Soil Health

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Conservation Agronomist
Franklin County Conservation District

My Background

My New Role as Conservation Agronomist

•Partnership with NRCS, NACD, and Land O'Lakes Truterra to bridge the gap between the public-private sector to grow and promote conservation practices & sustainability.

TRUTERRA


“ THE NATION
THAT DESTROYS
ITS SOIL
DESTROYS
ITSELF. ”
- FRANKLIN DELANO ROOSEVELT -
MERIT myth

Runoff from a farm field in New Mexico, 2016 (Natural Resources Conservation Service, USDA)

Dust storm near Ashland, Kansas, March 2018 (The Wichita Eagle)

Ray Archuleta - Soil Solubility (Slake) Test

Raythesoilguy Demonstrates the Slake (or Soil Stability) Test

What is Soil Health?

- A term that has been around since the 1990s
- NRCS Definition: **The continued capacity of the soil to function as a vital *living* ecosystem that sustains plants, animals, and humans.**
  - The term health was used purposely over quality because:
    - **Quality** implies analysis & quantifying
    - **Health** implies management actions that lead to a condition or state, there is something that can be done to change it in a positive trend.
- This definition speaks to the importance of managing soils so they are sustainable for future generations.
- Soil are alive and teaming with billions of bacteria, fungi, and other microbes that are the foundation of an elegant symbiotic ecosystem.

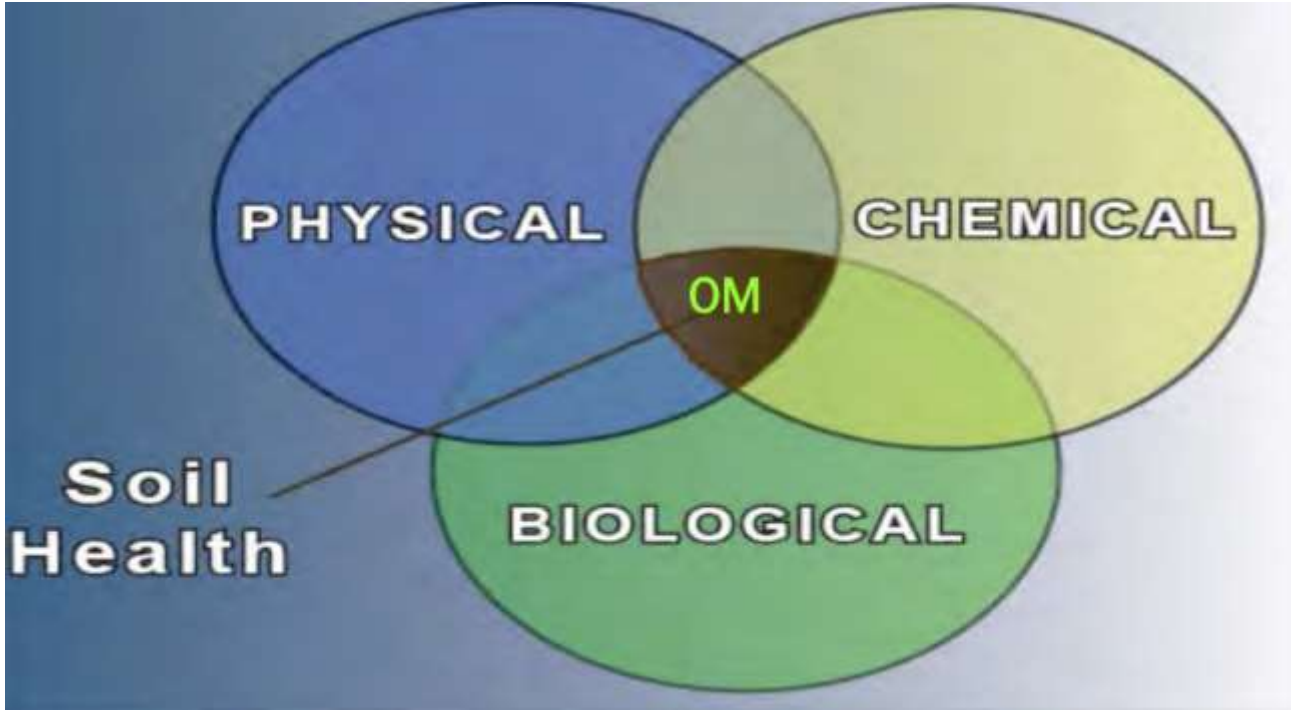
What is Soil's Function?

- **Nutrient Cycling** - Soil stores and cycles nutrients and other elements. Nutrients can be transformed into plant available forms, held in the soil, or even lost to air or water.
- **Water Relations** - Soil can regulate the drainage, flow and storage of water and solutes, which includes nitrogen, phosphorus, pesticides, and other nutrients and compounds dissolved in the water.
- **Biodiversity and Habitat** - Soil supports the growth of a variety of plants, animals, and soil microorganisms, usually by providing a diverse physical, chemical, and biological habitat.
- **Filtering and Buffering** - Soil acts as a filter to protect the quality of water, air, and other resources. Toxic compounds or excess nutrients can be degraded or otherwise made unavailable to plants and animals.
- **Physical Stability and Support** - Soil has the ability to maintain its porous structure to allow passage of air and water, withstand erosive forces, and provide a medium for plant roots.

