Soil Organic Matter and Nutrient Recycling With Cover Crops and Manure

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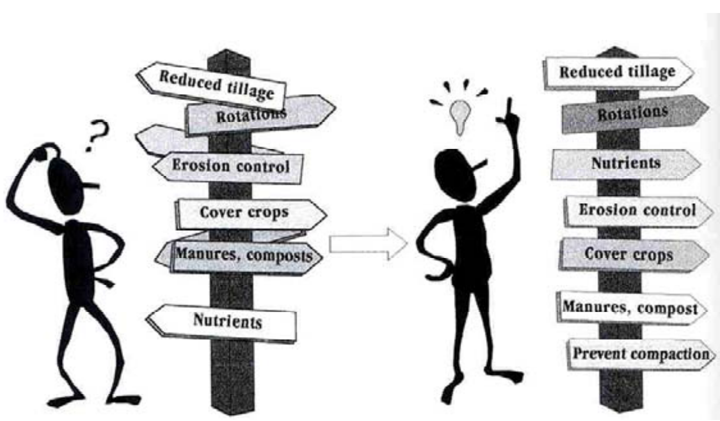
& Dr. Rafiq Islam



Nitrogen Losses in Corn

Corn has a high N requirement and is relatively inefficient, recovering only 30-70% of an annual fertilizer N input (Sims et al., 1995).

Most of the NO3-N leaching occurs during the fall and early spring months when the soil is fallow in the typical corn-soybean rotation of the U.S. Midwest (Owens et al, 1995).

No-till in Ohio

Wheat -80% No-till
Soybeans – 70% No-till
Corn – Less than 10%

1)Why is adoption of No-till Corn so much lower?

2)What is missing?

Making No-till Corn Work!

1)Why is adoption of No-till Corn so much lower? Expect 10-20% yield decrease.

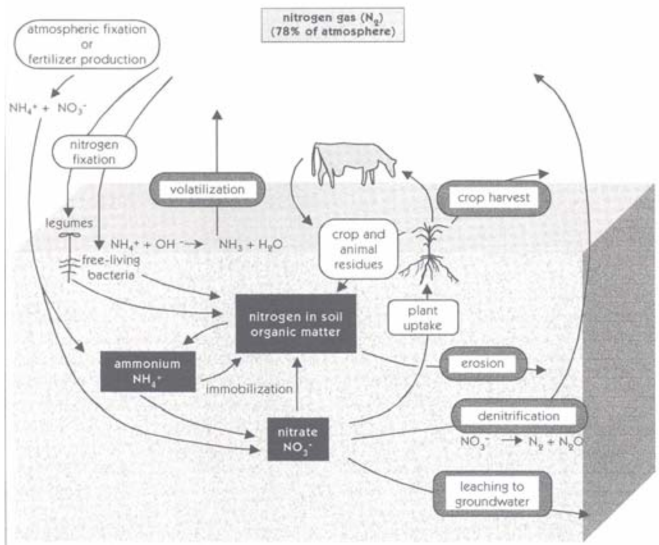
2)What is missing? Takes 7-9 years continuous no-till before soil recovers. Takes 2-4 years if add a continuous cover crop?

Soil Nitrogen Storage

Inorganic Forms: Nitrates ($N0_3$-)
Ammonium Ion(NH_4+) Very Mobile

Organic Forms: Proteins
Slow release
Stored in microbes, plants, crop residues, and soil organic matter.

Nitrogen Recycling



Source: Better Soils for Better Crops

Compare Long-term No-till to Conventional Tilled Soils

Conventional Soils	Long-term No-till Soils
1-3% organic matter	4-6% Organic matter
No residue on surface	High residue on surface
Plow Layer 8-10"	Macropores throughout soil profile
Microbial life dominated by bacteria	Microbial life composed of fungus and bacteria

