How to build soil organic matter

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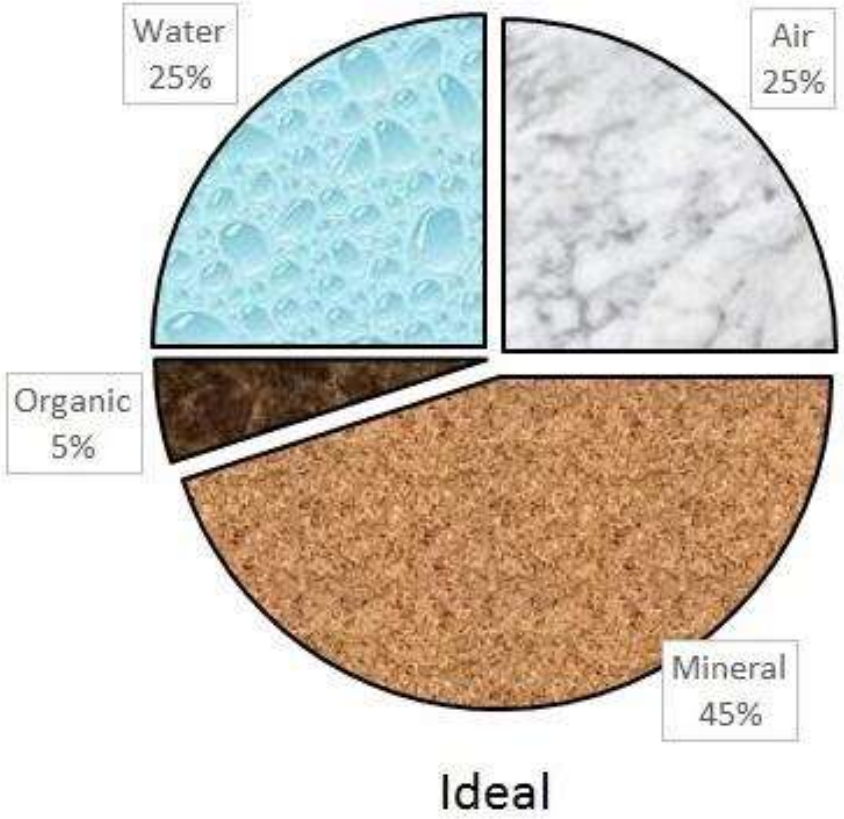
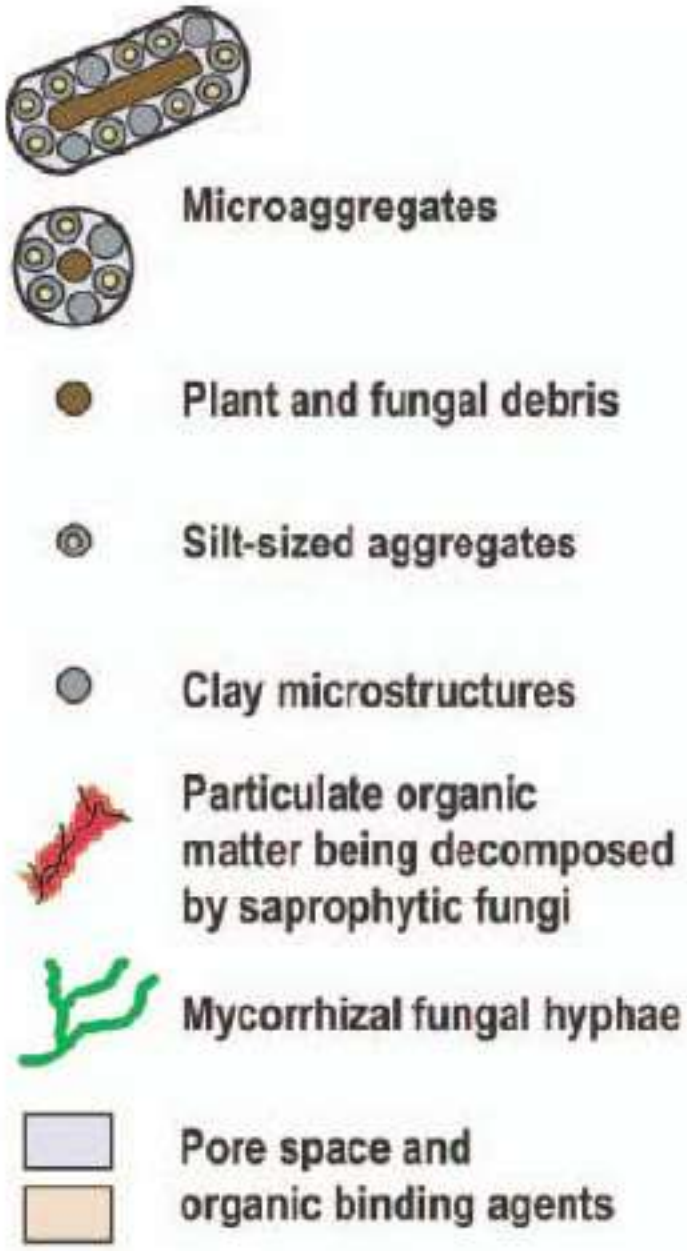
What is Soil Organic Matter?

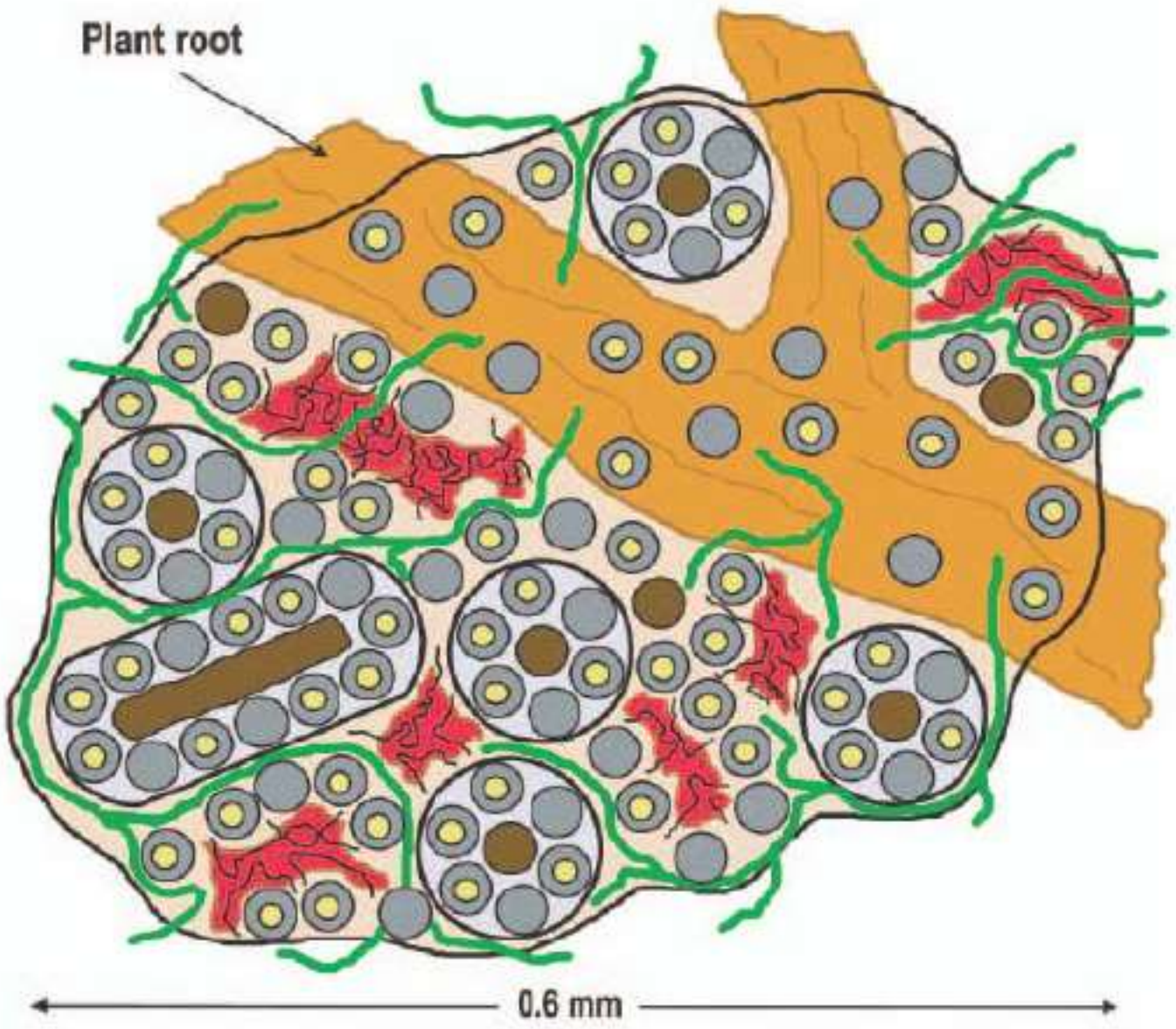
Definition:

The organic fraction of soil including plant, animal, and microbial residues, at all stages of decomposition.



