How Cover Crops Build Soil Health

Part 1 (Slides 1 – 47)

North Valley Organics (Minor Morgan, Albuquerque, NM)

Close up of Cover Crops growing between vegetable rows at Minor's Organic Farm

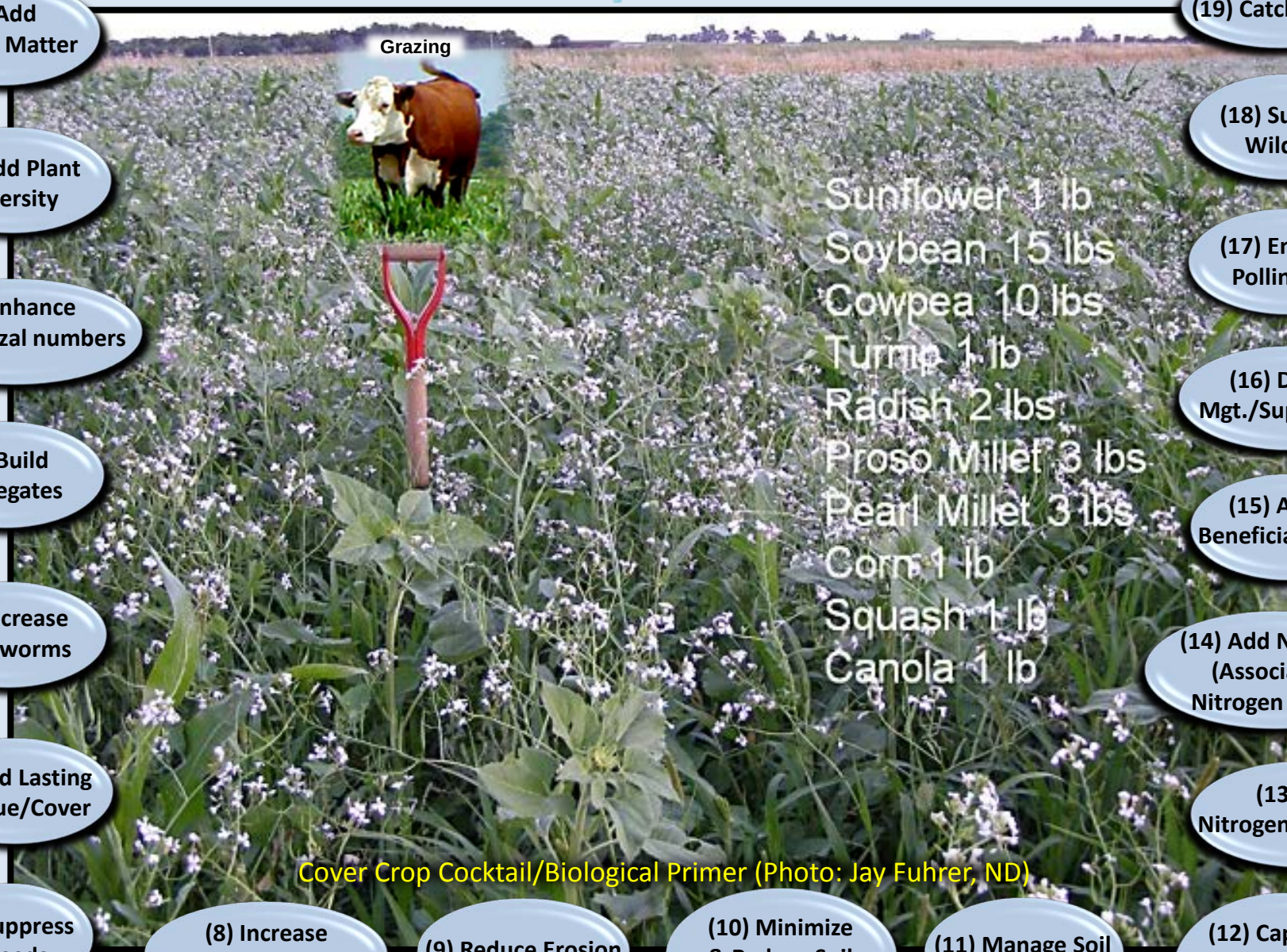
Soil Health & Assessments Training in NM

Rudy Garcia
USDA-NRCS Regional Soil Health Specialist
(NM, CO, UT, AZ)

NOTE: this presentation is about how cover crops help to build soil health. Many NRCS Soil Health Specialists/Conservationists, Producers, University Specialists, Ag Consultants and other Soil Health Partners have shared their work on how cover crops build soil health and increase productivity. Many thanks to all of you.

Agro.Tech.Note.76 (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/nm/technical/?cid=nrcs144p2_068965)

How Cover Crops Build Soil Health



Cover Crop Cocktail/Biological Primer (Photo: Jay Fuhrer, ND)

(1) Add Organic Matter

(2) Add Plant Diversity

(3) Enhance Mycorrhizal numbers

(4) Build Aggregates

(5) Increase Earthworms

(6) Add Lasting Residue/Cover

(7) Suppress Weeds

(8) Increase Infiltration of Water

(9) Reduce Erosion

(10) Minimize & Reduce Soil Compaction

(11) Manage Soil Moisture

(12) Capture & Recycle Nutrients (decrease nutrient loss)

(13) Add Nitrogen (Legumes)

(14) Add Nitrogen (Associative Nitrogen Fixers)

(15) Attract Beneficial Insects

(16) Disease Mgt./Suppression

(17) Enhance Pollinators

(18) Support Wildlife

(19) Catch Snow

rudy.garcia

Other Benefits: Clean Air, Clean Water, Healthy & Nutritious Plants, and much more.

Nurture Nature with System Synergies

(1) Cover Crops Add Organic Matter:

No Tillage

Cover Crops

Minimum carbon loss

Maximum carbon input

Dr. Don Reicosky
ARS, Morris, MN

Carbon management

Sustainability

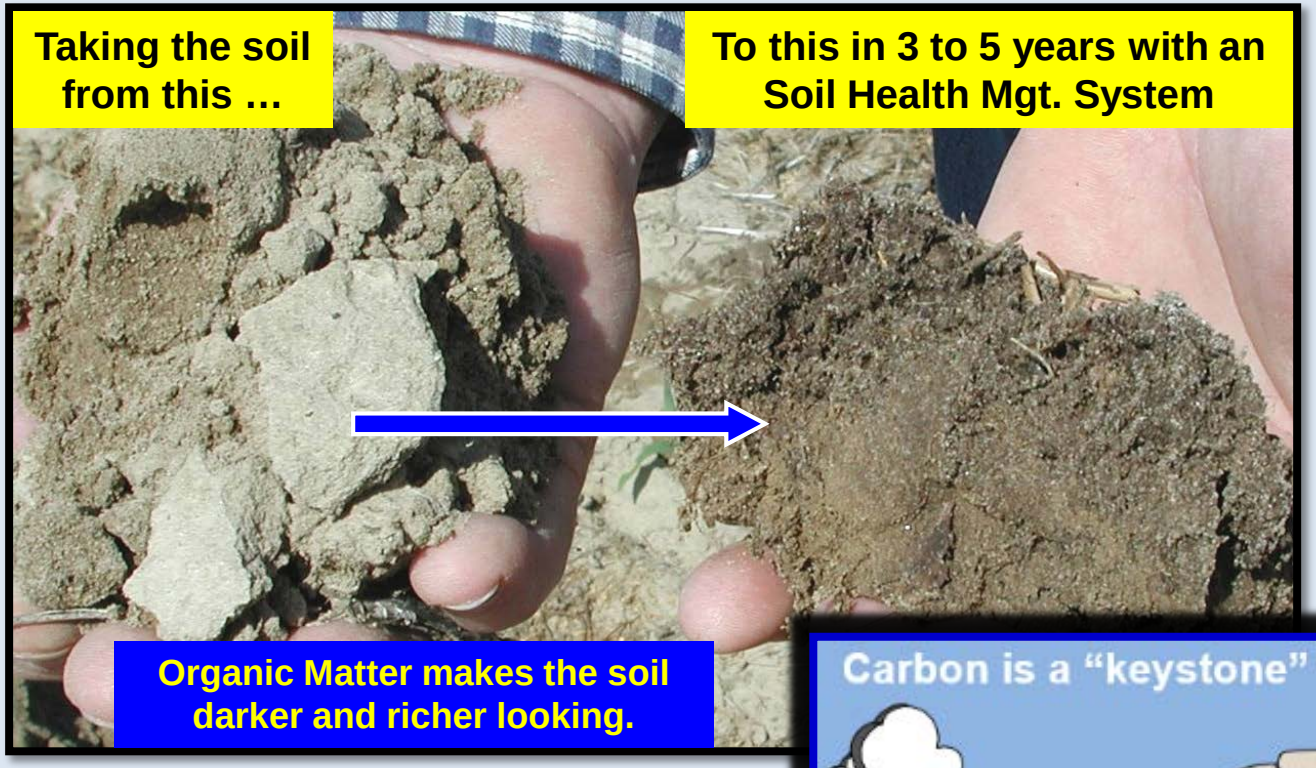
Cover Crops increase soil organic matter and improve Soil Health.

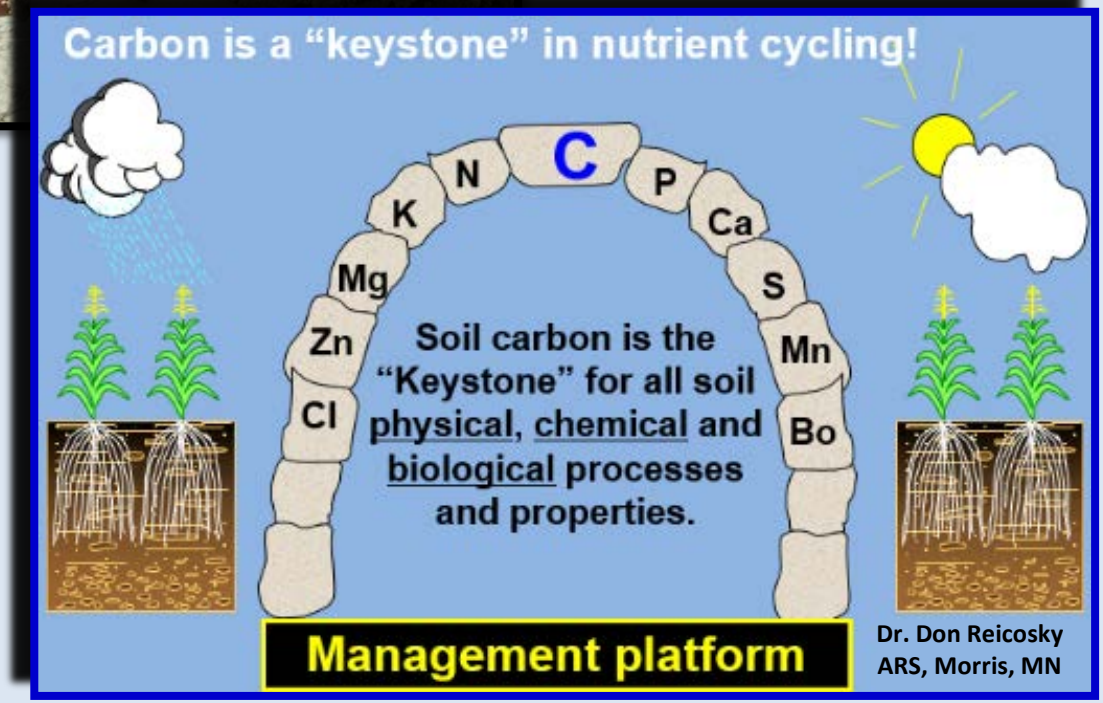
No Till, High Diversity, ZERO Synthetics, Livestock

Located in Close Proximity (Same Soil Type)

Ref.: Ray Archuleta

(1) Cover Crops Add Organic Matter:





Increase Soil Organic Matter

- Contributes directly to nutrient cycling, nutrient availability, nutrient holding capacity, and water holding capacity.
- Plays a significant role in the formation of water stable aggregates which affects infiltration, aeration, drainage and bulk density.
- Provides carbon and energy for soil organisms that are essential for maintaining a healthy soil.