NT SOM accumulation under different climate

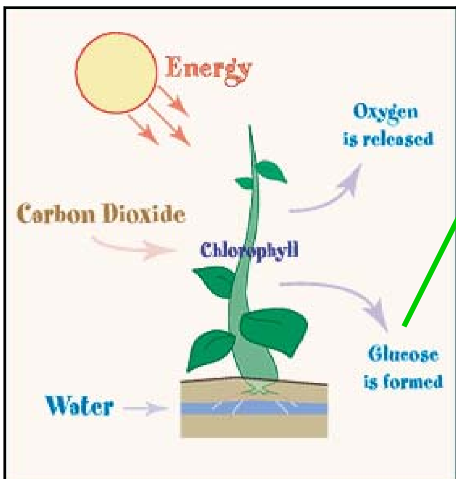
Temperate region (moderate cold): Maryland, USA
Total organic C = 280 lbs/ac/yr

Temperate region (moderate cold): Southern Ohio, USA
Total organic C = 600 lbs/ac/yr

Temperate region (cold): Northern Ohio, USA
Total organic C = 750 lbs/ac/yr

Subtropical/tropical region (hot/humid): Bangladesh
Total organic C = 88 to 150 lbs/ac/yr

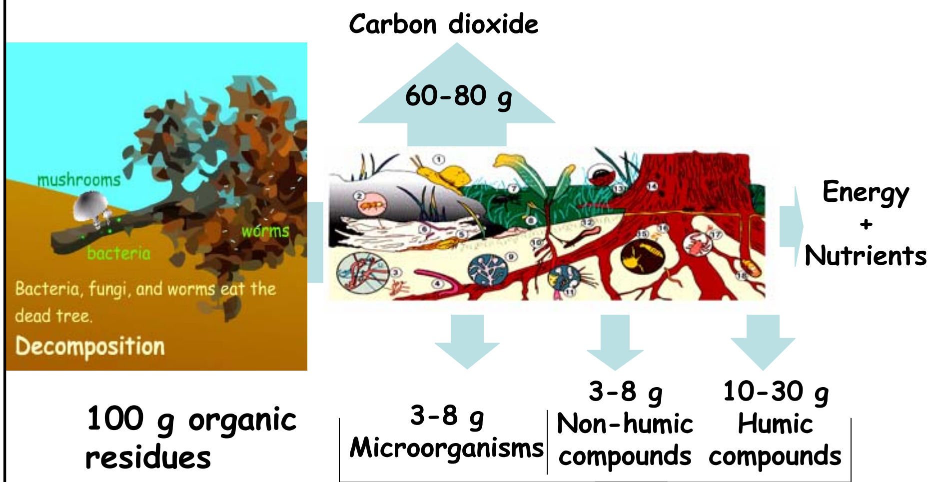
Ref. Islam (1998 to 2005)

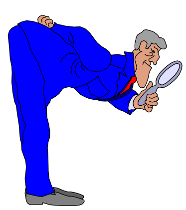


Glucose + Nutrients

Structural compounds
- Carbohydrates
- Amino acids/proteins
- Lipids (fat)
- Lignin

Non-structural compounds
- Enzymes
- Hormones
- Phenolics
- Vitamins





SOM formula

$C_{349}H_{40}N_{26}O_{173}PS$

Schulten and Schnitzer (1997)

Example: SOM accumulation changing from CT to NT system

In NT system, 40% residues left per year which is equivalent to 1.6 ton/ac/yr. If decomposition of crop residues is 0.3 (Hann 1977), then soil C content will be

> (1.6 *0.3)*(58/100) -> 0.28 ton/ac/yr

If **r** (0.99) is the part of soil C that left in the 2nd yr after the decomposition of soil C formed in the 1st yr, then the amount of soil C after 10 yr will be

$$Y = \text{soil } C * (1 - r^n)/(1 - r)$$

$$Y = 0.28*(1- 0.99^{10})/(1- 0.99) > 2.68 \text{ ton/ac}$$

Conventional agriculture is related to **soil**, air and water quality degradation

