Maryland Commission on Climate Change Mitigation Work Group
Baltimore Md. 11 May 2017

Soil Carbon: Major Player in Maryland's Greenhouse Gas Balance

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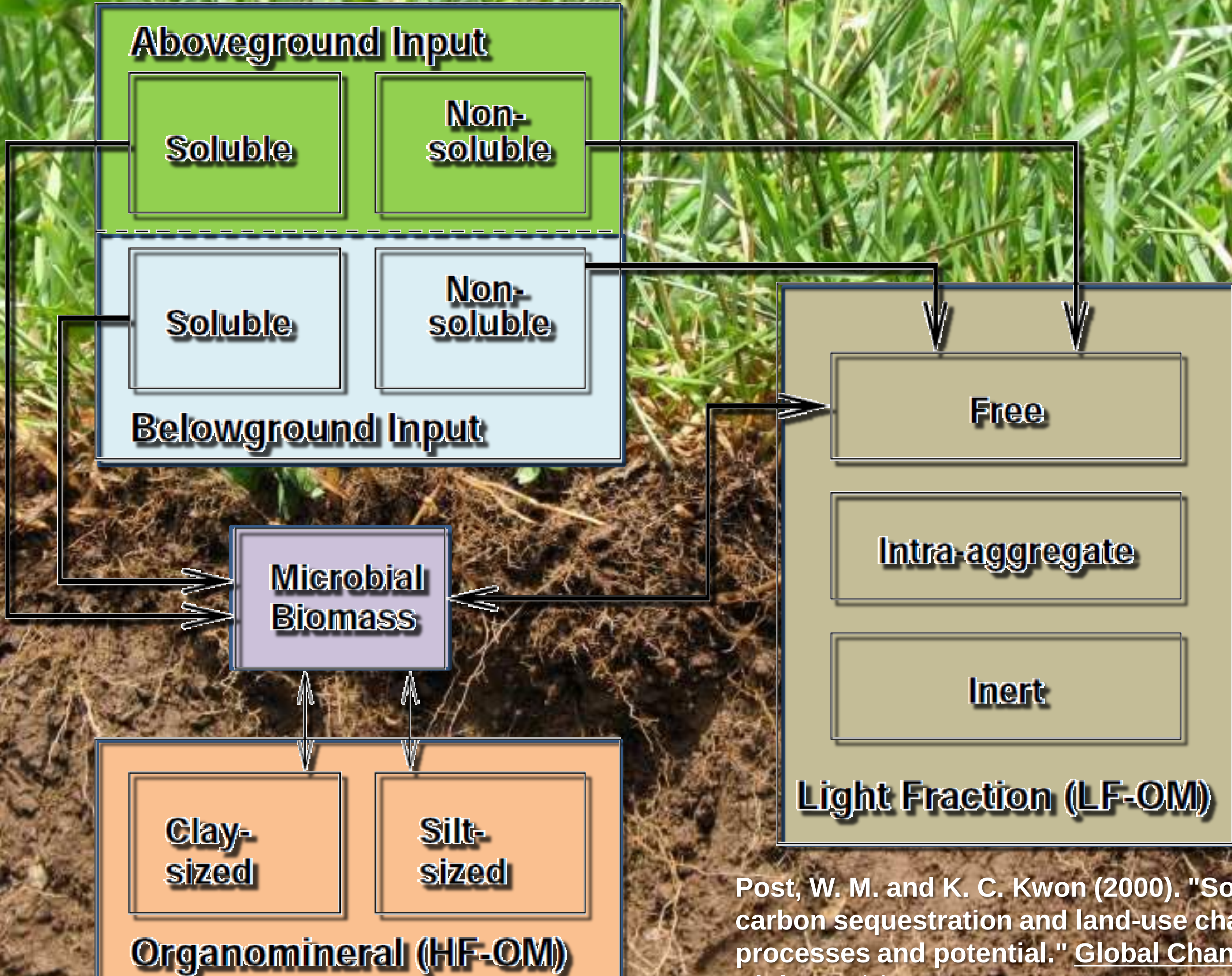
www.enst.umd.edu



Post, W. M. and K. C. Kwon (2000). "Soil carbon sequestration and land-use change: processes and potential." Global Change Biology 6(3): 317-327.

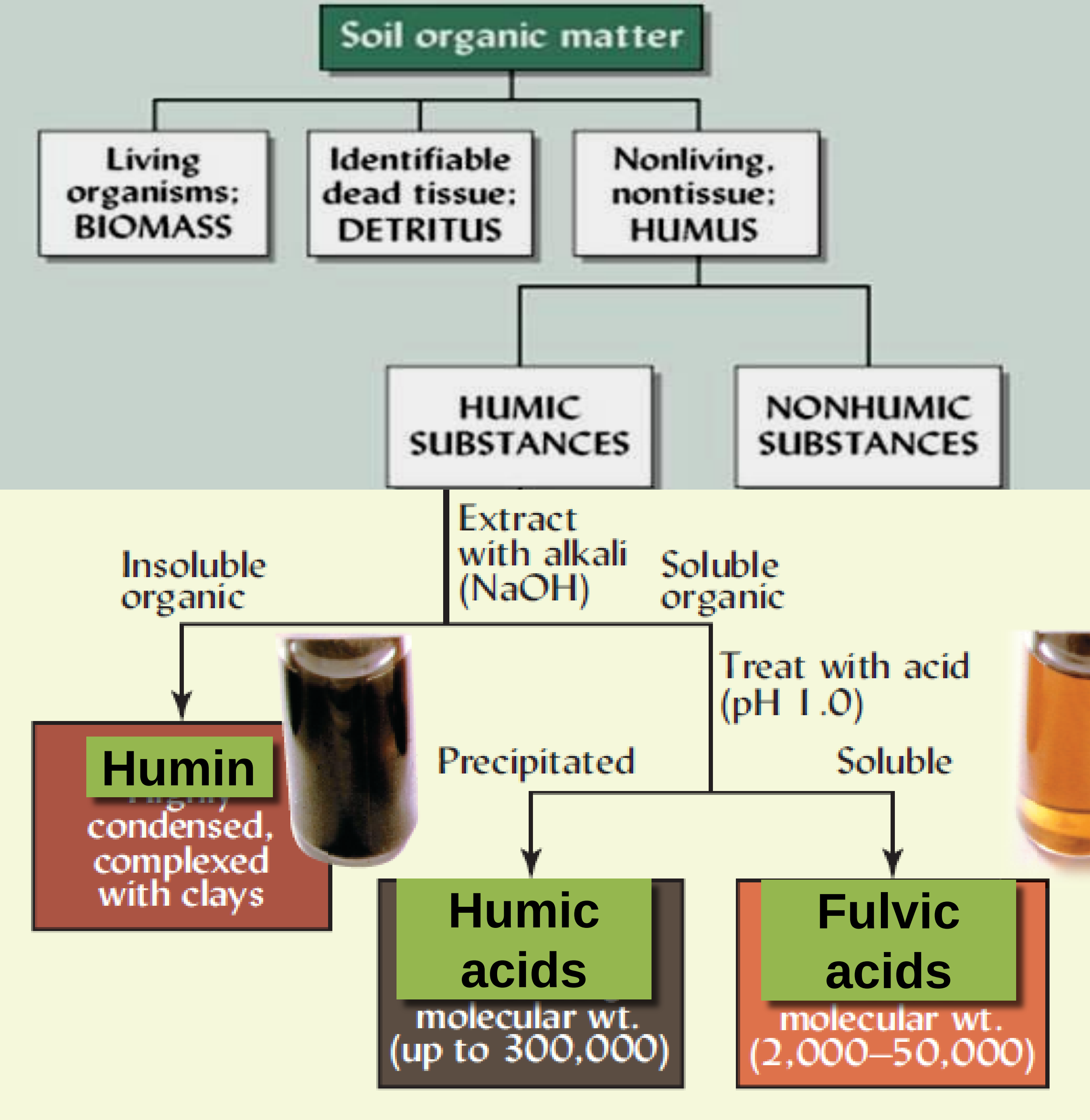
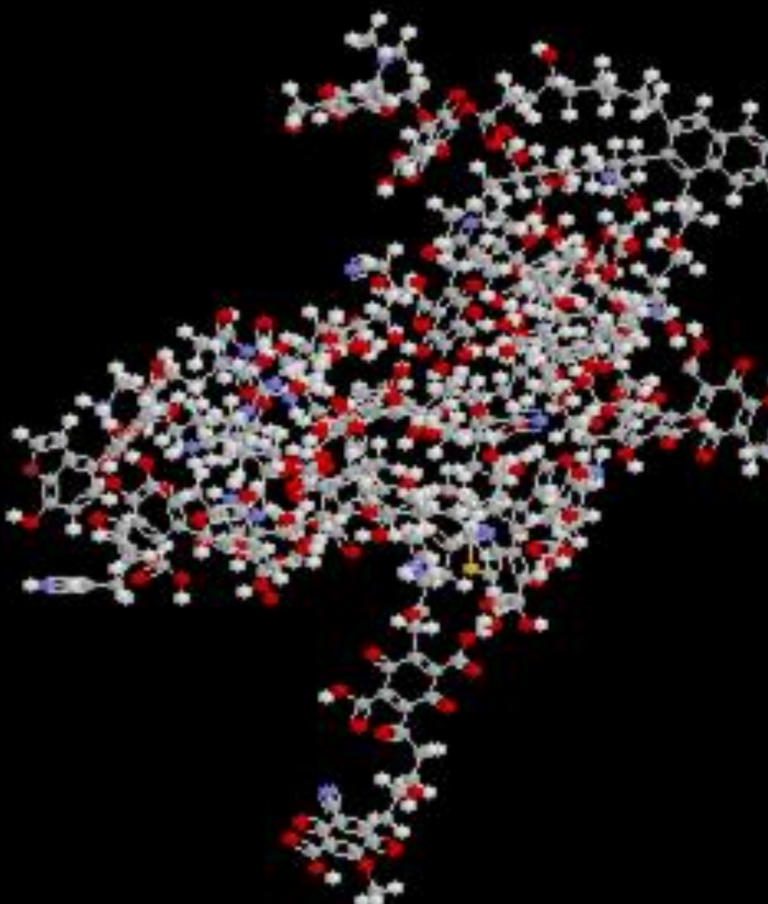


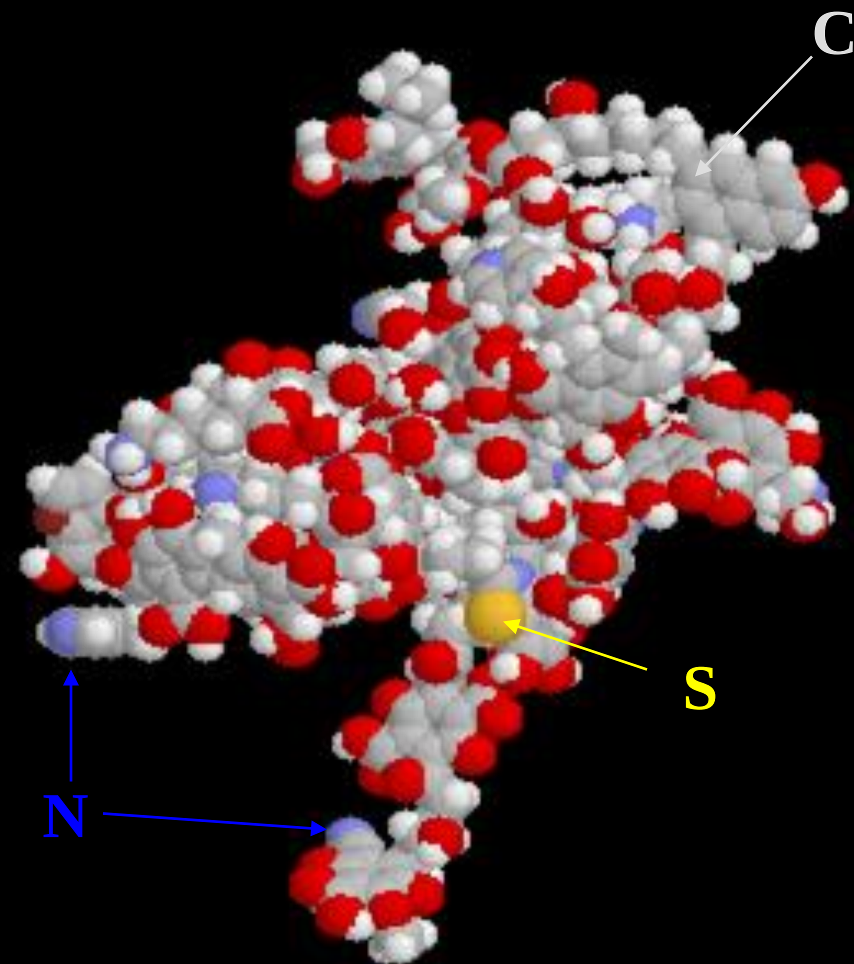
Fig. 12.11 from Brady & Weil, 14th edition, 2007

An often-cited model of "humic acid"

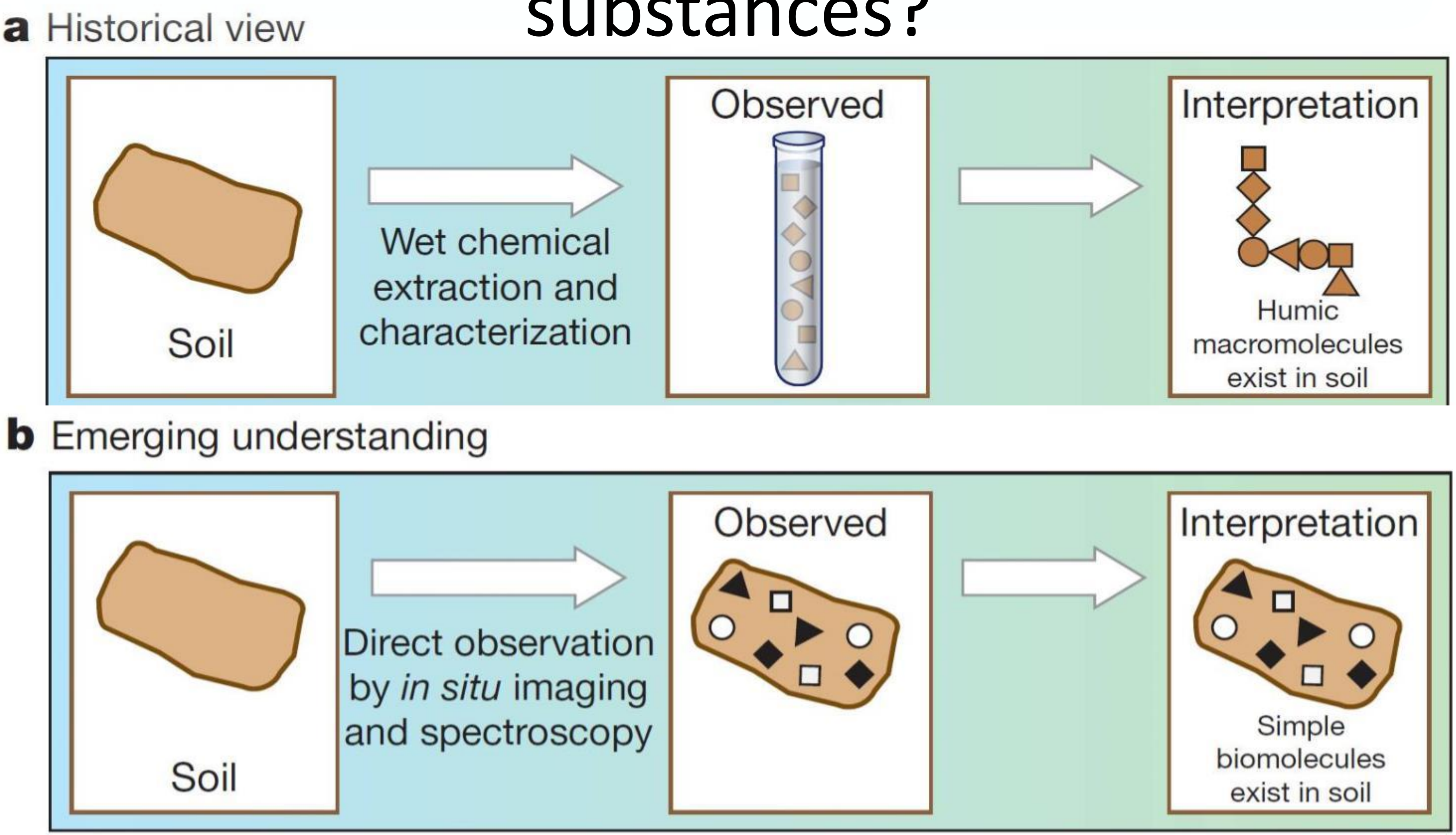
with carbohydrate, hexapeptide, and hydrating water molecules.