(2) Cover Crops Add Plant Diversity:

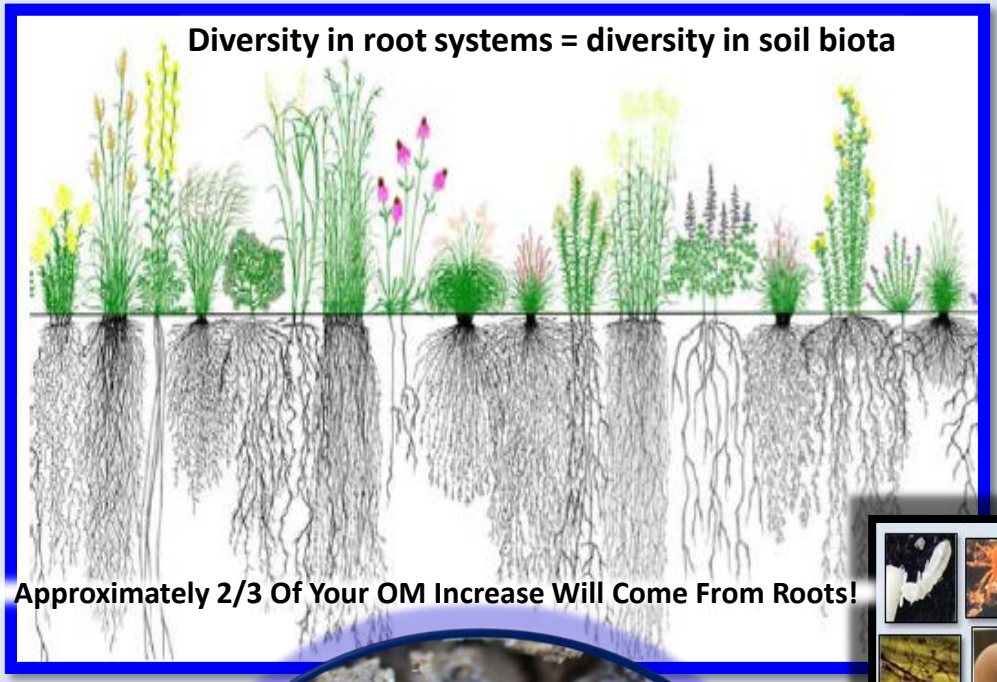
Cover Crop Role in Diversity

1. Allow you to look at cropping periods rather than years
2. Can be used to accelerate rejuvenating soil health
3. Getting 4 to 6 weeks of growth is adequate to get the "rotation" effect!
4. Will increase soil biological diversity "Diversity above= diversity below"

Plan on Diversity

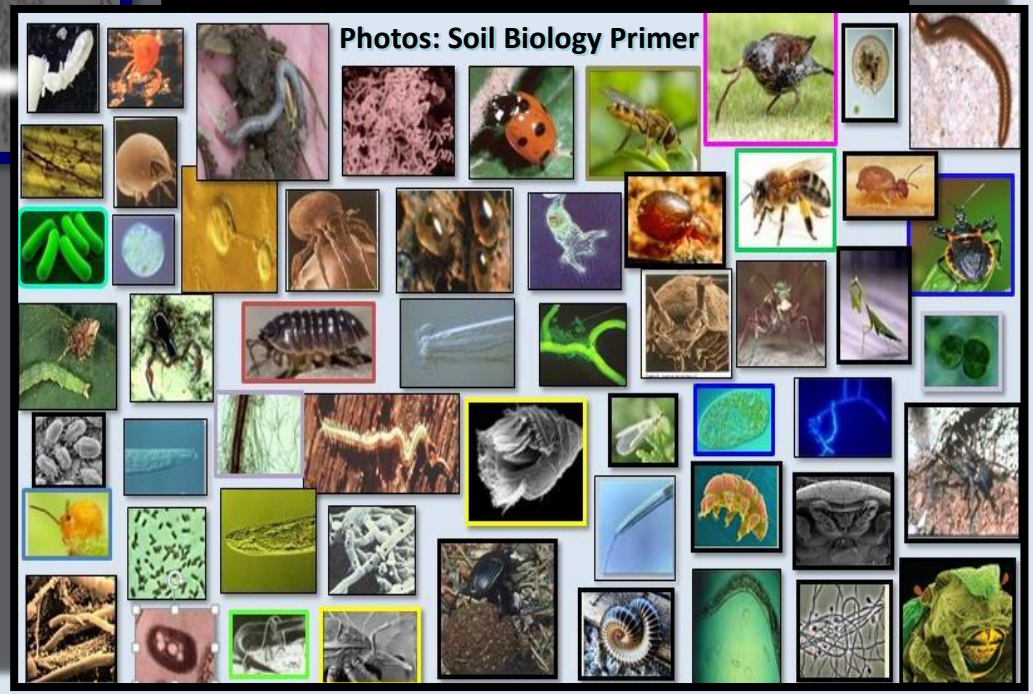
- What crop types do you lack?
  - Cool season grass
  - Warm season grass
  - Cool season broadleaf
  - Warm season broadleaf
- Multi-species always better
  - Remember nature!
- Soil foodweb does better on diverse diet

(2) Cover Crops Add Plant Diversity:



Diverse Plants = Diverse Soil Food Web = Healthy Soil, when implementing a Soil Health Mgt. System

Diverse Soil Organisms = Healthy Soil
(Are you feeding & caring for your Soil Livestock?)



- Providing quality habitat for soil microorganisms should be the goal of producers interested in improving soil health.
- Soil is a biological system that functions only as well as the organisms that inhabit it.

(2) Cover Crops Add Plant Diversity:

Why Build Diversity?

Diversity conduit for energy and nutrients.

Diversity increases other soil activities:

- Microbial community biomass
- Microbial composition (more species)
- Respiration
- Fungal abundance
- N mineralization rates (fast, medium and slow)

- If ***Soil Health*** is the goal, ***Crop Diversity*** cannot be ignored or overstated
- Plants were created to grow in diverse ecosystems
- *Resilience* comes from *Diversity*
- Balanced "diet" for soil biology
- Balance: because even good things (legumes, brassicas) when not used in moderated balance can be harmful

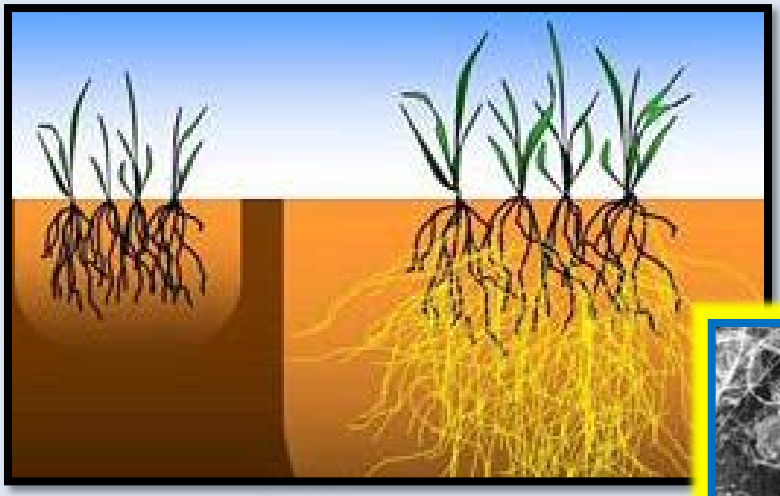
Increase Biodiversity

- Addition of different functional groups into an existing rotation (i.e. warm season grass, cool season grass, warm season broadleaf, cool season broadleaf)
- Adding diversity of plant species helps feed the biological life in the soil improving soil health

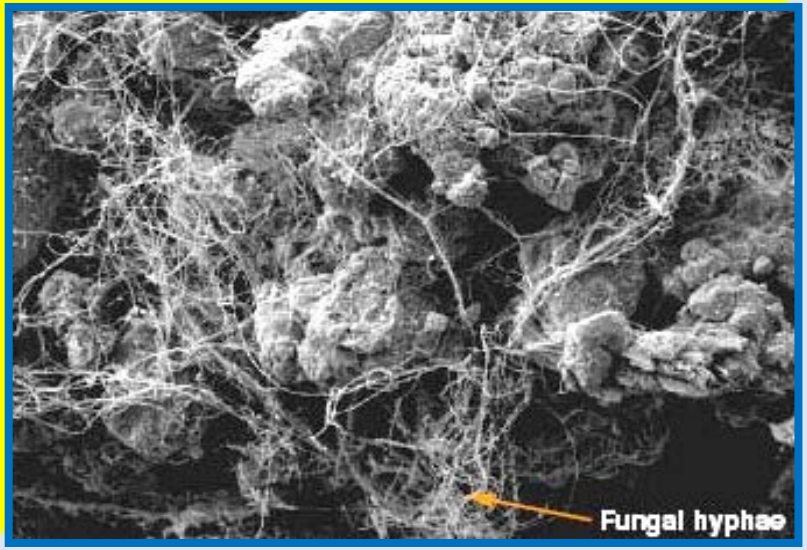
(3) Cover Crops Enhance Mycorrhizae numbers:

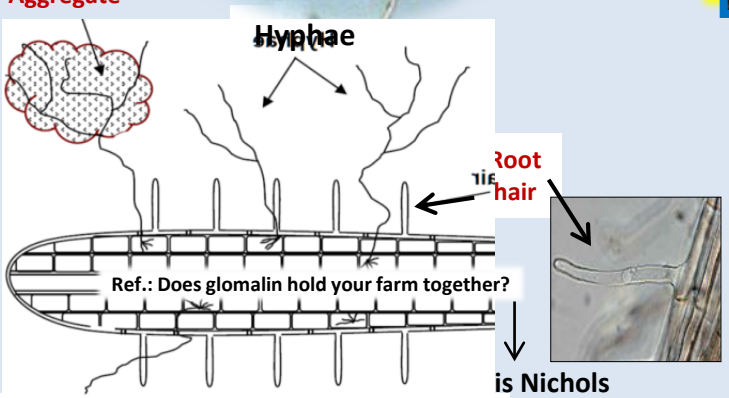
Soil Humus Formations:
1) Photosynthesis
2) Resynthesis
3) Exudation
4) Humification

Dr. Christine Jones

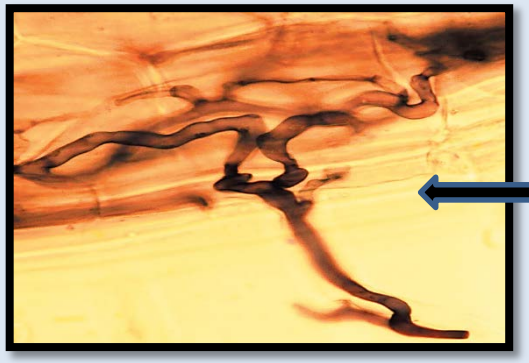


Fungal hyphae binding soil particles together into aggregates.





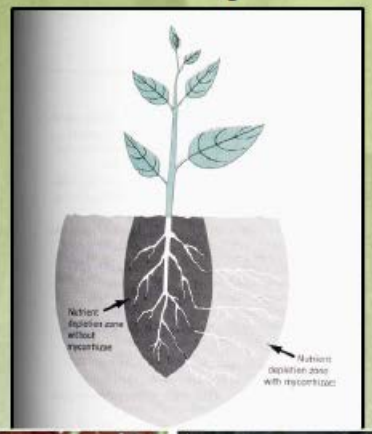
Hyphae of arbuscular mycorrhizae fungi grow beyond nutrient depleted zones found around roots and root hairs.



