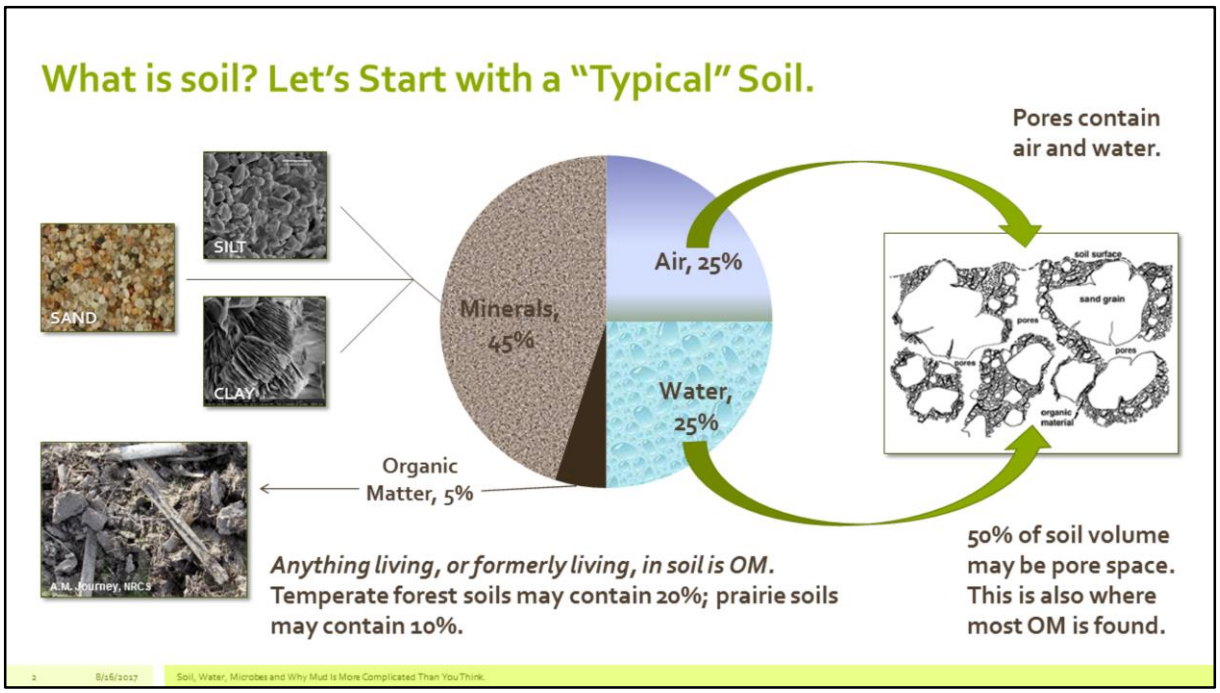
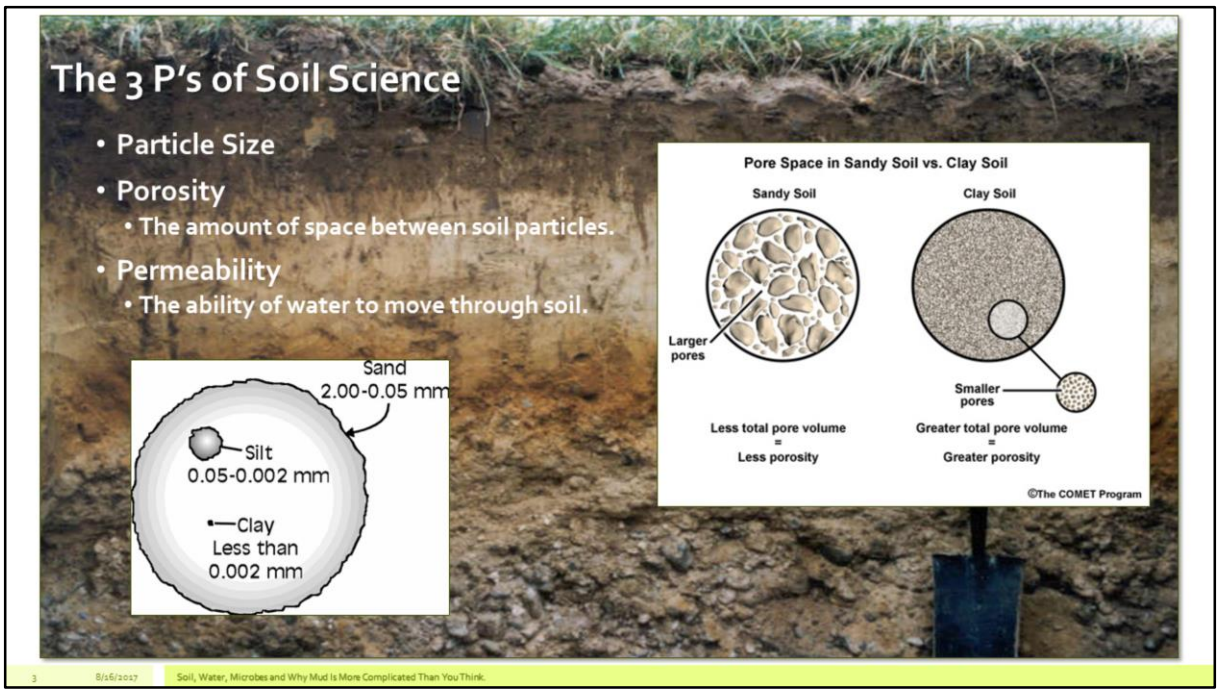
Soil, Water, Microbes and Why Mud Is More Complicated Than You Think.