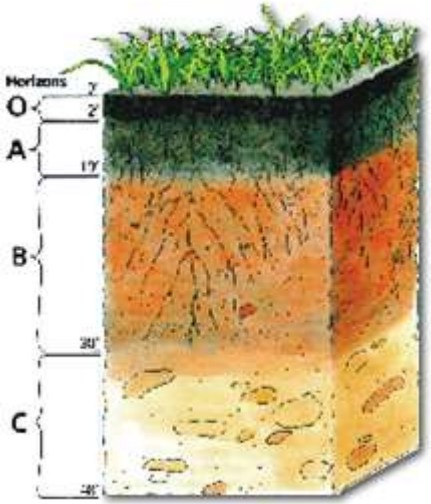
In order to fully understand how our soil is functioning we need to dig deeper!

Clipart Image

All soil parameters are important, but Biology is King!

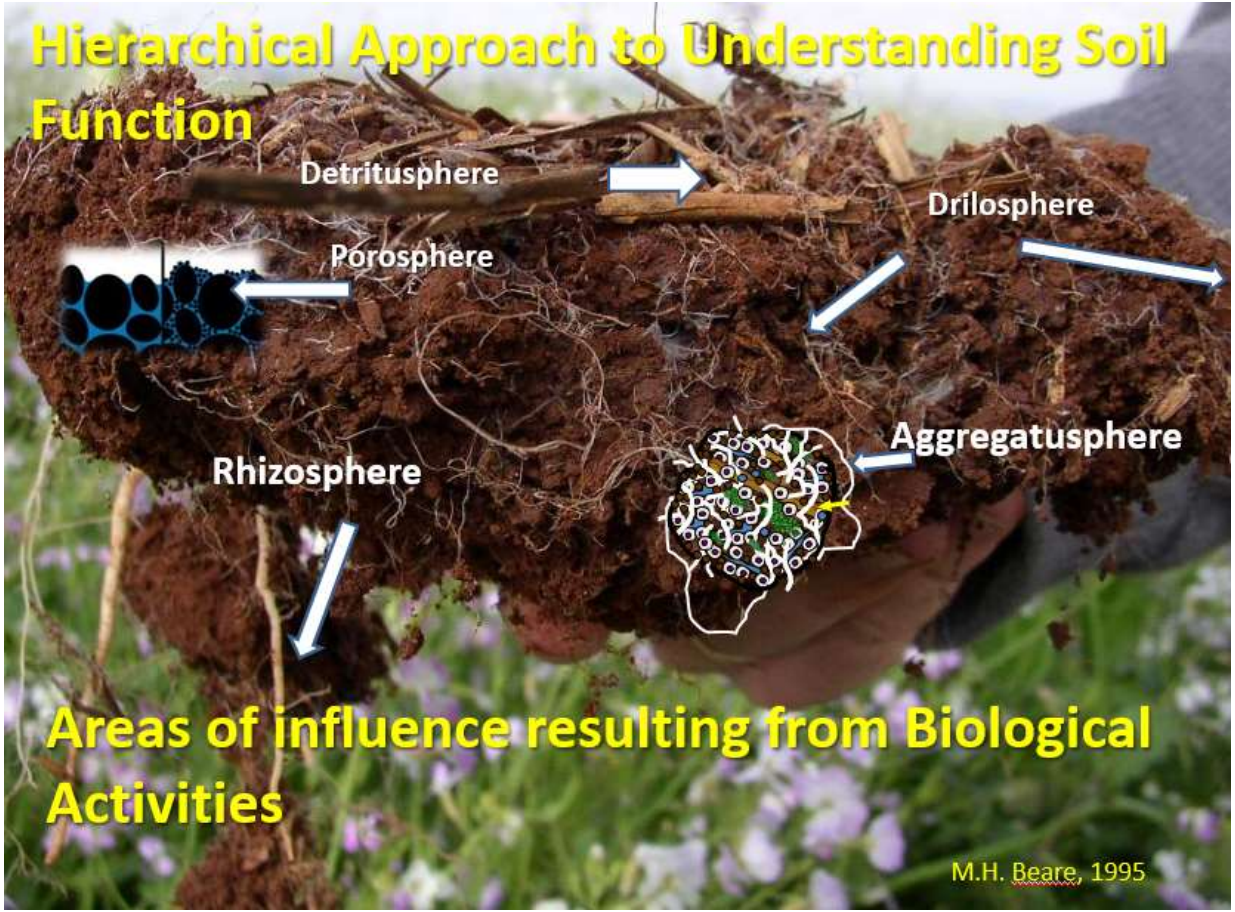



The Soil Livestock is a complex and diverse mix of species and represents the greatest concentration of biomass of anywhere on the planet.



