

Regenerative Agriculture

good for soil and water
good for farmers
good for consumers

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RACC Board Member

Bike Rider



a caveat...

- ▶ I am a geologist & gardener, not a farmer
- ▶ Most of what I know came directly from someone else
 - ▶ Tom Stanley
 - ▶ Mary and John Pederson
 - ▶ Steve Hart
 - ▶ Gabe Pent
 - ▶ Bill Hamilton
 - ▶ Glenn and Becky Szarzynski
 - ▶ and many others....



Regenerative Agriculture

- ▶ Many terms!
“organic” “natural”
“permaculture”
“sustainable”
- ▶ ***Regenerative Agriculture*** is a set of practices that focus on improving **Soil Health**
- ▶ **USDA**
“Soil health is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.”

% Organic Matter (dry weight) via Lab Test

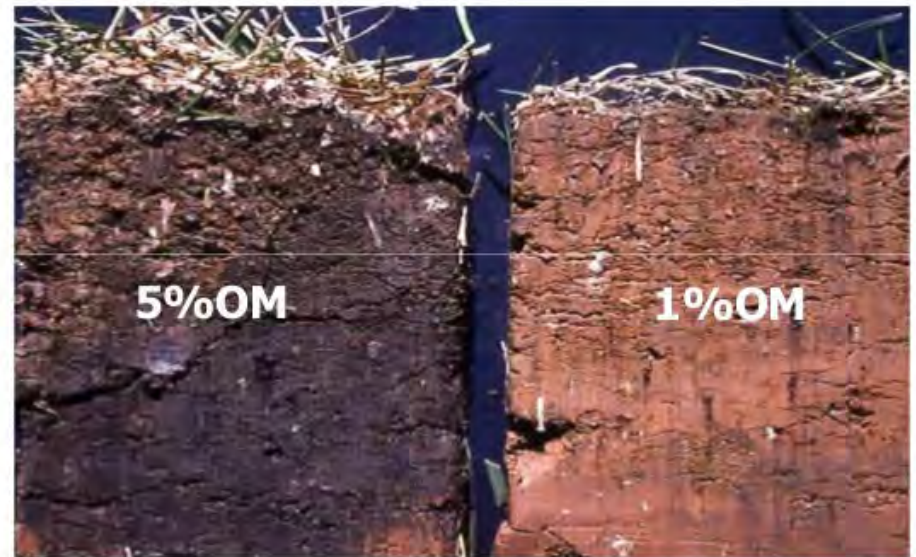
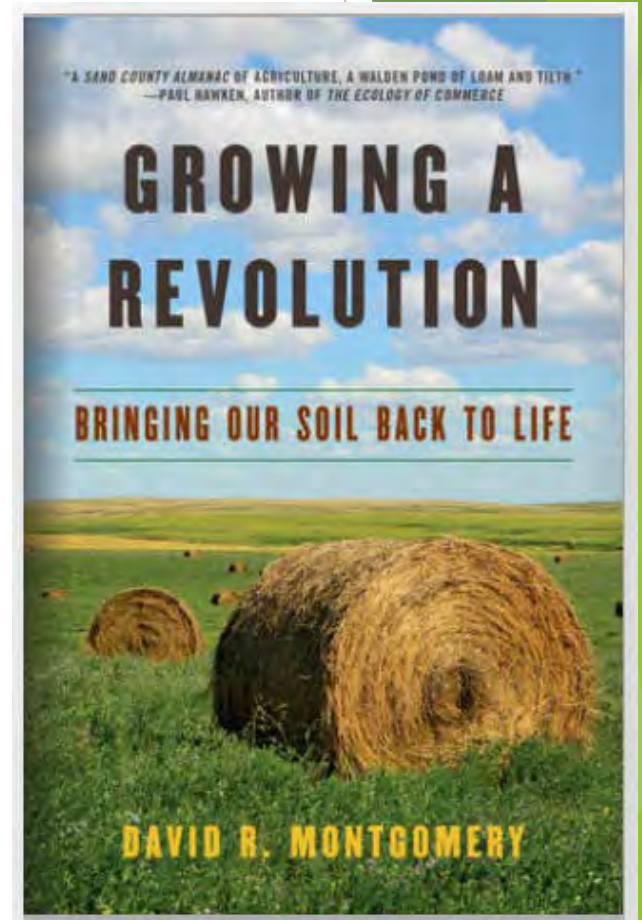


Image: Rodale Institute

Why is this important?

- ▶ “The degradation of soils and the loss of organic matter are the most underappreciated environmental crises humanity now faces. But the stage is set for ground-up transformational change, as the short-term interests of farmers increasingly align with preserving long-term soil fertility.”

Montgomery, David R. 2018. Growing a Revolution: Bringing Our Soil Back to Life (p. 30). W. W. Norton & Company.



What is the nature and scale of the “degradation?”

- ▶ Soil erosion
- ▶ Organic matter depletion
- ▶ loss of fertility
- ▶ loss of resilience



But first... soils and soil formation

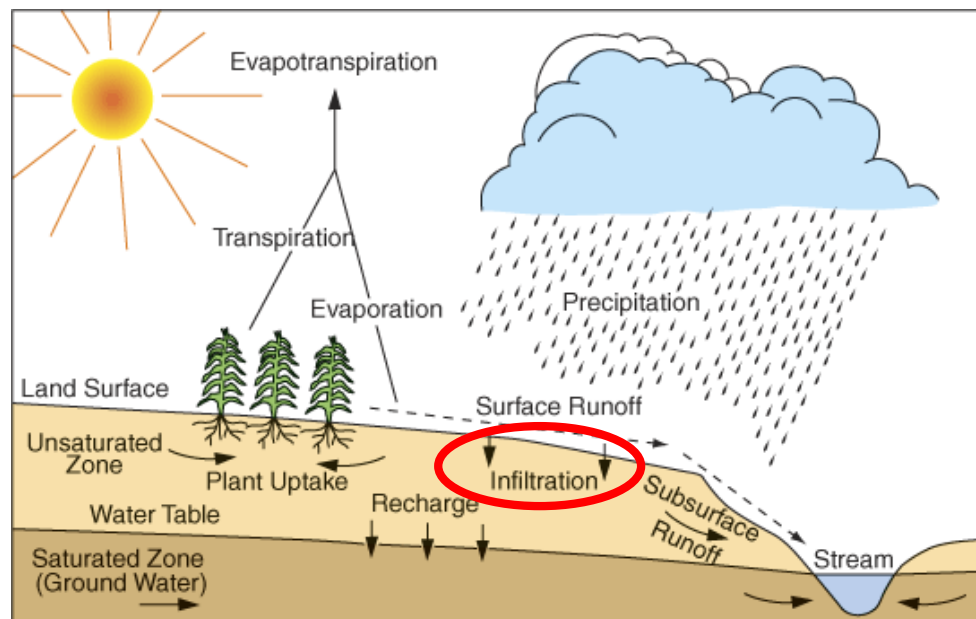


What is a soil?

- ▶ Soil Science Society of America
“The layer(s) of generally loose mineral and/or organic material that are affected by physical, chemical, and/or biological processes at or near the planetary surface and usually hold liquids, gases, and biota and support plants.”
- ▶ Geologists – a layered deposit that differs from the *parent material* due to chemical, physical and biological processes

Soils control the hydrologic cycle on land

- ▶ Soil and the vegetation it supports are part of the web of feedbacks between hydrology, soils, weathering and erosion
- ▶ Good soils absorb more rain and support healthier vegetation

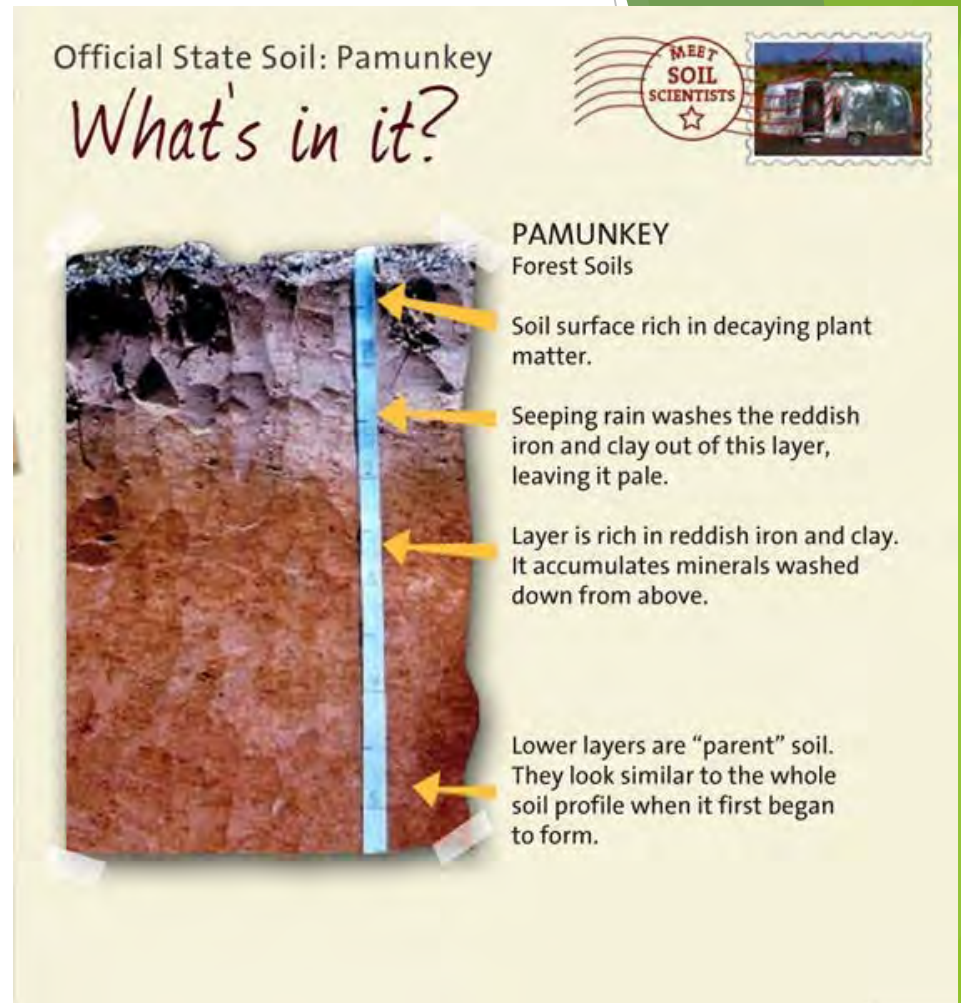


<https://www.quora.com/What-is-the-name-of-the-most-common-practice-of-recharging-groundwater>

Infiltration is the gatekeeper!

