OHIO STATE UNIVERSITY EXTENSION

ECO Farming in the 21st Century Recycling Soil Nutrients

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Healthy Soil versus Sick Soil

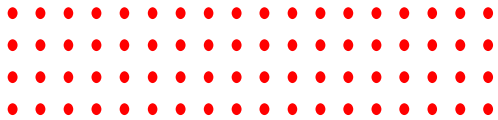
Healthy soils have these things in common:

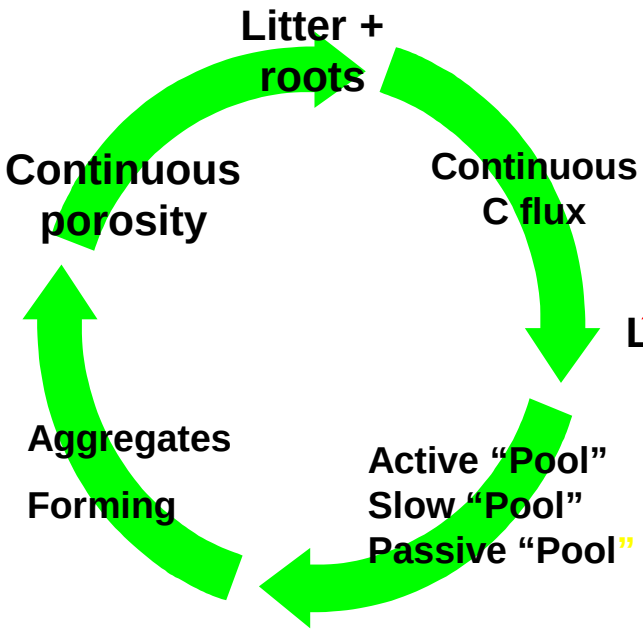
1) Live plants growing year round to absorb energy.
2) Healthy microbial populations. Microbes process 90% of the energy in soils.

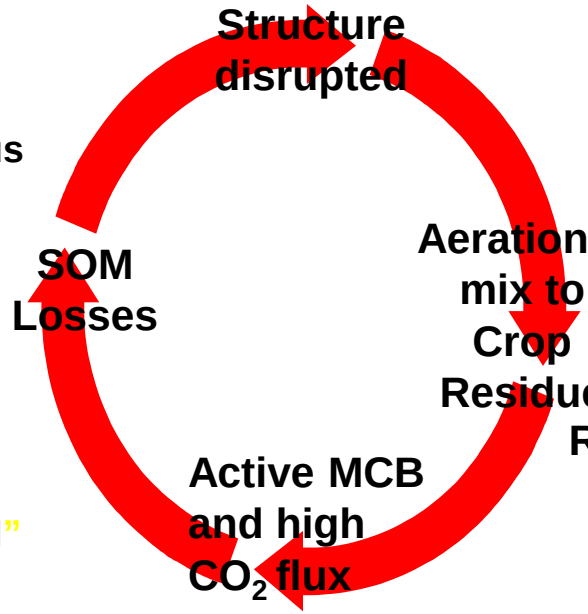
Sick soils have these things in common:

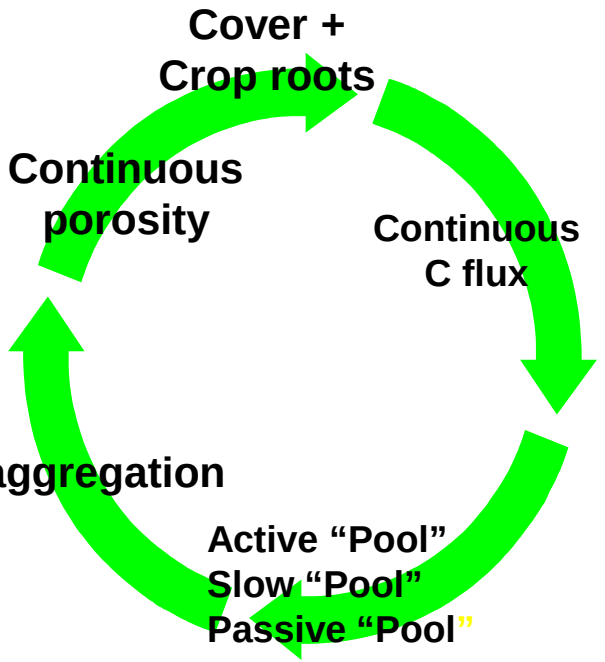
1) Compacted soils, high bulk density, poor water infiltration, lower water holding capacity and bare soils.
2) Low SOM and Nutrient Imbalances

Basic differences among land systems









ECO Farming

- **E**cological Farming with **E**ternal No-till
- **C**ontinuous Living Cover
- **O**ther Best Management Practices

- Economical for Farmer
- Ecologically Viable
- Environmentally Sound

ECO Farming Mimics Natural Cycles!

Soil Energy Comes from Plants

Conventional Tillage

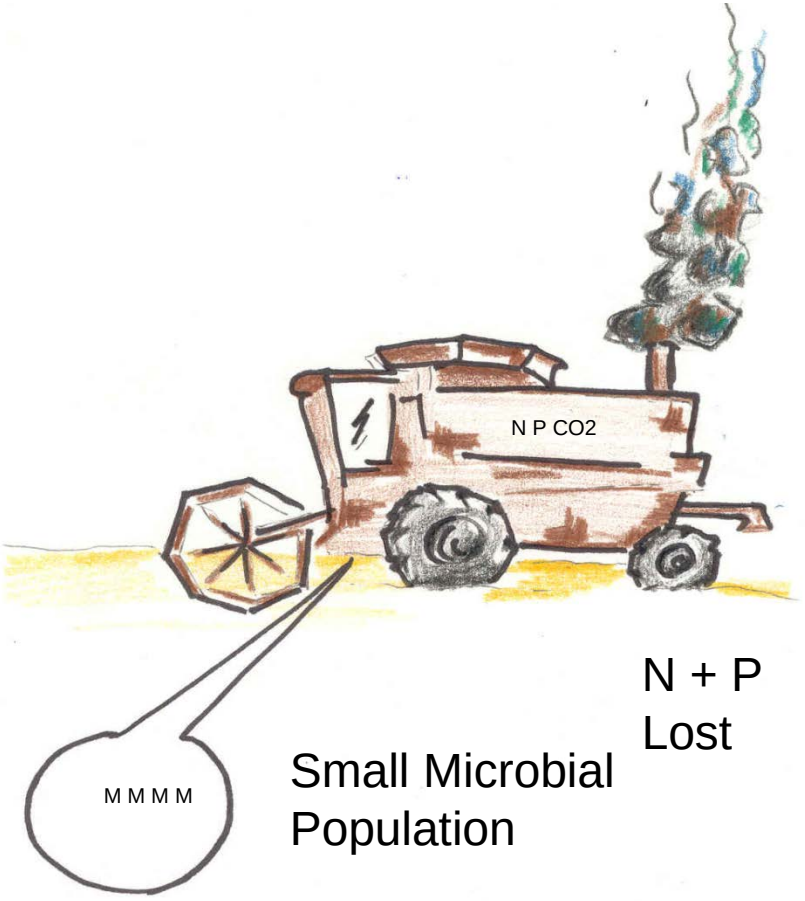
Plants 4 months out of 12 months
Fuel & Energy = 1/3 of time

No-till +Cover Crops
“ECO Farming”

Plants 12 months out of the year
Fuel & Energy = 100% of time

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Soil Microbes Harvest & Recycle Nutrients