Soil Health for the "Urban Oasis"

Ann Marie Journey
Soil Health Coordinator (ACES)
Minnesota Natural Resources Conservation Service (NRCS)



- **Definition:** Soil is a natural body that occurs on the land surface, is characterized by horizons and can support *rooted* plants (aquatic environment has sediment below 2.5 m). In reality, an *ecosystem.*
- 6 components. By volume, half solids–mineral components and SOM. SOM <6% of volume, 90% of function. The other half is air and water, which occupy pore spaces.



- Clay soils have tiny *page-like particles* (photographed with a scanning electron microscope) and miniscule pores. Sandy soils have large particles (visible to the naked eye) and pores. Note: *Clay "pages" hold a charge that attracts and holds salts and water-soluble contaminants (cation exchange capacity).*
- Odd but true: Micropores in clays add up to larger total pore volume (greater porosity). Sandy soils allow rapid H_2O movement (bigger pipes = greater permeability); clays slow it down. Inherent H_2O-holding capacity determined by texture class (% of sand, silt, clay). OM content determines maximum possible WCH. The more OM, the more H_2O a particular soil can hold.

Soil Forms in Horizons.

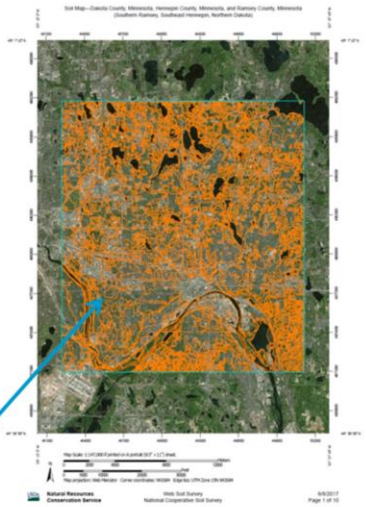
Soil profile, Mower County

O: Fresh/decomposing OM, little mineral content.

A: Topsoil. Rich in OM (provides dark color), still mainly mineral. Primary rooting zone.

B: Subsoil. Low in OM (so lighter in color). Minerals leaching from A accumulate here.

C: Substratum. "Rotten rock" (parent material) found here.



Each orange polygon encloses a "map unit," a discernably different soil.