Soil Formation

- ▶ A horizon (+O/E = “topsoil”)
 - ▶ accumulates humus
 - ▶ extensively bioturbated
- ▶ B horizon (“subsoil”)
 - ▶ clay & iron accumulate
 - ▶ rooting
- ▶ C horizon (or rock)
 - ▶ oxidized but unweathered
 - ▶ source of P, K



A “good soil”

Soil Properties

- ▶ Physical
 - ▶ Color
 - ▶ Texture
 - ▶ Structure
 - ▶ Depth
 - ▶ Water retention (“field capacity – wilting point”).
- ▶ Chemical
 - ▶ pH
 - ▶ CEC (cation/nutrient availability, bound to organics and clays, ...)
 - ▶ salt concentration
- ▶ Biological
 - ▶ abundance
 - ▶ diversity
 - ▶ resilience

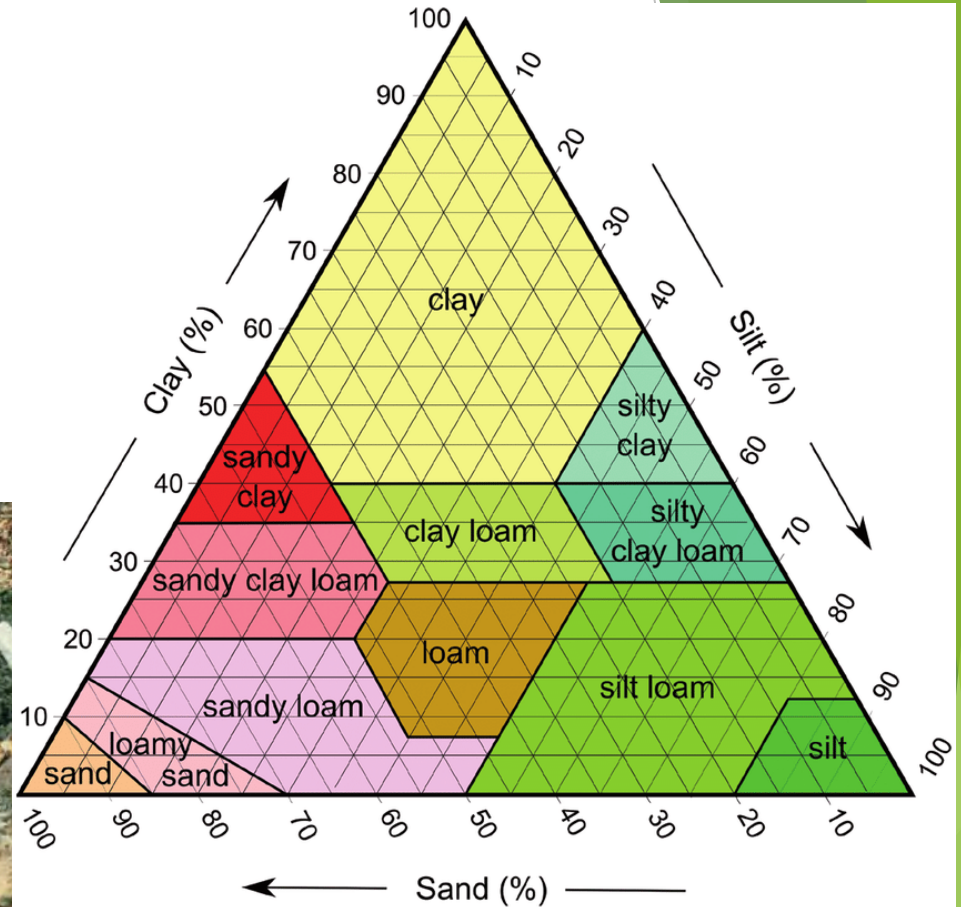
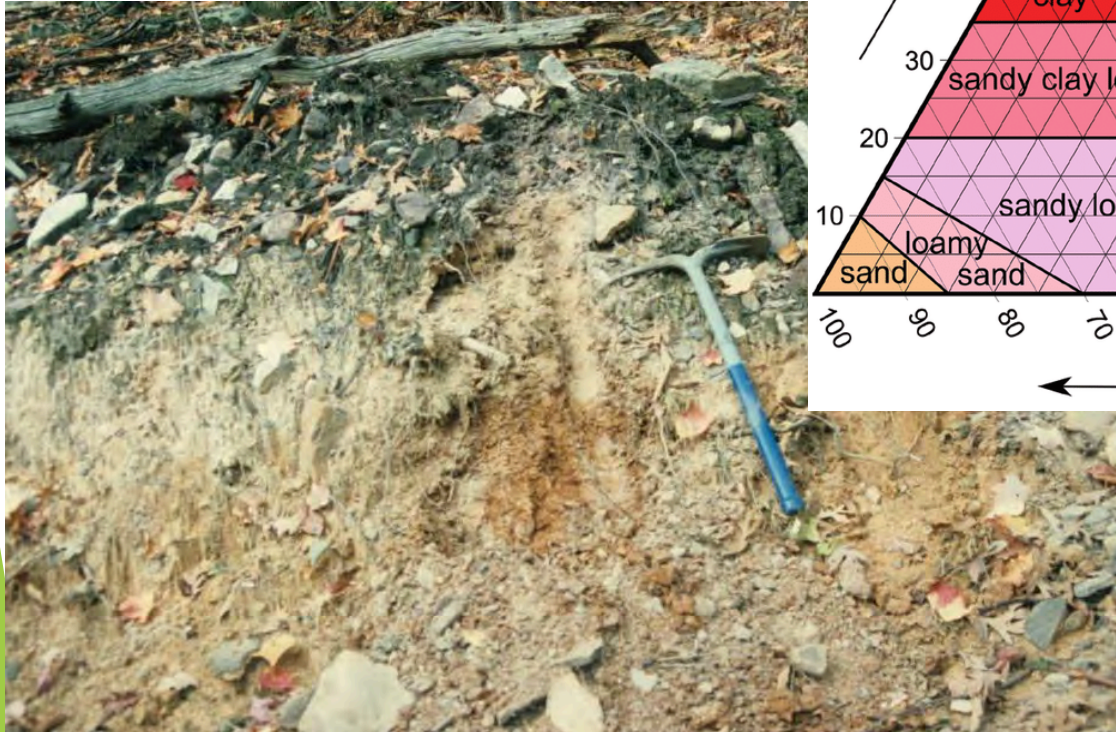
Soil Color

► “horizons”



Western Virginia, foot of a sandstone ridge

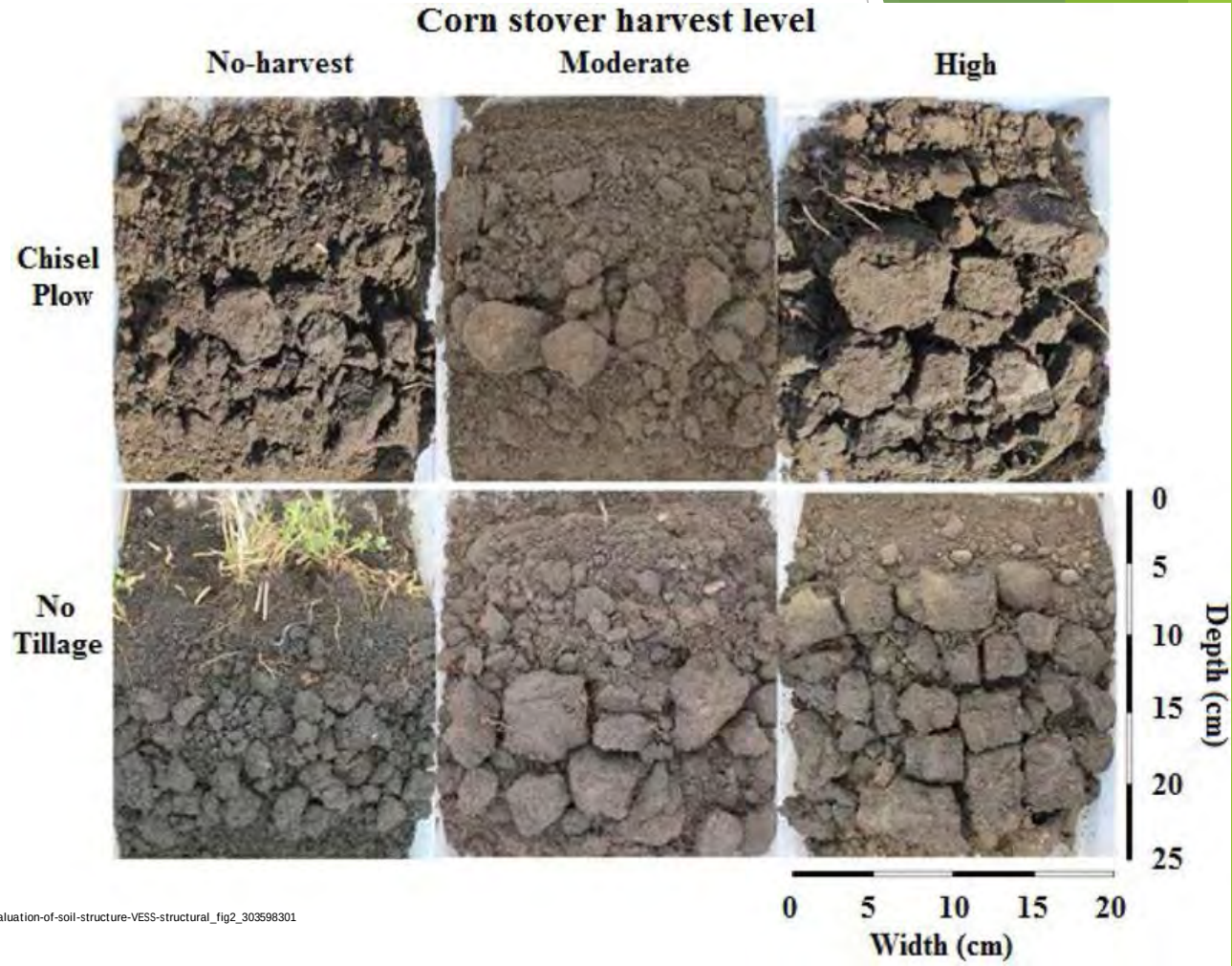
Soil Texture



https://www.researchgate.net/figure/A-soil-texture-diagram-soil-types-according-to-their-clay-silt-and-sand-composition-as_fig2_235884102