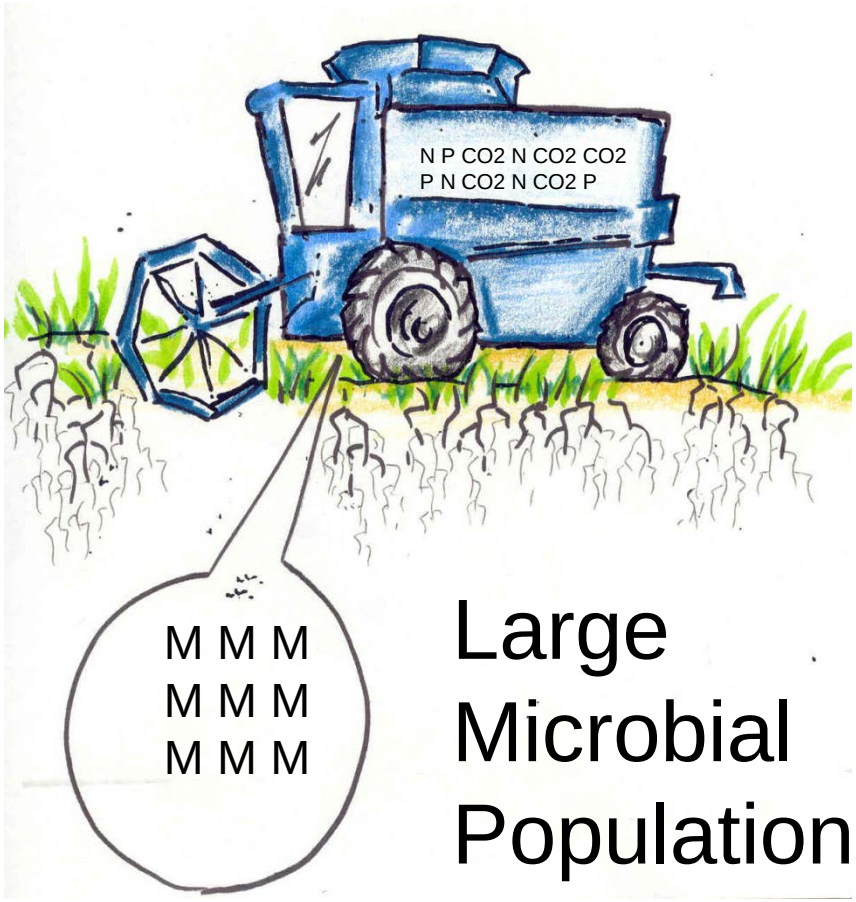


N + P
Lost

Small Microbial
Population

Conventional tillage

ECO Farming

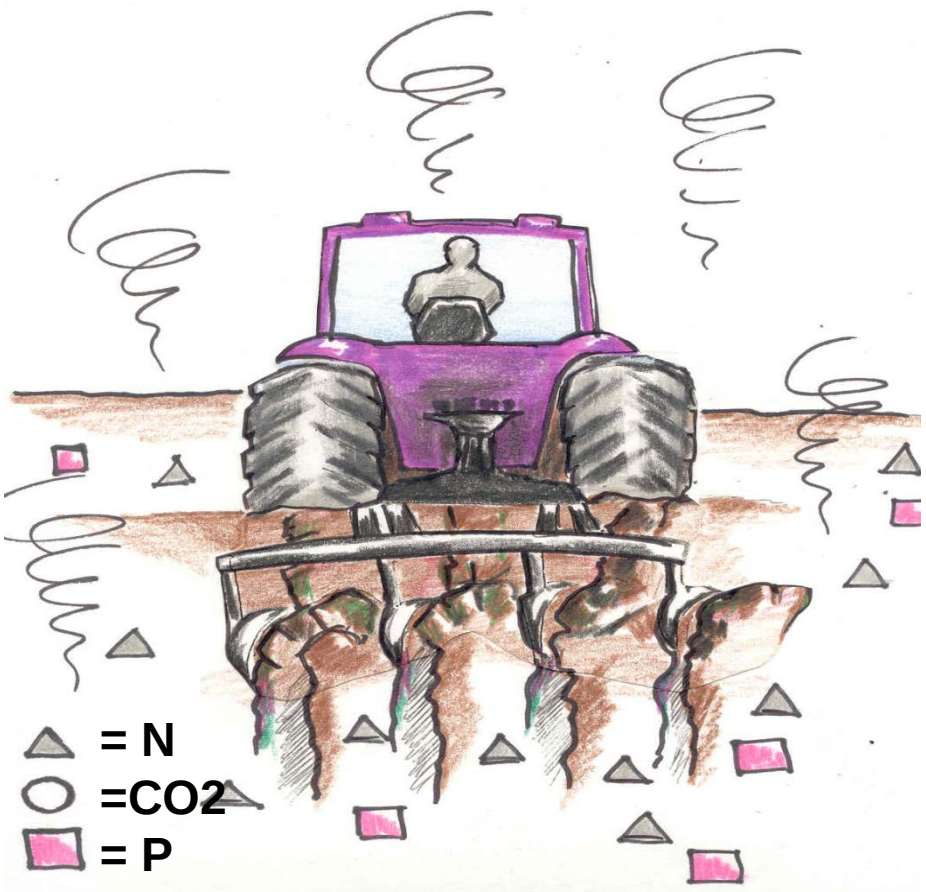


Large
Microbial
Population

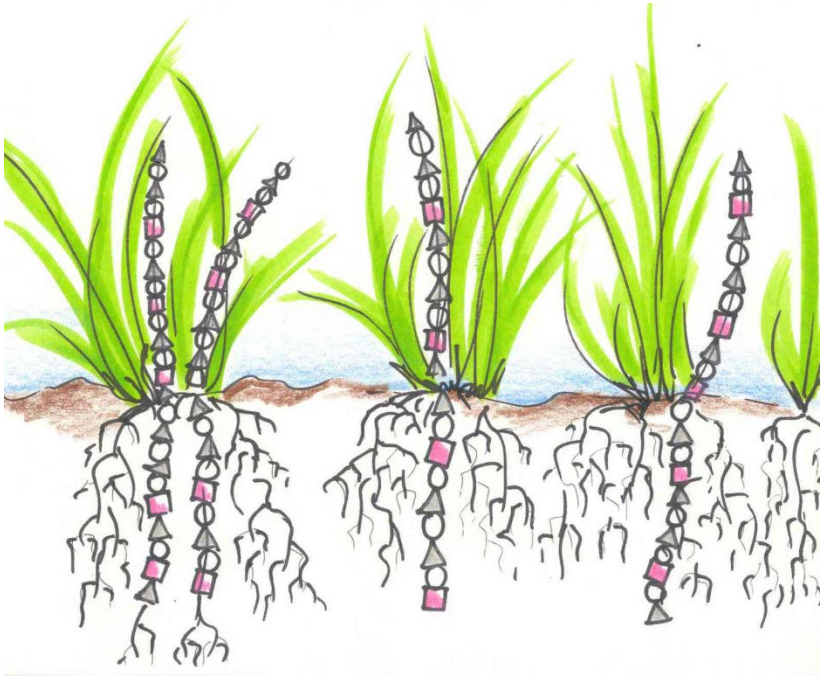
Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Tillage Burns Soil Organic Matter

Conventional Tillage



ECO Farming

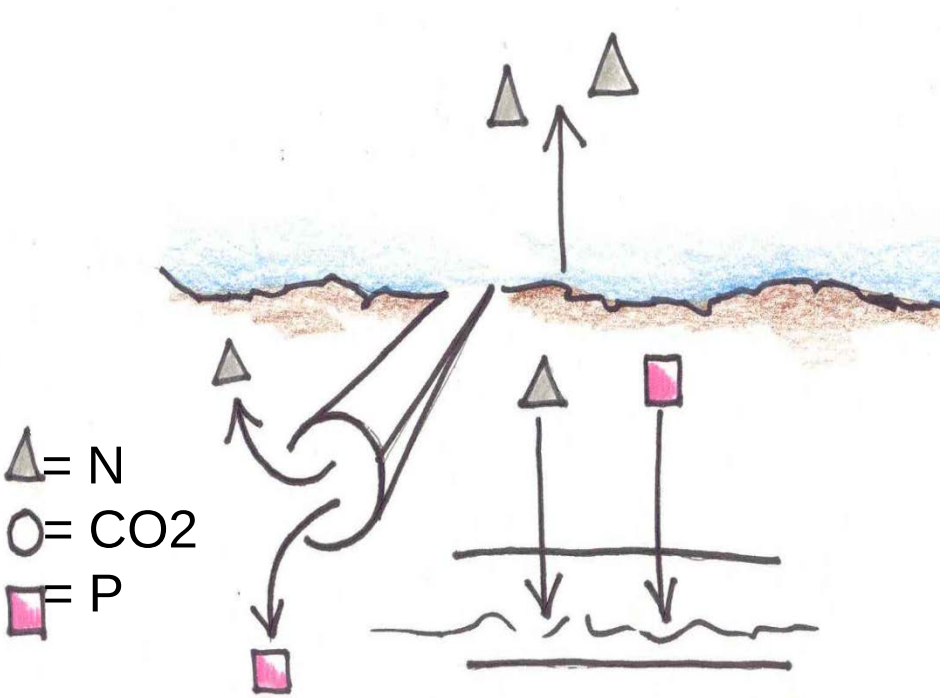


Nutrients (CO2, N, P) tied up in Plants.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Nutrient Fate in Winter and Spring

Conventional Tillage



Nutrients lost to air and water because no plant roots to absorb nutrients (N, P).

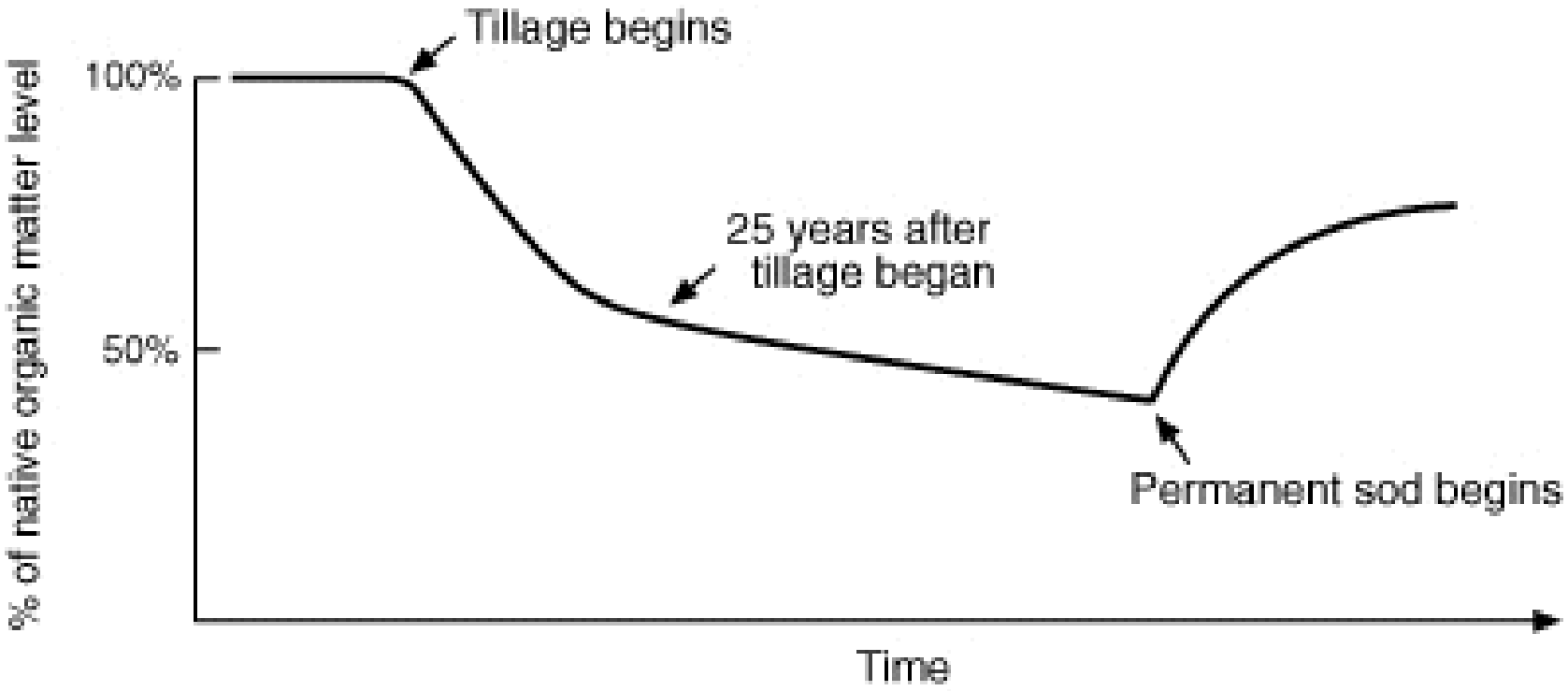
ECO Farming

Nutrients recycled in winter & spring & carried forward to next crop.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

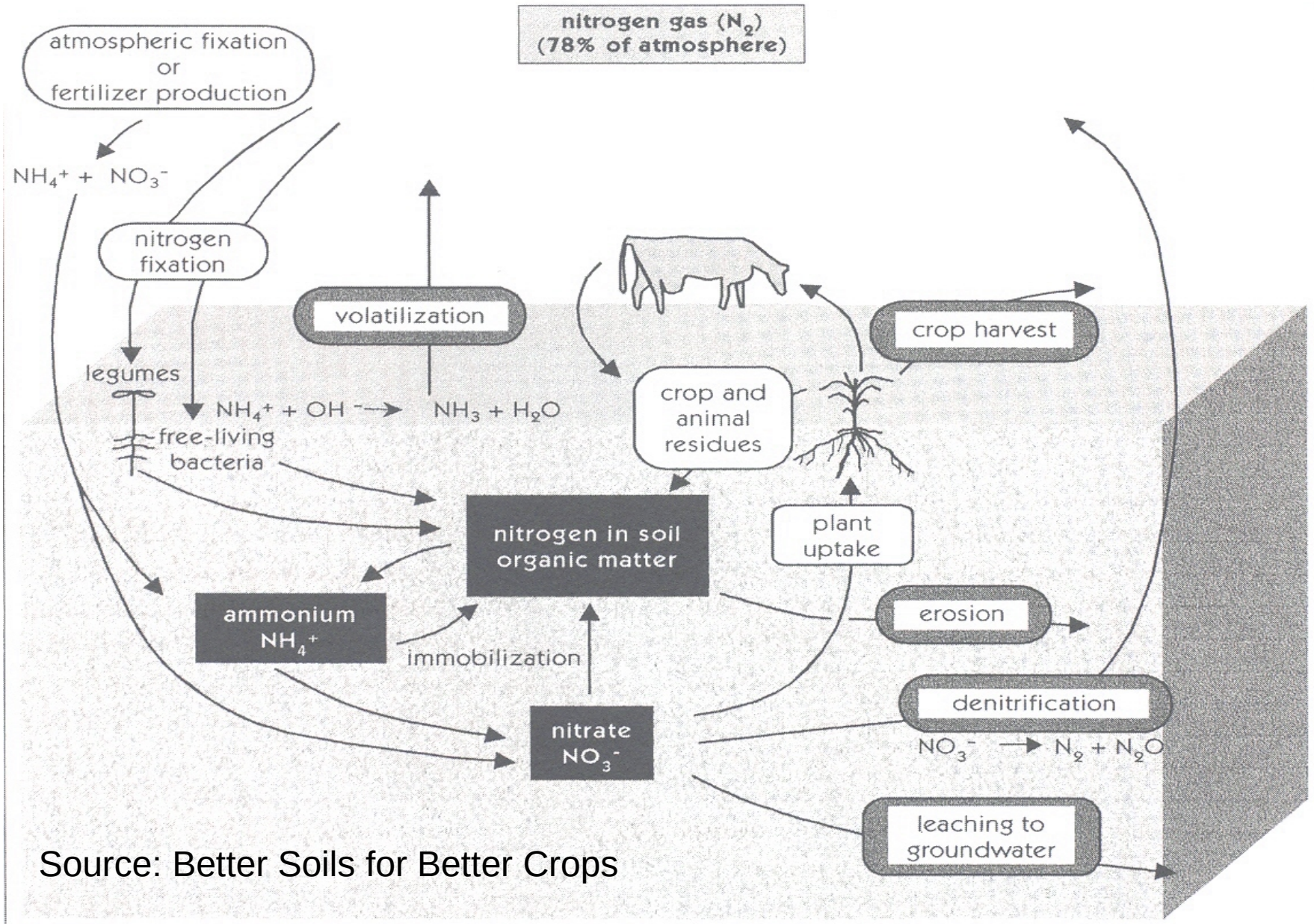
Soil Organic Matter Loss

Recent research



U of Minn

Nitrogen Recycling



Source: Better Soils for Better Crops

Do we get more N loss from inorganic (fertilizer) N or organic N?

