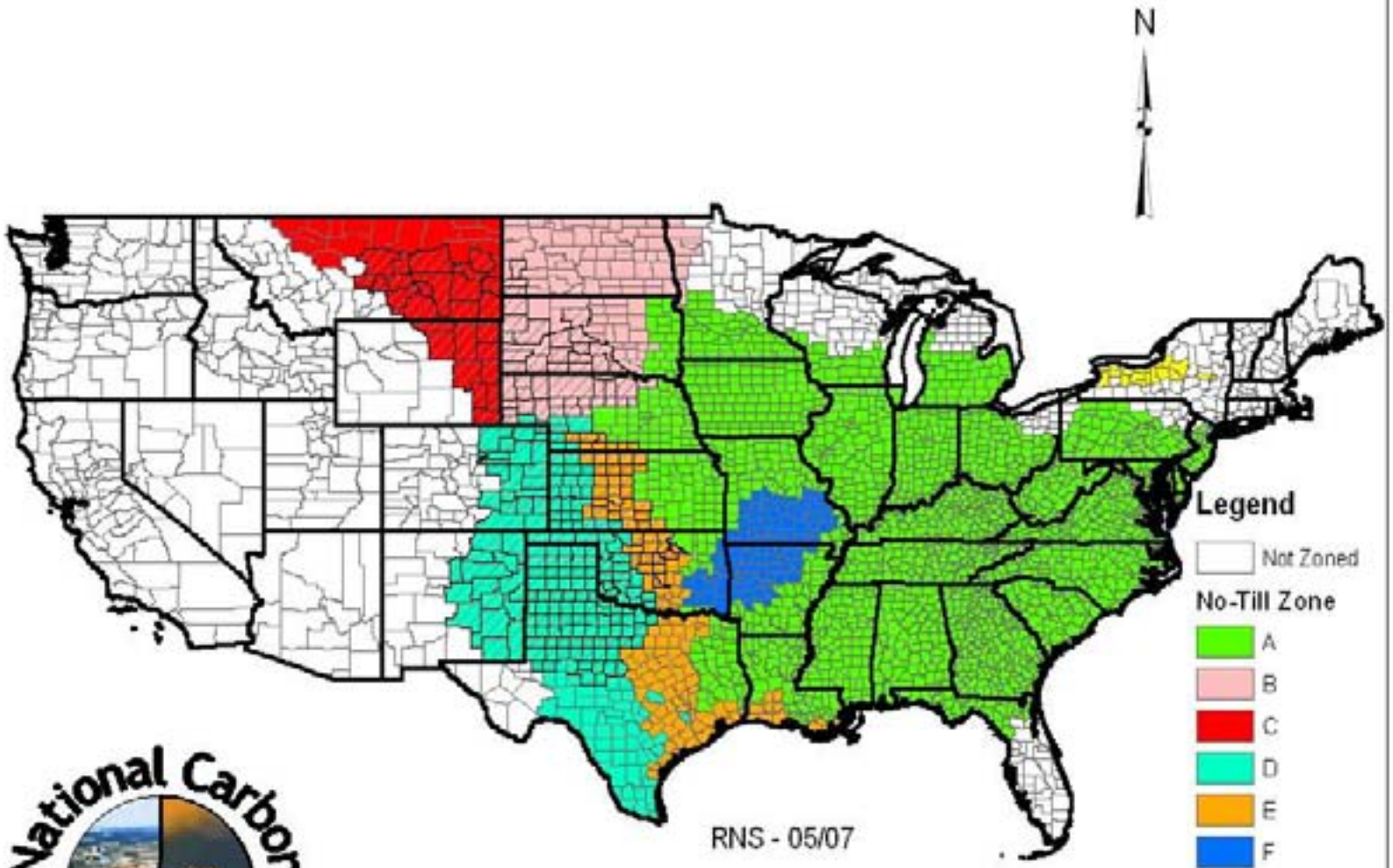
- Tree planting
- Grazing lands initiative
- Restoration of degraded soils
- Any practices that improve soil organic carbon

Chicago Climate Exchange - CCX

In units of 100 tons CO_2e

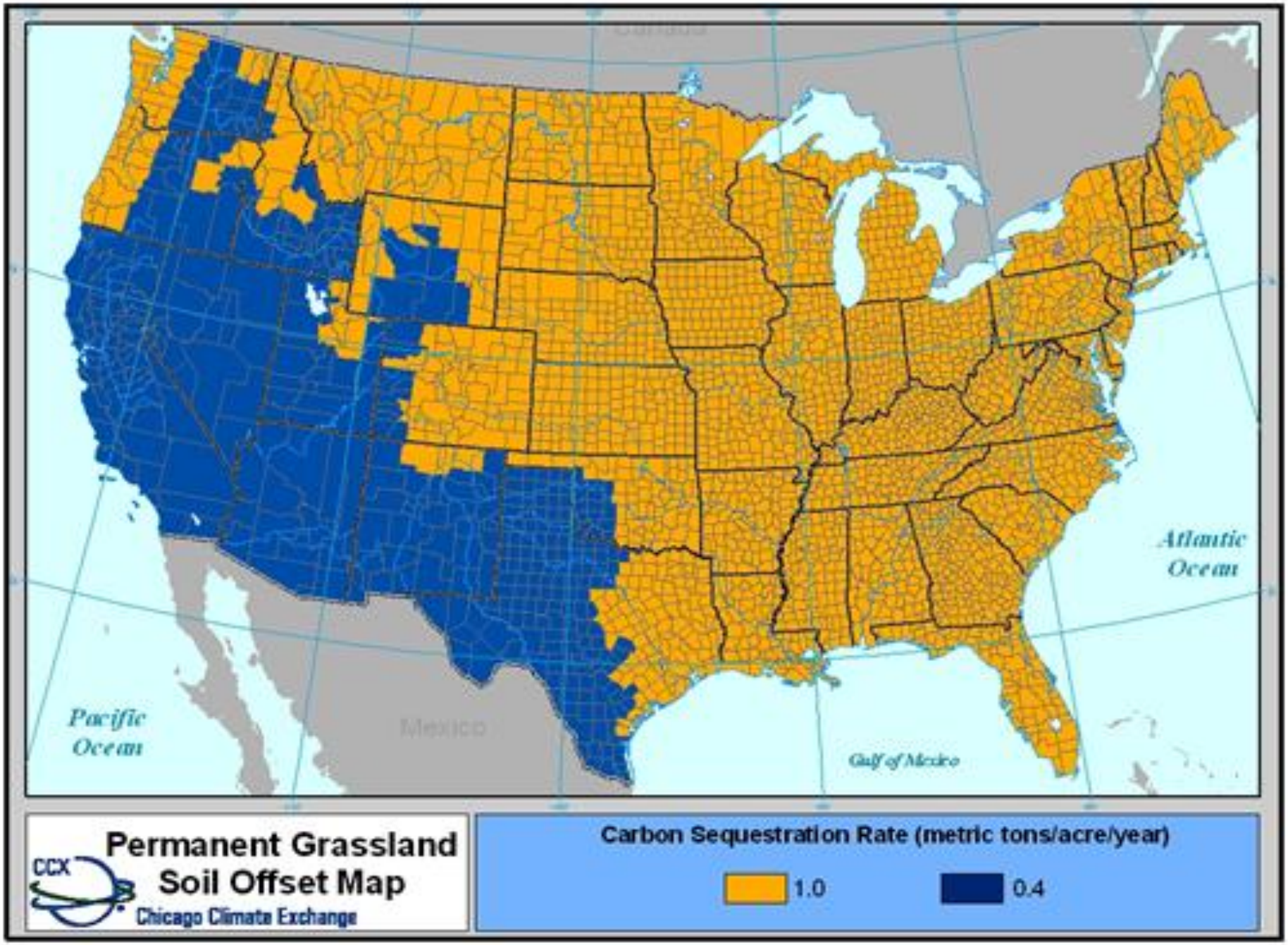
- XFO • Exchange Forestry Offsets
- XRO • Exchange Range Offsets
- XSO • Exchange Soils Offsets
- XMO • Exchange Methane Offsets

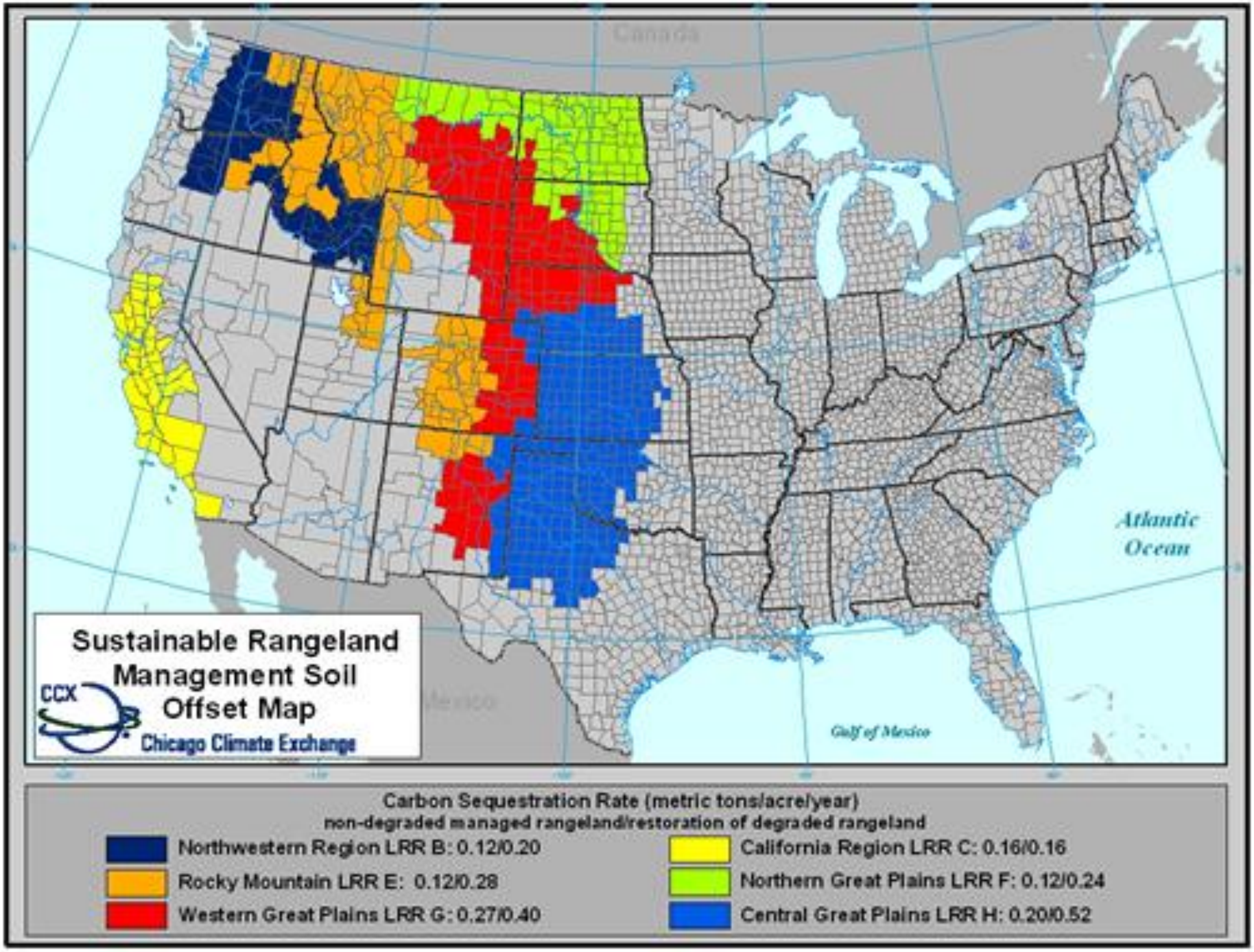
CCX NO-TILL ZONES



Taken from CCX Advisory 2007-05

National Carbon Offset Coalition


Canada
Mexico
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
Permanent Grassland Soil Offset Map
CCX
Chicago Climate Exchange
Carbon Sequestration Rate (metric tons/acre/year)
1.0
0.4


Canada
Atlantic Ocean
Gulf of Mexico
Sustainable Rangeland Management Soil Offset Map
CCX
Chicago Climate Exchange
Carbon Sequestration Rate (metric tons/acre/year)
non-degraded managed rangeland/restoration of degraded rangeland
Northwestern Region LRR B: 0.12/0.20
Rocky Mountain LRR E: 0.12/0.28
Western Great Plains LRR G: 0.27/0.40
California Region LRR C: 0.16/0.16
Northern Great Plains LRR F: 0.12/0.24
Central Great Plains LRR H: 0.20/0.52

Contracting Process

- Application;
- Contracting (5 yrs soil, 15 yrs forestry);
- Inclusion into Pool;
- Third Party Verification;
- Registration on Exchange;
- Trade completed;
- **1.8 million metric tons for 2009 trading**