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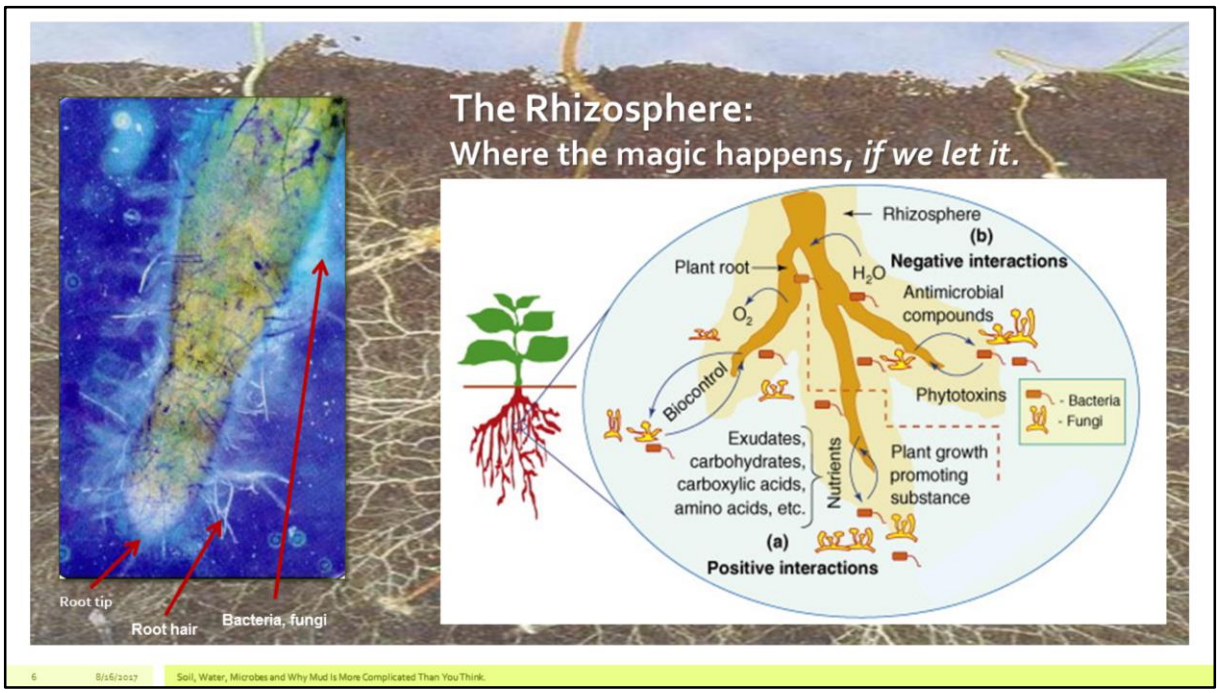
- A "typical" Midwestern soil has 5 major horizons: O, A, B, C, R (bedrock). A is the most productive, is home to the most soil life, and is the most vulnerable to human activity. Some soils (forests) also have an E horizon, between the A and B horizons. E = elluviated; minerals have been leached from this horizon.
- Soil forms slowly. It takes **500 to 1000 years** to form **1 inch** of soil.
- Soil forms in place (*in situ*). An intensely local process, as this map of southern Ramsey Cty. shows! But soil is not static; it is moved around by wind, water, glaciers and, now, humans. Most of the A horizon in my yard came from Scott and Dakota Counties. What might have come with it?

- ***Soil biome is the biggest, most diverse concentration of living biomass on Earth.*** You can think of it as an upended rainforest. Yet is it physically separated from the primary source of life-energy… the Sun.
- Total wt. of organisms in top 6": 5,000 - 20,000 lbs./A. (The average Holstein cow weighs 1300 lbs.)
- There are up to **11,000 species/g** (teaspoon) of *healthy* soil, including up to **10 billion** individual **microbes!** For reference, the **human** population was an est. **7.525B** on Aug. 15th.
- ***How is this possible?***



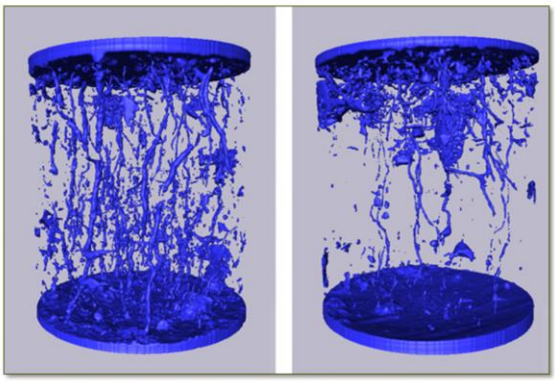
- **The rhizosphere is the soil within 1" of plant root**. It is the **most biologically active soil,** due to **root exudates. *50% of the energy captured via photosynthesis may be sent to the roots,*** in part to feed an underground "herd" of fungi, bacteria and other microorganisms living on, in and near roots.
- **Greatest impact on structure**. Arbuscular mycorrhizal (ARM) fungi make **glomalin,** a recently described glue that creates stable soil aggregates, which among other things, help plants stand upright. ARM are not the only synthesizers of soil glues in the rhizosphere-- bacteria, other fungi and plant roots also play a role-- but are critically important.
- **Highest nutrient cycling**. Plants feed microbes; microbes recycle nutrients to plant-available form. Fungi vastly extend roots' reach for nutrients, and perhaps moisture, in soil.
- **Most impacted by us.** Roots are densest in the top 8" of soil. Fungi, likewise concentrated, are extremely vulnerable to disturbance. ***Tillage = bulldozer in bedroom.*** *Are you gone during repairs, or do you move out entirely?*

Soil Health Practice #1: Minimize disturbance.