- Inorganic (fertilizer) N had significantly higher N losses.
- How much? 31% for fertilizer compared to 13% for crop residue (organic N).
- Crop residue has 73% more retention of N in the soil than fertilizer N (26% retention).
- Suggests slower N recycling in crop residues (or proteins) protects against N losses. (Delgado, 2011 in J S&W Conservation)

A Common *Myth* about inorganic fertilizers: They feed the plant directly

Fertilizer Nitrogen applied Kg/ha (pounds/ac) 	**Corn Grain Yield Mg/ha (Bu/ac)**	**Total N in corn plant Kg/ha (pounds/ac)**	**Fertilizer derived N in Corn Kg/ha (pounds/ acre)**	**Soil-derived N in corn, in Kg/ha (pounds/ acre)**	**Fertilizer-derived N in corn as percent of total N in corn %**	**Fertilizer-derived N in corn as percent of N applied %** 
50 (45)	3.9 (62)	85 (77)	**28 (25)**	60 (54)	**33**	56
100 (90)	4.6 (73)	146 (131)	**55 (50)**	91 (81)	**38**	55
200 (180)	5.5 (88)	157 (141)	**86 (78)**	71 (63)	**55**	43

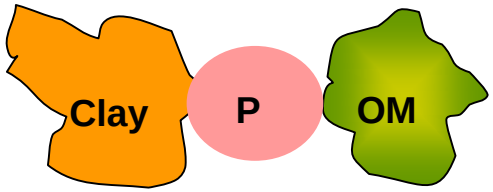
Source of Nitrogen in Corn in North Carolina on an Enon Sandy Loam Soil Fertilized with Three Rates Nitrogen as NH+4-NO-3 (tagged Isotope 15 N)

(Calculated from Reddy and Reddy 1993)
Page 725 13th Edition Nature and Properties of Soil

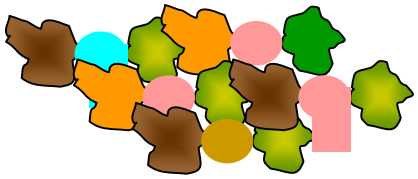
About 50-75% of the Available P in soil is organic.

P stabilizes the OM and forms a bridge to the clay.

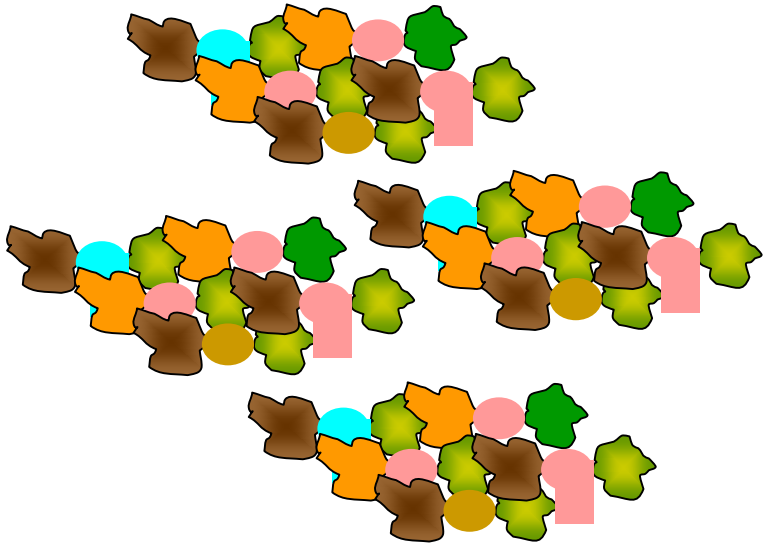
Our current P use efficiency is 10-50%. Microbes unlock P chemical bonds and make P plant available.



Clay-P-OM



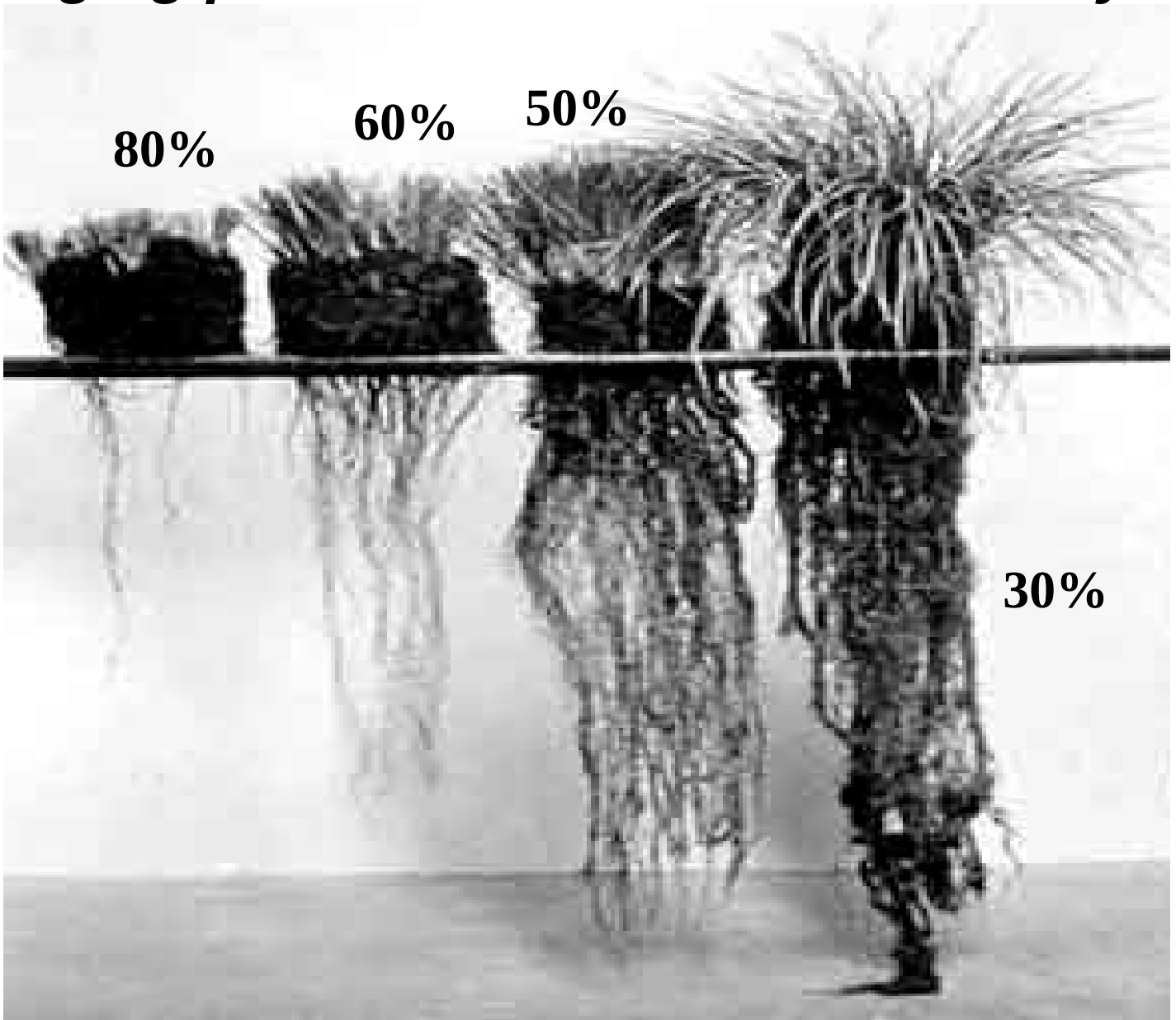
$(Clay\text{-}P\text{-}OM)_x$



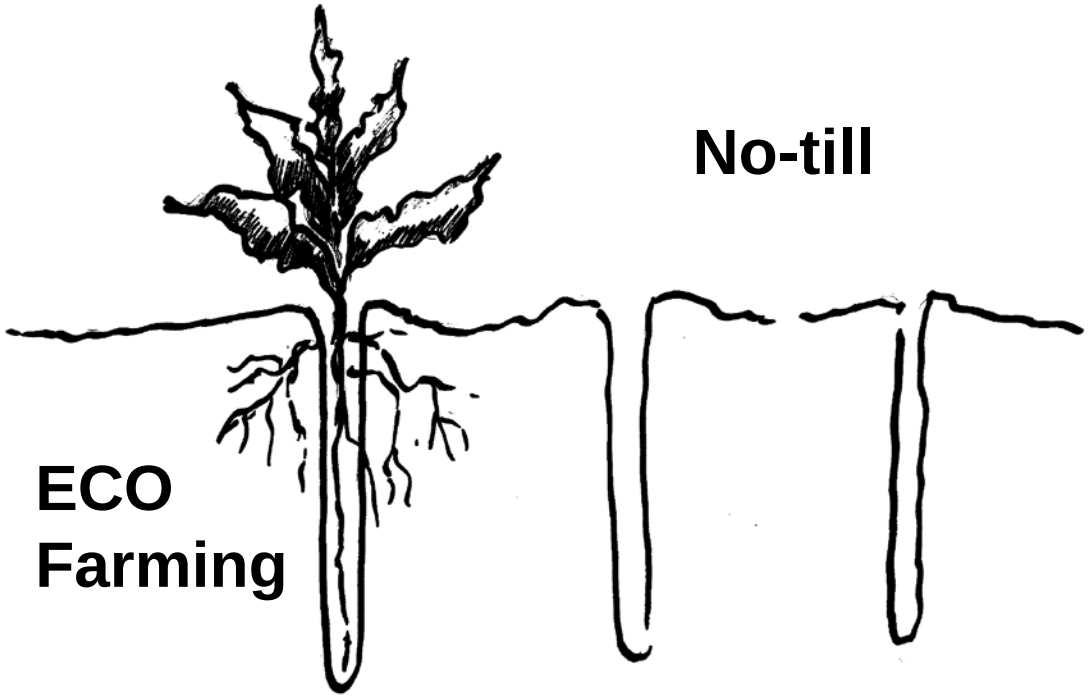
$((Clay\text{-}P\text{-}OM)_x)_y$

Islam, 2010

Managing plant roots affects nutrient recycling



N0-TILL creates macropores



ECO Farming & live roots acts like a biological valve to absorb N and P.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Carbon Storage North to South

Arctic Tundra

Carbon in North
Stored below soil

Tropics

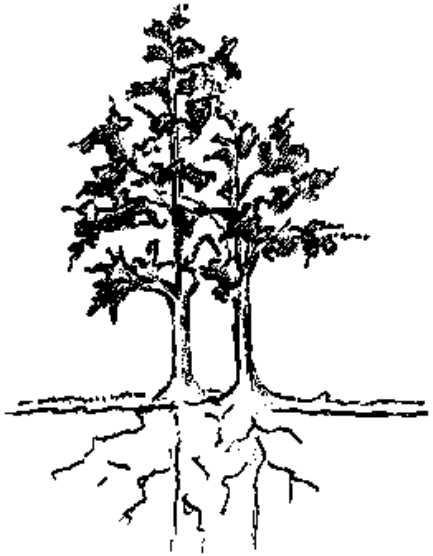
Carbon in tropics stored
Above the soil in trees