Although mycorrhizae don't make humus, it is difficult to start the humification Process without them. They bring large quantities of soluble Carbon in to the soil from plant roots, which feeds the microbes involved in the complex process.
Photo: Jill Clapperton

(3) Cover Crops Enhance Mycorrhizae numbers:

Soil Food Web Benefits: Symbiosis- Mycorrhizae



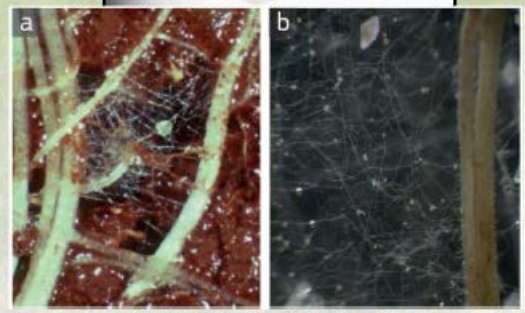


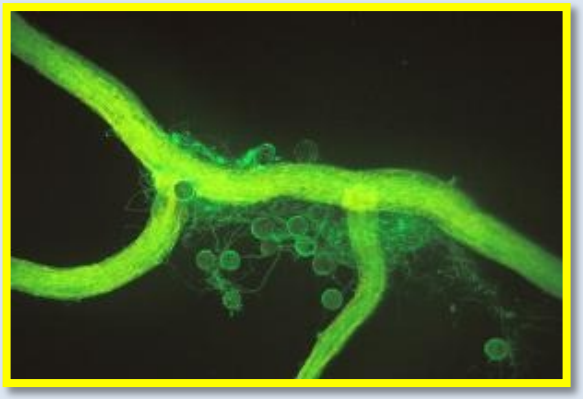
Photo citation: (2016). Global Soil Biodiversity Atlas. A. Orgiazzi, R. D. Bardgett, E. Barrios et al. Luxembourg, European Commission, Publications Office of the European Union: 176p.

- Myco (fungus)- rhiza (root)
- Plant uses 5-30% of energy (C) from photosynthesis to 'feed' fungi
- Fungi increase adsorptive surface area 10x or more of plant roots
- Increase nutrient uptake especially P, N, Zn
- Suppresses pests and disease
- Builds soil aggregates

Above: USDA-ARS research microbiologist Wendy Taheri found that arbuscular mycorrhizal spores were sparse from a tilled farm field, but abundant in an undisturbed prairie soil.

(3) Cover Crops Enhance Mycorrhizae numbers:

Photo taken when producer Dave Brandt was in Texas



A microscopic view of an arbuscular mycorrhizal fungus growing on a corn root. The round bodies are spores, and the threadlike filaments are hyphae. The substance coating them is glomalin, revealed by a green dye tagged to an antibody against glomalin.

Credit: Photo by Sara Wright

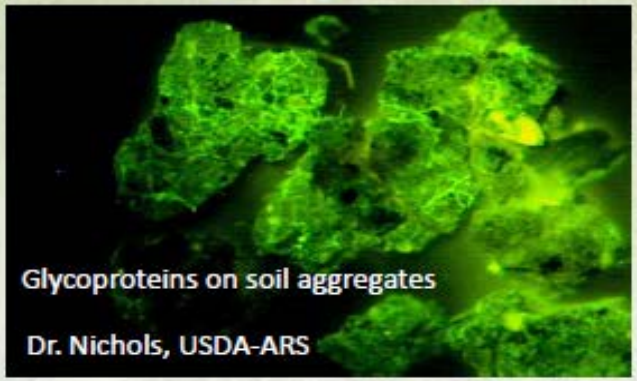
- **Plant species differ in abilities to acquire nutrients**
  - **Exudation of P mobilizing carboxylates (brassicas)**
  - **Fe- and other micronutrient (Zn) chelating phytosiderphores (depends on pH/legumes)**
  - **Mycorrhizas or other symbionts**
  - **Combination of all the above**

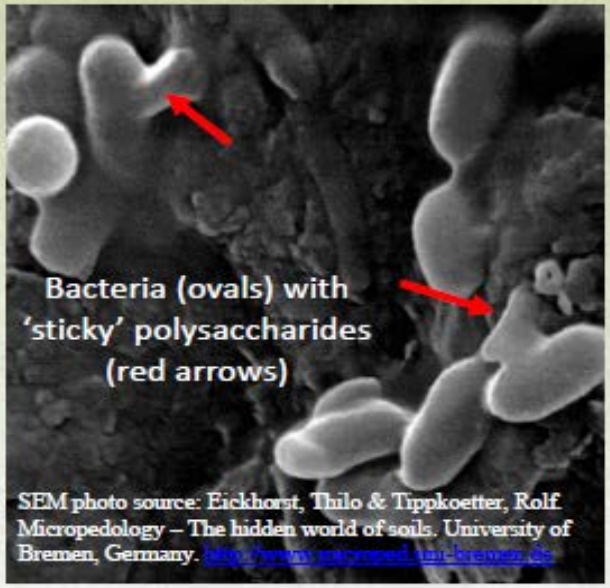
(4) Cover Crops build Aggregates:

Soil Food Web Benefits: Formation & Stabilization of Aggregates

How do soil aggregates form?

- Chemical interactions
  - Polysaccharides (sugars) released by bacteria act like glues to bind particles
  - Glycoproteins (glomalin-related soil proteins and other proteins) act like glues





Soil image with worm: Aaron Roth, NRCS-OR

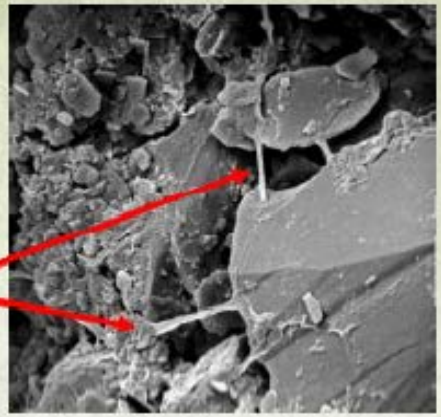
(4) Cover Crops build Aggregates:

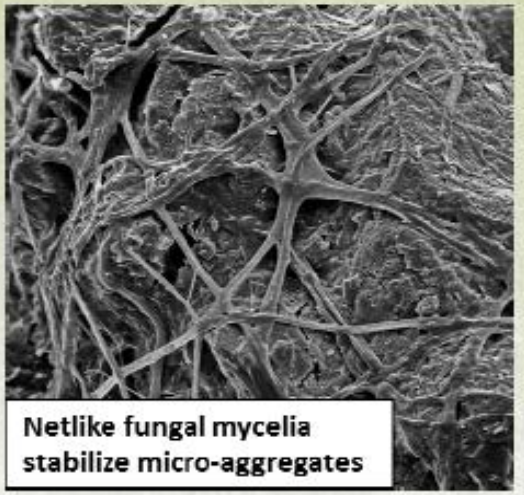
Soil Food Web Benefits: Formation & Stabilization of Aggregates

How do soil aggregates form?

- Physical interactions
  - Plant roots enmesh soil particles
  - Earthworms (casts) and termites (mounds)
  - Soil fungi and some Actinobacteria produce filaments that physically enmesh soil particles together

Stabilization of soil structure by actinomycete (bacterial) filaments





Netlike fungal mycelia stabilize micro-aggregates

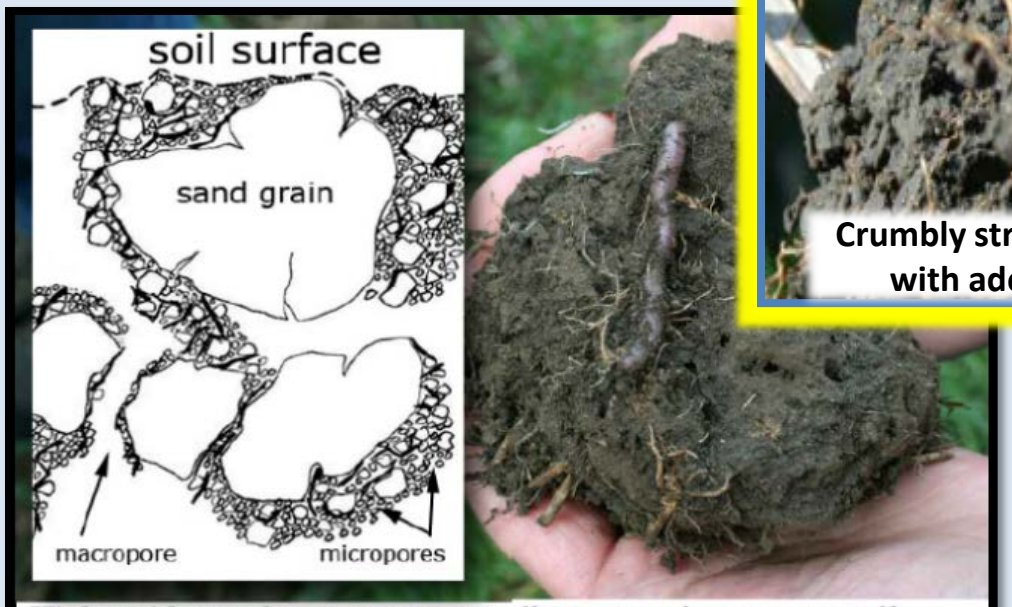
Soil image with worm: Aaron Roth, NRCS-OR

SEM photo source (accessed on 6/2/2016): Eickhorst, Thilo & Tippkoetter, Rolf. Micropedology – The hidden world of soils. University of Bremen, Germany. http://www.microped.uni-bremen.de

(4) Cover Crops build Aggregates:

The maintenance of a high degree of aggregation is one of the most important goals of soil management. (Ref.: The Nature and Properties of Soils, 14 Edition revised. Chapter 4)

Soil Structure & Macropores



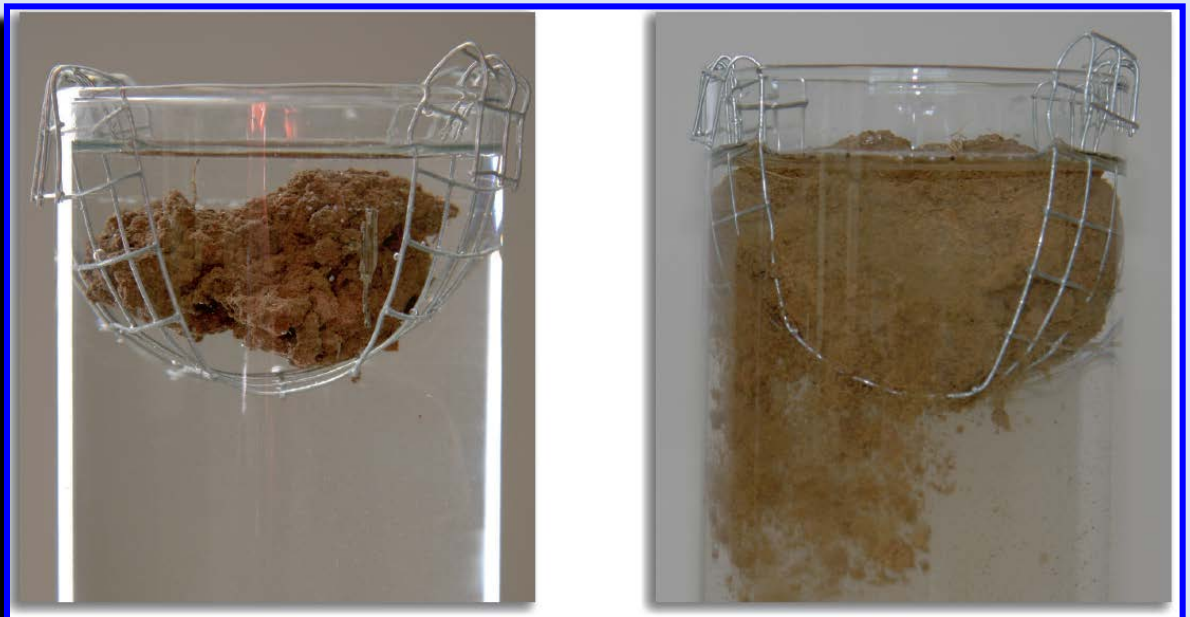
High residue and cover crops contribute organic matter to soil, while no-till management helps protect organic matter and allow accumulation. Organic matter provides food for earthworms and other soil biota. All play a role in developing or protecting soil structure and macropores to help soil function at a high level. Inset shows relationship of macro- and micropores to soil aggregates.