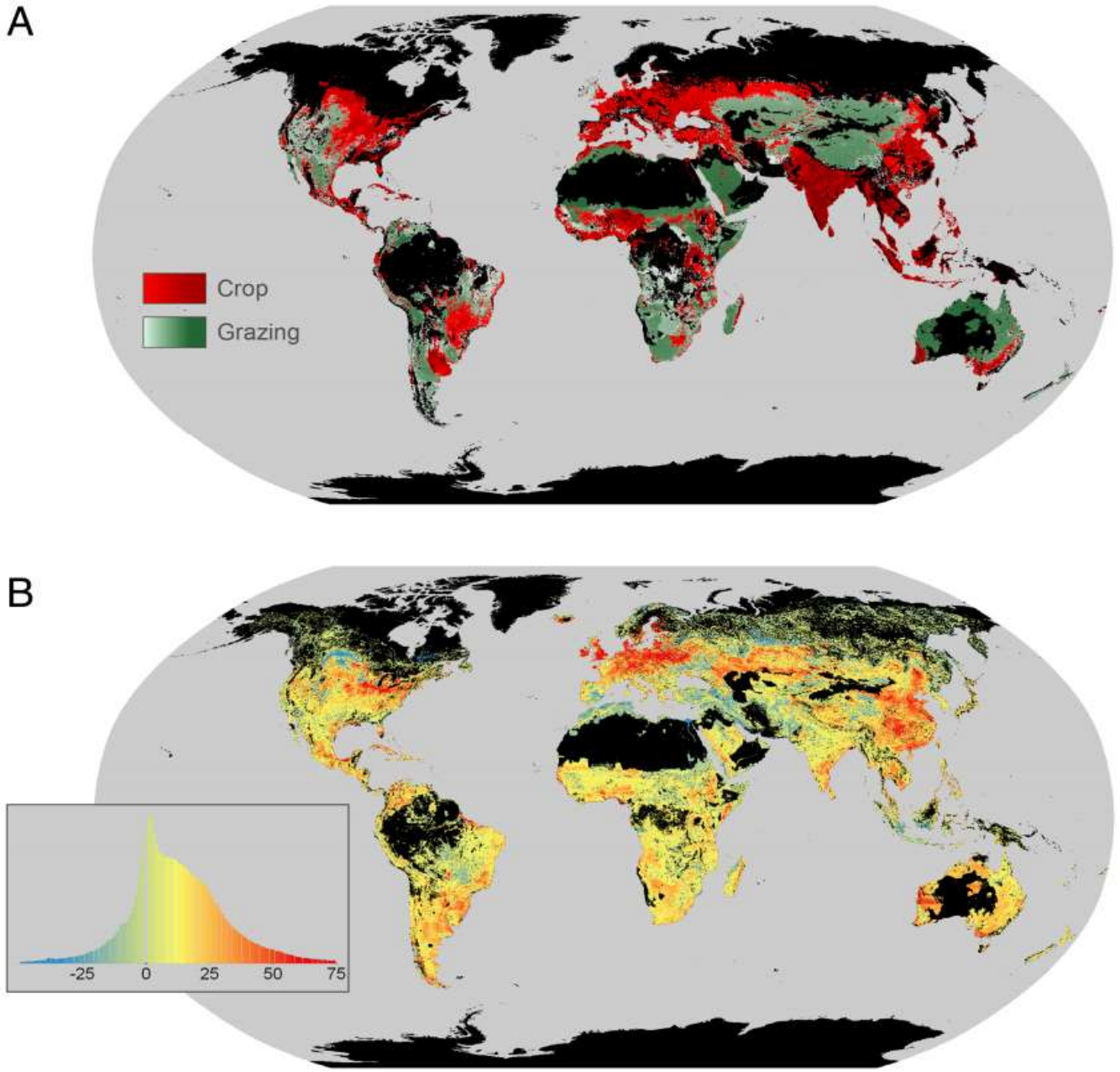
The organo-mineral complex





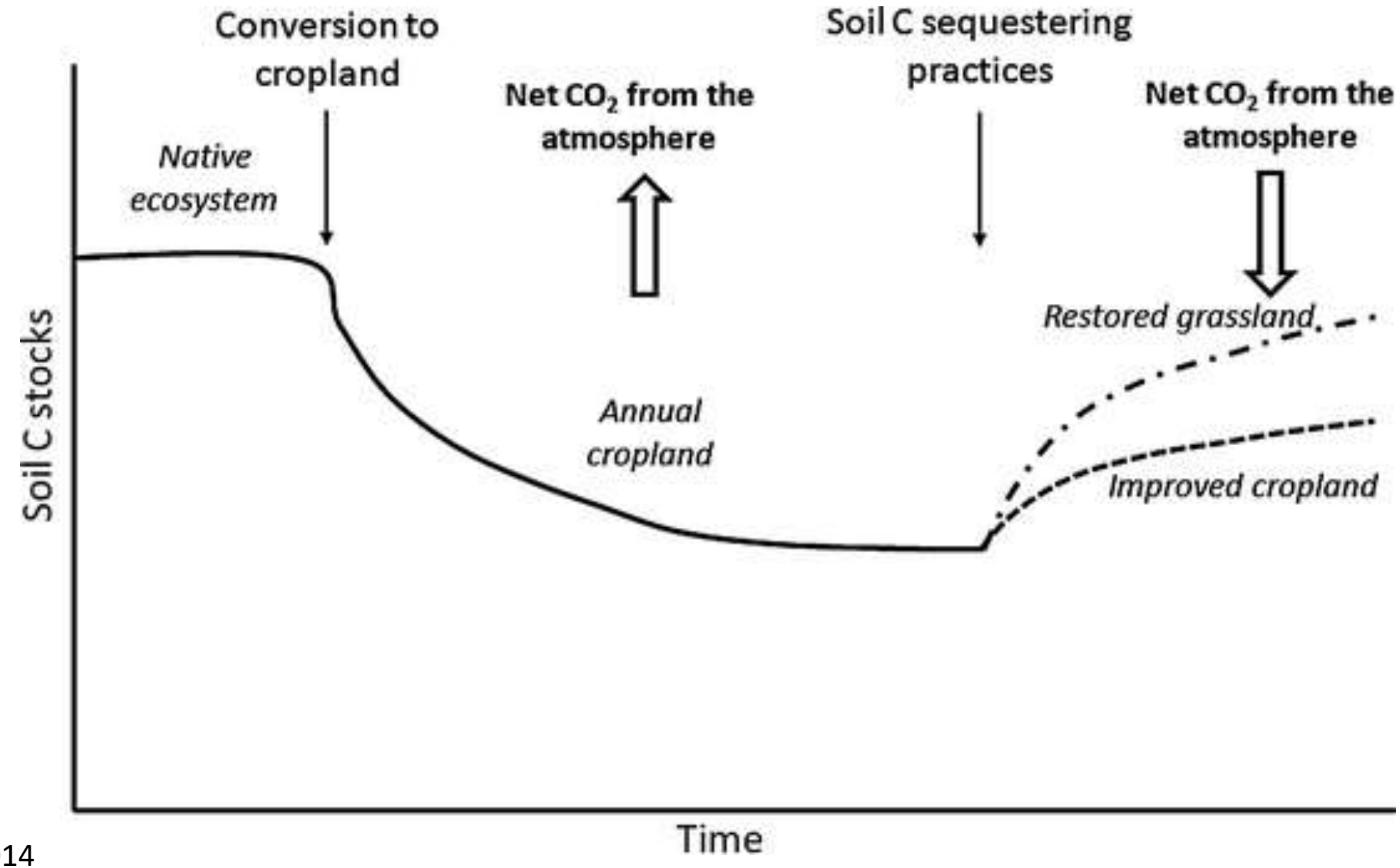
Anderson, 2009

Soil C loss due to land use



Map A shows the global distribution and intensity of crop production (red) and cattle grazing (green) and map B shows regional changes to soil carbon stocks since 10,000BC. On map B, blue represents the highest level of soil carbon gain since 10,000BC, while red shows the highest level of carbon loss. Black shows unfarmed desert regions

(Sanderman et al. 2017)



Paustian, 2014

The role of soil organic matter

Chemical functions	Physical functions	Biological functions
- Adds to the cation exchange capacity of the soil - Buffers changes in pH - Binds with cations (e.g. Mn^{2+} and Al^{3+})	- Improves structural stability through aggregate formation - Influences water retention, through aggregate formation - Buffers against extremes in temperature	- Creation of habitat - Source of carbon - Source of nutrients

Global meta-analysis of the relationship between soil organic matter and crop yields

Emily E. Oldfield[1], Mark A. Bradford[1], and Stephen A. Wood[1,2]

[1]School of Forestry and Environmental Studies, Yale University, 370 Prospect Street, New Haven, CT 06511, USA

[2]The Nature Conservancy, Arlington, VA 22201, USA

Corn and wheat yield gains occur with increases in SOM up to …

4%

Building carbon: things to consider

- Carbon inputs
- Carbon protection

Building carbon: things to consider

- **Carbon inputs**
- Carbon protection

Inputs

- Fertilizer
- Manure
- Crop residues
- Cover crops

What's the difference between SOM and SOC?