1.2 billion ton CO_2/y i.e. 570 M ton SOM loss

A 2% loss of SOM= 2200 lbs N/ac

Loss of SOM as CO_2

Value of Soil Organic Matter

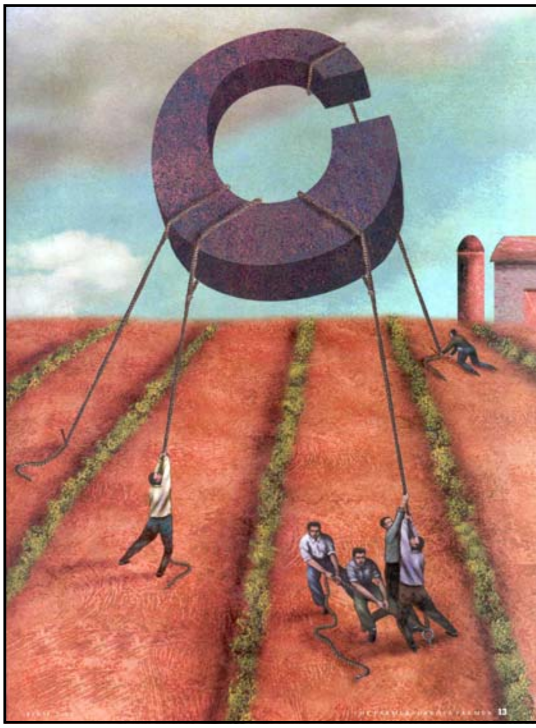
Assumptions: 2,000,000 pounds soil in top 6 inches
1% organic matter = 20,000#

Nutrients:

Nitrogen:	1100# * $.50/#N	=	$550
Phosphorous:	116# * $.40/#P	=	$ 46
Potassium:	105# * $.25/#K	=	$ 26
Sulfur:	145# * $.26/#S	=	$ 38
Carbon: 12,000# or 6 ton * $4/Ton		=	$ 24

Value of 1% SOM Nutrients/Acre = $684

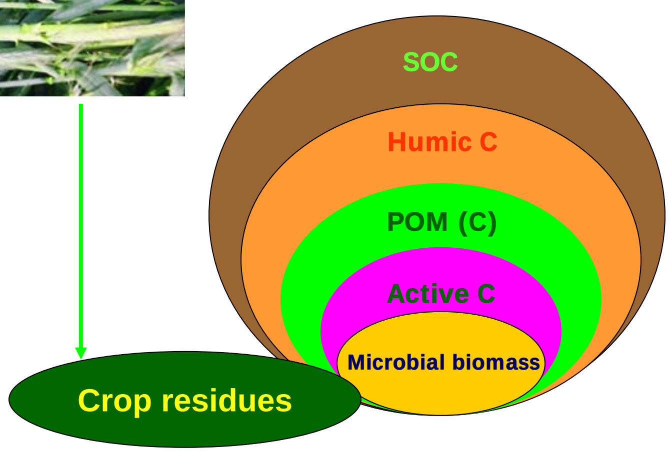
Jim Kinsella/Terry Taylor (2006)



Holding SOM (C) by no-till and crop rotation

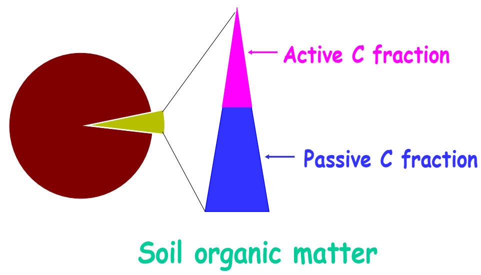
All the atmospheric CO_2 ~ only 40% of the soil's C holding capacity (Wallace 1984)