Soil Structure

- aggregate development



Humus

- ▶ holds water
- ▶ provides the “home” for soil biology
- ▶ adsorption sites for nutrients and minerals
- ▶ sequesters carbon as it thickens



Soil biology

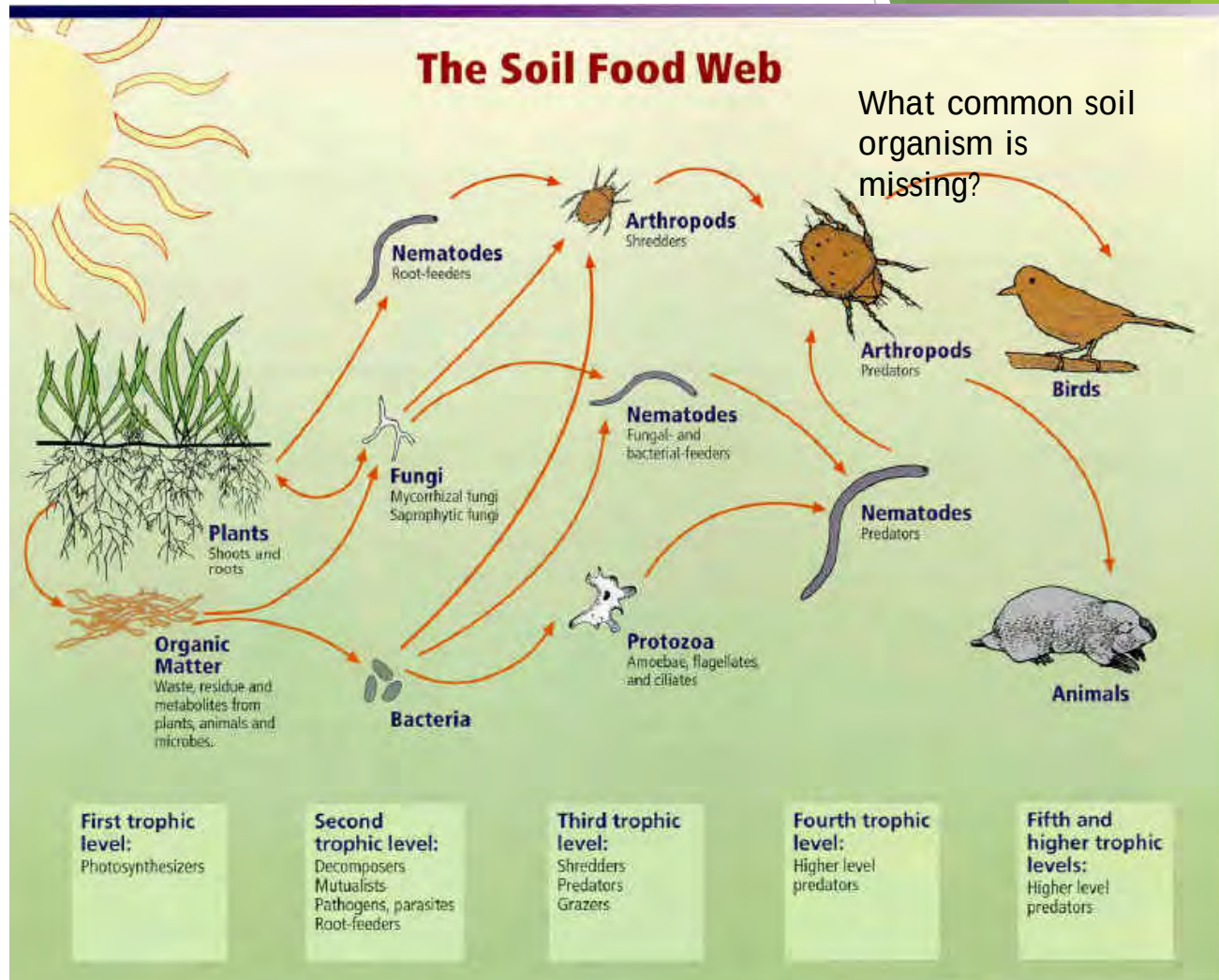


watch Bacteria, Fungi, Protozoa and Nematodes from soil

<https://www.youtube.com/watch?v=RY-JY-D4v7I>

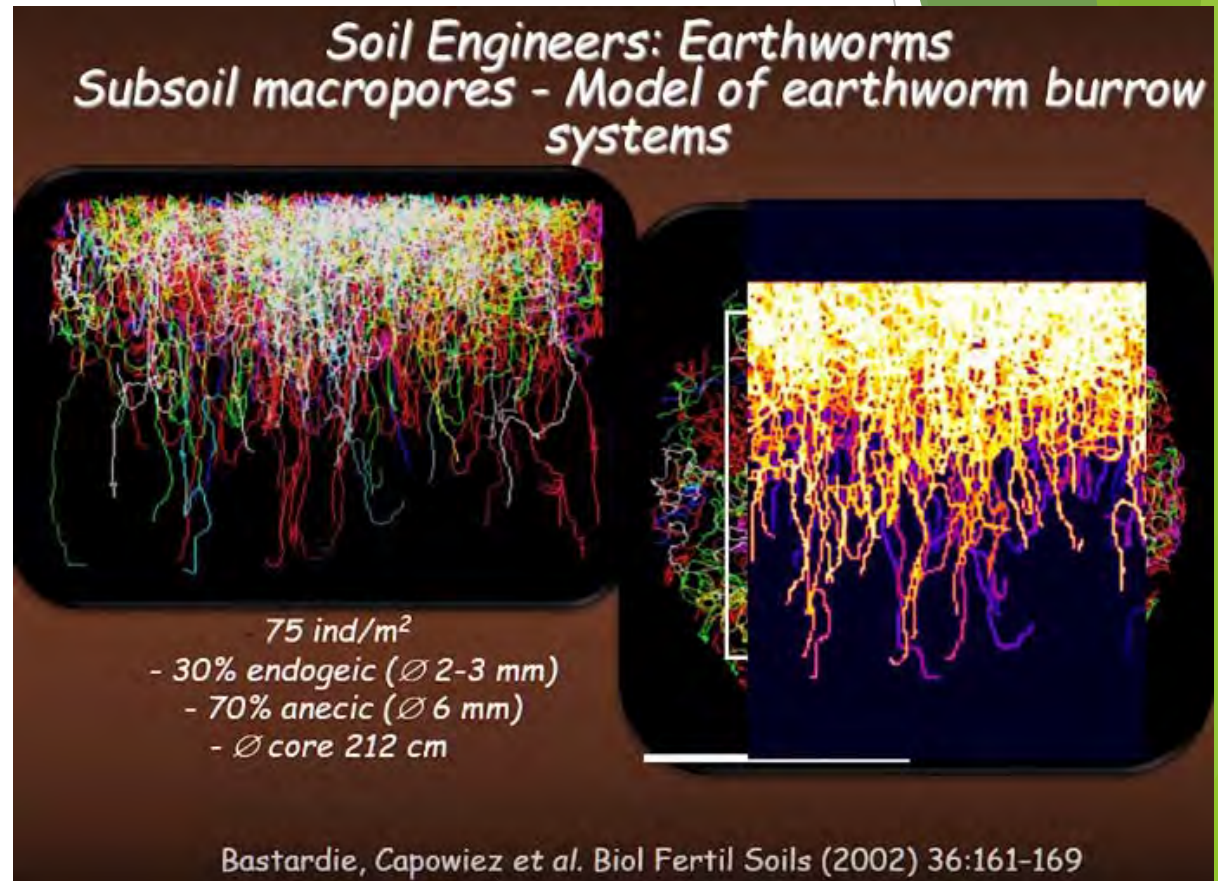
The Soil is a Food Web

- **Services include:**
- physical mixing
- aggregate formation
- generating humus that stores carbon
- “trading” nutrients for sugar
- breaking down rock



Example: Earthworms

- ▶ mixing
- ▶ shredding
- ▶ providing channels for roots



<https://www.youtube.com/watch?v=yExpSwpRkEs>
go to 46 minutes

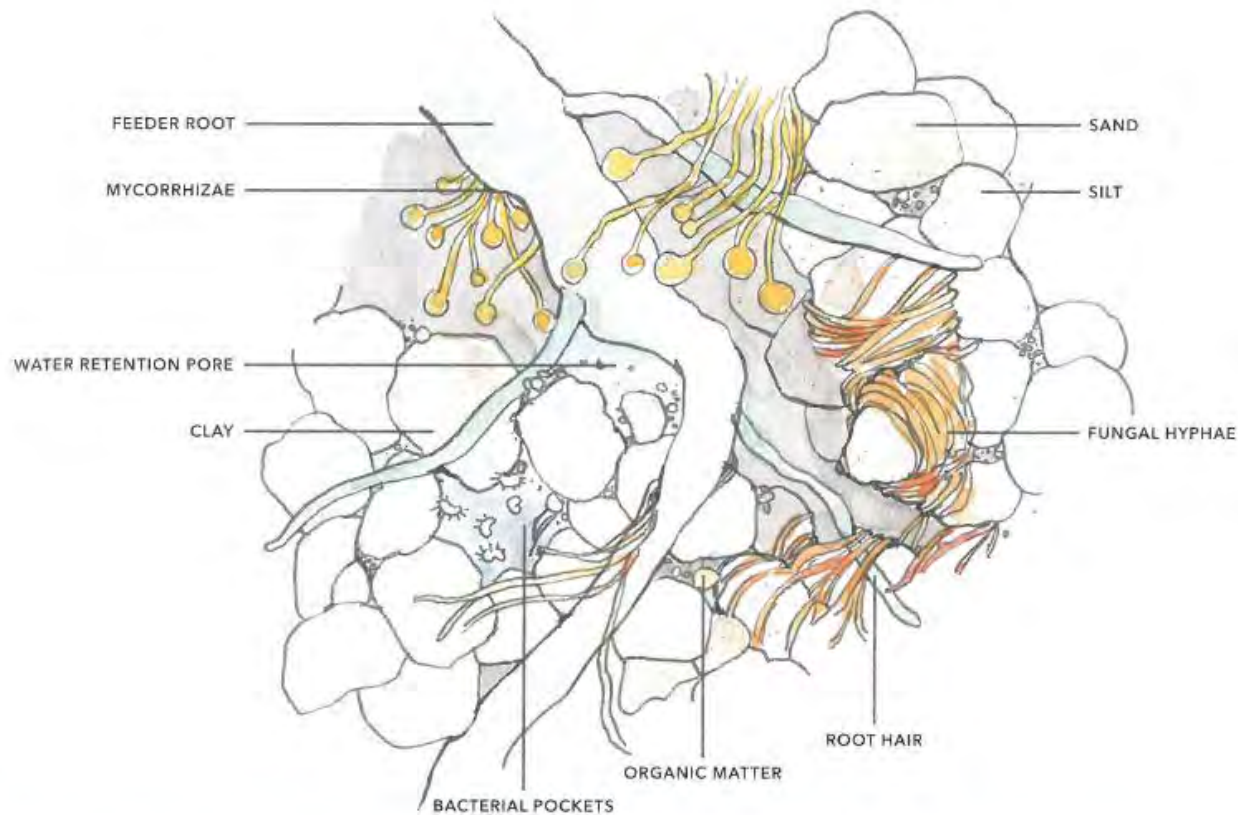
Examples: Arthropods



Soil Critters - Life in the Great Underneath <https://www.youtube.com/watch?v=mRiylsNjdzw>
Dr. Patricia Q. Richardson