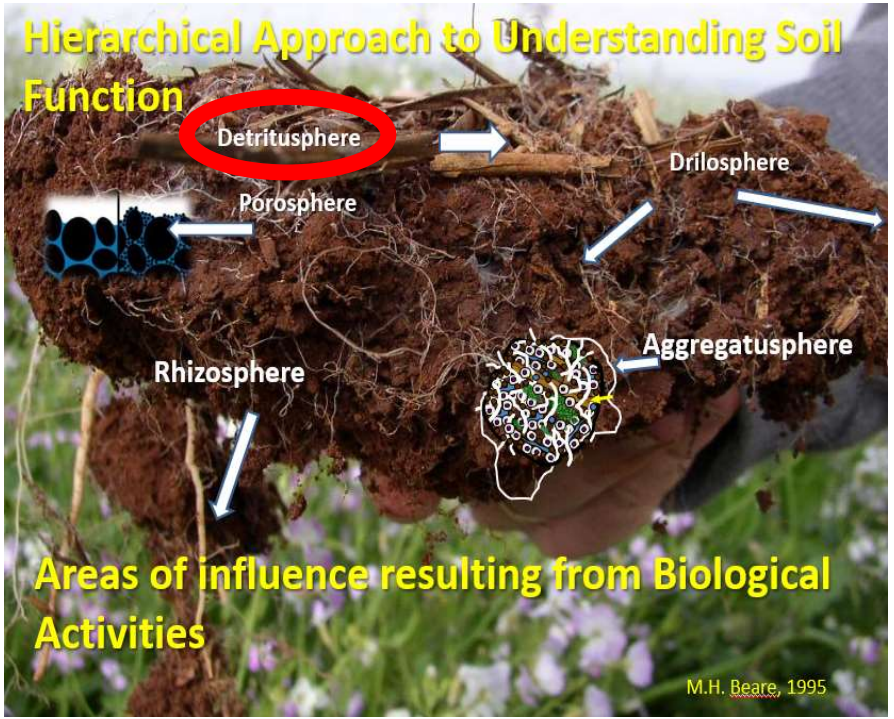
Penn State University

NRCS-USDA



The Detritusphere: Zone of Decay

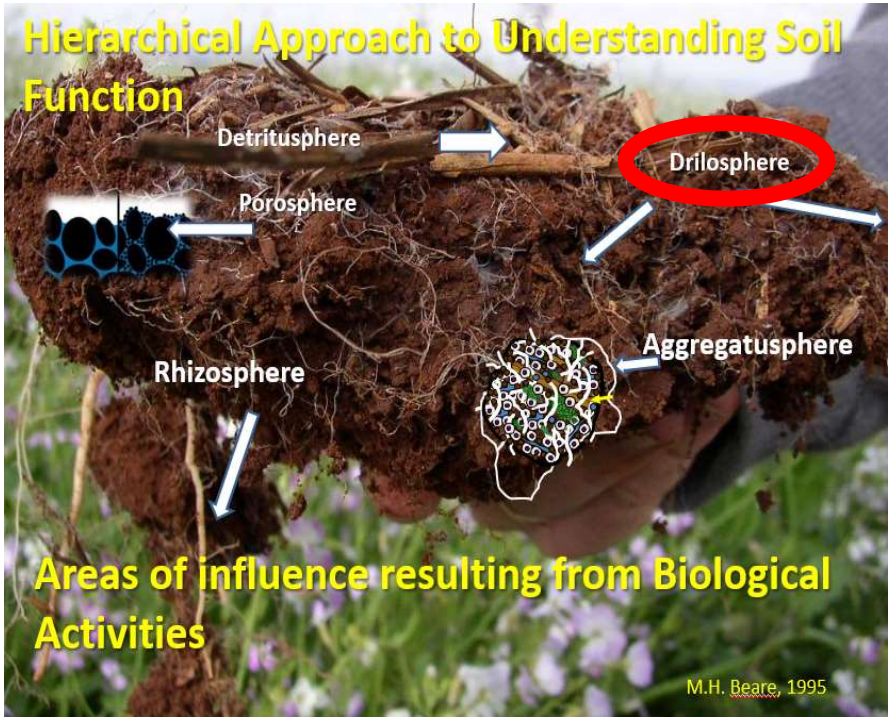
- Protects the soil aggregates (aggratusphere) and pores (porosphere) from sun, wind, and rain
- Lowers temperature
- Reduces evaporation
- Disturbance of layer destroys habitat for soil organisms
- Enhances nutrient cycling



The Drilosphere: Zone of Earthworm Influence

- Redistributes Carbon through the soil profile
- Soils are enriched with N, P, and organic matter
- Increased water infiltration

M.H. Beare, D.C. Coleman, D.A. Crossley Jr., P.F. Hendrix and E.P. Odum (1995)



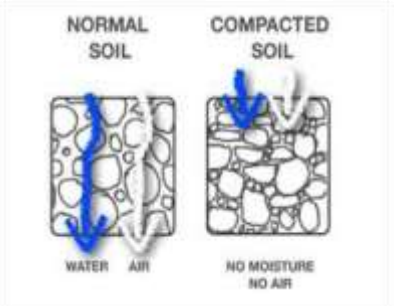
Earthworms

- Poor soils: 250,000 earthworms per acre
- Healthy soils: 1,750,000
- 1 or less per shovel indicates poor soil health
- 10 or more per shovel indicates good soil health
- Burrowing through tunnels forces air in and out of soil
- Earthworm casts contain
  - 11% of the humus
  - 7 times the nitrogen
  - 11 times the phosphorus
  - 9 times the potash **than surrounding soil**

USDA - NRCS

The Porosphere: Arrangement of Solids & Voids

- An aquatic habitat (water films) for protozoa, bacteria, Mycorrhizae, and nematodes
- Regulates water and air flow
- Site of nutrient exchange
- Important part of water cycle
- Poor air exchange leads to anaerobic conditions



