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Building Soil Organic Matter: What, Why, How?

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& TECHNOLOGY

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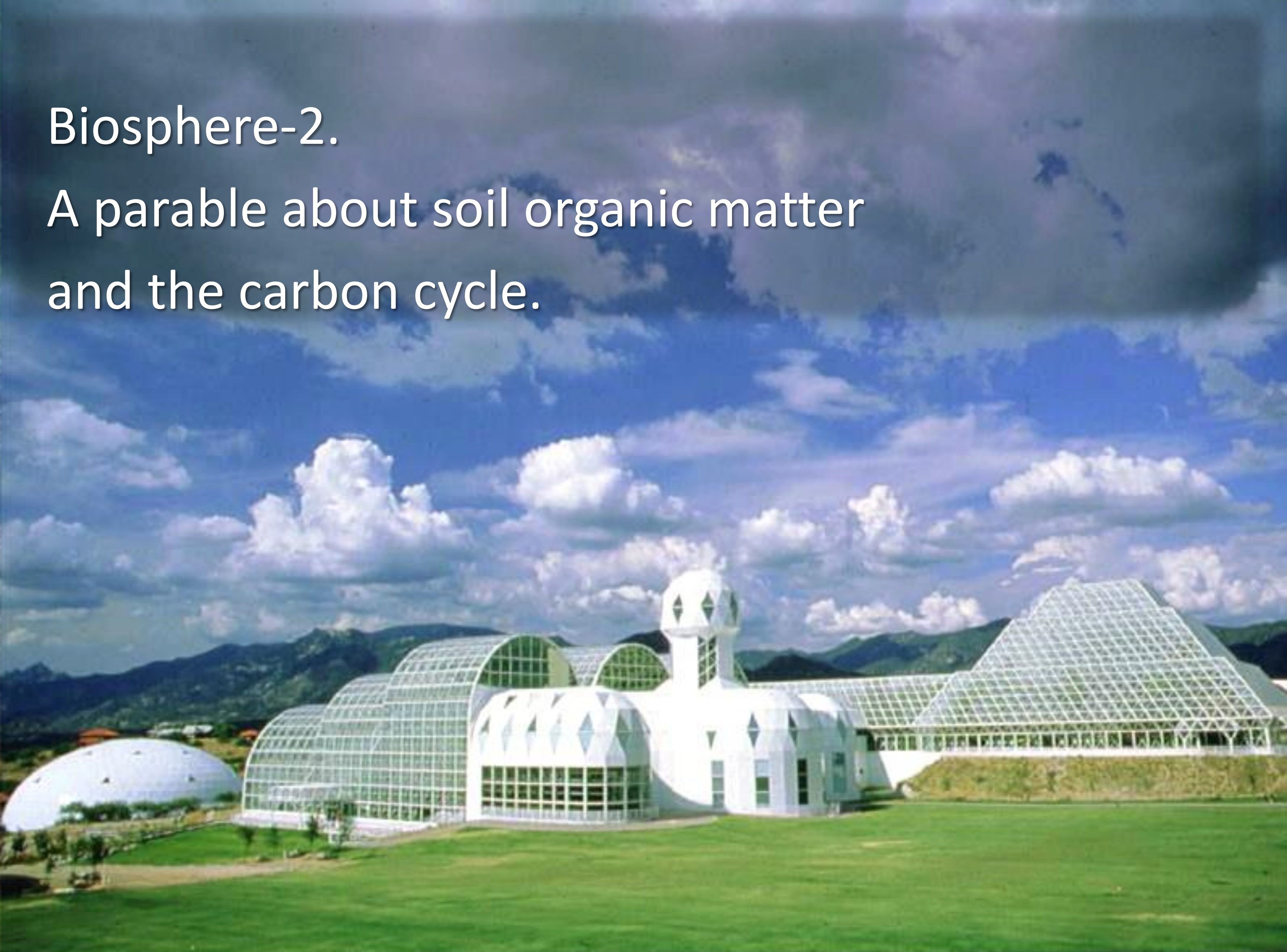
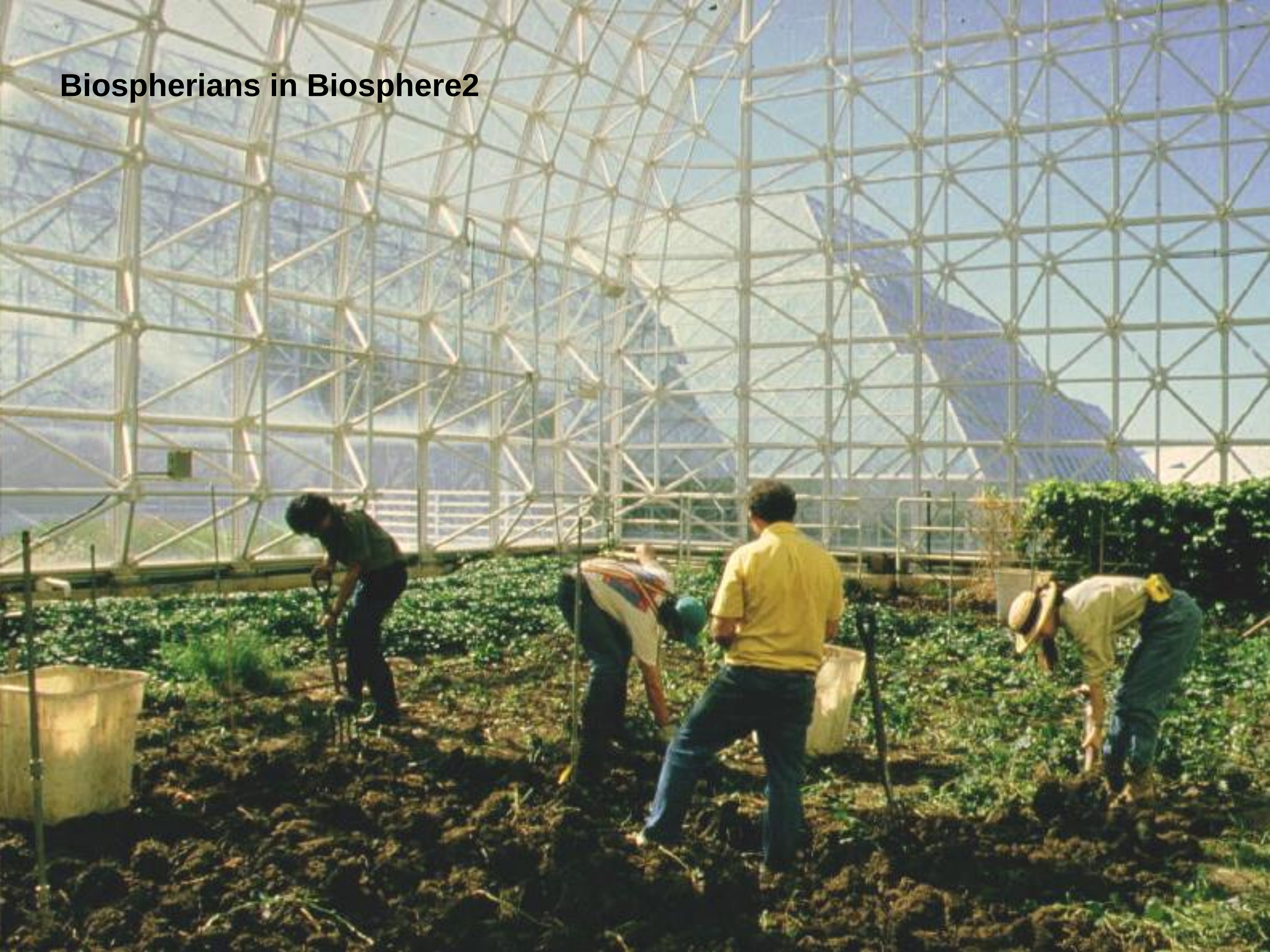
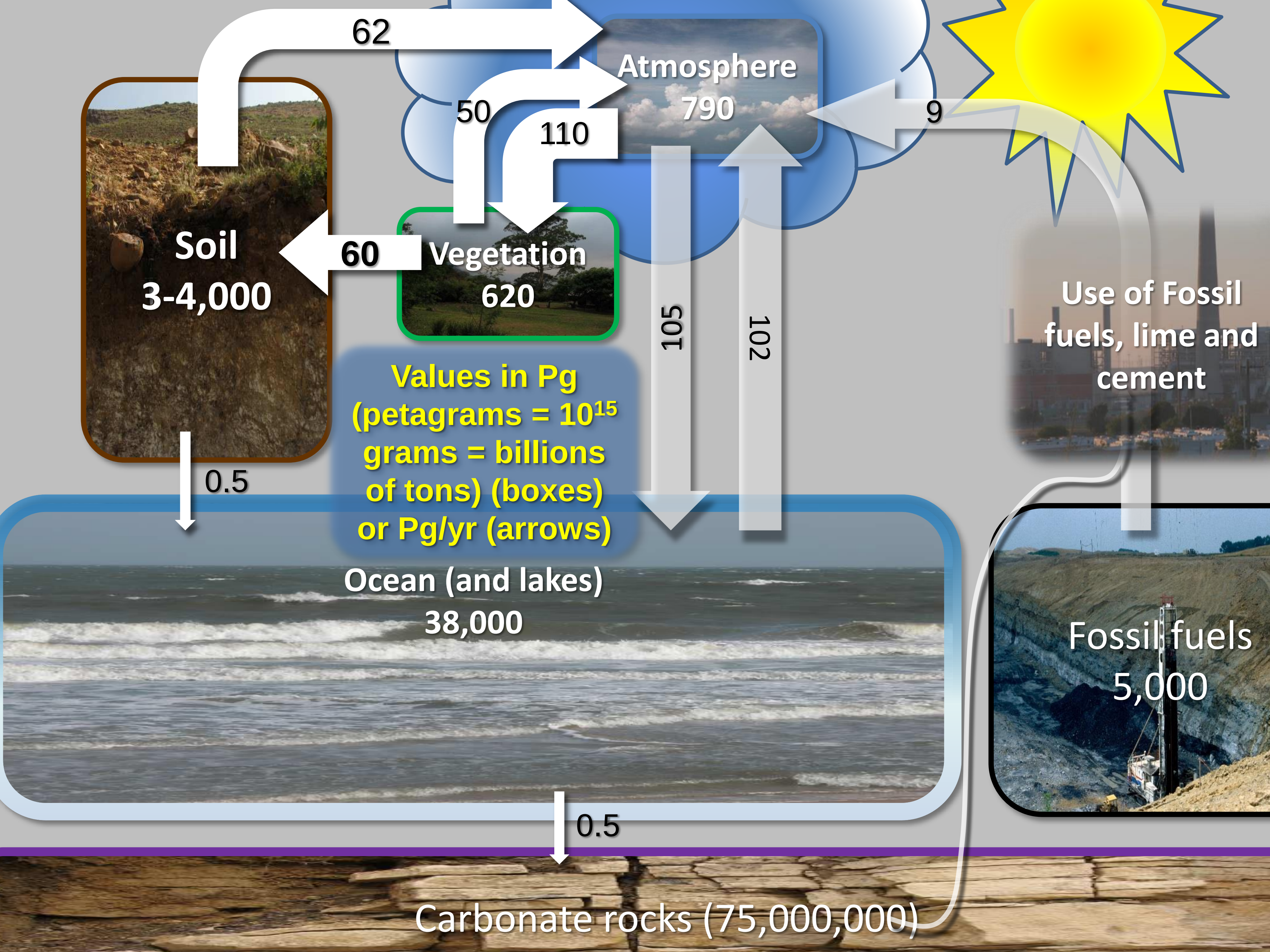
Biosphere-2.
A parable about soil organic matter and the carbon cycle.

