Principles of Soil Quality

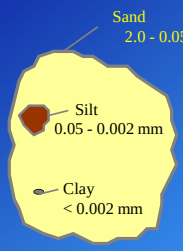
The keys to gaining agricultural productivity, environmental quality, and sustainability

Presented by:

Drexel Atkisson, Area Soil Health Specialist
USDA-NRCS Springfield, Missouri
417-831-5246 Ext 6
Drexel.Atkisson@mo.usda.gov

Managing for Soil Health

Soils: More than just sand, silt, clay



- The biological component of soils cannot be separated from the physical. Live and decaying plant residues, and the microbes and organisms that feed on them are just as important.
- Soil microbiology is by in large 'invisible' and thus a 'elusive' component to understand. However, it is *essential* to productive agriculture. (Kennedy and Papendick, 1992)

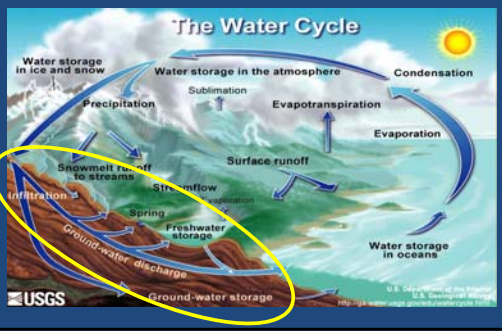
Key Soil Functions

- Receive rainfall and store water for root utilization.
- Decompose organic matter and other foreign material.
- Support plants or buildings.

James River, Stone County - stream bank erosion causes tree to lean. Photo: Steve Hefner, USDA-NRCS

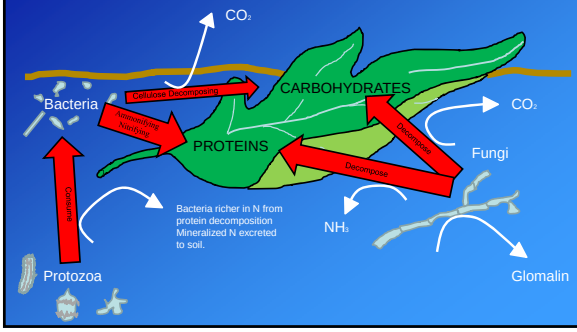
Tower of Pisa, Italy – inadequate foundation set in unstable soil. Wikipedia, 2010.

What is the most important item in the water cycle???

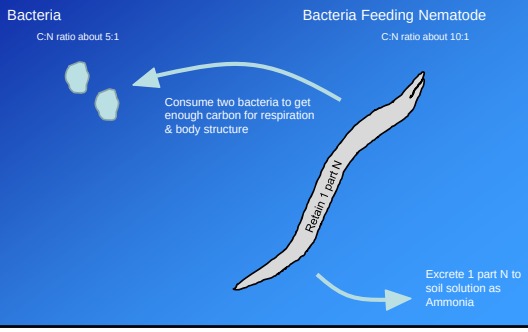


After adding water

Residue Decomposition



Nitrogen Mineralization



Energy Conversion

- Sun is ultimate source of energy.
- Energy is needed for life. Some organisms make their own energy (e.g. plants through photosynthesis)
  - Works only for some tissues (plant leaves, not roots) and at some times (day, not night)
  - Animals do not photosynthesize
- Turning chemical energy of carbohydrates, fats, and proteins into energy-bonds of ATP is respiration.

USDA-NRCS Photo

Two Things Create Aggregation

1. Biotic "Soil Glues"
2. "Exudates" from Plant Roots

Soil Structure

- Grouping of soil particles into aggregates, which can form into plates, columns, blocks, or spheres.
- Good soil structure includes poor space and is less dense than compacted. Structure permits air and water movement, and root penetration in the soil.
- "The soil should be half something and half nothing."