Soil aggregation and carbon sequestration are tightly correlated with the abundance of arbuscular mycorrhizal fungi: results from long-term field experiments

Gail W. T. Wilson,1* Charles W. Rice,2 Matthias C. Rillig,3 Adam Springer4 and David C. Hartnett5

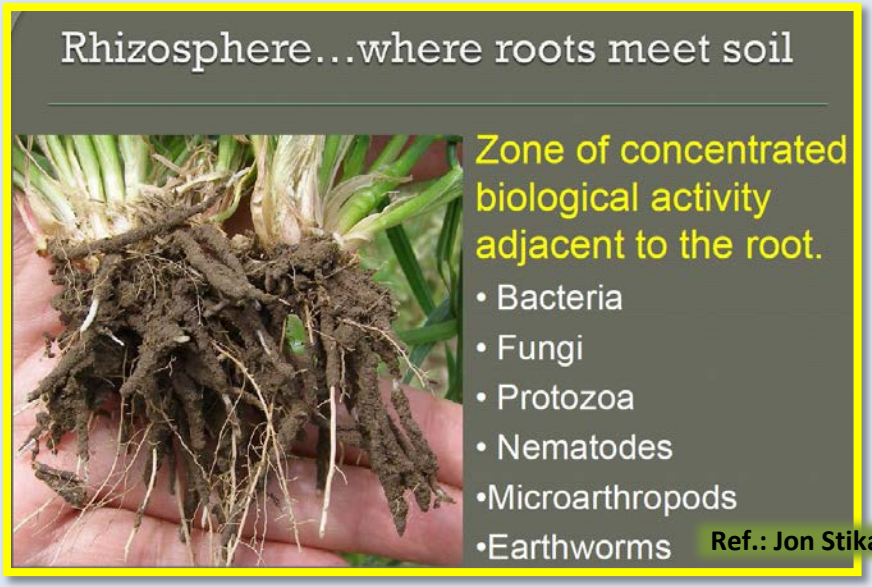
Ecology Letters, (2009) 12: 452–461

(4) Cover Crops build Aggregates:



Healthy soils are held together by soil glues, or glomalin, that are produced by fungi. Soils rich in soil biota hold together, while soils devoid of soil life fall apart and form a layer of sediment in the bottom of the jar. Pictured above, the soil on the left is from a field that has been managed using no-till for several years. The soil on the right is from a conventionally-tilled field.

Crumbly soils (left) have more pores and channels than cloddy soils (right). Pores and channels allow air and water to move into the soil.



Ref.: Jon Stika, ND

(5) Cover Crops Increase Earthworms:

Earthworms consuming cover crops and making healthy soil

Earthworms in Temple, TX

Earthworms in Temple, TX

(5) Cover Crops Increase Earthworms:

Earthworms

Poor soils contain 250,000 earthworms per acre while good soils contain 1,750,000 per acre

1 or less per shovel indicates poor soil health

10 or more per shovel indicates good soil health

Burrowing through lubricated tunnels forces air in and out of soil

Earthworm casts contain

11% of the humus

7X the nitrogen

11X the phosphorus

9X the potash

than surrounding soil

Earthworms

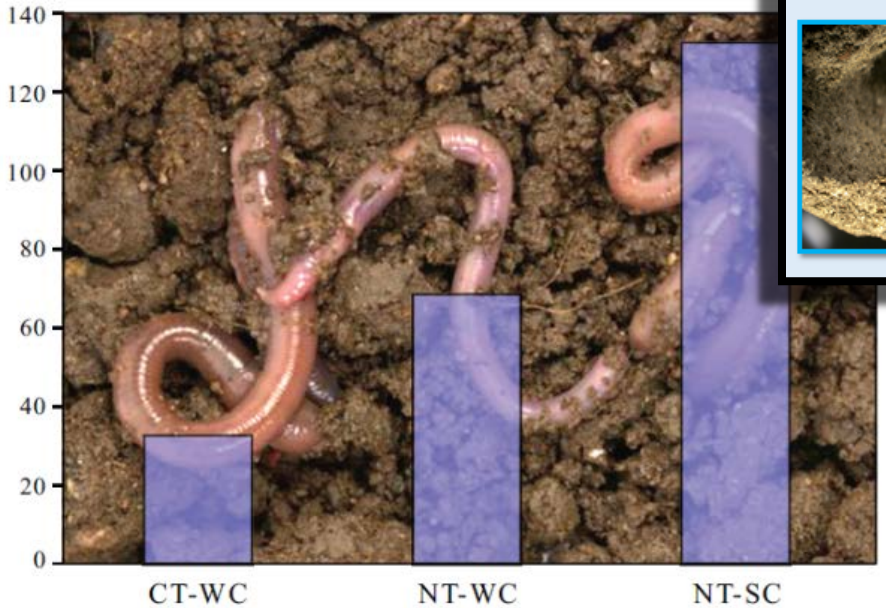
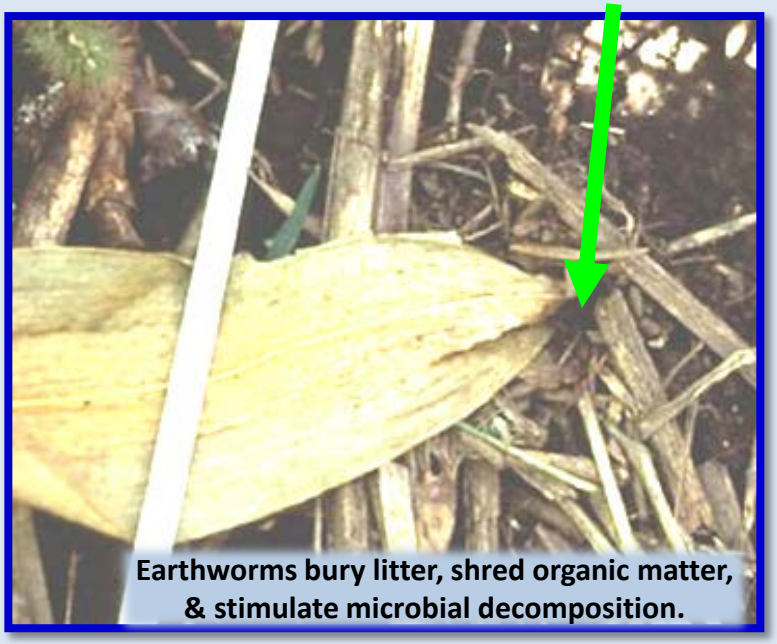


Figure 1. Effect of tillage and crop on earthworm number/m²
CT=conventional till, NT= no-till; W=wheat, C=corn, S=soybean
Adapted from Hubbard, et al. 1999.

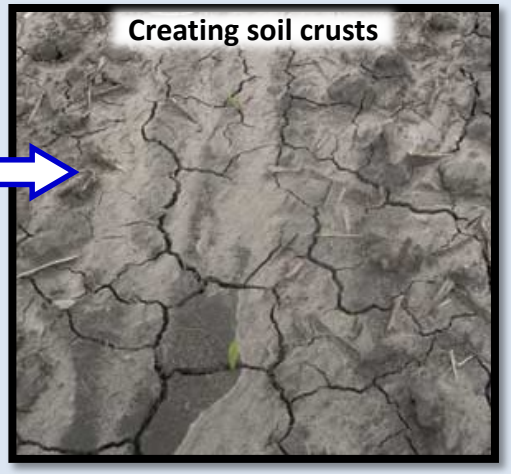
Ref.: NRCS Soil Quality Indicators



Earthworms bury litter, shred organic matter, & stimulate microbial decomposition.

(6) Cover Crops Add lasting residue/cover:

Crop Residues are needed to protect the soil surface and to feed the soil organisms.

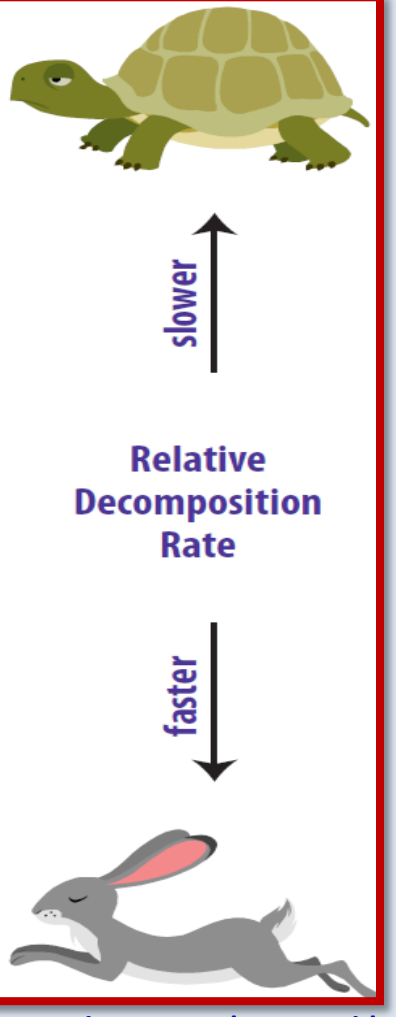


Cover Crop:

- Prevents soil particle detachment by wind and water
- Reduces raindrop impact
- Prevents crusting

(6) Cover Crops Add lasting residue/cover:

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



Additional lasting residue/cover :

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

- Cover crops added to a cash crop rotation can help manage nitrogen and crop residue cover in a cropping sequence.
- A low C:N ratio cover crop containing legumes (pea, lentil, cowpea, soybean, sunn hemp, or clovers) and/or brassicas (turnip, radish, canola, rape, or mustard) 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.
- Understanding carbon to nitrogen ratios of crop residues and other material applied to the soil is important to mange soil cover and crop nutrient cycling.

(6) Cover Crops Add lasting residue/cover:

Brown's Ranch (Same Field)

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

Photo are from Gab Brown's farm in ND and demonstrate how quickly residue can breakdown when soils are healthy

High Carbon Cover Crops

- Armor the soil
- Increase soil OM
- Capture & recycle nutrients (slower release)
- Manage soil moisture
- Moderate soil temperature

Low Carbon Cover Crops

- N fixation (legumes)
- Scavenge N (quick release)
- Help break down high carbon residues

July 1, 2009 (Rapid residue decomposition)

Residue should be broken down and incorporated into the soil profile in a healthy soil!

Residue is thought to be a good indicator of soil health, lots of residue equals healthy soils, but this is only looking at the erosion aspect.
Residue shouldn't stick around for multiple years, if so than there is something not functioning in the soil, poor microbial action.