Fungi

PROVISIONING THE MYCORRHIZOSPHERE

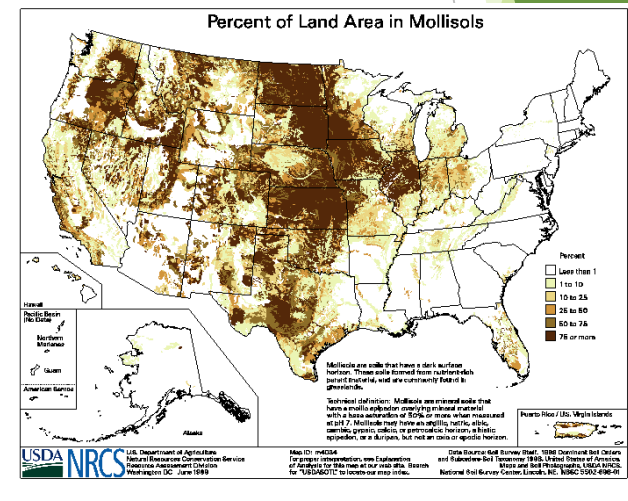
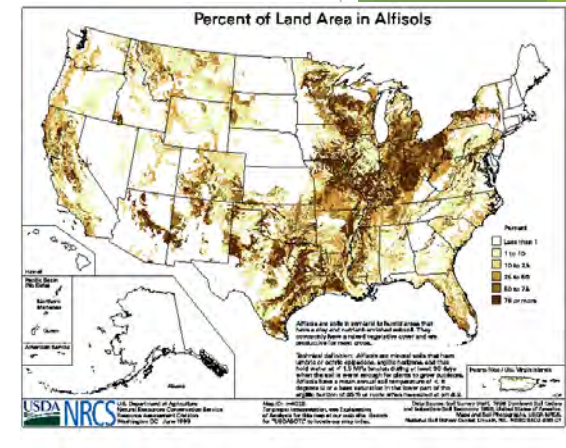


Soil aggregates are the result of good fungal stewardship. Hyphae will abide within, delivering fertility in long-lasting fashion.

Soils in Rockbridge

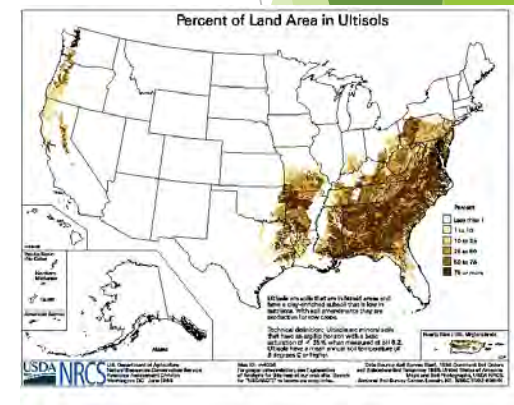
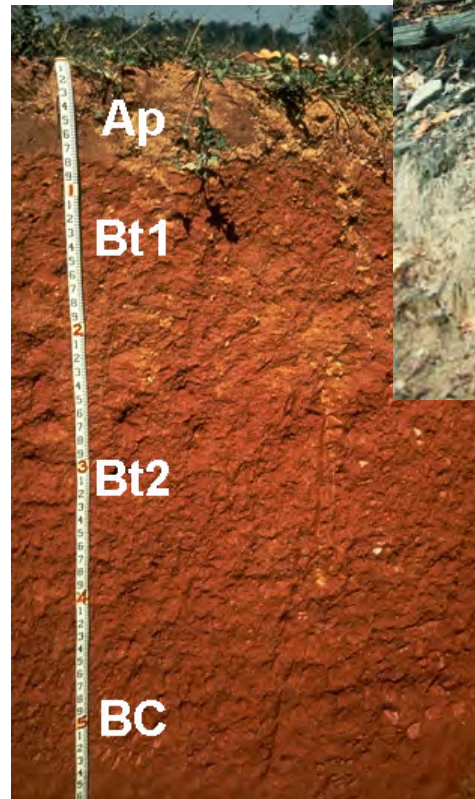
Alfisols - Mollisols

- ▶ short- and long-grass prairie soils
 - ▶ phytoliths
 - ▶ intense grazing



Soils in Rockbridge

- ▶ intensely weathered
- ▶ infertile subsoil
- ▶ leached of nutrients/minerals
- ▶ fragile topsoil



Keeping soil in place!



Soil erosion is a big deal

Only 60 Years of Farming Left If Soil Degradation Continues

Generating three centimeters of top soil takes 1,000 years, and if current rates of degradation continue all of the world's top soil could be gone within 60 years, a senior UN official said

- ▶ erosion continues
- ▶ 1/5 of the added carbon in the atmosphere came from soil
- ▶ it continues to be 1/6th of the carbon emissions

Soil erosion contributes significantly to global carbon emissions

June 1, 2015

Soil erosion that occurs in rainy seasons leads to a significant amount of carbon being released into the atmosphere, a new study shows.

Investigators who analyzed 240 runoff plots from different regions of the world found that organic carbon losses from soils corresponds to about one-sixth of annual fossil fuel-induced carbon emissions with highest rates for semi-arid soils followed by tropical soils and temperate soils.

"The organic carbon lost from soils is more likely to reach the atmosphere under semi-arid sandy soils of weak structure compared to clayey tropical or temperate soils where organic matter is more protected," said Dr. Vincent Chaplot, co-author of the study published in *Earth Surface Processes and Landforms*.

<https://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/>
<https://phys.org/news/2015-06-soil-erosion-contributes-significantly-global.html>

Soil degradation creates a
POSITIVE feedback loop
--degradation produces
more degradation

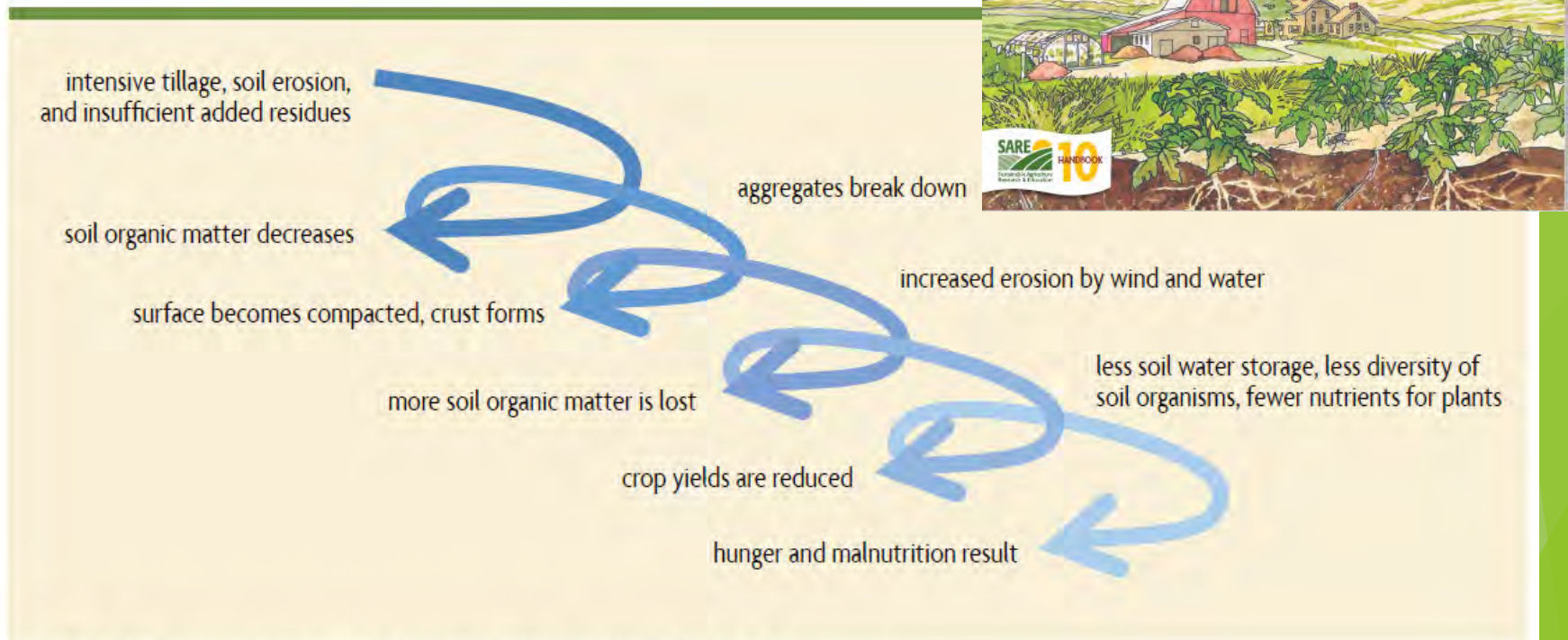
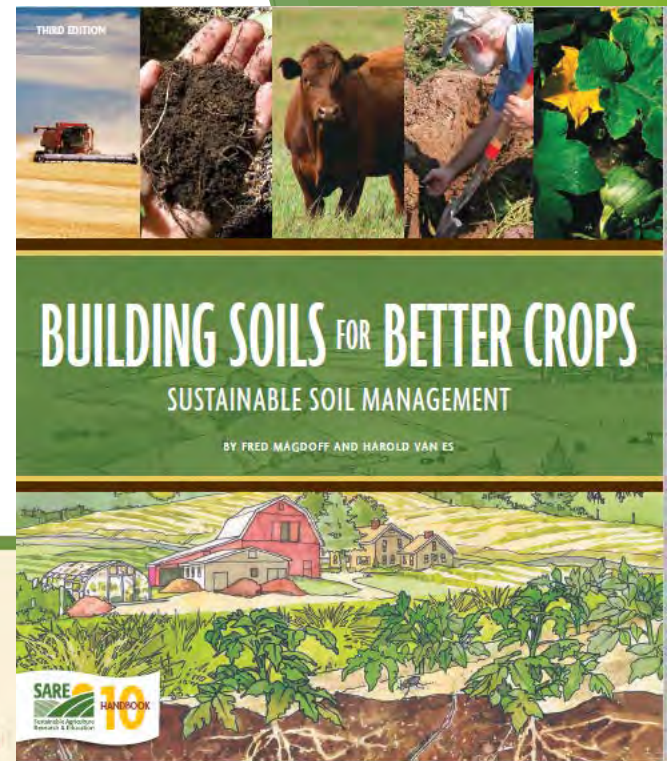


Figure 1.1. The downward spiral of soil degradation. Modified from Topp et al. (1995).