To till, or not to till.... That is the question.

Or is it? Tillage means driving, as well.
How many passes are too many?

The physical impact of machinery on soil can be visualized with a CT scan.



Dorthe Wildenschild, Oregon State University. Posted March 26, 2015. http://www.producer.com/2015/03/ct-scan-tech-used-to-check-soil-health/

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- **Moldboard overturns A horizon**; **destroys structure** (leading to **plow pan** formation), **introduces** O_2 that ***jump-starts microbial respiration of SOM***. This makes soil a **net greenhouse gas producer**. **Shank** moves less soil, but **still shreds fungi** and disrupts surface. **No-till drills** have the **smallest disturbance footprint** and ***introduce the least*** O_2.
- **Left-hand core** was taken from **undisturbed soil**. Note dense network of pores, especially the vertical **"arterial pores"** (water pipes). **Right-hand soil** had been run over by a beet harvester, ***once, 14 years earlier***. Even worse, these cores came from the **subsoil**. Imagine how compacted the topsoil was!

If it applies on the farm, it applies in your yard.

http://www.husqvarna.com/us/products/tillers/, accessed 8/8/17.

Husqvarna: "Experience *groundbreaking* power."

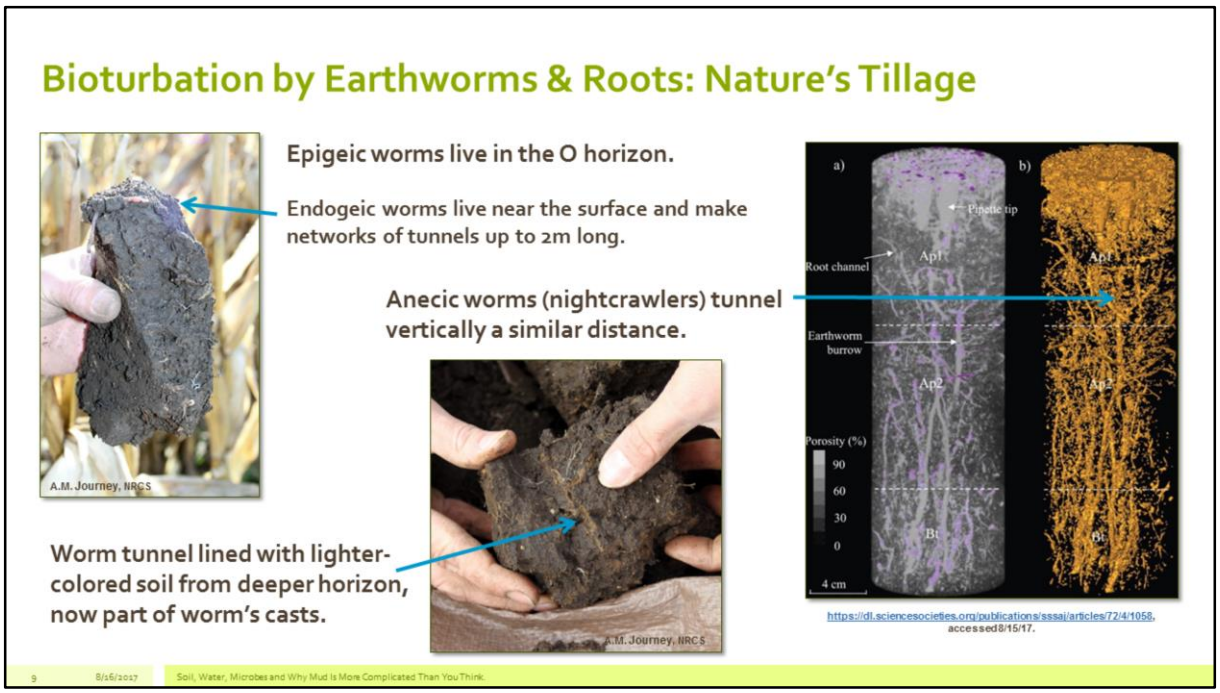
1-pass ease vs. the competition.

http://powerequipment.honda.com/tillers/why-choose-honda-tillers, accessed 8/14/17.