(6) Cover Crops Add lasting residue/cover:

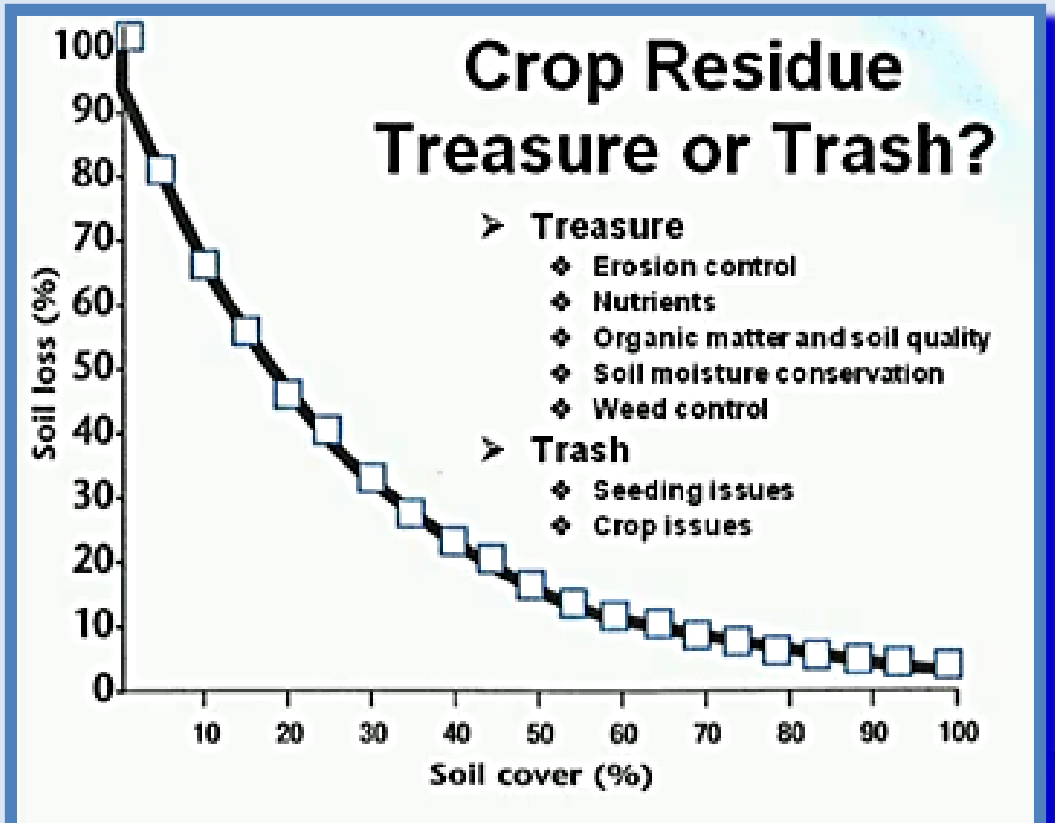
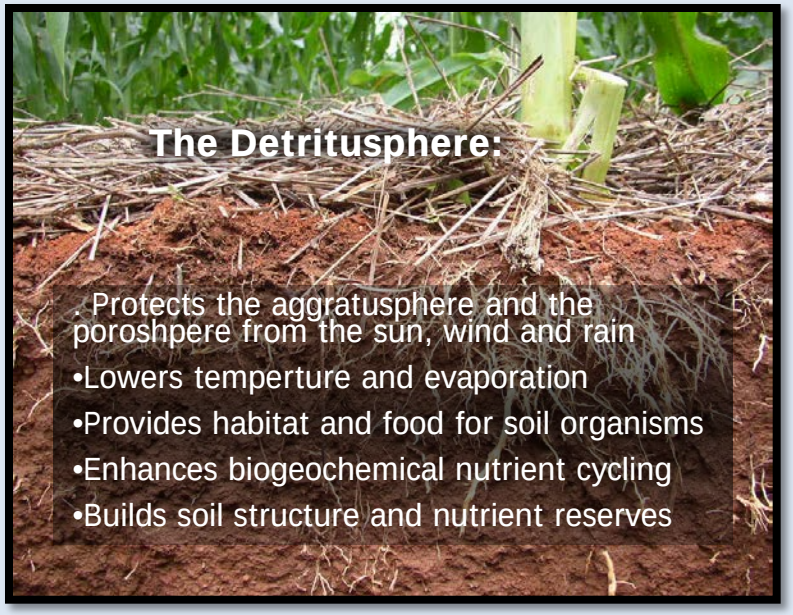


FIGURE 6. Residue cover – relative soil loss relationship. With 30% residue cover, soil loss is reduced 70%.



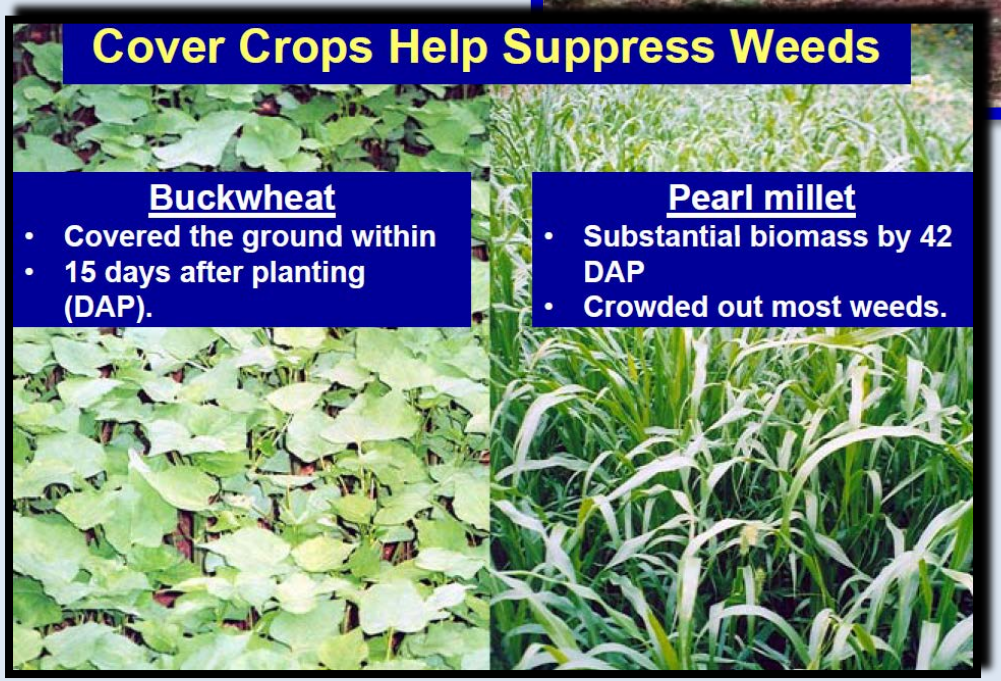
Soil mites such as this Ametrop species process crop residues into soil organic matter (Jill Clapperton)

(7) Cover Crops Suppress Weeds:

- **Adequate lignin content (boot stage)**
- **Moisture use considerations**
- **Lack of growing season?**
- **Same direction as planting**
- **Weed control by mulching**

- A healthy stand of cover crops can out-compete weeds for light and nutrients.
- The mulching effect of some types of cover crops can reduce weed pressure.
- Some types of cover crops produce chemical exudates that can inhibit weed growth.
- In addition to controlling weeds cover crops can help break pest cycles
- Terminate cover crop before they produce viable seed
- Cover crops can become weeds if not properly managed
- Site preparation: Early weed control is essential

(7) Cover Crops Suppress Weeds:



Weed Control: **The more diversity in the rotation, the easier it is to control weeds. Cover crops compete with weeds and crop residue serves to suppress establishment of the weeds.**

(8) Cover Crops Increase Infiltration of Water:

What Tillage does to the Soil:

- Destroys aggregates
- Exposes organic matter to decomposition
- Compacts the soil
- Damages soil fungi
- Reduces habitat for the Soil Food Web
- Disrupts soil pore continuity
- Increases salinity at the soil surface
- Plants weed seeds

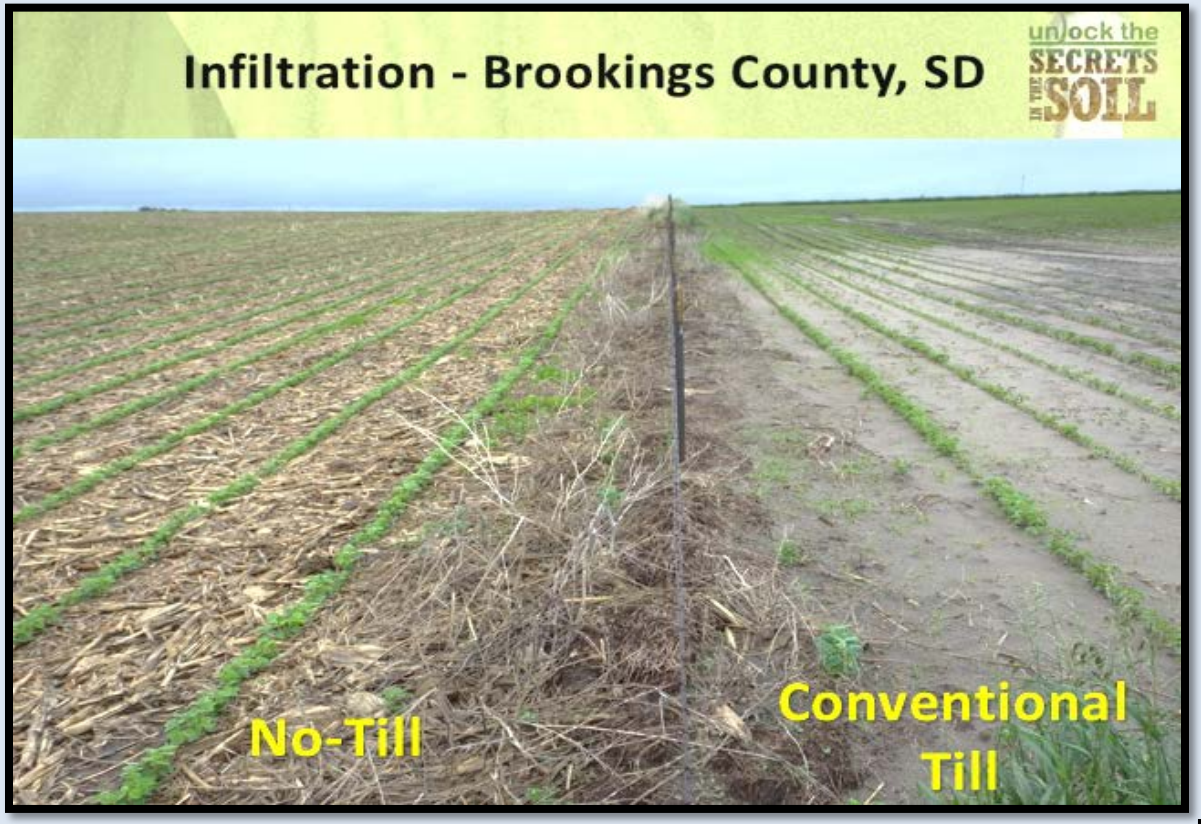
Runoff & Erosion Results

Rainfall Simulator Demonstration

Tillage disrupts ecosystems processes

Infiltration Results

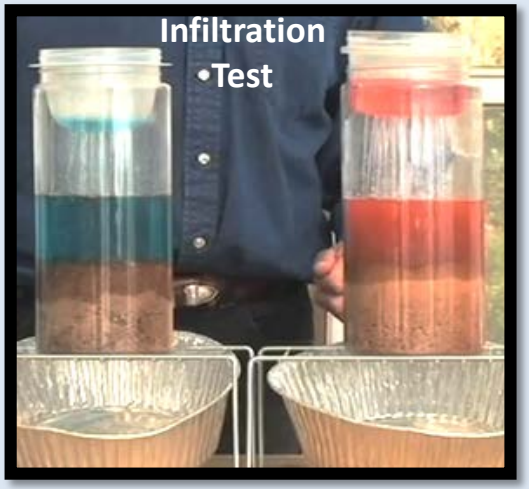
(8) Cover Crops Increase Infiltration of Water:



This picture shows two fields, one on each side of a fence, in Brookings County, SD. The soil was saturated from a series of rain events.

Hours after a storm left almost another inch of rain, water in the no-till field was able to infiltrate into the soil.

