Understanding Soil Health

Farming in the 21st Century

a practical approach to improve

Soil Health

Steve Woodruff

Agronomist

ENTSC

Why in Now?

- World population is estimated to be at 9.1 billion by 2050
- To sustain this level of growth, food production will need to rise by 70 percent
- Between 1982-2007, 14 million acres of prime farmland in the U.S. was lost to development
- Energy demands
  - Increase use of biofuels (40% of corn used for ethanol)
  - Increase use of fertilizer (use of Anhydrous up 48%, Urea up 93%)


Erosion from bare fields
5/2007


Lubbock Texas Oct.
17,2011

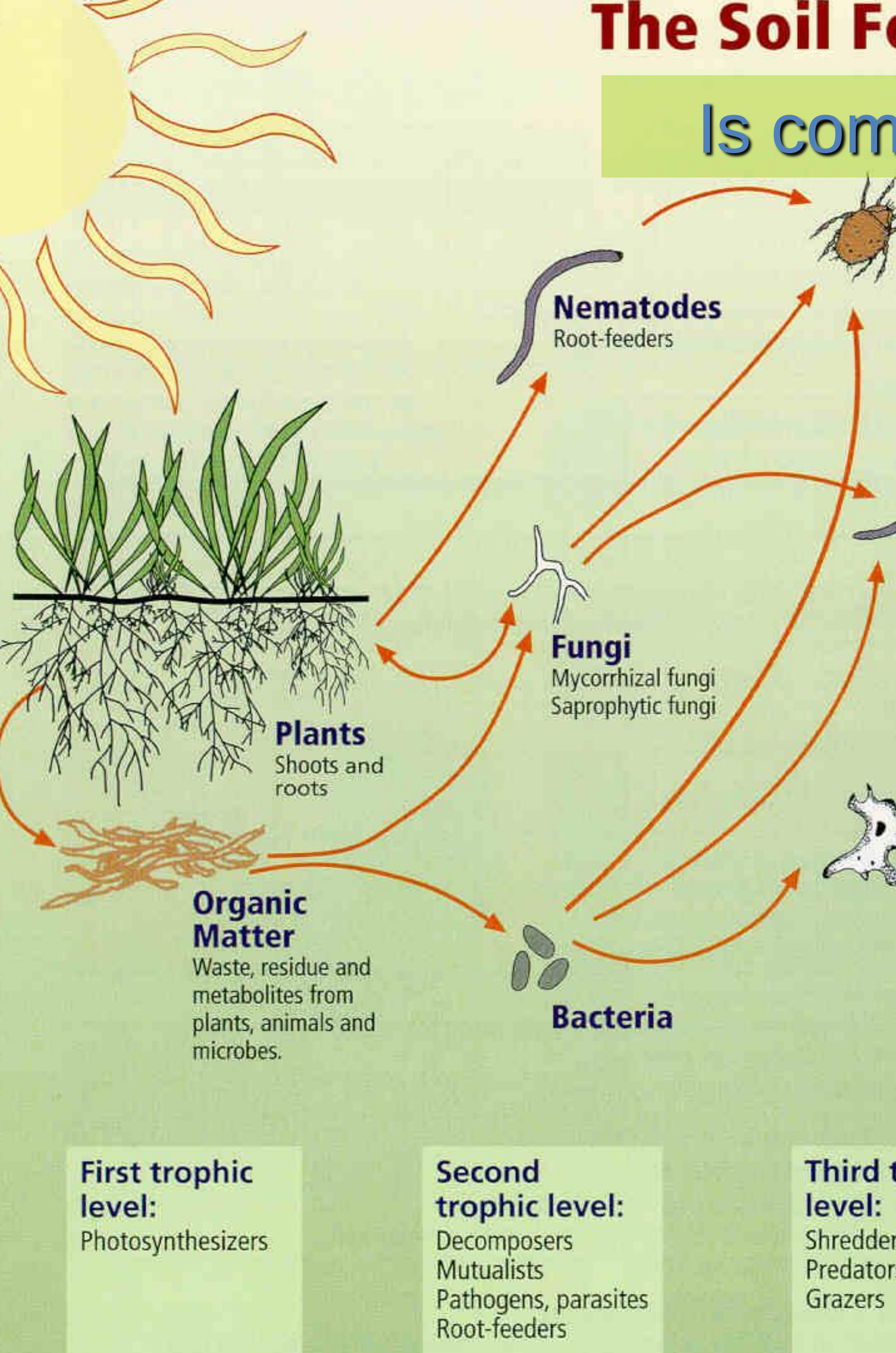

Is the Buffer working?
6 /2007


Lubbock Texas Oct.
17,2011

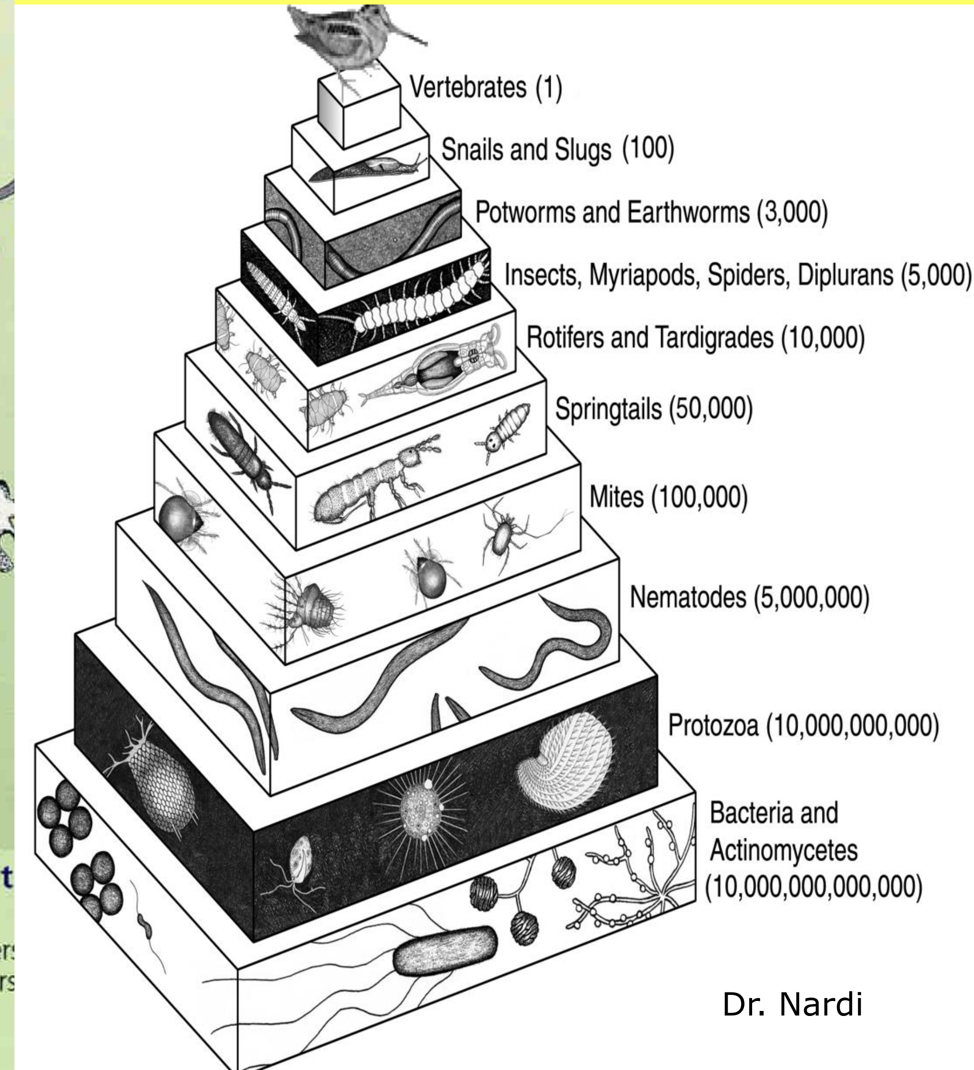
Soil Health What is It?

- The continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans
  - Nutrient cycling
  - Water (infiltration & availability)
  - Filtering and Buffering
  - Physical Stability and Support
  - Habitat for Biodiversity

Is complex



Every trophic level must function for the soil food web to function!



Dr. Nardi

Soil is a Living Factory

- Macroscopic and microscopic organisms
  - Food
  - Water
  - Shelter
  - Habitat
  - Powered by sunlight

- Management activities improve or degrade soil health
  - Tillage
  - Fertilizer
  - Pesticides
  - Grazing
  - Plant Diversity

What can Soil Organisms Do ?

- Improve Soil Aggregation/Strength
- Improve Water Holding capacity
- Improve Nutrient Cycling
- Improve Infiltration
- Reduce pest problems

growth

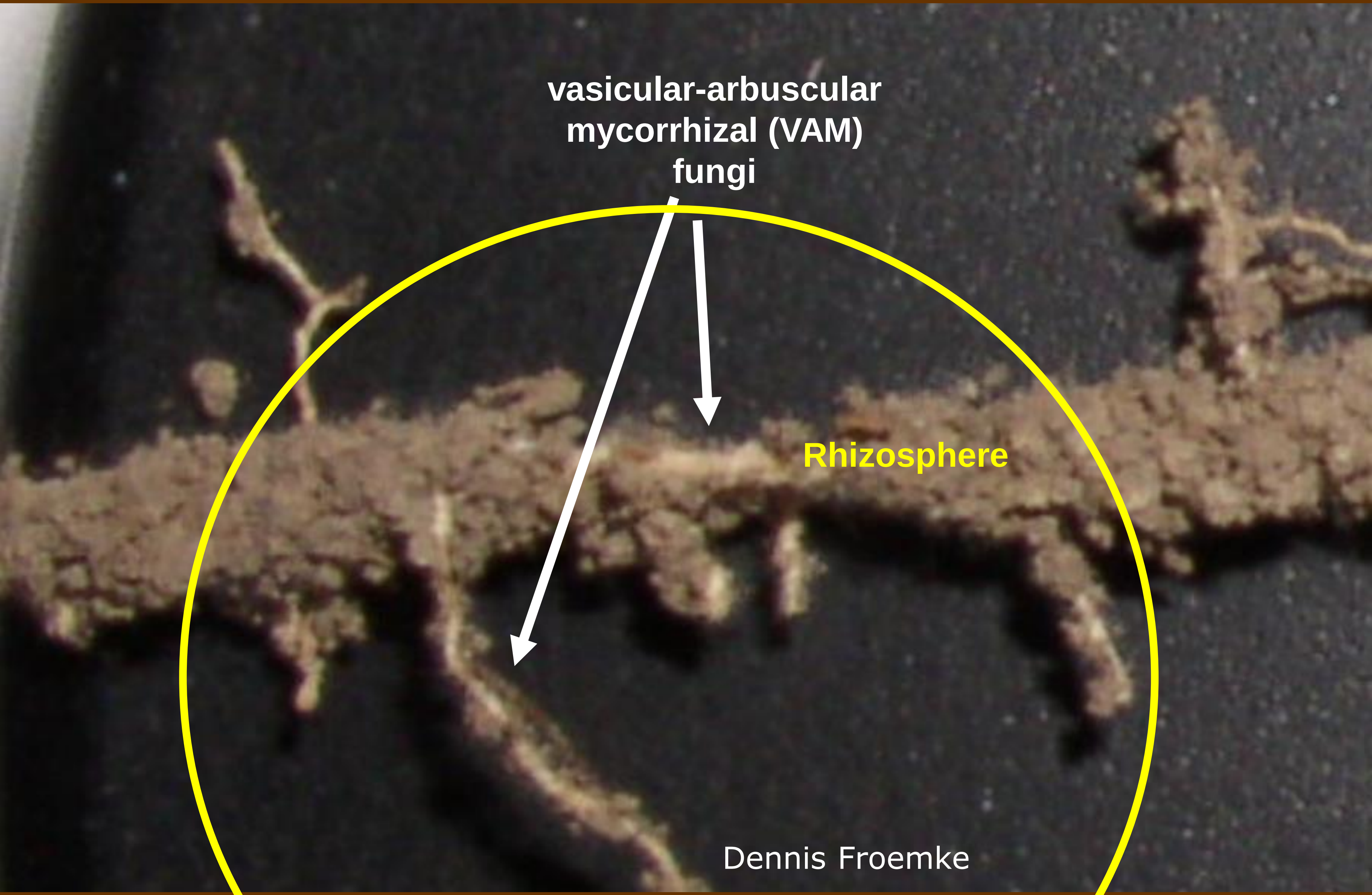
Typical Numbers of Soil Organisms in Healthy Ecosystems