H.-R. Schulten and M. Schnitzer. 1997. Soil Sci.162:115-130.



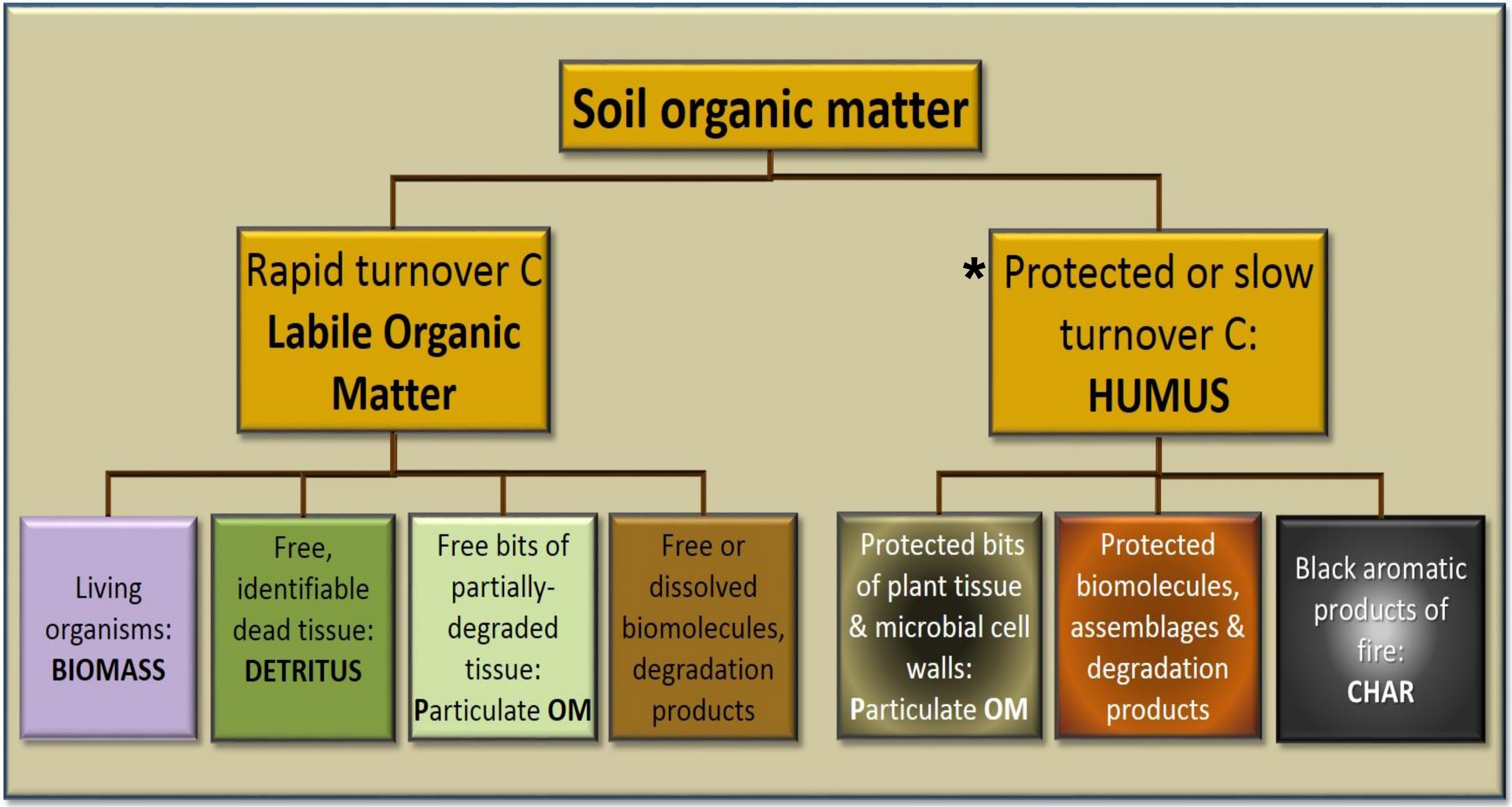


But is soil humus really made of humic substances?



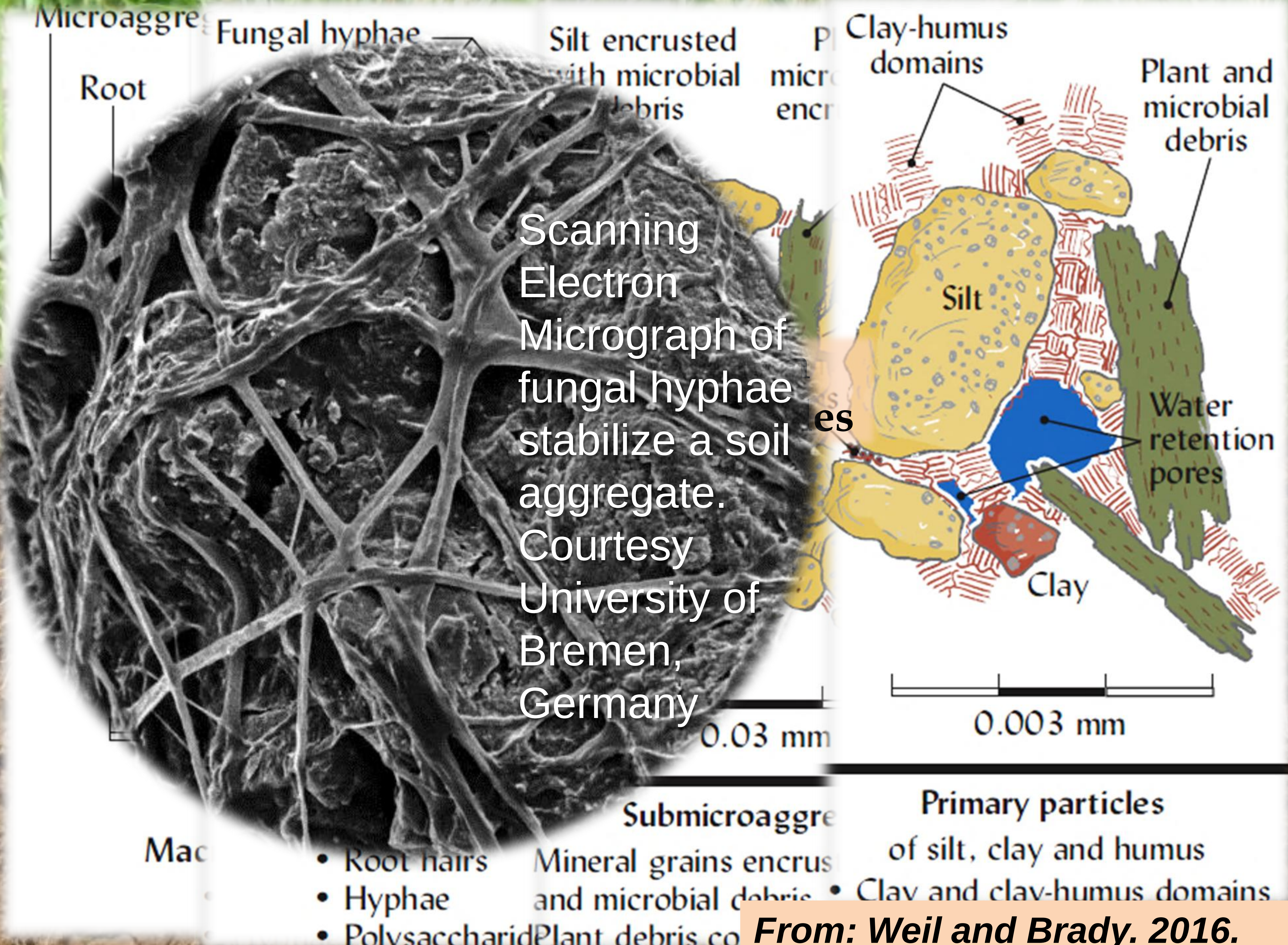
Schmidt, et al. 2011. Persistence of soil organic matter as an ecosystem property. Nature 478:49-56.

New classification of SOM pools and fractions based on recent insights



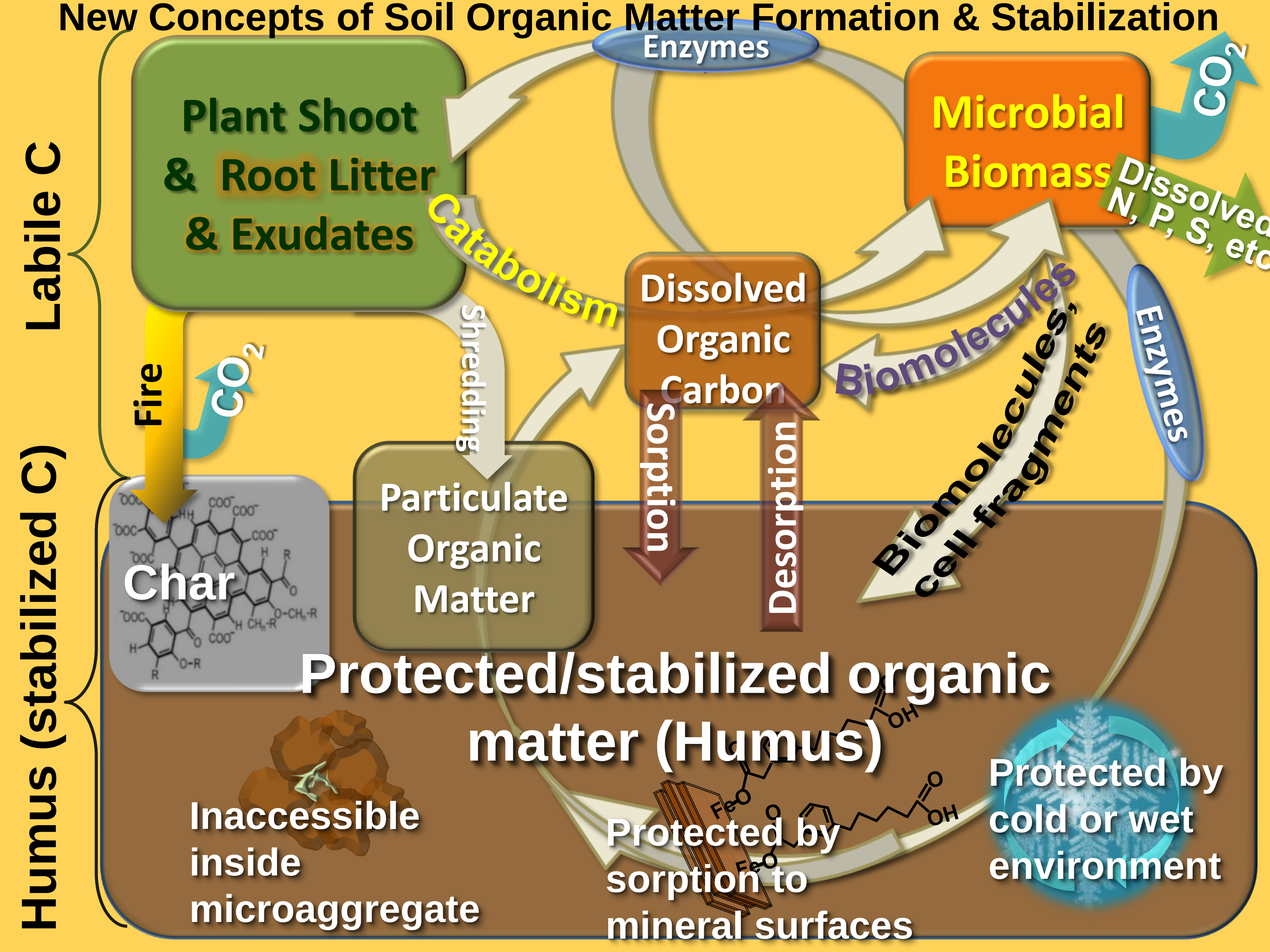
*Protected on clay surfaces, in aggregates and in ultramicropores.

From: Weil and Brady. 2016. The Nature and Properties of Soils. 15th ed. Pearson

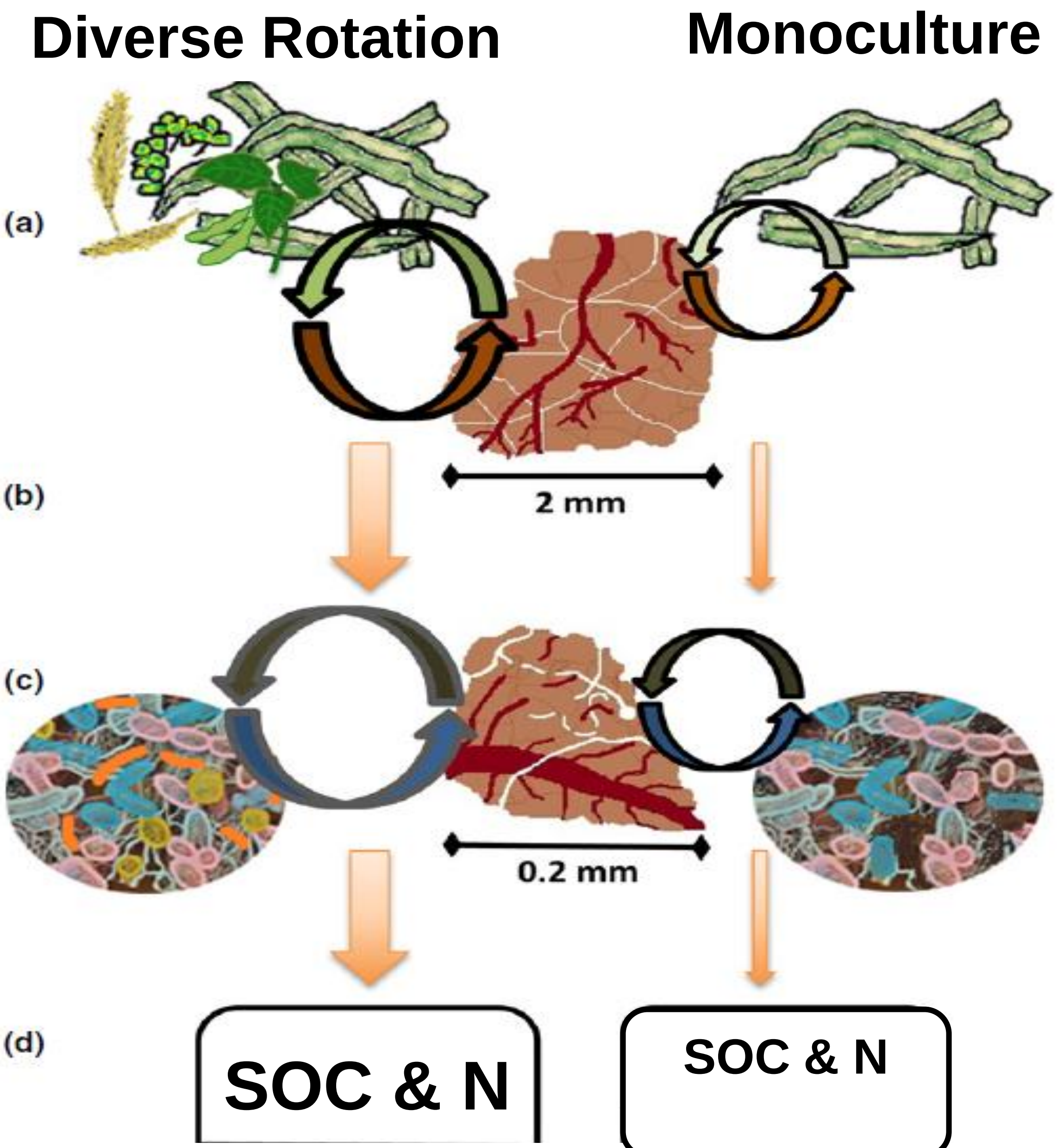


Scanning Electron Micrograph of fungal hyphae stabilize a soil aggregate. Courtesy University of Bremen, Germany

From: Weil and Brady. 2016.