By contrast, the adjacent field under conventional tillage was still ponded, and had runoff that moved tons of topsoil off the field.

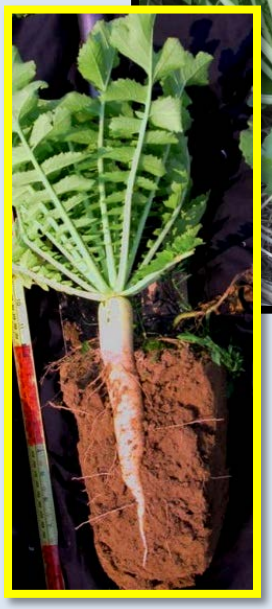


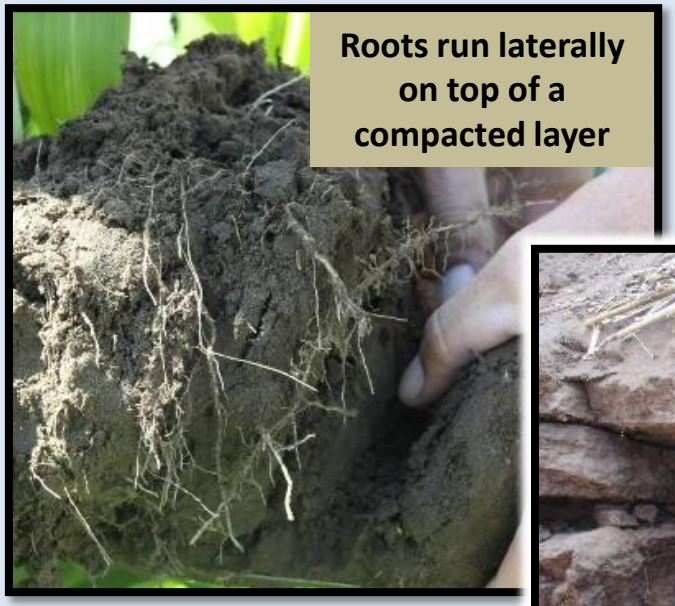
(9) Cover Crops Reduce Soil Erosion:

Cover Crops build aggregates and protects the soil from wind and water erosion.

Ref.: Ray the Soil Guy

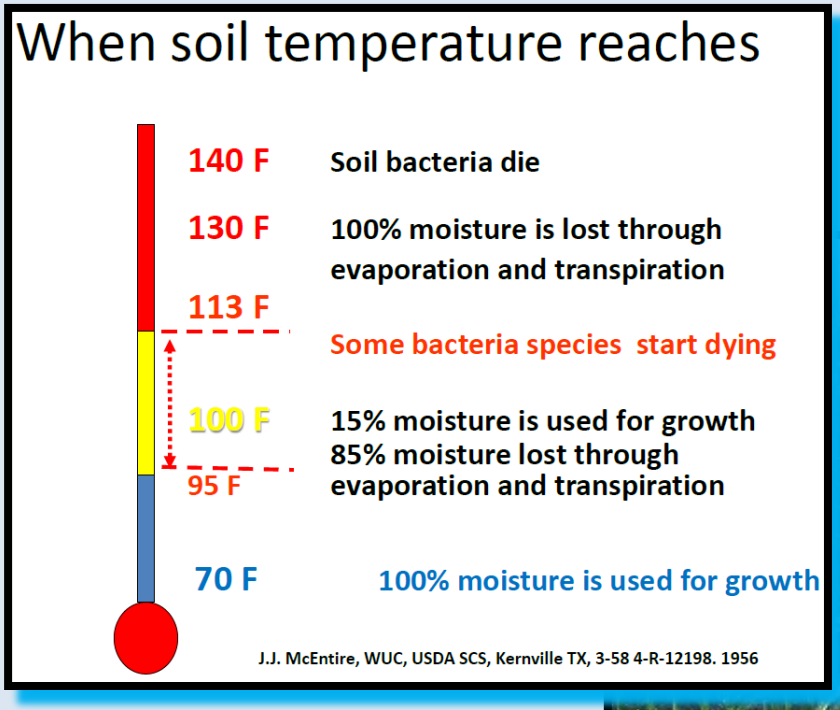
(10) Cover Crops Minimize & Reduce Soil Compaction:





Soil Compaction – soil pit in conventional tilled field, roots growing sideways

(11) Cover Crops used to Manage Soil Moisture:



In areas of limited soil moisture, terminate growth of the cover crop sufficiently early to conserve soil moisture for the subsequent crop. Cover crops established for moisture conservation shall be left on the soil surface

For every 1% that you increase SOM

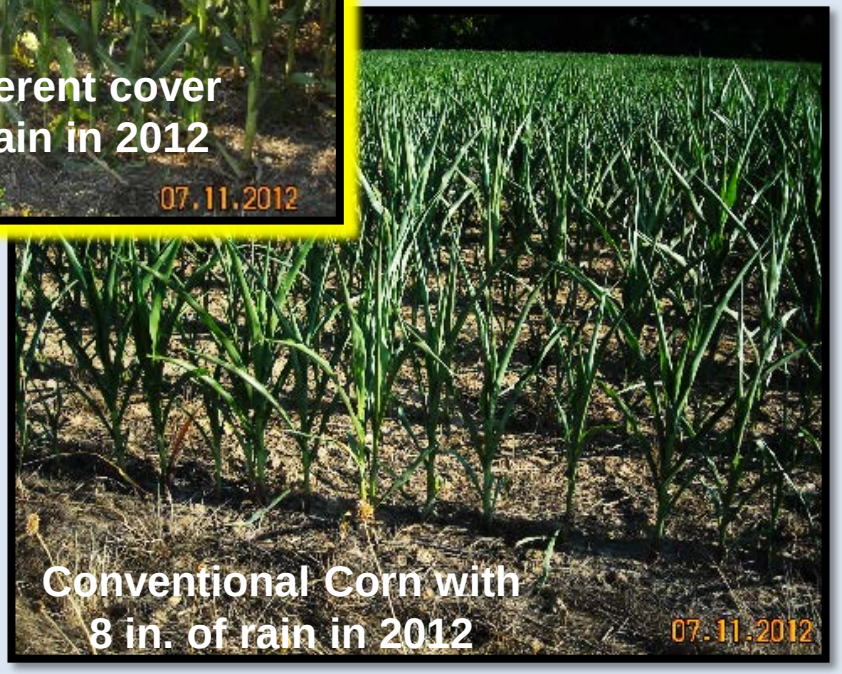
Waterholding capacity increases 20,000-25,000 gallons per acre

SOIL CARBON is the key driver for the nutritional status of plants – and therefore the mineral density in animals and people

SOIL CARBON is the key driver for soil moisture holding capacity (frequently the most limiting factor for production)

Soil carbon is the key driver for farm **profit**

Dr. Christine Jones



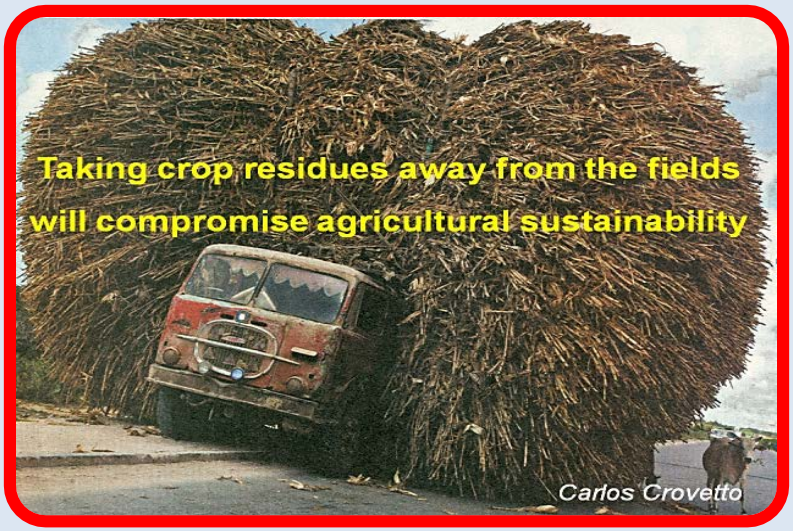
(11) Cover Crops used to Manage Soil Moisture:

Reduce Evaporation with cover

- Crop residue improves infiltration and reduces soil evaporation. **Maintaining adequate residue cover takes the "E" out of ET.**
- A study in Kansas found that leaving crop residue in place resulted in a savings of 3.5" of soil water. That is equivalent to an extra 40 bu/ac dryland corn or an irrigation savings of $25 to $35 per acre.

Cover Crop in Rainfall and/or irrigation:

- **Increases infiltration**
- **Reduces Evaporation**
- **Removes Excess Moisture** (In areas of potential excess soil moisture, allow the cover crop to grow as long as possible to maximize soil moisture removal)
- **Terminate while cover crop is vegetative (before peak water use occurs)**
- **Six weeks of growth to achieve "rotation effect"**



(11) Cover Crops used to Manage Soil Moisture:

Ref.: Adam Daugherty, NRCS District Conservationist in TN

(11) Cover Crops used to Manage Soil Moisture:

Competition or Collaboration?

- Stress Gradient Hypothesis (Bertness and Callaway , TREE, vol. 9, no. 5,1994)
  - As environmental stress increases, plants in a community collaborate rather than compete.
  - Diverse cover crop mixes are more productive under good or bad conditions.

Turnip cover crop July 2006 Bismarck, ND

Radish cover crop

Six specie cover crop July 2006 Bismarck, ND 1.8" growing season precip to date

(12) Cover Crops Capture & Recycle Nutrients:

Nitrogen Storage Tank

- Cover crops such as wheat, rye, oats and sorghum-sudangrass which establish quickly and have fibrous roots systems are ideal for scavenging excess nitrates from the soil profile (i.e., they decrease nutrient loss).
- Brassicas such as oilseed radish and turnips are also good scavengers although they establish more slowly and will winter kill.
- Growing deep rooted cover crops may help redistribute micro-nutrients in the soil profile and make them more available for the subsequent crop.
- Use deep-rooted species to maximize nutrient recovery.

Give it least 3 to 5 years for diversity to repair the soil before it is starts to increase nutrient cycling…

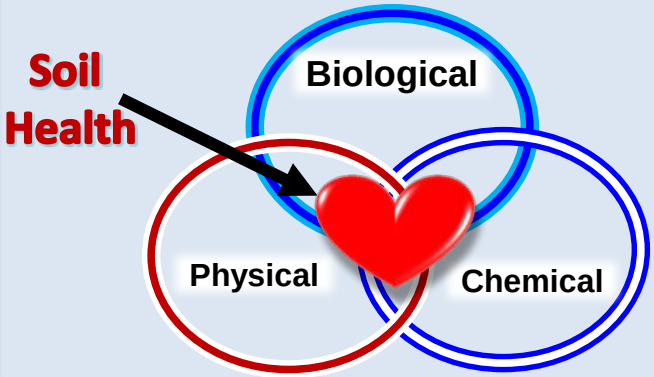
Soil biological processes are responsible for supplying approximately 75% of the plant available nitrogen and 65% of the available phosphorus in the soil. Like all organisms, those inhabiting your soil need food & a favorable environment. Adequate organic matter content, ample aeration, moderate moisture, neutral pH, and warm temperatures all favor increased microbial activity.

Cover crops can reduce nutrient losses

- Nitrate leaching in the fall is a concern.
- Non-legume cover crops help reducing nitrate leaching by taking-up the extra N
  - Cereal rye
  - Wheat
  - Barley
  - Oats
  - Ryegrass

(12) Cover Crops Capture & Recycle Nutrients:

Soil Health Management System (Managing SOM)



(Orchard with a cover: soil has an "Optimal" Bio-Geo-Chemical Nutrient Cycle)

Grass is mowed several times during the growing season (residues are left on the surface to decompose & recycle back to the soil)

Bare Surface (poor nutrient cycling)

rudy.garcia

(12) Cover Crops Capture & Recycle Nutrients:

Cover Crop mix (grasses, legumes & brassicas): Soil building/nutrient cycling

90% N,P,K eaten is returned to soil.