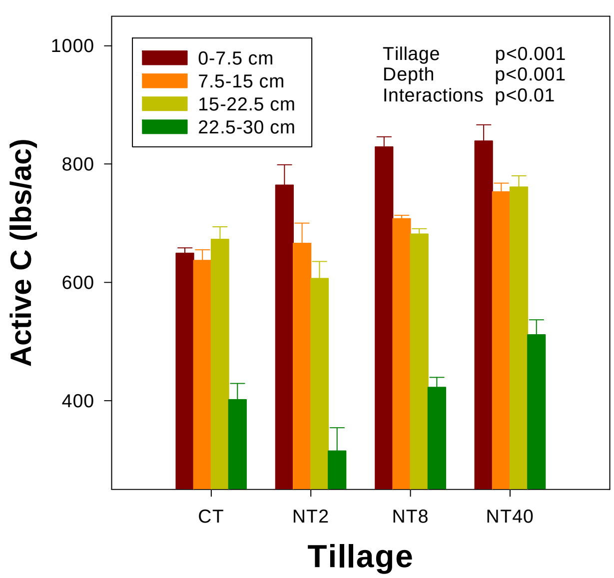
Response of SOM fractions (Domino effect)

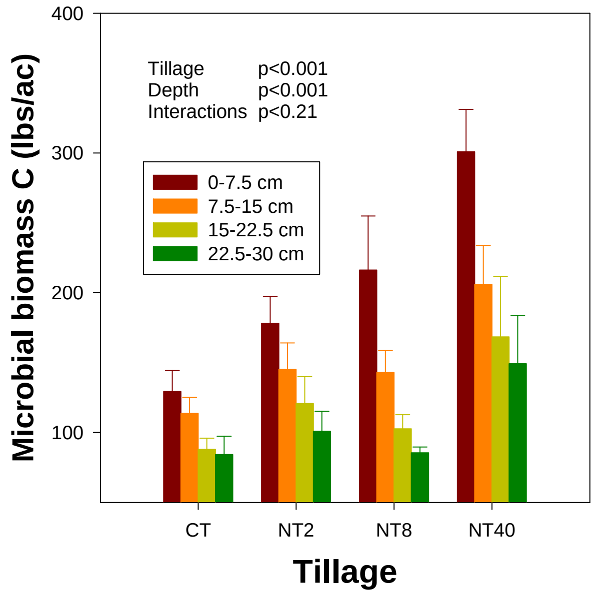


Most important to soil quality is the active SOM fraction (10 to 35%) which is composed of partially decomposed plant and animal residues, microbial biomass and metabolites.

Most of what's left is the passive SOM fraction which is resistant to microbial decomposition.



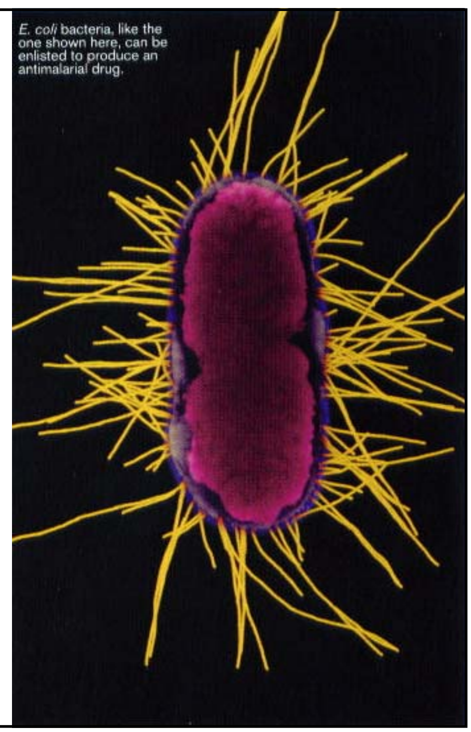




In CT system

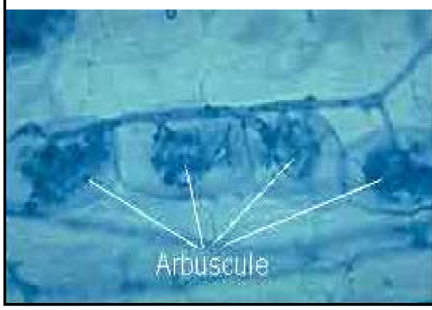
Bacteria-dominated food web

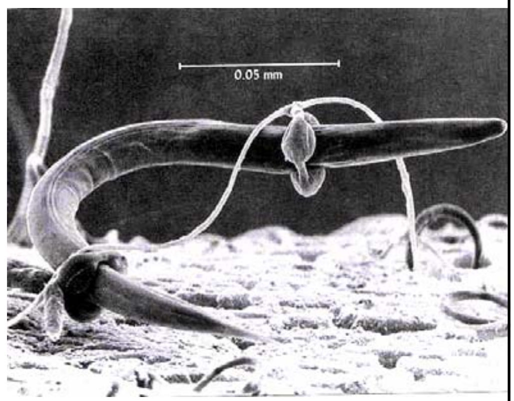
(Bacteria have 20-30% C-use efficiency)