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Carbon Storage
West to East

Prairie - West

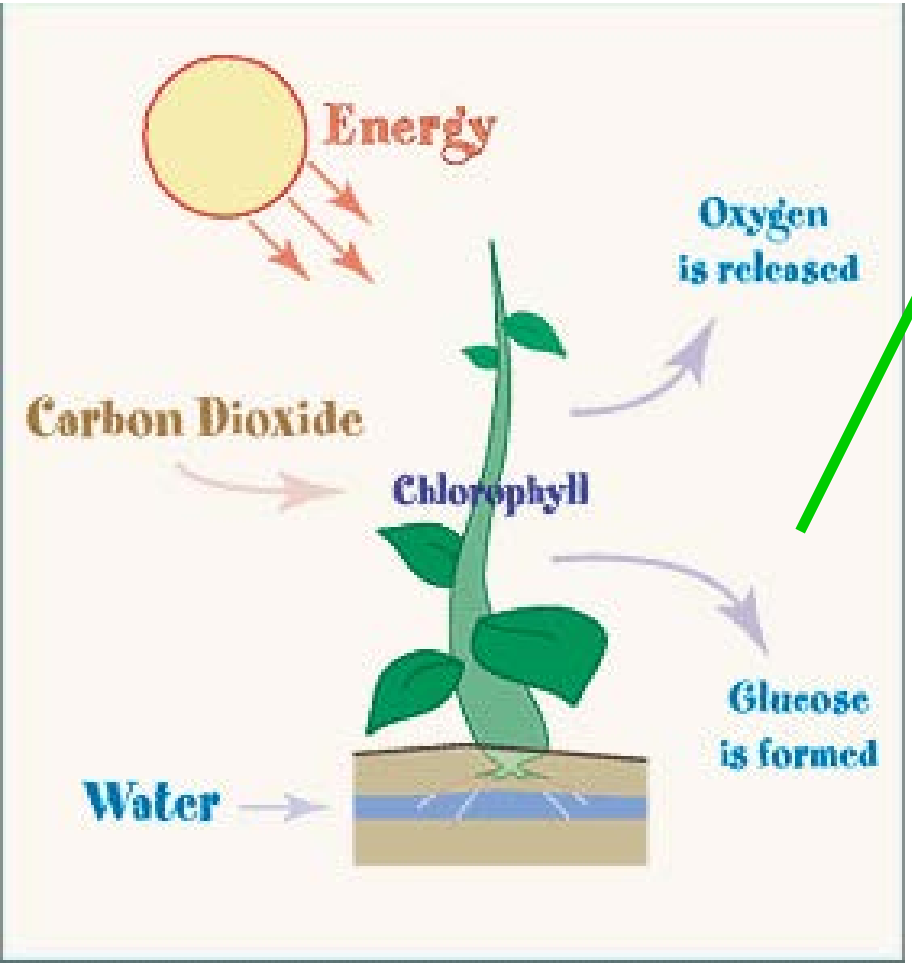
Deep soils high in organic matter due to grass roots and fast root turnover



Hardwood trees

Low organic matter levels in due to slow root turnover.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman



Glucose + Nutrients

Structural compounds

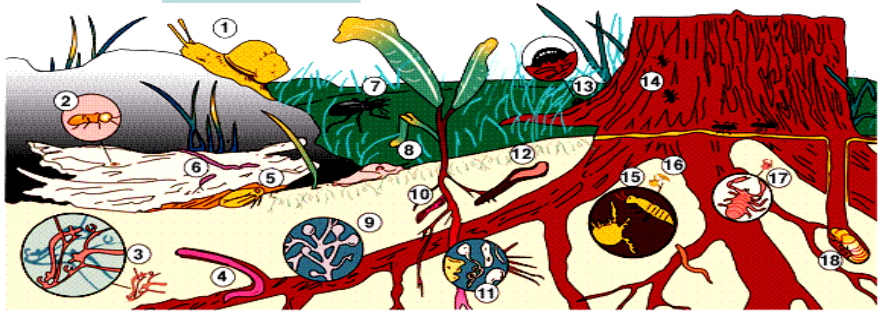
- Carbohydrates
- Amino acids/proteins
- Lipids (fat)
- Lignin

Non-structural compounds

- Enzymes
- Hormones
- Phenolics
- Vitamins

Carbon dioxide

60-80 g



Energy + Nutrients

100 g organic residues

3-8 g Microorganism Polysaccharides	3-8 g Non-humic compounds	10-30 g Humic compounds
Living	Dead	Very Dead

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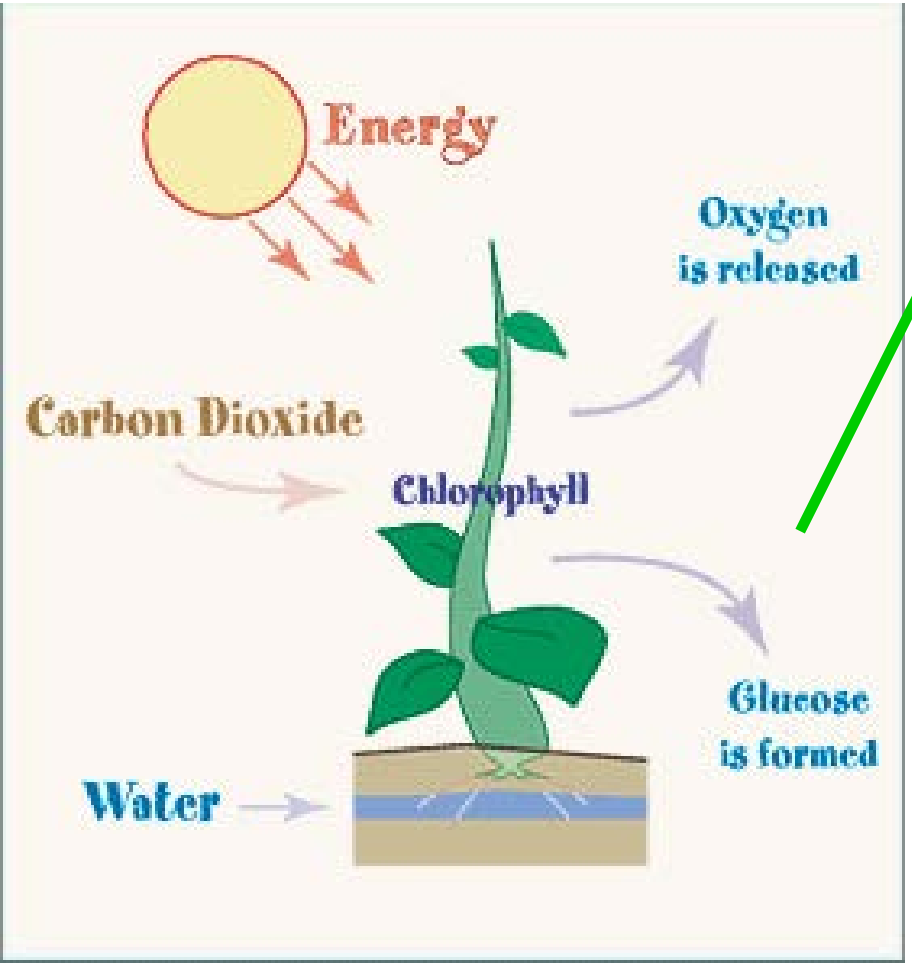

Glucose + Nutrients

Structural compounds

- Carbohydrates
- Amino acids/proteins
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Non-structural compounds

- Enzymes
- Hormones
- Phenolics
- Vitamins

Value of Soil Organic Matter

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

Nutrients:

Nitrogen:	1000# * $0.50/#N	=	$500
Phosphorous:	100# * $0.70/#P	=	$ 70
Potassium:	100# * $0.50/#K	=	$ 50
Sulfur:	100# * $0.50/#S	=	$ 50
Carbon: 10,000# or 5 ton	* $?/Ton	=	$ 0

Value of 1% SOM Nutrients/Acre = $670

Original Jim Kinsella/Terry Taylor(2006)/revised Jim Hoorman (2011)

How much N from SOM?

- Estimate 1-3% of N in SOM

2% SOM * 1000#N/1% SOM * 1% = 20 #N/A

4% SOM * 1000#N/1% SOM * 1.5% = 60 #N/A

6% SOM * 1000#N/1% SOM * 2.0% = 120 #N/A

6% SOM * 1000#N/1% SOM * 2.5% = 150 #N/A

The amount of N mineralized depends on soil moisture, temperature and biological activity.

Turmoil of Tillage = HEFT

Tillage to soil microbes is like the worst:

H = Hurricane

E = Earthquake

F = Forest Fire

T = Tornado

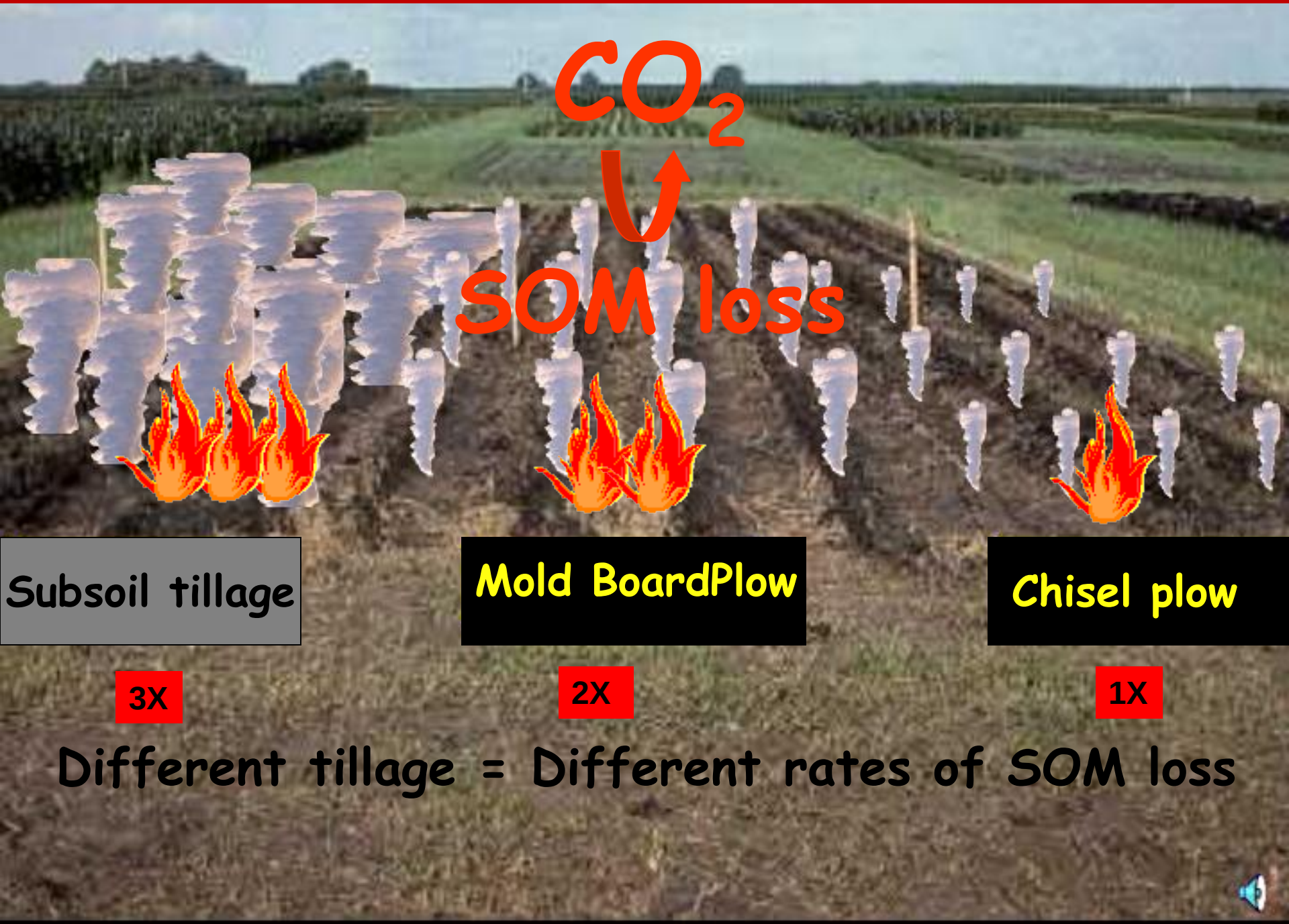
all wrapped into one event!