~75% of N and K in Urine

~75% of P in Manure

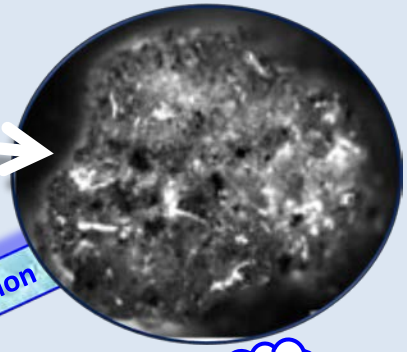
Impact of Manure and Urine recycling

(12) Cover Crops Capture & Recycle Nutrients:

Cover Crops create the Optimal environment for Soil Organisms to cycle nutrients efficiently

Macroaggregate

Microaggregate
Consisting of Clay, silt, humus, particulate organic matter, very fine sand, precipitated minerals, microorganisms & other organic compounds.



CO_2

Oxygen (O_2 gas in macro pores)

Carbon Dioxide (CO_2 gas in macro pores)

Factors affecting Nutrient Cycling & Soil Health:

- Temperature
- Oxygen
- Soil Moisture
- Soluble Organic Carbon
- C:N ratio
- Salinity
- pH
- Predation
- Nutrients
- Competition

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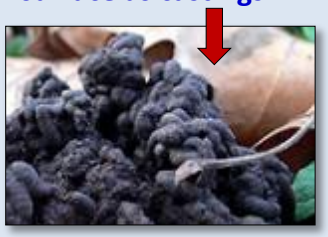
(12) Cover Crops Capture & Recycle Nutrients:

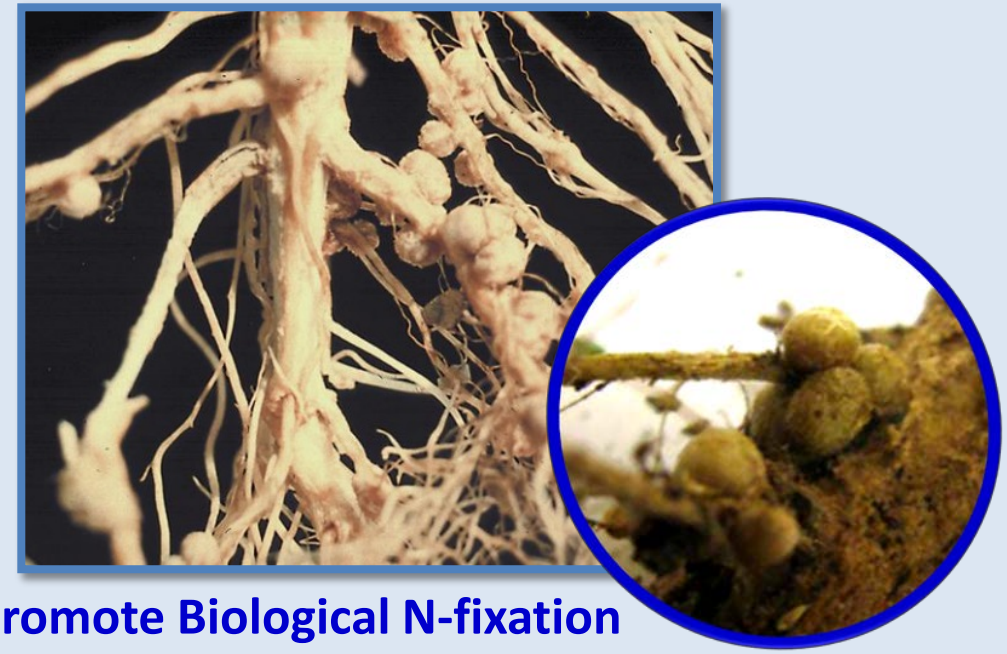
Dung Beetles move fecal material down up to 18 inches

Soil eaten by earthworms with organic matter is deposited on the soil surface as castings.



April 29, 2014 evaluating soil of the cover crop field: Worms underneath decomposing cow pie. 165 worms per cubic foot. 7.2 million worms per acre. (Ref.: Marlon Winger)

(13) Cover Crops Add Nitrogen (Legume):



- Legumes are Symbiotic with Ryzobium & AMF, important in pastures to drive the carbon and nutrient cycles.
- AMF bring in Zn, P, Moly, and Fe needed for nodulation (Much more efficient system).
- Legumes add the most plant-available N if terminated when about 30% of the crop is in bloom.

Promote Biological N-fixation

- Legumes can fix atmospheric N through a symbiotic relationship between the plant and Rhizobium.
- Growing legume cover crops can supply additional N for the subsequent crop providing that a majority of the above ground biomass is returned to the soil.
- Considerations:
  - Works best when N is limiting
  - Legumes need to be properly inoculated

Legumes- Biological N fixation

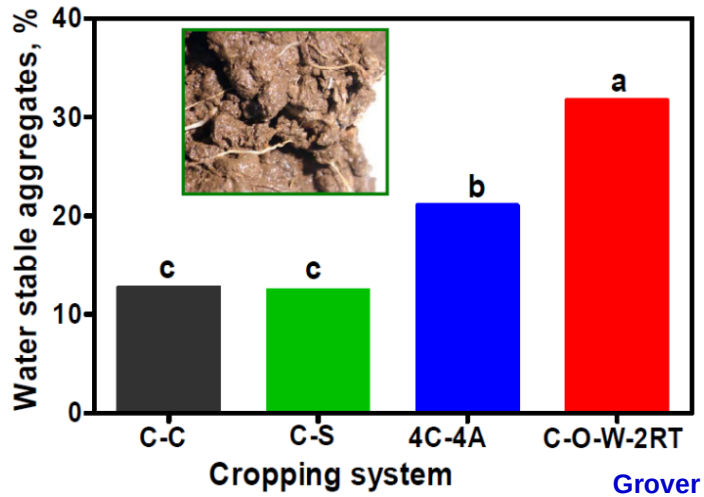
Legume	N fixed lb/acre
Alfalfa	195
Red clover	115
Cowpea	90
Pea	63
Common bean	41

www.sare.org

(13) Cover Crops Add Nitrogen (Legume):

Sesbania Nodulation, Fall 2011

Soil Aggregate Stability with Cover Crops



Grover et al., 2009

Key issues to focus on in water limited environment:

- Water requirements of the cover crop - is the demand high or low?
- Drought tolerance of the cover crop - does the cover crop tolerate dry spells and to what extent?
- Is the cover crop easy to manage - watch out for tendency to become weeds

Putting it all together

- Cover crops are an important component of sustainable crop production.
- Multiple benefits of cover crops.
- Specific functions.
- Things to consider while selecting a cover crop.
- Integration of cover crops into cropping systems.
- Management challenges.
- Potential cover crops for the region.

Drier Climates

- Delayed termination of a winter cover crop
  - may result in moisture deficiency for main summer crop.
- Kill the cover crop before it removes too much soil water.

Ref.: Dr. Kulbhushan Grover, NMSU

(14) Cover Crops Add Nitrogen (Associative Nitrogen Fixers):

Nitrogen: the double-edged sword
Christine Jones, PhD
www.amazingcarbon.com

It is important to recognize that the ability to fix nitrogen is not limited to bacteria associated with legumes. Chlorophyll is part of a protein complex - hence wherever you see green plants - there will also be an association with nitrogen-fixing bacteria or archaea.

In addition to nitrogen-fixing bacteria and archaea, mycorrhizal fungi are also vitally important to the N-fixing process. **Although mycorrhizal fungi do not fix nitrogen, they transfer energy, in the form of liquid carbon (Jones 2008) to associative nitrogen fixers**. They also transport biologically fixed nitrogen to plants in organic form, for example, as amino acids, including glycine, arginine, chitosan and glutamine (Leake *et al.* 2004, Whiteside *et al.* 2009).

The acquisition and transfer of organic nitrogen by mycorrhizal fungi is highly energy efficient. This pathway closes the nitrogen loop, reducing nitrification, denitrification, volatilization and leaching. Additionally, the storage of nitrogen in the organic form prevents soil acidification.

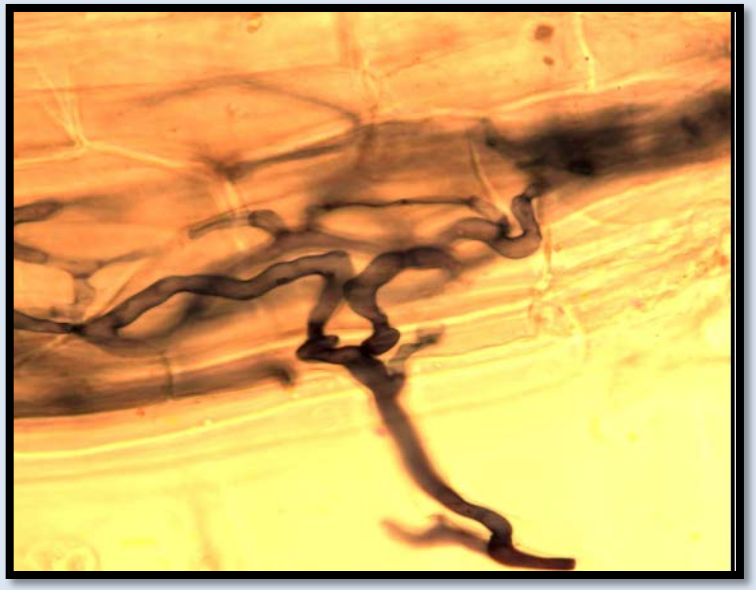
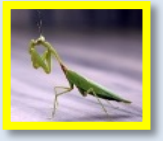
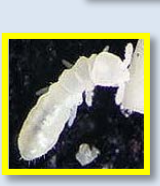


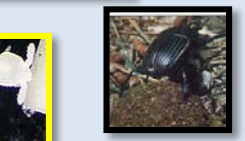
Fig.1. Cross section of a plant root showing the thread-like hyphae of mycorrhizal fungi. **Mycorrhiza deliver sunlight energy packaged as liquid carbon to a vast array of soil microbes involved in plant nutrition and disease suppression**. Organic nitrogen, phosphorus, sulphur, potassium, calcium, magnesium, iron and essential trace elements such as zinc, manganese and copper are returned to plant hosts in exchange for carbon. **Nutrient transfers are inhibited when high rates of inorganic nitrogen and/or inorganic phosphorus are applied**. Photo Jill Clapperton.

(15) Cover Crops Attract Beneficial Insects:

Build it… they will come!







162,000 weed seeds/ 1 sq. meter of a farm field. 137,000 to 161,000 predators per acre of corn canopy.

Approximately 10 percent of weed seeds are eaten per day by Millipedes, Small crickets, Isopods, Field Crickets an Carabid Beetles.

Jan 9, 2015. Dr. Jonathan Lundgren SD ARS/USDA.