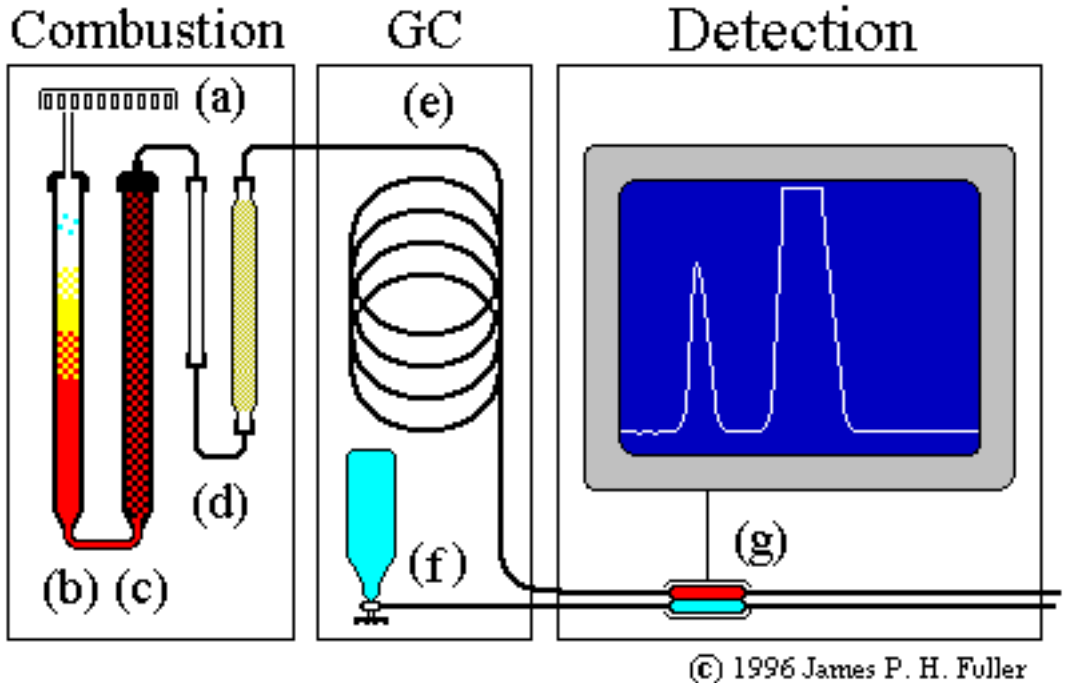
Soil organic matter

- Measured as loss on ignition
- Mass loss

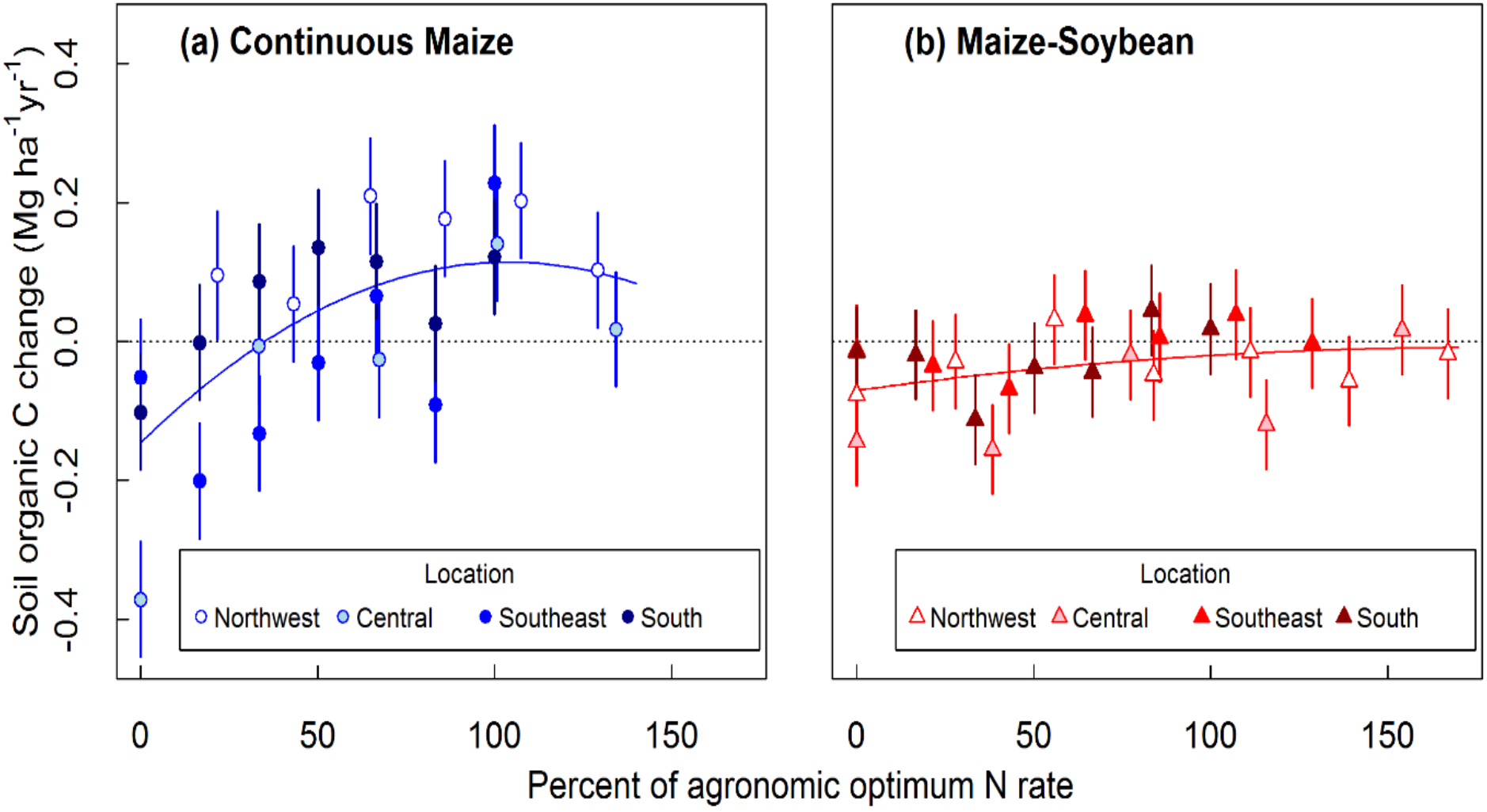
Soil organic carbon

- Dry combustion, measured as CO_2

SOM x 0.52 = SOC



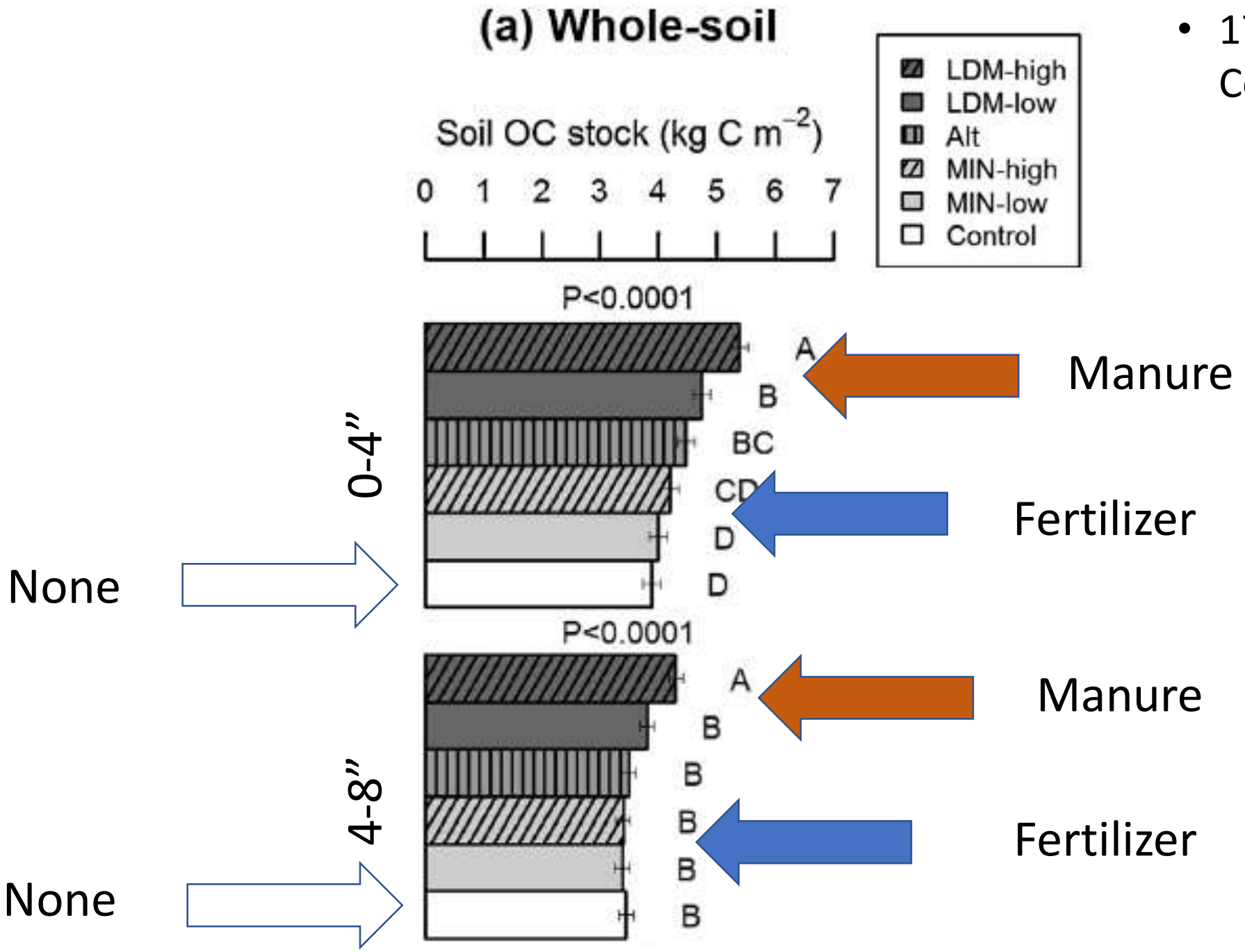
- Optimizing N fertilizer is critical for SOM maintenance
- More biomass means more SOM



All responses from previous slide scaled as a percent of the optimum rate at each site
0-6” soil sampling, fall chisel plow

Poffenbarger et al., 2017

- 17 year study in British Columbia, Canada



Most studies that use organic N sources (animal manure or green manure) show gains in SOC over time, while gains with just inorganic N were minimal.