Soil Erosion Land Clearing

- for grazing and crops



Soil Erosion

The Plow & bare soil

- ▶ disrupts mycelia
- ▶ leads to compaction (beneath Ap - plow horizon)
- ▶ dries topsoil & oxidizes organic matter
- ▶ promotes runoff



Photo courtesy of Duane and Company



Soil Erosion Overland Flow

- ▶ produces gullies and rills
- ▶ removes “topsoil”



Soil Erosion

The Dust Bowl

- ▶ drought
- ▶ bare soil
- ▶ no wind row



The huge Black Sunday storm—the worst storm of the decade-long Dust Bowl in the southern Plains—just before it engulfed the Church of God in Ulysses, Kansas, April 14, 1935. Daylight turned to total blackness in mid-afternoon. Courtesy of Historic Adge Museum
<https://www.neh.gov/divisions/public/featured-project/the-dust-bowl-neh-and-national-museum-american-history-national>

Soil Erosion Overgrazing

Iceland



<http://www.valtours.is/textar/enskir/spestor4.htm>



USDA NRCS

- ▶ and other organizations like the FAO
- ▶ promote conservation practices



“On April 27, 1935 Congress passed Public Law 74-46, in which it recognized that “the wastage of soil and moisture resources on farm, grazing, and forest lands . . . is a menace to the national welfare,” and it directed the Secretary of Agriculture to establish the Soil Conservation Service (SCS) as a permanent agency in the USDA.” www.nrcs.usda.gov

Soil Conservation Practices

- ▶ fence rows
- ▶ contour plowing
- ▶ strip cropping
- ▶ grassed waterways
- ▶ no-till
 - ▶ chemical
 - ▶ organic



<http://www.mda.state.mn.us/protecting/conservation/practices.aspx>

But soil erosion continues.....

USDA Rule of thumb: 1 acre-inch of soil weighs about 167 tons. If 167 tons form in 30 years, the annual soil formation rate is 5.6 ton/year. **5 tons erosion per acre per year** is generally **considered tolerable**.

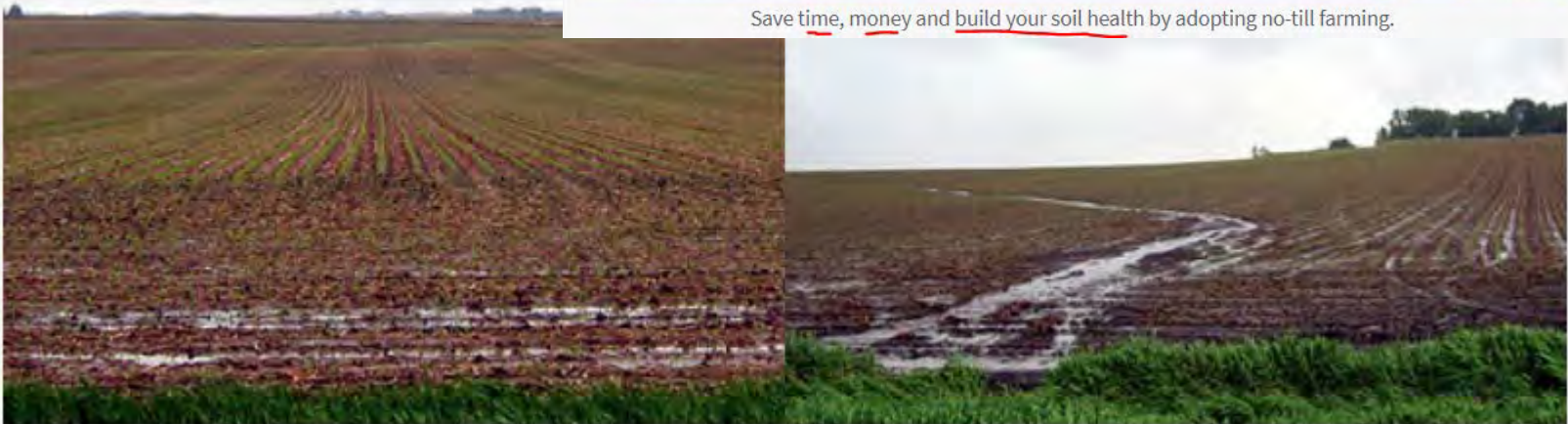
Regenerative Agriculture Practices

- ▶ Build soil health and promote a lively ecology
 - ▶ Minimize disturbance of the soil (No-till, reduce compaction)
 - ▶ Keep the soil covered (mulch, stubble, cover crops)
 - ▶ Rotate crops and animals for diversity
 - ▶ Maintain living roots

No-till



Save time, money and build your soil health by adopting no-till farming.



(Left): A no-tillage corn field after a week of 0.5 to 1.5 inch scattered rain showers in Northwest Iowa. (Right): A conventional tillage corn field after a week of 0.5 to 1.5 inch scattered rain showers in Northwest Iowa. Photos

No-till in Rockbridge



and contour plowing too!

photo by EC Meyers, W&L '20

Soil cover - plant residues



Southern Minnesota, June 2019

Soil cover

- cover crops (row cropping)

- higher yields, improved soil health



Sustainable Agriculture
Research and Education

<https://www.sare.org/resources/cover-crops/>

Cover crops in Rockbridge County



photo by Kate Nassab, W&L '22

Cover crops



photos by Grace Roquemore, W&L '21

Crop & animal rotation

- ▶ resilience to pests
- ▶ builds fertility (e.g. legumes)