	Crop Land	Prairie	Forest
	Organisms per gram (teaspoon) of soil		
Bacteria	100 mil. -1 bil.	100 mil. -1 bil.	100 mil. -1 bil.
Fungi	Several yards	10s – 100's of yds	1-40 miles (in conifers)
Protozoa	1000's	1000's	100,000's
Nematodes	10-20	10's – 100's	100's
	Organisms per square foot		
Arthropods	< 100	500-2000	10,000-25,000
Earthworms	5-30	10-50	10-50 (few in conifers)

growth

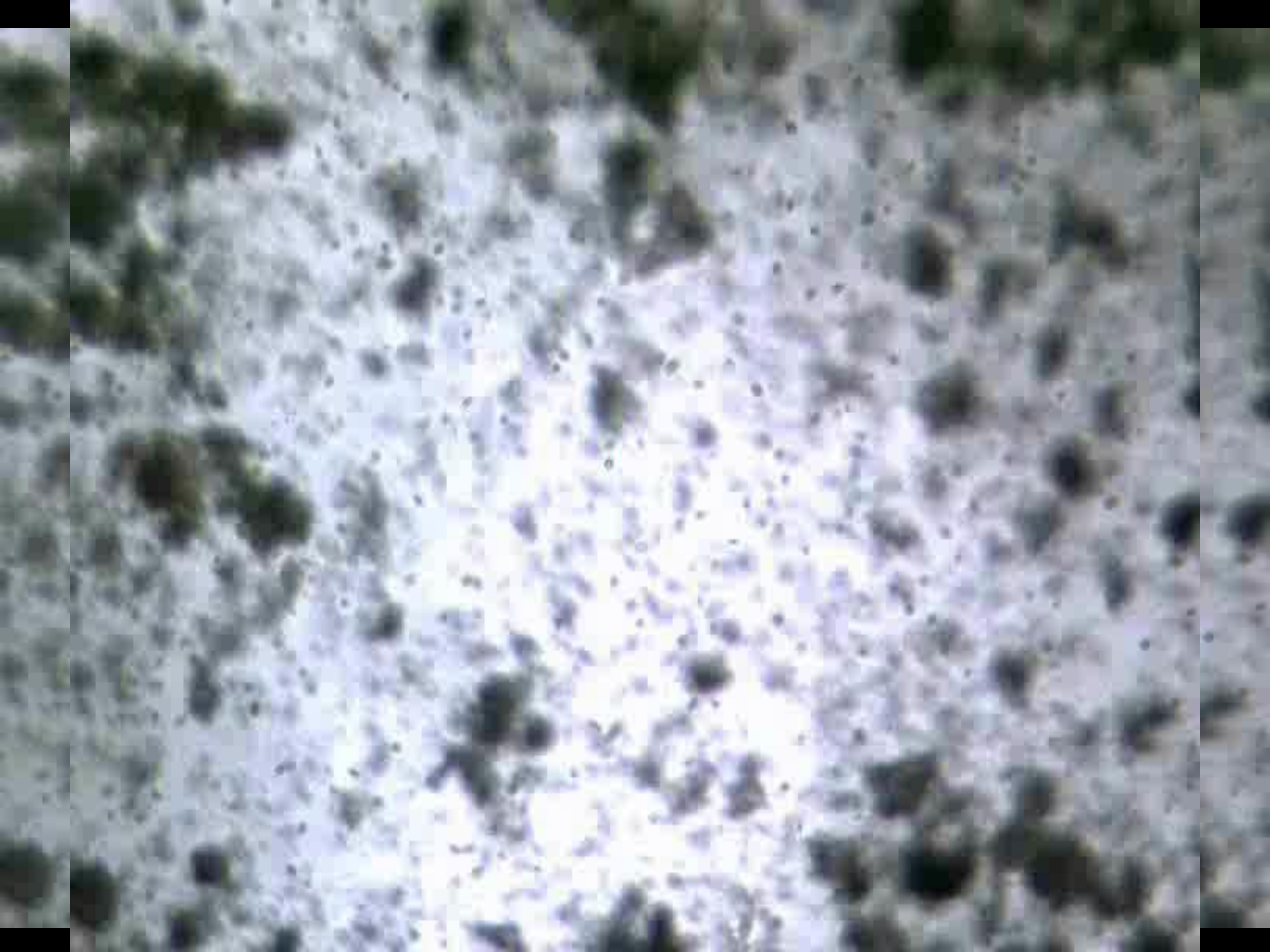
Fantastic Voyage into the Rhizosphere


Dennis Froemke
ND Area Range Specialist



Dennis Froemke

ND Area Range Specialist



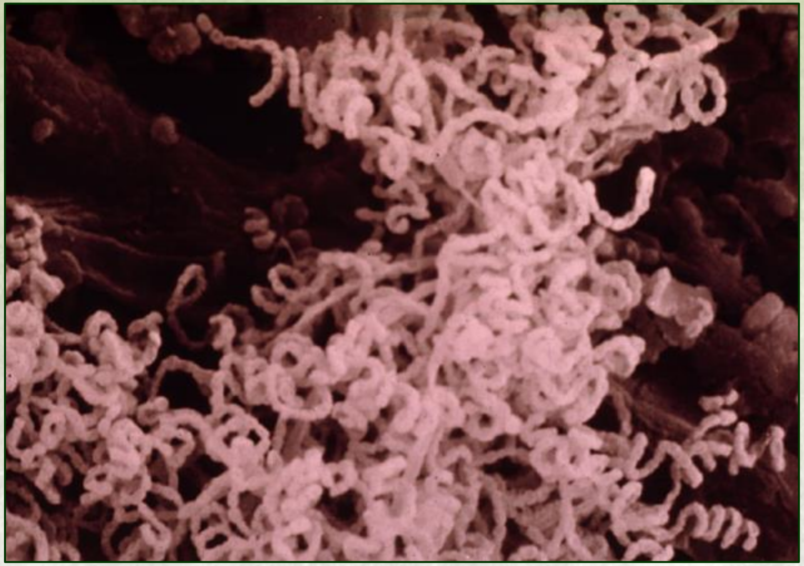
Rhizosphere
Where Roots Meet Soil

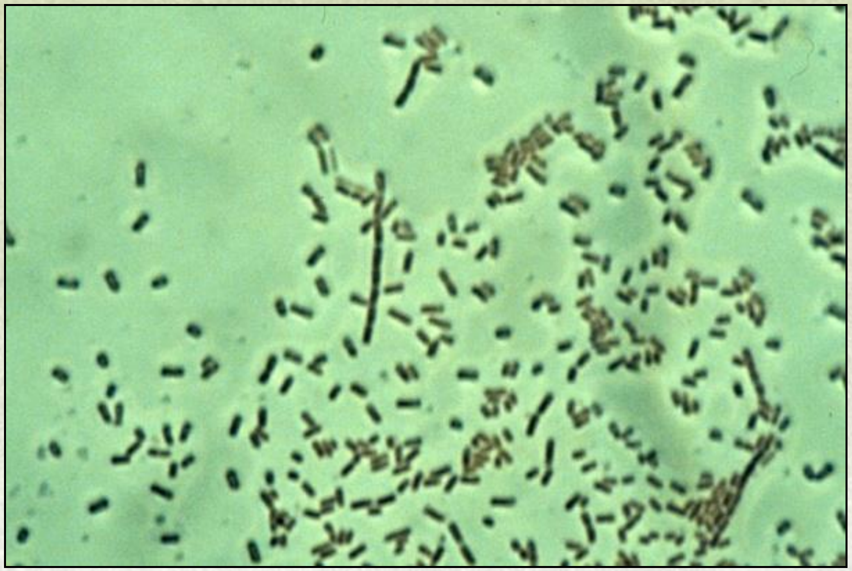
Zone of Concentrated Biological Activity

- Bacteria
- Fungi
- Protozoa
- Nematodes

BACTERIA - Functions

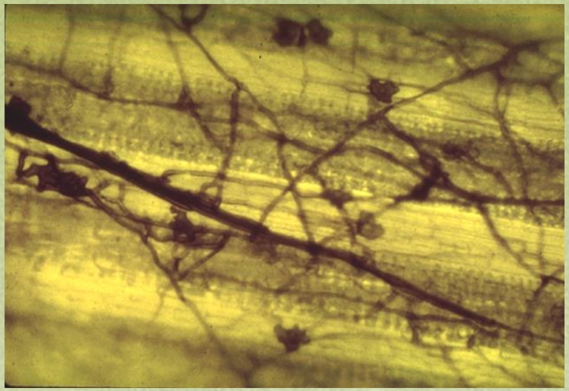
- Decompose Organic Matter
- Keeps Nutrients in the Root Zone and Out of Water
- Enhance Soil Structure by making some “glues”
- Competes with Disease Causing Organisms
- Filters and Degrades Pollutants
- Actinombacteria (filamentous bacteria) – Soil Smell
- Feed other members of the food web (Prey)