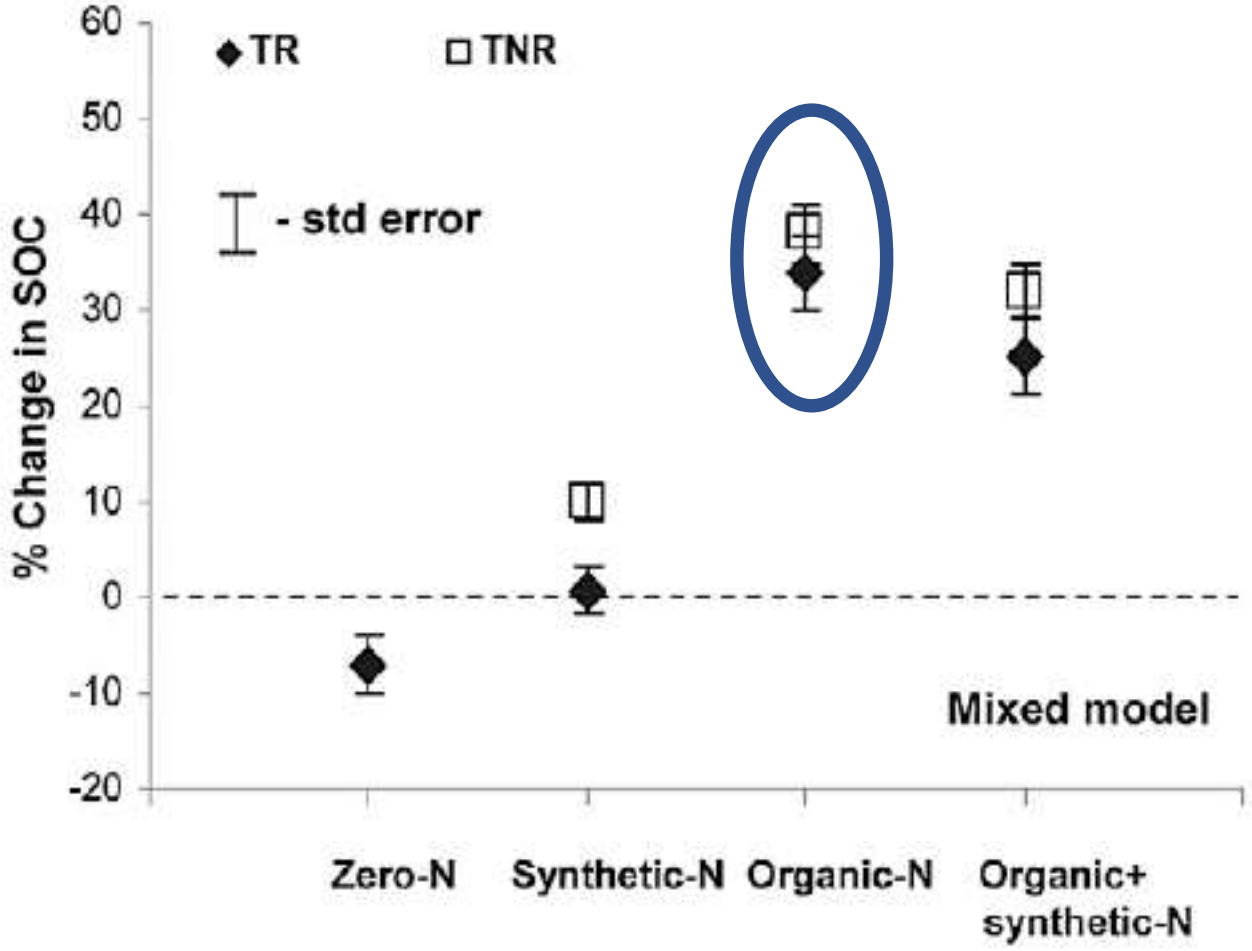


Fig. 2. Percentage response in soil organic carbon (SOC) and soil organic nitrogen (SON) to N fertilizer input as calculated by time response (TR) ratio and time by fertilizer N response (TNR) ratio using the mixed model and meta-analysis.

Ladha et al., 2012

10 Mg/ha = 10,000 kg/ha = 9,000 lb/ac

37 different studies

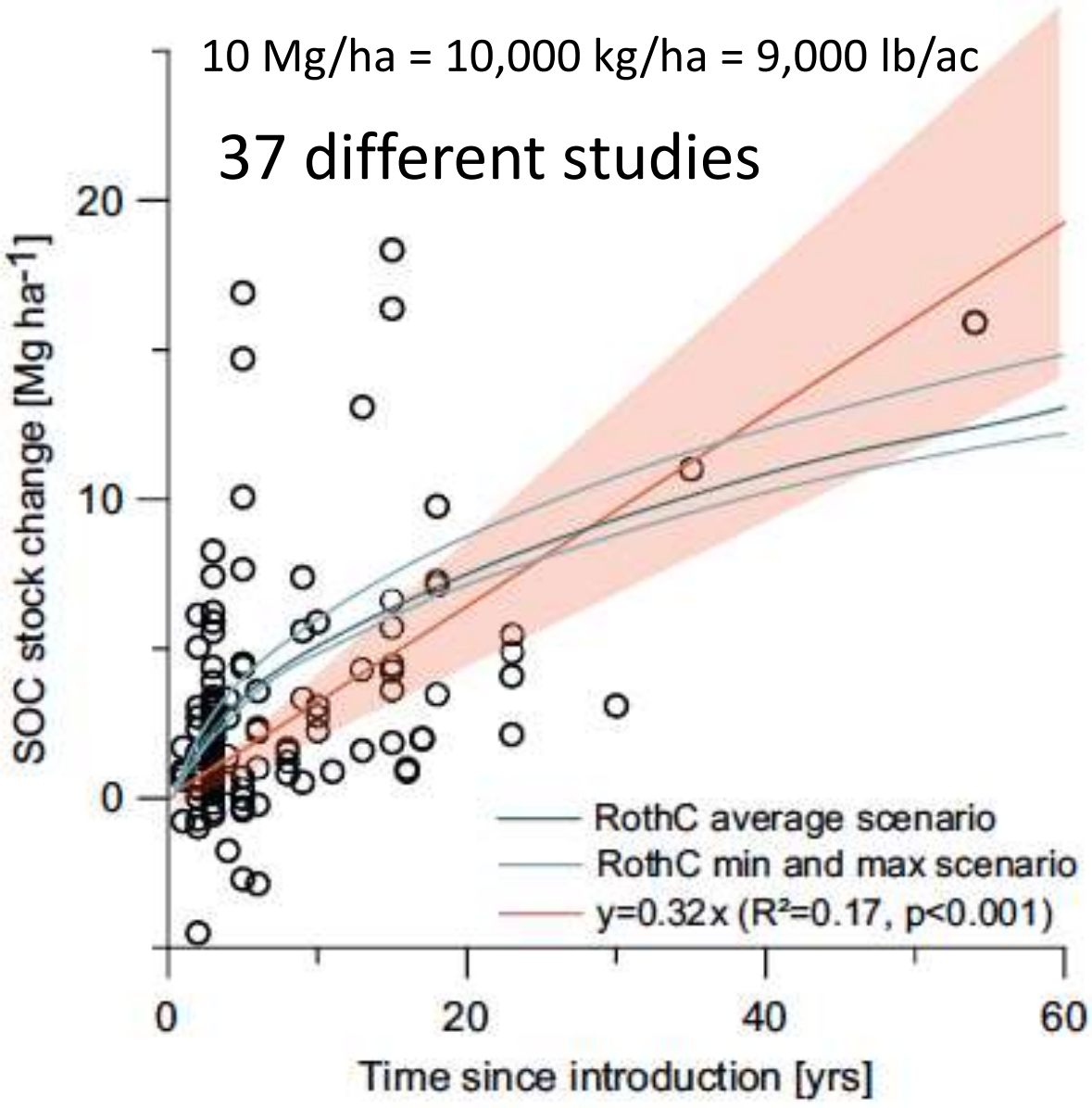


Fig. 2. SOC stock change after cover crop introduction as a function of time with linear regression (with 95% confidence interval) and the RothC simulated average cropland (with min and max scenario).