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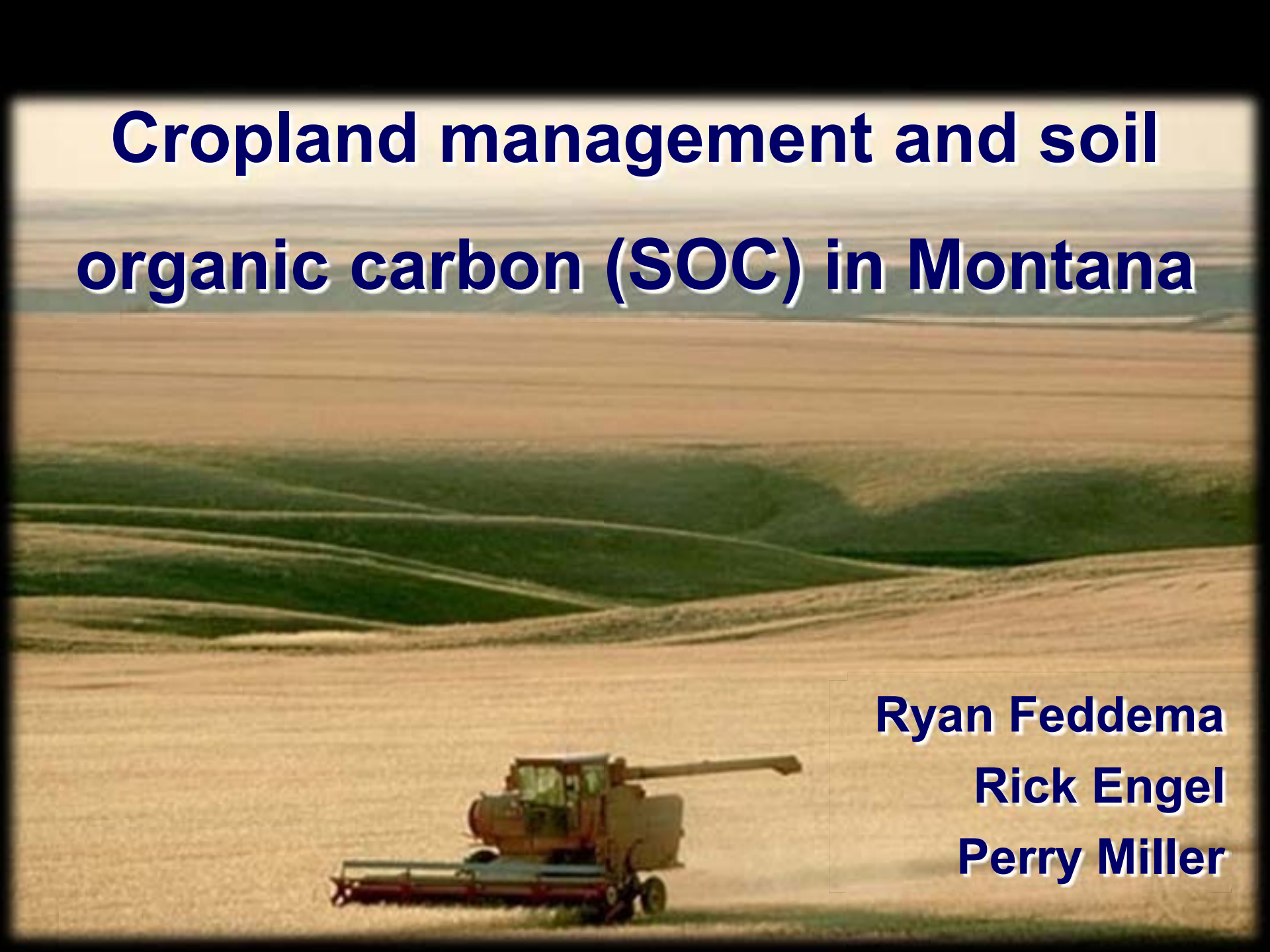
Cropland management and soil organic carbon (SOC) in Montana



Ryan Feddema
Rick Engel
Perry Miller

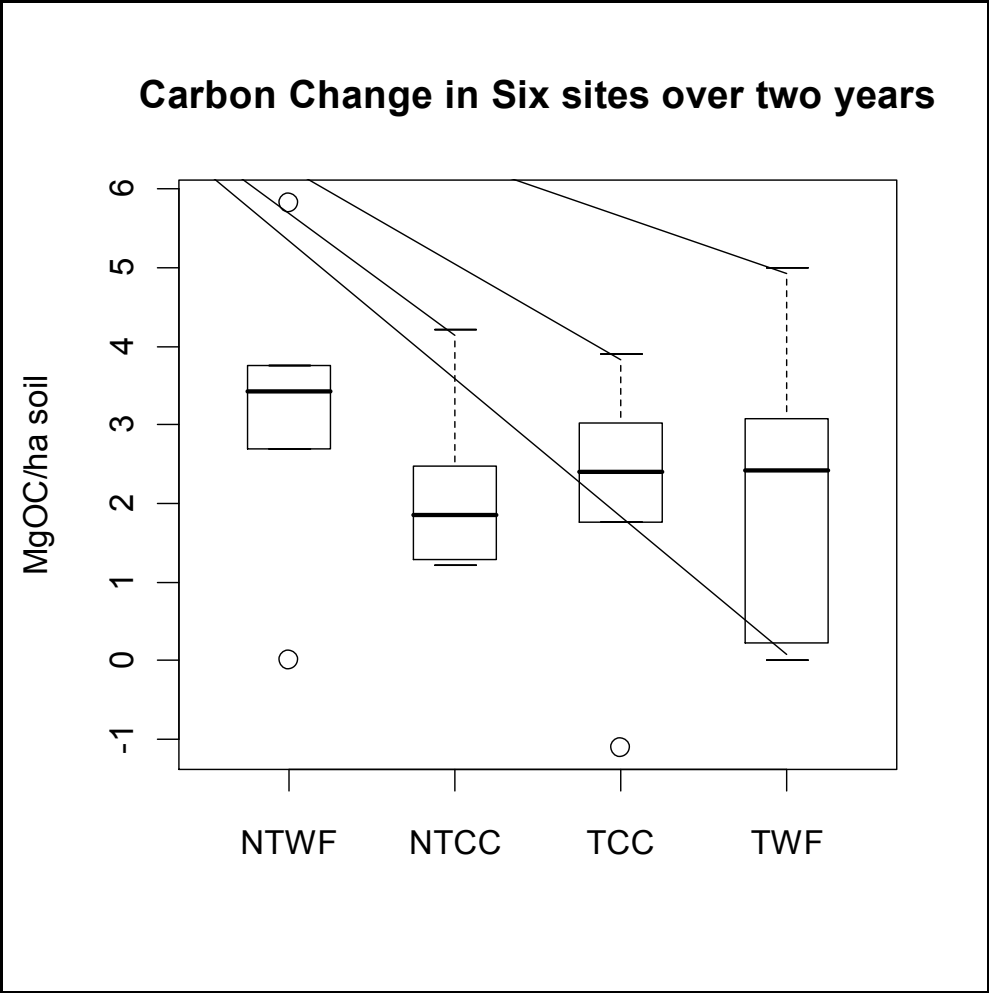
Objective (Montana controlled sites):

- **ΔSOC over 6 years**
  - SOC = TC-IC
  - Particulate Organic Matter (POM)
  - Active Microbial Biomass Carbon

Treatments

Challenges (Montana controlled sites)

- ΔSOC << SOC stock
- Inorganic carbon dominates



^{13}C and ^{14}C Tracers

Carbon Movement & Storage in Agricultural Fields

L. Cisneros-Dozal, J. Fessenden, R. Feddema, R. Bricklemyer

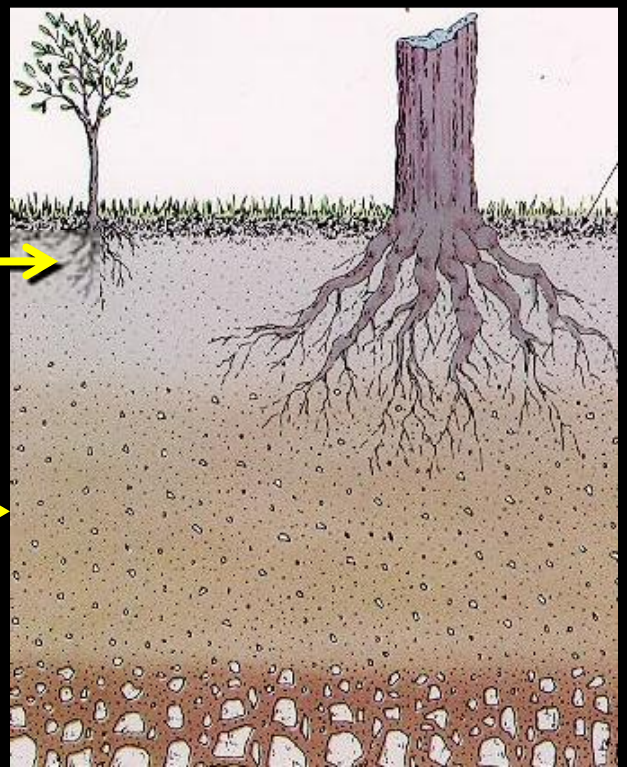
CO_2 Flux = Rate of soil respired CO_2 (organic C)

$\delta^{13}C$ (CO_2) = Depth of carbon, root carbon vs. soil carbon

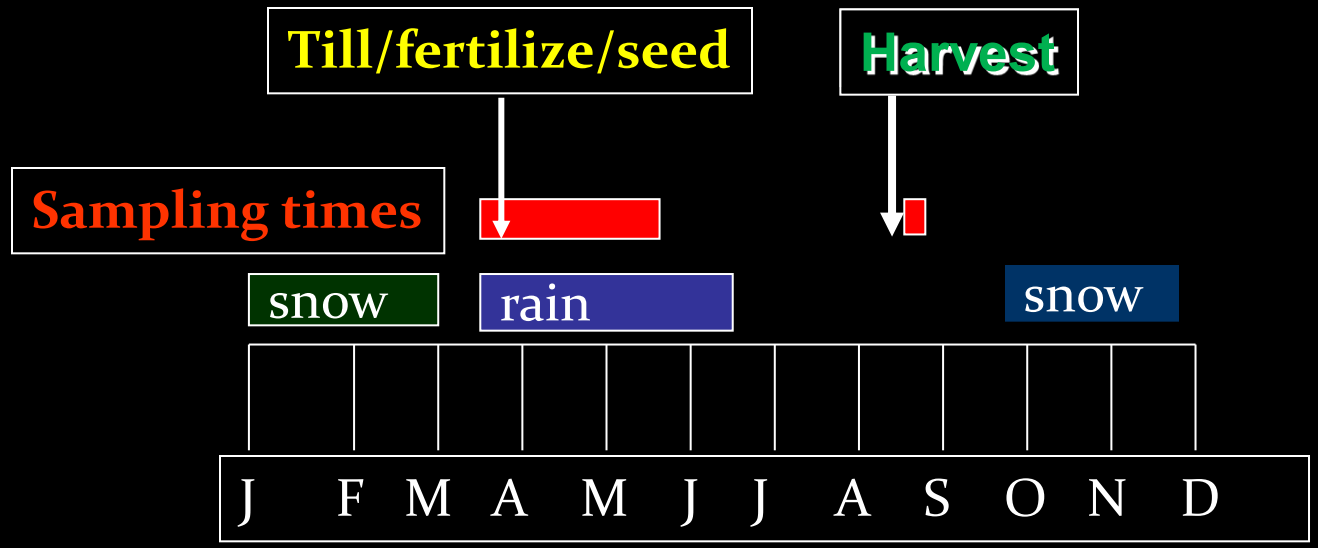
$\Delta^{14}C$ = Age of Carbon – f(x) depth

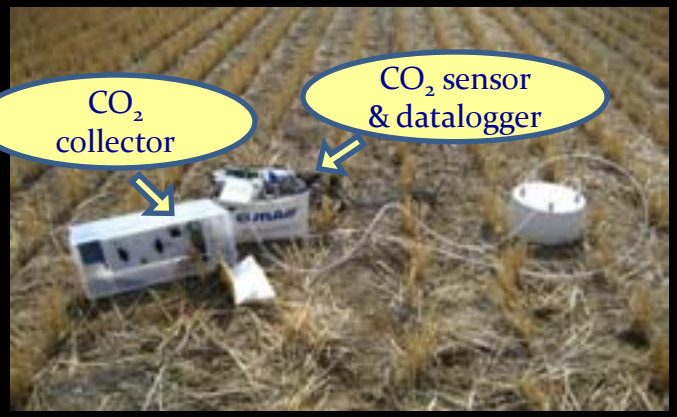
young carbon, ^{13}C-poor →

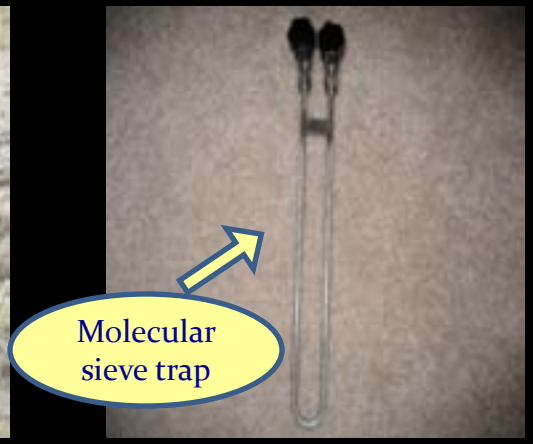
old carbon, ^{13}C-rich →



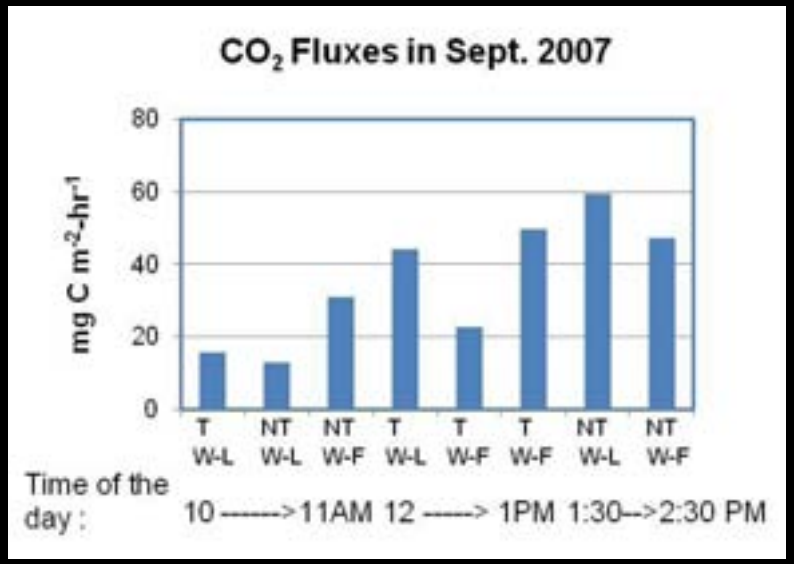
Methods – Measured C Flux: Sampling Time & Instruments