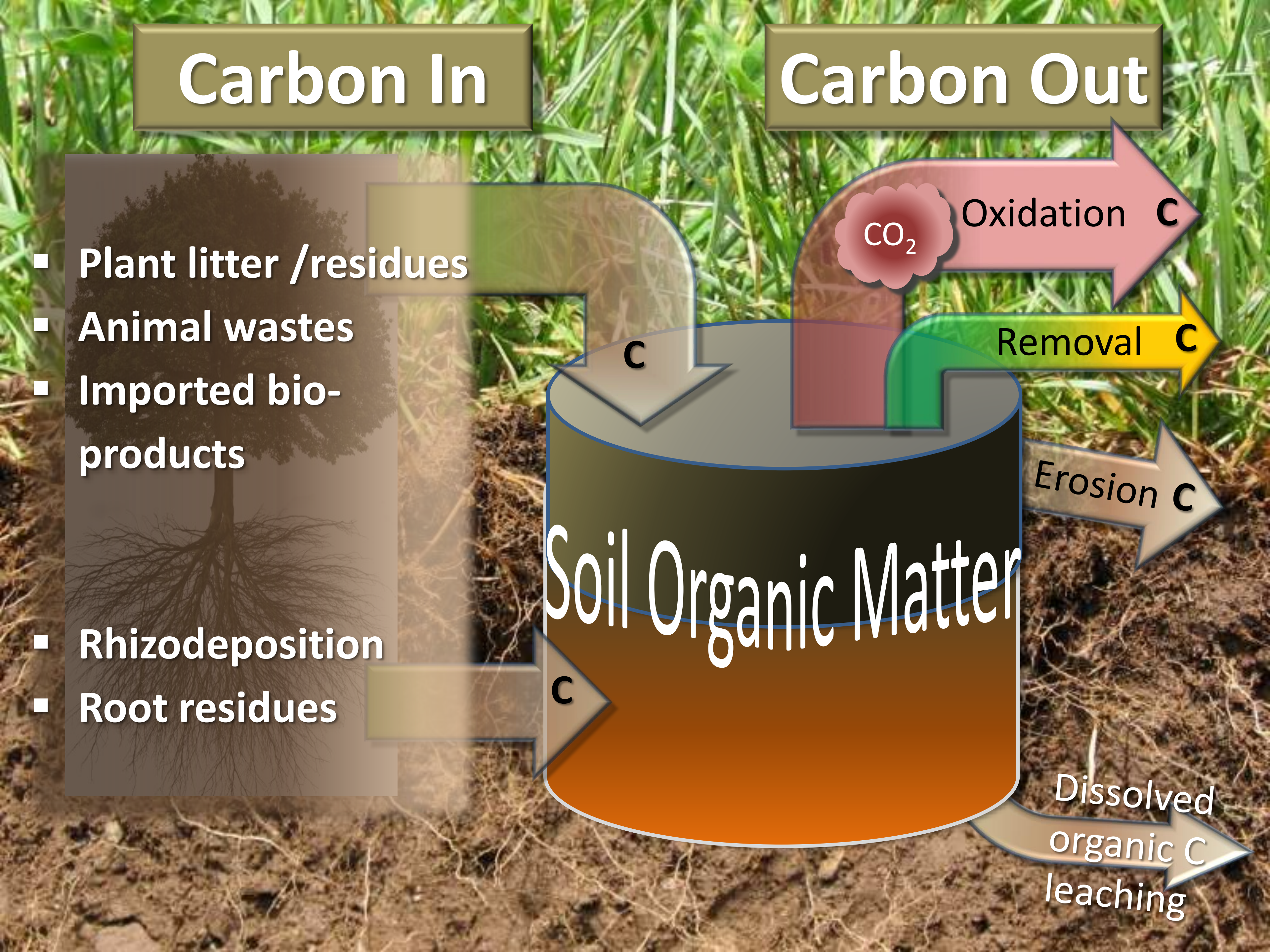


Biospherians in Biosphere2



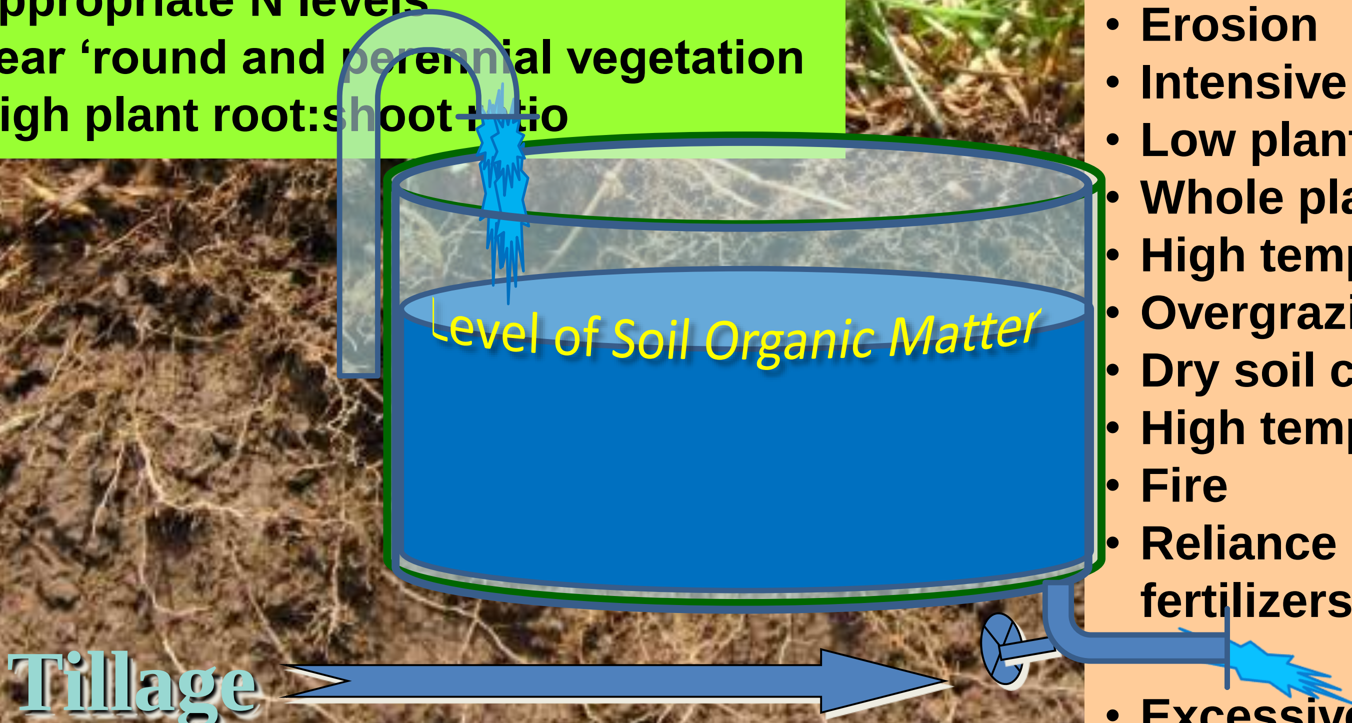


62
Atmosphere
790
50
110
9
Soil
3-4,000
60
Vegetation
620
105
102
Use of Fossil fuels, lime and cement
Values in Pg (petagrams = 10^{15} grams = billions of tons) (boxes) or Pg/yr (arrows)
0.5
Ocean (and lakes)
38,000
Fossil fuels
5,000
0.5
Carbonate rocks (75,000,000)


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
Soil Organic Matter
Dissolved organic C leaching