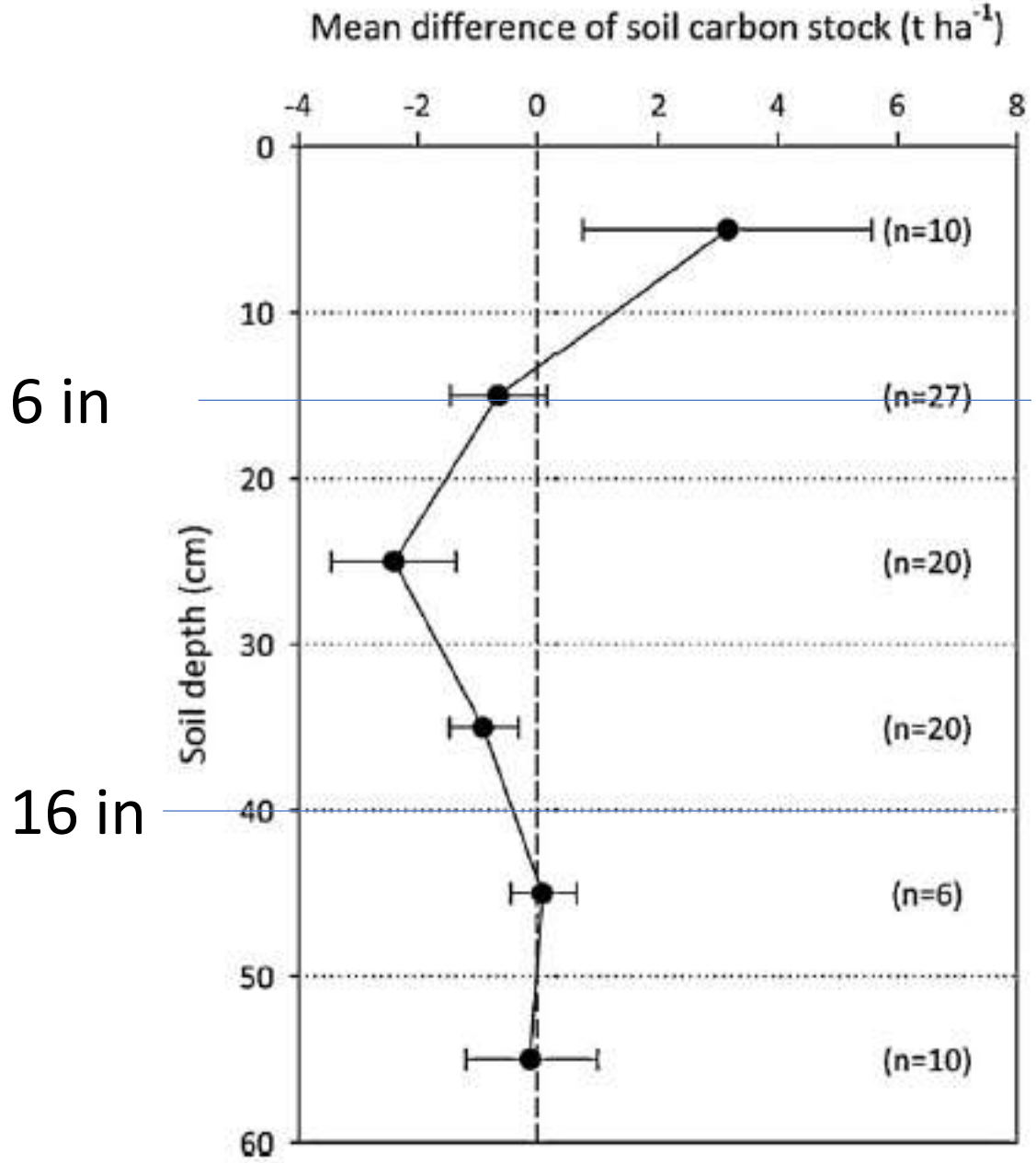
Cover cropping leads to gains in SOM, but results across studies have been quite variable

Building carbon: things to consider

- Carbon inputs
- **Carbon protection**

Can no-tillage stimulate carbon sequestration in agricultural soils? A meta-analysis of paired experiments

Zhongkui Luo[a,b], Enli Wang[b,*], Osbert J. Sun[c]



How does tillage intensity affect soil organic carbon? A systematic review

Neal R. Haddaway[1*], Katarina Hedlund[2], Louise E. Jackson[3], Thomas Kätterer[4], Emanuele Lugato[5], Ingrid K. Thomsen[6], Helene B. Jørgensen[2] and Per-Erik Isberg[7]