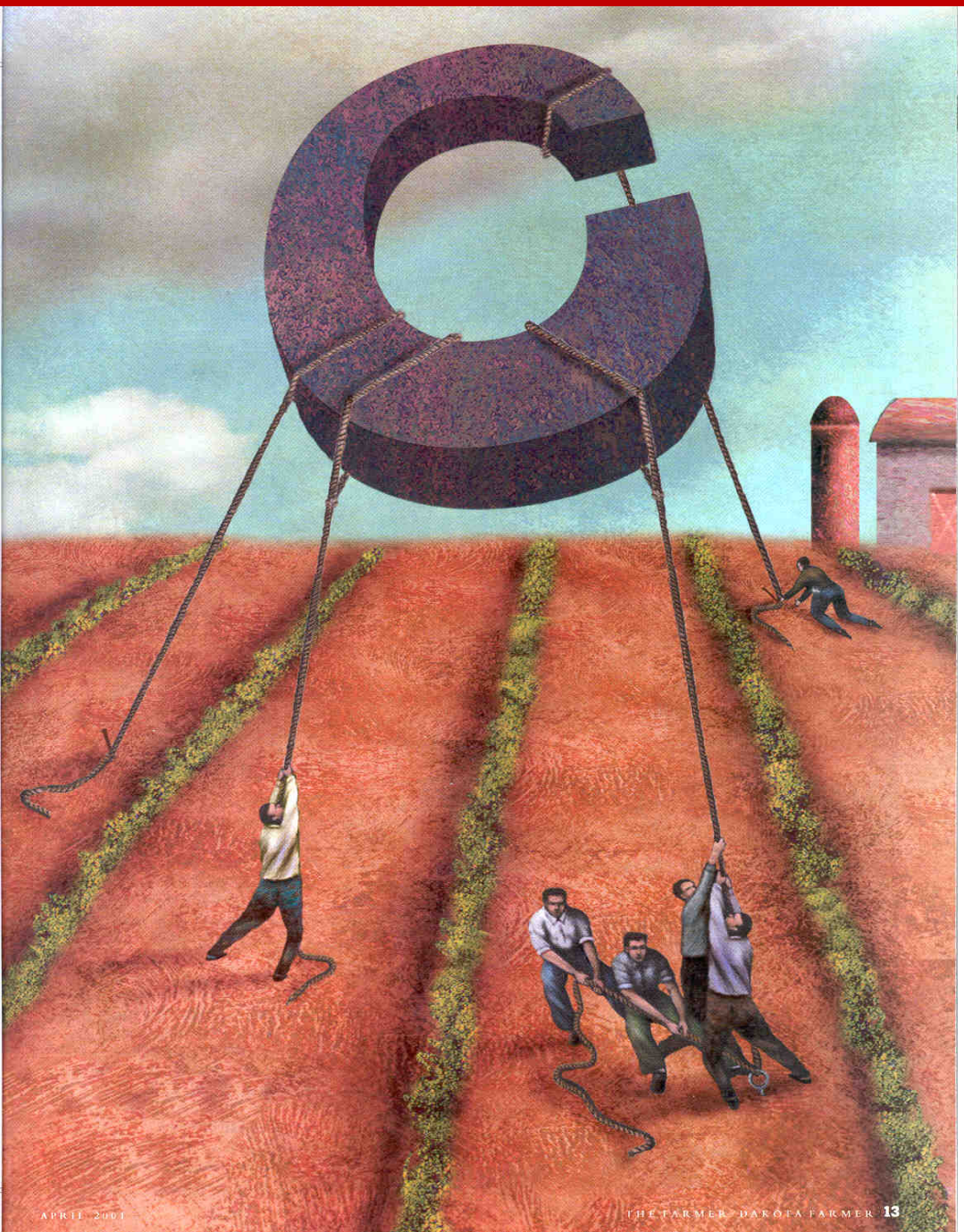
Conventional agriculture is related to **soil**, air and water quality degradation

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

A 1% loss of SOM= 1000 lbs N/ac Tilled fields Erode 10-100X Faster. 0.5% of all world's soils lost per year or 1" in 60 years.

Loss of SOM as CO_2


CO_2
SOM loss
Subsoil tillage
Mold BoardPlow
Chisel plow
3X
2X
1X
Different tillage = Different rates of SOM loss



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)

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.

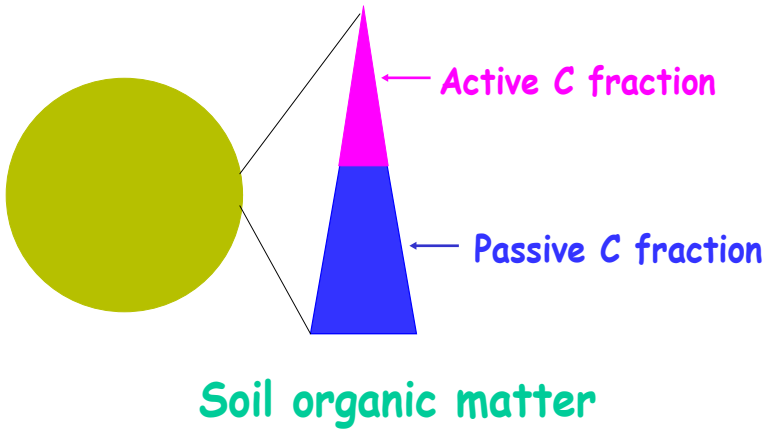
Most of what's left

is the passive SOM

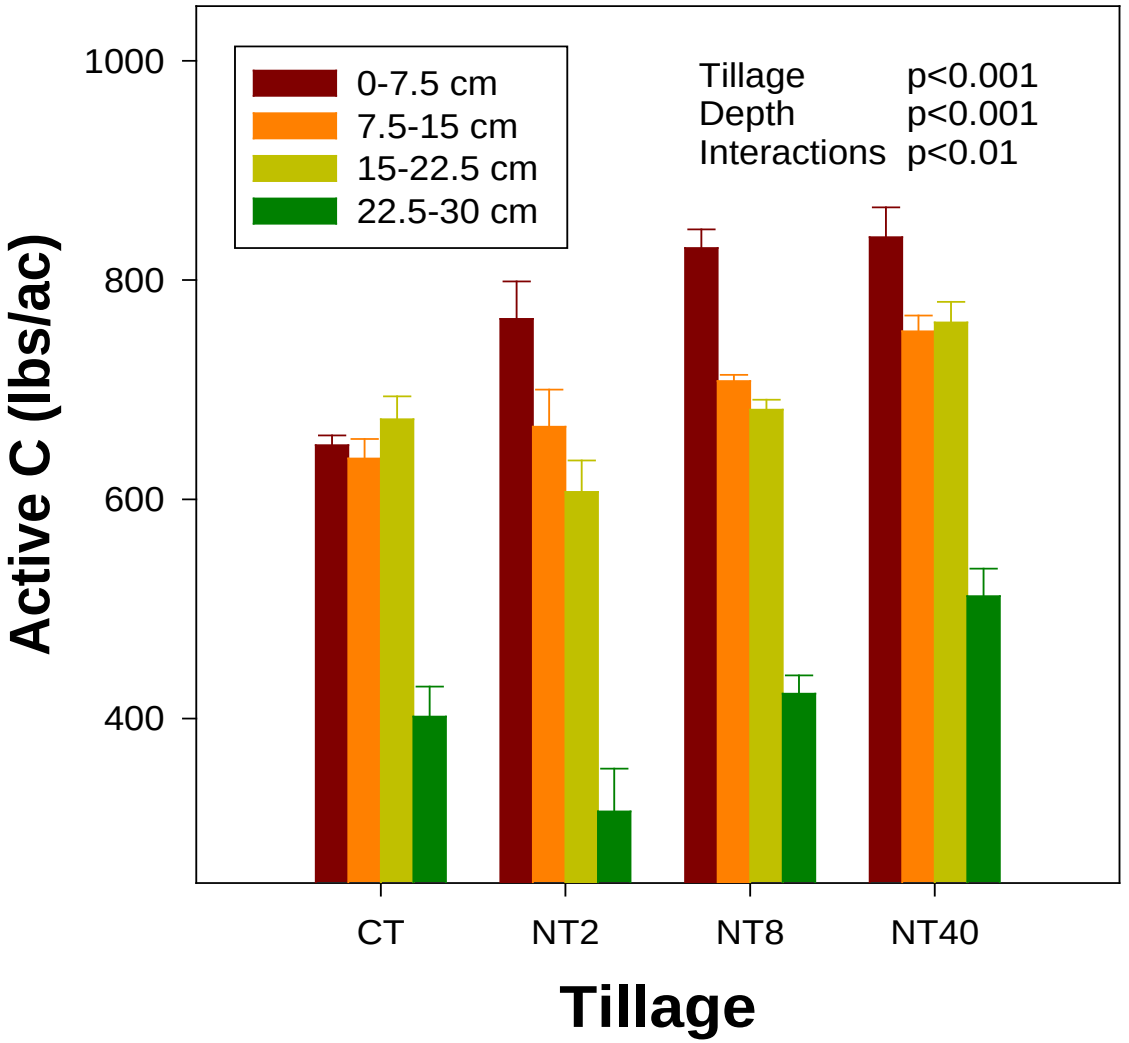
fraction which is

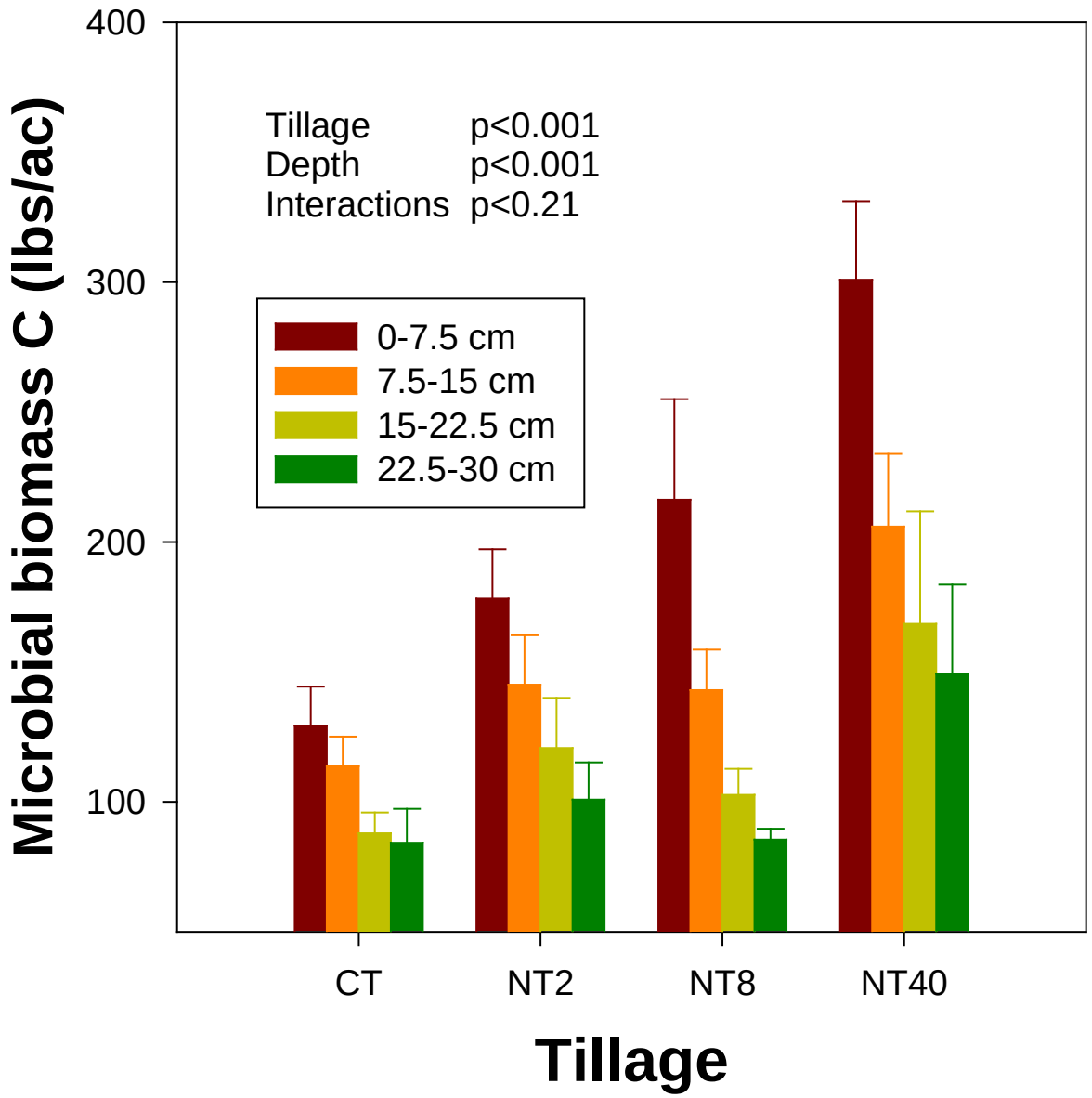
resistant to microbial

decomposition.