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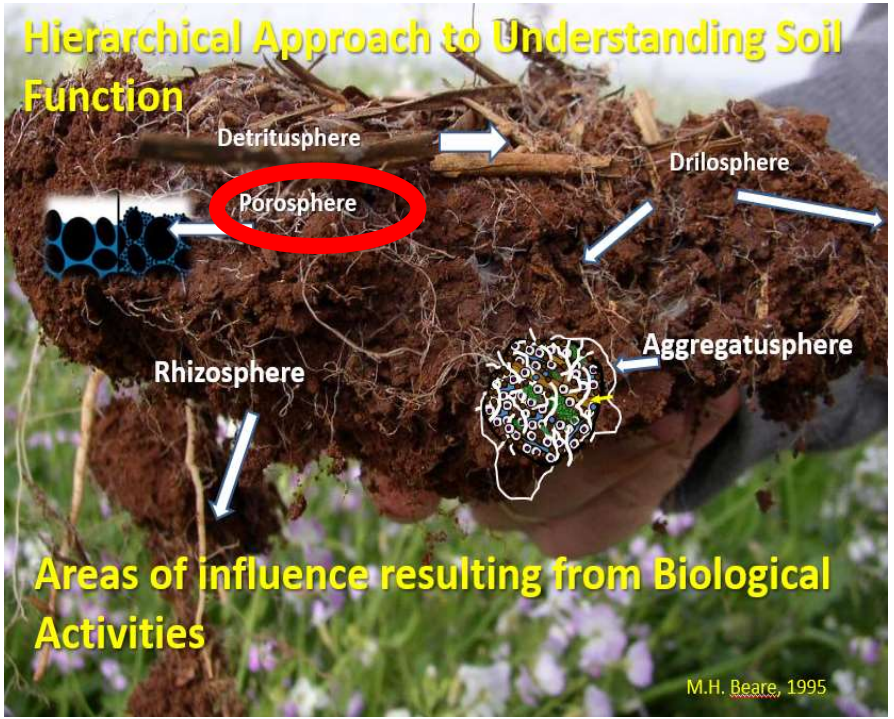


Bacteria

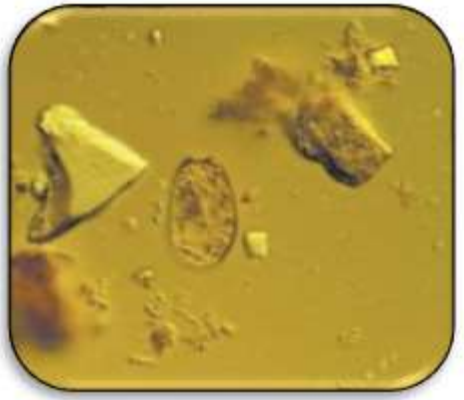
- Decomposition of OM
- Nutrient cycling
- Nitrogen fixation-symbiosis with legume roots
- Nitrification- convert NH4 to nitrates
- Denitrification - nitrates to nitrous oxide gas
- Disease Suppression
- Breakdown of difficult compounds
    - Actinomycetes

Fungi

- Decomposition of OM
- Glomalin secretion develops soil structure
- Extract & Hold Nutrients

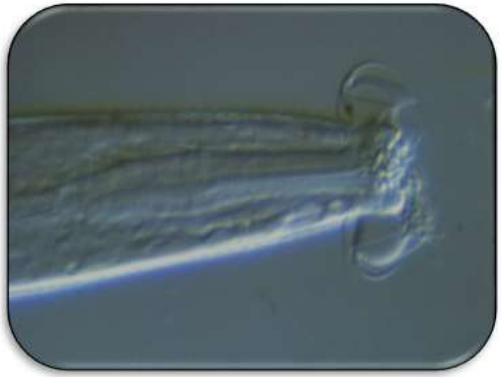
Protozoa

- Nutrient Mineralization
- Regulation of bacterial populations
- Food source themselves

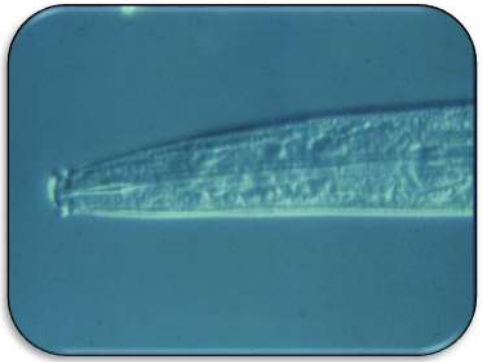


Nematodes

- Control disease
- Cycle nutrients
- Disperse bacteria & fungi



Bacteria feeding nematode

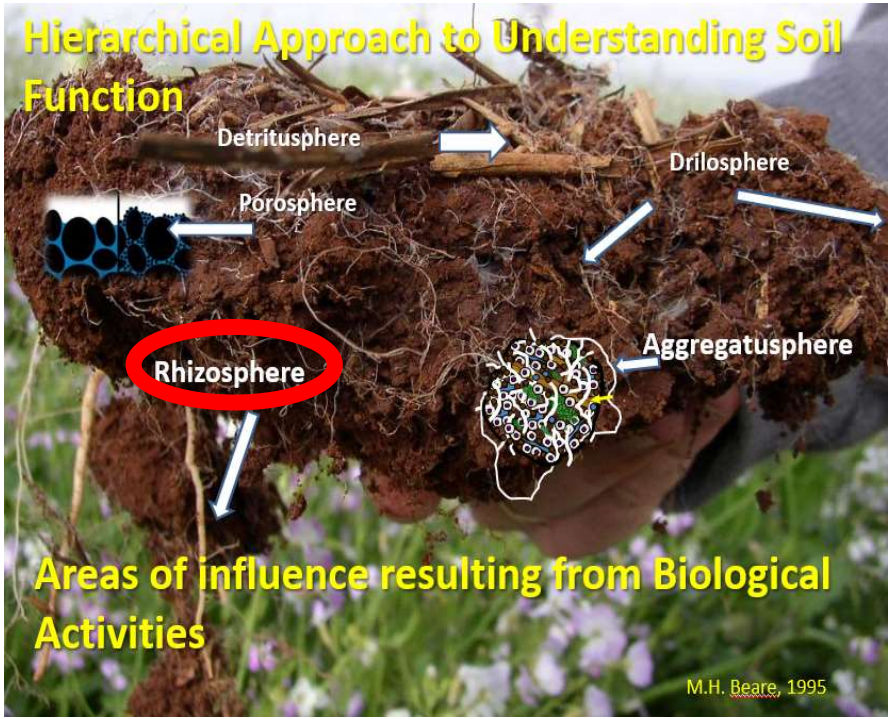


Fungal feeding nematode

M.H. Beare, D.C. Coleman, D.A. Crossley Jr., P.F. Hendrix and E.P. Odum (1995)