Fungi - Functions

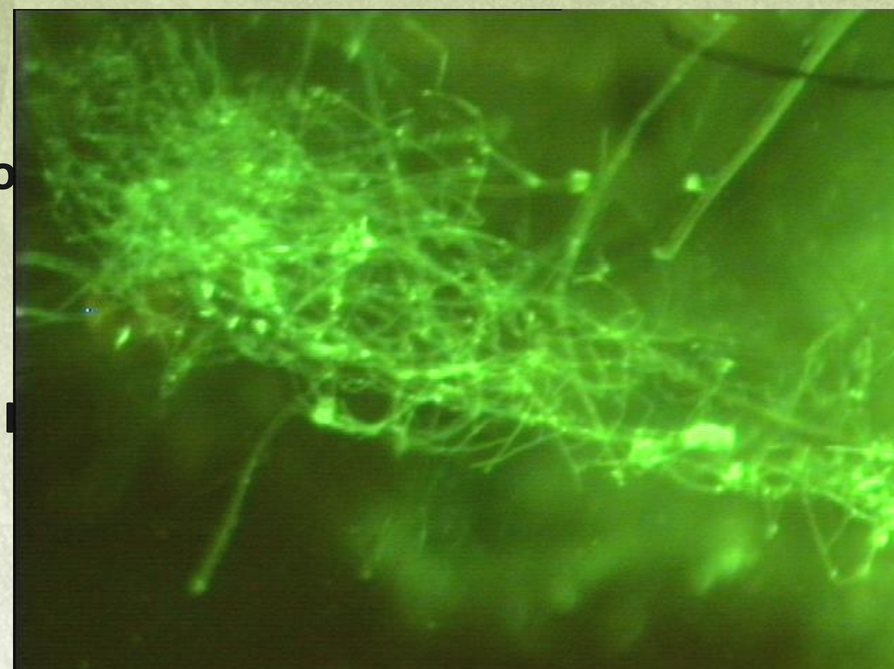
- Decompose carbon compounds
- Improve OM accumulation
- Retain nutrients in the soil
- Bind soil particles with Glomalin
- Mycorrhizal fungi – Associate with Plants
- Compete with plant pathogens
- Food for the rest of the food web



What is GLOMALIN?

- **Glycoprotein (Sugar Protein)**
  - **4-6% sugar**
- **Coats and protects hyphae**
- **Heat and enzymatically stable**

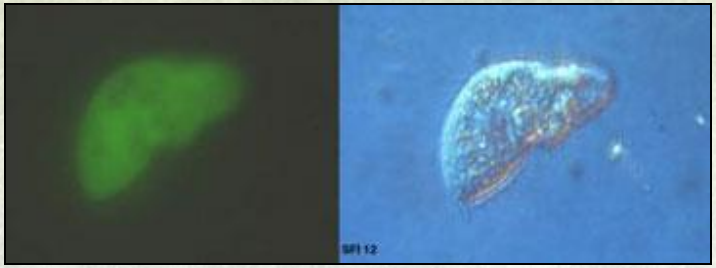
Hyphae from a pot culture of *Gi. gigantea* at 90X under bright field.

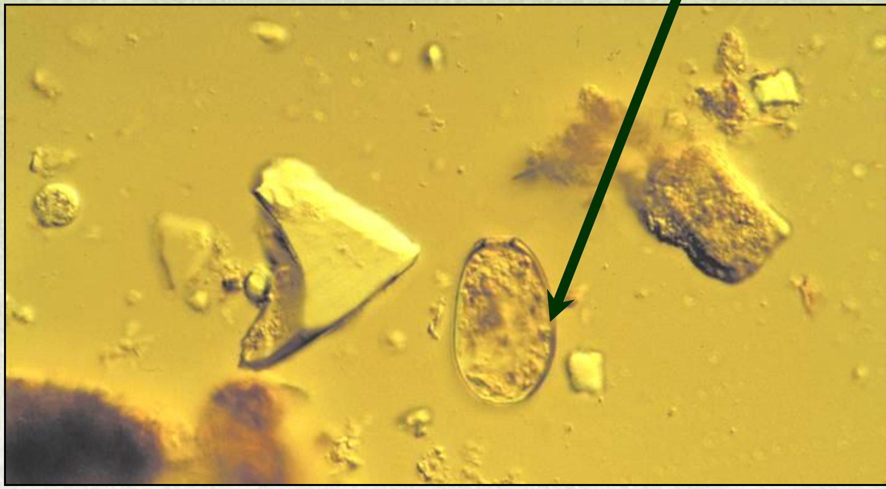


Same picture, except under fluorescence.

PROTOZOA-(Predator) Flagellates-Amoebae-Ciliates

- Single Celled Animals
- Feed on Bacteria and Release Nutrients (N)
- Increase Decomposition Rates
- Food Source for Other Soil Organisms
- Prevent some Pathogens From Establishing on Plants
- Need Soil Moisture to Move



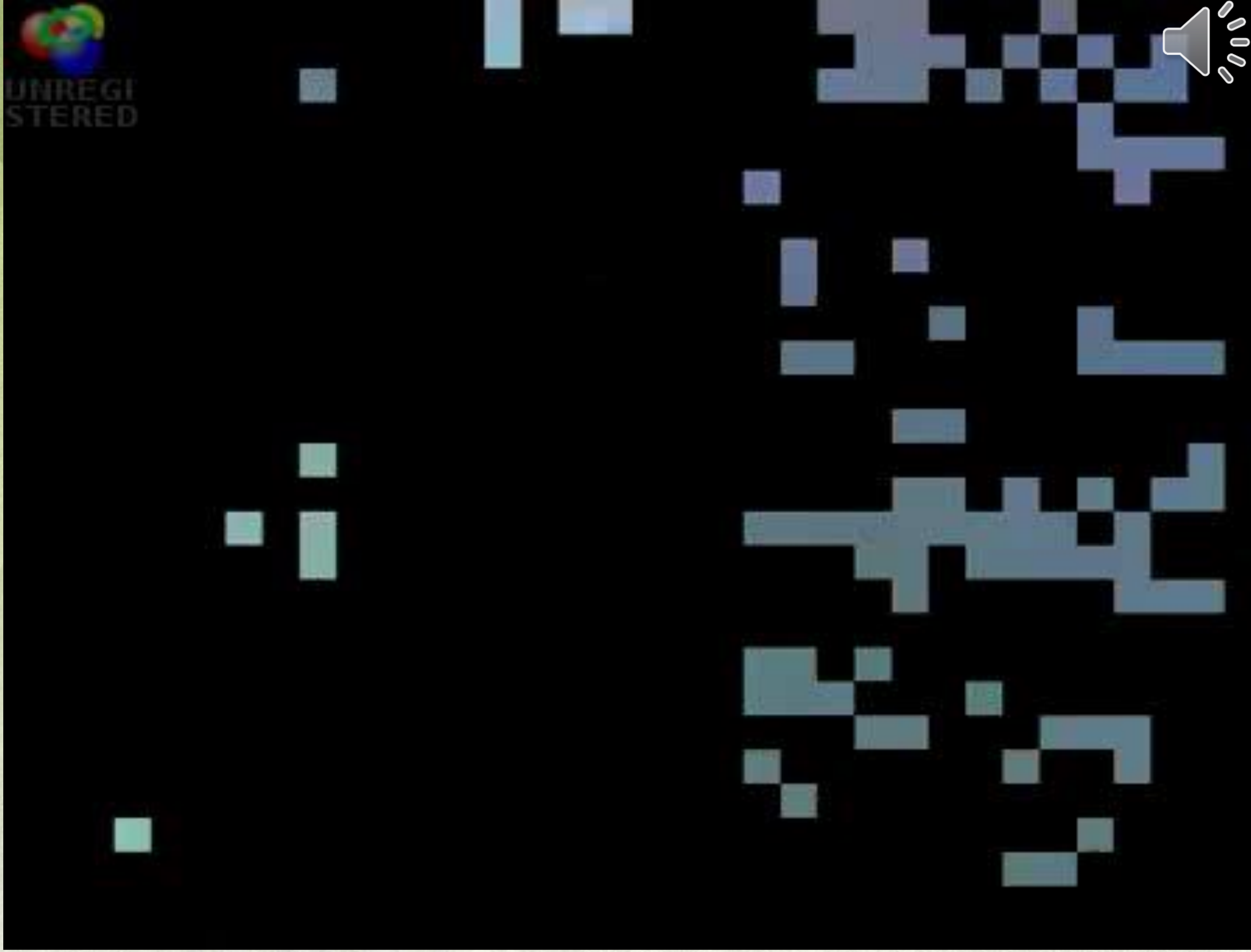


NEMATODES

Non-Segmented Worms

Most are Good for the Soil and Plants

- Regulate Populations of Other Organisms
- Mineralize Nutrients into Plant-Available Forms
- Consume Disease Causing Organisms
- Distribute Bacteria and Fungi Through the Soil Along Plant Roots
- Provide a Food Source for Other Organisms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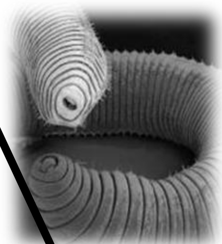
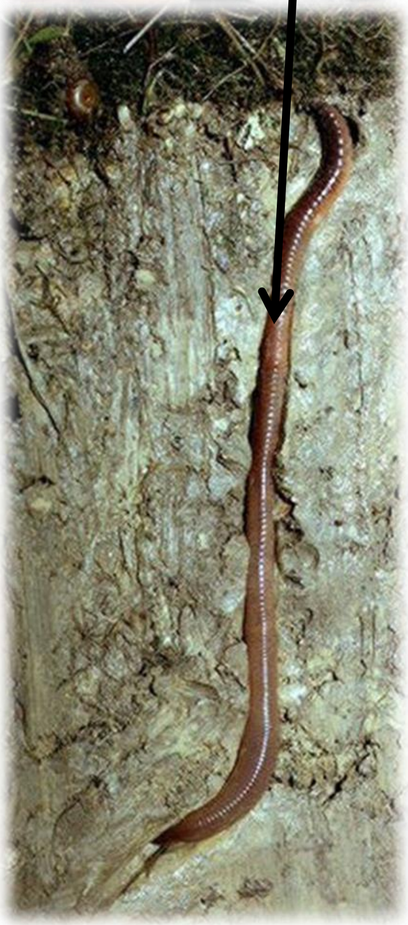
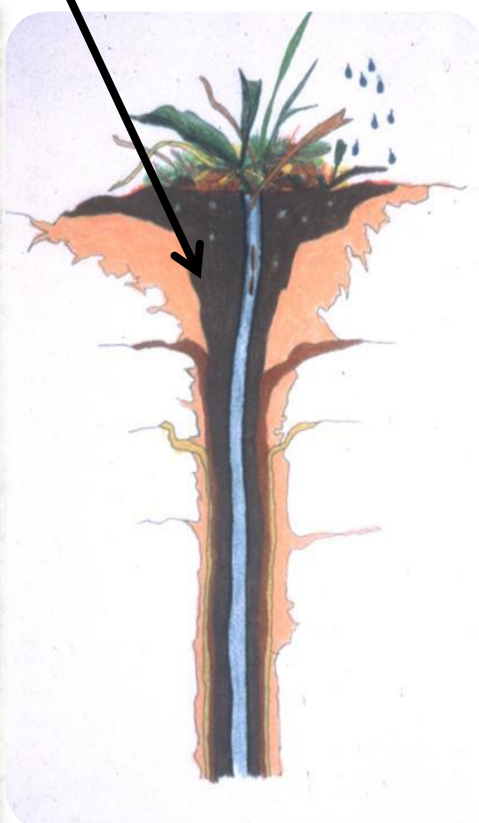
Drilosphere: Zone of earthworm influence