In NT system

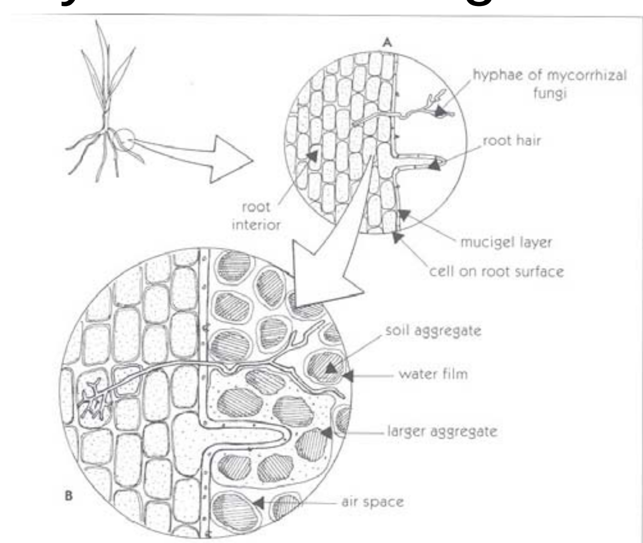
Fungi-dominated food web



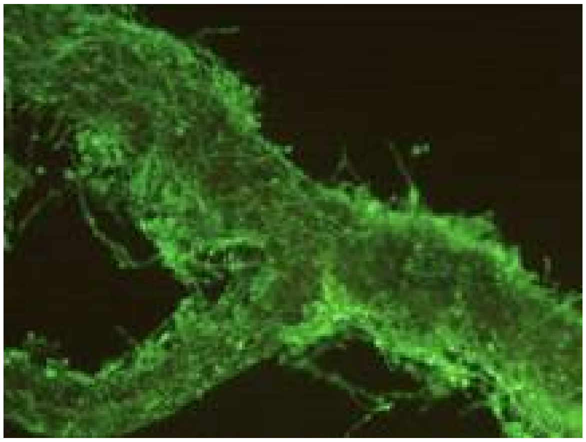


Nematode and fungal relationship
(Fungi has 40-55% C-use efficiency)

Mycorrhizal Fungus

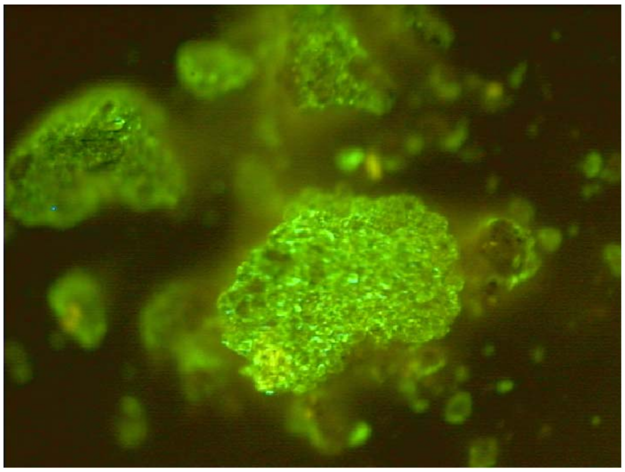


Source: Better Soils for Better Crops



Sticky substance, glomalin, surrounding root heavily infected with mycorrhizal fungi.