Bottom Photos: Soil Biology Primer

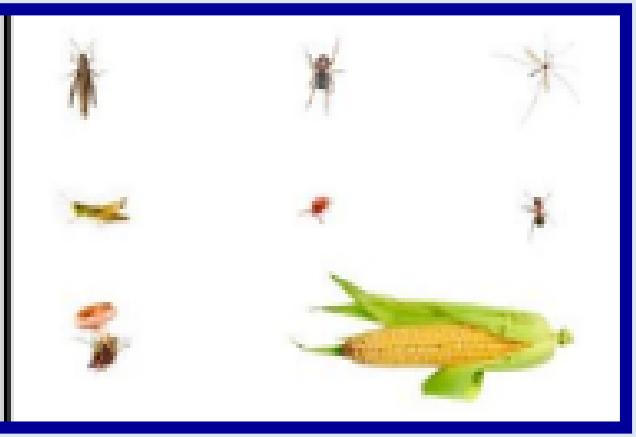
(15) Cover Crops Attract Beneficial Insects:

Plant Diversity = Beneficial Insect Diversity

Costa Rica
150 Plants & Animals
24 Hours - Forest

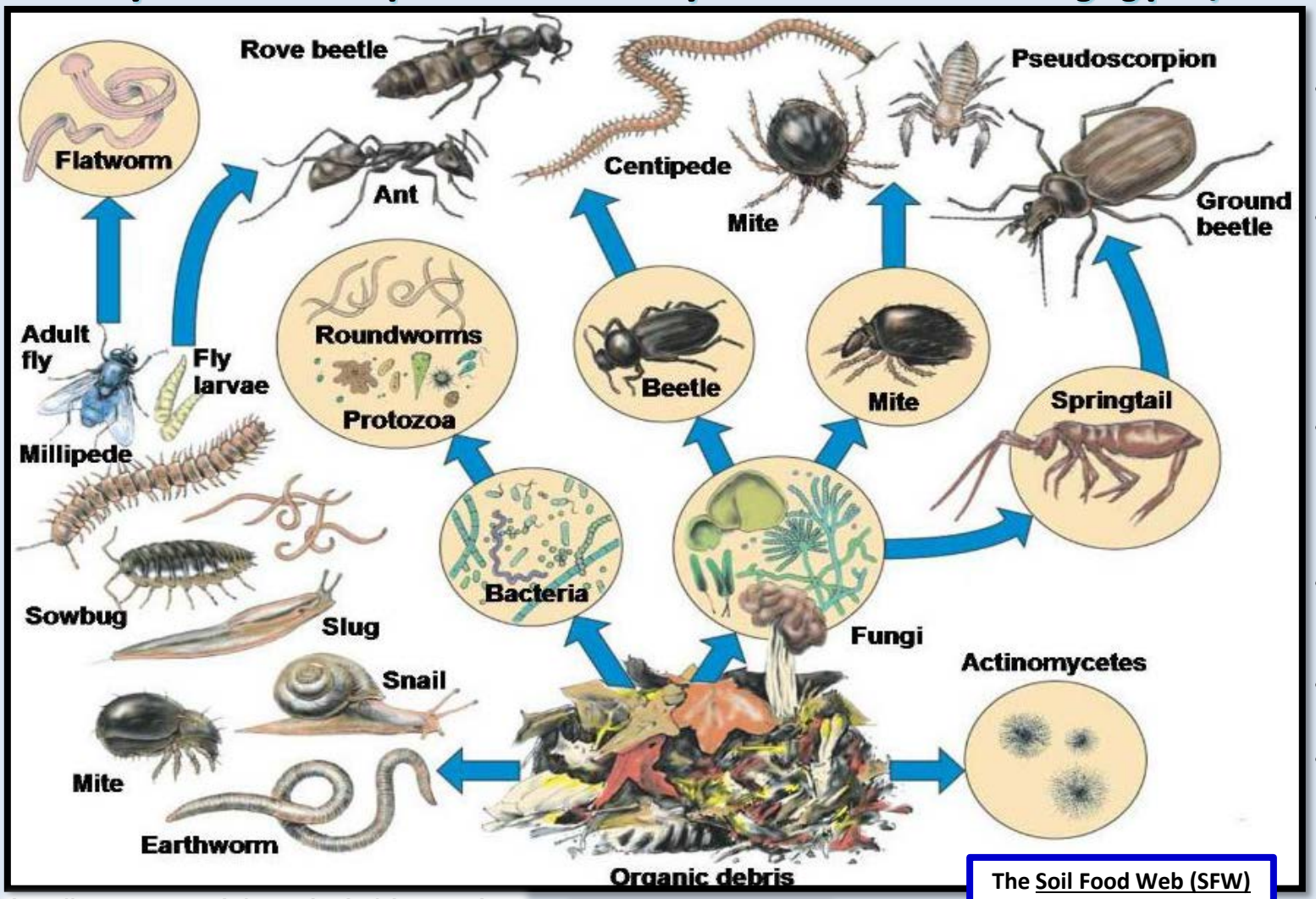
Cape Town, South Africa
100 Plants & Animals
24 Hours - Grassland

Iowa Corn Field
8 Plants & Animals
24 Hours



(16) Cover Crops are used for Disease Mgmt./Suppression:

Healthy Soil: Provides Optimal Predator-Prey conditions and for managing pest/disease problems



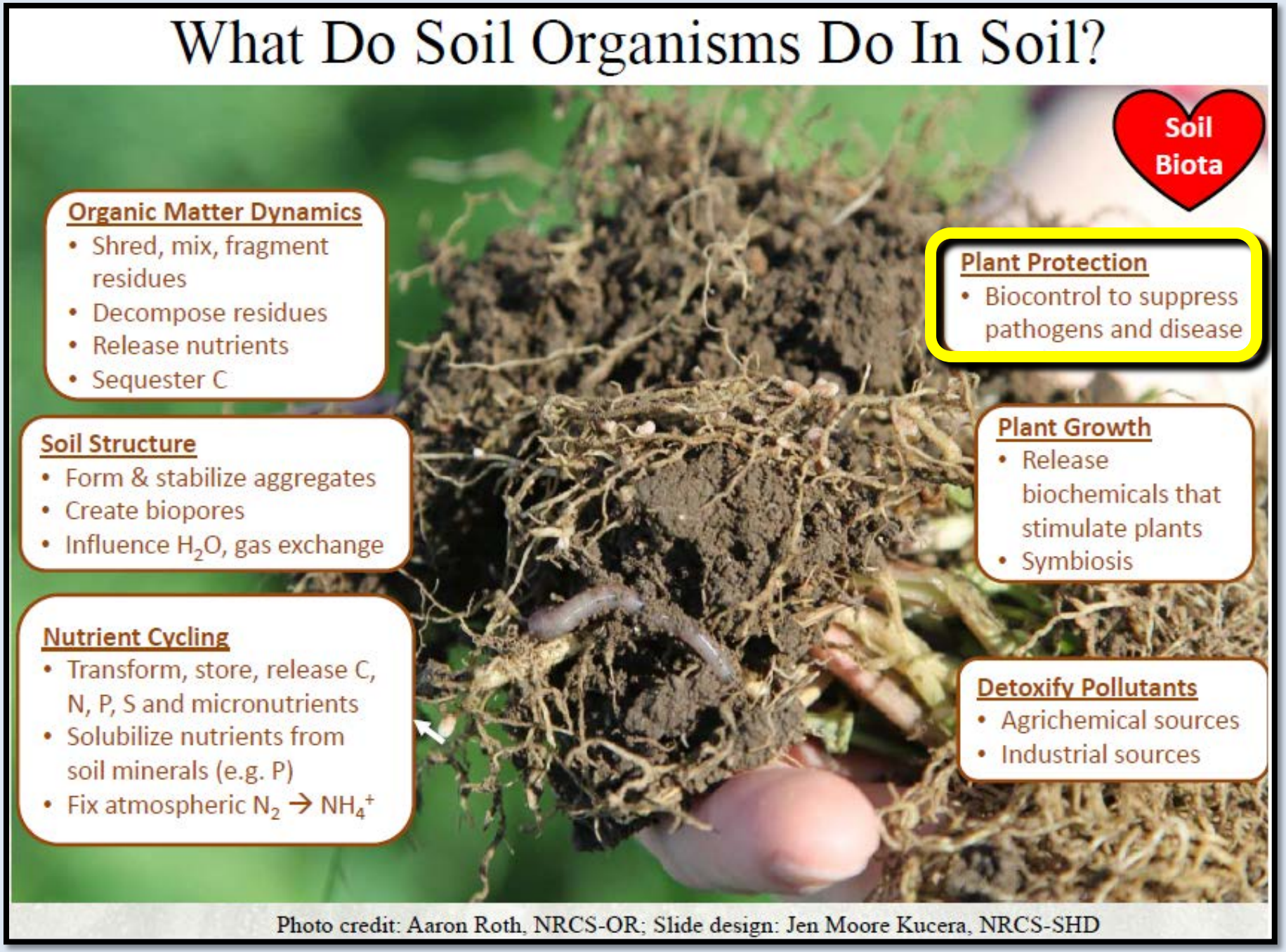
http://www.rw.ttu.edu/2302_butler/chapter6.htm

5% OF SOIL ORGANIC MATTER IS LIVING ORGANISMS

The Soil Food Web (SFW) is a complex association of organisms responsible for breaking down crop residues and cycling plant-available nutrients in the soil.

- Cover Crops Provide food or habitat for natural enemies of pests
- Cover crops may be selected that release biofumigation compounds that inhibit soil-borne plant pests and pathogens
- Species can be selected to serve as trap crops to divert pests from production crops
- Mycorrhizae suppresses pests and diseases
- Cover Crops break pest cycles
- Avoid cover crop species that harbor or carry over potentially damaging diseases or insects
- Use an Integrated Pest Management (IPM) Plan

(16) Cover Crops are used for Disease Mgmt./Suppression:

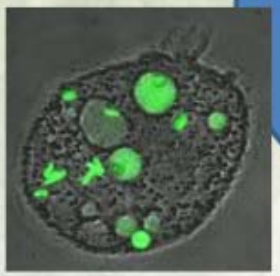


(16) Cover Crops are used for Disease Mgmt./Suppression:

Soil Food Web Benefits: Population Control (Predation)

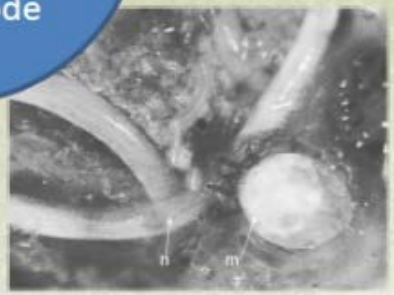
unlock the SECRETS IN THE SOIL

Nematode trapping fungi



Predation
Protozoa consume billions of bacteria; some consume fungi

Predation
Mite consuming springtail and a nematode



(17) Cover Crops Enhance Pollinators:

Use plant species that enhance forage opportunities for pollinators by using diverse legumes and other forbs.

Pollinators: Flowering plants that support pollinators also support beneficial predatory & parasitic insects.

Beneficial Insectary: Many of the nectar sipping & pest-eating insects that are attracted to flower pollen will also pollinate your fruit and vegetable crops & increase your yields.

(18) Cover Crops help support Wildlife:

Wildlife winter food & shelter

Provide food and cover for wildlife habitat management.

(19) Cover Crops catch Snow:

Planting/Seeding Cover Crops:

Get 4 Things Right

1. **The Right Species**
2. **The Right Inoculants**
3. **The Right Seeding Rates**
4. **The Right Seeding Time**

- **Select plants from all functional groups (diversity).**
- **Select at least two plant species within each functional group to provide some redundancy and insurance against failure of one species.**

<u>OTHER Cover Crop Planning/Management Considerations</u>:

- **Become a "committed" student and a observer**
- **Be Patient: Do not go cold turkey…..**
- **Find a mentor or community of believers of this type of holistic thought and planning process**
- **At least a two year break between crop types**
- **Plant the opposite crop type for your cover crop rotation**

Considerations for successful cover crop planning

- Economics (yields, cost of establishment, soil improvement)
- Establishment of next cash crop
- Residue management (cash crop) before and after cover crop emergence
- Timing and species (adequate growing season)
- Site and moisture conditions
- Seeding method/seed-soil contact (broadcast vs. drilling; adequate equipment)
- Crop rotation (diversity)
- Herbicide carryover (i.e., Label restrictions on herbicide use)
- Site preparation: Early weed control is essential

Cover Crop Seed Mix