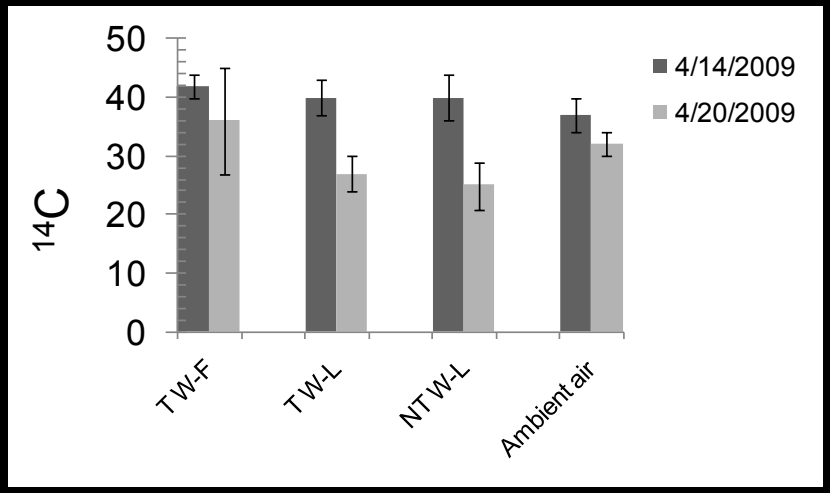


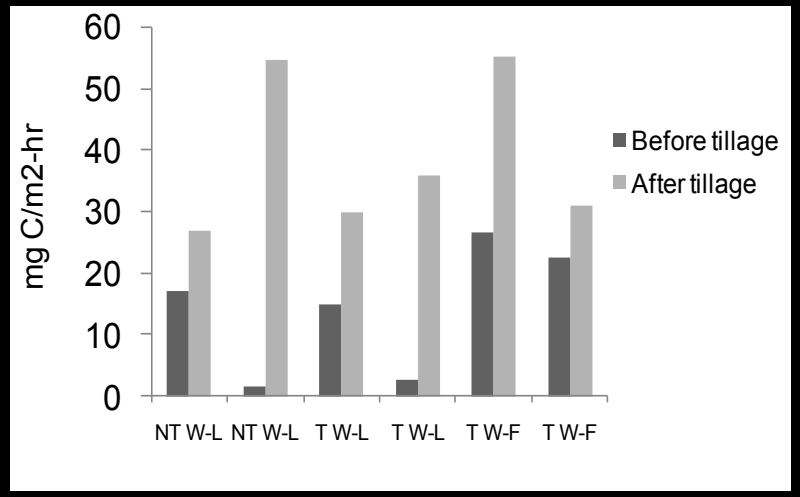




Results: 2007 – 2009 – Flux and 14C change due to seasonality and management







Soil CO_2 Fluxes → temp. & moisture

$\delta^{13}C$ ratio → Tillage and soil carbonates

$\Delta^{14}C$ → Impact with treatment

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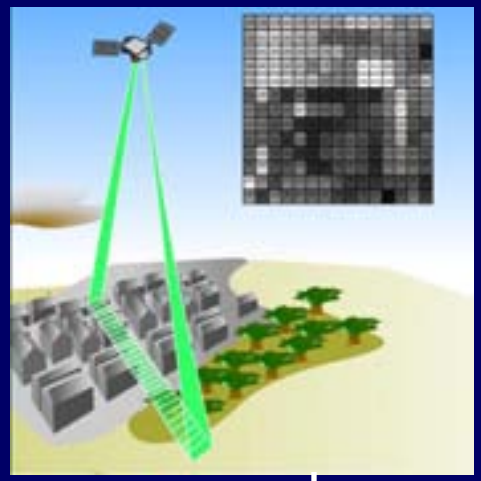
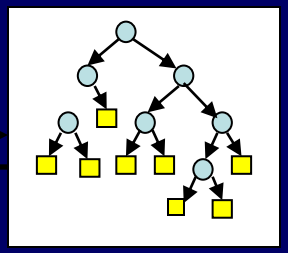
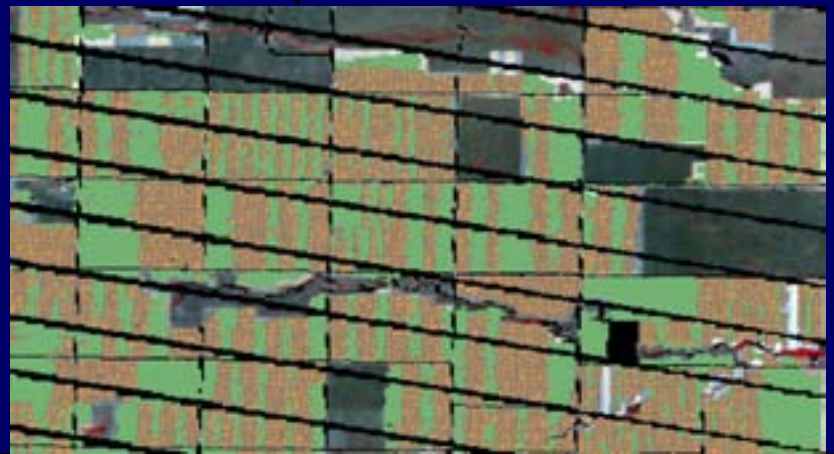
Cropland MMV Remote Sensing

- Classify w/ remote sensing
  - crop/fallow,
  - cropland/CRP,
  - tillage/no-till (NT)
- Efficient
  - No travel required
  - 100% monitoring
  - Information on crop health, etc…







How it works:

- **Landsat satellite**
  - ✓ every 16 days
- **Predictive model(s)**
  - ✓ known calibration sites
- **Predict for region**
  - ✓ known validation sites

Enrolled Sites MMV

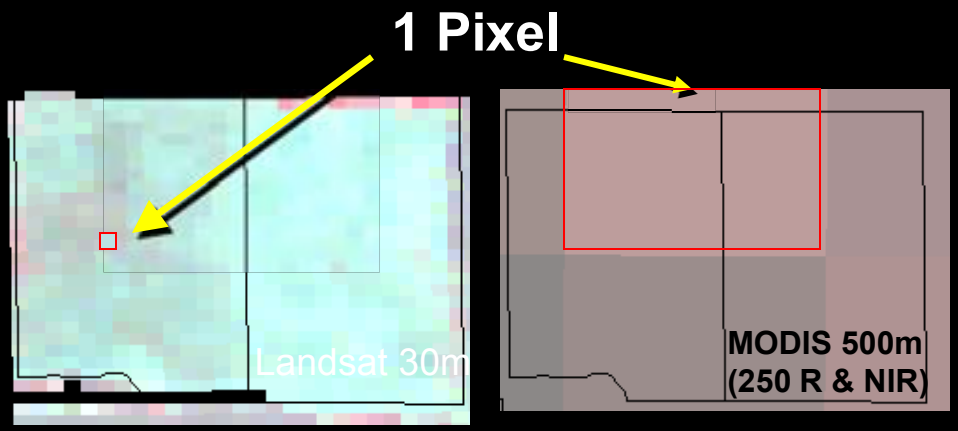
- Remote Sensing

Model	Class	Producer's	User's
No-Till & Tillage			
May Pixel-based	NT	92%	79%
	Till	23%	50%
May Object-based	NT	91%	71%
	Till	31%	67%
Crop & CRP			
May Object-based	Crop	100%	96%
	CR	90%	100%
Crop & Fallow (2004-2007)			
Late Summer/Fall Object-based	Crop	$\geq$ 93%	$\geq$ 93%
	Fallow	$\geq$ 82%	$\geq$ 84%

- **Successes**
  - ✓ crop vs. fallow
  - ✓ crop vs. CRP
- **Difficulties**
  - ✓ Till vs. no-till

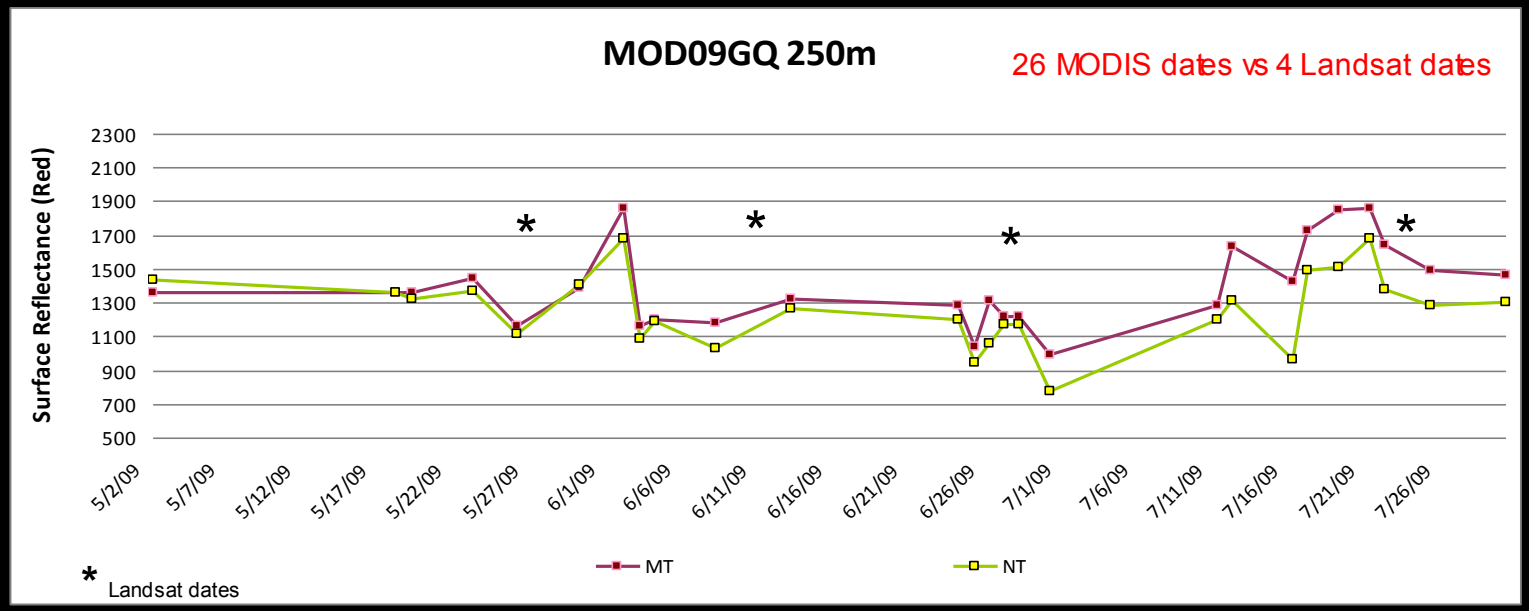
Incorporate MODIS data

Spatial resolution lower than Landsat



- Spectral resolutions similar
- Convert daily MODIS to daily Landsat (30m)
- Improve *till vs. no-till* class accuracies?

Higher temporal resolution than Landsat (daily vs. 16 days)



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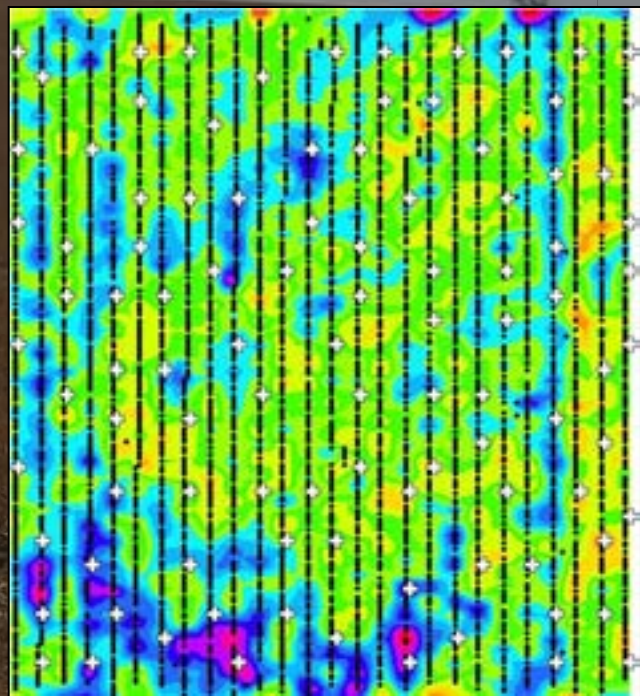
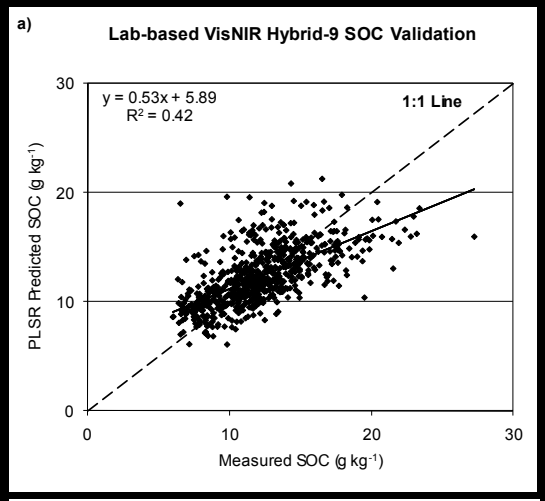
Cropland MMV

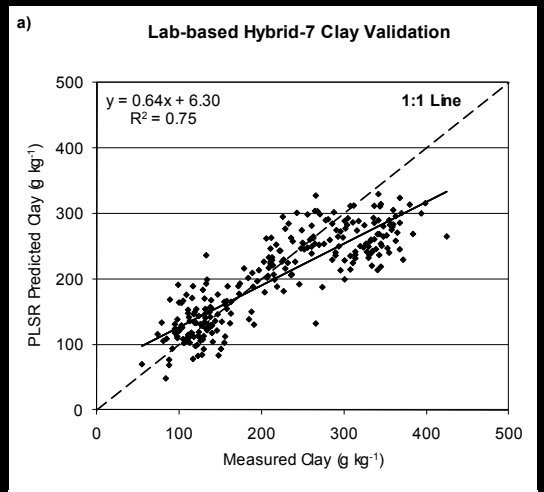
- Accurate point measurements of SOC
- **Spatial variability >> ΔSOC**
  - ~ 10^2 measures/field to detect change
- Accurate ΔSOC with repeated measures at fixed locations.
  - *Representative locations ?*
  - *Var(ΔSOC) << Var(SOC) ?*