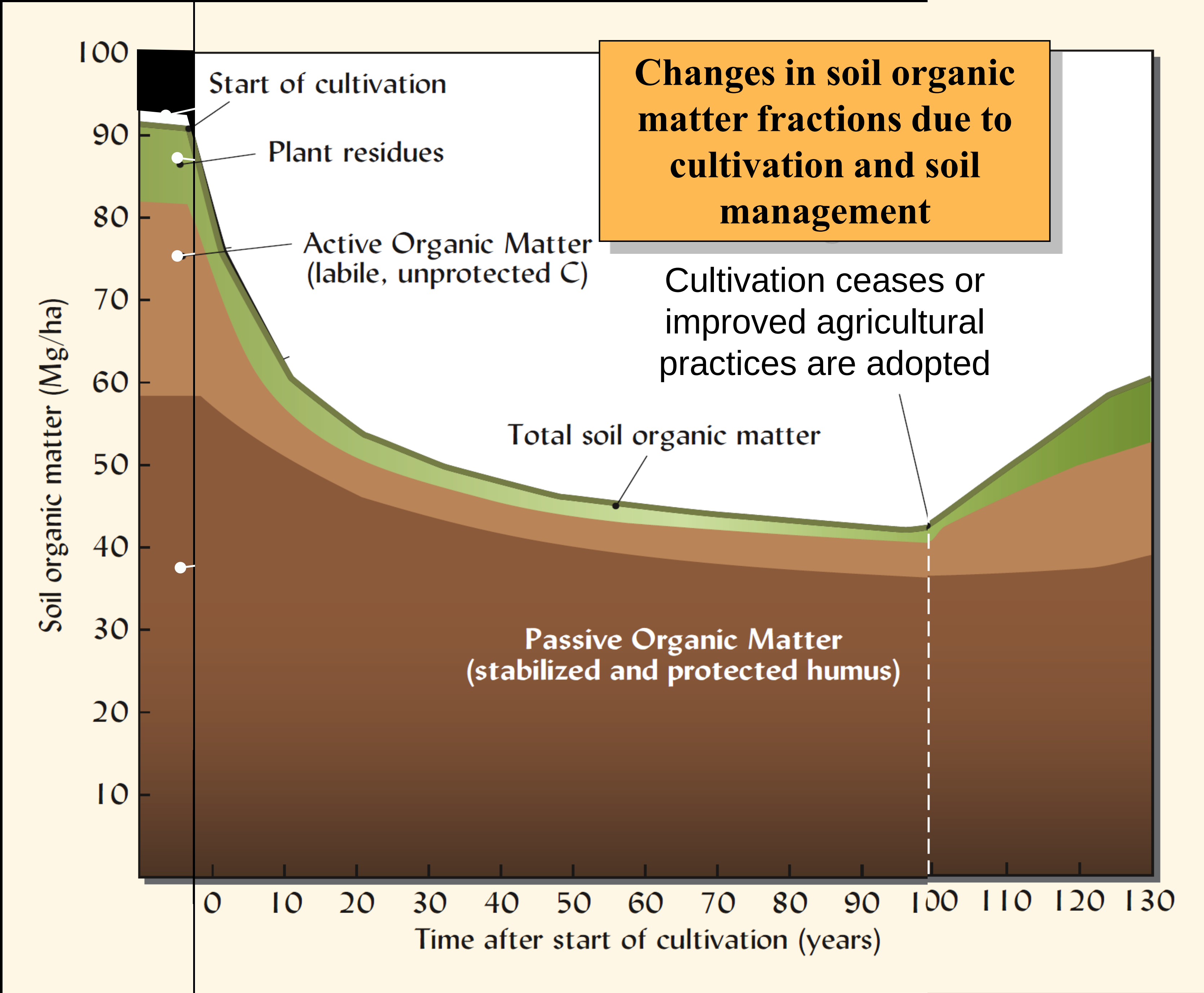


New Concepts of Soil Organic Matter Formation & Stabilization
Labile C
Humus (stabilized C)
Plant Shoot & Root Litter & Exudates
Enzymes
Microbial Biomass
CO_2
Dissolved N, P, S, etc
Catabolism
Dissolved Organic Carbon
Biomolecules
Biomolecules, cell fragments
Enzymes
Fire
CO_2
Shredding
Sorption
Desorption
Char
Particulate Organic Matter
Protected/stabilized organic matter (Humus)
Inaccessible inside microaggregate
Protected by sorption to mineral surfaces
Protected by cold or wet environment



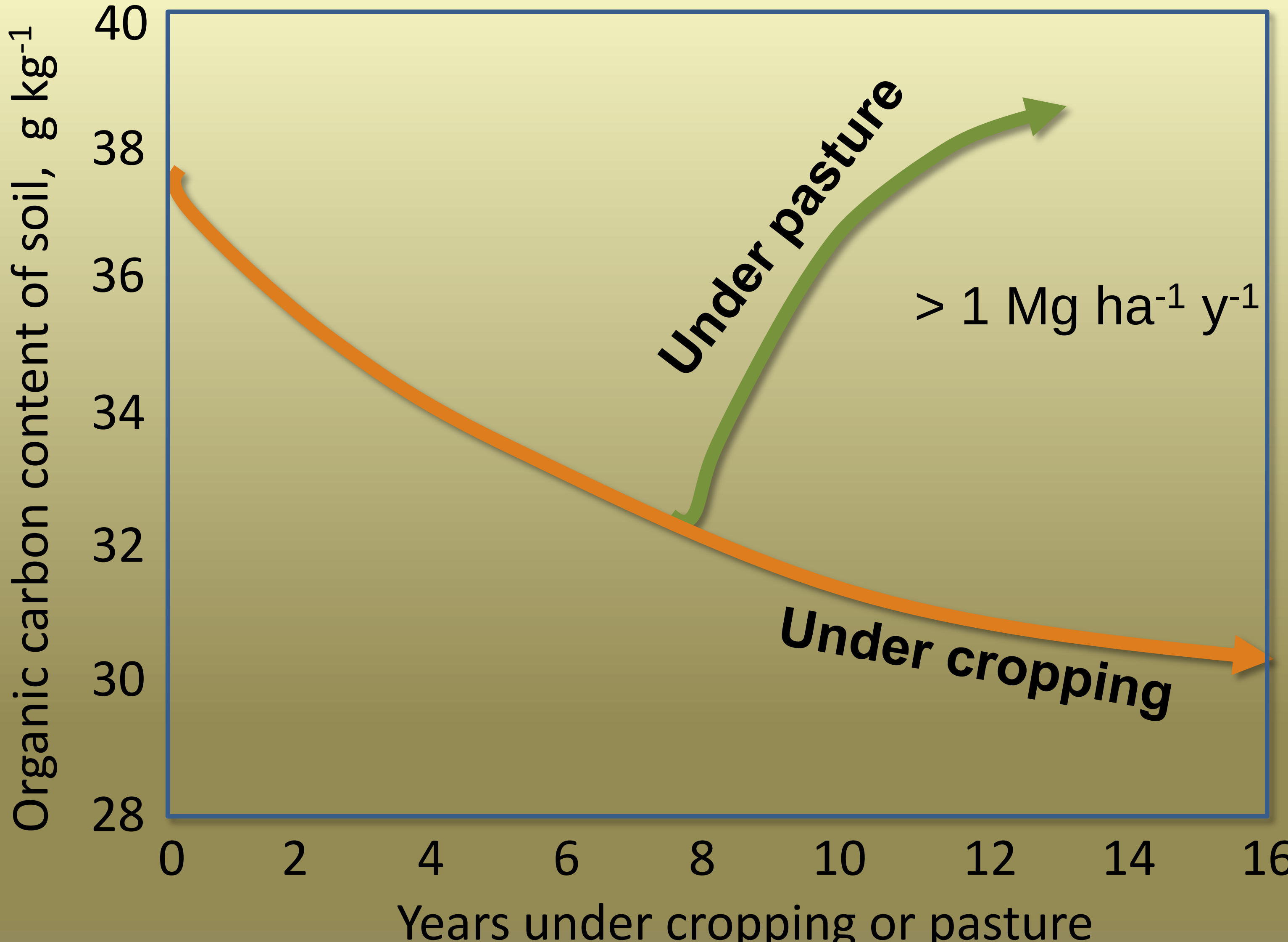
SOM under diverse rotation versus monoculture.
(a) Greater quantity and quality of residues enhances microbial activity
(b) mega-aggregate formation and stabilization.
(c) enhanced microbial activity
(d) increasing stocks of stable SOC and TN.

Tiemann, L.K., A.S. Grandy, E.E. Atkinson, E. Marin-Spiotta, and M.D. McDaniel. 2015. Crop rotational diversity enhances belowground communities and functions in an agroecosystem. Ecology Letters 18:761-771.

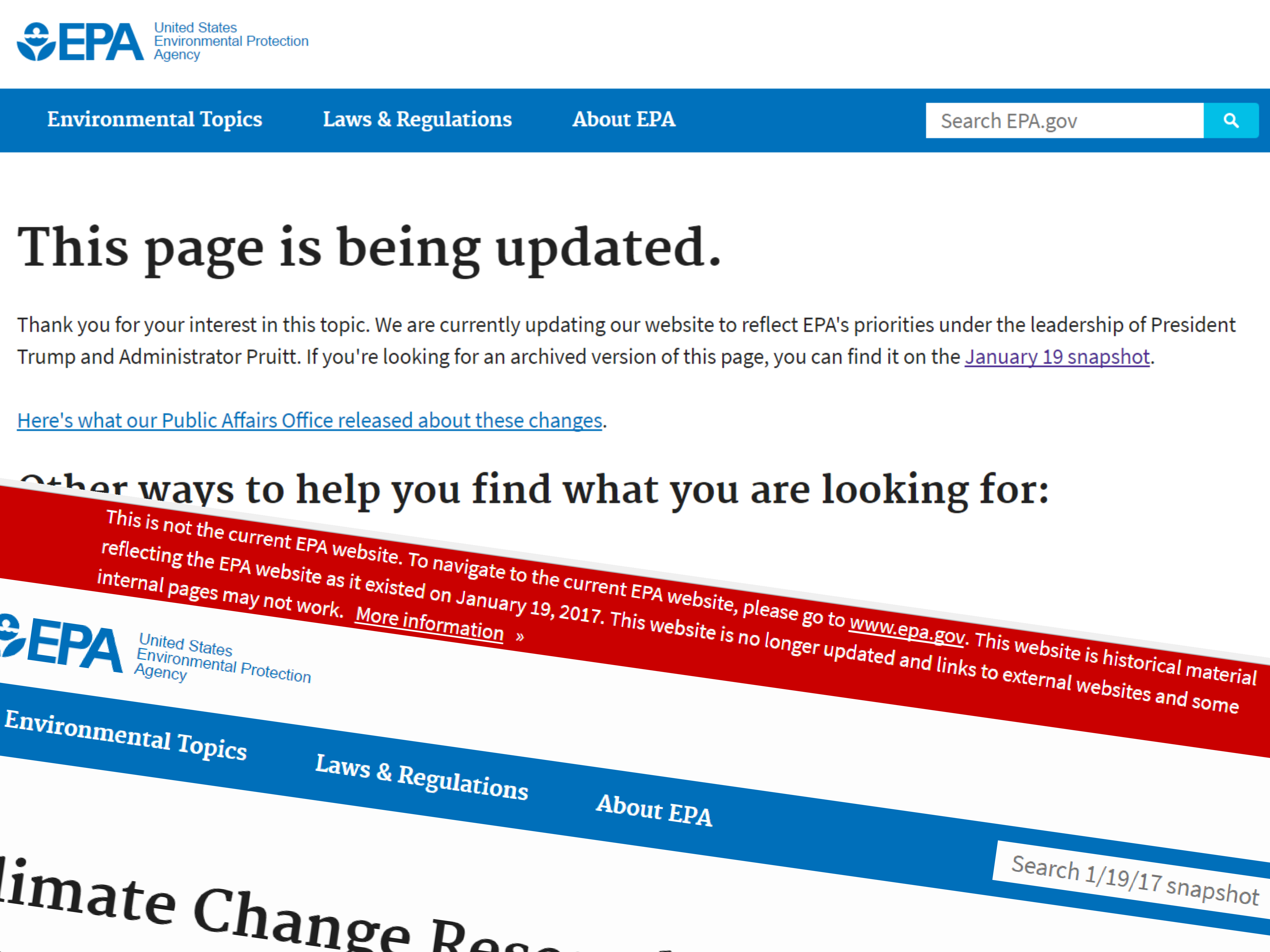


From: Weil and Brady. 2017.*The Nature and Properties of Soils*. 15th edition. Pearson.