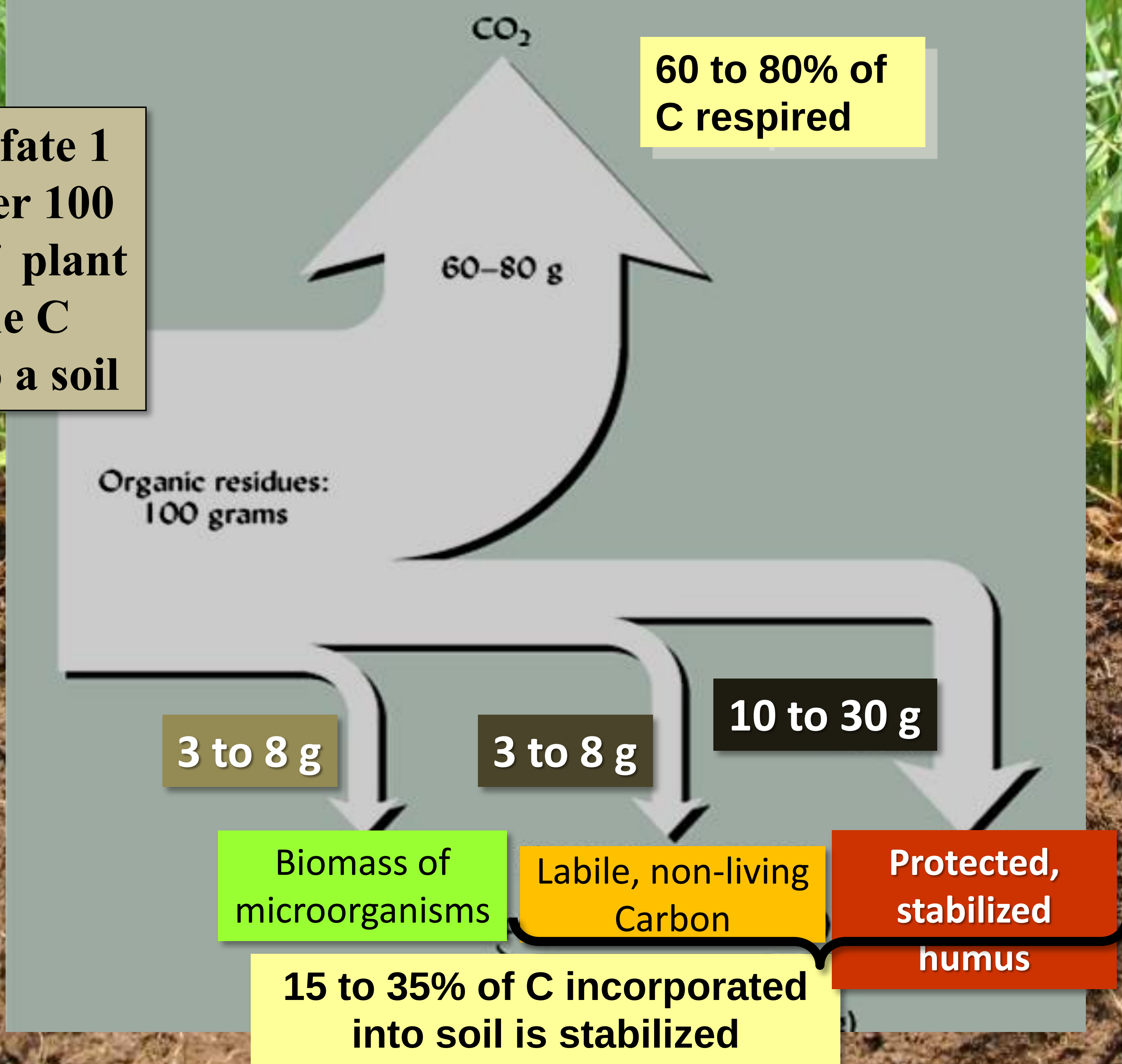
Soil Organic Matter Management: Balancing C inputs with output

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



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

Typical fate 1 year after 100 grams of plant residue C added to a soil



Traditional soil organic matter concepts

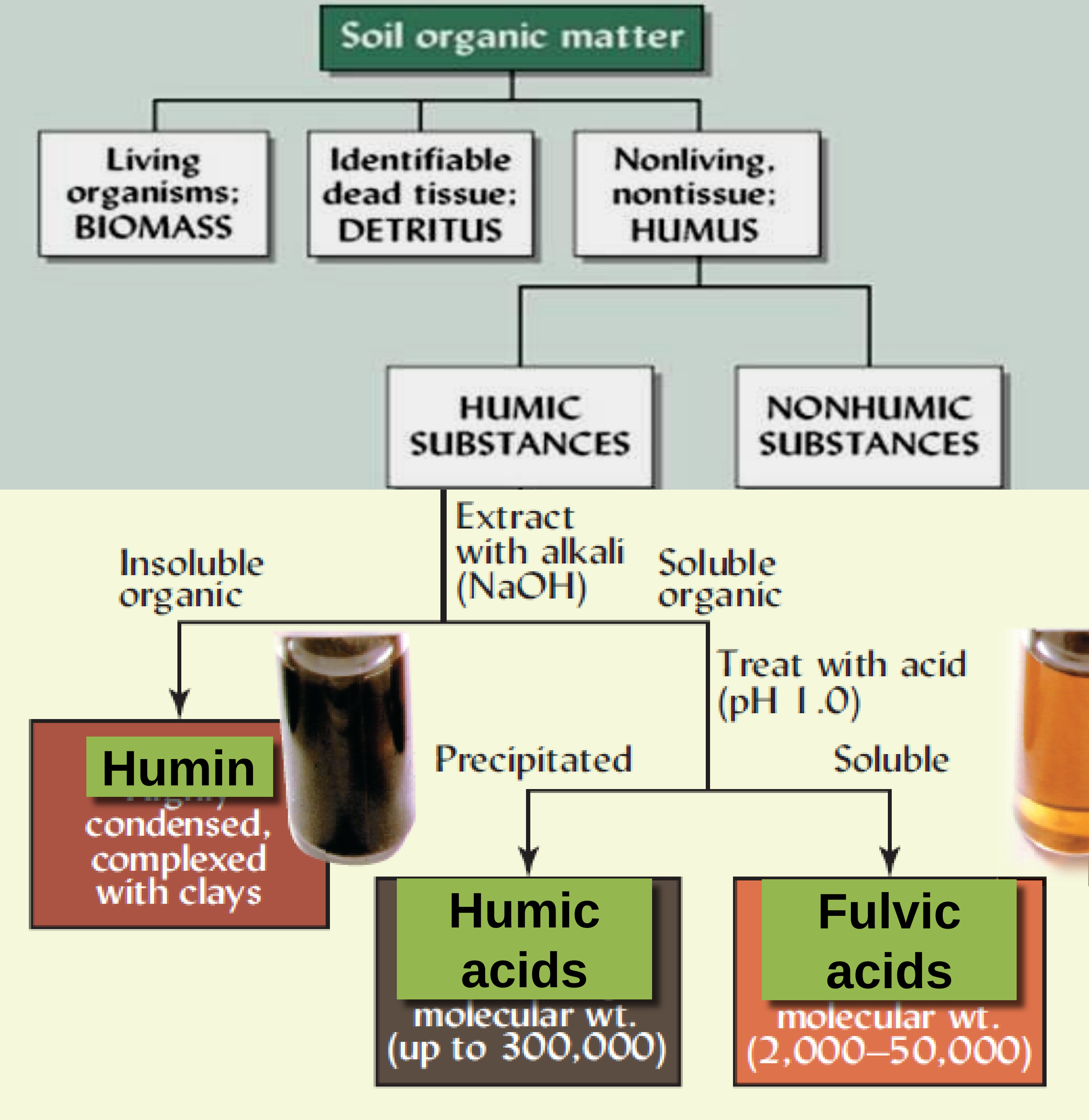
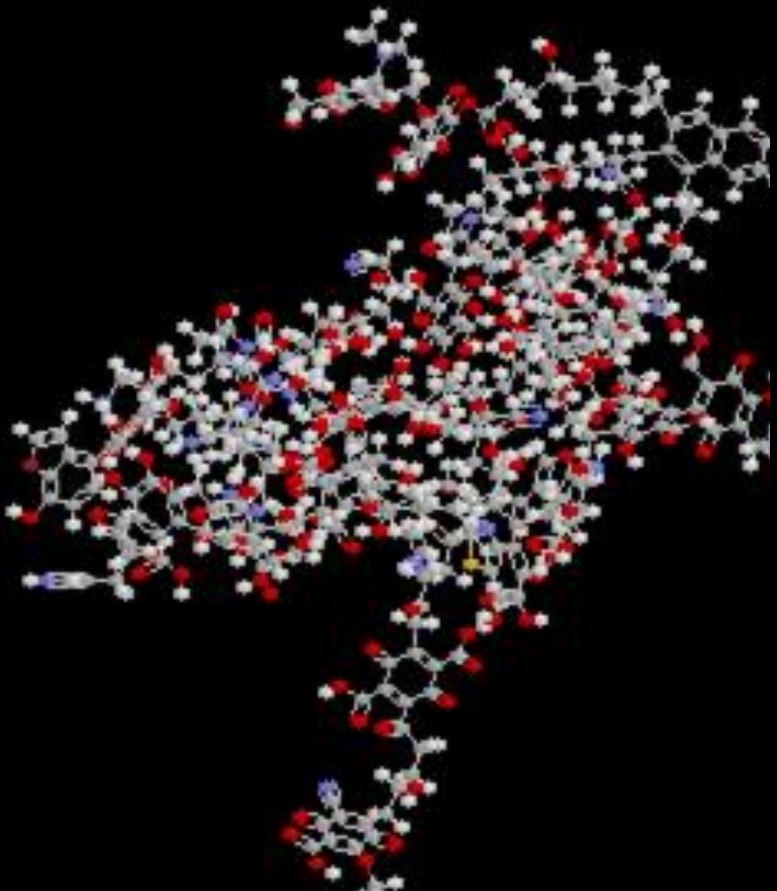