The Benefits of Crop Rotation and Diversity

<https://usfarmersandranchers.org/>

Crop rotation in Rockbridge



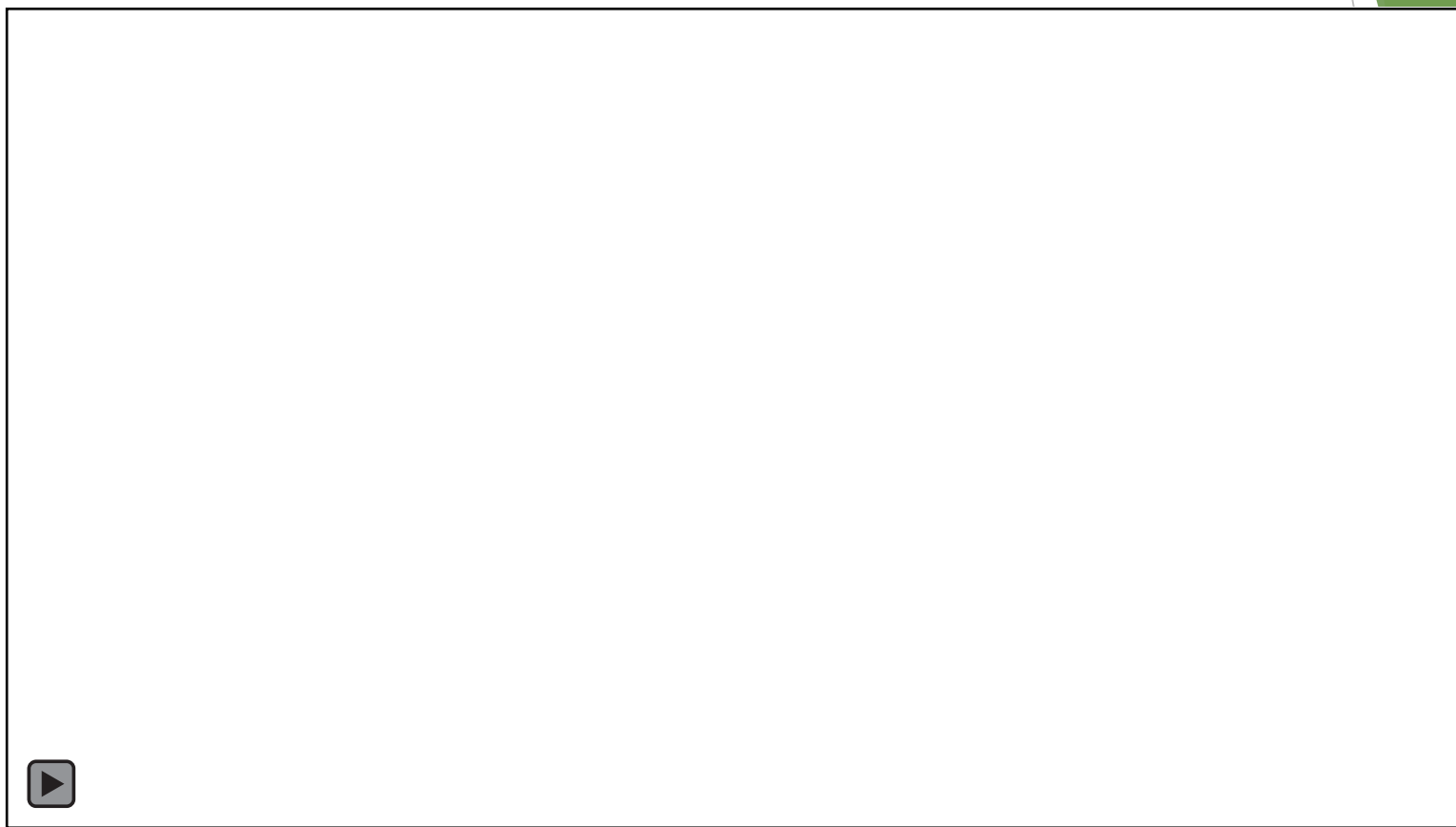
photos by Olivia Brister, W&L '21

Animal rotation



Verdant Acres, Raphine VA

Animal rotation



Animal Rotation - back grazing



<https://www.planet.com/stories/green-up-rotational-grazing-ijrhtpiMg>

Animal Rotation

- summer stockpiling

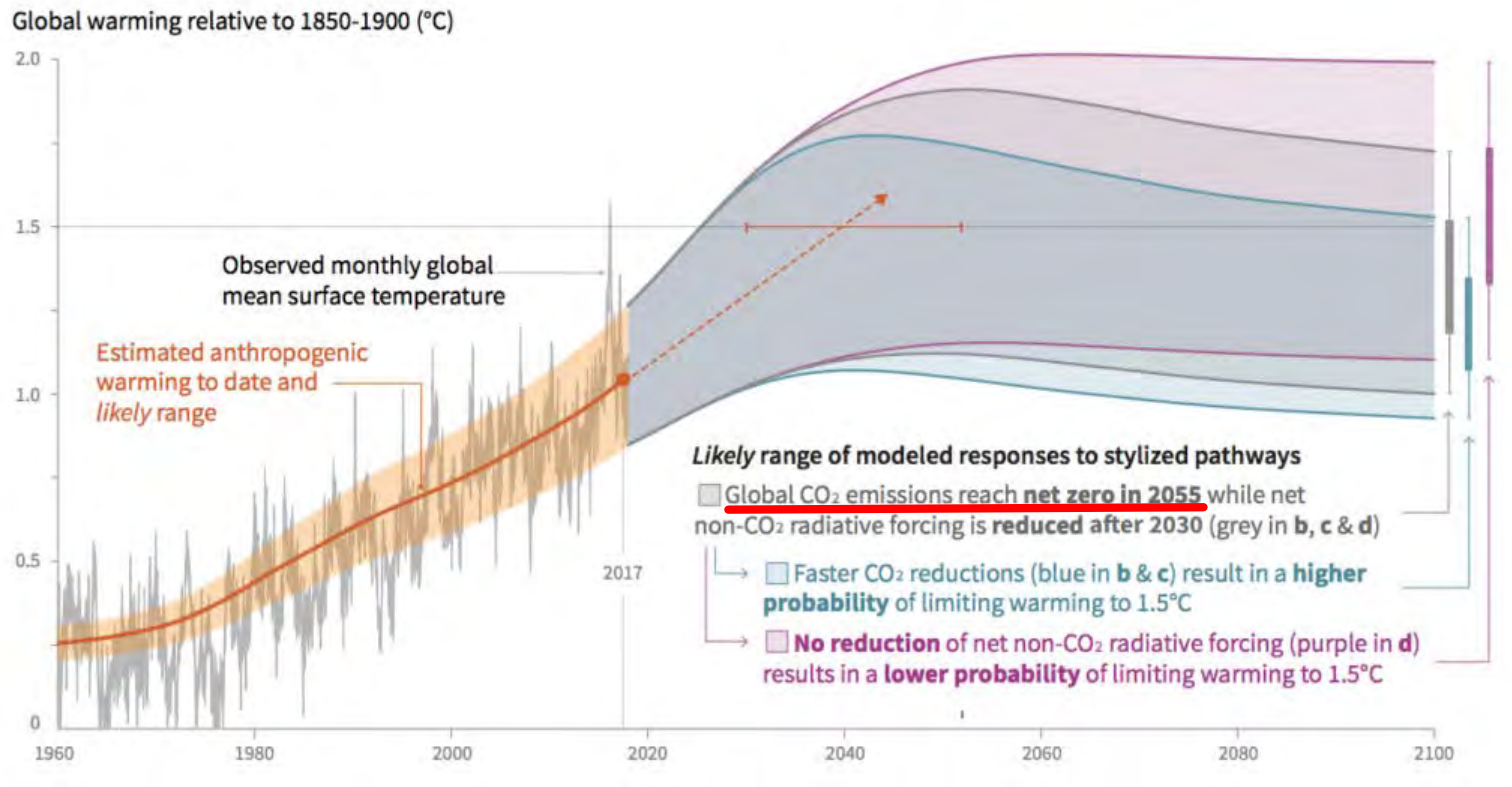


<https://ext.vt.edu/agriculture/graze-300.html>

Benefits of Regenerative Ag

- ▶ Increased resilience against drought and pests
 - ▶ better soil moisture
 - ▶ more diverse soil biology
- ▶ Increased fertility
 - ▶ better soil biological function
 - ▶ retention of nutrients
 - ▶ decreased erosion
- ▶ Increased farmer margin
 - ▶ “grass fed” premium
 - ▶ organic premium
 - ▶ decreased herbicide and fertilizer inputs
- ▶ Drawdown of greenhouse gases
 - ▶ payments for carbon sequestration

IPCC special report 1.5 °C will be bad enough

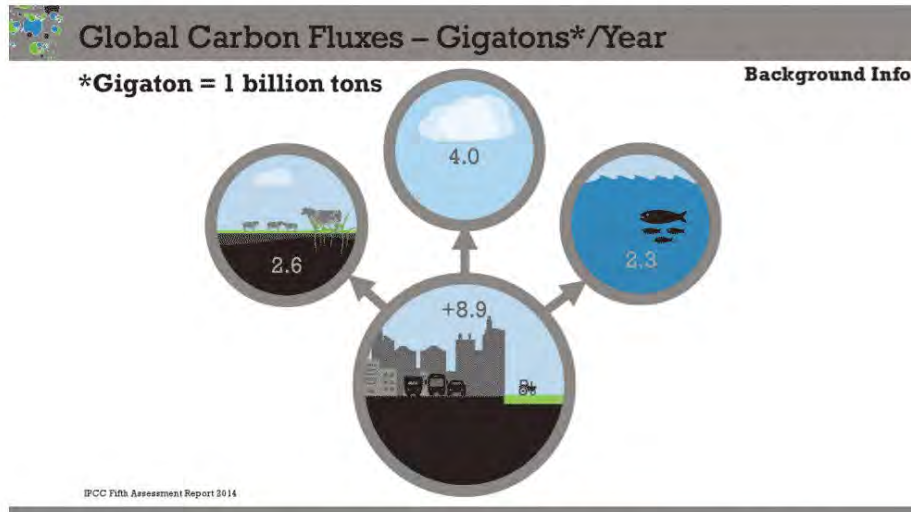


note!

Grazing? Eating meat? Really, you're kidding.

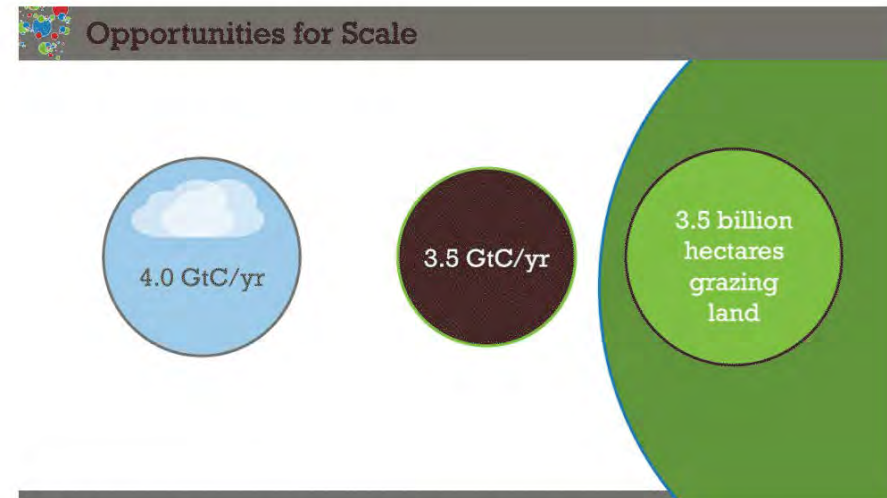
carbon cowboys

about films research science carbon cowboys



- Human activities emit 8.9 Gigatons of carbon (GtC) annually
- Soil+Plants absorb 2.6 GtC; Oceans absorb 2.3 GtC; 4.0 GtC remains in air
- Up to 1/5 of all this airborne carbon originates from poor soil stewardship
- Degraded soils have very high additional carbon storage potential

others say it is more



- 3.5 billion hectares of grazing land worldwide
- Capturing extra 1 ton of carbon/hectare/year on all 3.5 billion hectares would be 3.5 GtC, nearly equal to the 4 GtC excess carbon left in air

Consumers support the change

Big Food is Betting on Regenerative Agriculture to Thwart Climate Change

General Mills is one of several big companies investing in regenerative agriculture. Will it reverse climate change or just help sell more products?



Benefits of “grass-fed”

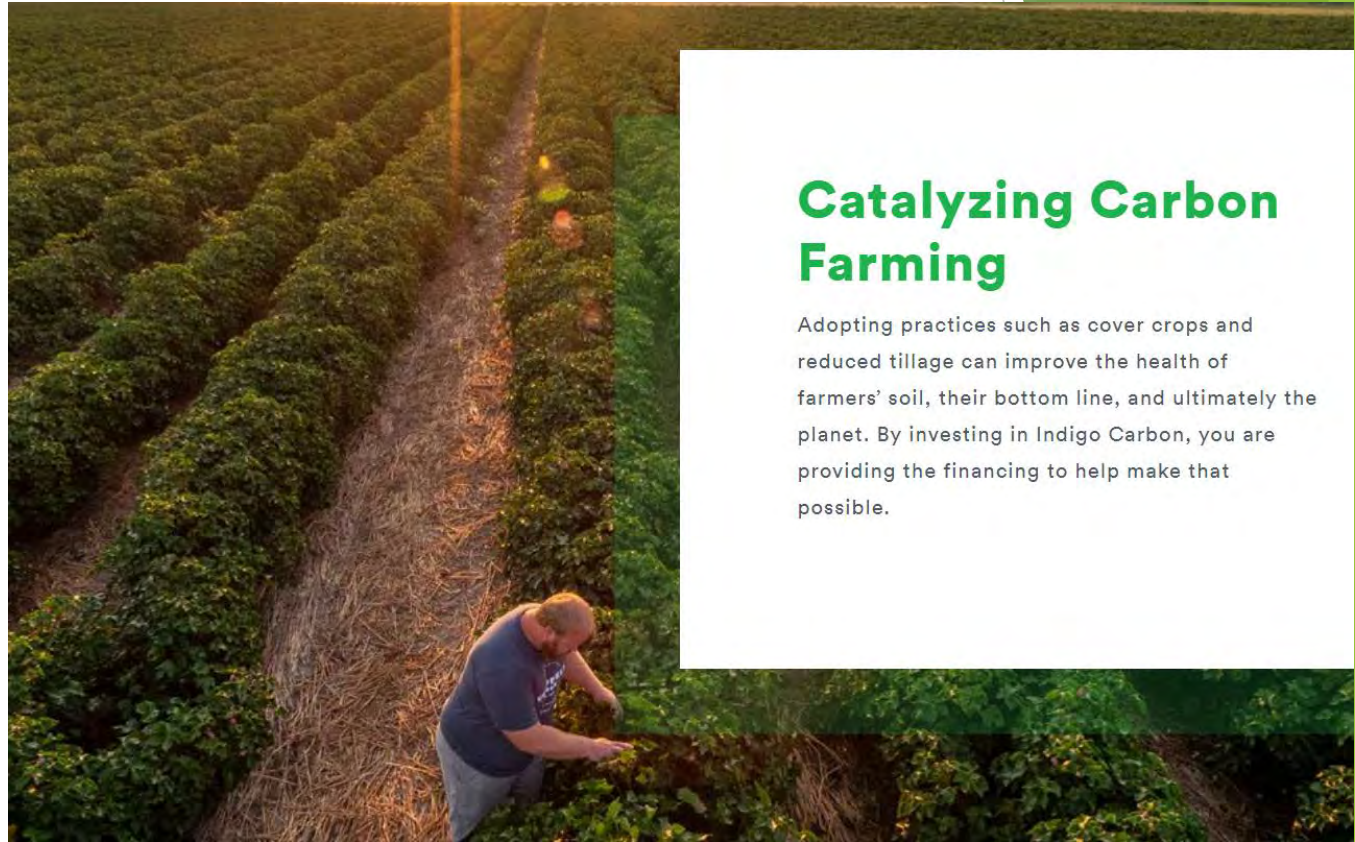


Grass-fed beef has several health benefits. It contains more vitamins and minerals, omega–3 fatty acids, and CLA than grain-fed beef. These nutrients have been shown to fight a number of diseases and ailments.