Conversion of cropland to pasture in temperate Argentina



Studies on SOM dynamics in Mollisols within the southeast of the Pampas region : In Argentina. Wingeyer, A., et al. (2015). "Soil Quality Impacts of Current South American Agricultural Practices." <u>Sustainability 7(2): 2213-2242.</u>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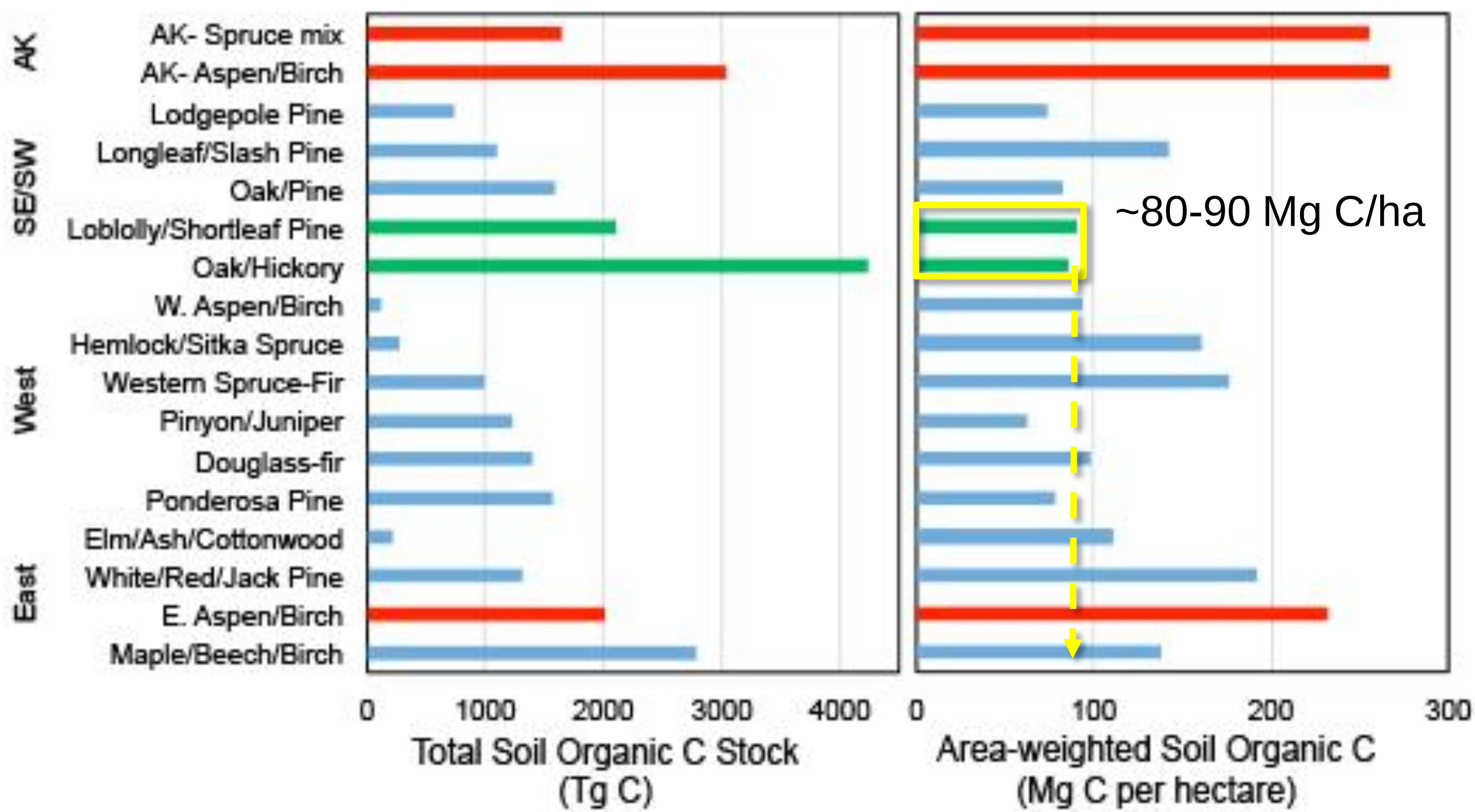
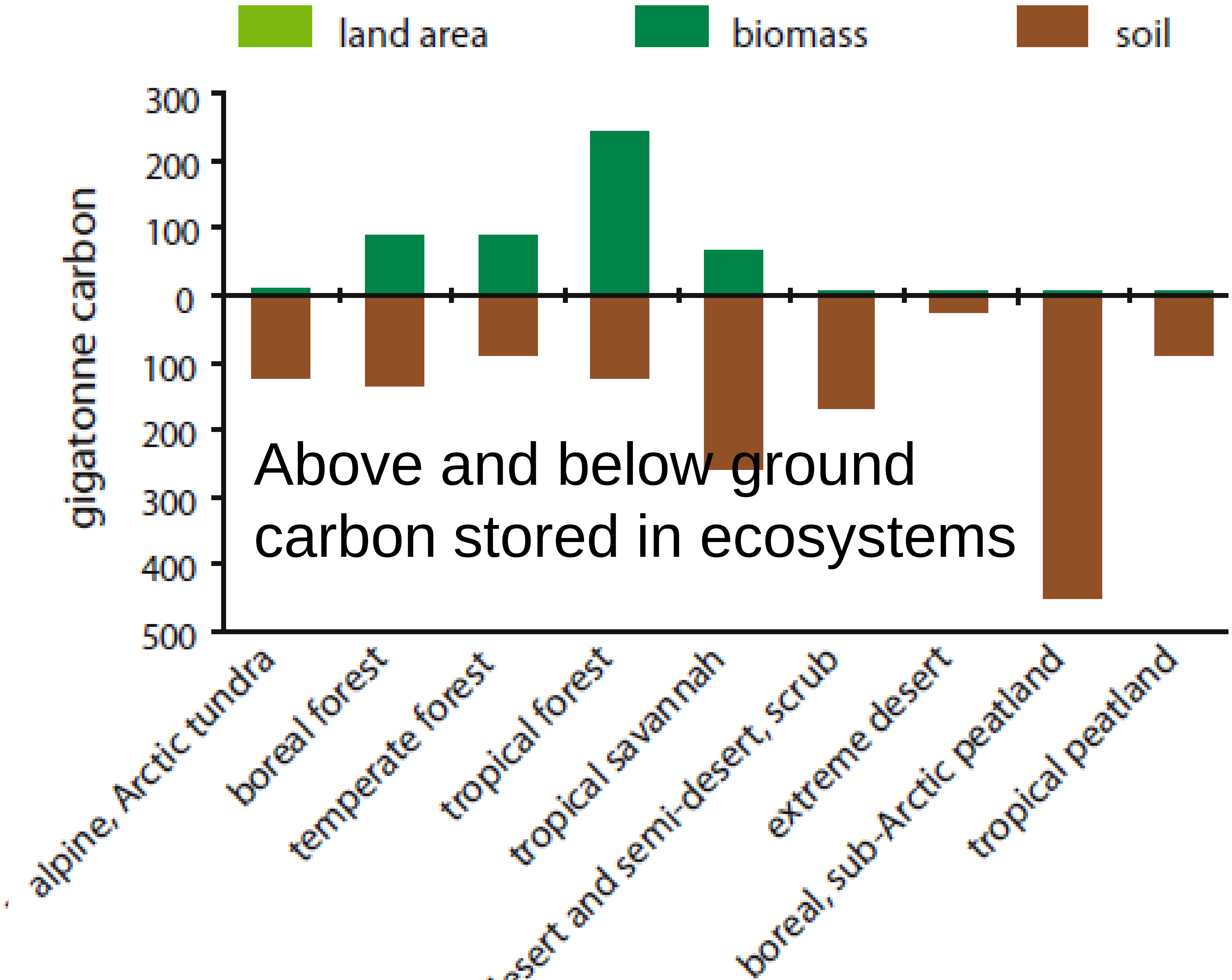
Below ground (soil) carbon stocks in US Forests

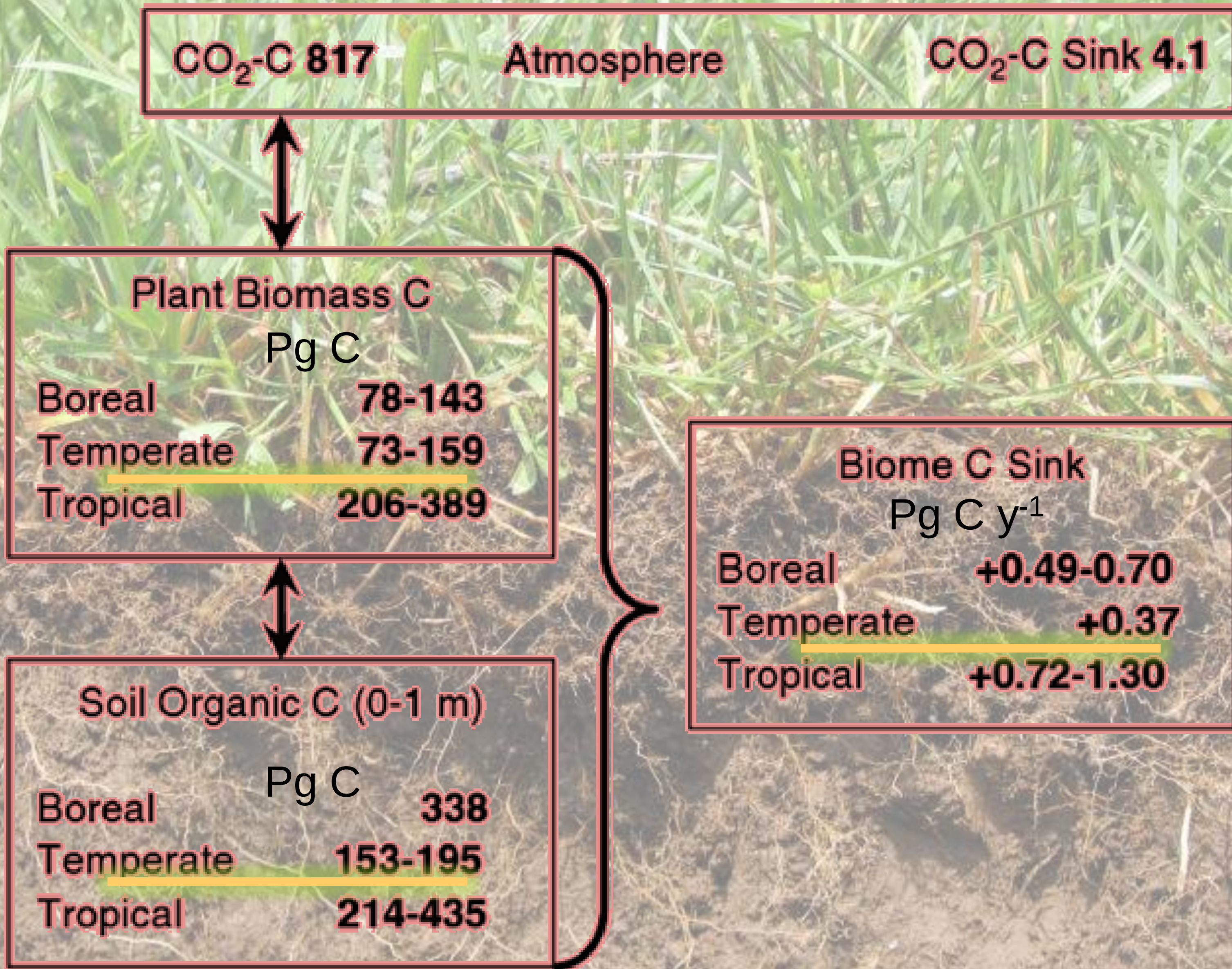
"Total amount of carbon stored in aboveground forest biomass (living and dead) varies far less across diverse forest types than does belowground C, with an average aboveground stock for US forests being 55 Mg C ha-1; this is dwarfed in comparison by how much C is harbored in belowground pools."



D'Amore, D. and E. Kane (2016). Climate Change and Forest Soil Carbon, U.S. Department of Agriculture, Forest Service.

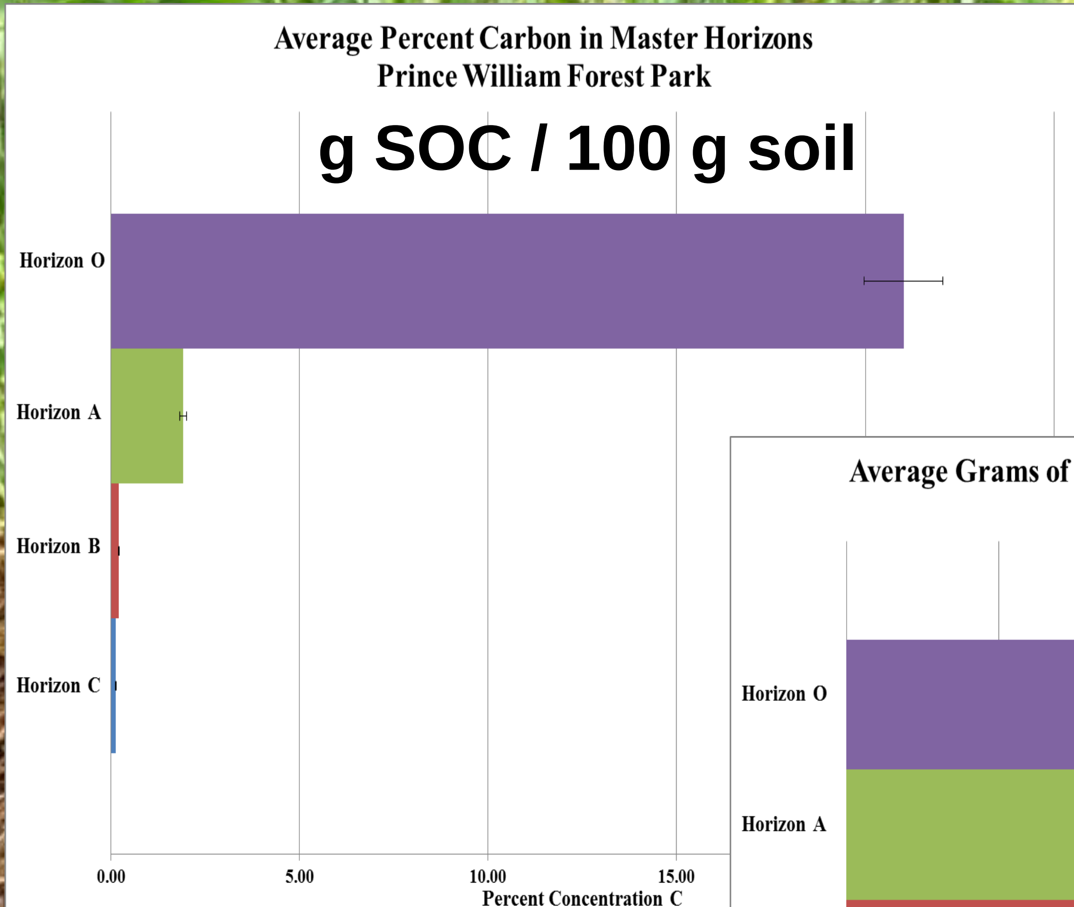


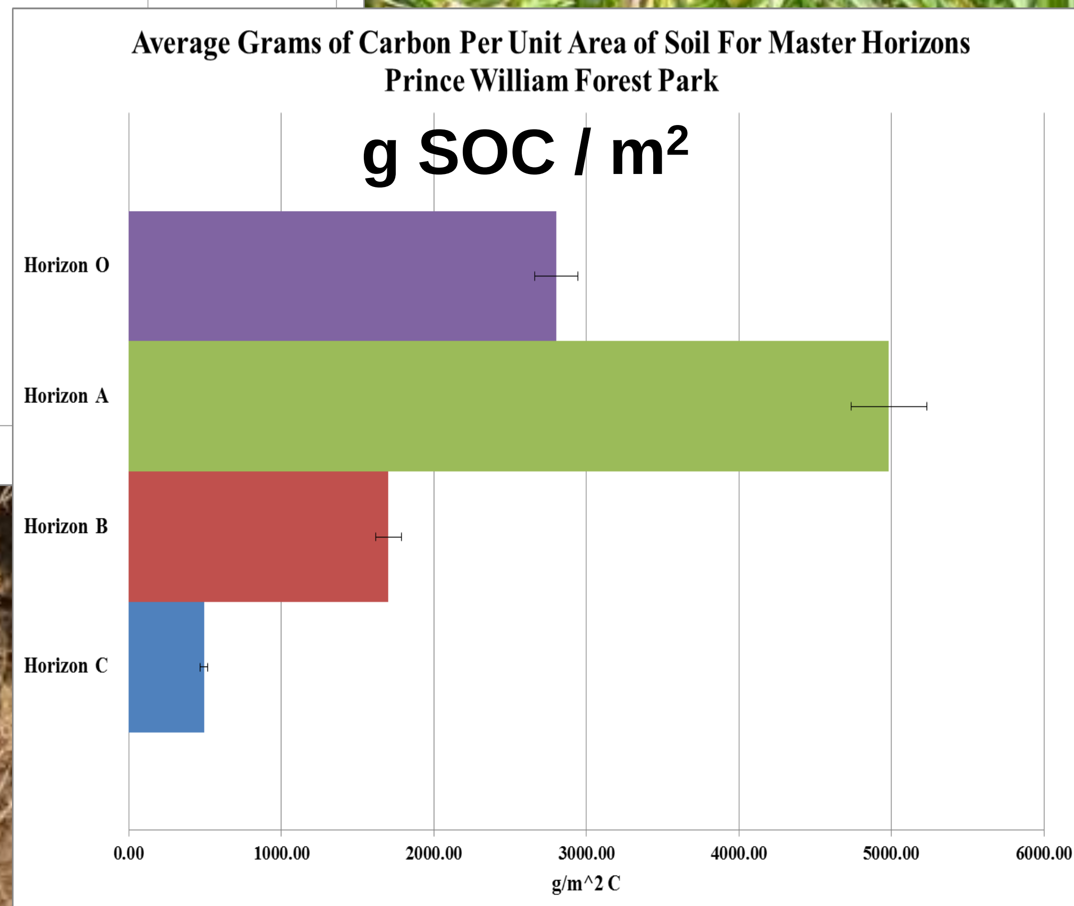
Above and below ground carbon stored in ecosystems



Lorenz, K. & R. Lal (2010). Carbon sequestration in forest ecosystems. New York, Springer.