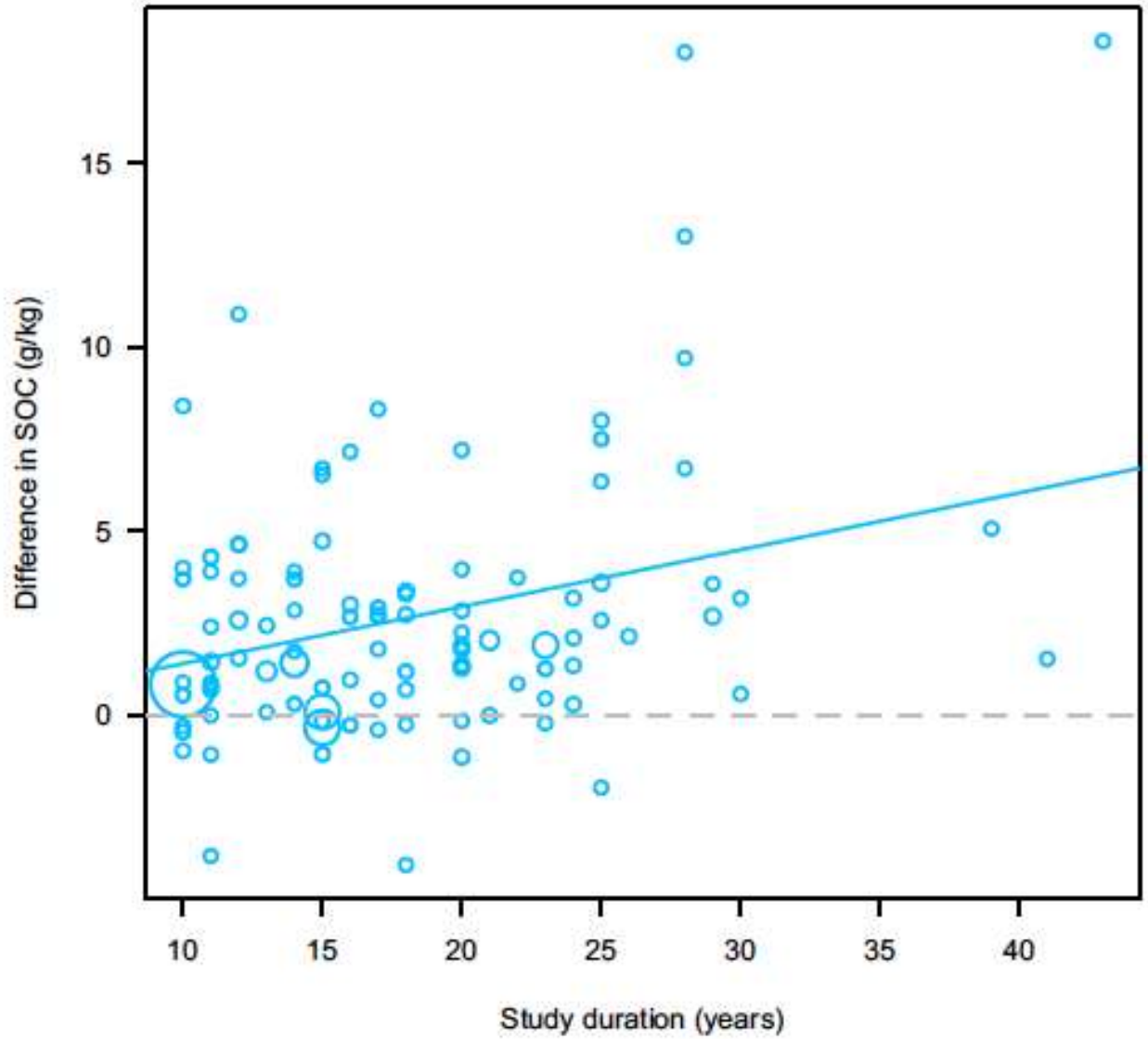


Fig. 14 Meta-regression of SOC concentration against study duration for NT–HT at 0–15 cm. *NT* no tillage, *HT* high intensity tillage (see text for explanation). Point size represents study weighting in the analysis (inverse variance)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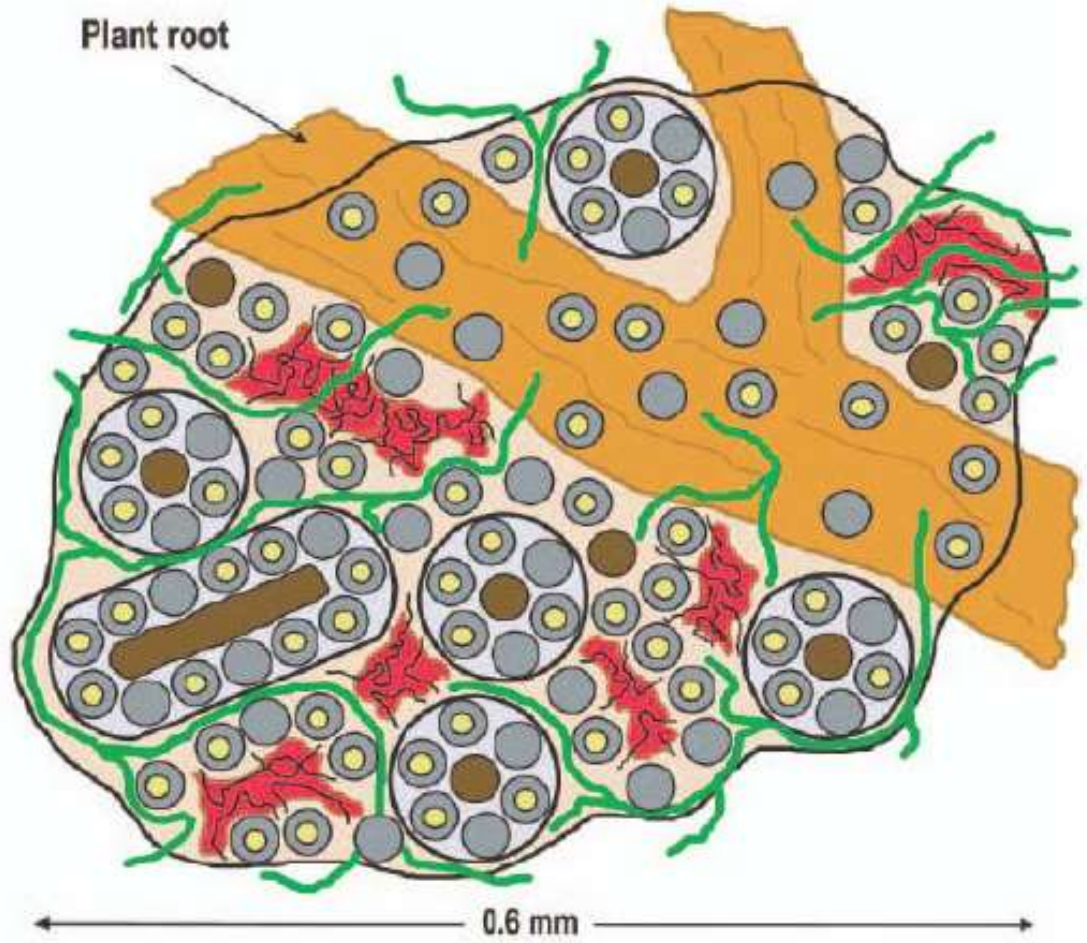
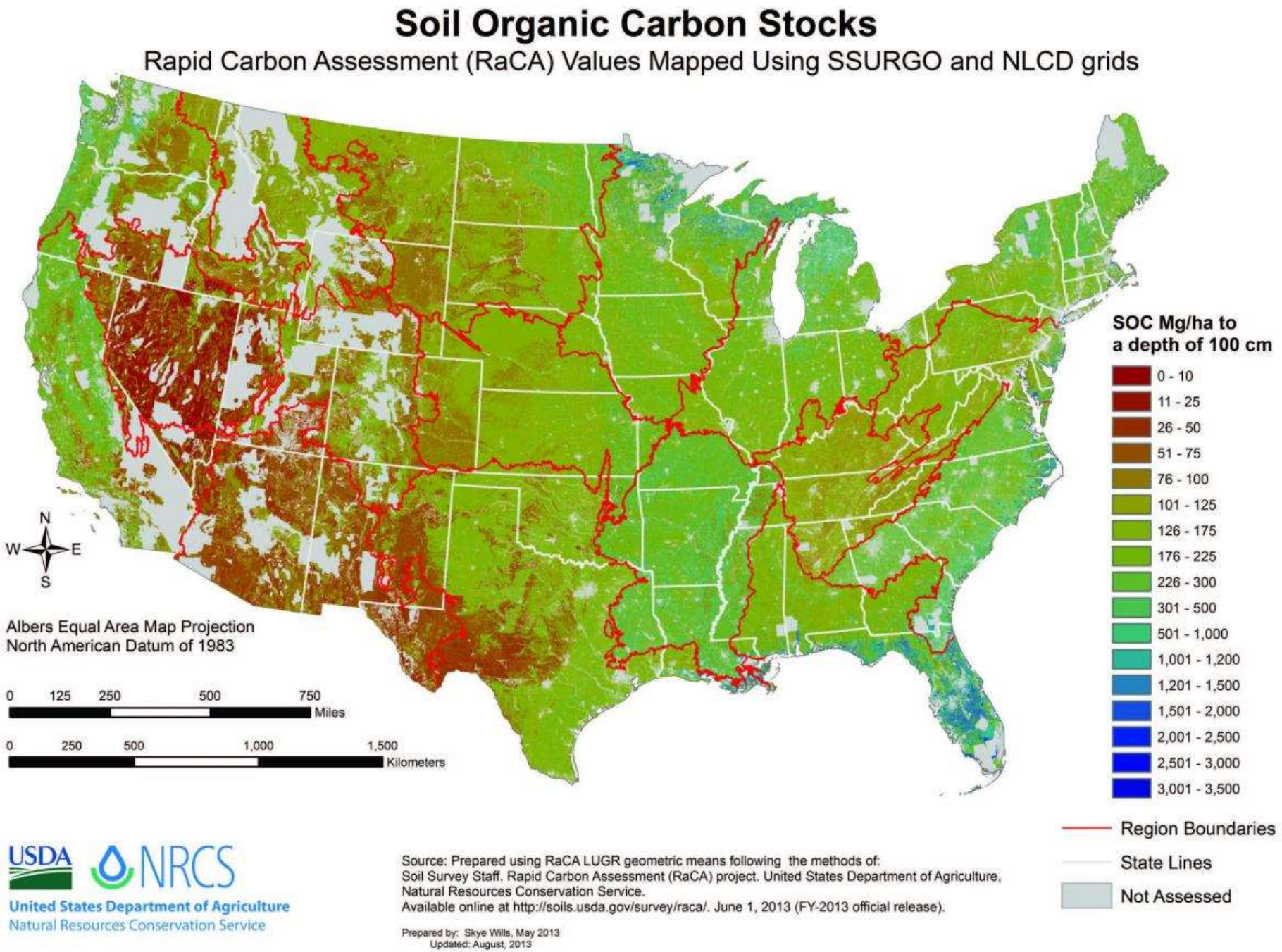
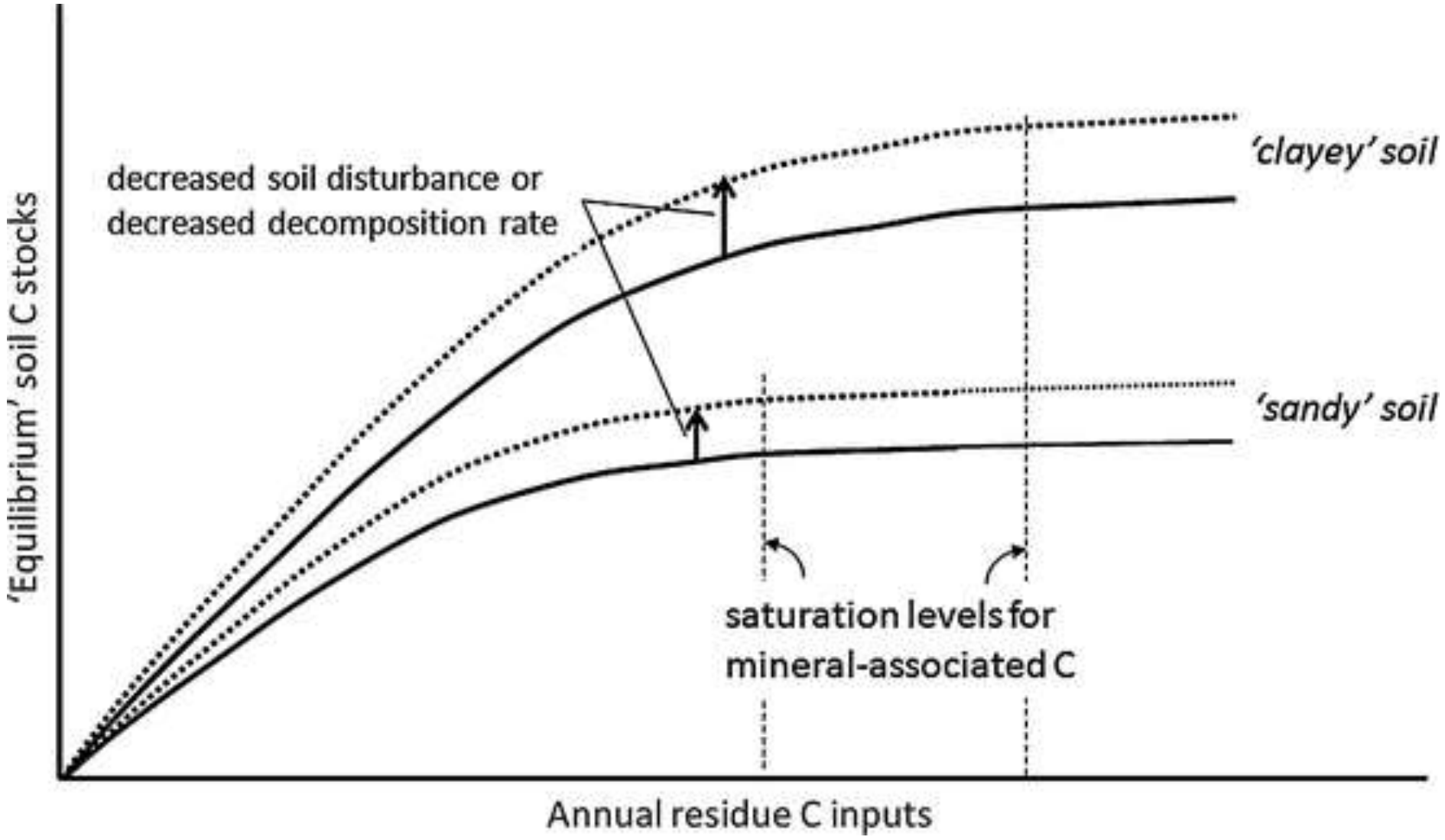