"Working depth" of 6.5 inches (or more) puts me at risk!

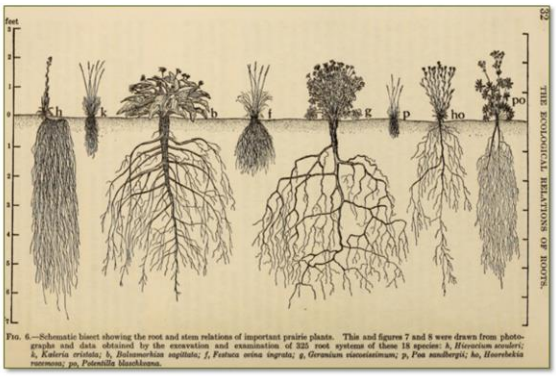
"Honda tillers have specially configured tines designed to produce **loam grade soil** quickly and easily.... *Honda tillers churn through just about anything.*"

- Up-front admission: *Occasional* tillage (a one-off event) may alleviate surface compaction in urban or suburban settings. BUT rototilling = putting soil in a blender, on "frappe." Repeated tillage can produce a plow pan (subsoil compaction) just as easily in a garden as it does in a cornfield.
- **LOAM IS A TEXTURE,** not a **grade**: Equal parts sand, silt and clay. If loam texture is not already present, you'd have to augment one or more of those components to achieve it by mixing.
- But you can easily mix soil into powder, a poor growing medium for plants. Aggregates (physical stability for roots) are fractured. Fungi are torn. SOM is digested, with a resulting CO_2 "burp," reducing the effect of mixing in compost.



- **Epigeic** & **endogeic** worms **shred and mix O-horizon OM into the A horizon**, the first step of building SOM. They are extremely vulnerable to tillage. **Anecic** worms surface to feed from depth, thus are somewhat protected from tillage. Their tunnels are vital for water infiltration, deep root penetration (route of least resistance, lined with fertilizer). See CT scan!
- Earthworms eat OM, thus OM-poor (sandy) soil has few worms. Since worms eat while tunneling, they move soil from point of ingestion to point of excretion, mixing it with new soil along with way.
- Earthworms are the largest soil invertebrate group by biomass. **50-300/m²** in **crops**, **100-500/m²** in temperate **woods, grasslands**.
- **EARTHWORMS ARE NOT A UNIVERSAL GOOD!** 15 exotic species– all from Europe or Asia– can be found in Minnesota. More are on the way, including, if not already present: "jumping worms." All of the worms we find familiar are invaders, and they are wreaking ecological havoc in our forests. Rapid incorporation of the duff layer (O horizon) interferes with nutrient cycling (speeding it up to the point of leaching loss) and germination success of native plant seeds. DO NOT INTRODUCE EARTHWORMS to soils not already infested! DO NOT MOVE MULCH from one location to another (jumping worm risk).

Soil Health Practice #2: Increase plant diversity.



Weaver, John. 1919. *The Ecological Relations of Roots.*
https://www.flickr.com/photos/internetarchivebookimages/14773450265/

- Plants have particular microbial partners, some unique, others shared.
- The more "individual rhizospheres," the more robust the soil community.
- Dissimilar root systems deposit OM at different depths… "starter fuel" for next year's plants & their partners!

A monoculture, be it corn, soybean or turf, is the equivalent of living on soda/pop & pizza for six months, then fasting for six. ***If your mother wouldn't let you do this, should you let your soil do it?***

- ***What's on the surface matters.*** **Soil microbes eat year-round!** Diverse vegetation, including cover crops in farm fields and weeds in lawns, provides consistent, varied food **(root exudates and organic debris).**
- Plants also benefit. Deep-rooted species reach H_2O and nutrients beyond the rooting zone of shallow-rooted plants, and make some available via exudates. Legumes (clover) fix N_2, likewise transferring some to non-legumes. A mixture of species also supports more beneficial insects (predators, pollinators) than a monoculture.
- Note scale on left: **Rooting depth in feet**. Most **turf grass** root systems penetrate **less than 6" deep**. *Poa* (bluegrass) roots to a mere 2" deep.
- Additional benefit! Varied canopy **keeps soil covered** during growing season. Gabe Brown's 20-species cover crop mix is pictured. Yes, that is a soybean field, and he gets better-than-county-average yields from it.