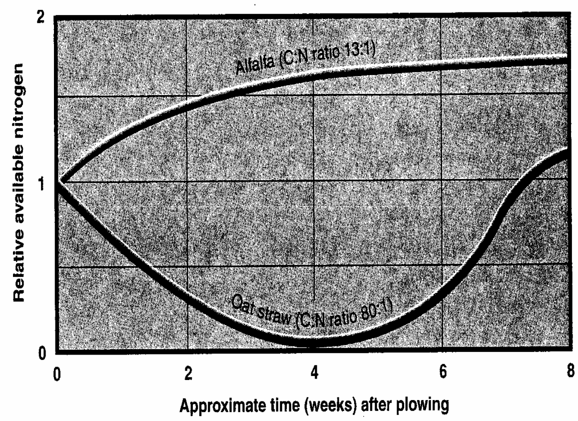
Photo by Sara Wright.



Sticky substance, glomalin, surrounding soil aggregates.

Photo by Sara Wright.

FIGURE 5-9 The carbon–nitrogen (C:N) ratio of young alfalfa and mature oat straw affects available nitrogen in the soil. Immediately after plowing, alfalfa releases nitrogen to the soil. Plowing oat straw decreases available nitrogen for about 4 weeks, at which time the microbial population subsides, releasing nitrogen.

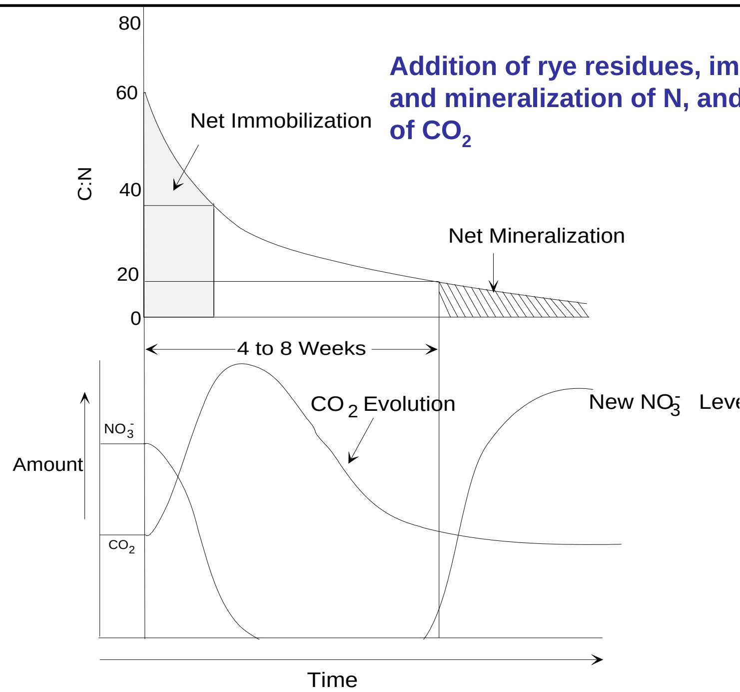


C:N Ratio of Organic Organic Matter

As a rule of thumb:
At C:N >20:1, NH_4^+ is immobilized (tied up)
At C:N < 20:1, NH_4^+ is mineralized (released)

Organic matter plus microbe N → (C:N < 20:1) → NH_4^+

NH_4^+ → (C:N >20:1) → Organic matter plus microbe N



Addition of rye residues, immobilization and mineralization of N, and evolution of CO_2

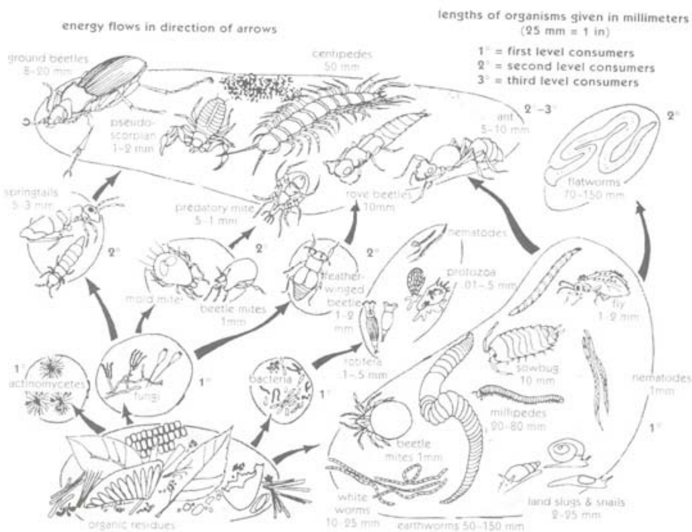
Carbon to Nitrogen ratio of Microbes
Bacteria: 5:1 (20% Nitrogen)
Fungus: 10:1 (10%Nitrogen)