Active Carbon (Sugars) are higher in No-till Soils




Microbial biomass C (lbs/ac)
400
300
200
100
Tillage p<0.001
Depth p<0.001
Interactions p<0.21
0-7.5 cm
7.5-15 cm
15-22.5 cm
22.5-30 cm
CT
NT2
NT8
NT40
Tillage

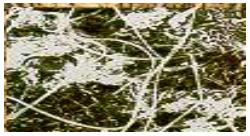
Relative amount of microbes in soil

Amount of organism in 100 to 200 g of soil

Relative amount of microbes in handful of soil

Bacteria **up to 50 billion**

Actinomycetes **up to 2 billion**



Fungus **up to 100 million**

Protozoa **up to 50 million**

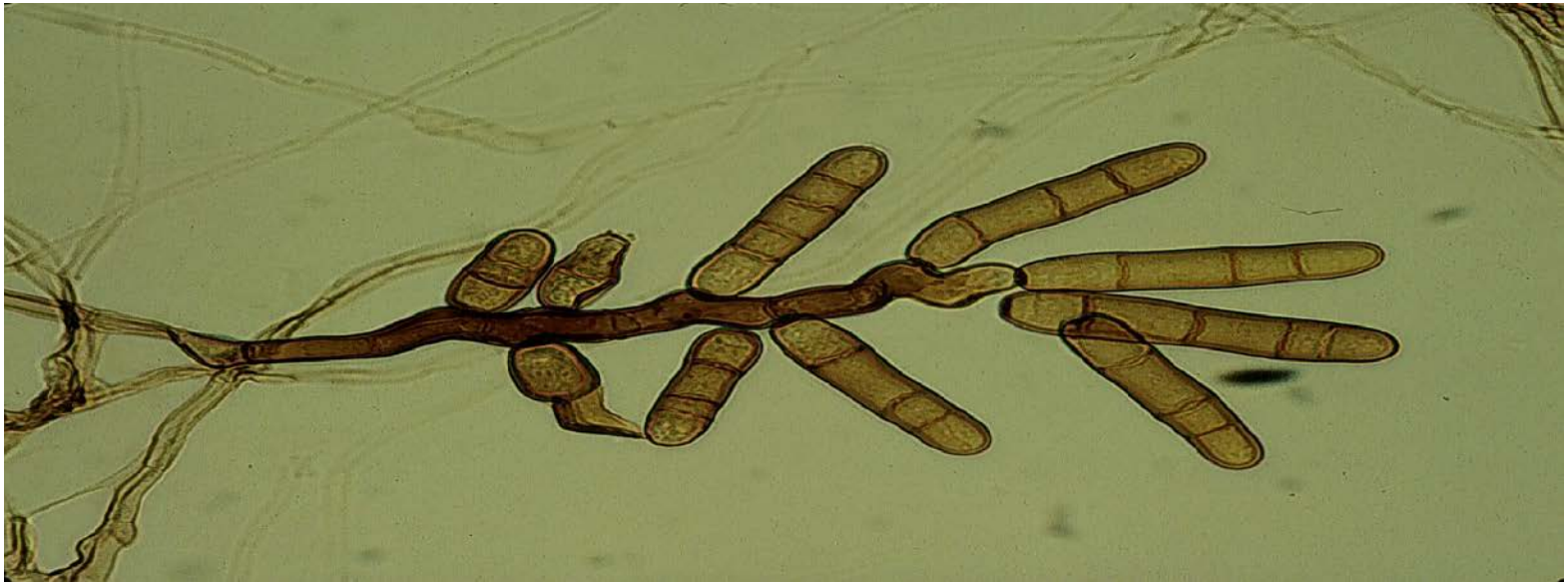
Nematodes **10,000**

Arthropodes **1000**

Earthworm **0 to 2**

Plant roots feed the Microbes!

Plant roots use 25 to 40% of their root carbohydrate supplies to feed the microbes!



Plants actively use hormones to attract and “farm” bacteria, fungus, and other organisms to help them recycle soil nutrients and water.

Rhizosphere

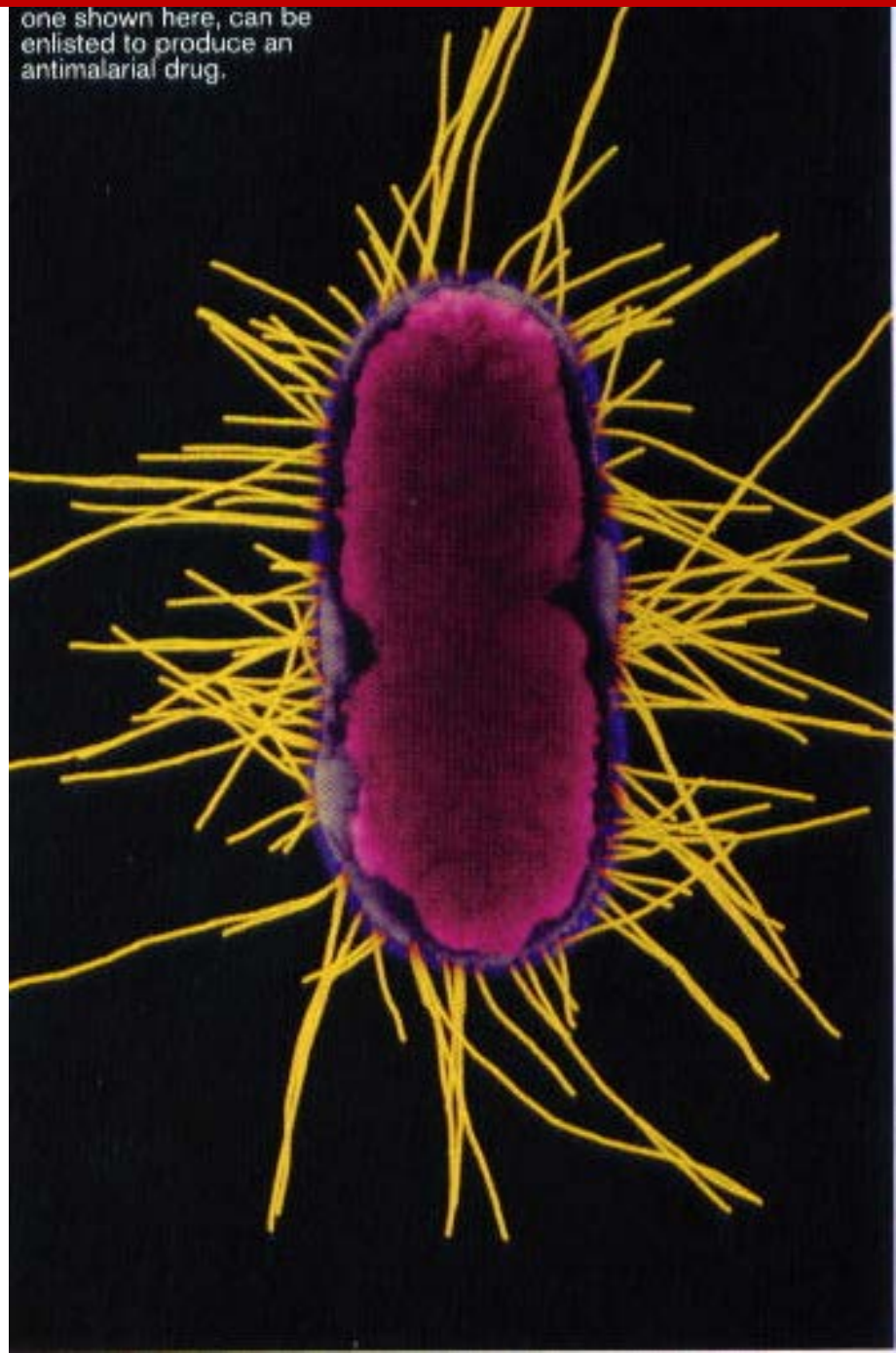
Living roots release many types of organic materials into the rhizosphere within 50 µm of the surface of the root. There are over 1000-2000 times more microbes associated with a live root than in the bulk soil.