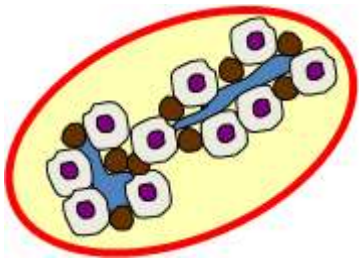
The Rhizosphere: Influenced by Roots

- Narrow region of soil directly around roots
- Living roots release many types of organic materials
- These compounds attract bacteria that feed on the protein & sugars
- Highest biological activity due to the high concentration of photosynthetically derived carbon (~70%) (Zuma,1993)
- Most impacted by aboveground management



The Aggregatusphere: Influence of Soil Aggregates

- Closed Habitat of Micropores
- Protects OM from decay
- Storage site for OM
- Protects & maintains the integrity of the porosphere
- Linked by fungi hyphae & root fibers



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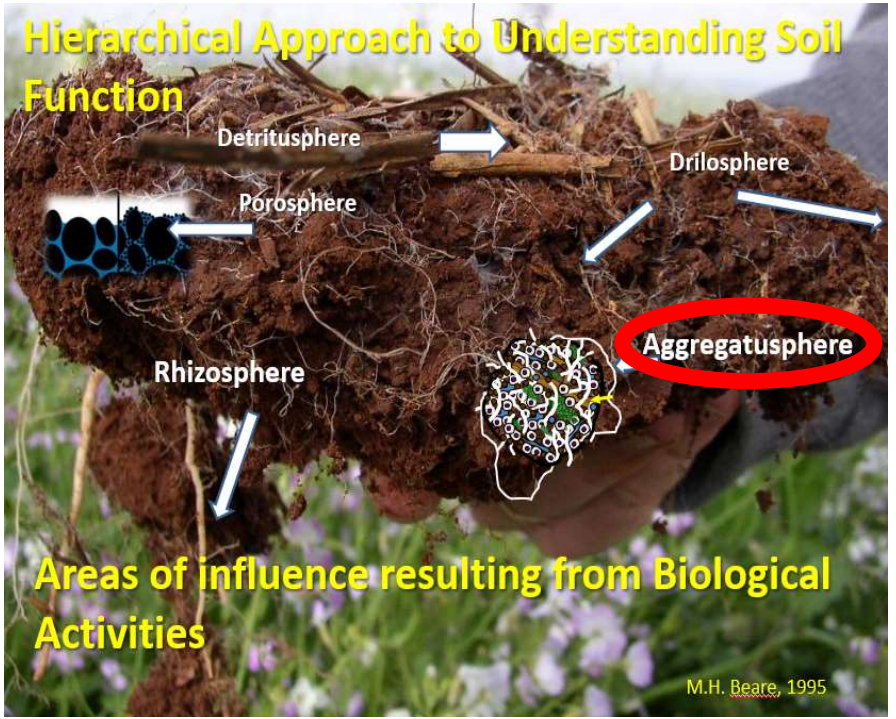
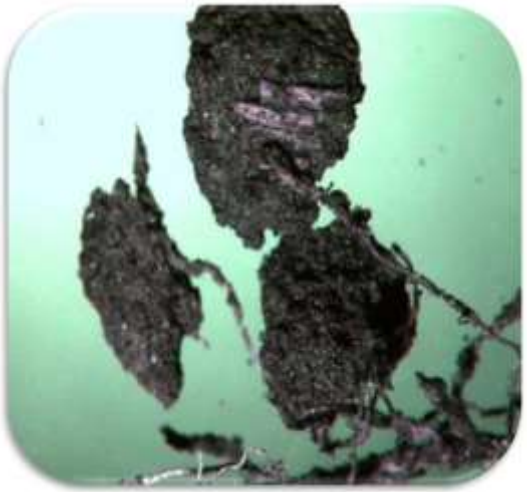
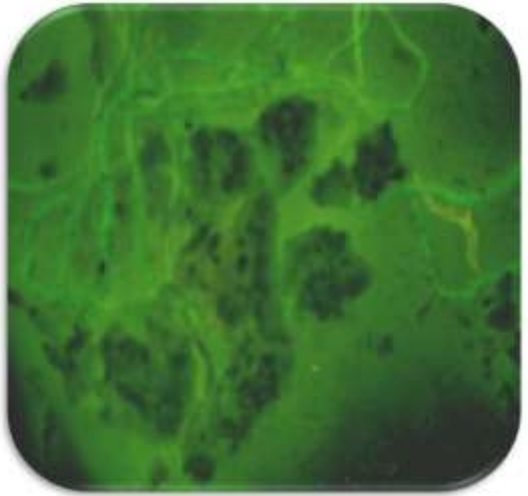


Root and Mycorrhizal Fungi Association



Enlarged Soil Aggregates



Glomalin and Hyphae
Biotic Glues

Dr. Kris Nichols, Microbiologist,ARS

Root and Mycorrhizal Fungi Association

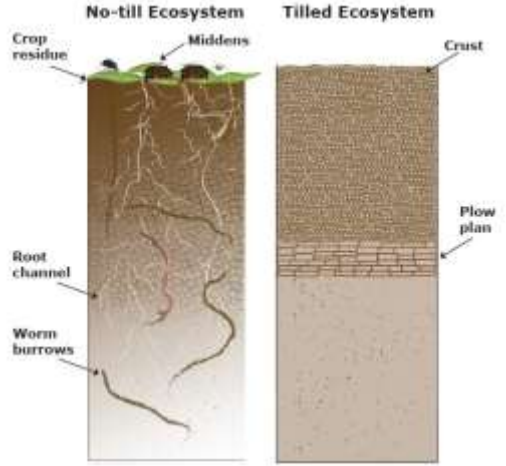
- Round bodies are spores
- Threadlike filaments are hyphae
- Hyphae can grow (1 -2 in) beyond roots to access nutrients
- Hyphae coated in glomalin, revealed by a green dye
- Glomalin is produced to keep water & nutrients from getting lost on the way to & from the plant