More nitrogen less carbon in Bacteria than in Fungus

Reproduction Phase
Bacteria: 30 minutes Fungus: ??
Protozoa: 6 hours Nematodes: 2 years

Where are the microbes located? 10,000 more located next to the roots.

Soil Fauna



Source: Better Soils for Better Crops

Annual Ryegrass Nitrogen Uptake

ARG had 5-5.3% N in the tissue.

With 4-4.5 tons of biomass (above and below ground), equals 400-450# of N being recycled. Maximum values: 700 pounds/A.

Cereal ryegrass has 4-4.5% N in tissue or 350 to 400# of N.

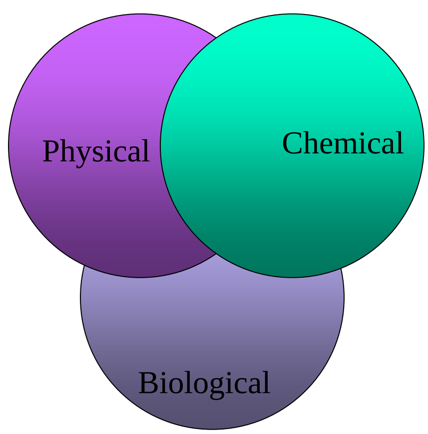
2005 Demonstration results in Southern Illinois

Tillage/cover crop	Yield bu./A.
Conventional tillage	82
No cover crop no-till	124
Ryegrass 1 year no-till	137
Ryegrass 6 years –claypan	165
Ryegrass 6 years no claypan	215

Rain fall …. May- Sept. 2.3”

Soil Health Indicators

- **Bulk density**
- **Penetration resistance**
- **Aggregate stability**
- **Water infiltration rate**
- **Water holding capacity**
- **Pore size distribution**



- **% OM**
- **“Active” C, N in OM**
- **Cation exchange capacity**
- **N, P, K**
- **Micronutrients**
- **[Toxins, pollutants]**
- **[Glomalin]**

- **Soil disease suppressive capacity**
- **Beneficial and pathogenic nematodes, [other pathogens]**
- **N mineralization rate (PMN)**

- **Decomposition rate**
- **microbial biomass**
- **Respiration rate**
- **Earthworm counts**
- **Genetic diversity**

Making No-till Corn Work!

Nitrogen Changes in the Soil with No-till

1) Less Nutrient release from crop residues.
2) More microbial biomass
3) Building SOM (Soil Bank of N)
4) Initially Soil Compaction (Denitrification) moving to aerated soils (less denitrification) with cover crops and no-till.

Water Quality Benefits from Winter Cover Crops

Reduces nutrient and pesticide runoff by 50% or more.

Decreases Soil Erosion by 90%

Reduces Sediment Loading by 75%

Reduces Pathogen Loading by 60%

May decrease flooding potential by increasing infiltration.

Cost Effectiveness of BMP'S

BMP	$/Ton of Sediment	BMP	$/Ton of Sediment
Cover Crops	$1.99	Diversions	$18.10
No-till	$2.99	Sediment Retention	$50.21
Permanent Cover	$6.95	Average Cost	$8.71
Wind break	$12.10	CRP Program	$22.95
Sod water way	$13.50		

Summary Soil Organic Matter and Nutrient Recycling :

*SOM is critical to No-till
*Cover Crops supply food and form macropores for good air/water exchange.
*SOM increases Microbial Life
*Microbial Life recycles nutrients
*C sequestration **(C-N)**
Increased Soil life/diversity
Increased Soil/water/air quality
Increased Farmer Yields and Profits