Conventional tillage system

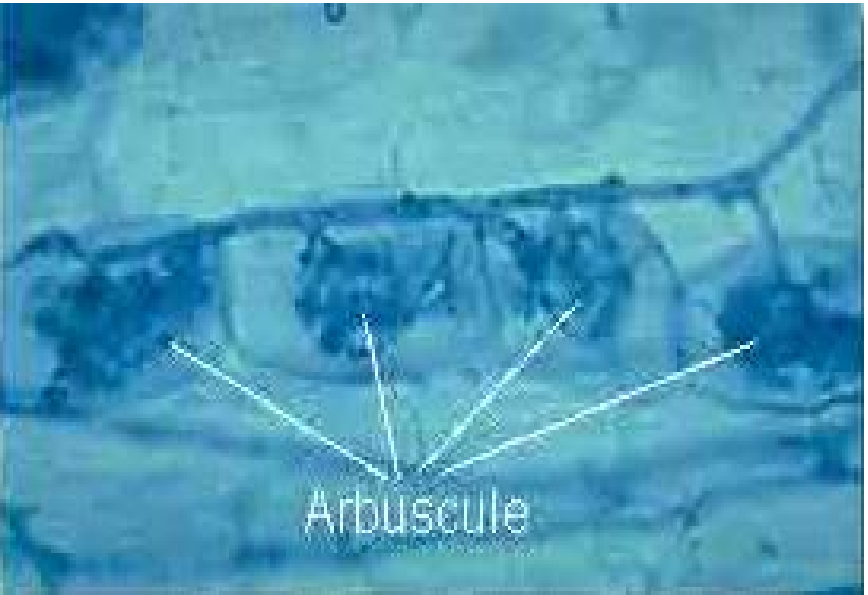
Bacteria-dominated

Bacteria have 20-30% C-use efficiency

Prefer Aerobic Conditions



Fungi-dominated



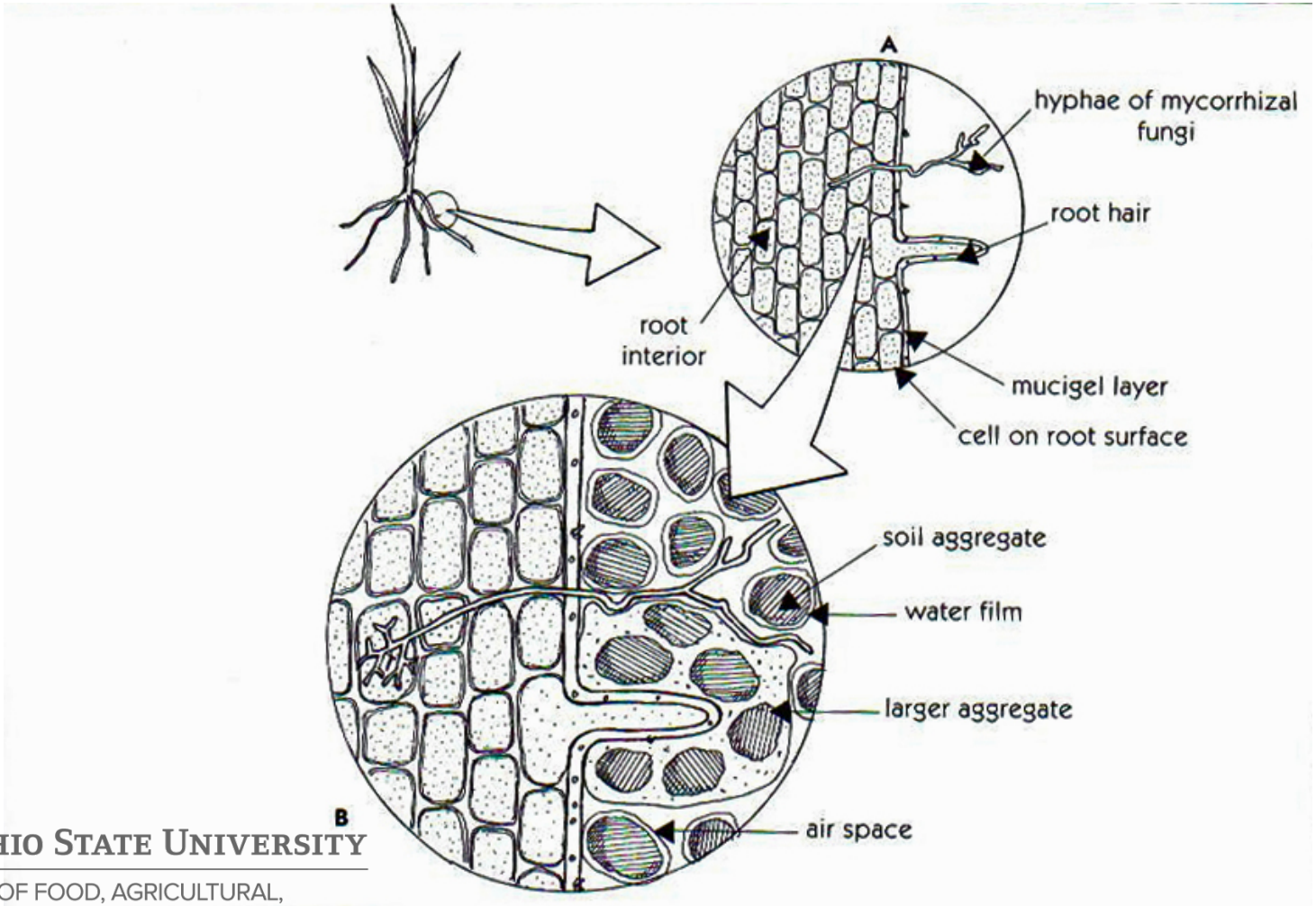
In No-till system

Nematode and fungal relationship

Fungi has 40-55% C-use efficiency

Obligate aerobes & Heterotrophs

Mycorrhizal Fungus



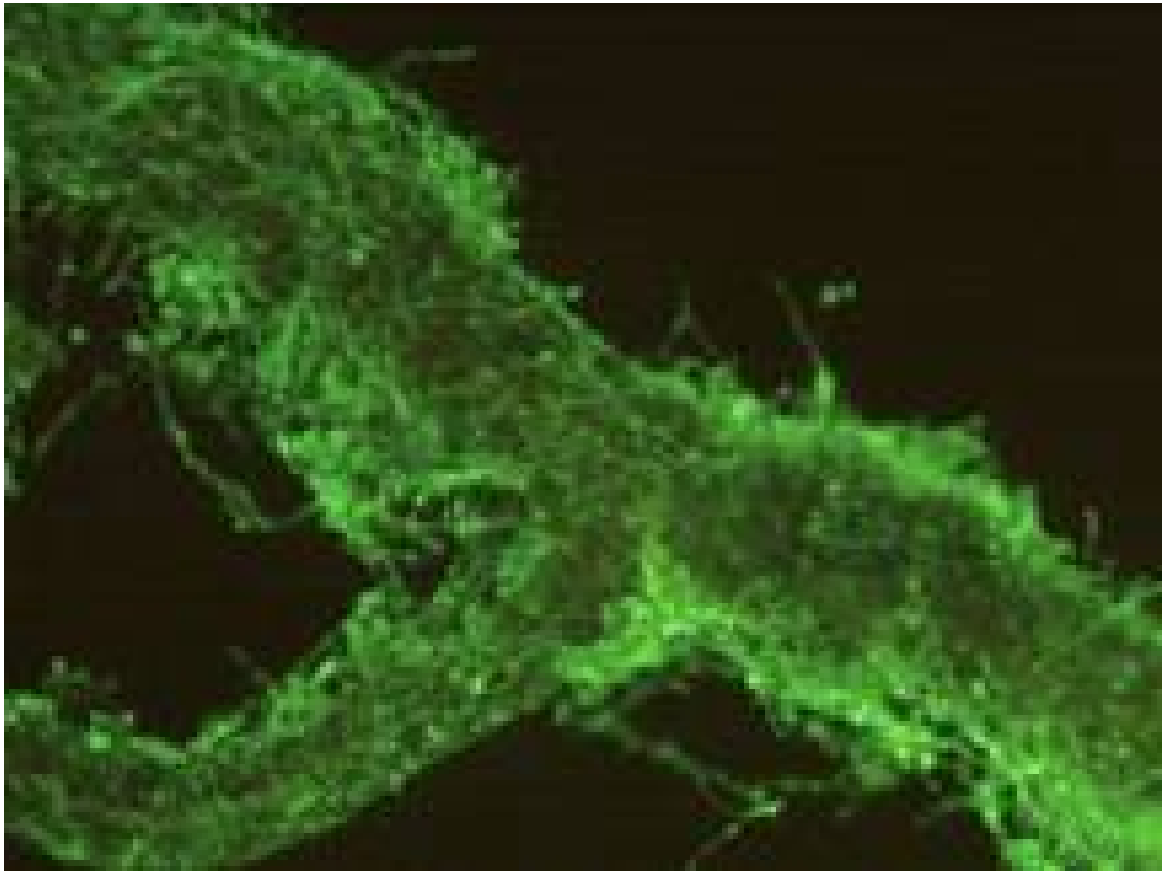
Source: Better Soils for Better Crops

Mycorrhizal Fungus

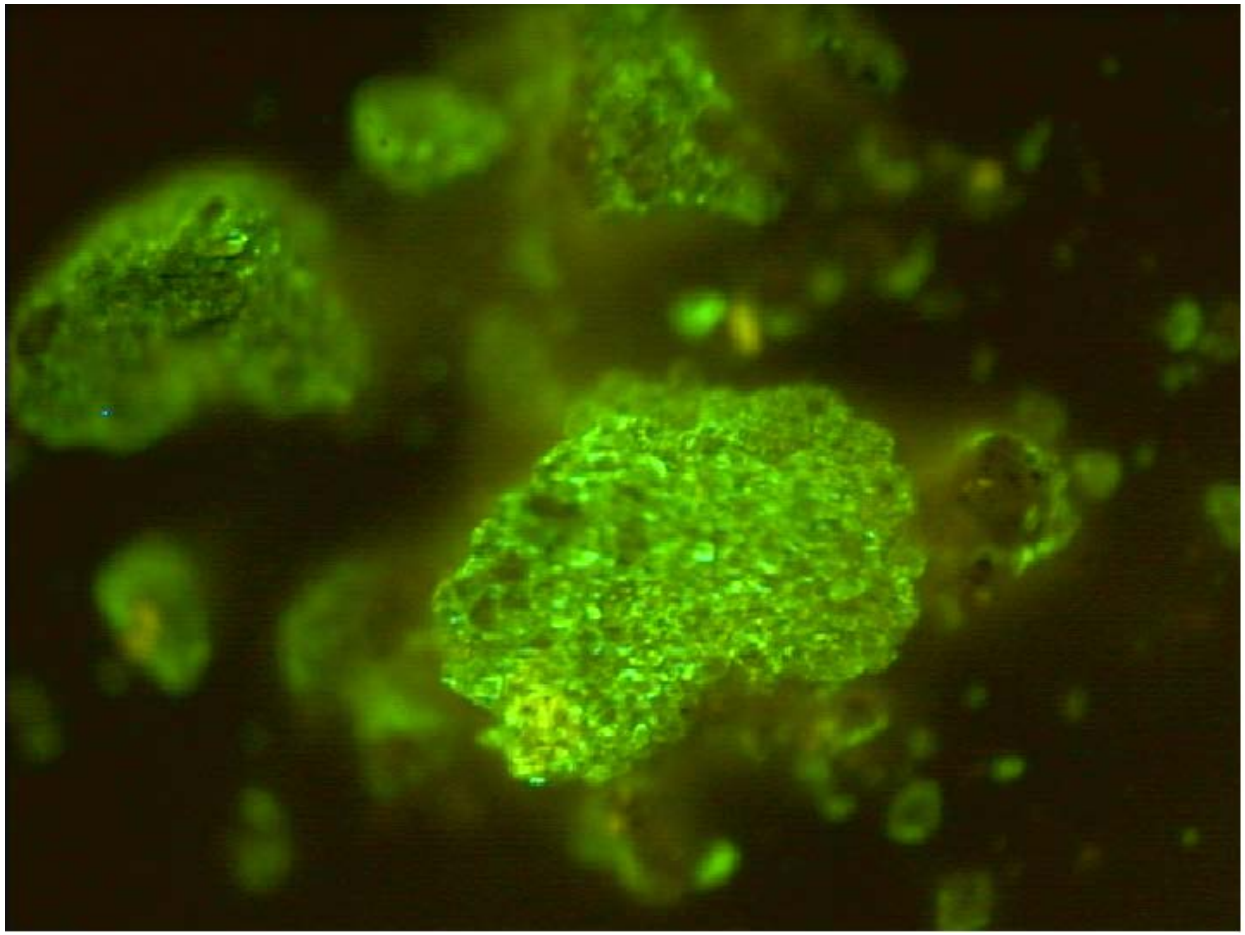
- Chlorophyll content is critical for conversion of essential amino acids to vitamins. Increase plant uptake of P, Ca, Zn, Fe, B and Cu.
- Increases plant resistance to drought.
- Determines the microbial community in the rhizosphere.
- Protect plant roots from some predators.
- Are sensitive to tillage and P fertilization.
- Supply P for efficient N fixation. Hyphae take up 6x more P than root hairs, increased surface area. If AMF not active, less P released. Corn and soybeans more efficient with AMF present and require less fertilizer (Clapperton, 2013).

Mycorrhizal Fungus & Roots

Fungus equals white or yellow filaments, roots are light brown to tan in color. Absorb 6x more P than root hairs!



Sticky substance, glomalin, surrounding root heavily infected with mycorrhizal fungi. Fungi help roots explore up to 20% of the soil volume. A root by itself can only explore 1% of the soil volume. Photo by Sara Wright.



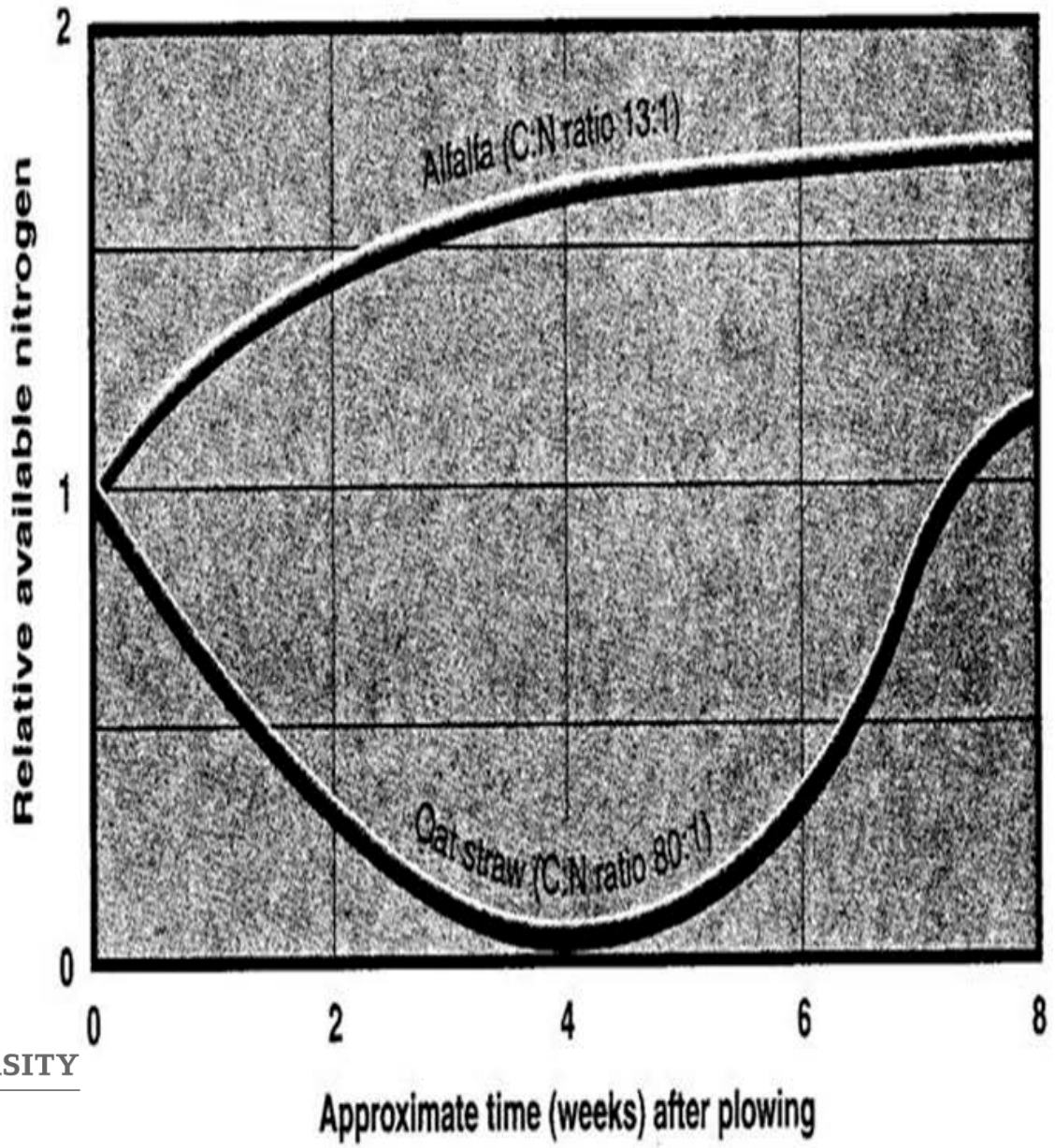
Sticky substance, glomalin from fungus, surrounding soil aggregates, water insoluble. Photo by Sara Wright.