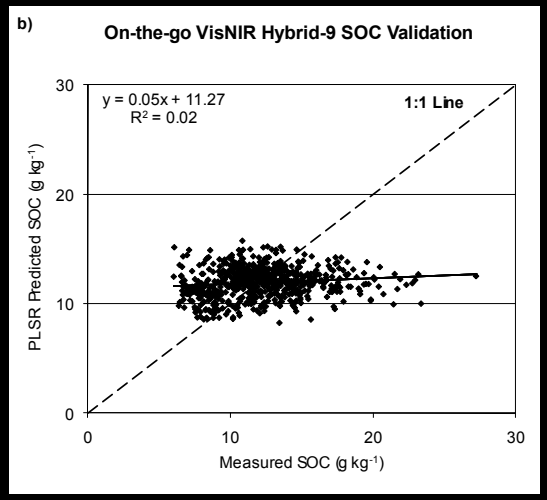


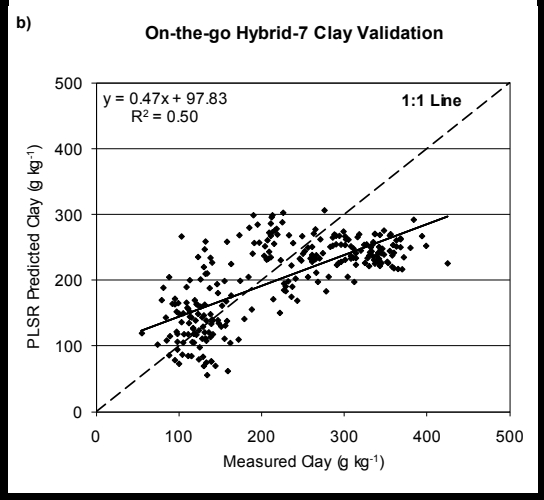
Enrolled Cropland Site MMV

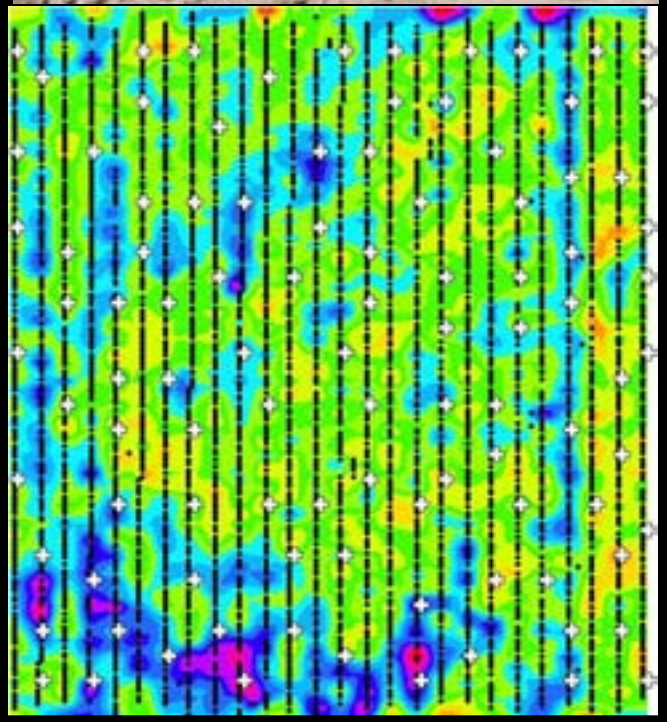
- "on the go" surface VisNIR







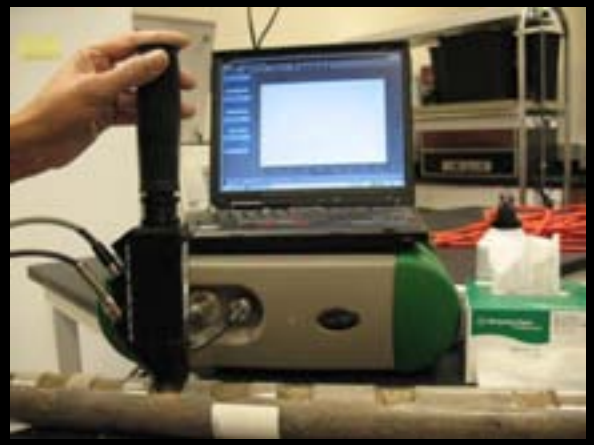


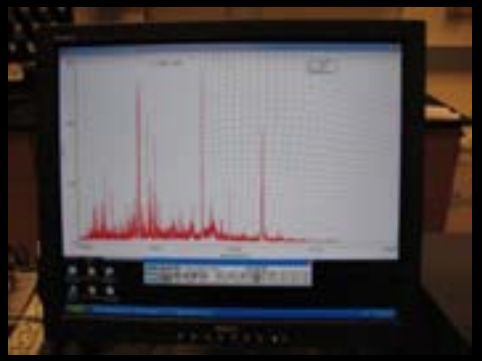


Bricklemyer, R.S. and D.J. Brown. Accepted. On-the-go VisNIR: Potential and limitations for mapping soil clay and organic carbon. Computers and Electronics in Agriculture.

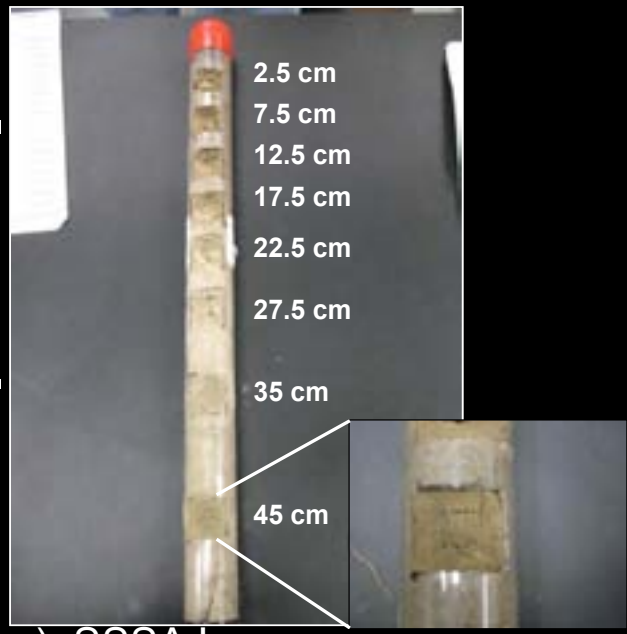
Enrolled Sites MMV

- **Intact Cores w/ LIBS & VisNIR**
  - 8 Fields
  - 200-900 nm





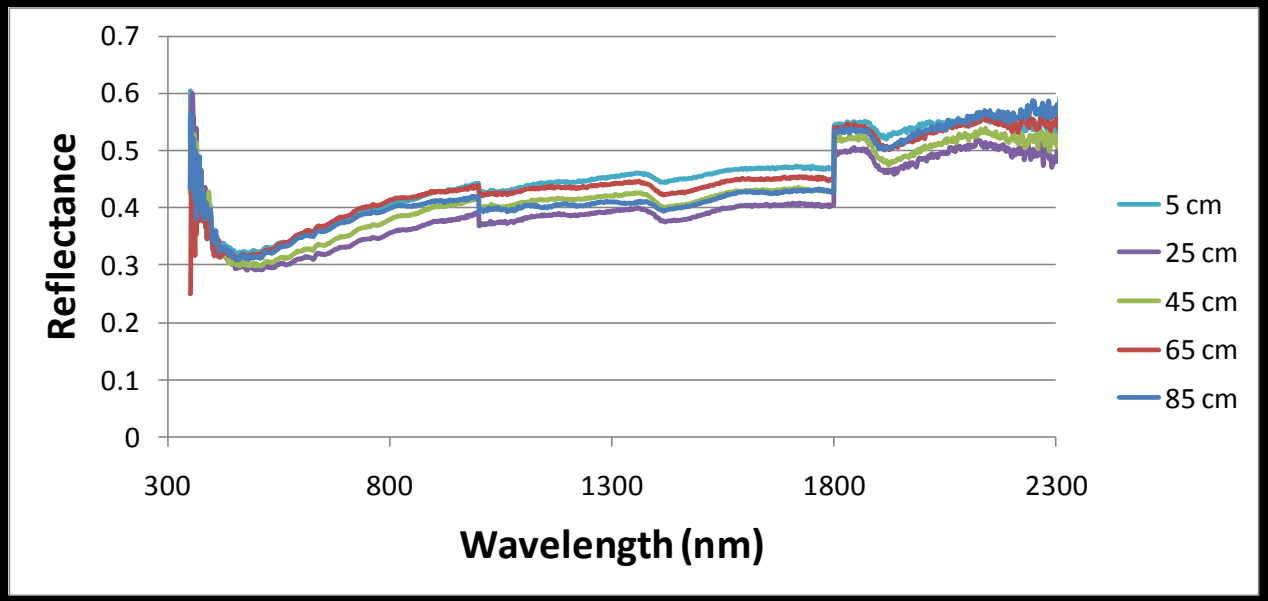
Technique	Measure	SEP	R^2
LIBS	TC	5.3	0.62
LIBS	IC	4.1	0.75
VisNIR	SOC	3.5	0.33
		g kg^{-1}	

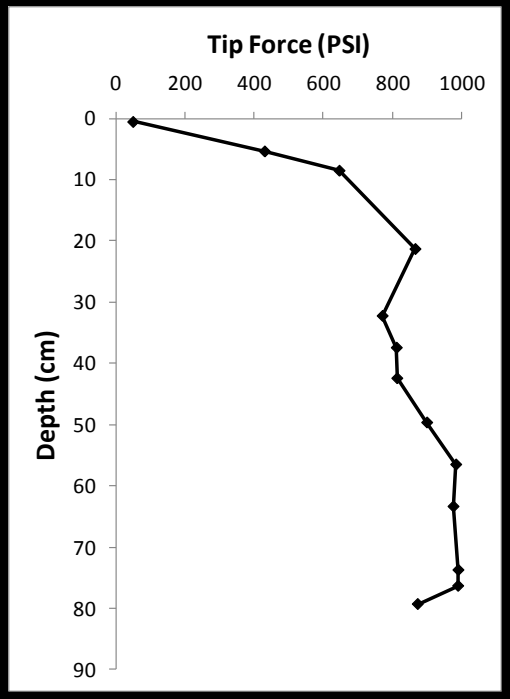


Bricklemyer, R.S., D.J. Brown, J.E. Barefield, S.M. Clegg. (In Review). SSSAJ.

Future of Soil Mapping VisNIR Penetrometer

- Experimental Equipment
- Preliminary Data
  - Tip Force
  - VisNIR





Acknowledgements

- David Brown – WSU
- Ted Dodge – NCOC
- Rick Lawrence – MSU
- Jenny Watts – MSU
- Perry Miller – MSU
- Rick Engel - MSU
- Ryan Feddema – MSU
- Sam Clegg – LANL
- Julianna Fessenden – LANL
- Malu Cisneros-Dozal – LANL

Montana State University
College of Agriculture & Montana Agricultural Experiment Station

Los Alamos National Laboratory EST. 1943

Washington State University

University of Idaho

National Carbon Offset Coalition

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A NEW ENERGY FUTURE FOR MONTANA, IDAHO, WYOMING, SOUTH DAKOTA, THE PACIFIC NORTHWEST, AND THE NATION

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Forest Aboveground Carbon MMV Preliminary Results

Prepared by Lee Vierling, Eva Strand

University of Idaho

Andy Hudak

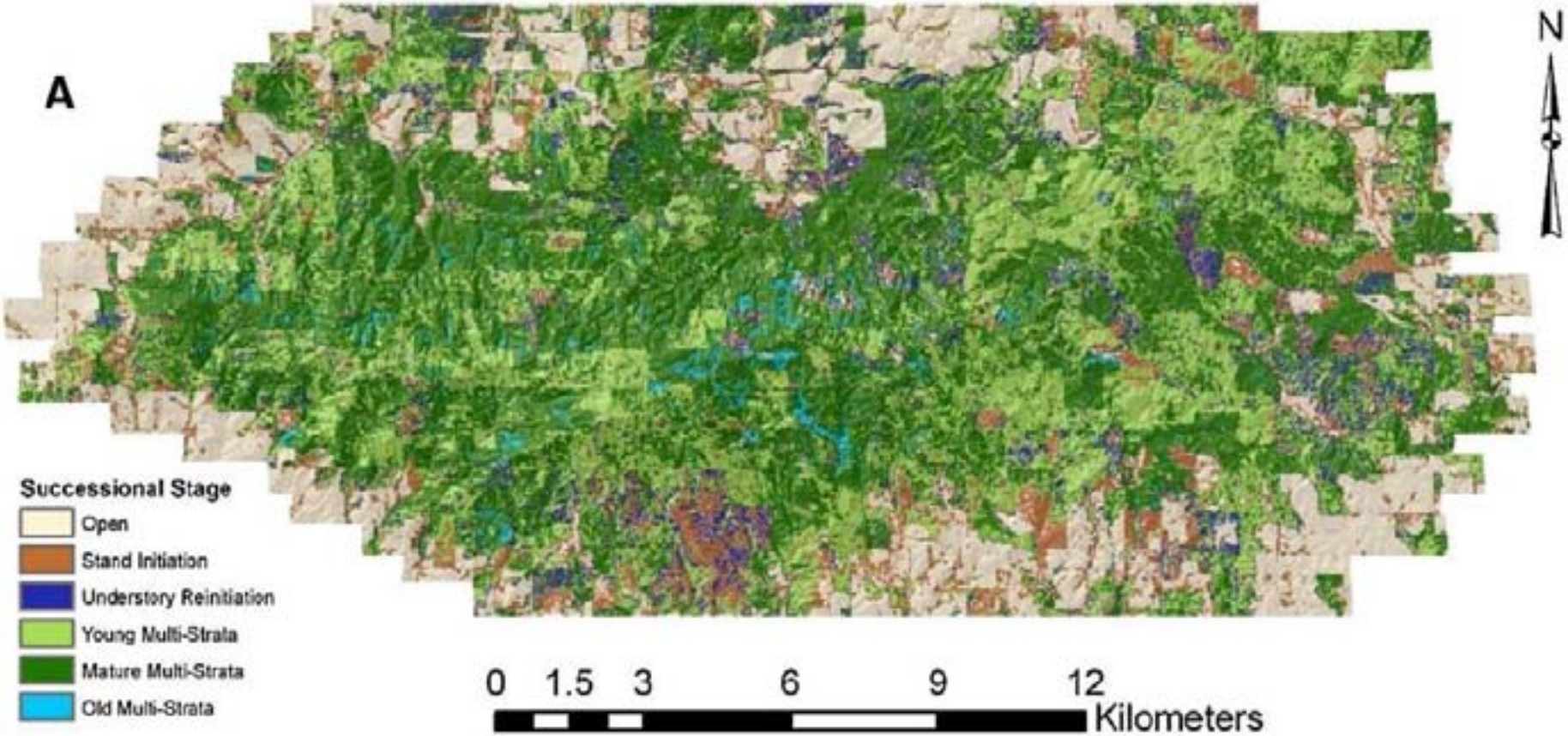
US Forest Service, Rocky Mountain Research Station