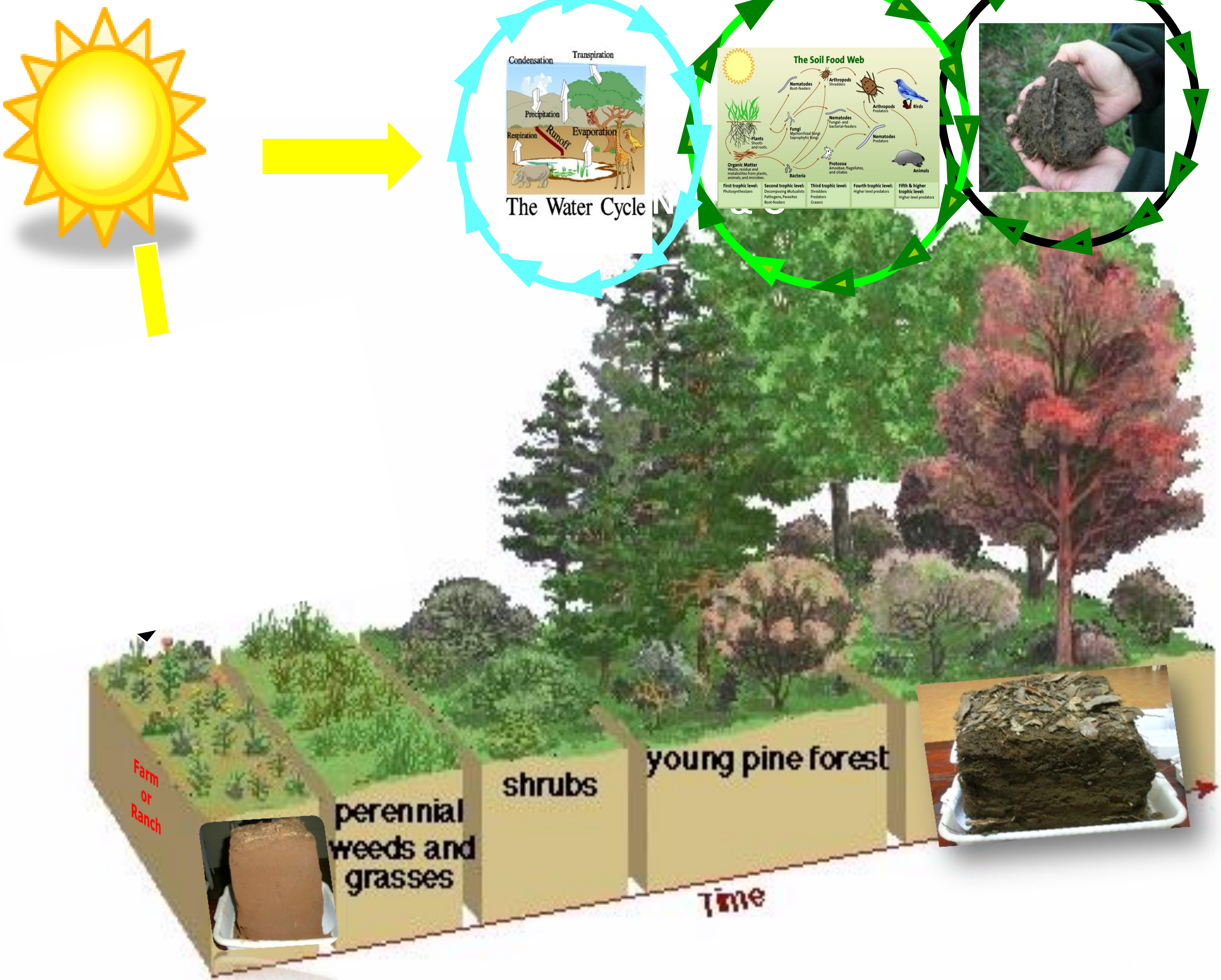




- Redistributes plant litter "Carbon" throughout the soil the profile
- Soils are enriched with N,P, and humified organic matter
- Increase water infiltration
- Provide a bio pore for plant roots
- Homogenize soil surface
- Increase bio-diversity in soils

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

Nature's residue managers


Condensation
Transpiration
Precipitation
Runoff
Respiration
Evaporation
The Water Cycle
The Soil Food Web
Farm
or
Ranch
perennial
weeds and
grasses
shrubs
young pine forest
Time

Soil Health
Planning Principles

- Manage more by Disturbing Soil Less
- Use Diversity of Plants to add diversity to Soil Micro-organisms
- Grow Living Roots Throughout the year
- Keep the Soil Covered as Much as Possible

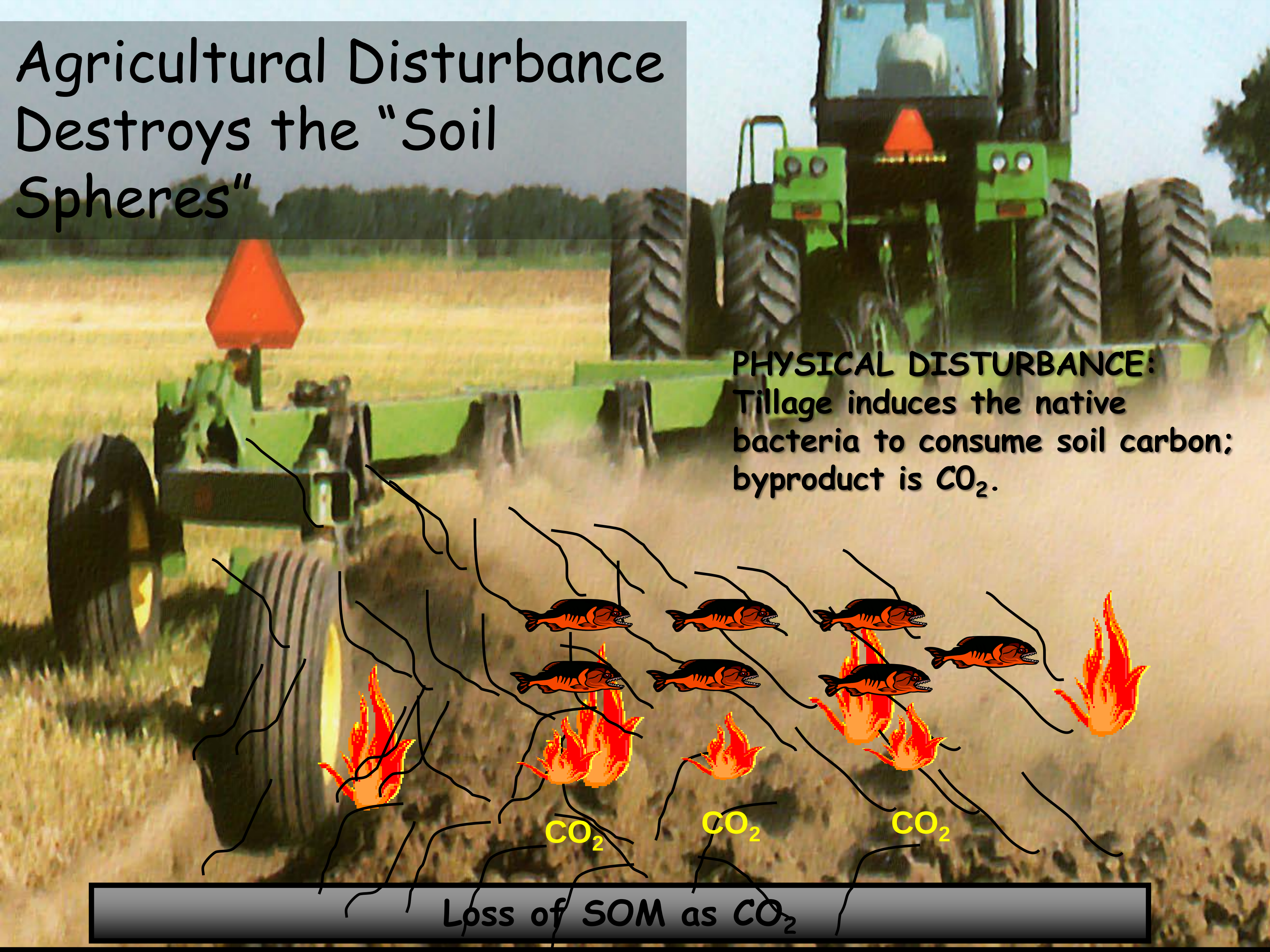
Goal: To create the most favorable habitat possible for the soil food web

Disturbance: What things change when you stop tilling the soil?