Plant root
0.6 mm

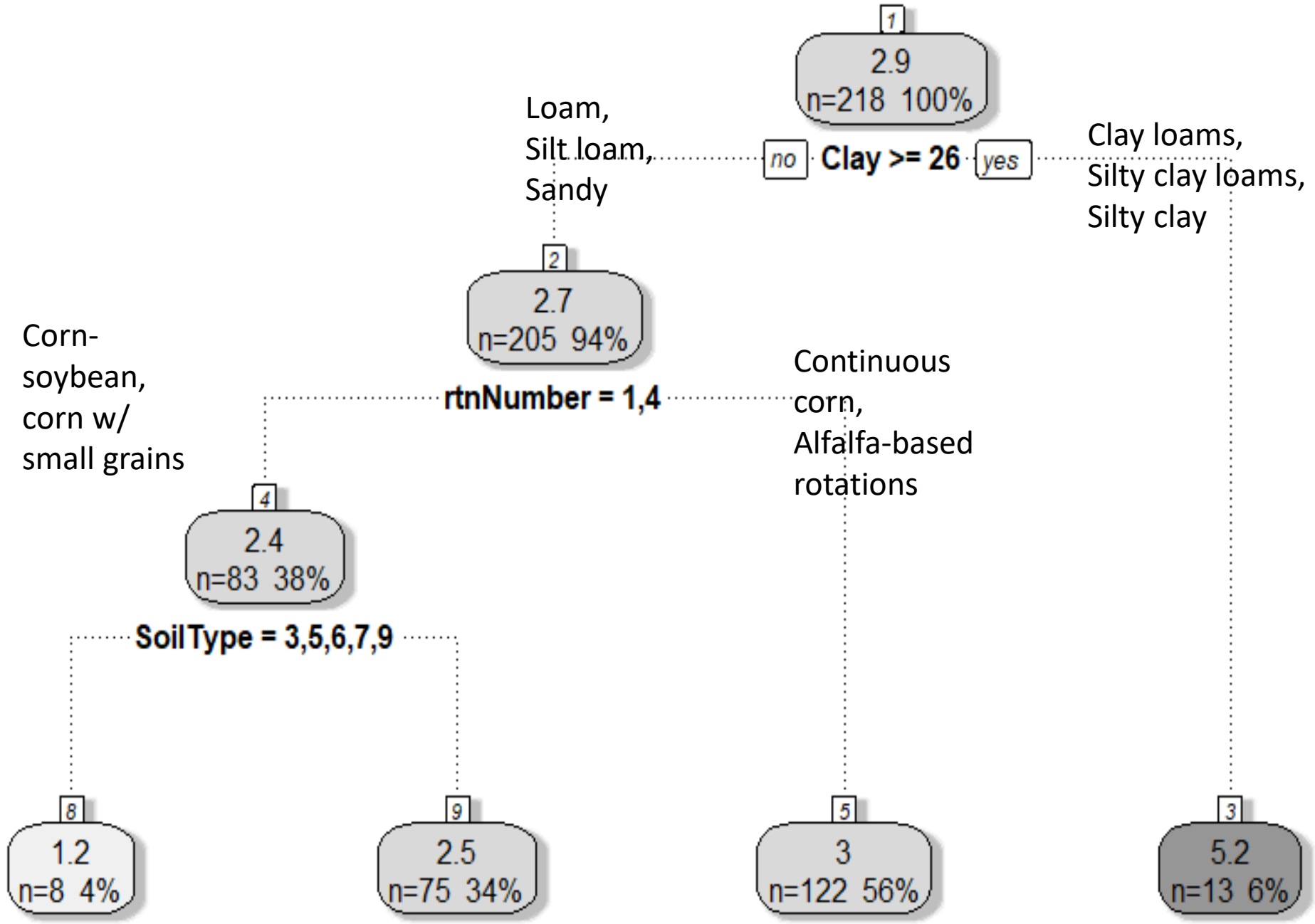
Why do soils have different SOC levels?





Paustian, 2014

SOM


1
2.9
n=218 100%
no
Clay >= 26
yes
Loam,
Silt loam,
Sandy
Clay loams,
Silty clay loams,
Silty clay
2
2.7
n=205 94%
rtnNumber = 1,4
Corn-
soybean,
corn w/
small grains
Continuous
corn,
Alfalfa-based
rotations
4
2.4
n=83 38%
SoilType = 3,5,6,7,9
8
1.2
n=8 4%
9
2.5
n=75 34%
5
3
n=122 56%
3
5.2
n=13 6%

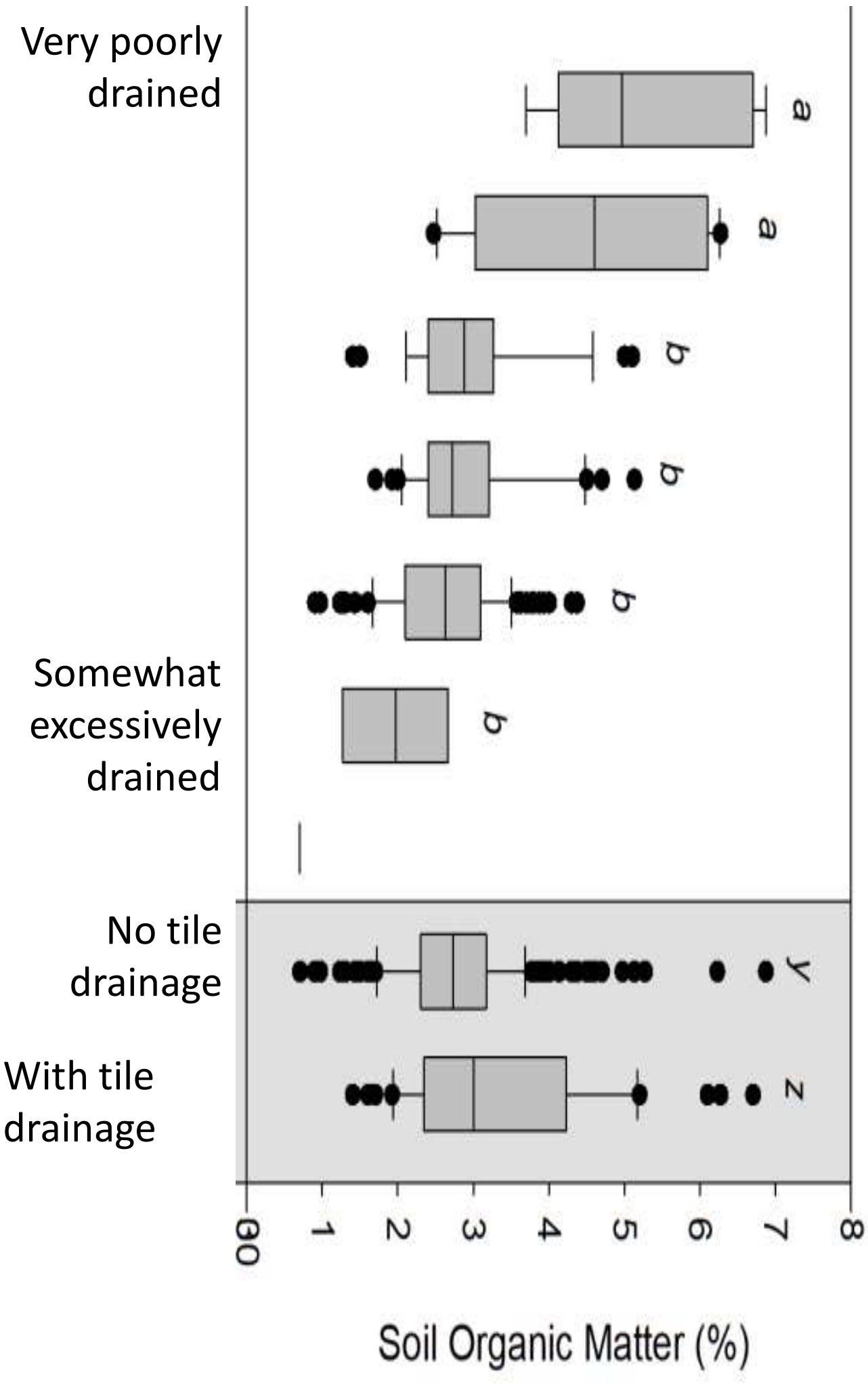
Sequestering or building carbon: things to consider

- Carbon inputs
  - More = more
    - Crop residue and cover crops are important
    - Long-term manure can help
- Carbon protection
  - Reduction in tillage with increase in carbon inputs will be most beneficial
- Carbon saturation
  - Soils have a limit to how much C they will sequester based tillage and texture

Building organic matter

- There is evidence that:
  - Optimizing yield
  - Reducing tillage
  - Using cover crops
  - Applying manure

  will lead to gains in SOM
  …over time
  …and all management practices and soil texture interact
  …and can’t tell you exactly how much it will increase


Very poorly drained
Somewhat excessively drained
No tile drainage
With tile drainage
a
a
b
b
b
b
y
z
0
1
2
3
4
5
6
7
8
Soil Organic Matter (%)