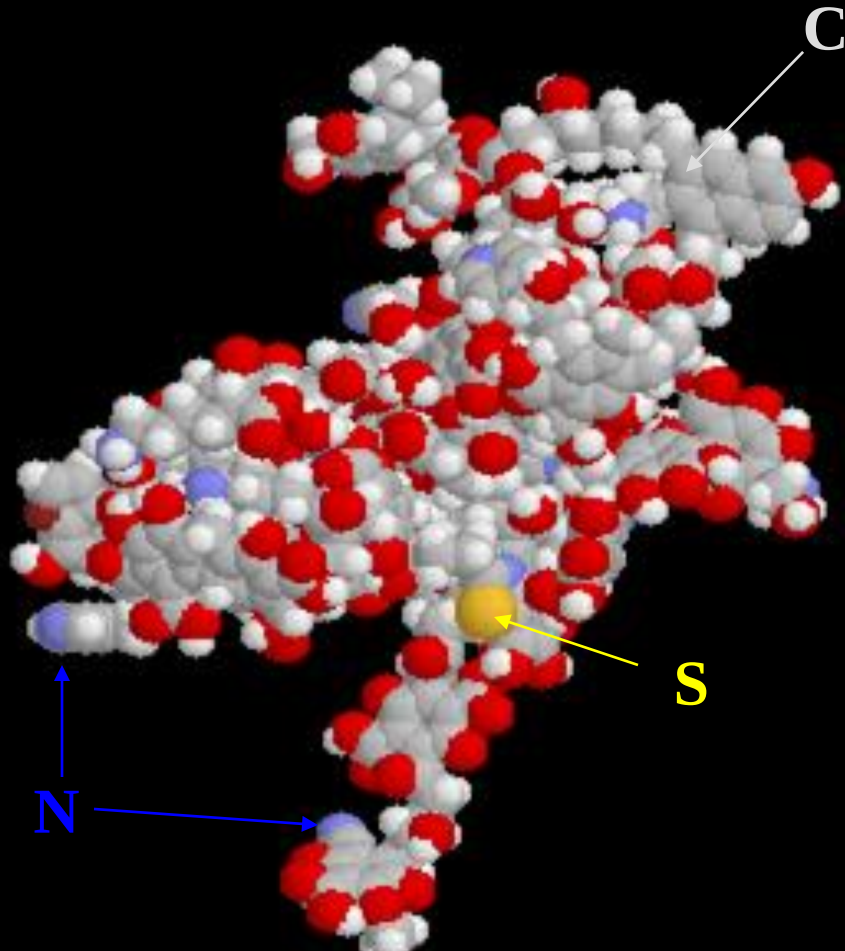
Fig. 12.11 from Brady & Weil, 14th edition,2007

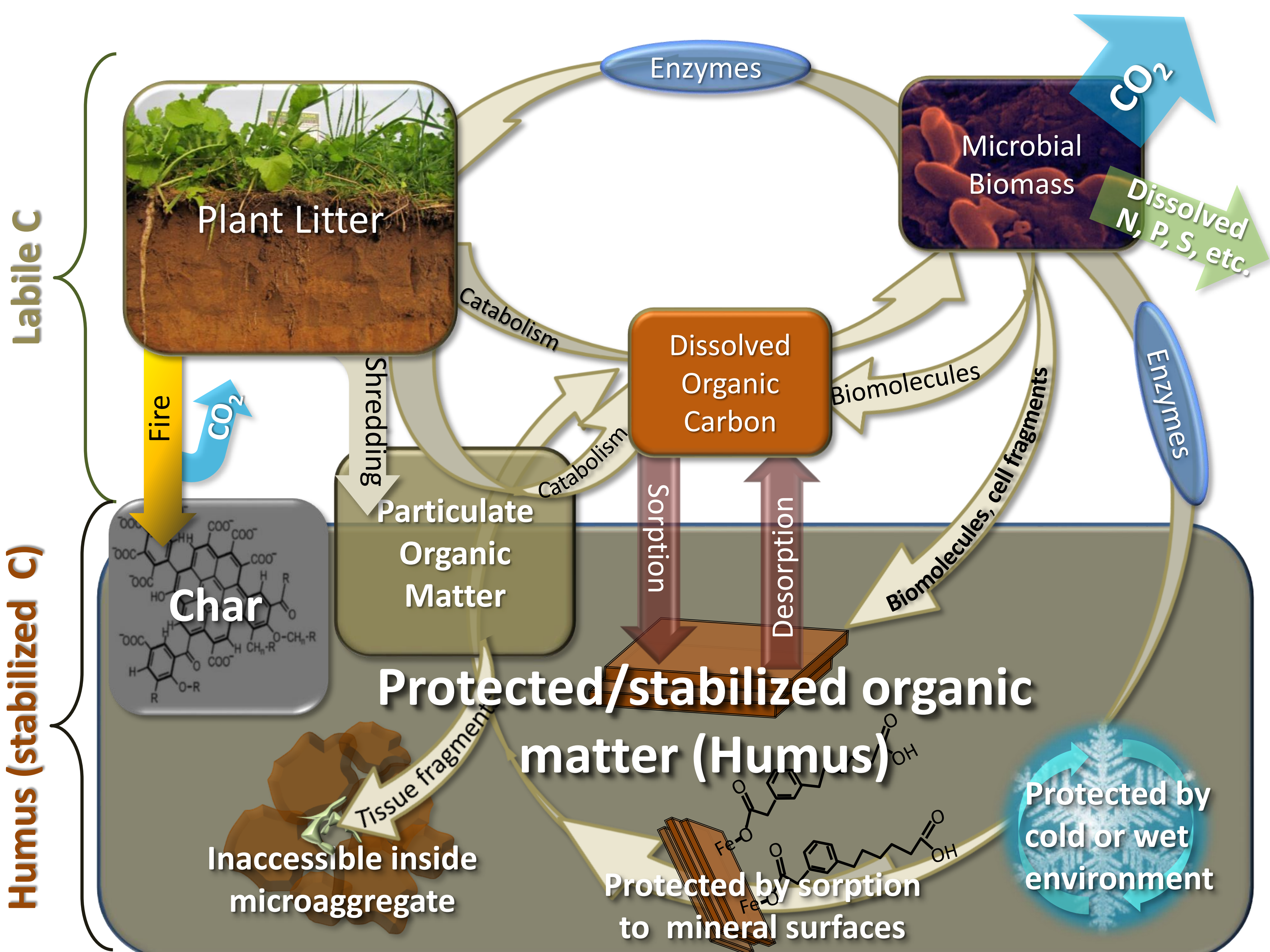
An often-cited model of "humic acid"

with carbohydrate, hexapeptide, and hydrating water molecules.

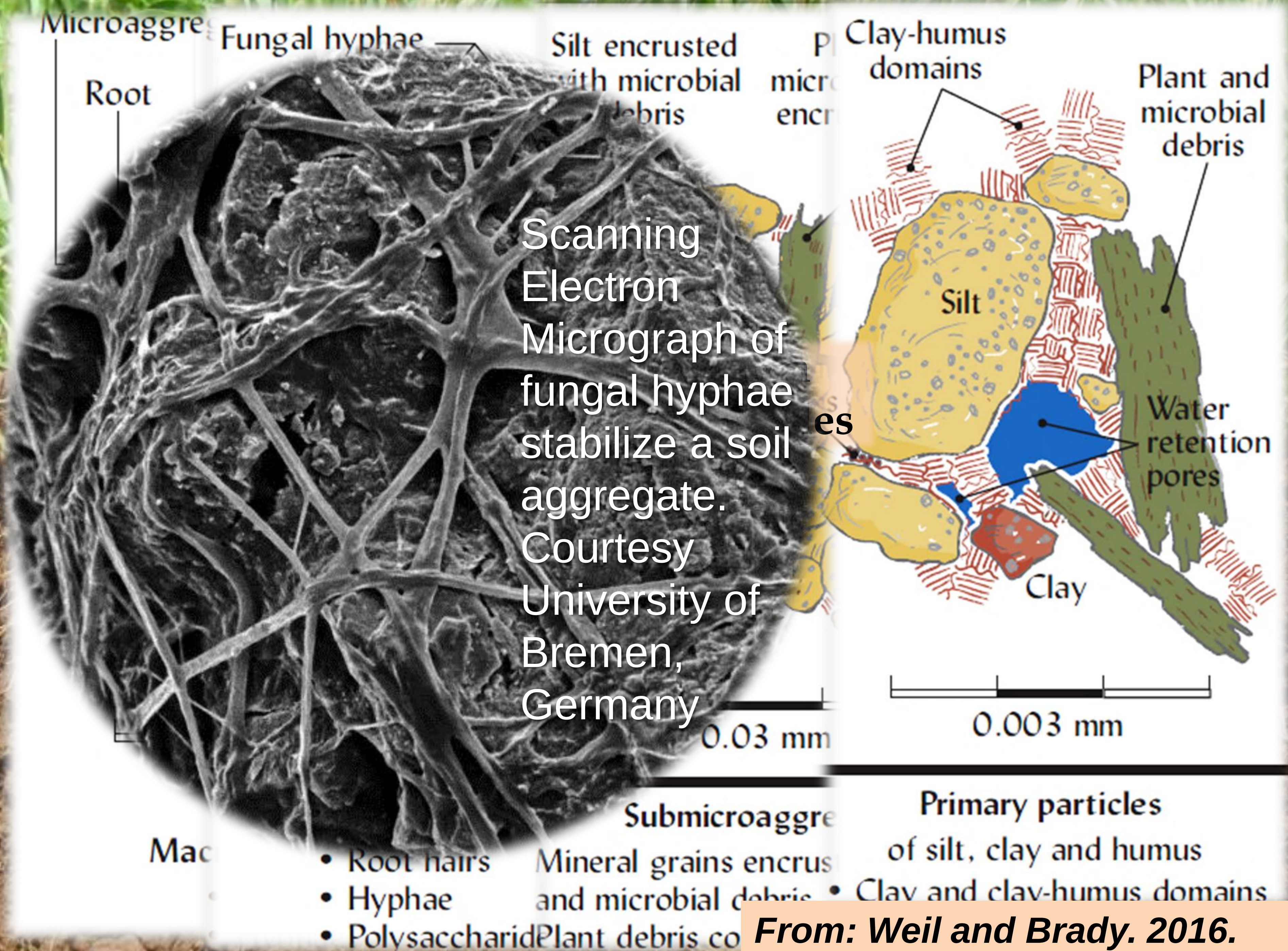
H.-R. Schulten and M. Schnitzer. 1997. Soil Sci.162:115-130.