<https://www.heartstonefarm.me/>

Paying Farmers for carbon

- ▶ Indigo Ag
- ▶ Nori
- ▶ local??



Catalyzing Carbon Farming

Adopting practices such as cover crops and reduced tillage can improve the health of farmers' soil, their bottom line, and ultimately the planet. By investing in Indigo Carbon, you are providing the financing to help make that possible.

Research by W&L Geology Students



Iszack Morgan and Ryan Monson with Becky Szarzynski at Mountain Glen Farm

Field Sampling



Field Sampling

► Augering



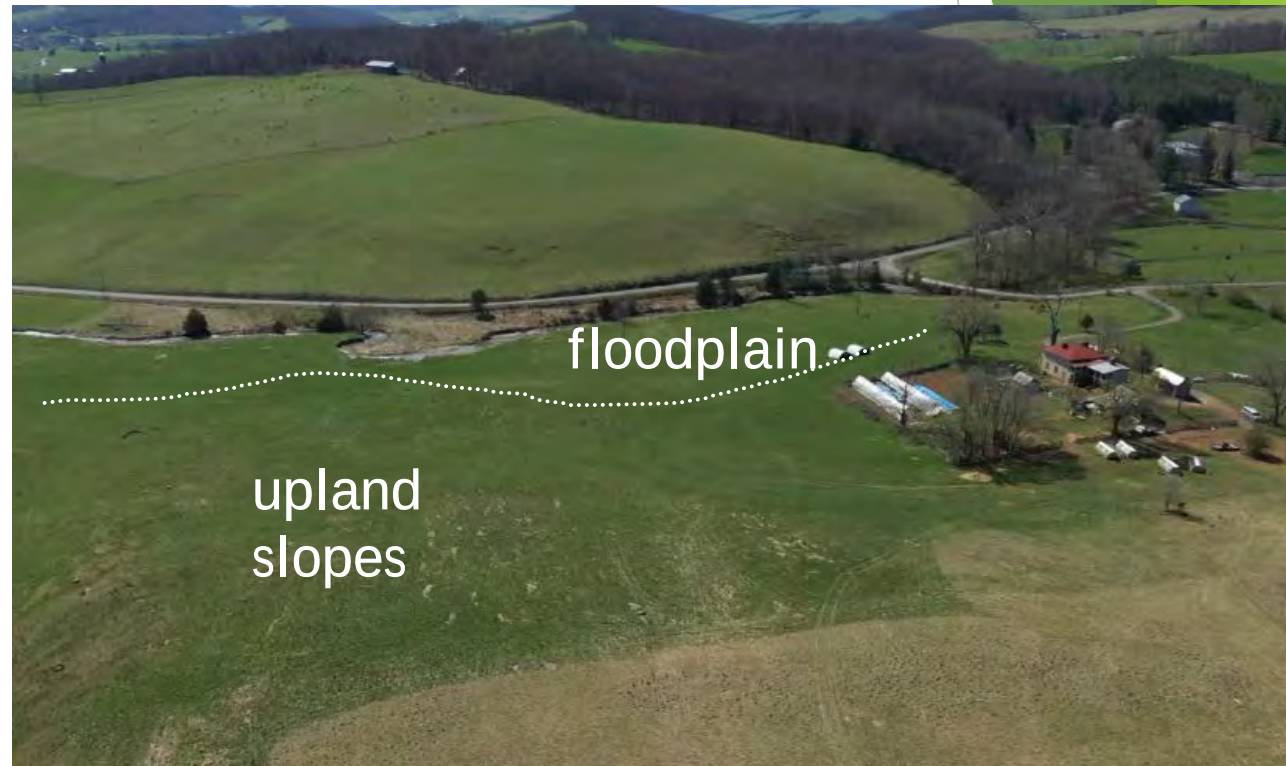
Field Sampling

- ▶ Iszak Morgan
- ▶ Selecting points at random within a field
 - ▶ select similar areas
 - ▶ topography
 - ▶ soils
 - ▶ ID random points within each polygon in GIS



Field Sampling

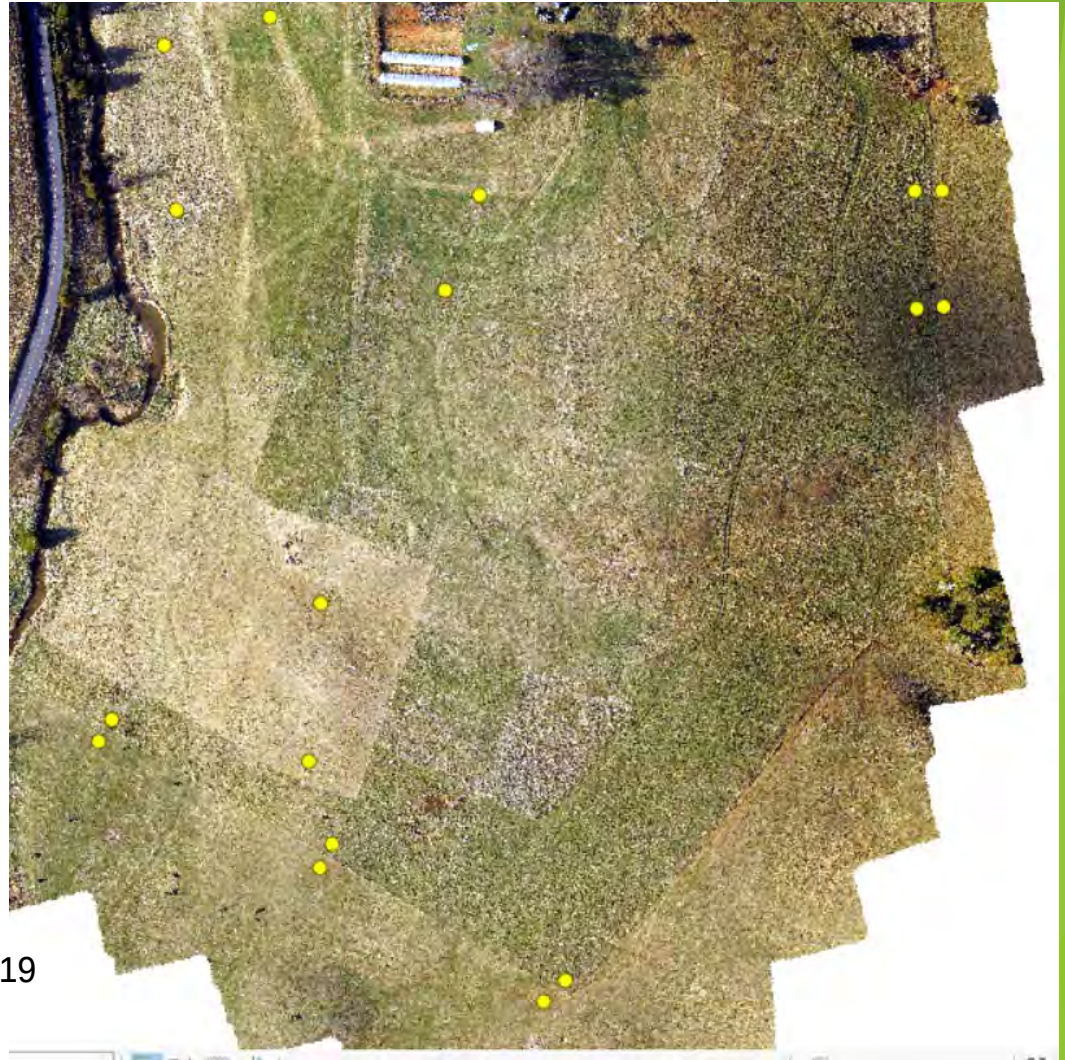
- ▶ Iszak Morgan
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 - ▶ soils
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Field Sampling

- ▶ Ryan Monson
- ▶ Comparative sampling
 - ▶ adjacent pastures
 - ▶ repeat area samples