Carbon concentrations v. stocks





Estimates of Organic C in Maryland Soils

Land Use	acres x 10^6 in Md	ha x 10^6 in Md	SOC in 1 m (Mg/ha)	SOC in Md to 1 m (Mg)	SOC to 1 m in Md (Tg)	MMtCO2e in Md
forest	2.4	0.972	80	77760000	78	285
crops	1.5	0.6075	50	30375000	30	111
turfgrass	1.3	0.5265	80	42120000	42	154
wetlands (non-tidal)	0.23	0.09315	200	18630000	19	68
total vegetated	5.43	2.19915		168885000	169	619
annual potential sequestration			0.3 - 1.0		0.66 - 2.2	2.4 - 8
(sequestration would decline over 20-30 years)						

References for land areas:

Wetland: https://water.usgs.gov/nwsum/WSP2425/state_highlights_summary.html and http://planning.maryland.gov/PDF/OurWork/LandUse/County/Statewide.pdf

Cropland:www.mdp.state.md.us/...Farmland/2012_Census_of_Agriculture_Farms_Farmlands.pdf

Turfgrass:http://www.environmentmaryland.org/reports/mde/urban-fertilizers-chesapeake-bay

Forest:http://planning.maryland.gov/PDF/OurWork/LandUse/MDP2010_LU_Summary.pdf

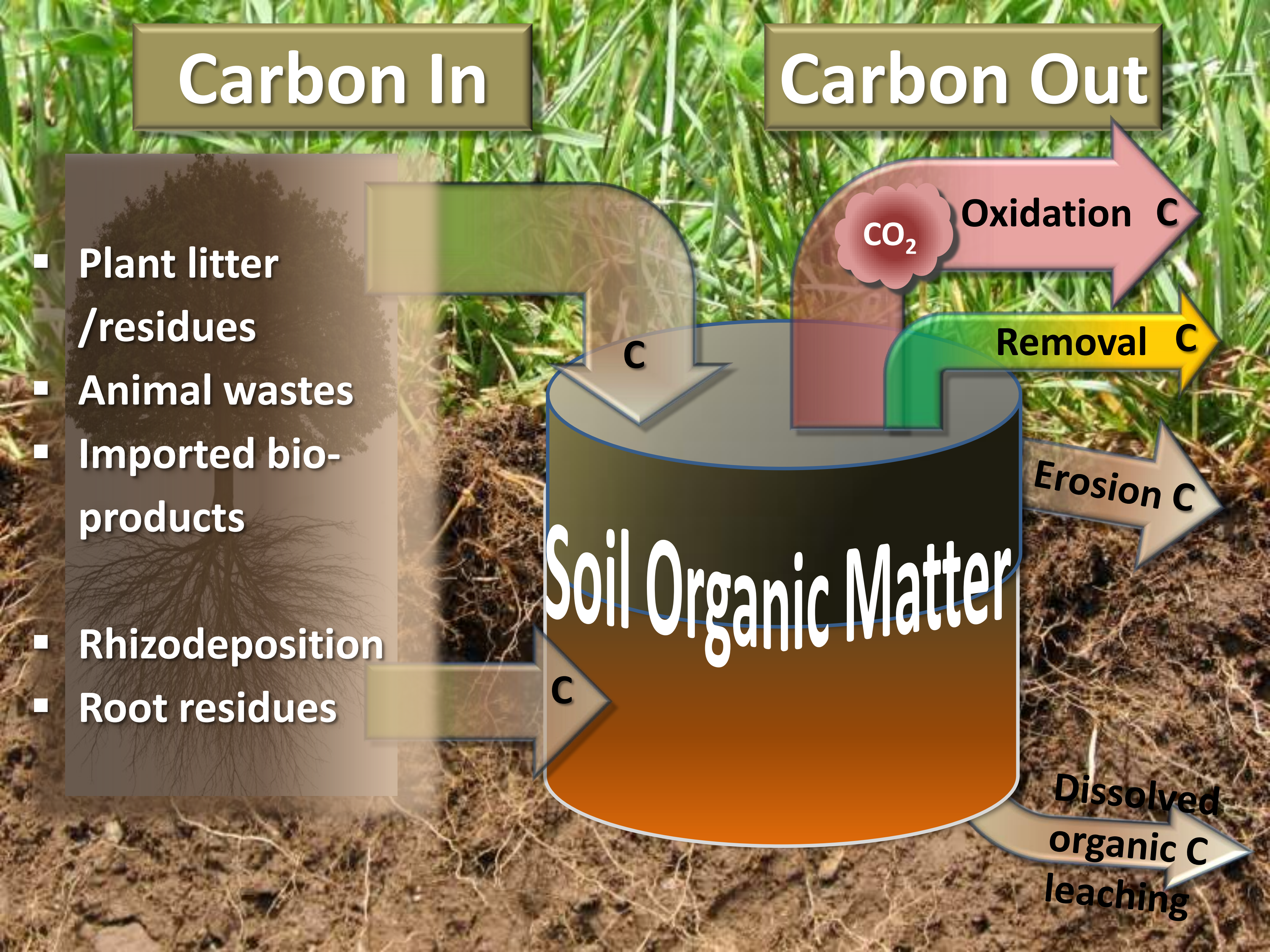
References for C stocks:

Wetland: Fenstermacher, D. E., et al. (2016). "Carbon in Natural, Cultivated, and Restored Depressional Wetlands in the Mid-Atlantic Coastal Plain." J of Envi Qual 45(2): 743-750.

Cropland: Wang, F., et al. (2017). "Total and permanganate-oxidizable organic carbon in the corn rooting zone of US Coastal Plain soils as affected by forage radish cover crops and N fertilizer." Soil and Tillage Research 165: 247-257.

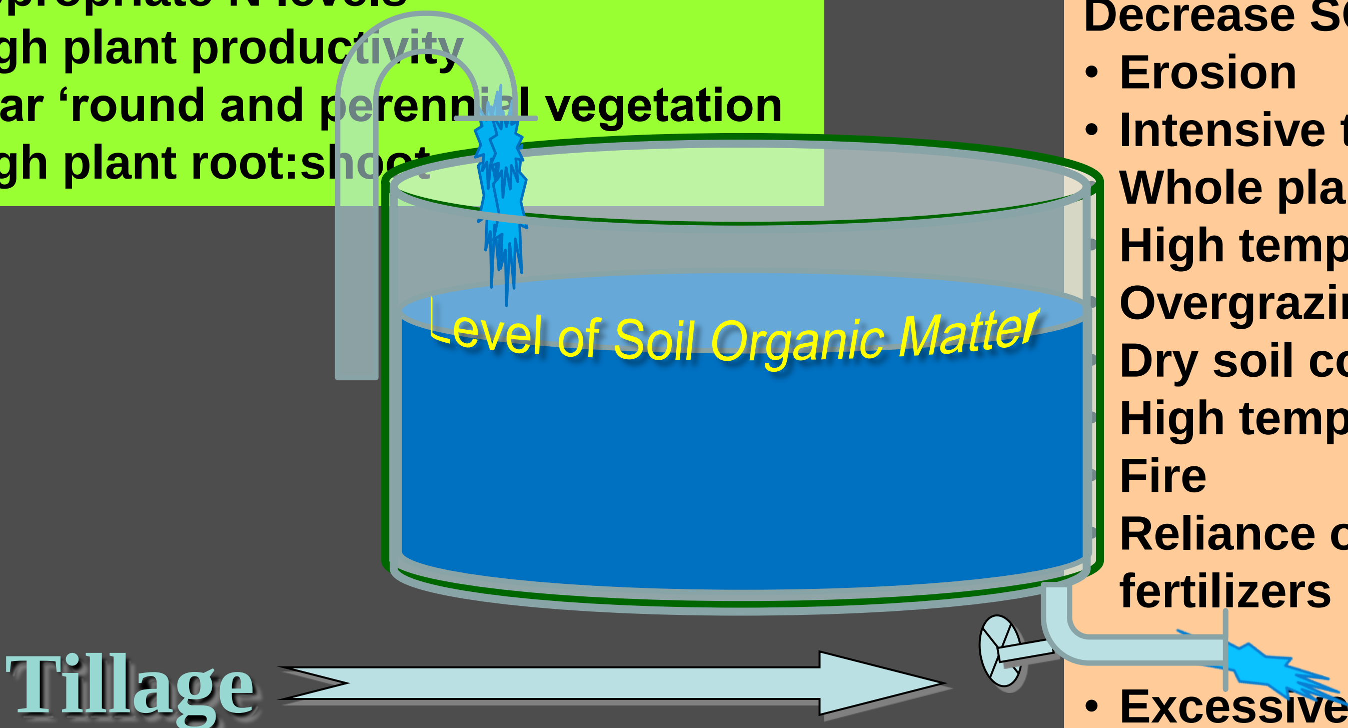
Turfgrass: Selhorst, A. and R. Lal (2013). "Net Carbon Sequestration Potential and Emissions in Home Lawn Turfgrasses of the United States." Environmental Management 51(1): 198-208.

Reference for potential sequestration rates: Lorenz, K. and R. Lal (2010). Carbon sequestration in forest ecosystems. New York, Springer.

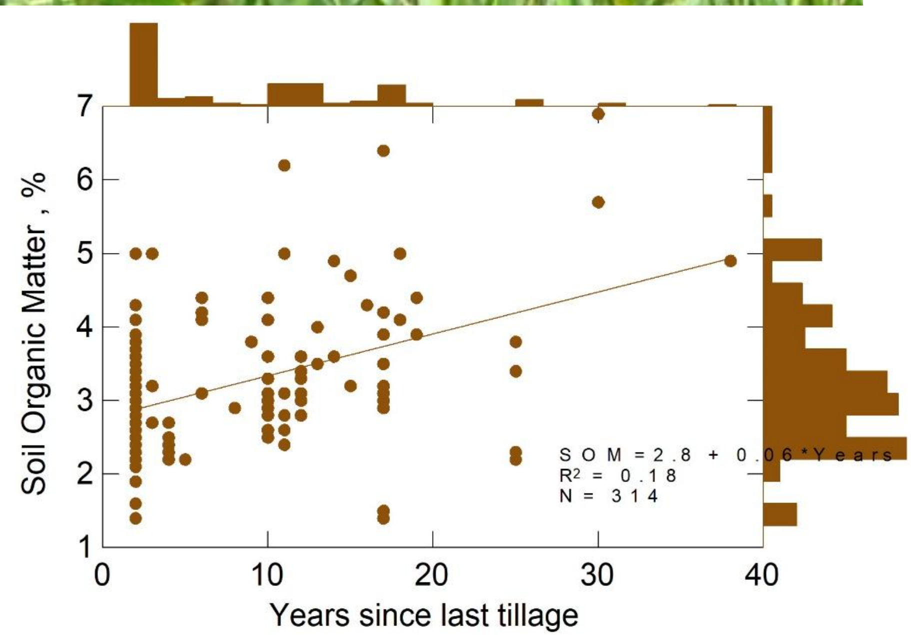

Carbon In
Carbon Out
Plant litter /residues
Animal wastes
Imported bio-products
Rhizodeposition
Root residues
C
C
CO_2
Oxidation C
Removal C
Erosion C
Dissolved organic C leaching
Soil Organic Matter

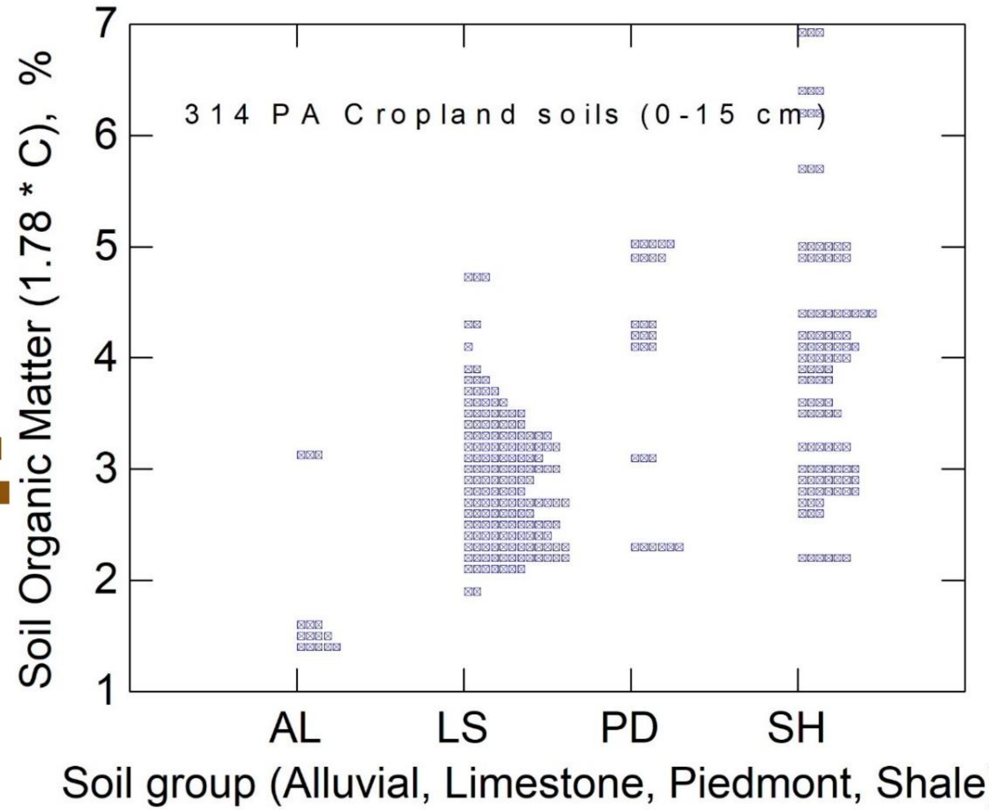
Soil Organic Matter Management: Balancing C inputs with output

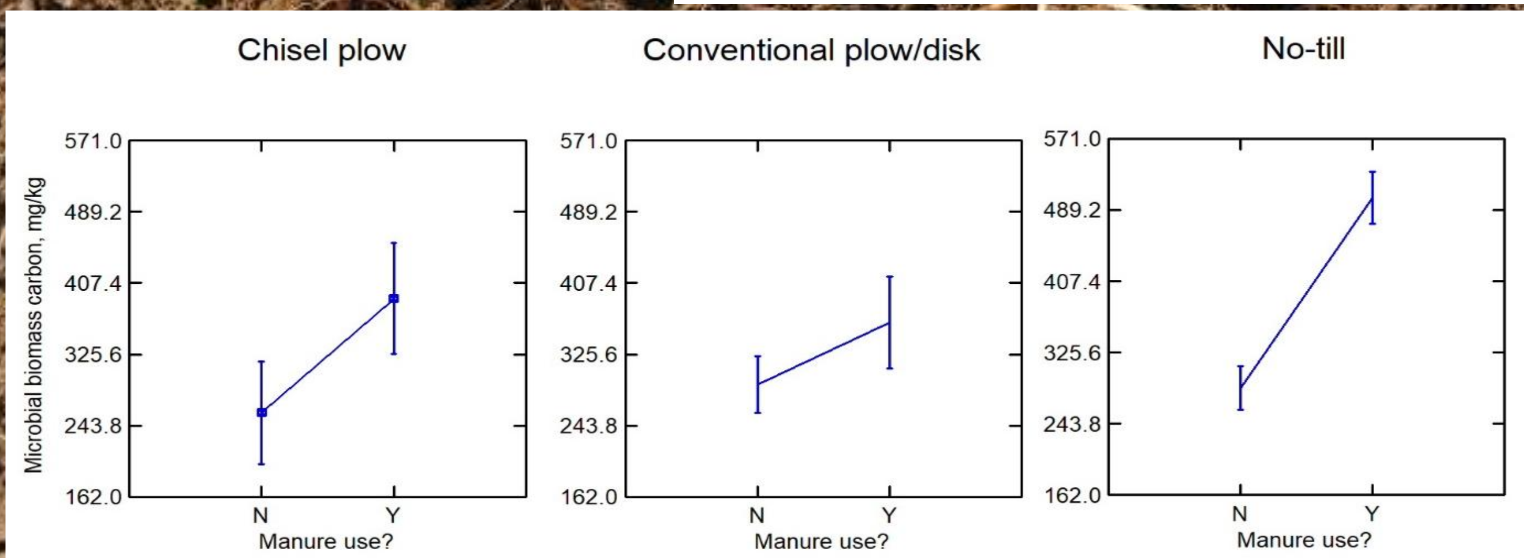
Increase SOM levels by:
- Soil conservation
- Green manures / cover crops
- Return of plant residues
- Controlled grazing
- High soil moisture
- Surface mulch
- Composts & manure
- Appropriate N levels
- High plant productivity
- Year 'round and perennial vegetation
- High plant root:shoot