Labile C
Humus (stabilized C)
Enzymes
Plant Litter
Microbial Biomass
CO2
Dissolved N, P, S, etc.
Catabolism
Dissolved Organic Carbon
Biomolecules
Biomolecules, cell fragments
Enzymes
Fire
CO2
Shredding
Catabolism
Char
Particulate Organic Matter
Sorption
Desorption
Protected/stabilized organic matter (Humus)
Tissue fragments
Inaccessible inside microaggregate
Protected by sorption to mineral surfaces
Protected by cold or wet environment



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

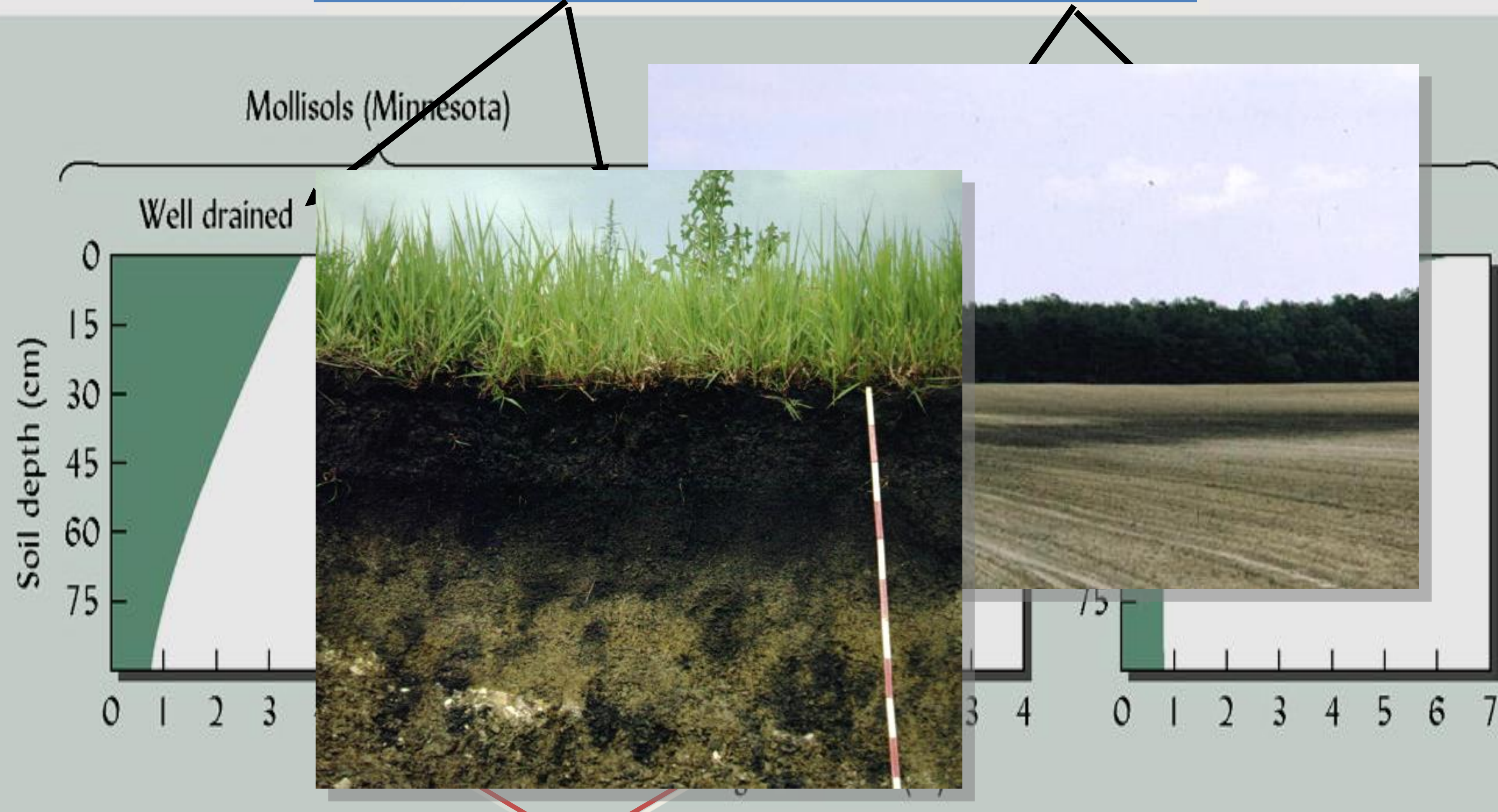
From: Weil and Brady. 2016.

Much soil organic matter is the remains of microbial *rather than* plant cells

Necromass: dead cells of bacteria and fungi adsorbed to particle surfaces

Influence of environment on organic matter levels in soils.

Poorly drained soils accumulate more SOC



If water is equal, grassland soils accumulate more SOC

Strickling, 1975

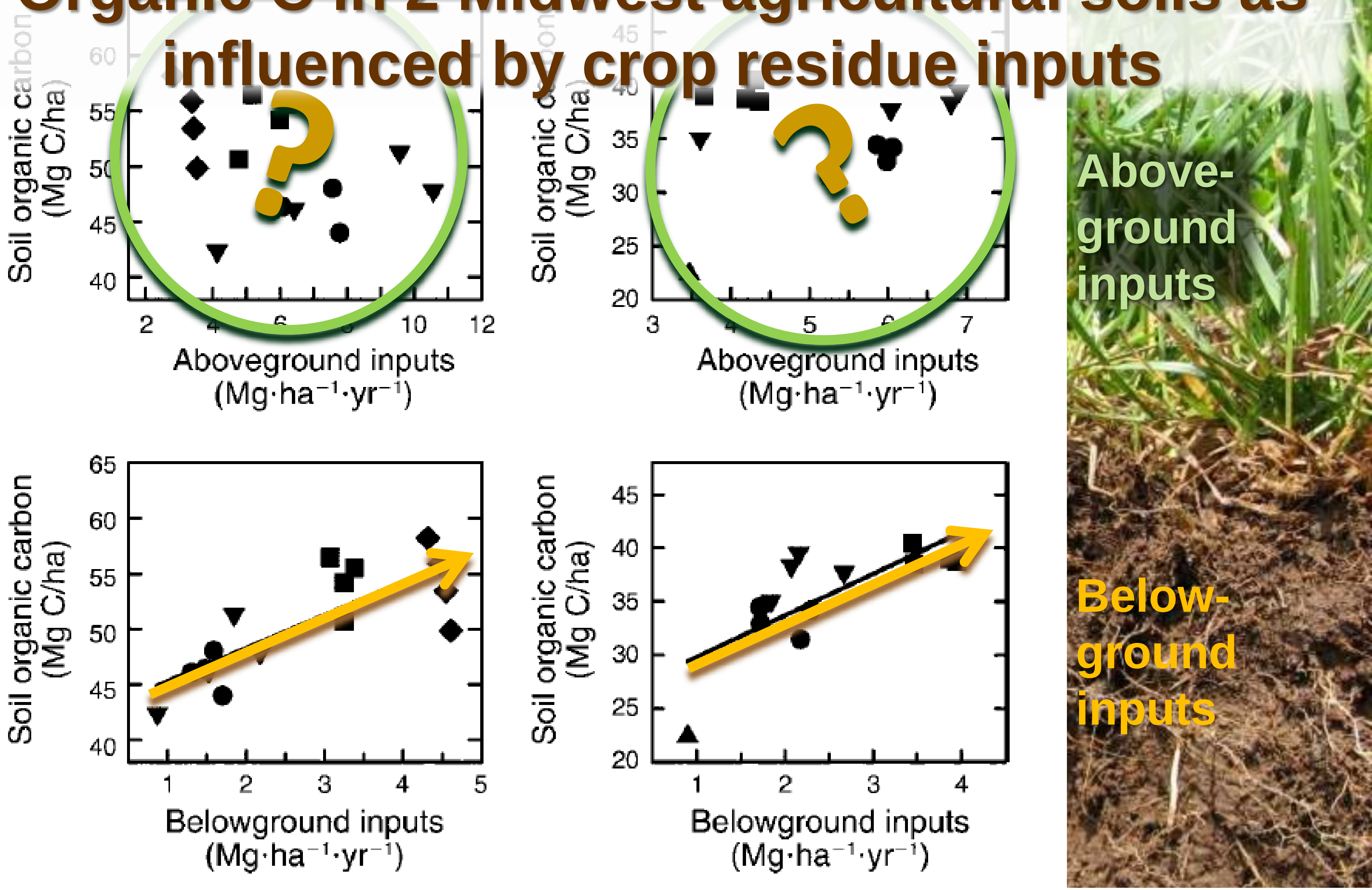
Soils sampled from Ed Strickling’s rotation plots.

After adding water to soils from the rotation plots.

Soils from the rotation plots after drying.