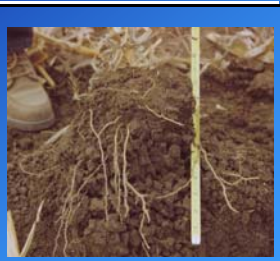


Photo Courtesy of USDA-NRCS East National Technology Support Center

Soil Biology

From the Invisible to the Visible

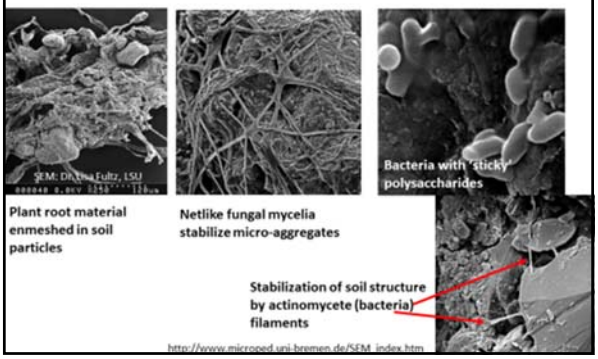
BACTERIA – Break down the proteins and carbohydrates in residue which serves as the source of food. Fix and release nitrogen.

FUNGI – decomposition of proteins and carbohydrates in residue, glomalin secretion, assist with phosphate uptake.

ARTHROPODS –invertebrates with exoskeletons and jointed legs. This millipede is a plant shredder.

Photo credits: Serita Frey, Colorado St U; Randy Molina, Oregon St U; David B. Richman, New Mexico St U

Aggregation is a Biological Process



Living Roots: Stimulate Soil Life

- Plant roots exude sugars.
- Soil biology feeds on sugars.
- Microbial activity cycles nutrients.

Cover crops used in Indiana to improve soils with platy soil structure. Photo: Steve Hefner, USDA-NRCS

Nutrient Uptake

- Plant roots are "leaky" and exude compounds like sugars, amino acids, carbohydrates to attract microbes.
- High carbon cover crops (wheat) feeds fungi.
- Low carbon cover crops (legumes) feeds bacteria.
  - Plants can get nitrate from bacteria early in the season and then ammonium from fungi later.

Soil Biology

- Plant roots exude sugars from photosynthesis
- Soil fungi use the sugars to live
- In return, fungi expand the root system and assist with phosphorus and water uptake.
- Fungi in the rhizosphere also help protect against disease agents and vectors.

Photo: Steve Hefner, USDA-NRCS

Soil Health Principles

"The principles to soil health are universal. How you get there and how fast is up to you."

Jay Fuhrer

1. Keep Soil Covered
2. Less Disturbance
3. More Diversity
4. Living Roots

Jay Fuhrer, USDA-NRCS District Conservationist, Burleigh County, North Dakota

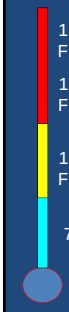
Soil Temperature

Bare soils promote drought even though we irrigate.

Covered Soil

Bare Soil

When soil temp reaches. . .



140° F	Soil bacteria die
130° F	100% moisture lost through evaporation & transpiration
100° F	15% moisture is used for growth 85% moisture lost through evaporation & transpiration
70° F	100% moisture is used for growth

J.J. Mc Entre, USDA SCS, Kerrville, TX, 1956

Less or No Tillage

- Add more residue than microbes can consume, carbon is sequestered in the soil. Add less residue than microbes can consume, carbon is depleted.
- Tillage or disturbance adds oxygen to the soil and accelerates microbial activity and consumption of carbon sources.
- To build OM reduce tillage, grow high residue crops, and leave undisturbed root systems in the soil for microbes.

USDA-NRCS Photo

Physical Disturbance in the form of tillage destroys the biological and ecological integrity of the soil ecosystem.