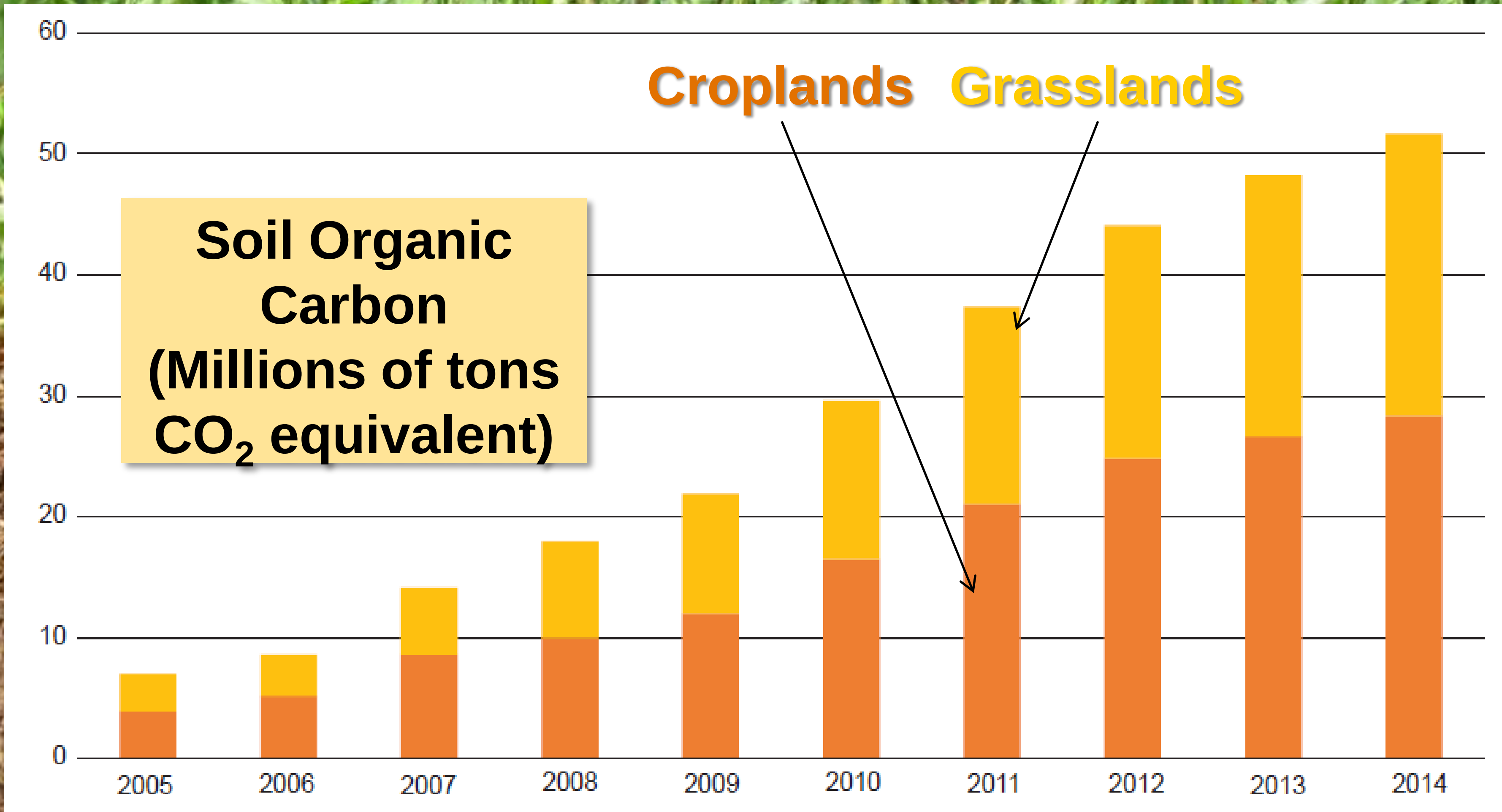
Decrease SOM by:
- Erosion
- Intensive tillage
- Whole plant removal
- High temperatures
- Overgrazing
- Dry soil conditions
- High temperature/direct sun
- Fire
- Reliance on inorganic fertilizers
- Excessive mineral N
- Low plant productivity
- Low plant root:shoot


Soil Organic Matter , %
Years since last tillage
S O M = 2 . 8 + 0 . 0 6 * Y e a r s
R2 = 0 . 1 8
N = 3 1 4
0
10
20
30
40
1
2
3
4
5
6
7


3 1 4 P A C r o p l a n d s o i l s (0 - 1 5 c m)
Soil Organic Matter (1.78 * C), %
AL
LS
PD
SH
Soil group (Alluvial, Limestone, Piedmont, Shale)
1
2
3
4
5
6
7

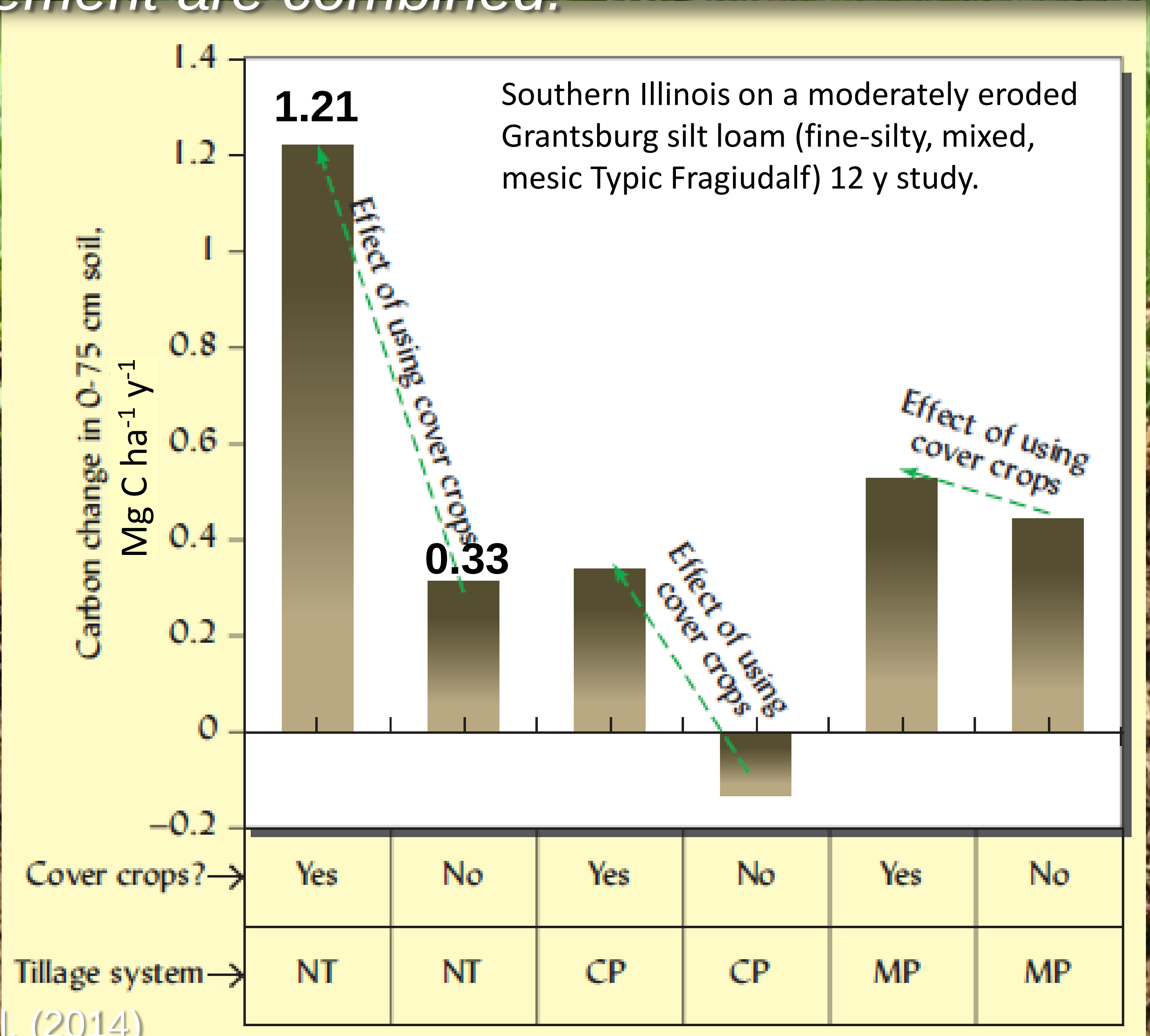

Chisel plow
Conventional plow/disk
No-till
Microbial biomass carbon, mg/kg
571.0
489.2
407.4
325.6
243.8
162.0
N
Y
Manure use?

Soil Organic Carbon Added by NRCS Practices to USA Cropland/Grassland Soils



From:Chambers, A., R. Lal, and K. Paustian. 2016.

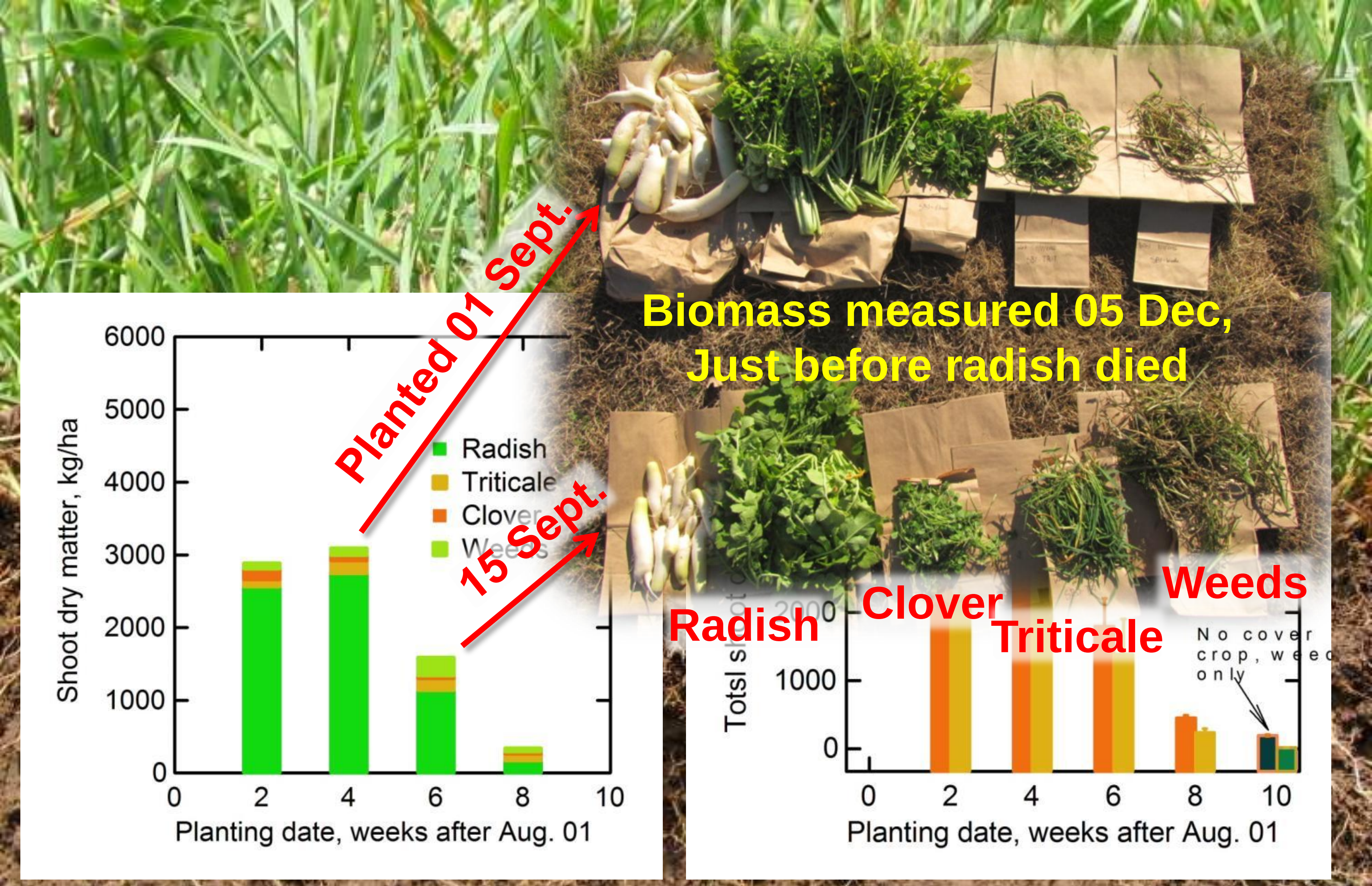
Synergistic effect on soil health when cover crops and no-till management are combined.



data from Olson et al. (2014)

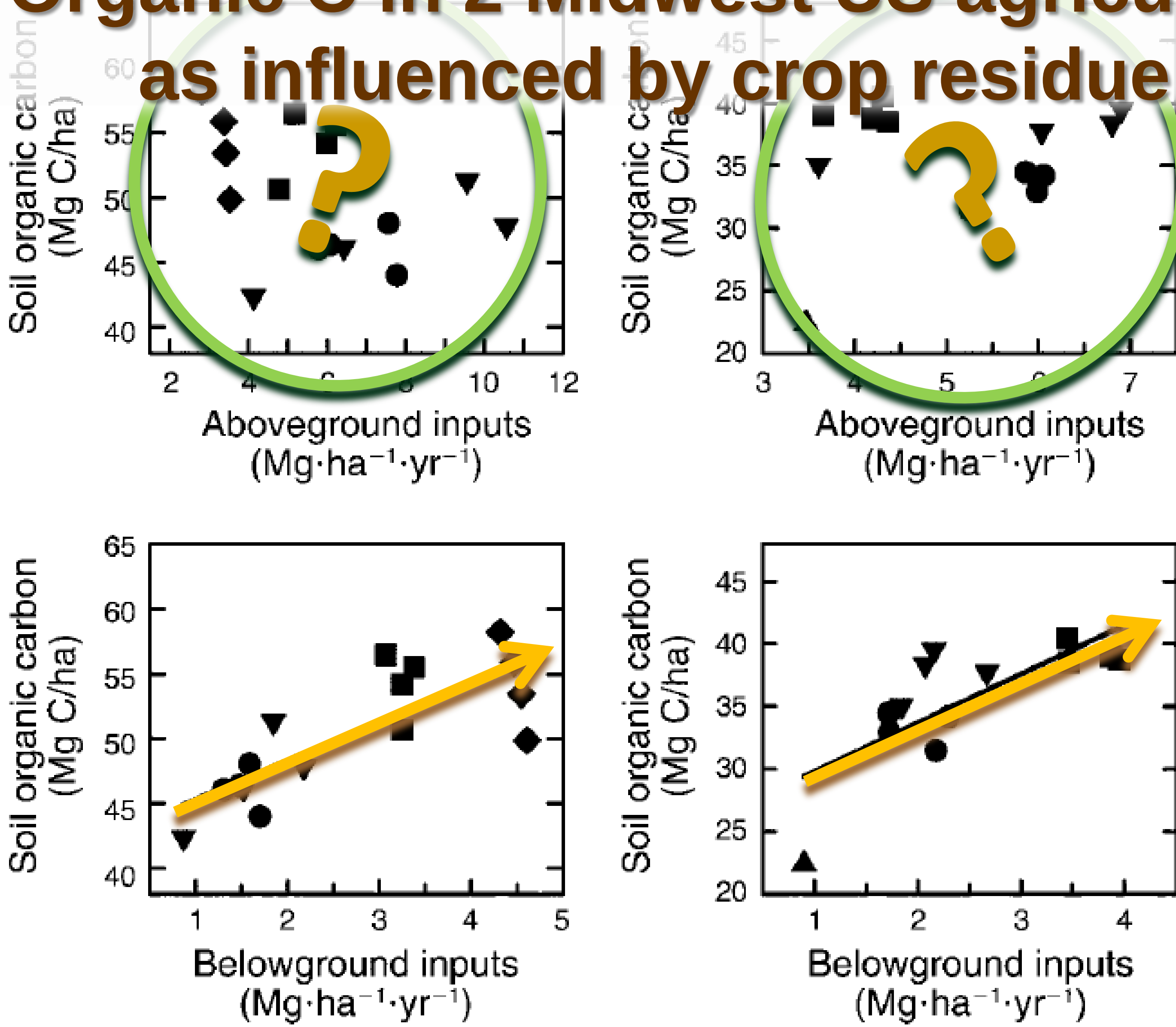
Our mid-Atlantic project on “Deep Nitrogen”

Triticale, radish and clover after silage corn



Cover crop mixes: what you sown is not necessarily what you see

Organic C in 2 Midwest US agricultural soils as influenced by crop residue inputs