Mycorrhizal Fungi growing on a corn root

Dr. Kris Nichols, Microbiologist,ARS

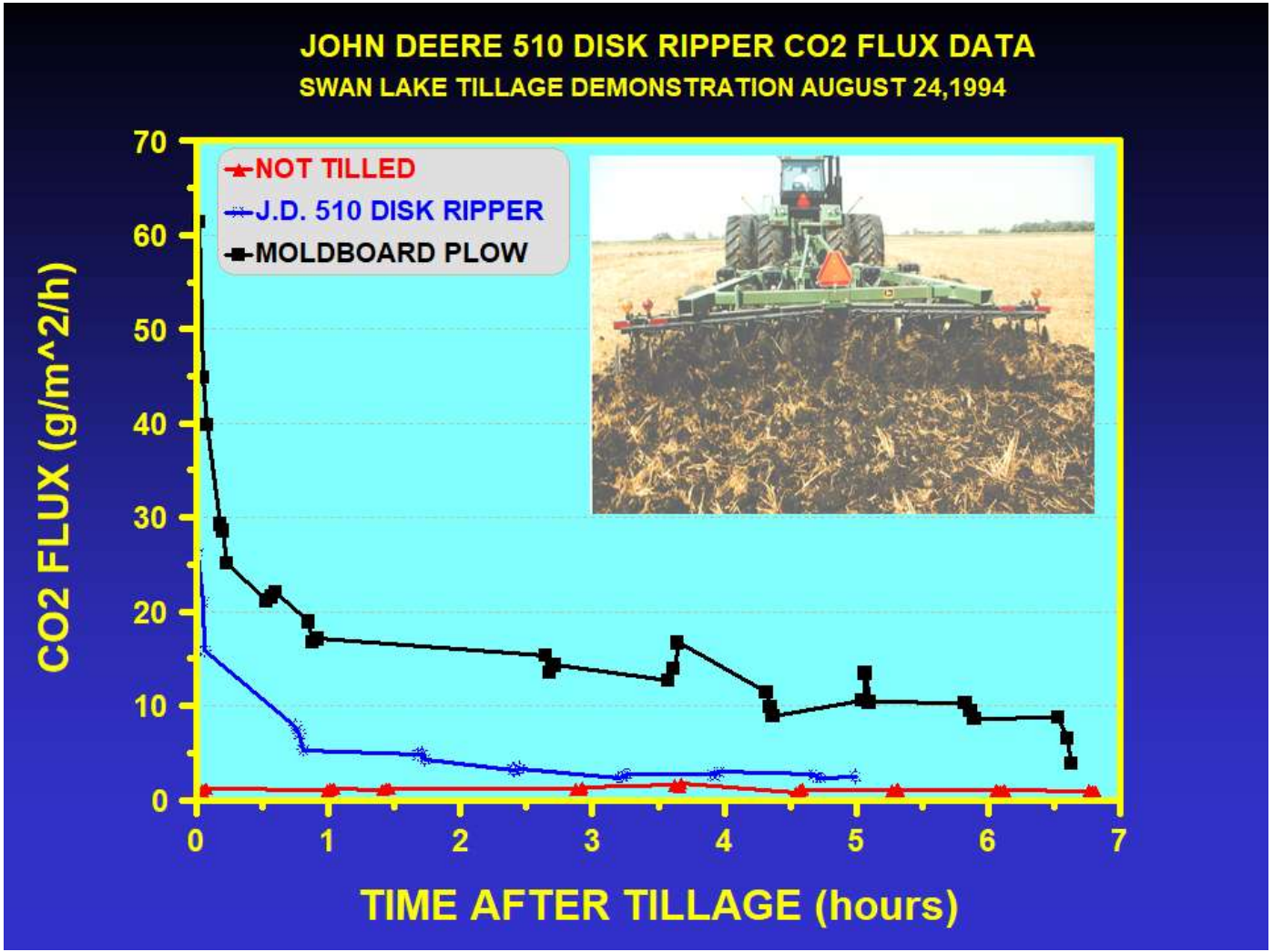
5 Key Principles of Soil Health

1. Least Amount of Disturbance As Possible



The entire soil profile will be modified when you use continuous no-till. The surface will be covered by mulch, granular aggregates, and earthworm middens. The topsoil will have a granular structure that gradually turns into a blocky structure with depth. The soil matrix is firm and yet the soil is perforated with thousands of pores created by roots, fungal hyphae, surface and deep-dwelling earthworms, and many other types of organisms. Old root channels and earthworm burrows leave pores that are continuous from the surface deep into the subsoil.

USDA-NRCS


JOHN DEERE 510 DISK RIPPER CO2 FLUX DATA
SWAN LAKE TILLAGE DEMONSTRATION AUGUST 24,1994
NOT TILLED
J.D. 510 DISK RIPPER
MOLDBOARD PLOW
CO2 FLUX (g/m^2/h)
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
TIME AFTER TILLAGE (hours)

No-Till Advantages

- Increased water infiltration
- Increased organic matter
- Better soil aggregation
- Adequate residue on surface
- Reduction of wind & water erosion
- Increased microbial life
- Reduction of fuel, labor, & maintenance

The plow is one of the most ancient and most valuable of man’s inventions; but long before he existed the land was in fact regularly ploughed, and continues to be thus ploughed by earthworms.