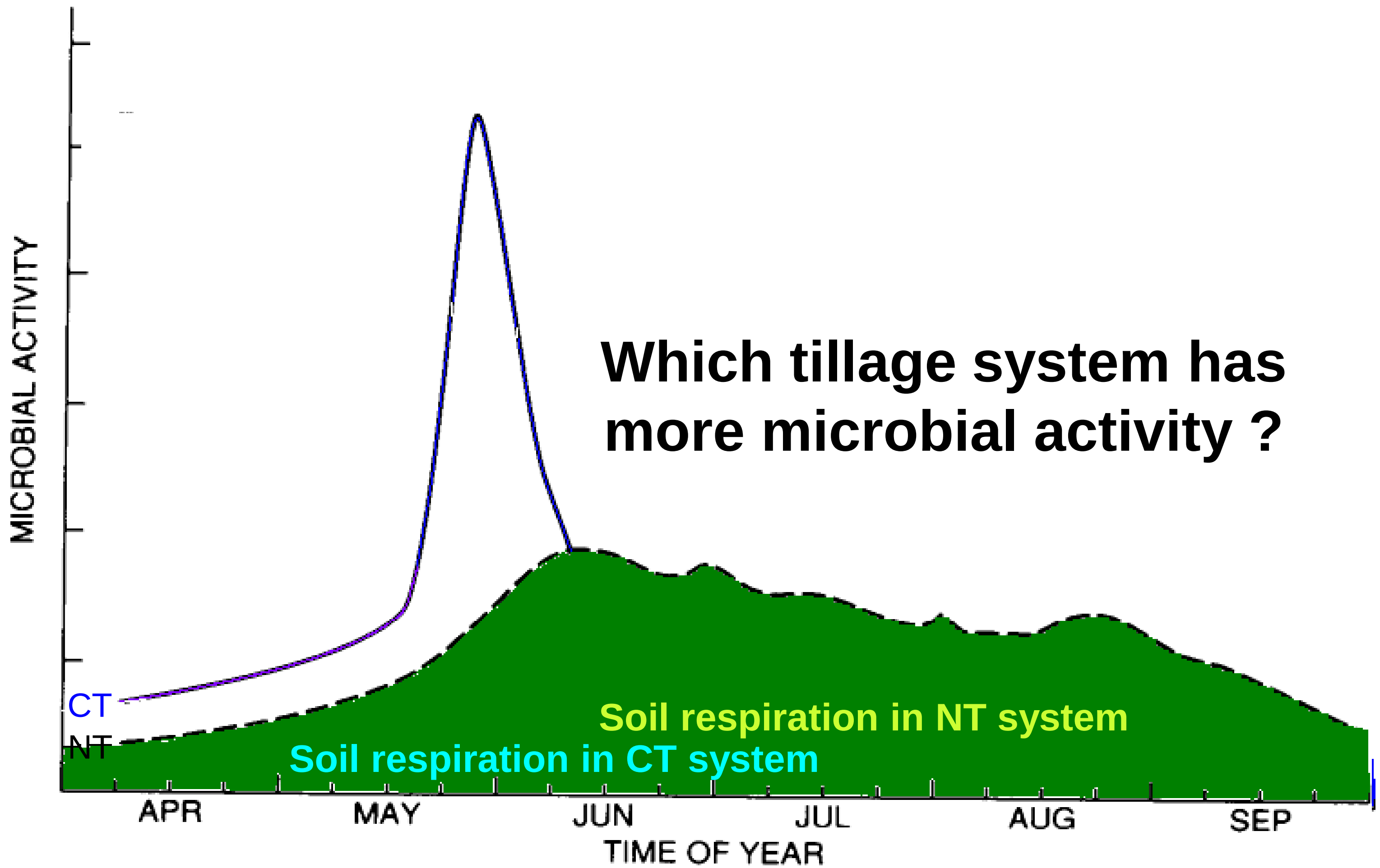
- Soil pores remain continuous
- Soil aggregates form and are not destroyed
- Soil Food Web increases and diversifies
- Weed seeds are not planted
- Water is captured and stored
- Bulk density decreases
- Soil fungi and earthworms increase
- Microarthropods increase (>20% of nutrient cycle)

Agricultural Disturbance Destroys the "Soil Spheres"

PHYSICAL DISTURBANCE: Tillage induces the native bacteria to consume soil carbon; byproduct is CO_2.



Effect of tillage on microbial activity



Which tillage system has more microbial activity ?

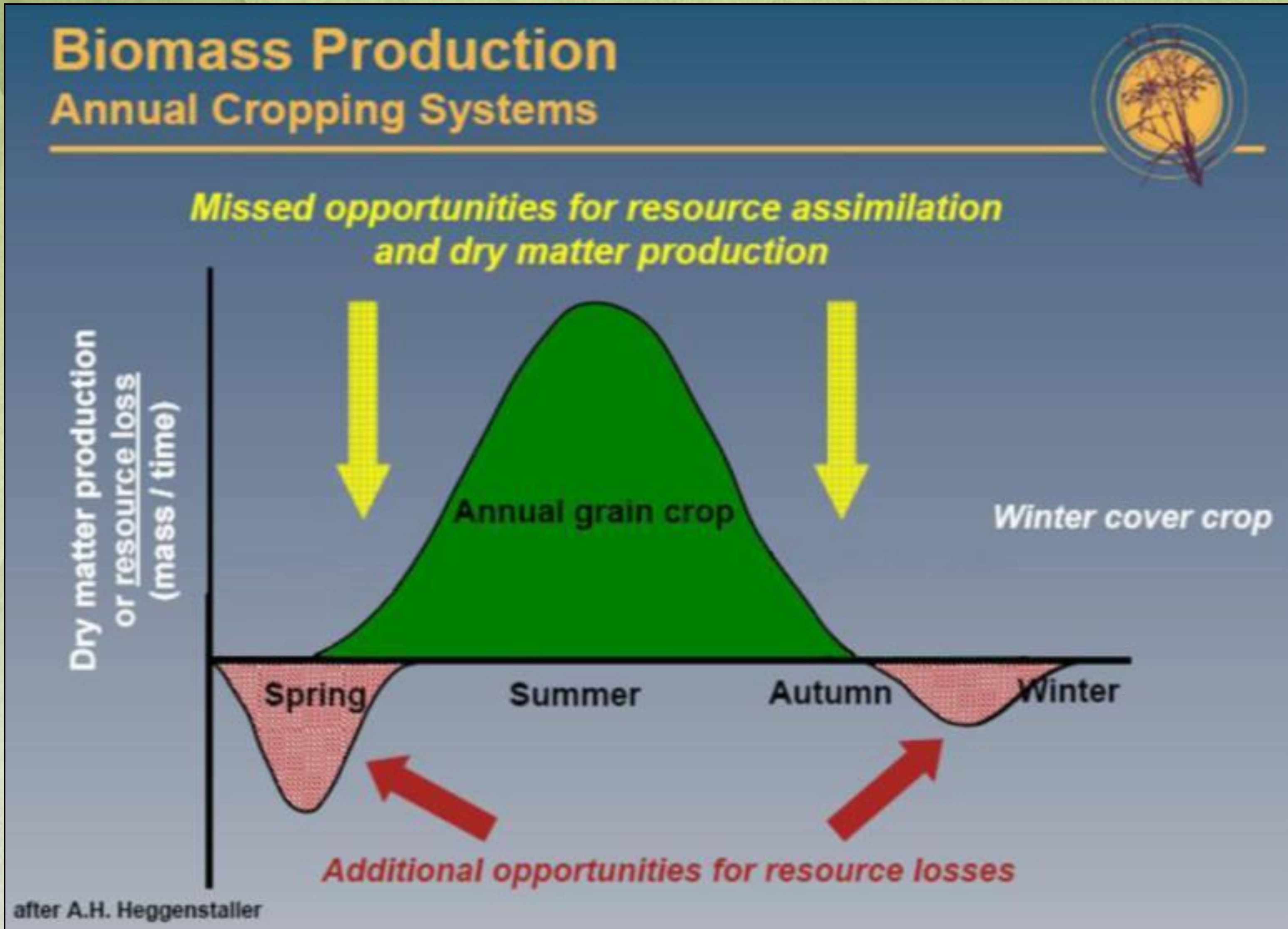
Havlin et al. (1999)

Soil Health Principle

Grow Living Roots Throughout the Year

Benefits:

- Increases microbial activity influences the N mineralization and immobilization
- Increases plant nutrient/vitamin uptake/ concentrations with mychorrhizal and bacteria associations
- Increases biodiversity and biomass of soil organisms
- Improves physical, chemical and biological properties of soils
- Sequesters and redeposit nutrients
- Increases OM



A. H. Heggenstaller, University of Alberta

Soil Health Principle

Keep it Covered as Much as Possible

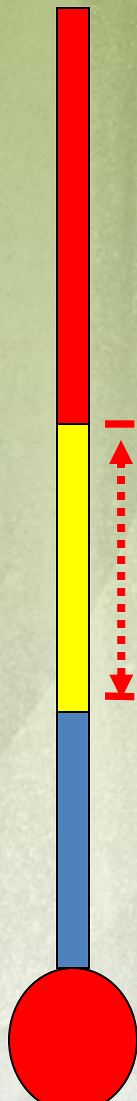
Benefits:

- Control Erosion
- Protect Soil Aggregates
- Suppresses Weeds
- Conserves Moisture
- Cools the Soil
- Provides Habitat for Soil Organisms

Soil Temperatures

- Conserve moisture and reduce temperature.
- Crop yields are limited more often by hot and dry, not cool and wet.

When soil temperature reaches



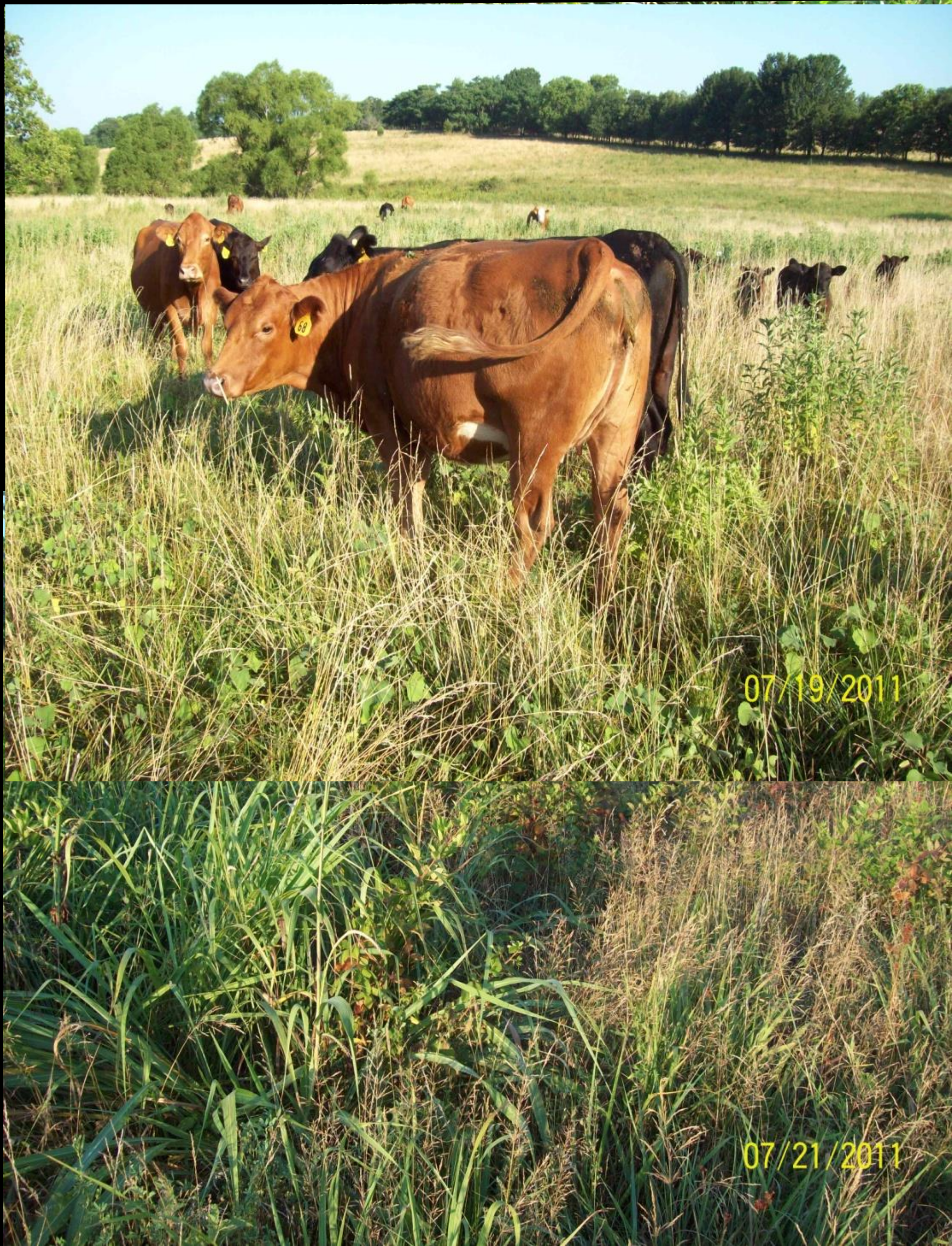
140 F	Soil bacteria die
130 F	100% moisture is lost through evaporation and transpiration
113 F	Some bacteria species start dying
100 F	15% moisture is used for growth 85% moisture lost through evaporation and transpiration
95 F	
70 F	100% moisture is used for growth