Forestry Field Validation Test Specific Objectives

Remote sensing methodologies:

- Quantify aboveground C sequestration
- Impact of forest growth and disturbance
- Evaluate lidar time series for forest MMV

Study Area



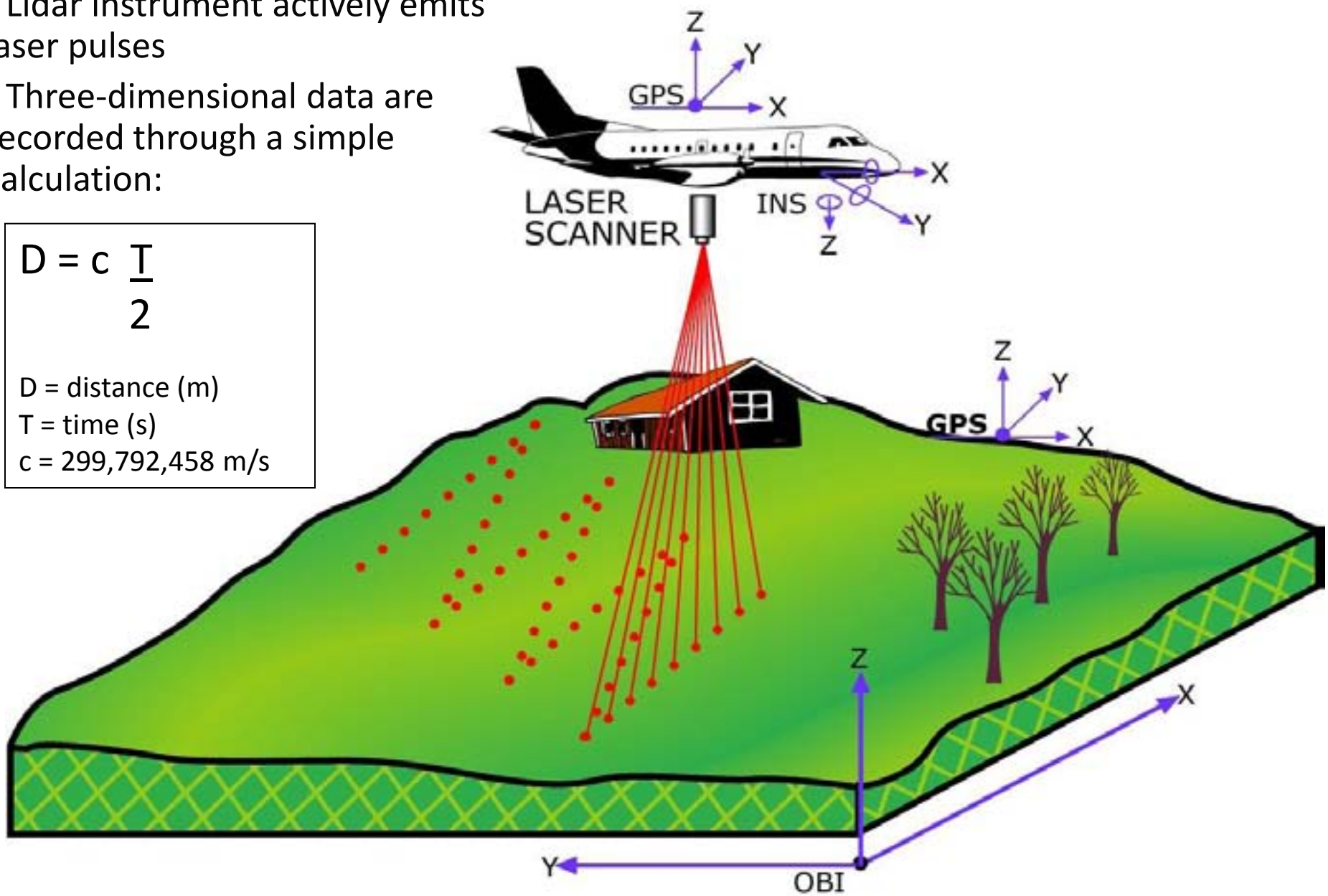
(Forest successional map by Falkowski et al. 2009)

LASER SCANNING

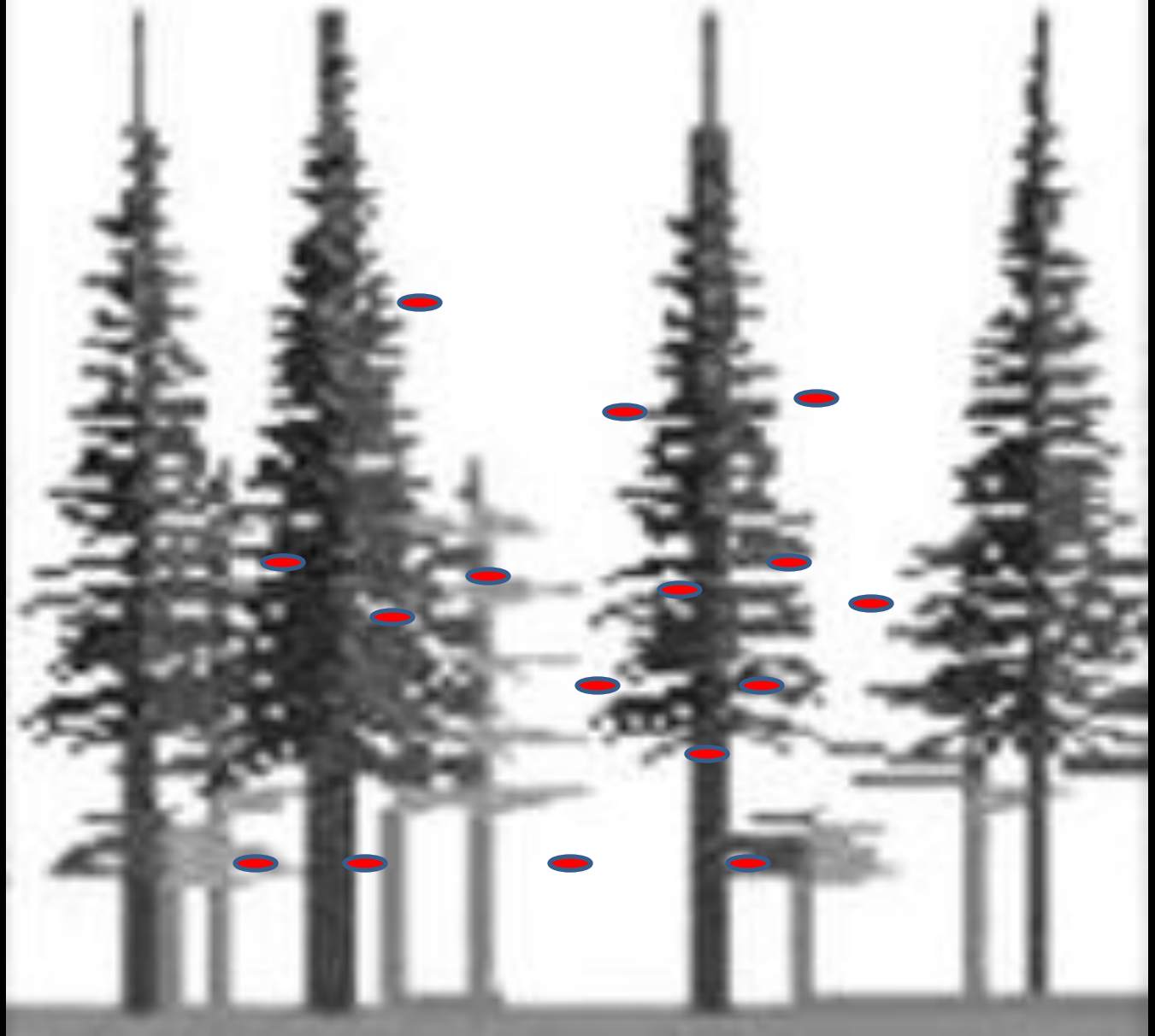
- Lidar instrument actively emits laser pulses
- Three-dimensional data are recorded through a simple calculation:

$$D = c\,\frac{T}{2}$$

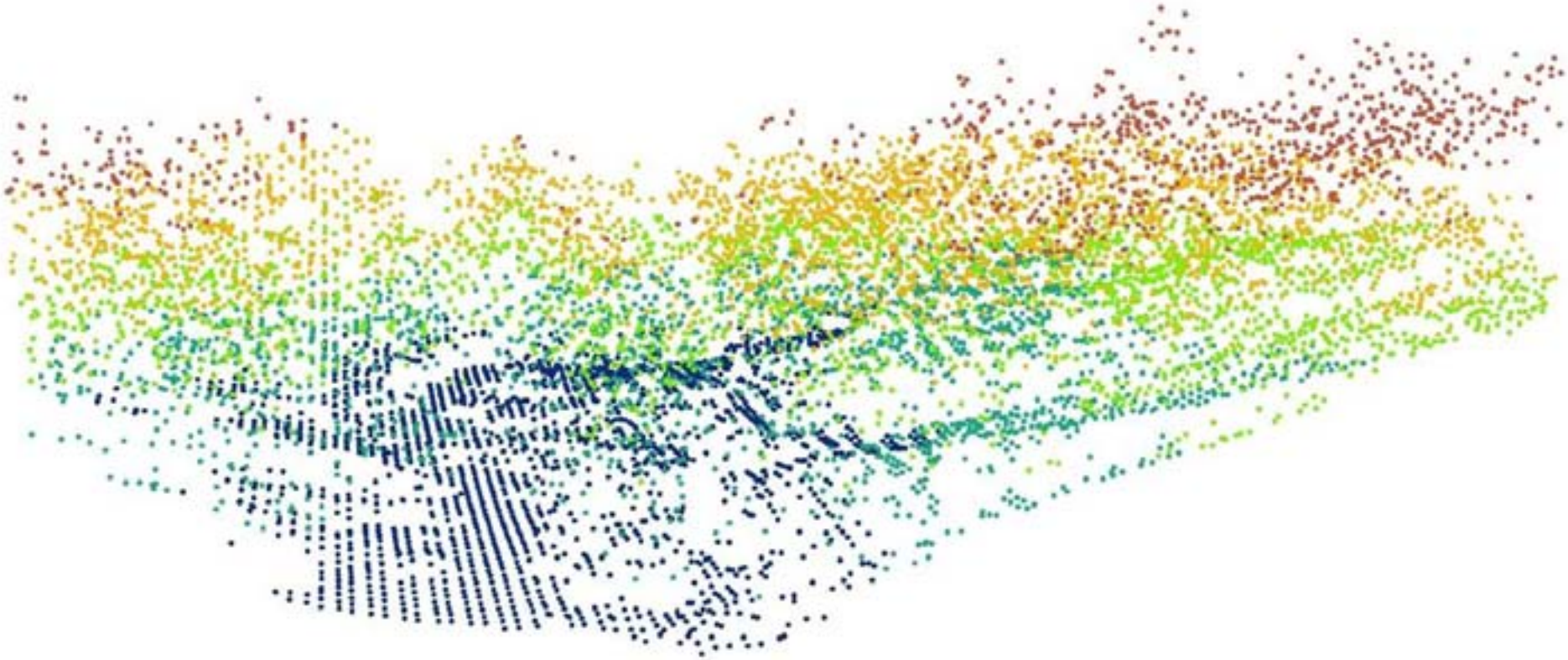
D = distance (m)
T = time (s)
c = 299,792,458 m/s



LiDAR is a sampling system

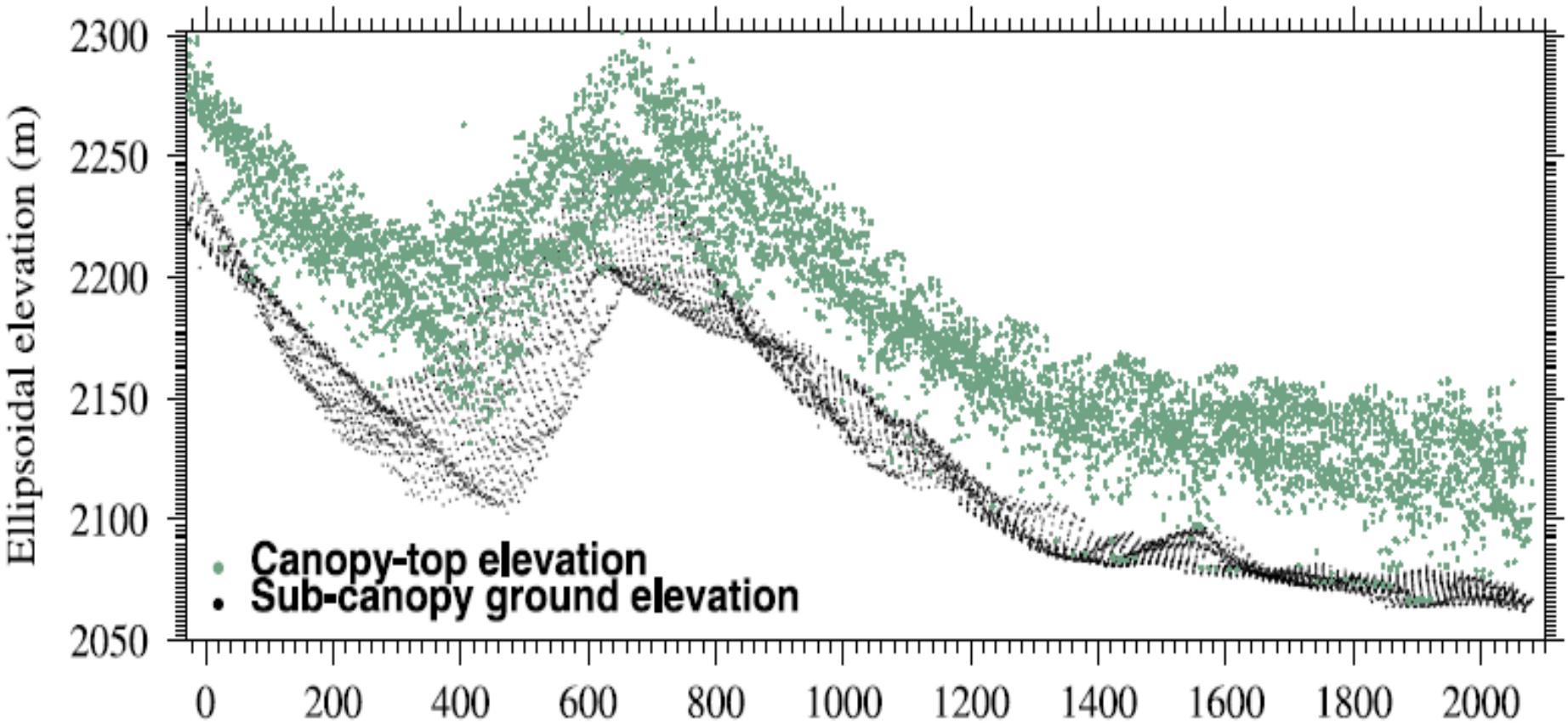


A Raw “Point Cloud”