-Charles Darwin, 1881

No-Till Disadvantages

- Lack of weed suppression, although all tillage eventually results in more weeds which often results in increased applications of herbicides.
- Can slow warming of soils in spring, but warming can be overcome by having a crop rotation with the correct carbon:nitrogen ratios.

Same Soils: Dynamic Soil Properties Changed!

62.8% loss of SOM after 17 yr intensive tillage

Gabe Brown

2. Armor on the Soil

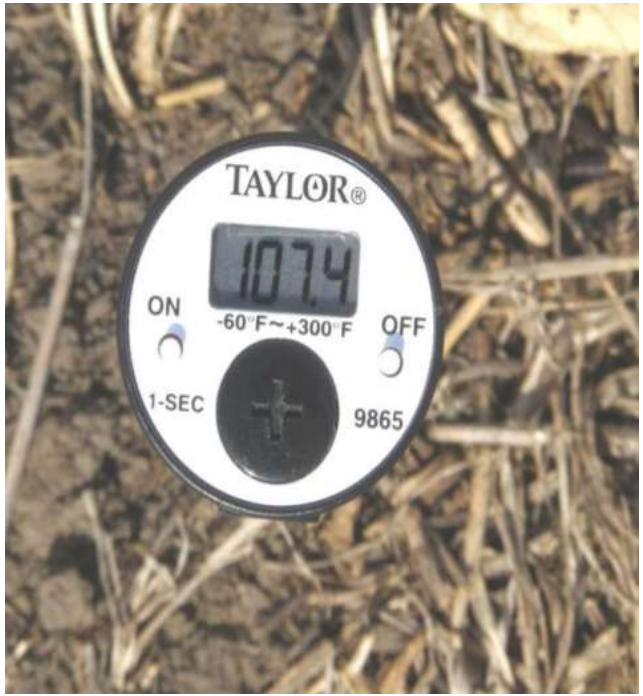
- Buffers drought, heat, and cold
- Covers can feed livestock & microbes
- Buffers soil temperatures
- Protects bare soil from sprouting weeds
- Limits impact of raindrops
- Diverse mix of plants will release root exudates (sugars) to feed microbes that are create soil aggregations (glues)

University of Nebraska - Lincoln - Cropwatch

Conventional Soil Ecosystem

This soil is naked, hungry, thirsty, and running a fever! - Ray Archuleta, 2007

Soil Temperature: Bare vs. Covered Soil



NRCS-USDA

When soil temperature reaches...

140 F Soil bacteria die

130 F 100% moisture is lost through evaporation and transpiration

113 F Some bacteria species start dying

100 F 15% of moisture is used for growth
85% moisture lost through evaporation and transpiration

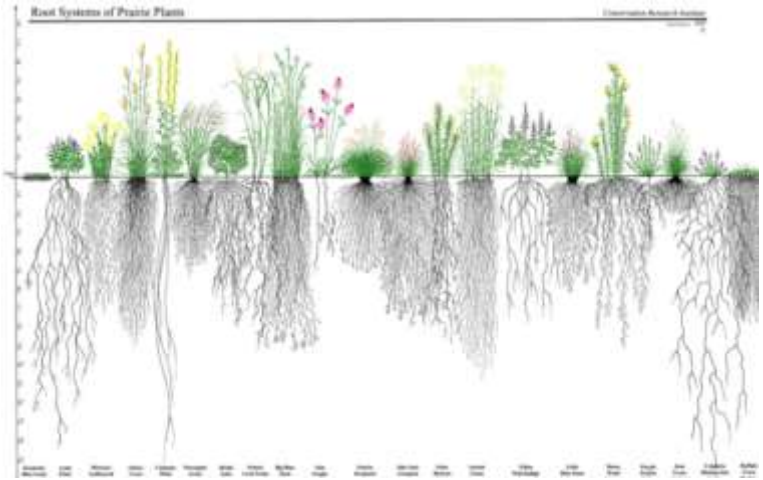
95 F

70 F 100% moisture is used for growth

J.J. McEntire, WUC, USDA SCS, Kernville TX, 3-58 4-R-12198, 1956

3. Diversity

- Diverse crop rotations in planned sequences takes advantage of the power of diversity and reduces overall risk.
- Goal is to mimic the natural water & nutrient cycle, while maximizing the amount of sunlight captured.
- Recent interest in diversifying crops is due to commodity prices that are low relative to costs of fertilizer, machinery, labor, and pesticide inputs.
- Diverse plant populations provide a much more diverse diet of root exudates for soil microbes.



Conservation Research Institute


Diversity Drives Soil Health!
Kansas State University

Cover Crop Cocktails

- In 2006, Dr. Ademir Calegari proposed that cover crops should be seeded as multi-species cocktails.
- In his trial, the six-species blend yielded two to three times as much biomass as the single-species cover crops.

2006 Burleigh Co. ND

Turnip July 31

Oilseed Radish July 31

Cover Crop Mix July 31

Production On District Plot

- Oilseed Radish 1260 Lbs.
- Purple Top Turnip 1513 Lbs.
- Pasja Turnip 2070 Lbs.
- Soybean 1496 Lbs.
- Cowpea 1914 Lbs.
- Lupin 1232 Lbs.
- Cocktail Mix (1/2 Rate) 4785 Lbs.
- Cocktail Mix (Full Rate) 4350 Lbs.