SOM genesis: microbial biomass as a significant source

Anja Miltner · Petra Bombach · Burkhard Schmidt-Brücken · Matthias Kästner

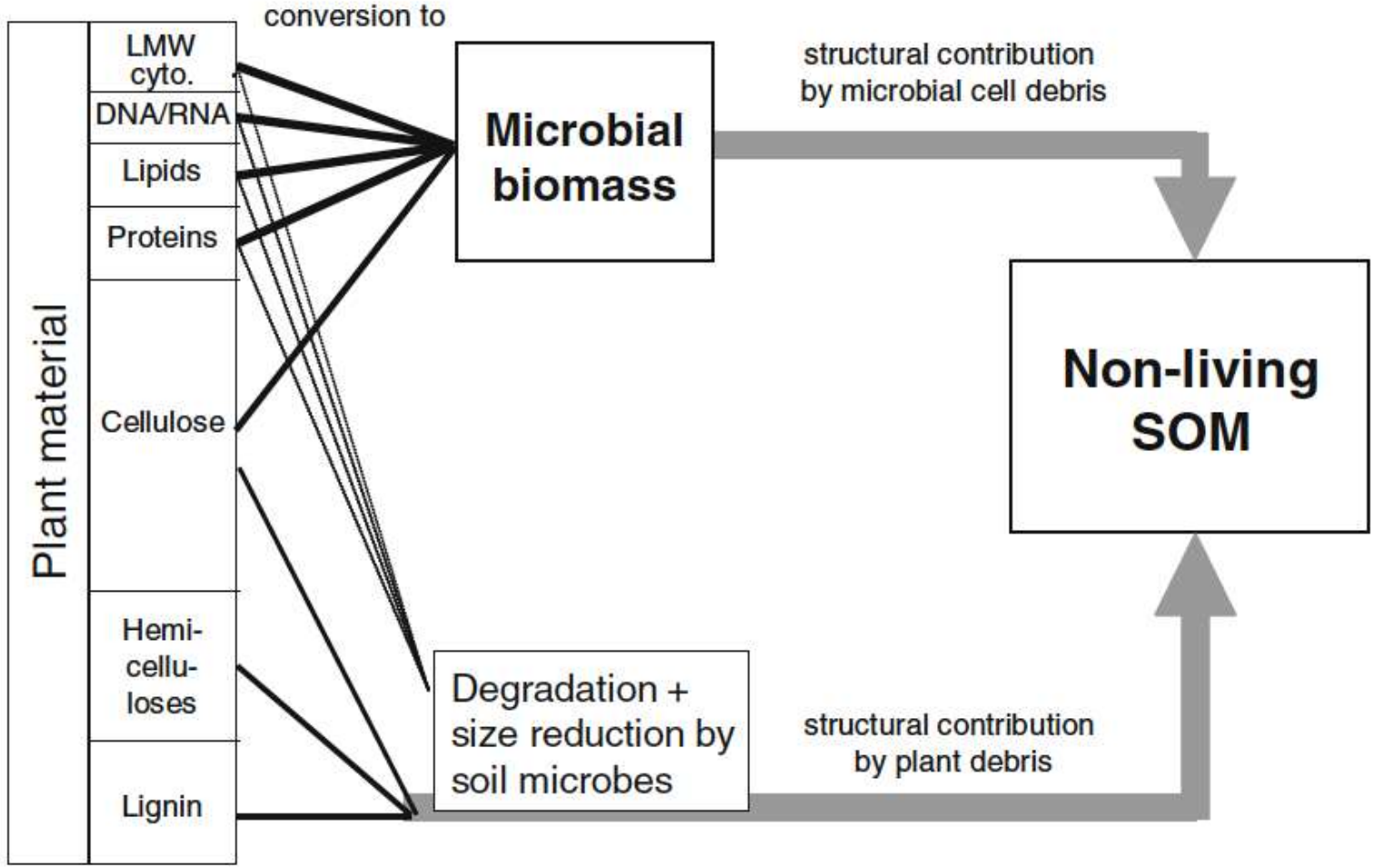
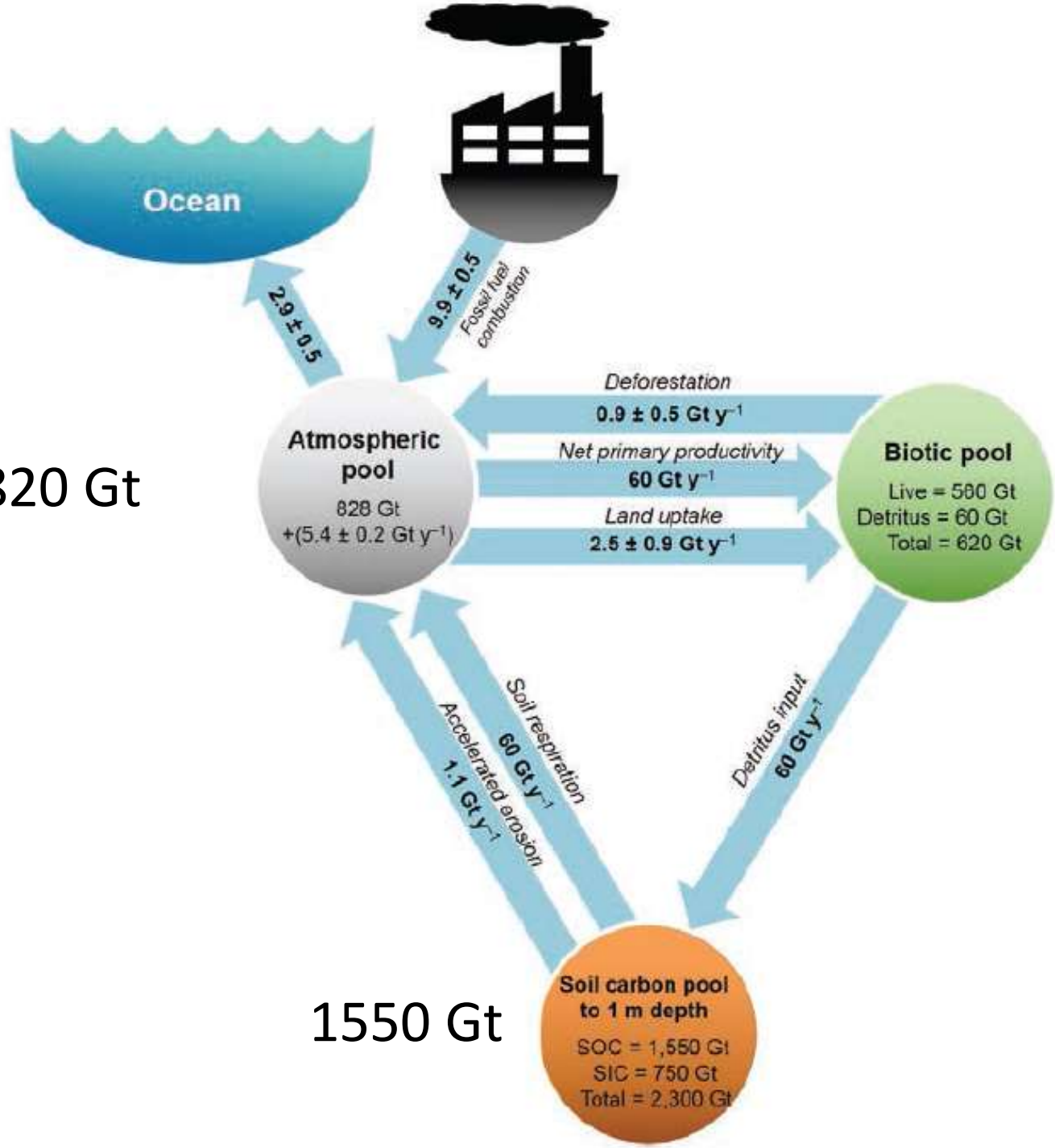


Fig. 6 Conceptual scheme of the C flow during degradation of plant debris in soil. Although the C is originally derived from plant organic matter, the molecular characteristics of this C are derived from microbial biomass because it is processed by the microbes (*LMW cyto.* low molecular weight soluble cytosolic compounds, *DNA/RNA* nucleic acids)



820 Gt

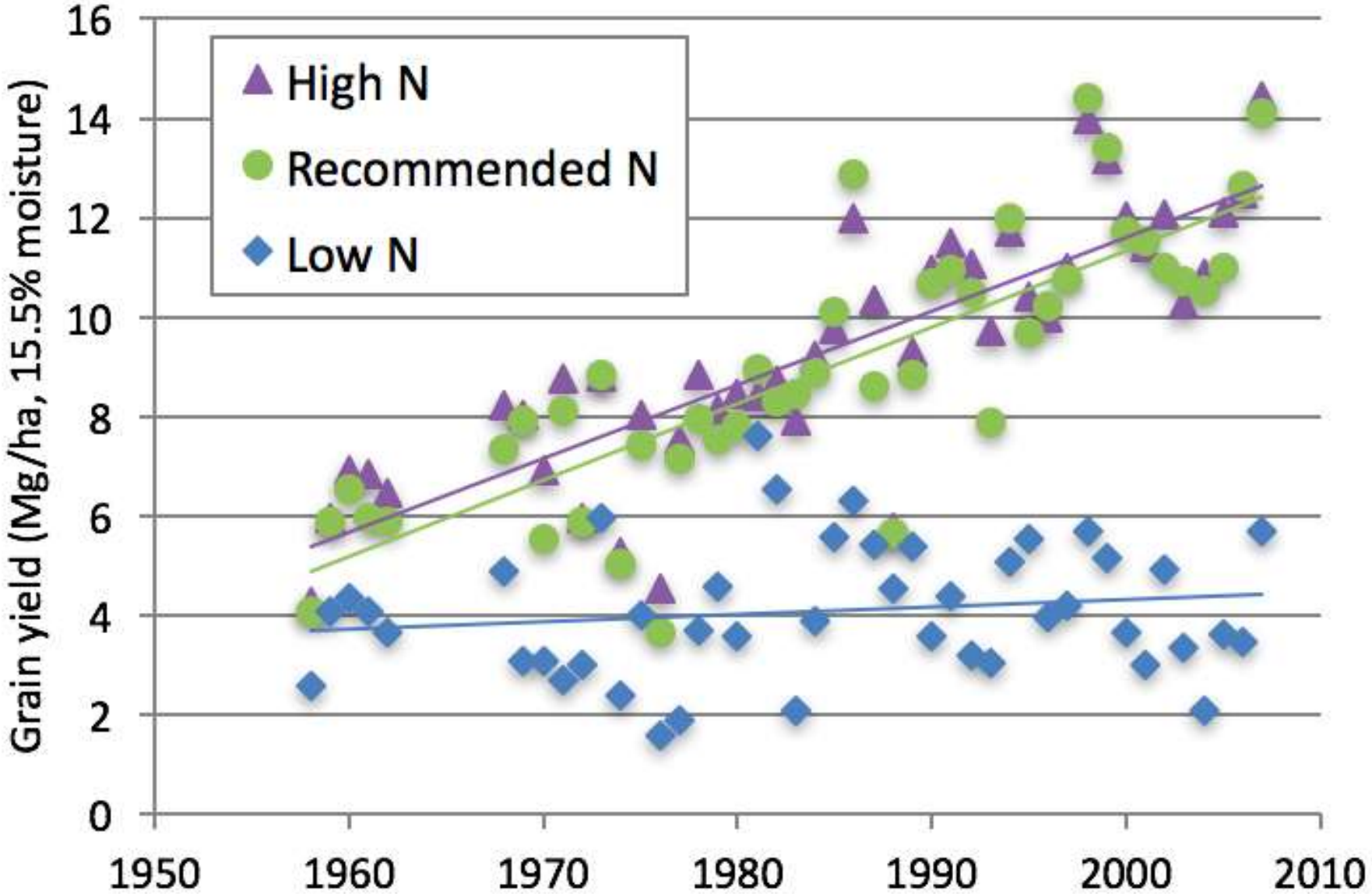
620 Gt

1550 Gt

Lal et al., JSWC

Grain Yield 1958-2007

Low=0, Rec=125, High=250 lb-N/ac



In a moldboard plowed system, nitrogen additions (and continual yield gains) offset SOM losses

0-6 in