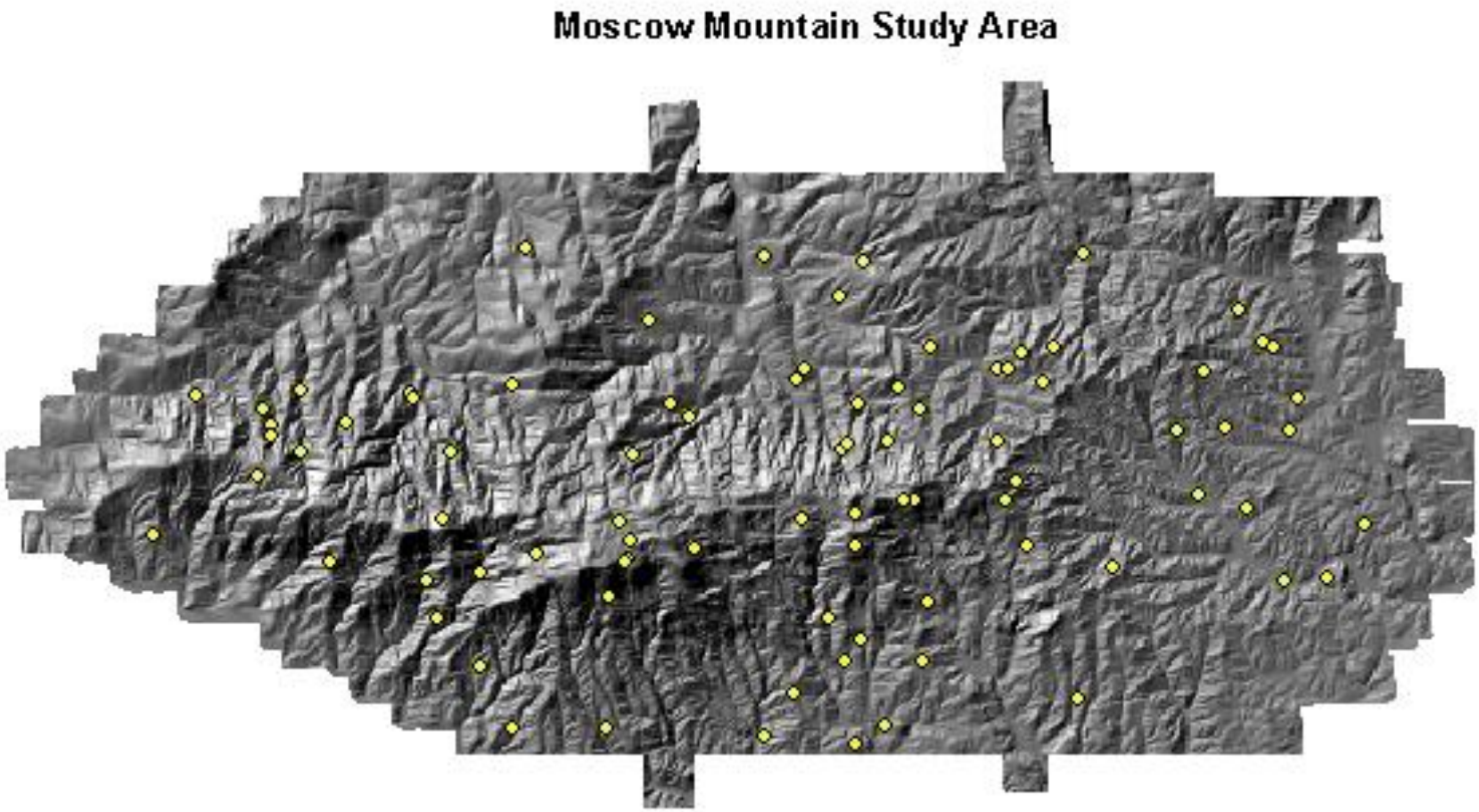


Hudak and Evans

Differentiating ground from canopy



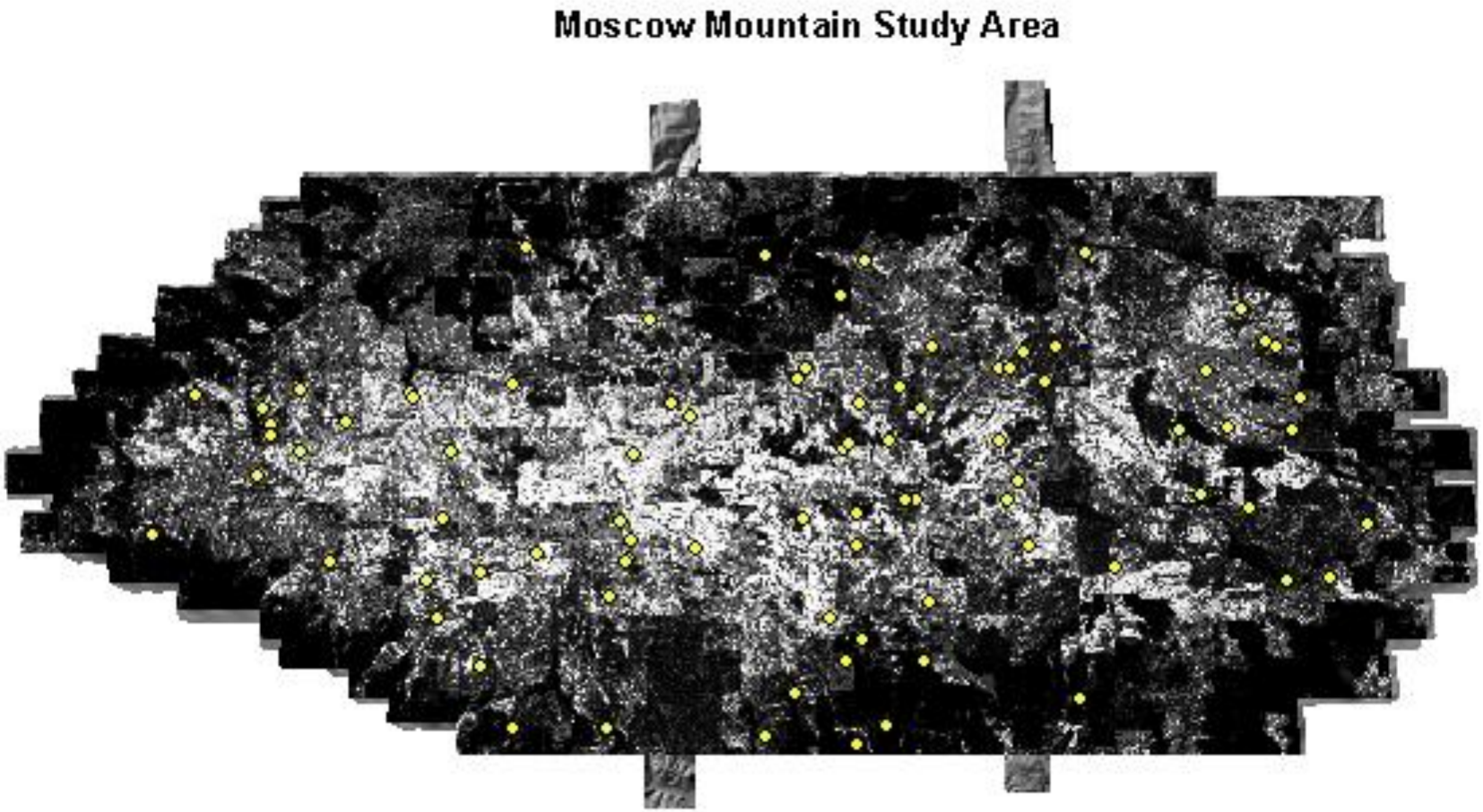
DEM + ground plots (2003)



Evans and Hudak. (2007) A multiscale curvature algorithm for classifying discrete return lidar in forested environments. *IEEE Transactions on Geoscience and Remote Sensing* 45(4): 1029-1038.

Moscow

Ground points intensity (2003)



Hudak *et al.* (2006). *Canadian Journal of Remote Sensing* 32: 126-138.

Hudak, *et al*. (2008). *Remote Sensing of Environment* 112(5): 2232-2245.

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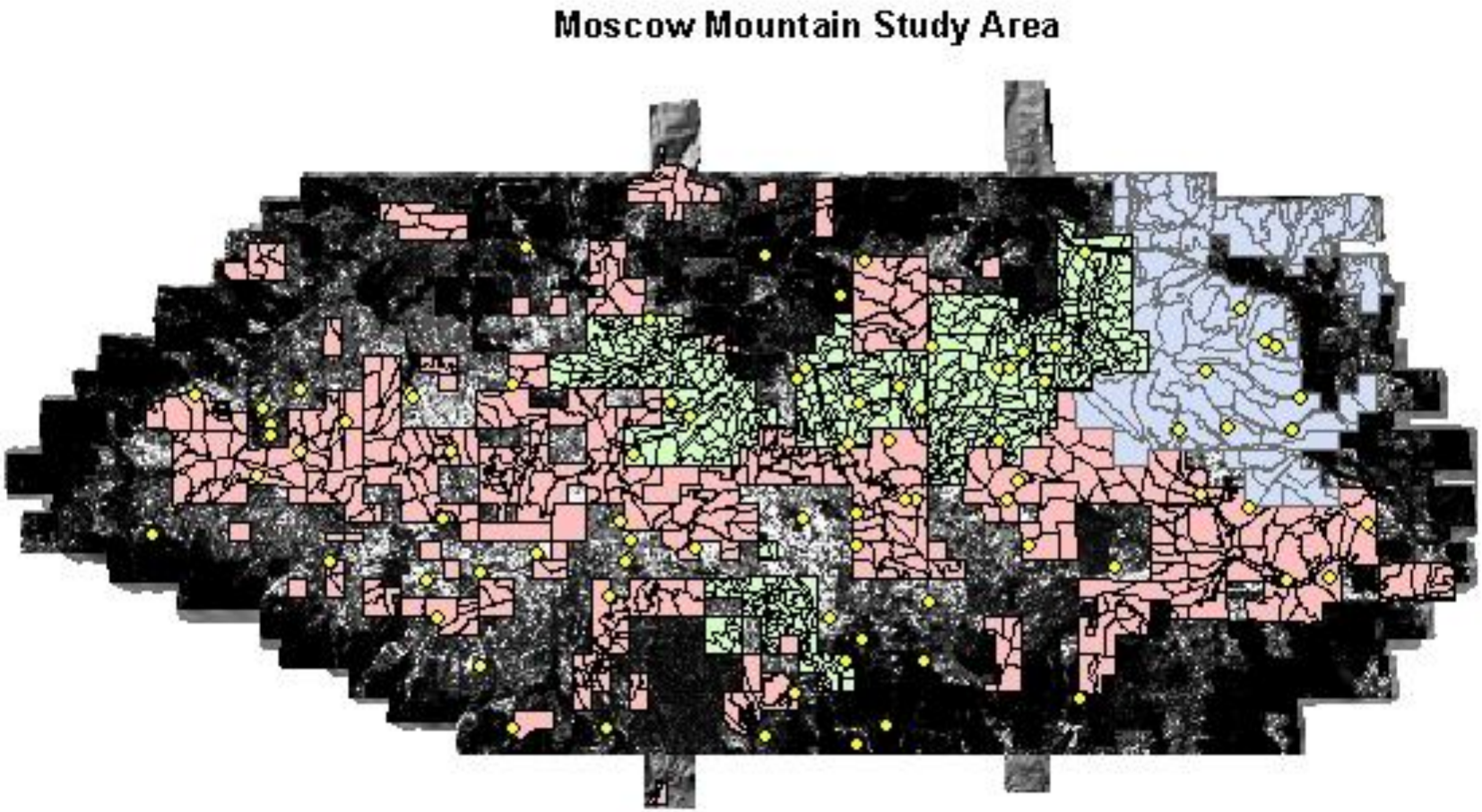
Stand Polygons (2003)



Hudak *et al.* (2008). *Third Forest Vegetation Simulator Conference Proceedings* RMRS-P-54. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. pp. 133-146.