Nutrient cycles mediated by soil organisms

- **N cycle – 75% of Available N released by soil microbes**
- **C cycle**
- **S cycle**
- **P cycle* – 65% of DRP released by microbes.**
- **Micronutrients***
- * weathering of soils is also important

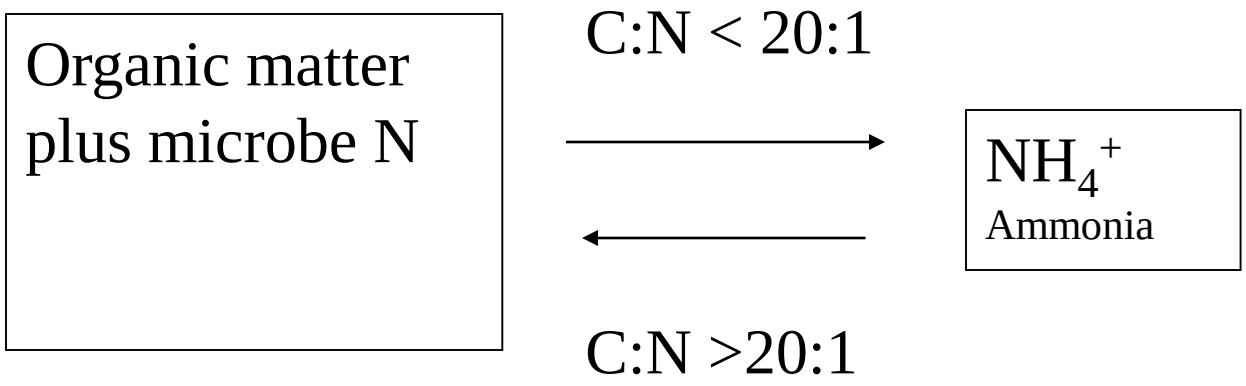
Alfalfa
Low C:N
Ratio C:N = 13:1

Oat Straw
High C:N
Ratio C:N = 80:1



C:N Ratio of Organic Matter

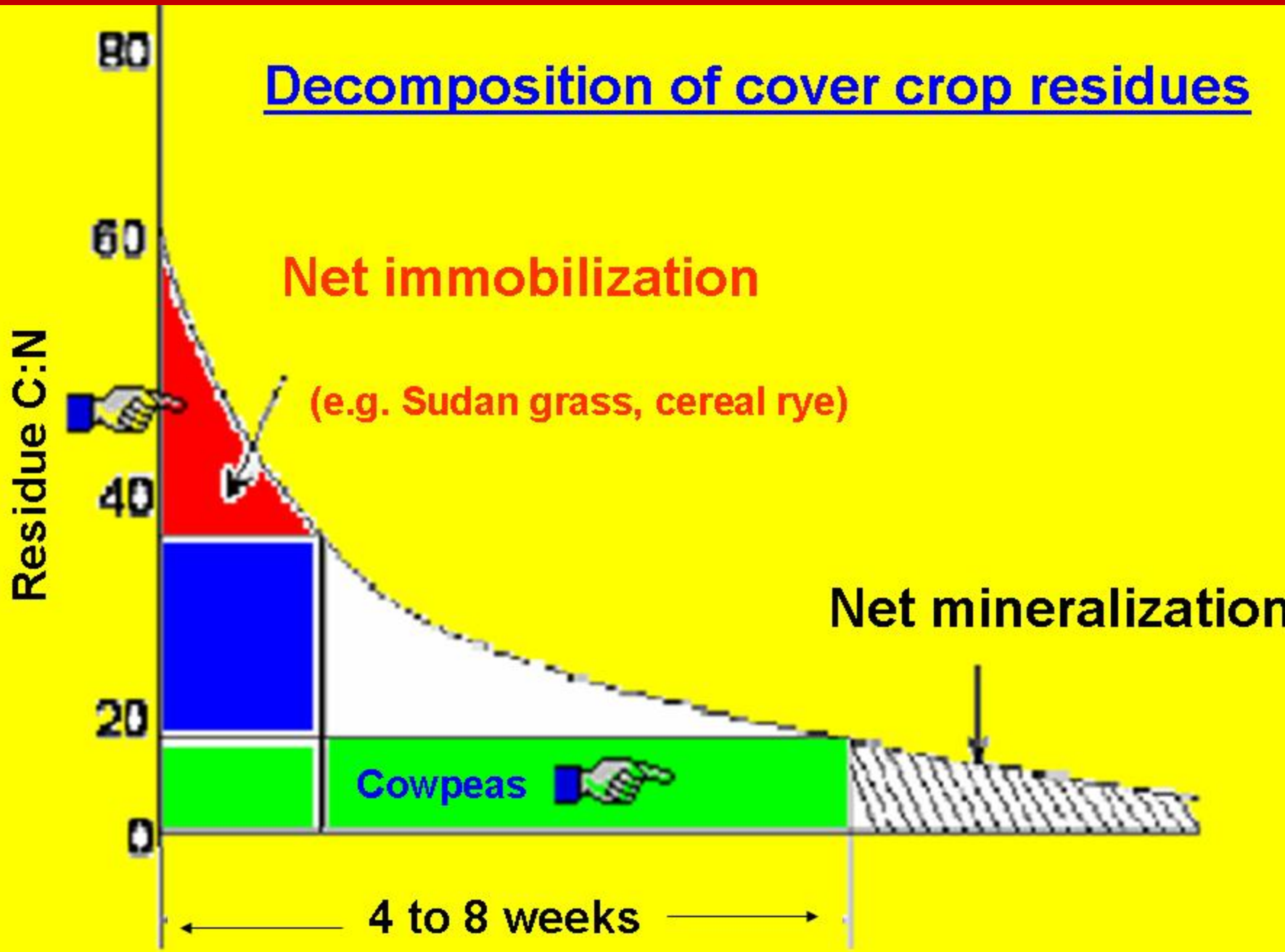
As a rule of thumb:
At C:N >20:1, NH_4^+ is immobilized (tied up)
At C:N < 20:1, NH_4^+ is mineralized (released)

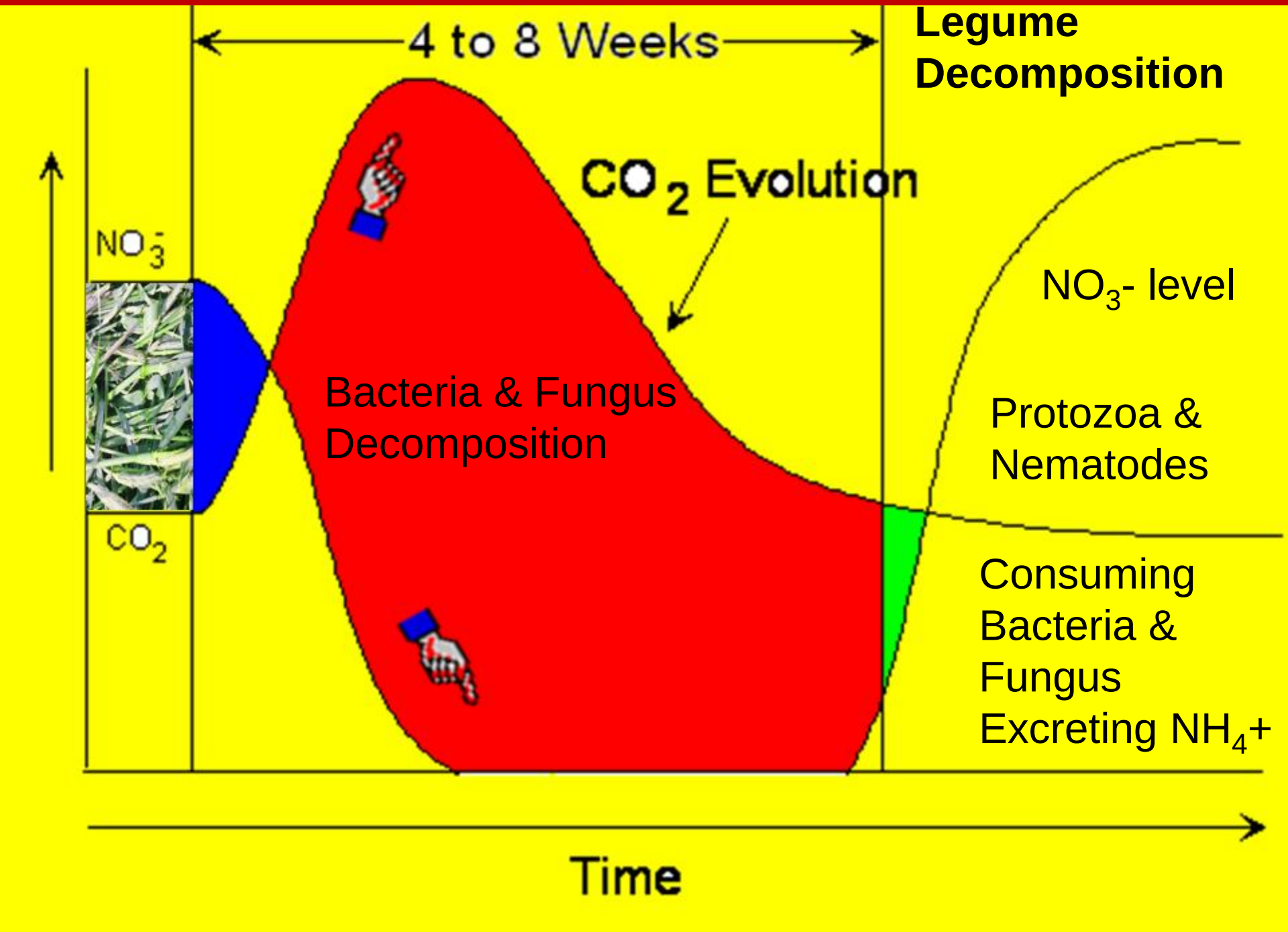


Typical C:N Ratio in soil is 10-12

C:N Ratio of organic residues

Rye straw	**82:1**
Wheat straw	80:1
Oat straw	70:1
Corn stover	57:1
Rye cover crop (anthesis)	37:1
Rye cover (vegetative)	26:1
Mature alfalfa hay	25:1
Ideal microbial diet	**24:1**
Rotten barnyard manure	20:1
Legume hay/beef manure	17:1
Young alfalfa hay	13:1
Hairy vetch cover crop	11:1
Soil microbes (average)	8:1


Decomposition of cover crop residues
Residue C:N
80
60
40
20
0
Net immobilization
(e.g. Sudan grass, cereal rye)
Net mineralization
Cowpeas
4 to 8 weeks


4 to 8 Weeks
Legume Decomposition
CO2 Evolution
NO3-
NO3- level
Bacteria & Fungus Decomposition
Protozoa & Nematodes
CO2
Consuming Bacteria & Fungus Excreting NH4+
Time

Summary

- How we manage the soil impacts soil nutrient recycling and nutrient availability.
- No-till is an important first step in keeping soils healthy. Cover crops or live plants is the second step.
- Soil microbes are just soluble bags of fertilizer to plants, so healthy microbial populations promote plant growth.
- ECO Farming mimics natural process and restores soil health.

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ECO Farming in the 21st Century Recycling Soil Nutrients

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