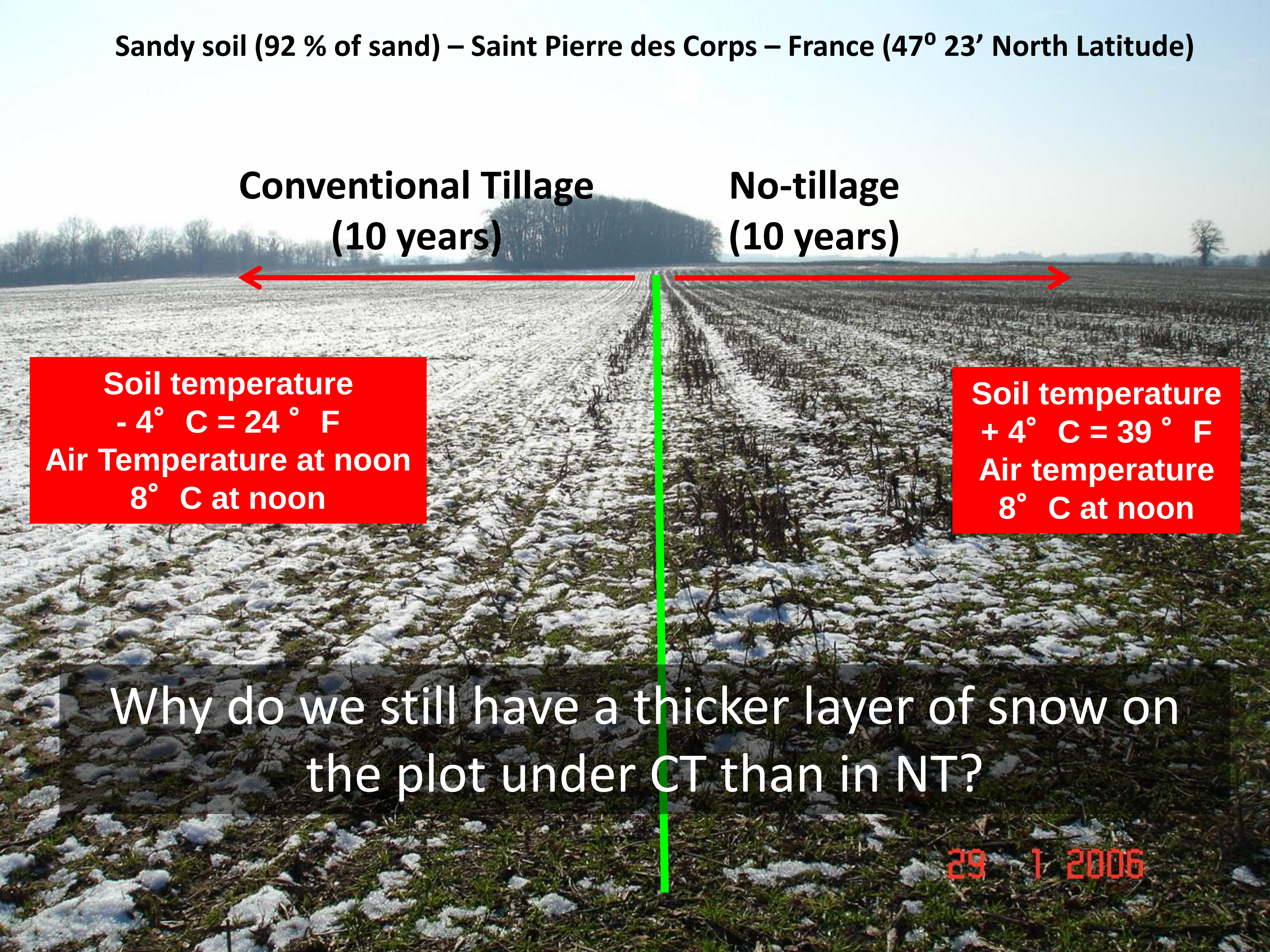
J.J. McEntire, WUC, USDA SCS, Kernville TX, 3-58 4-R-12198. 1956

2011 Drought

Neighbor's Pastures

Mark Brownlee's Pastures




Sandy soil (92 % of sand) – Saint Pierre des Corps – France (47° 23’ North Latitude)
Conventional Tillage (10 years)
No-tillage (10 years)
Soil temperature - 4° C = 24 ° F Air Temperature at noon 8° C at noon
Soil temperature + 4° C = 39 ° F Air temperature 8° C at noon
Why do we still have a thicker layer of snow on the plot under CT than in NT?
29 1 2006

Soil Health Principle

Use Diversity of Plants to add diversity to Soil Organisms

- Plants interact with particular microbes
  - Trade sugar from roots for nutrients
- Microbes convert plant material to OM
- Requires a diversity of plant carbohydrates to support the variety of microbes
- Lack of plant diversity will drive system to favor some microbes more than others

How to Increasing Diversity in a Crop Rotation

- Lengthen the rotation by adding more crops
  - Increases soil organic matter
  - Breaks pest cycles
  - Improves nutrient utilization and availability
  - Utilize available water deeper in the soil profile
  - Provide windows for management
    - spread manure
    - Plant & harvest crops
- Add more plants in the current crop rotation
  - Utilize cover crops during non-cropping part of the year

Simplified Crop Classification

- Plant morphology
  - Broad leaf
  - Grasses
- Plant growth habits
  - Cool season
  - Warm season