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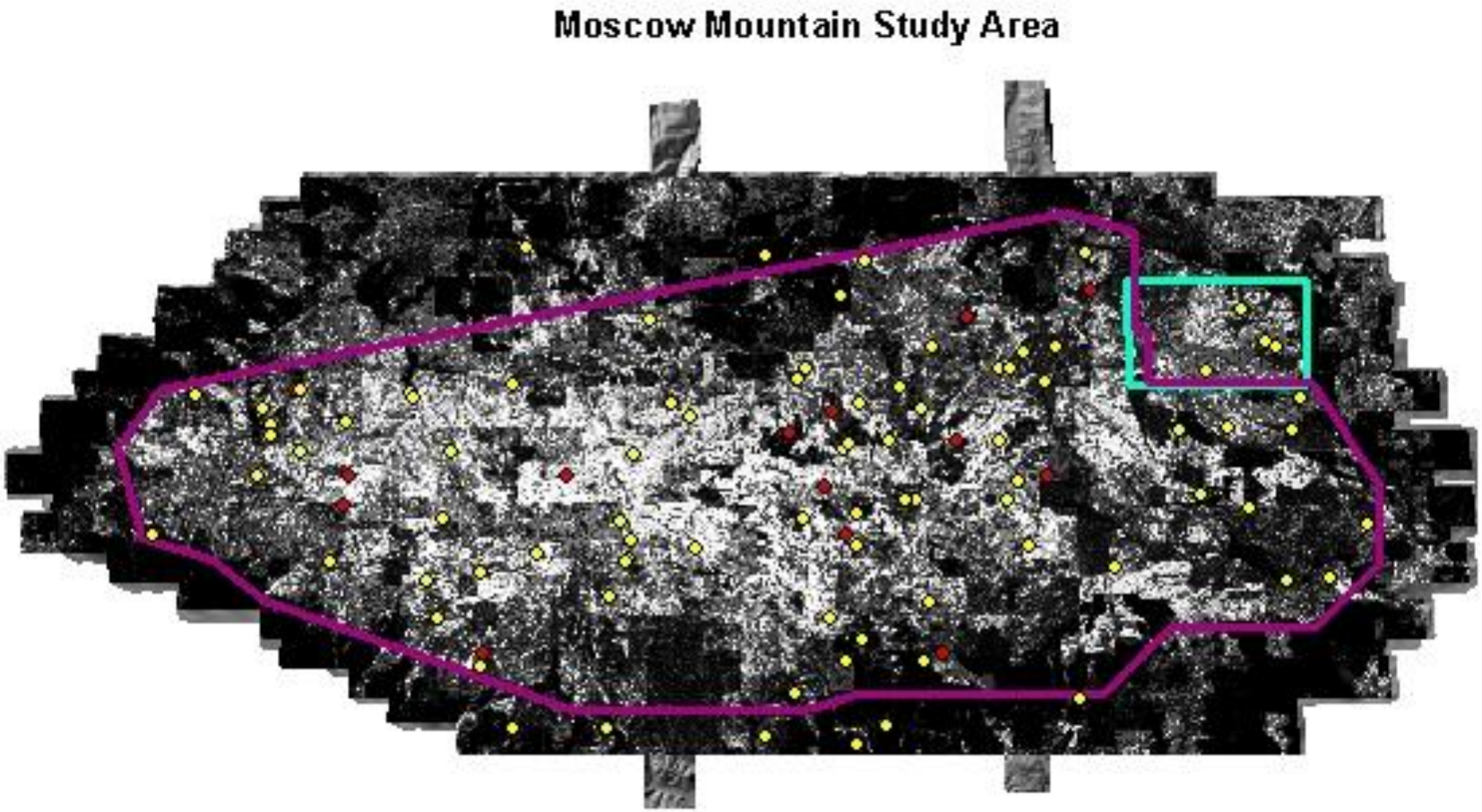
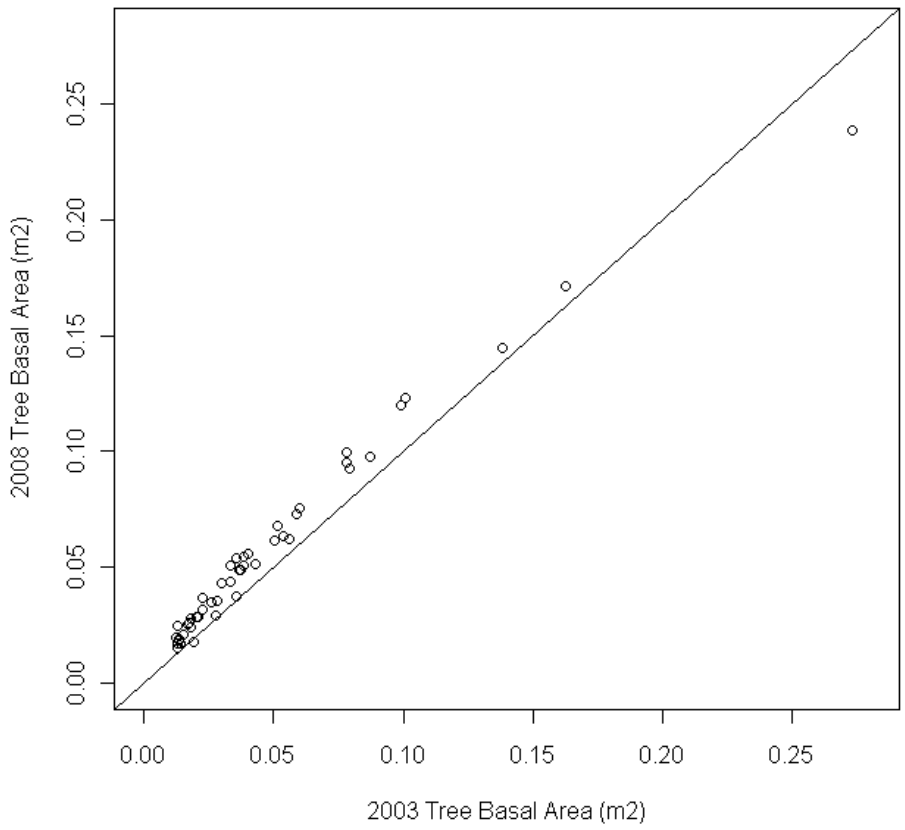
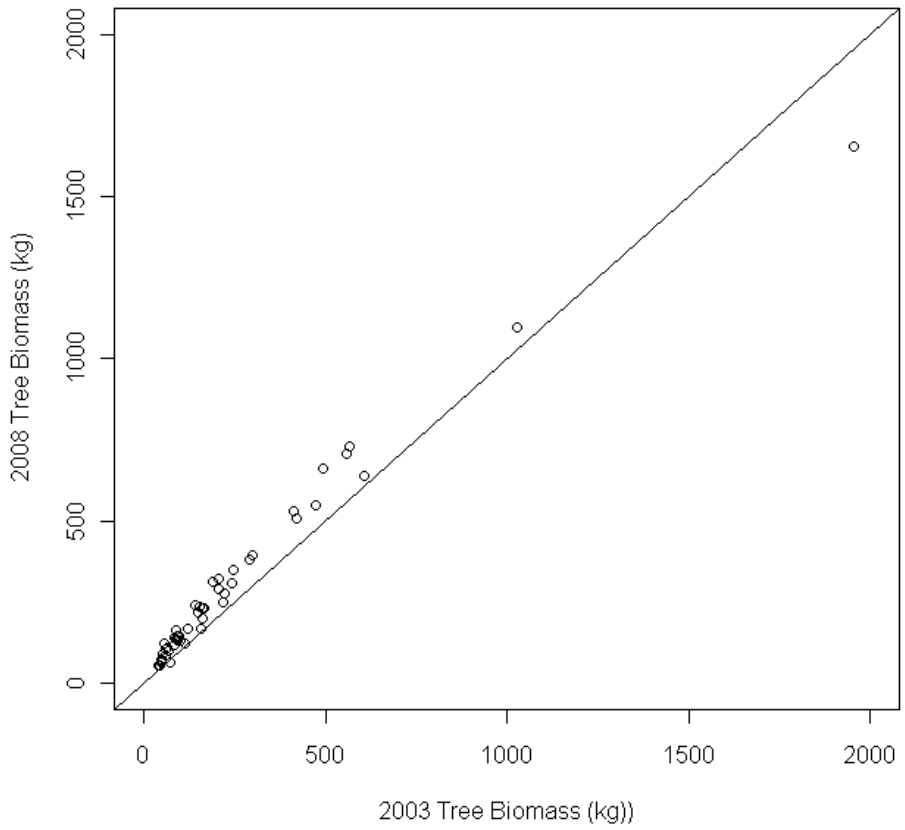
Repeat LIDAR (2007, 2009)



Moscow

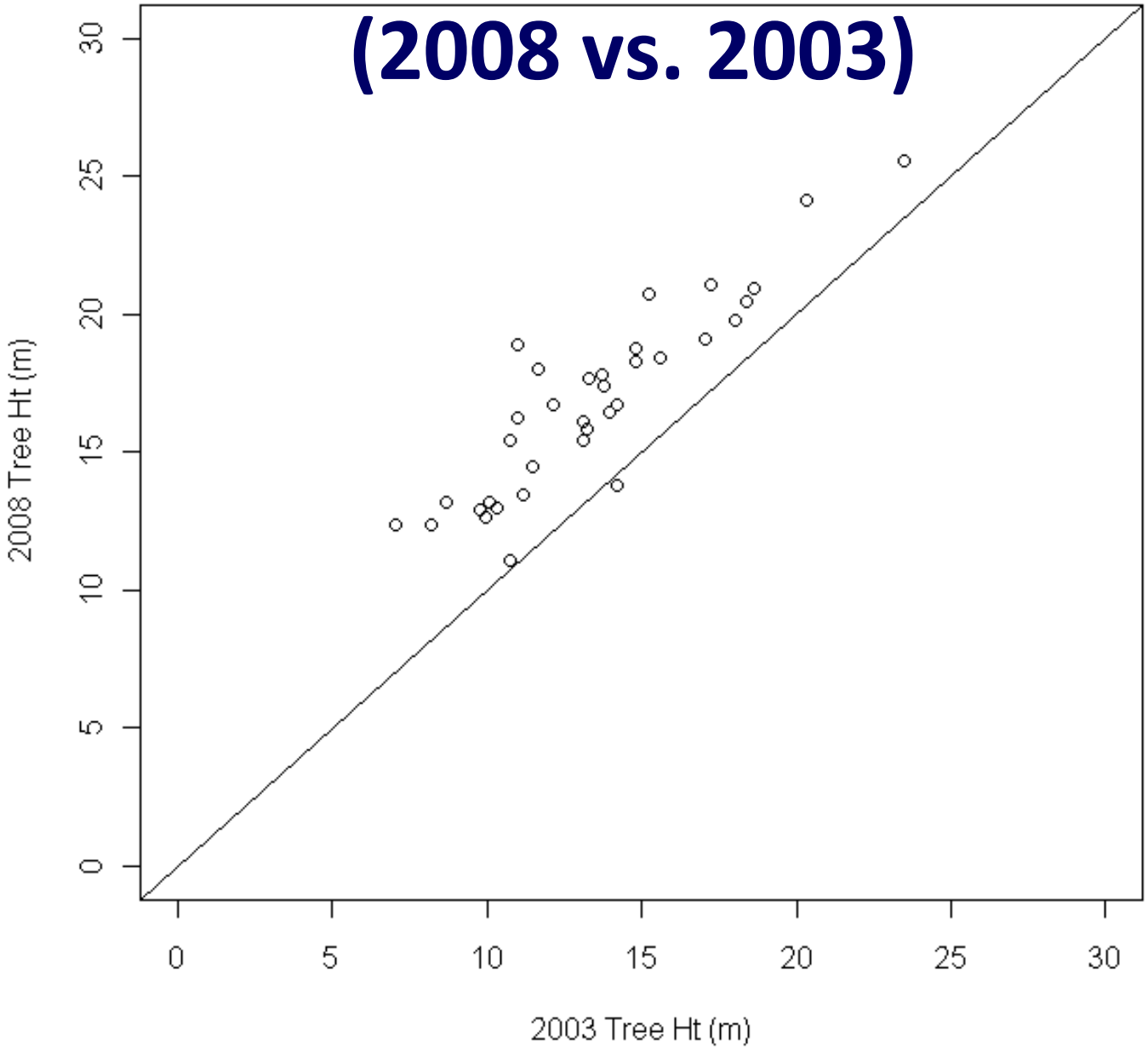
Field diameter at breast height (dbh) measures