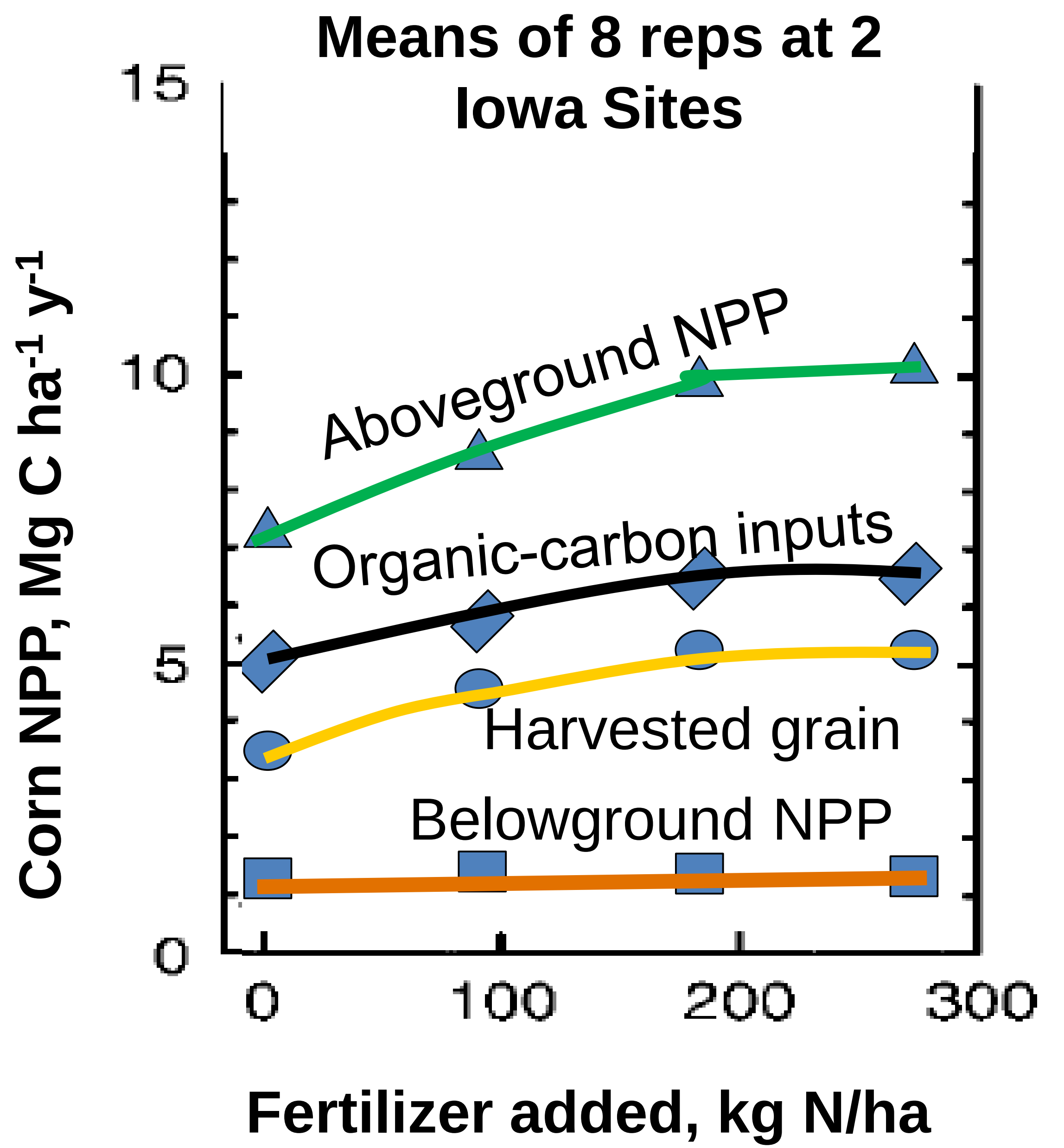

30 years in grass and trees
Conventional tillage with potato/wheat/bean rotation
Aggregate stability or slaking of tilled and untilled soil
Air-dry a few clods of your own soil and try this at home!

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



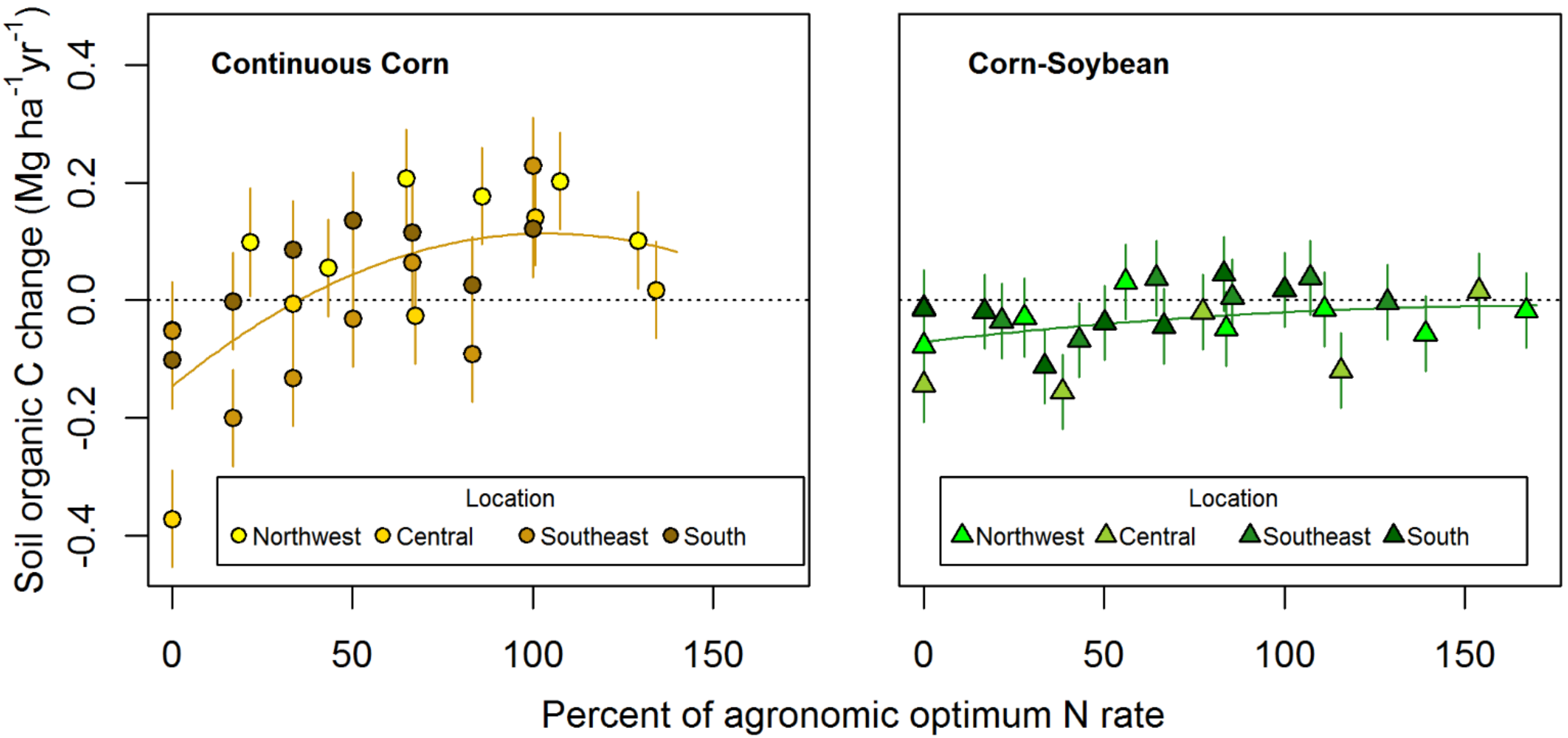
Russell et al.(2009). Nitrogen fertilizer effects on soil carbon balances in Midwestern U.S. agricultural systems. Ecological Applications 19:1102-1113.