Crop Classification Warm Season

Grasses
- Corn
- Millet
- Sudan
- Sudex
- Sorghum

Broadleaf
- Alfalfa
- Soybean
- Buckwheat
- Chick pea
- Cow pea
- Sunflower

Crop Classification Cool Season

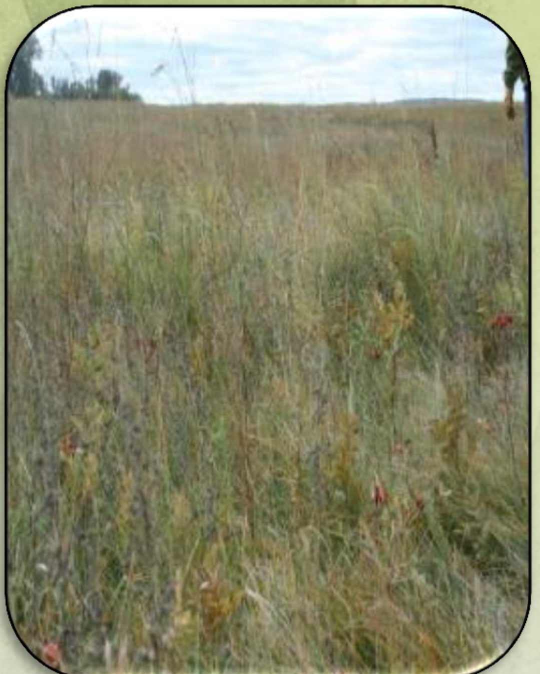
Grasses

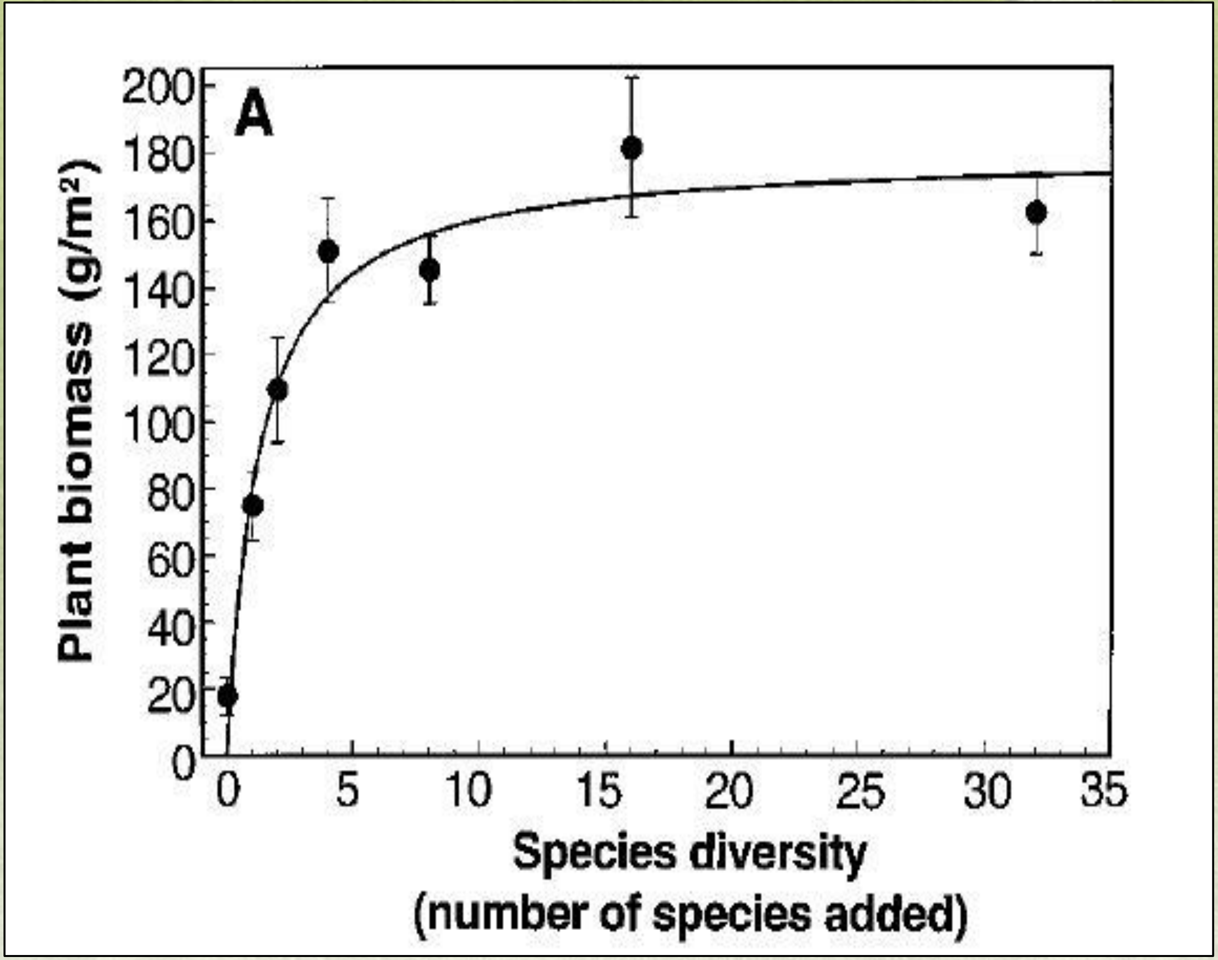
- Barley
- Rye
- Triticale
- Wheat

Broadleaf

- Canola
- Clovers
- Mustards
- Pea
- Radish
- Turnips

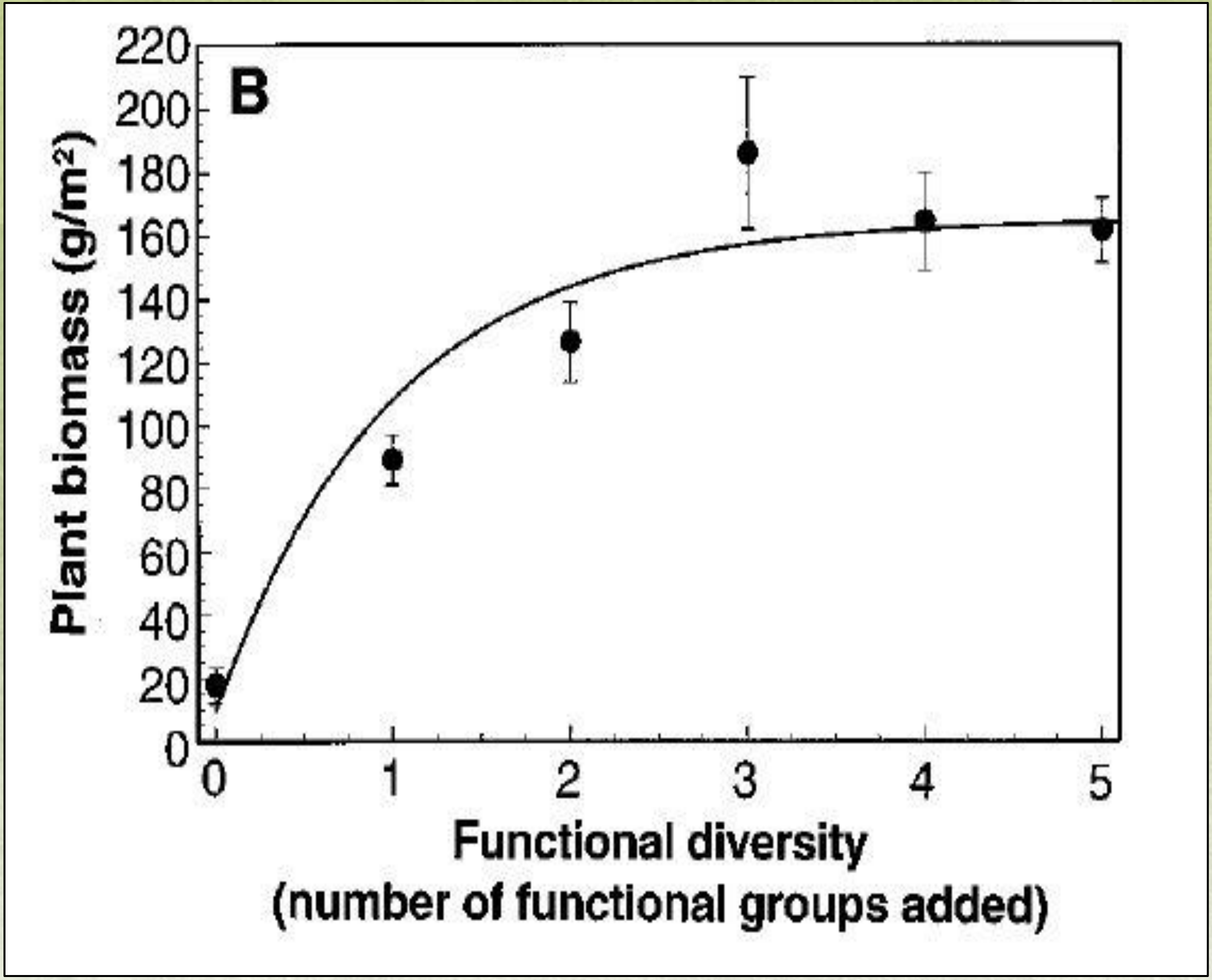
The Influence of Functional Diversity and Composition on Ecosystem Processes





David Tilman,* Johannes Knops, David Wedin, Peter Reich,
Mark Ritchie, Evan Siemann

The Influence of Functional Diversity and Composition on Ecosystem Processes



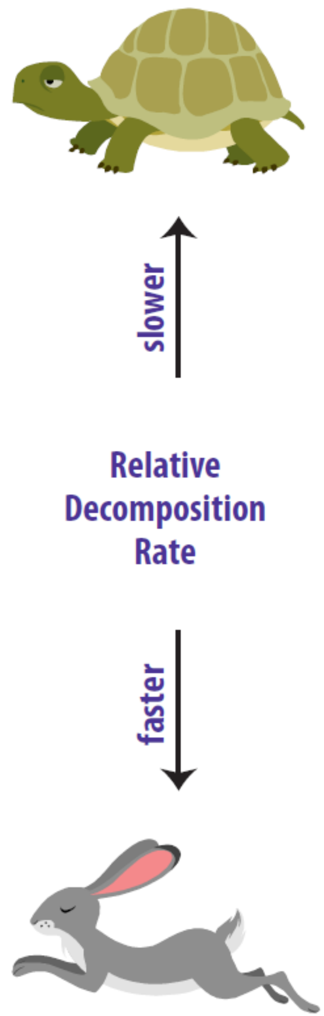
David Tilman,* Johannes Knops, David Wedin, Peter Reich,
Mark Ritchie, Evan Siemann

Mixture of cereal rye, hairy vetch, and field peas as a winter cover crop

Mixture of cereal rye, hairy vetch and crimson clover

C:N Ratio 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



Rye
- High C:N
- Ties up N
- Compounds problem following another high C:N crop

Hairy Vetch
- Low C:N
- Release lots of N
- Decomposes Fast

Rye & Hairy Vetch Mix
- Balance C:N ratio
- Control decomposition
- Ideal cover crop mix

Hard to believe that the same results can be achieved using simpler biological methods!!!


12 species

All Plots Harvested October 18, 2011

Study 3

190 bu/ac corn grown with zero N input at planting

Cover Crop Economics

All Data is Per Acre Except Where Noted

Nitrogen input:
60/40 blend of Super U
and Ammonium Sulfate,
at $0.795 / lb

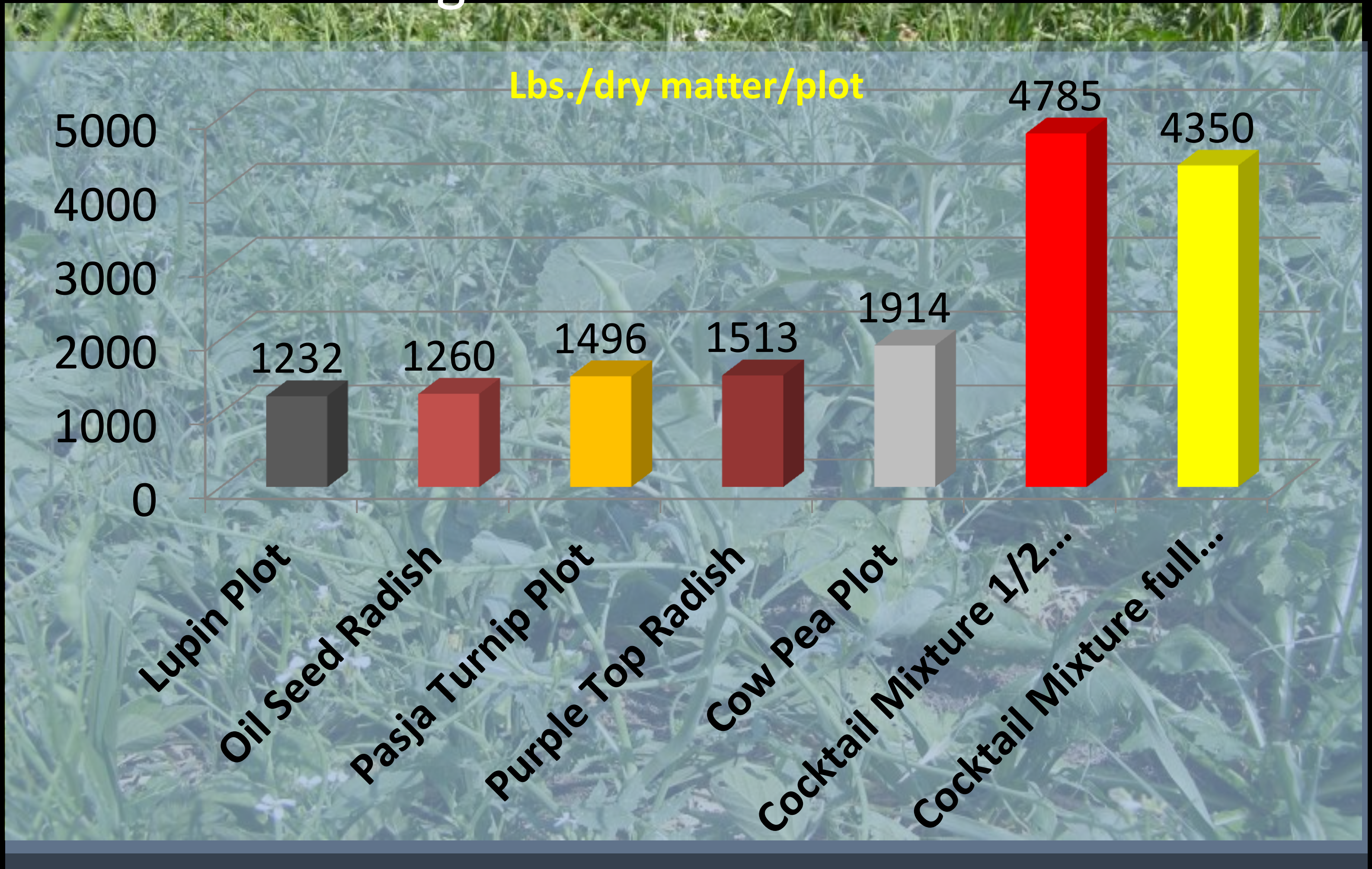
190.8 bu/ac	205.6 bu/ac	198.1 bu/ac	196.9 bu/ac
Zero Units / N	60 Units / N	90 Units / N	120 Units / N