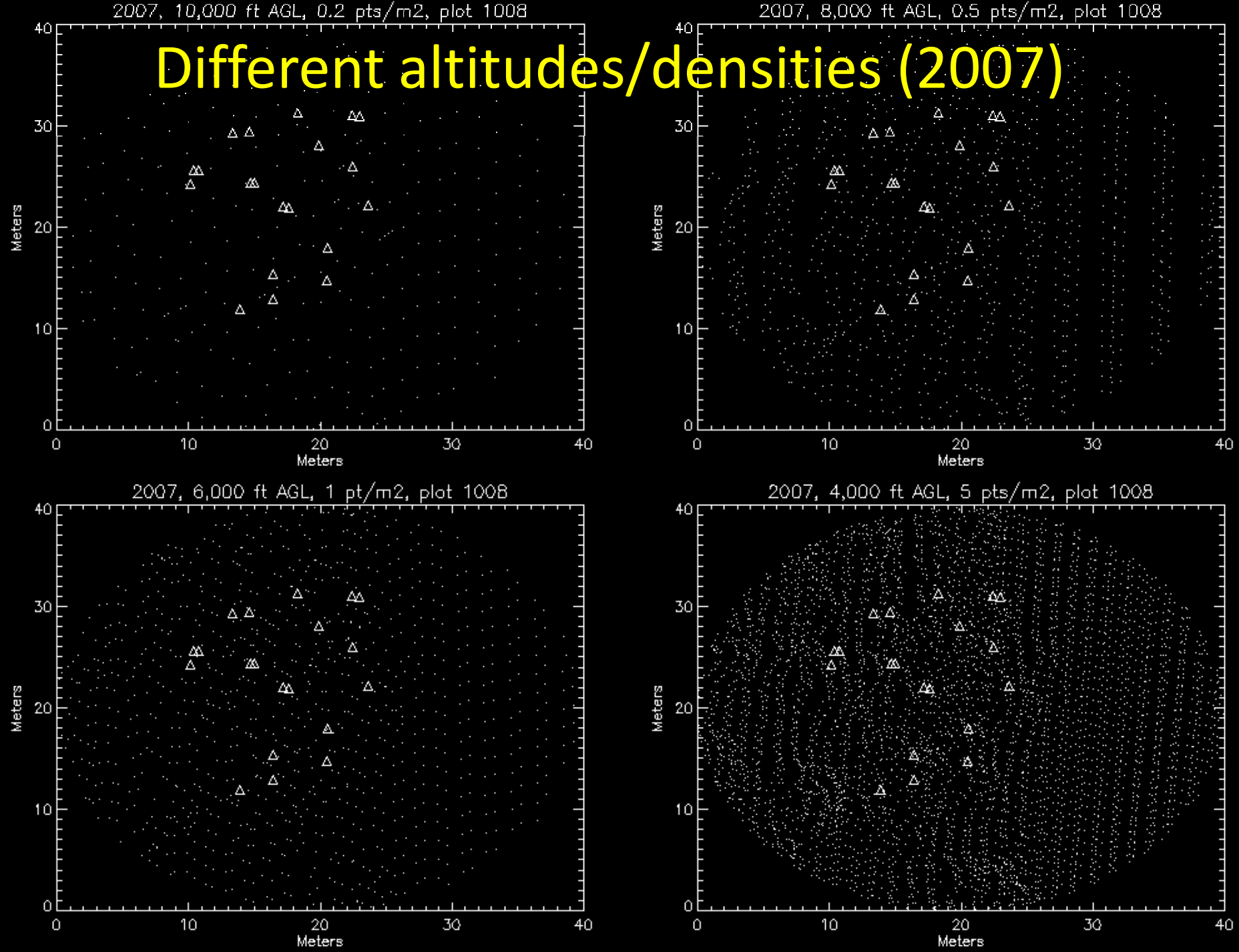


Carbon = Biomass x 0.5

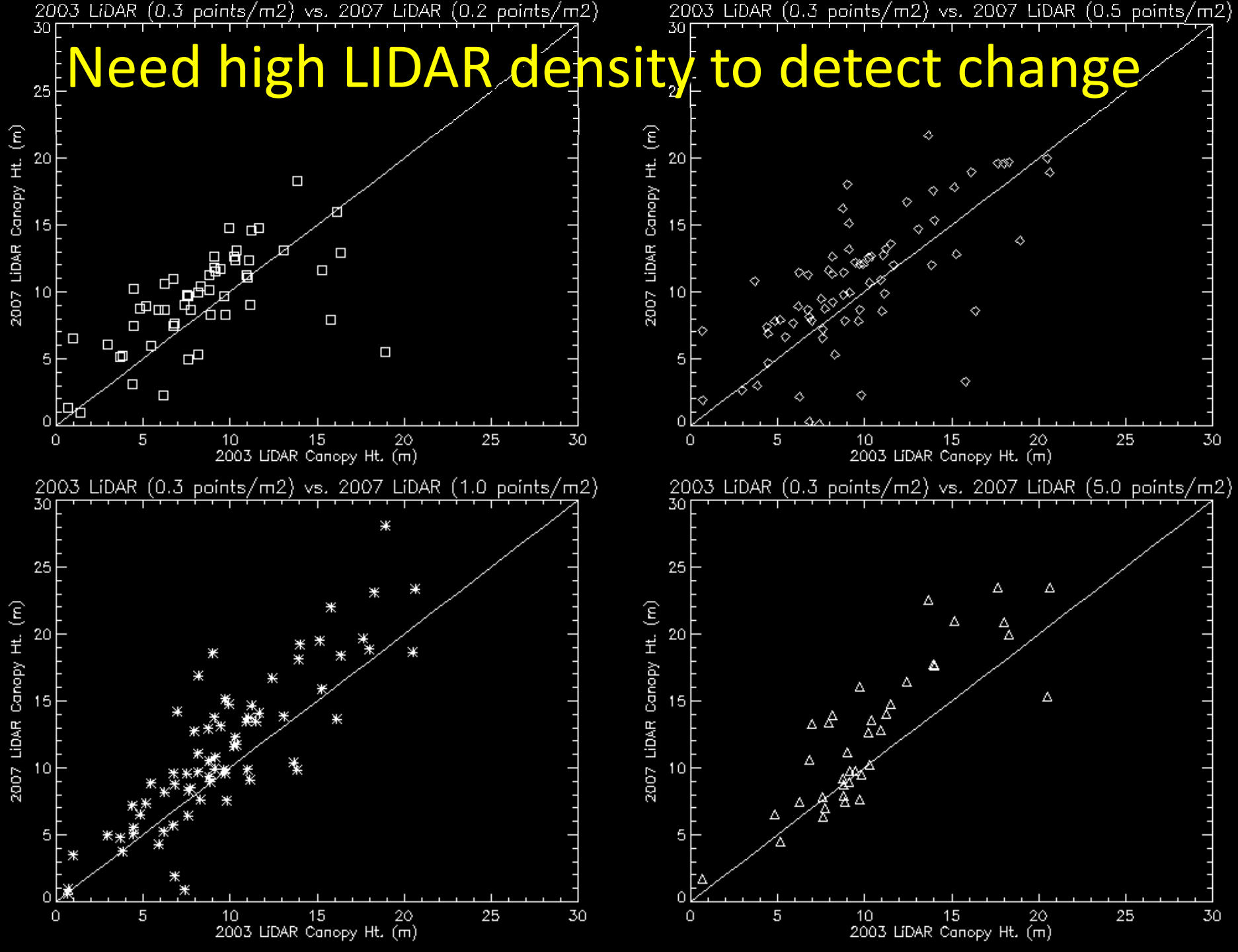
Field height measures (2008 vs. 2003)



Different altitudes/densities (2007)



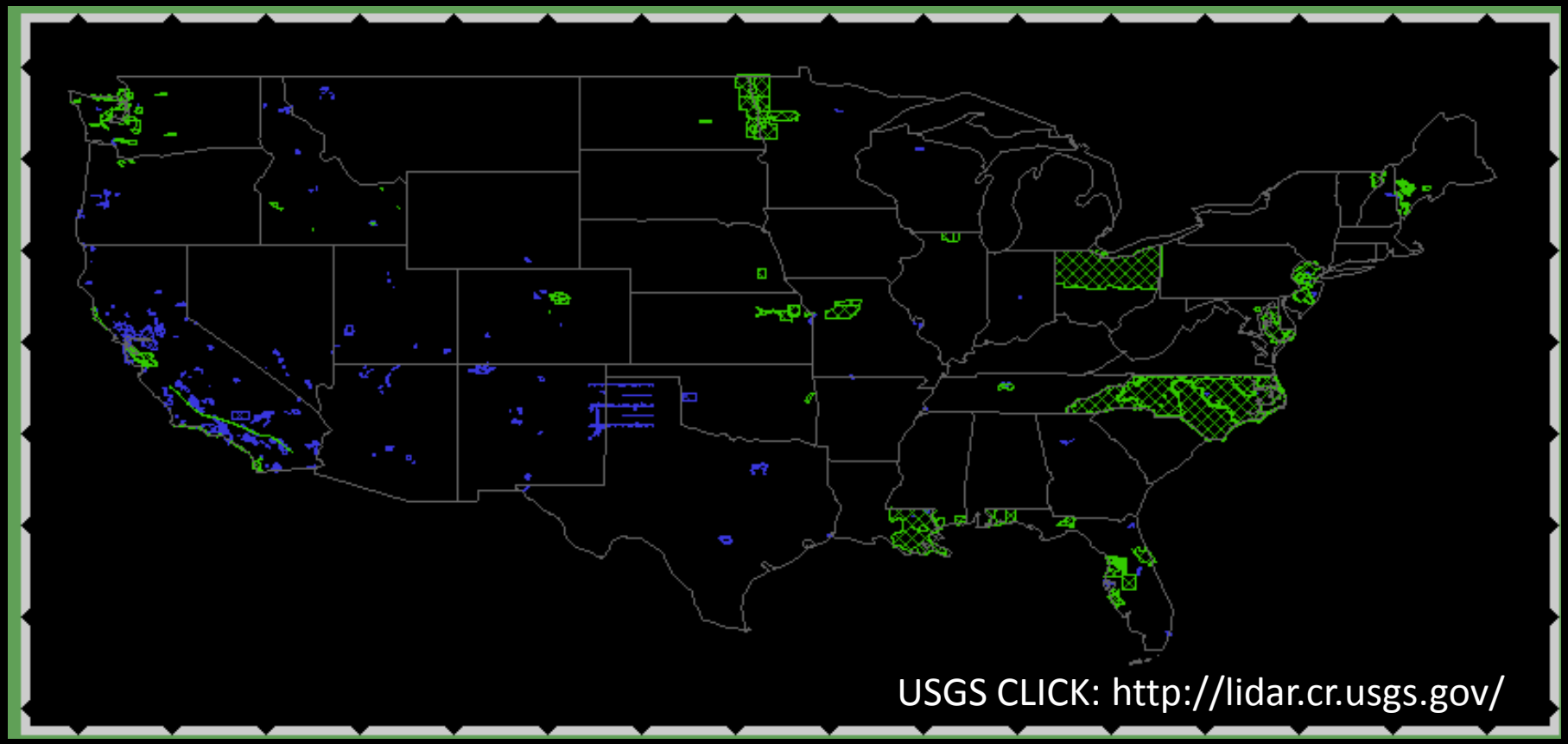
Need high LIDAR density to detect change



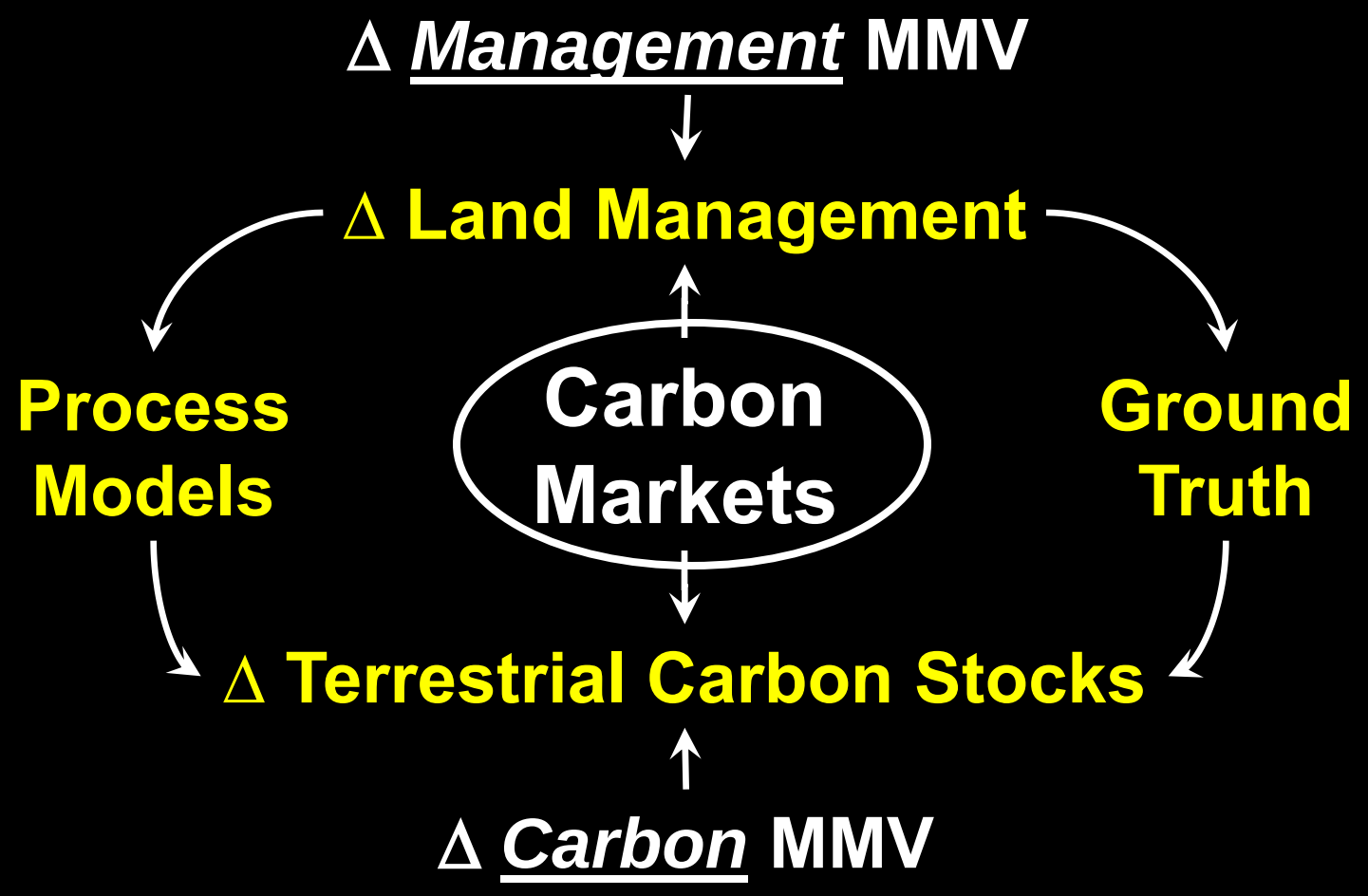
Data and Tools for Forest Carbon Assessment

- Remote Sensing
  - 2003, 2007, and 2009 LiDAR data for modeling/mapping
- Field Data
  - Plot-level data for modeling:
  - 1354 trees measured in 2003 on 73 plots
  - 73 trees tallied in 2008 on 4 plots (this presentation)
  - 2310 trees measured in 2009 on 83 plots
    - 73 re-measured plots from 2003, plus 14 new plots
    - ~2/3 of plots from 2003 were undisturbed (use for growth calibration)
    - ~1/3 of plots from 2003 were disturbed (use for harvest calibration)
  - Stand-level data for validation:
    - Bennett Lumber Products, Inc.
    - Potlatch Forest Holdings, Inc.
    - University of Idaho Experimental Forest
- Forest Vegetation Simulator
  - Project growth, harvest, and climate effects on forest C sequestration

Towards National & Global LiDAR Coverage



Terrestrial Carbon Sequestration MMV



Terrestrial Carbon Sequestration

- Ready now
- Positive externalities
- MMV improvements required