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



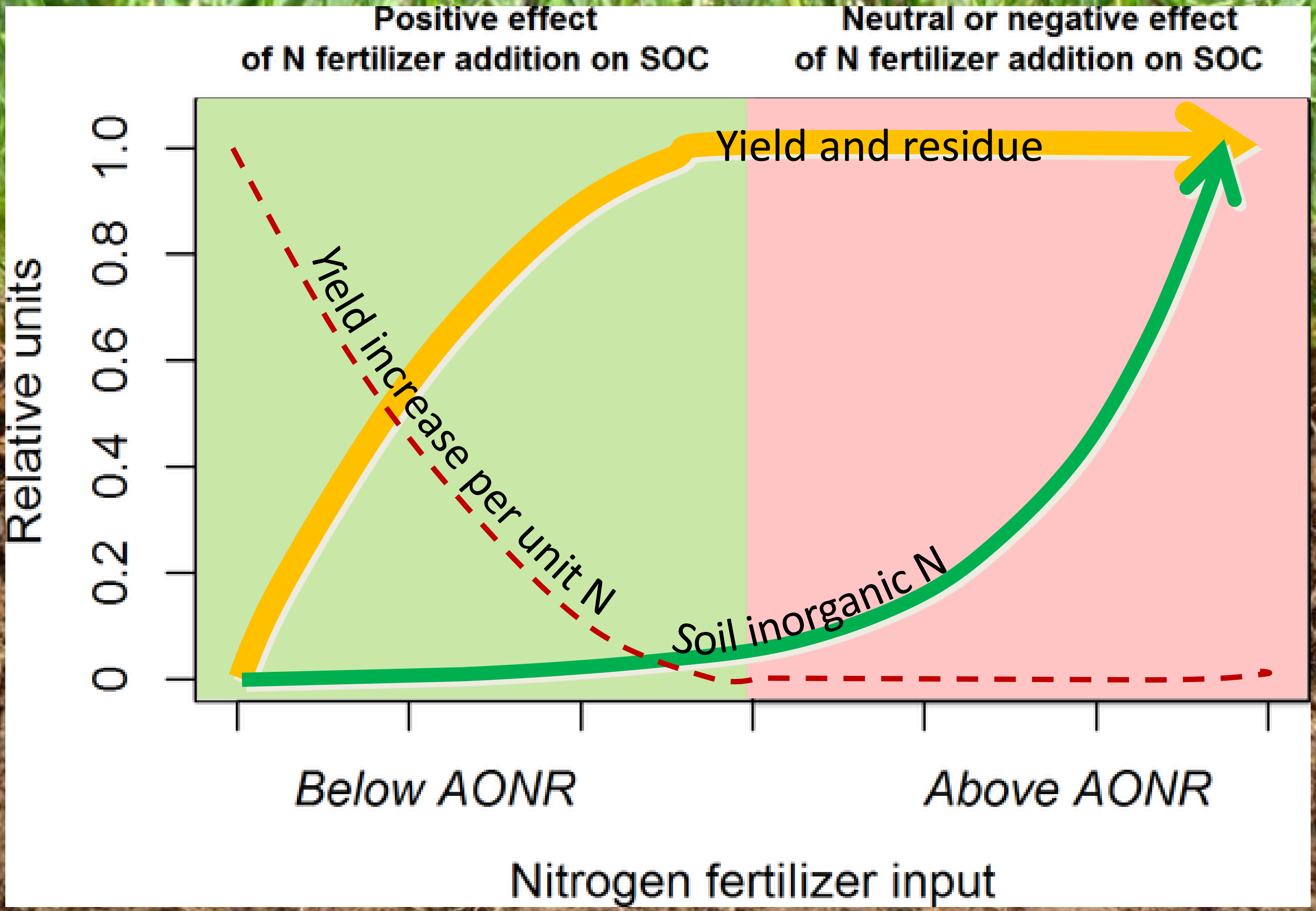
Russell et al.(2009).

Nitrogen inputs are necessary to maintain or increase soil organic carbon in corn-based cropping systems.



Poffenbarger et al. 2017 *PLOS ONE*

Conceptual relationships among N fertilizer, corn yield, residue production, and residual soil inorganic N



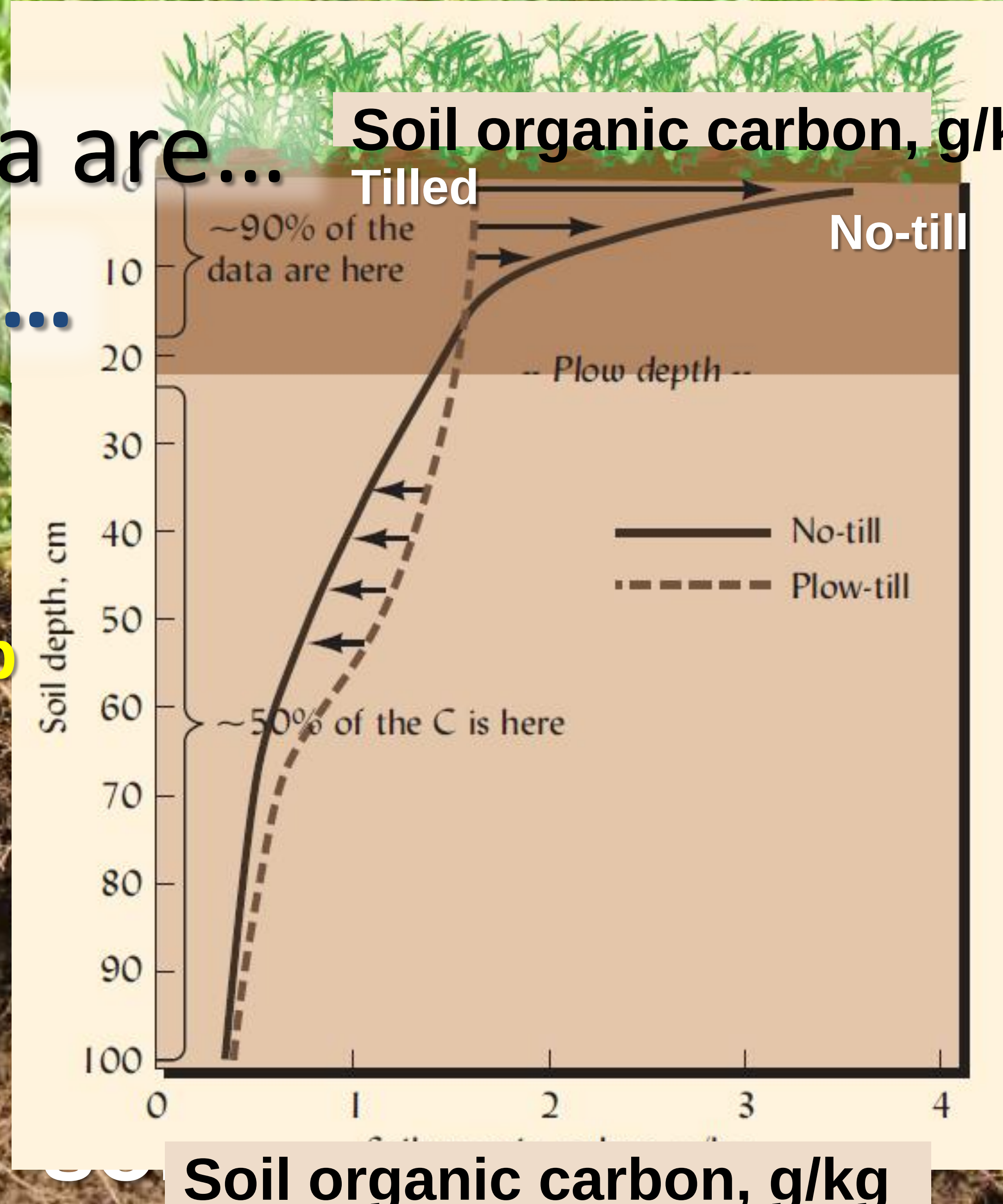
Poffenbarger, et al. (2017) Maximum soil organic carbon storage in Midwest U.S. cropping systems when crops are optimally nitrogen-fertilized. PLOS ONE 12(3): e0172293.

Most of the data are…

from top 20 cm…

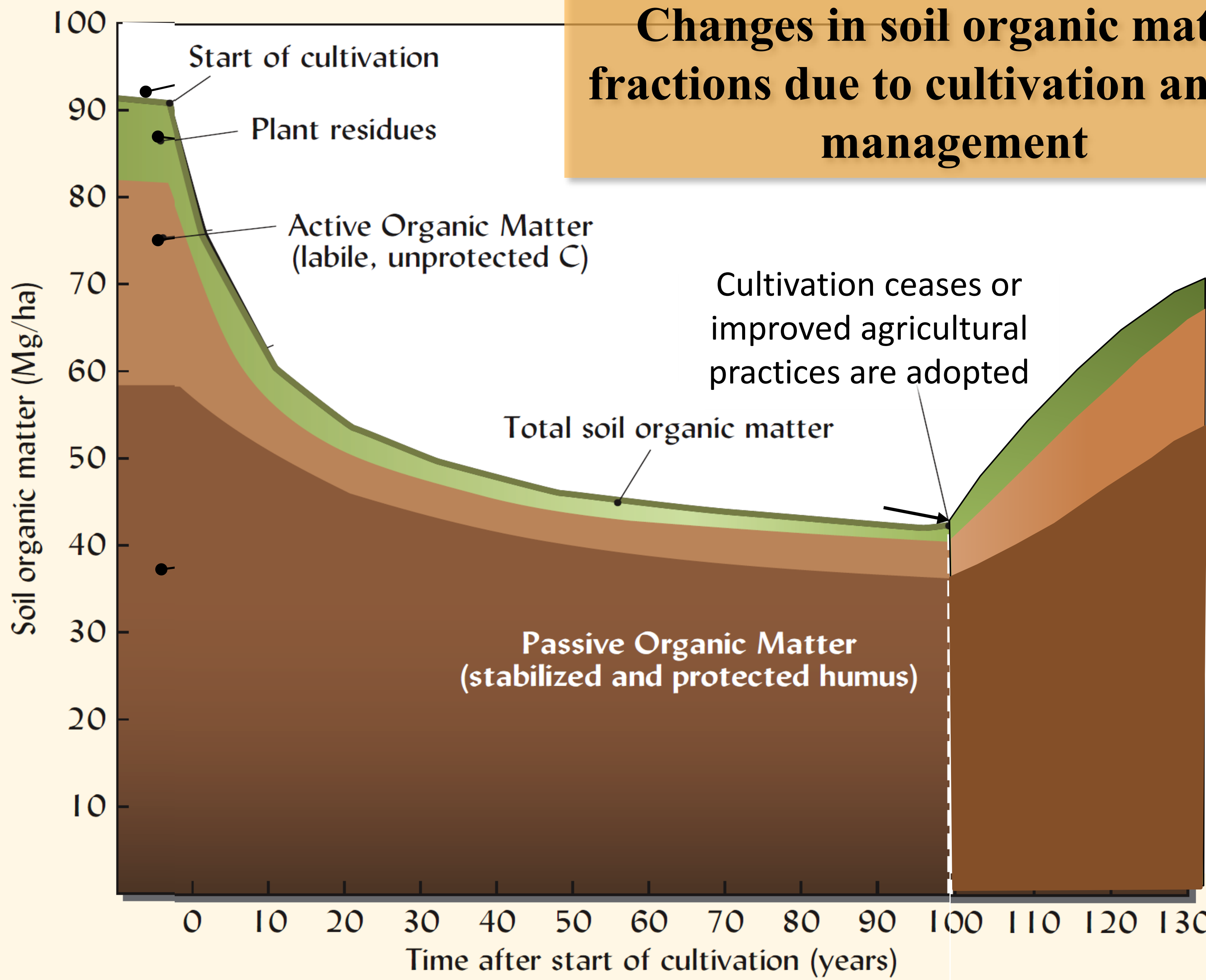
but most of the carbon is deeper

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.