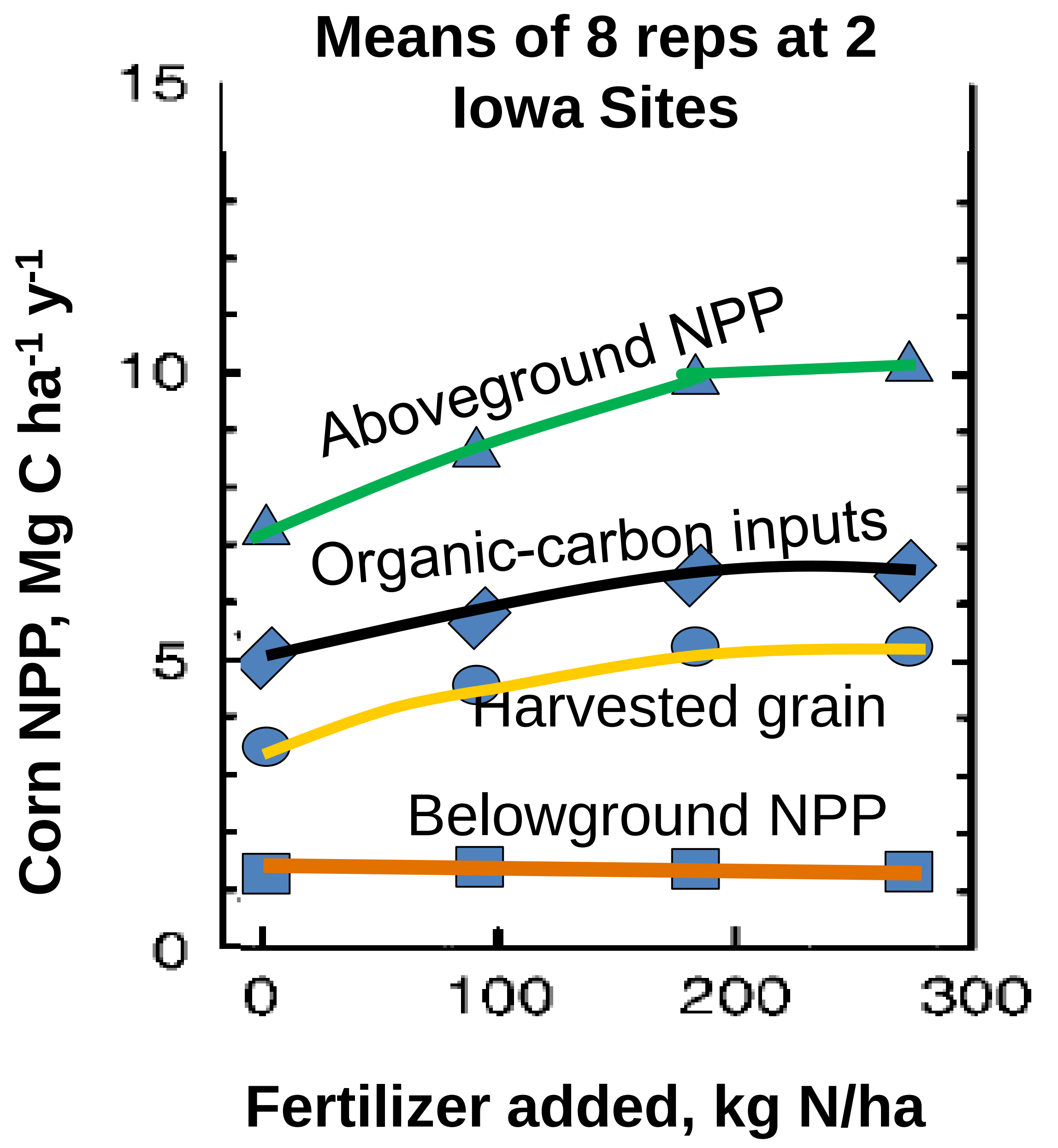
Above-ground inputs

Below-ground inputs

Russell et al.(2009). Nitrogen fertilizer effects on soil carbon balances in Midwestern U.S. agricultural systems. Ecological Applications 19:1102-1113.

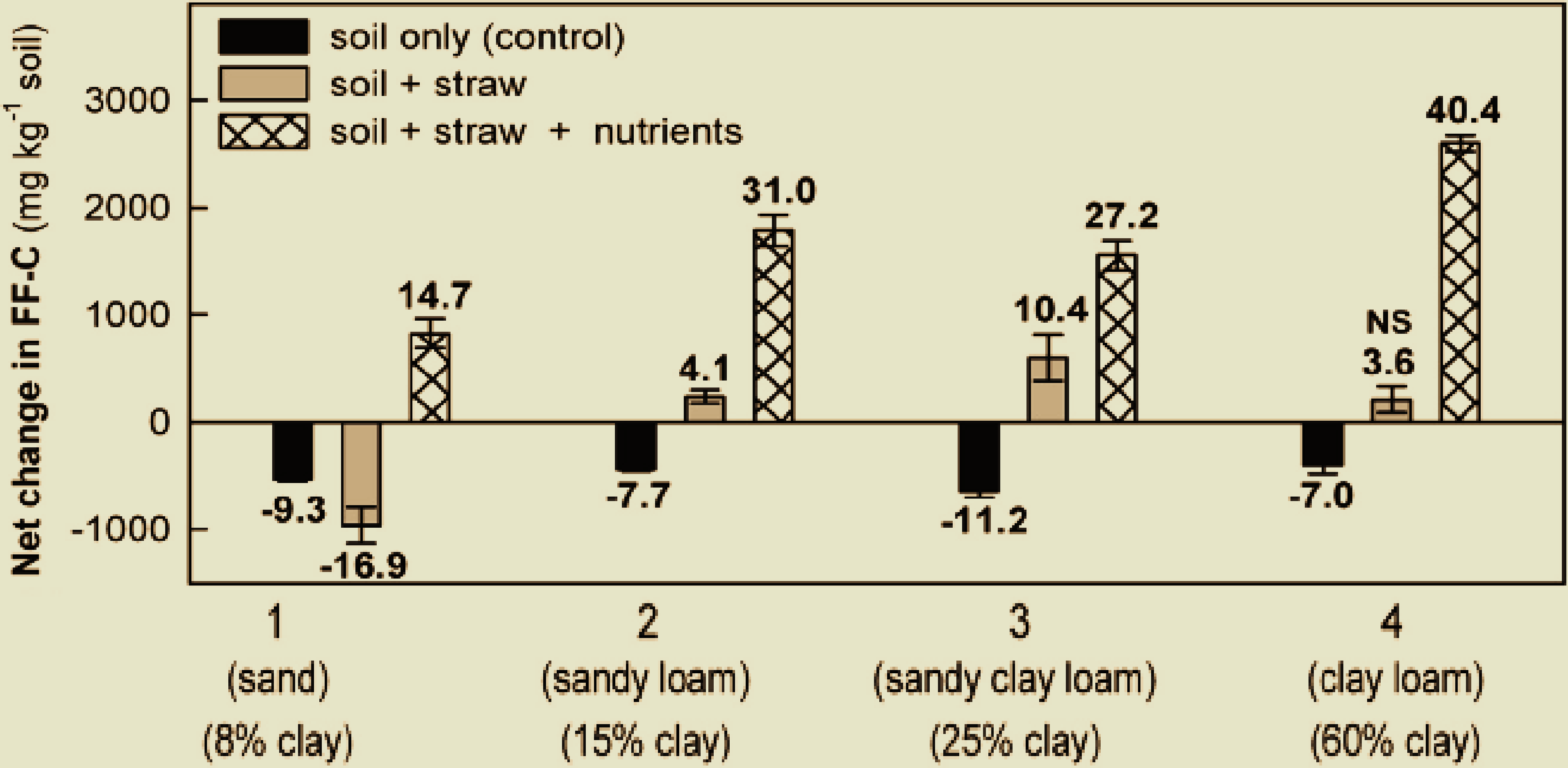
Response of net primary production (NPP) of corn to N fertilization

Russell et al.(2009).



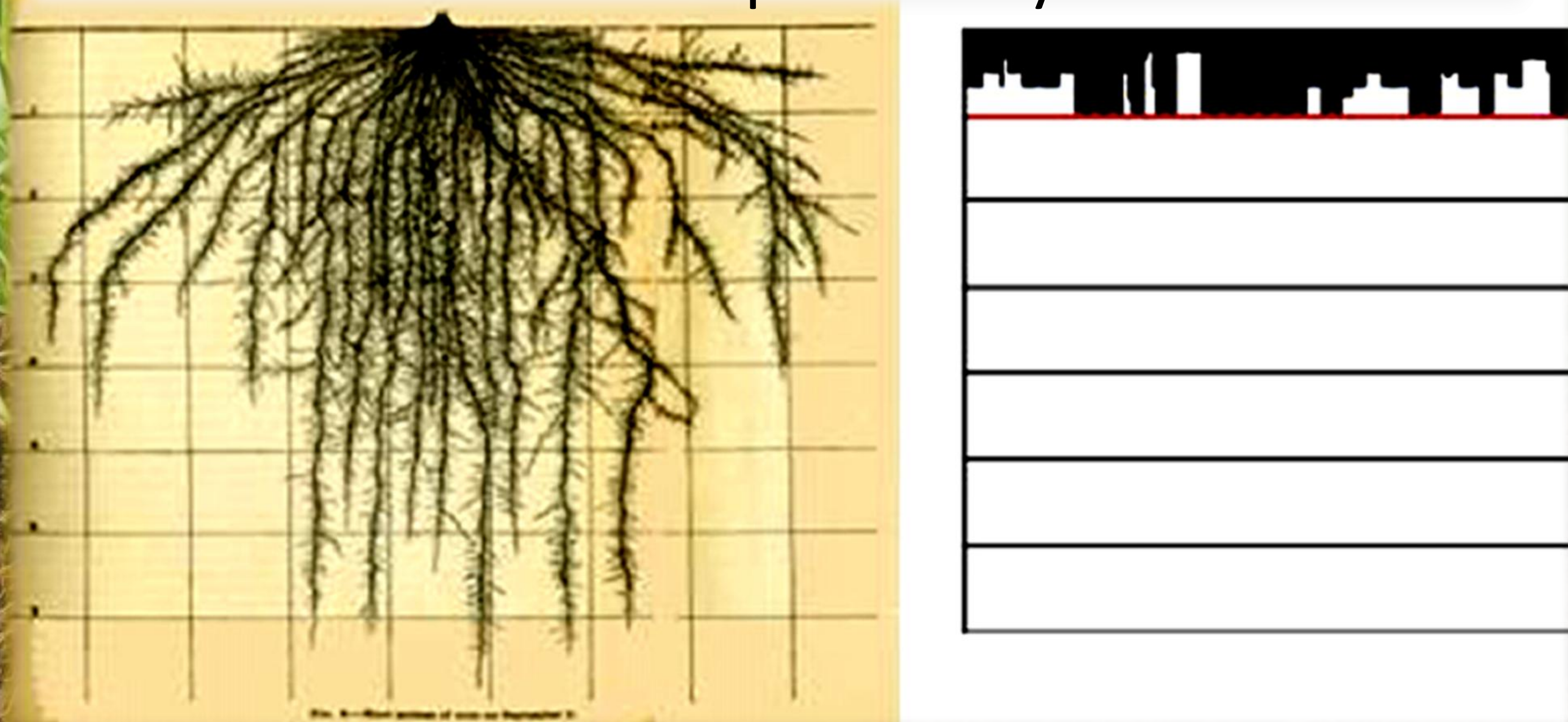
Net change in stable soil C after 56 day soil incubation with wheat straw & N, P, S (No Live Plants)

Stable soil organic C (fine fraction SOM or FF-C) contains C, H, O as well as N, P and S in approximately constant ratios. The availability of N, P and S is thus needed for the formation of FF-SOM.



Kirkby et al. 2014. Soil Biology & Biochemistry 68:402e409

No-till increases SOC in surface layers - but what about in deeper soil layers?



Corn root system (Weaver 1929) and sampling depths used in 140 studies of tillage impacts on soil carbon. Scale marks 1 ft. = 30cm.

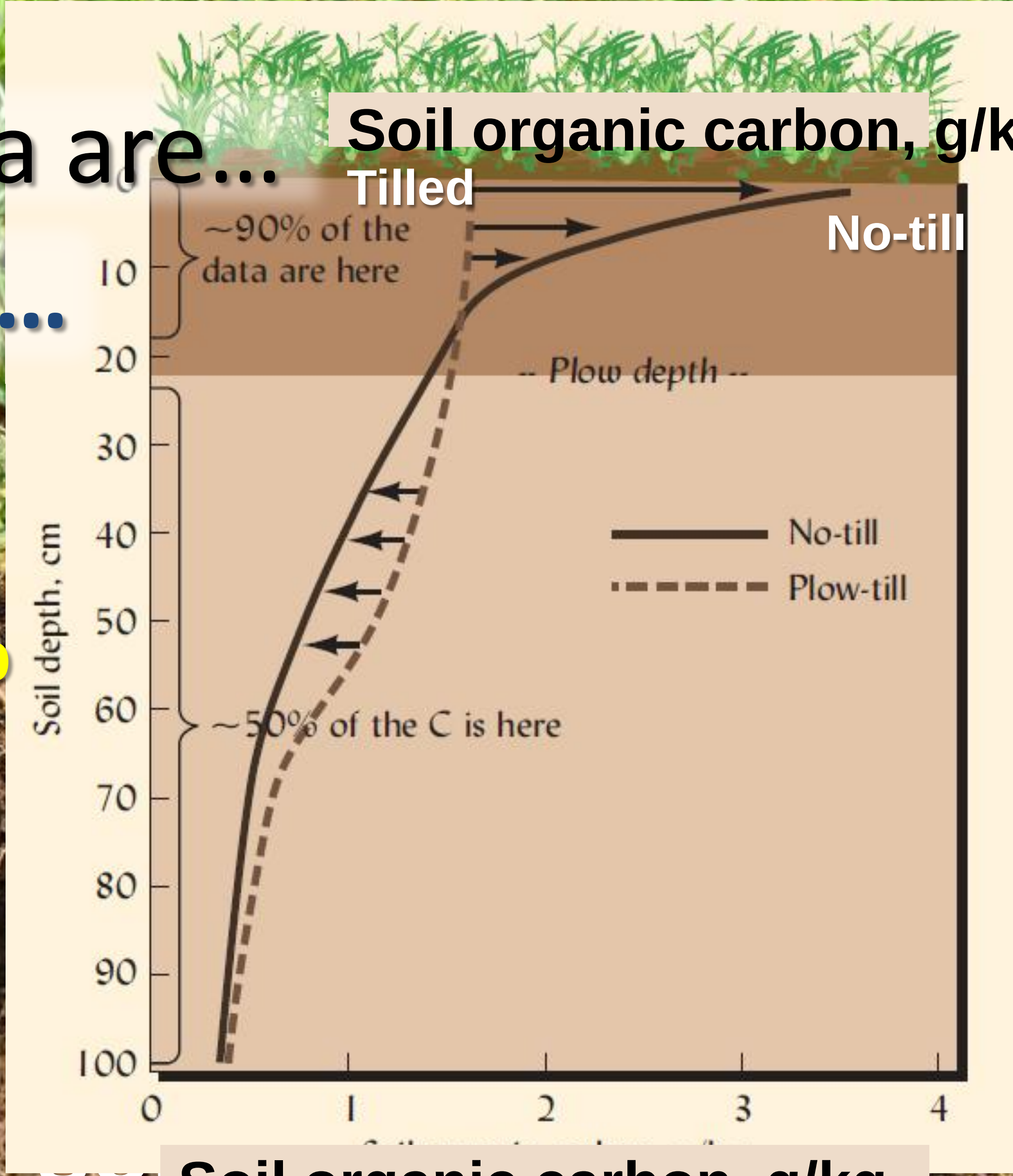
From: Baker, et al. 2007. Agric, Eco & Envi118:1-5.