RESEARCH SPONSORED BY

COVER CROP SOLUTIONS

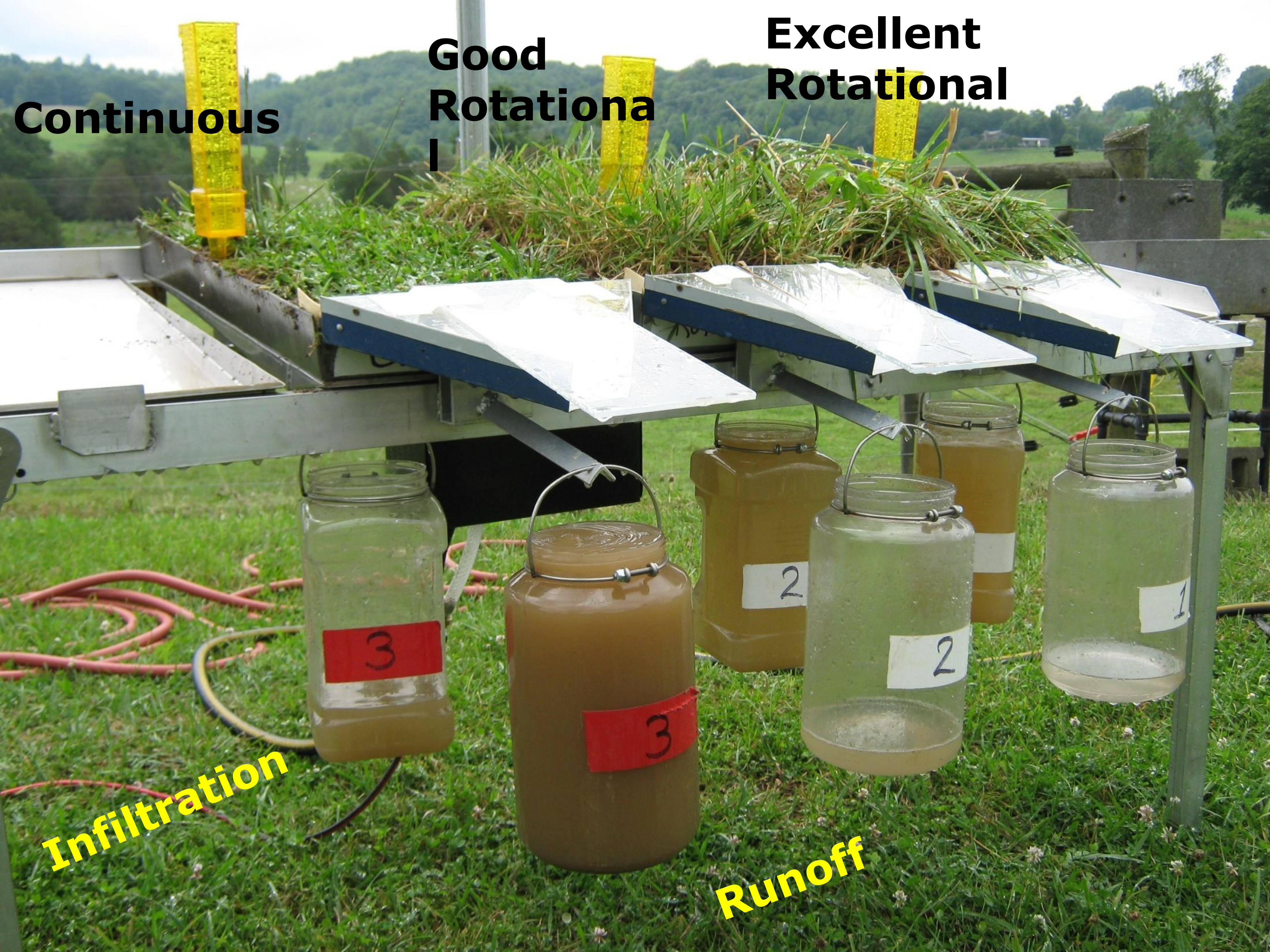
Home of the Tillage Radish

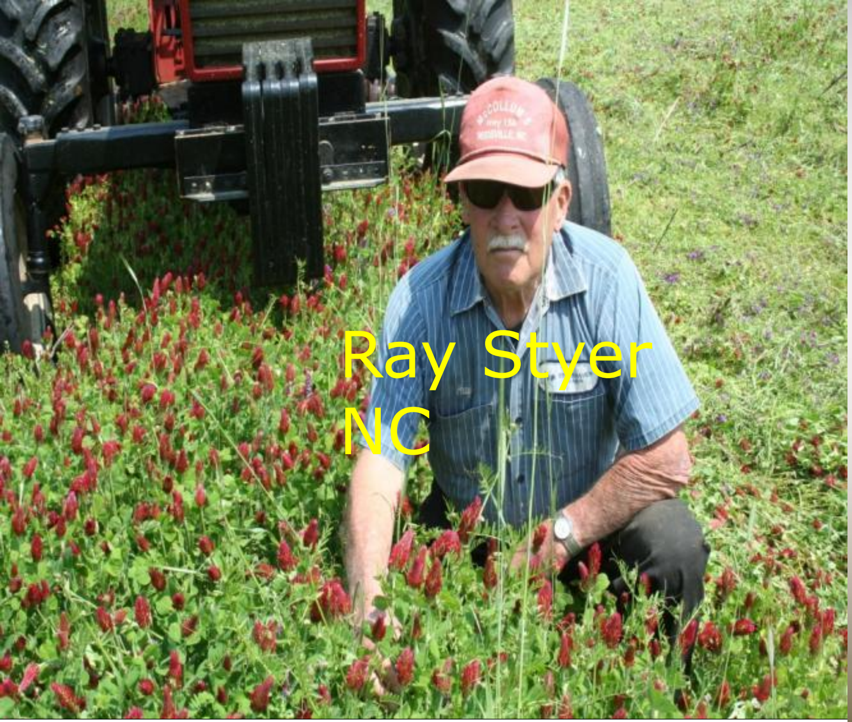
Utilize energy efficiently- understand the power of diversity: Collaboration is more apparent than Competition: ND case study: 2006 Production On Burleigh District Plot with 1.8 in. of rain




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

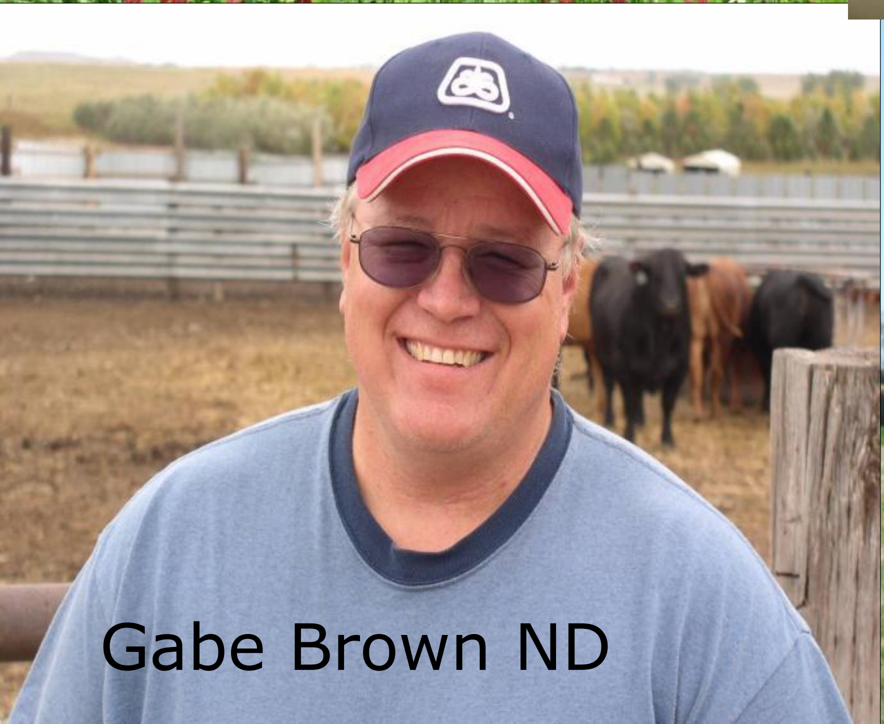

Agricultural soils do not have a water erosion/runoff problem, they have a water infiltration problem.


Continuous
Good Rotational
Excellent Rotational
3
3
2
2
1
Infiltration
Runoff


Ray Styer
NC


Dave
Brandt OH


Steve Groff
PA


Gabe Brown ND


Ray McCormick
IN

SOM'S Revolving Nutrient Bank Account.

- A furrow slice is 6 7/8 inches = 2,000,000 lbs of soil per acre.
- 1.0% SOM X 2,000,000 lbs = 20,000 lbs of SOM per acre.
- 1.0% SOM = approximately 10,000 lbs Carbon, 1,000 lbs Nitrogen, 100 lbs Phosphorous, and 100 lbs of Sulfur.
- Mineralization Rate = 2-3% from Organic N to Inorganic N, which does not stop at harvest time.

Soil Organic Matter and Available Water Capacity
Inches of Water/One Foot of Soil

Percent SOM	Sand	Silt Loam	Silty Clay Loam
1	1.0	1.9	1.4
2	1.4	2.4	1.8
3	1.7	2.9	2.2
4	2.1	3.5	2.6
5	2.5	4.0	3.0

Berman Hudson
Journal Soil and Water Conservation 49(2) 189-194
March – April 1994
Summarized by:
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