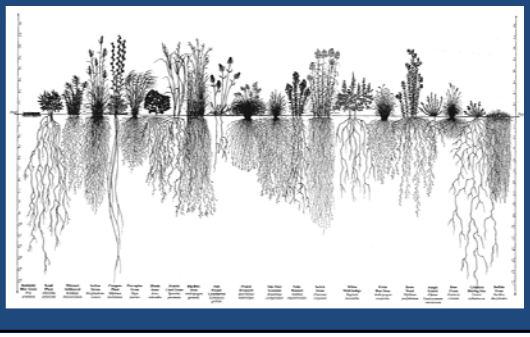
1. Disturbance stimulates the first responders--increased weed population
2. Destroys soil pores by shearing and smashing -impacts infiltration
3. Diminishes the soils ability to respire
4. Disrupts the habitat of most microorganisms arthropods
5. Simplifies the soil fauna over time
   -fungi don't like disturbance
   -Mycorrhizal fungi – uptake of P, Zn, Cu, Fe

Soil Quality Solutions: More Plant Diversity

- Crop rotations should include as many crop types as possible – cool season grass, cool season broadleaf, warm season grass, warm season broadleaf.
- 8, 12, and 15 cover crop "cocktail" mixes were being evaluated with positive results.

Photo: Steve Hefner, USDA-NRCS

Root Diversity



Cover Crops

- Feeds soil microbes and helps with nutrient cycling.
- Inhibits weed growth
- Protects from erosion
- Less energy required
- Build OM and soil structure

Photos: Rodale Institute

Elements of Sustainable Cropping Systems

- Rotation intensity – water use of the crops in rotation.
- Rotation diversity – use crop types and the intervals within the rotation.
  - Warm season grass
  - Cool season grass
  - Warm season broadleaf
  - Cool season broadleaf
- Management – tillage and planting methods to reduce soil disturbance.

Field pea, a cool season broadleaf.
Photo: Midwest Cover Crop Council

Cover Crop Considerations

- ID the Resource Concern
- Crop Rotation
- Timing
- Termination
- Cost and Availability

Turnips in a cover crop mix in North Dakota.
Photo: Steven Hefner, USDA-NRCS

Use C:N Ratio in your favor

- Need more residue for erosion protection or moisture conservation, then use a cover crop with a high C:N ratio.
- Need less residue for nutrient cycling, then use a low C:N ratio.

Newspaper	400-850:1
Sawdust	~250:1
Wheat straw	100:1
Corn Stalks	60-80:1
Rye	14-20:1
Crimson Clover	15:1
Hairy Vetch	15:1
Cow Manure	10-30:1
Fungi	10:1-25:1
Nematodes	~10:1
Soil	10:1
Sewage Sludge	5-16:1
Cottonseed Meal	7:1
Bacteria	5:1-7:1
Blood Meal	3:1

Sullivan, 2003. ATTRA Publication # IP024

Carbon to Nitrogen Ratio's

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
rye cover crop (vegetative)	26:1
mature alfalfa hay	25:1
Balanced Microbial Diet	**24:1**
rotted barnyard manure	20:1
daikon radish	19:1
legume hay	17:1
beef manure	17:1
ryegrass (vegetative)	15:1
young alfalfa hay	13:1
hairy vetch cover crop	11:1
soil microbes (average)	8:1

Carbon : Nitrogen Ratio

- Carbon makes up large component of organic matter. Nitrogen comparatively less.
- Soil microbes need nitrogen (for proteins) for life cycle and compete for the limited amounts.
- A high C:N (lots of carbon) does not permit much microbial activity and release of nitrogen.

The C:N ratio of straw can approximate 100:1.
Photo: Steve Hefner, USDA-NRCS

Contact Information

Drexel Atkisson
Area Soil Health Specialist SW MO
USDA-Natural Resources Conservation Service
417-831-5246 ext 6 office
417-298-9041 cell
drexel.atkisson@mo.usda.gov
Thanks

USDA EQUAL OPPORTUNITY STATEMENT

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille large print, audiotape, etc.) should contact USDA's TARGET Center at 202-720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, 1400 Independence Avenue, SW, Washington, DC 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.