Soil Health Practice #3: Maintain living roots.

Liatris in mixed perennial border, Lyndale Park Butterfly & Hummingbird Garden, Minneapolis.

Soybeans sowed into rye cover crop that was terminated soon after planting. Dakota County.

One size does NOT fit all.

3-species cover crop mix seeded into corn. Scott County.

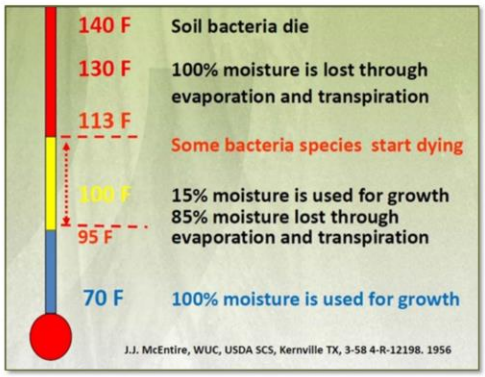
Perennials work well where practical. Try some in a vegetable garden. (Added benefit: *Pollinators will love you*.) Trees and bushes do, too. The healthiest soil in many fields is along a tree-line.

A *succession of plants*, including a cover crop (preferably, a mix) that "springs up" when the "crop" dies back or is harvested, is another option. Choose what works best!

- Practice #3 pairs with #2. **Roots provide microbial food** as long as they're **active**. **Microbes need food** to keep the nutrient cycle turning, and ***will use stored SOM if root exudates are missing or removed*** at any point during the growing season. They **can deplete labile forms before themselves becoming inactive. Think about the 2016 growing season! 222 days.**
- This also happens when soil is tilled, yet another reason to follow Practice #1!

Soil Health Practice #4: Keep the soil covered.

Protecting soil from erosion is one reason.



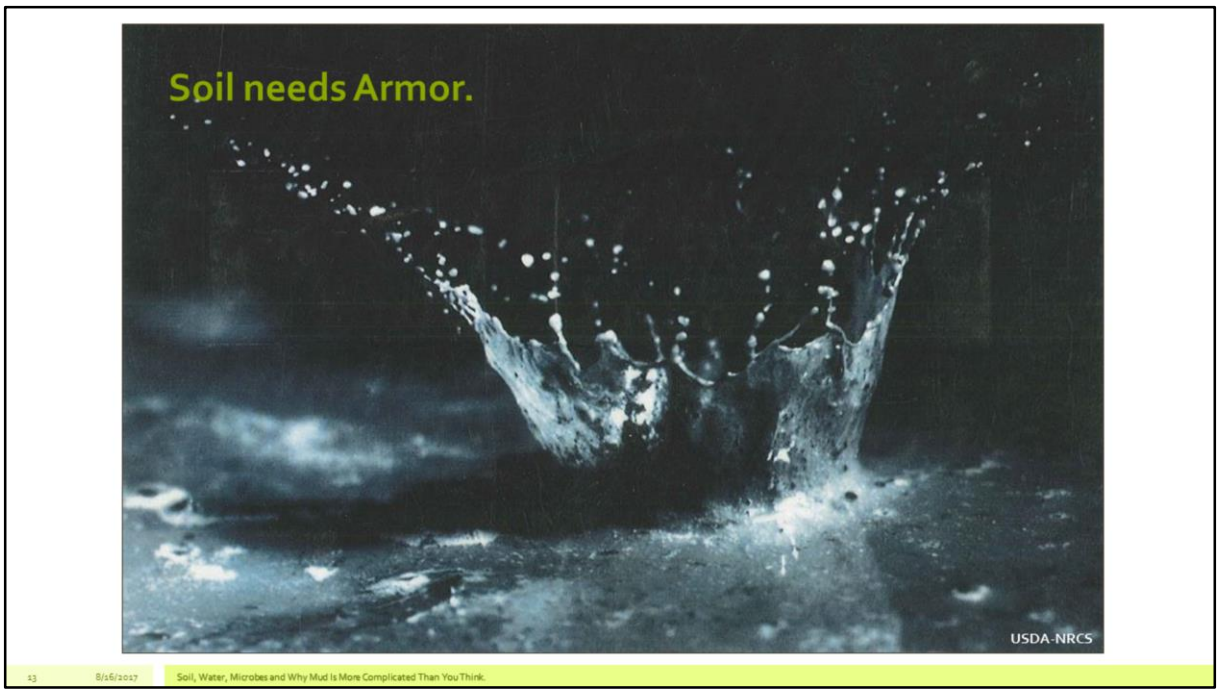
There are others.