Brown’s Ranch Residue on Same Field

June 16, 2009
Corn planted into previous years’ cover crop residue

July 1, 2009
Rapid residue decomposition

Managing Cover Crops to Feed Soil Microorganisms

- Soil microorganisms have C:N ratio near 8:1, but to stay alive microbes need a diet with C:N ratio near 24:1
- Higher C:N
    - Microbes don’t get enough N, results in tying up N
    - Residue doesn’t compose
    - Accumulates on surface
    - Microbe populations decline
  - Lower C:N
    - Microbes get excess N, results in N being available
    - Residue decomposes quickly
    - Microbe population explodes, then dies off
  - Balance C:N Ratios with Cover Crops

C:N Ratios for Various Crops

Material	C:N Ratio
rye straw	82:1
wheat straw	80:1
oat straw	70:1
corn stover	57:1
rye cover crop (anthesis)	37:1
pea straw	29:1
rye cover crop (vegetative)	26:1
mature alfalfa hay	25:1
Ideal Microbial Diet	**24:1**
rotted barnyard manure	20:1
legume hay	17:1
beef manure	17:1
young alfalfa hay	13:1
hairy vetch cover crop	11:1
soil microbes (average)	8:1

slower

Relative Decomposition Rate

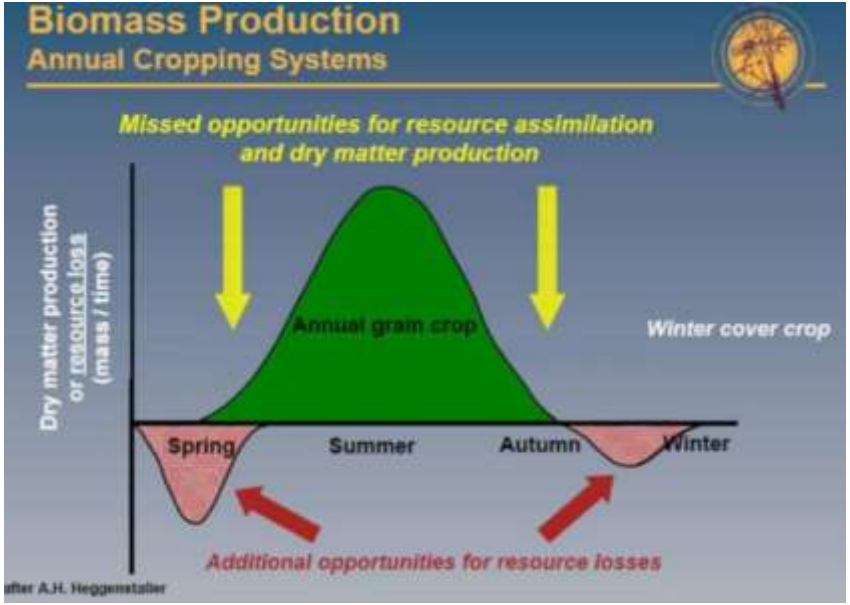
faster

- A low C:N ratio cover crop containing legumes and/or brassicas can follow a high C:N ratio crop such as corn or wheat, to help those residues decompose, allowing nutrients to become available to the next crop.

- Similarly, a high C:N ratio cover crop that might include corn, sorghum, sunflower, or millet can provide soil cover after a low residue, low C:N ratio crop such as pea or soybean, yet decompose during the next growing season to make nutrients available to the following crop.

4. Living Root as Often as Possible

- Living root will feed the soil microbes through carbon-rich root exudates
- When crop rotations only consist of annual monocultures, the microbes are only being fed for 3-4 months out of the year.
- Living roots trade their carbon-rich root exudates to soil microbes in exchange for plant nutrients.



The more photosynthesis, the more carbon!

No Till Farmer

Cover Crops: Design for what you DON’T have

Resource Concerns

- Provide crop diversity
- Provide soil surface armor
- Build soil aggregates
- Improve the water cycle
- Integrated Pest Management
- Build soil organic matter
- Nutrient cycling
- Enhance pollinators
- Adjust carbon/nitrogen ratios
- Wildlife winter food & shelter
- Livestock integration

Cover Crop Species

Non Legume
Annual Ryegrass
Barley
Buckwheat
Oats
Pearl Millet
Sorghum-Sudangrass
Sudangrass
Triticale
Sunflower

Brassicas
Radish
Rapeseed/Canola

Legumes
Cowpea
Forage Soybean
Hairy Vetch
Sunnhemp
Sweet Clover
Winter Pea

K-STATE Research and Extension

Why Diversity in Cover Crop Mixes?

- If SOIL HEALTH is the goal, crop diversity cannot be ignored or overstated.
- Plants created to grow in diverse ecosystems
- Resilience comes from diversity
- Balanced “diet” for soil biologicals
- Need balance because even good things (legumes + brassicas) in EXCESS can be harmful

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)

5. Livestock Integration

- Bison and other ruminants roamed the land centuries ago.
  - Grazed on the move, causing plants to release root exudates to attract biology needed for regrowth
    - Plants had ample time to recover, thus pumping large amounts of carbon into system.
- Integrating Livestock properly can aid in nutrient cycling
  - 85% of the nutrients consumed during grazing are returned to the field in the form of manure and urine.
  - Nutrients are distributed through rotational grazing management strategies.

Iowa State University Extension


You can't go back and
change the beginning,
but you can start where
you are and change
the ending.
C.S. LEWIS

We cannot do this alone. We need your help to join in and draft the best story of agriculture yet or someone will tell our story for us. The future of conservation needs you. We have both an obligation and opportunity to enable the next generation to be informed leaders, equipped with the knowledge and skills to manage natural resources with the future in mind.

I challenge you to go out on your farm and OBSERVE. Thank you.

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NRCS-USDA