Most of the data are…

from top 20 cm…

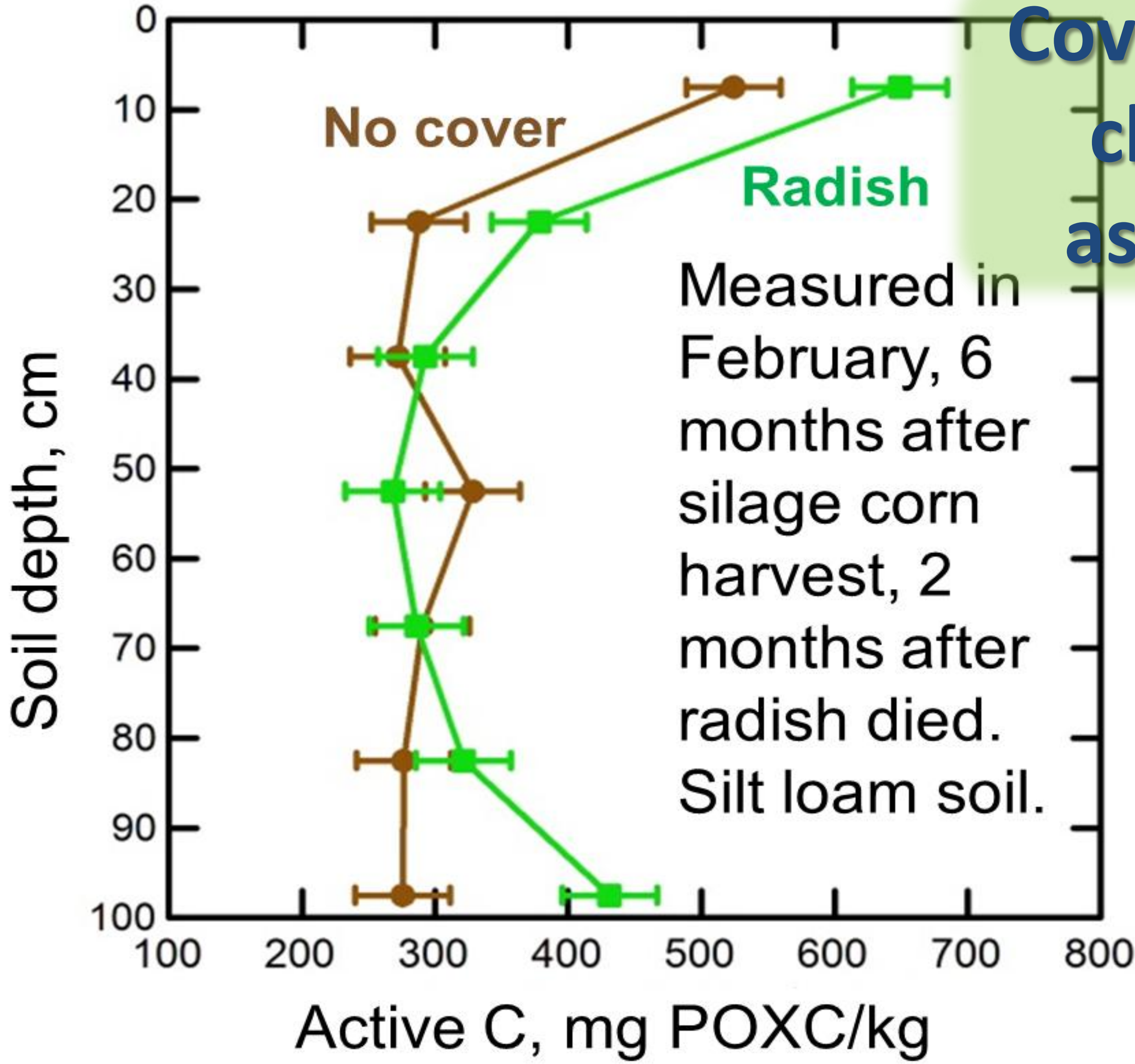
but most of the carbon is deeper

Studies that look deep suggest that no-till may change the location but not the amount of carbon stored in soils.



From Weil and Brady. 2016.

Cover crops may change that assessment…



Active carbon in 0-100 cm soil layer

Based on data from : Wang, F., R. Weil, and X. Nan. 2017. Soil & Tillage Research 165:247-257.

Learning about roots isn't easy – digging them up and counting them!

Core-break method to determine at root numbers with depth

Taking soil cores to depth of 2-3 ft

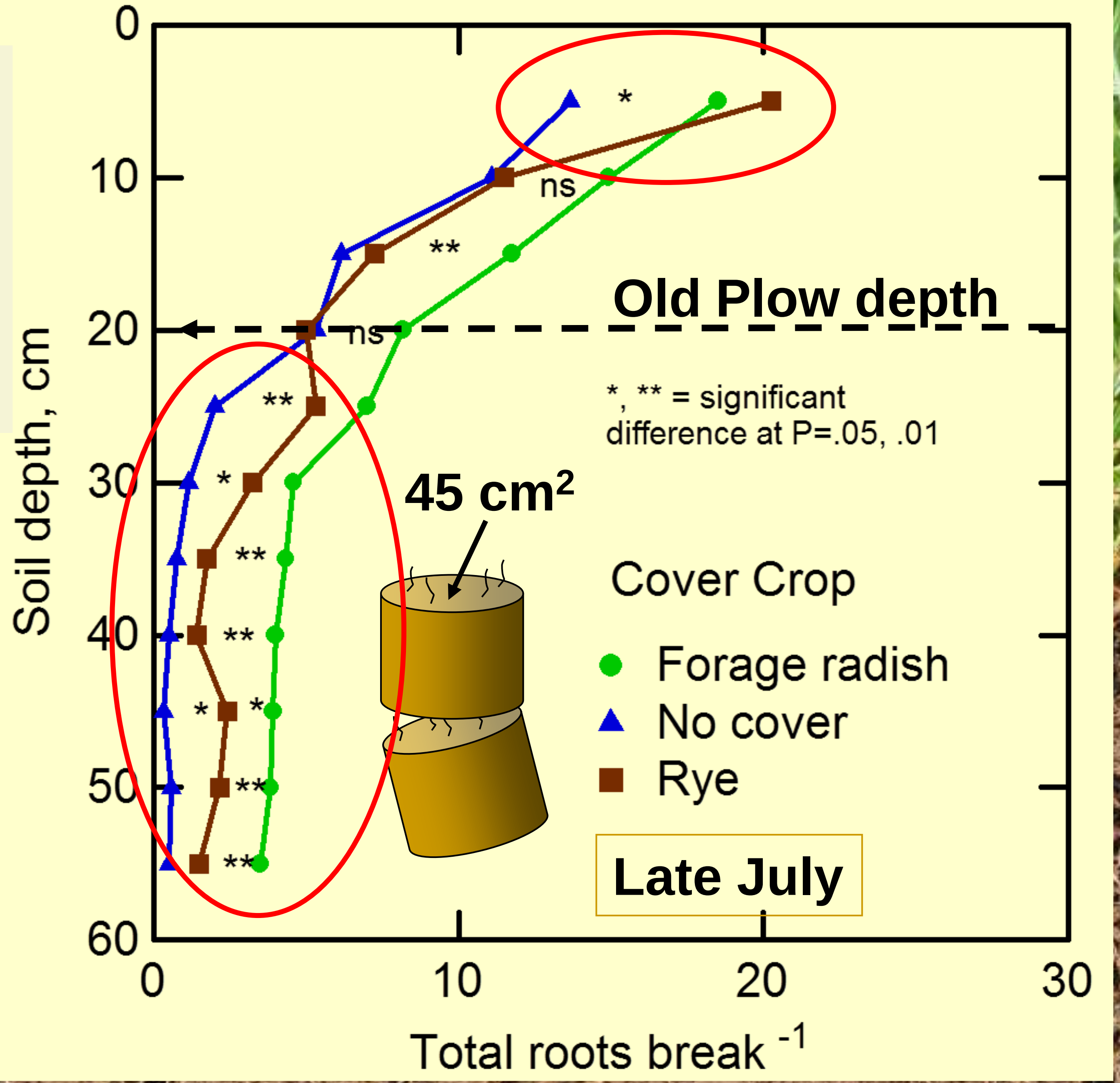
Counting root numbers at the breakage faces

Investigating roots with fiber optic camera: Mini-rhizotron

First proof of "*bio-drilling*" to alleviate subsoil compaction published in 2004

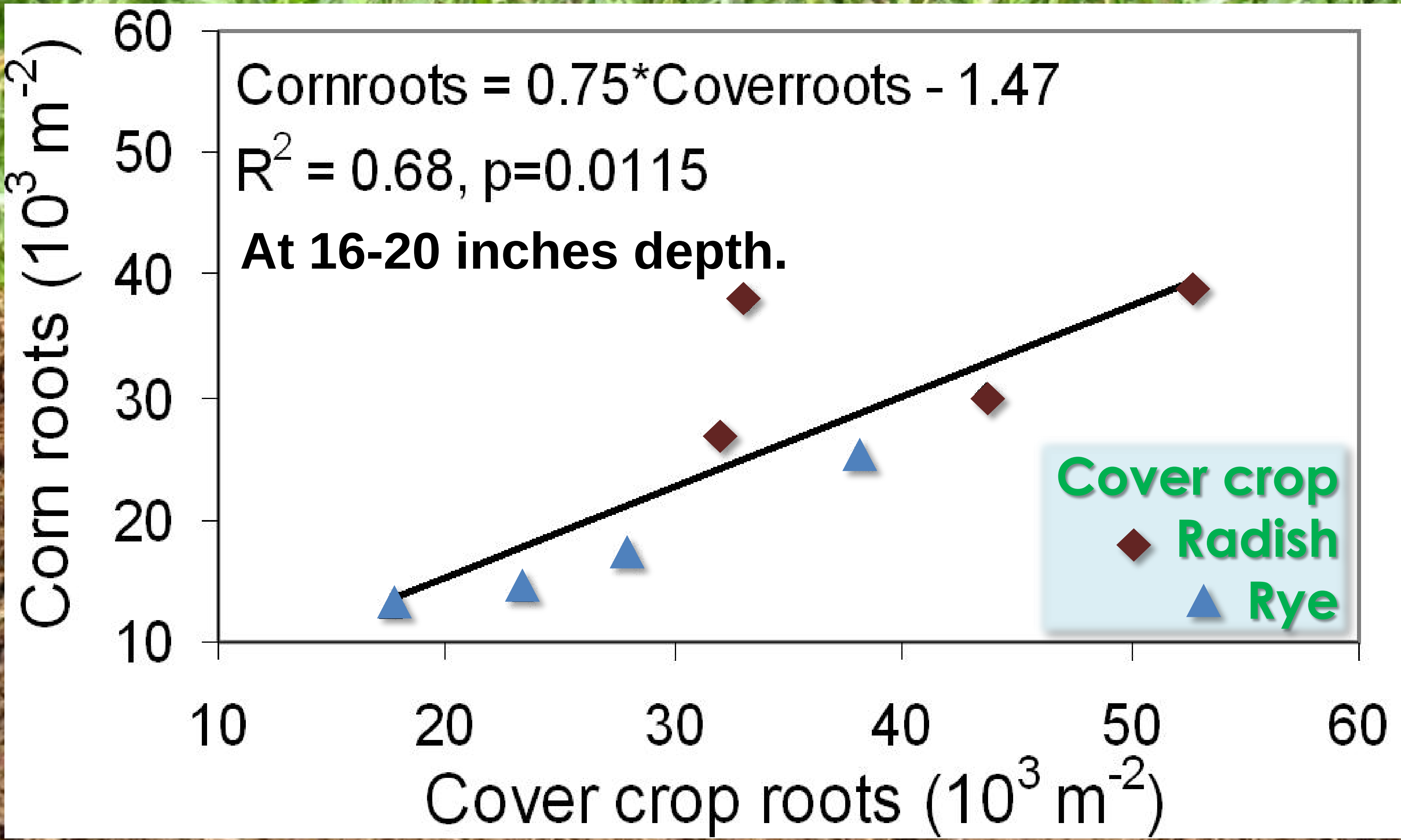
Williams and Weil (2004)

Roots of corn following rye, radish or no winter cover crop



Chen and Weil, unpublished

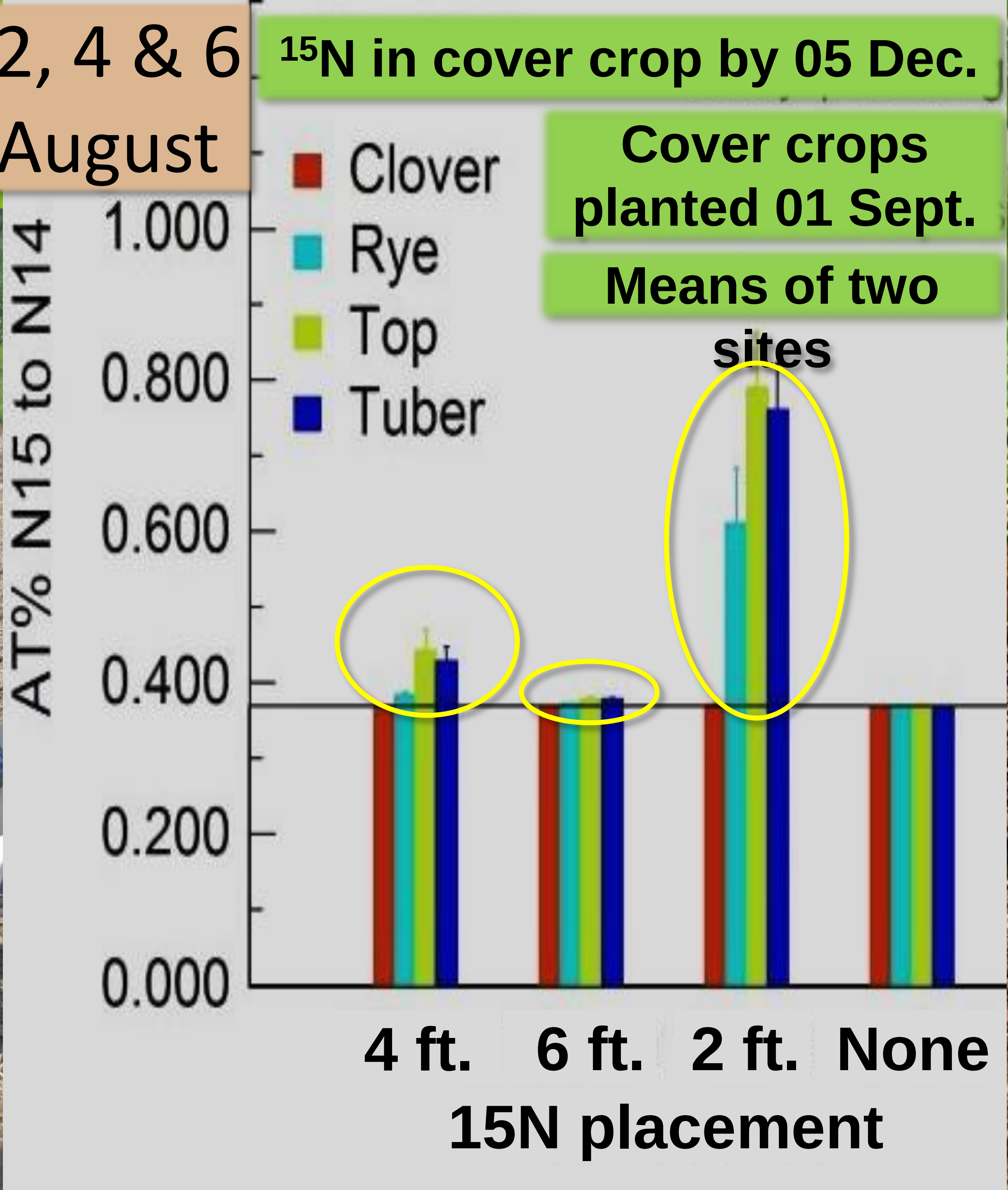
Subsoil roots: corn v cover



Data of Chen and Weil. unpublished.


POTASSIUM NITRATE
(15N, 99%)
NLM-765-1
PSO #:15D-591
Lot #:
May intensify fire, oxidizer.
Sampled biomass
0 cm
50 cm
100 cm
150 cm
200 cm
Bentonite seal
Solution with labeled fertilizer

^{15}N tracer Placed 2, 4 & 6 feet deep in late August



Conclusions

- Soil carbon is a major player in climate change/ GH gases cycles
- Most ecosystems have far more C below than above ground
- Land use & soil management changes typically release or sequester soil C at 0.2 to >1 Mt C y^{-1}.
- The more degraded the soil, the greater its potential for C sequestration
- Maryland soil may be able to sequester 2 to 8 MMtCO2e annually
- Soils also play major role for NO_x and CH_4.