- Optimum temperature for photosynthesis: 77 to 95F.
- Plants air-condition their leaves to stay in that zone.
- Air conditioning requires water, drying soil.
- Dry soil warms more easily. Bacteria start to die at 110F.

Cover crops shaded this soil from the noon sun.

Without shade, this soil was dangerously warm. Hours of sun remained.

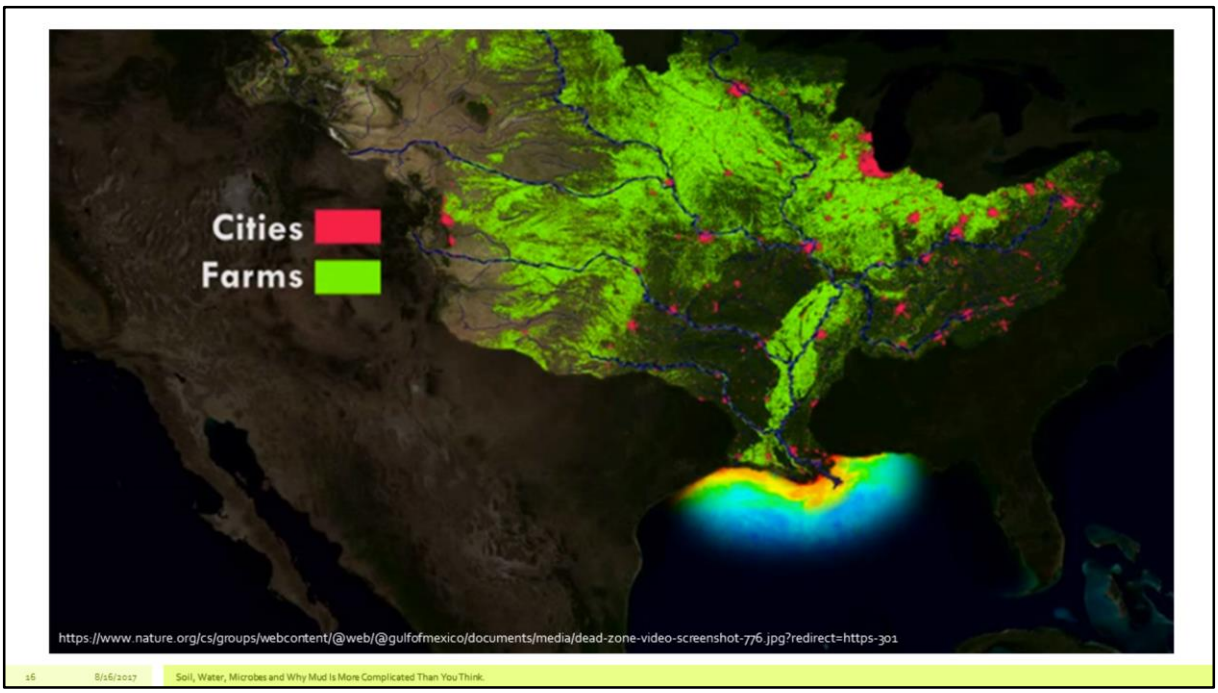
- When the air temperature exceeds the optimum for photosynthesis, plants use evapotranspiration to their cool leaves, taking water from soil and releasing it through stomata (portholes) on leaves.
- Evaporating water cools the leaf and the air around it– which is why stepping under a tree on a hot, sunny day makes you feel *so much cooler*– and returns the leaf to the photosynthetic optimum.
- Water-intensive! Can see evapotranspiration on weather radar!