Changes in soil organic matter fractions due to cultivation and soil management

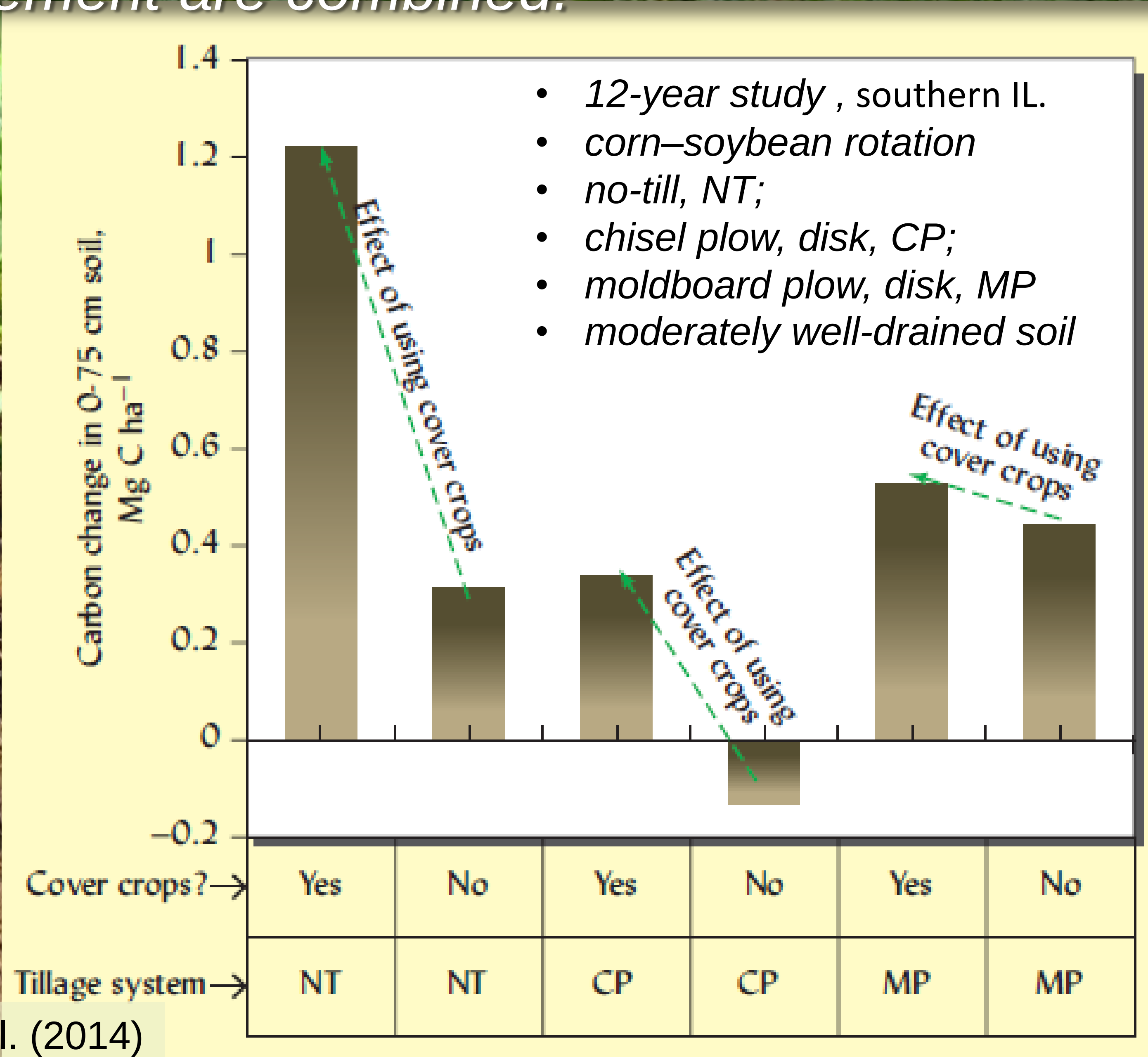


From: Weil & Brady. 2017.*The Nature and Properties of Soils*. 15th edition. Pearson.

How soon am I likely to see an increase in my soil organic matter (carbon) numbers once I start cover cropping?

- Careful **SOC measurements** typically have at least a **10% error** range: e.g. 2.0% SOC (~ 4.0% SOM) could be measured as 1.9% or 2.1% SOC.
- 2.0% SOC= 2% of 2 million lbs/acre or 40,000 lbs /acre (to 7 inches deep).
- This can be measured as accurately as 38,000 to 42,000 lbs/acre.
- To be detected, SOC would have to increase by > 4,000 lbs/acre.
- If 75% of added organic C in residues is respired within a year, 4,00/0.75 = 16,000 lbs of residue C are needed for detectable increase in SOC.
- At about 40% C, **40,000 lbs of dry matter additions are needed.**
- This could be accomplished with about **5 years of really heavy (8,000 lb/acre DM) cover crops**,
- But it would take **40 years of the typical 1,000 lbs/acre cover crops** often reported on farms in the Corn Belt.

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



data from Olson et al. (2014)

Functions

Active Organic Matter

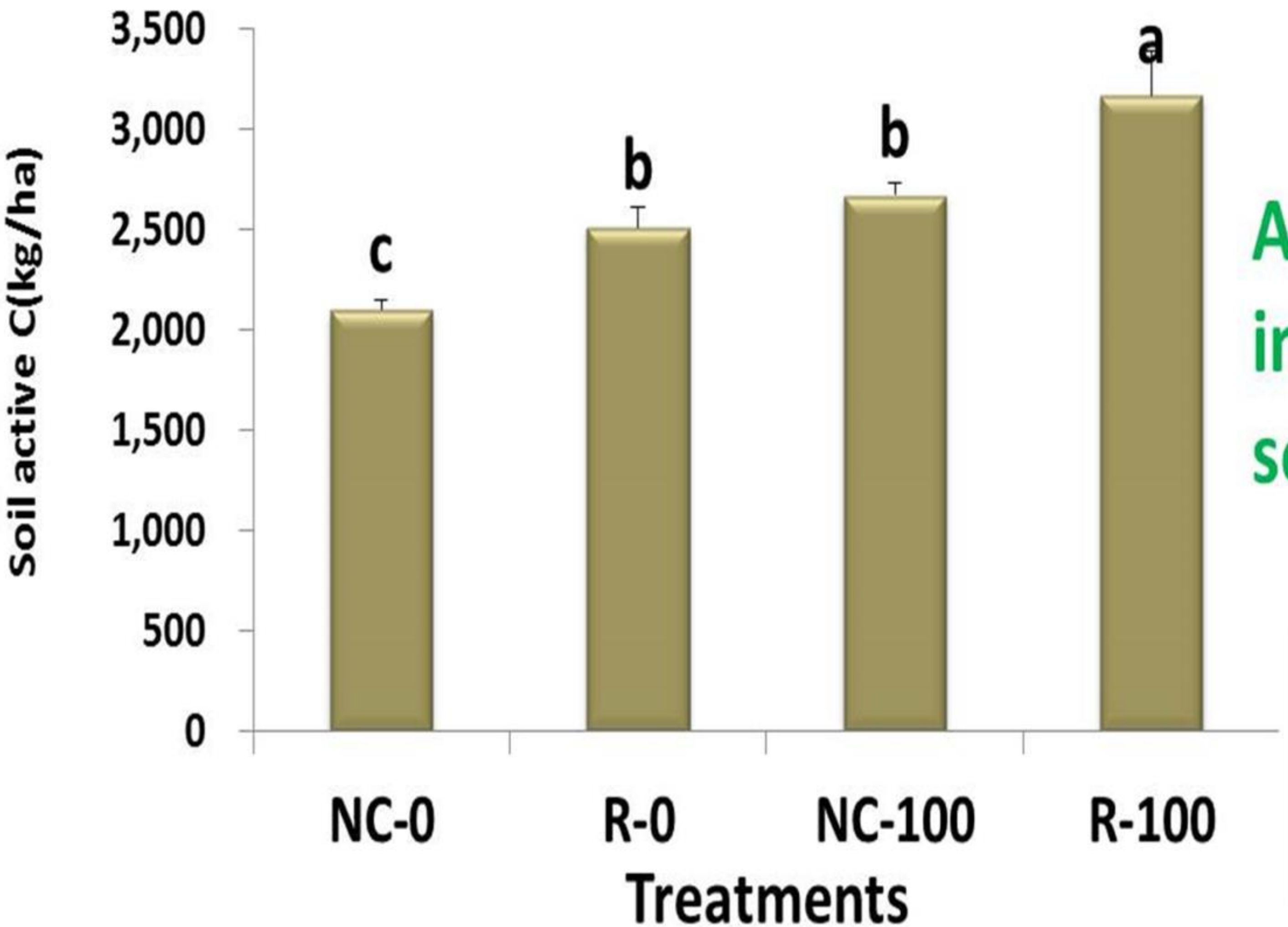
- **Feeds the Biomass Soil Food Web**
- **Releases Nitrogen, Sulfur, Phosphorus, etc.**
- **Promotes and Stabilizes Aggregate Structure**

Unprotected Labile Organic Matter Components

Active Organic Matter (POXC ?)

- Easily Oxidized Organic C (e.g. POXC)
- Particulate Organic Matter (POM)
- Light Fraction Organic Matter
- Soluble Carbon
- Fungal sugar-proteins and bacterial polysaccharides

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.


THANK YOU!