- ***Raindrops fall at speeds up to 20 mph and can throw soil particles five feet horizontally, two vertically. One storm can wash 0.4" of soil away-- 5 tons/A (half a dump truck).***

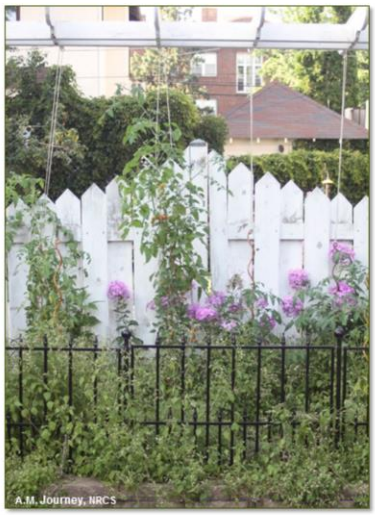
- This field has armor (Brown Ranch). Not tilled, soil is always covered. Many different plants. Healthy soil, lots of glomalin. This is how it looked after ***13 inches of rain in one day!***

- In contrast, this 4" storm in IA. Topsoil washed into ditch, field damaged. From ditch, soil, fertilizer and pesticides go to waterways, degrading water quality locally and regionally.
- ***This problem is NOT limited to agricultural lands!*** Impervious surfaces reduce infiltration and exacerbate runoff in cities. 6-19-14 storms flooded Minnehaha Creek, taking soil, pet waste and lawn fertilizer (the Big 2 of N, P in urban runoff) to the Mississippi river.



- ***3/4 of the N-load entering the Lower Mississippi watershed comes from MN***; the rest is from WI, IA, SD. Heard of the **Dead Zone** in the Gulf of Mexico? It has been the size of Delaware in recent years. In 2017, before Hurricane Harvey stirred that part of the Gulf, it had reached the size of New Jersey. Soil, and soil health, impacts water quality.

Closer to home, Covered Soil = Healthier Tomatoes.



"What matter are tomatoes.... *A spiritual experience*.

The spontaneity of the tomato compared to the manufactured sweetness of the glazed doughnut. An awakening takes place, light shines in your soul."

--Garrison Keiller

https://www.washingtonpost.com/opinions/we-will-survive-this/2017/08/01/7be9322c-76f0-11e7-8839-ec48ec4cae25_story.html?utm_term=.8dc7a34aac54)

M. Grabowski, http://www.extension.umn.edu/garden/yard-garden/vegetables/disorders-of-tomato/, accessed8-15-17.

Blossom End Rot, the ruin of Roma tomatoes and denier of sauce.

Blossom-End Not!

- Blossom end rot is a common problem in tomatoes, caused by calcium deficiency in the plant.
- It is *not* a sign of inadequate soil Ca^{2+}.
- Conserving soil moisture by keeping the soil covered can improve nutrient uptake (UMN Ext.).
- Adding crushed egg shells to this bed did not help. Whatever that weed is, did.

Soil Health: It's not "just for farmers," anymore.

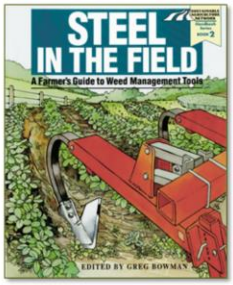
Grocery stores are the front lines.

Top 10 US Food & Beverage Producers (2015):

1. PepsiCo, Inc.
2. Tyson Foods, Inc.
3. Nestle
4. *JBS USA (beef, pork and lamb processor, cattle feedlot operator)
5. Coca Cola, Inc.
6. Anheuser-Busch InBev
7. *ConAgra Foods, Inc.
8. *Kraft Foods, Inc.
9. Smithfield Foods, Inc. (hog producer, pork processor, packaged meat manufacturer)
10. General Mills

*No hits for "soil" or "soil health" on website.

Does organic = soil healthy?



Weed control is a challenge for organic growers.

Tillage is "organic."

As is flame-weeding.

So, it depends.

Dr. Wayne A. LePori, Department of Agricultural Engineering, Texas A&M.
https://attra.ncat.org/attra-pub/viewhtml.php?id=110

- Proposed: A simple test. Go to any food corporation homepage. Search for "soil," then "soil health." Good luck.
- Major players include: General Mills (partnered with Nature Conservancy on Soil Health Roadmap), PepsiCo (member of Midwest Row Crop Collaborative, supporting Soil Health Partnership), Smithfield (in-house targets for grain purchases, soil health), Anheuser-Busch (SmartBarley Benchmarking Program launched globally).
- The question to ask is how much of this may be window-dressing, and how much represents a durable change in practice.

Any questions?

THANK YOU!

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