Drone image from Fall November 14, 2019
Sampled on the next day



Measuring Carbon

► Lab Methods

- **Elemental Analyzer (EA)**
Combusts powdered sample and records mass of C (and N) using gas chromatography
- **“Loss on Ignition”**
Combust organic matter in a powdered soil sample at 360°C in a furnace

sample
in

burn
it

filter
it

gas
chromatography

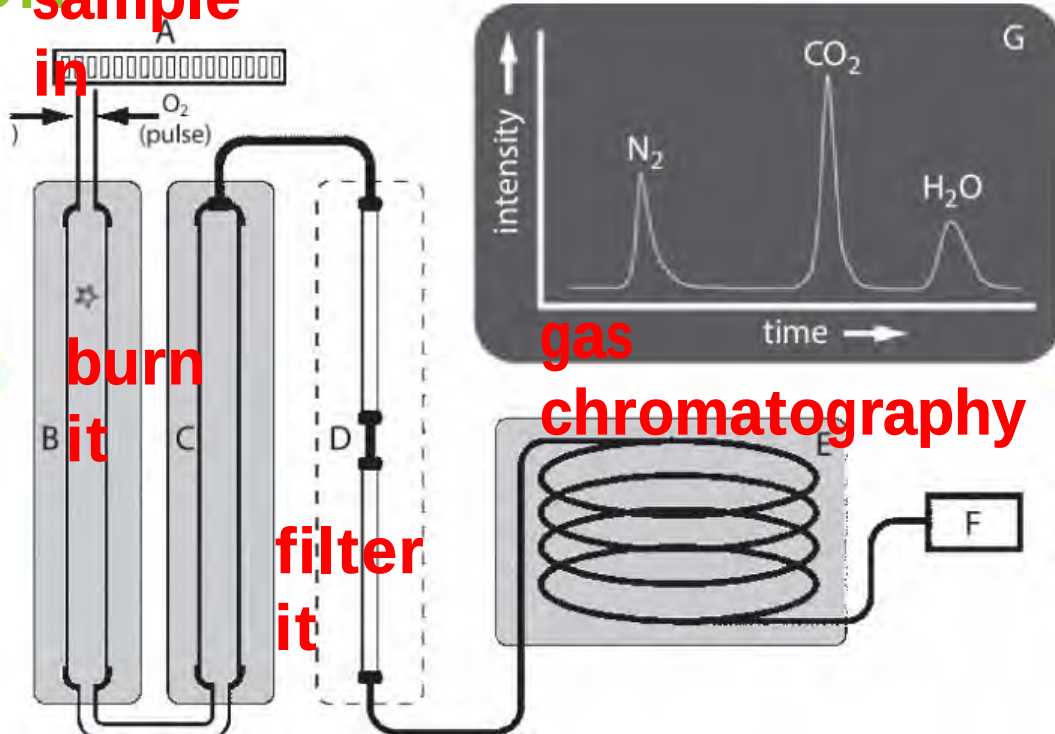


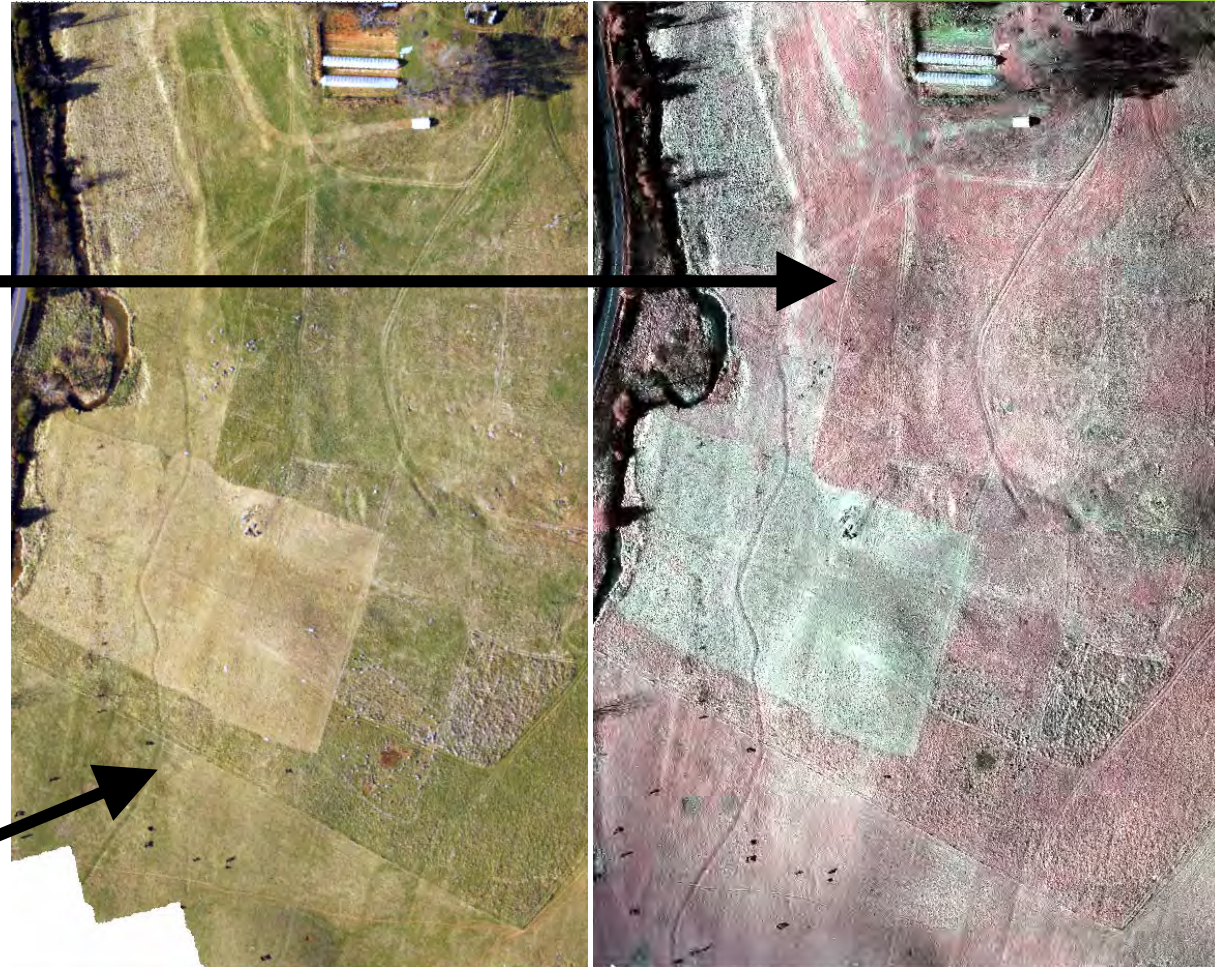
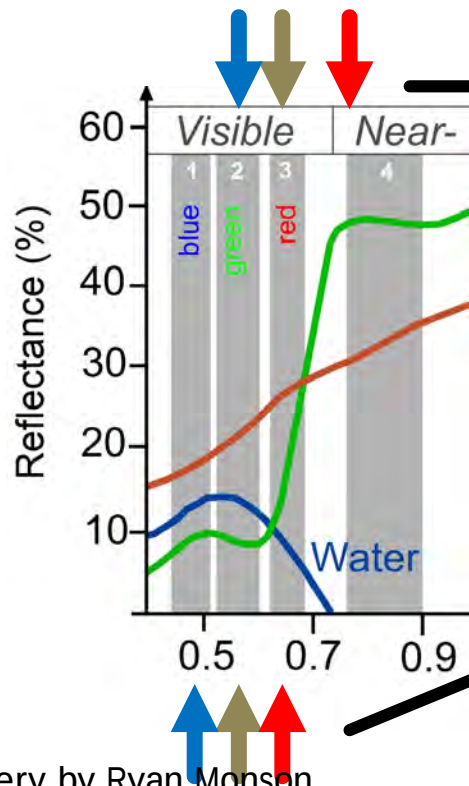
figure credit

Remote Sensing and Carbon

- ▶ What can we learn from imagery about soil conditions and SOC?
- ▶ Correlating **Soil Health** with **SOC**?
- ▶ or correlating **Soil Moisture** with **SOC**?



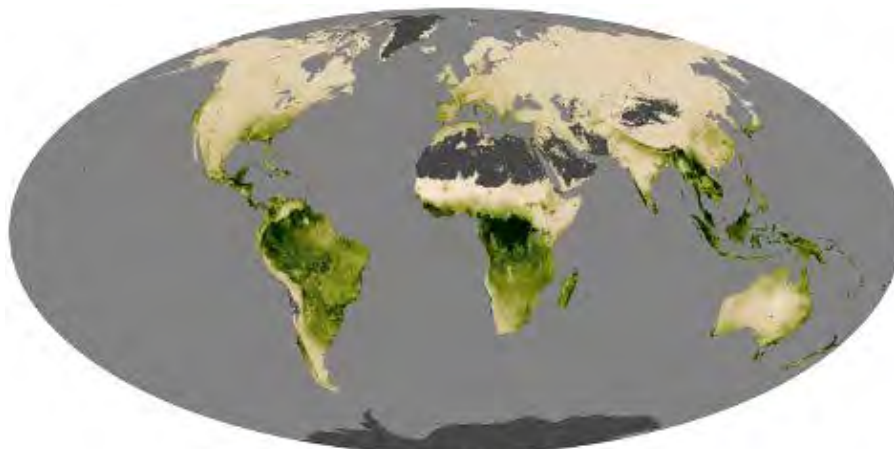
Using Infrared Imagery



Imagery by Ryan Monson

Primary Productivity and NDVI

$$\frac{VNIR - RED}{VNIR + RED}$$

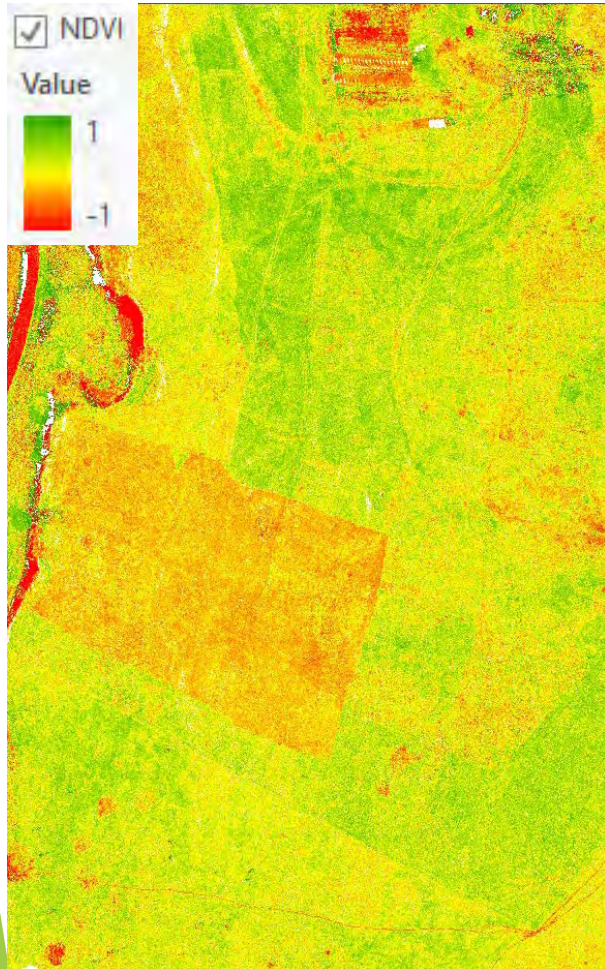


Net Primary Productivity
gC/m²/day
-1.0 0 6.5



Vegetation Index (NDVI)
-0.1 0.4 0.9

March 2000



Imagery by Ryan Monson

Sampling Issue ?

- Are we doing this right?
- Gain C at surface, lose C at depth?

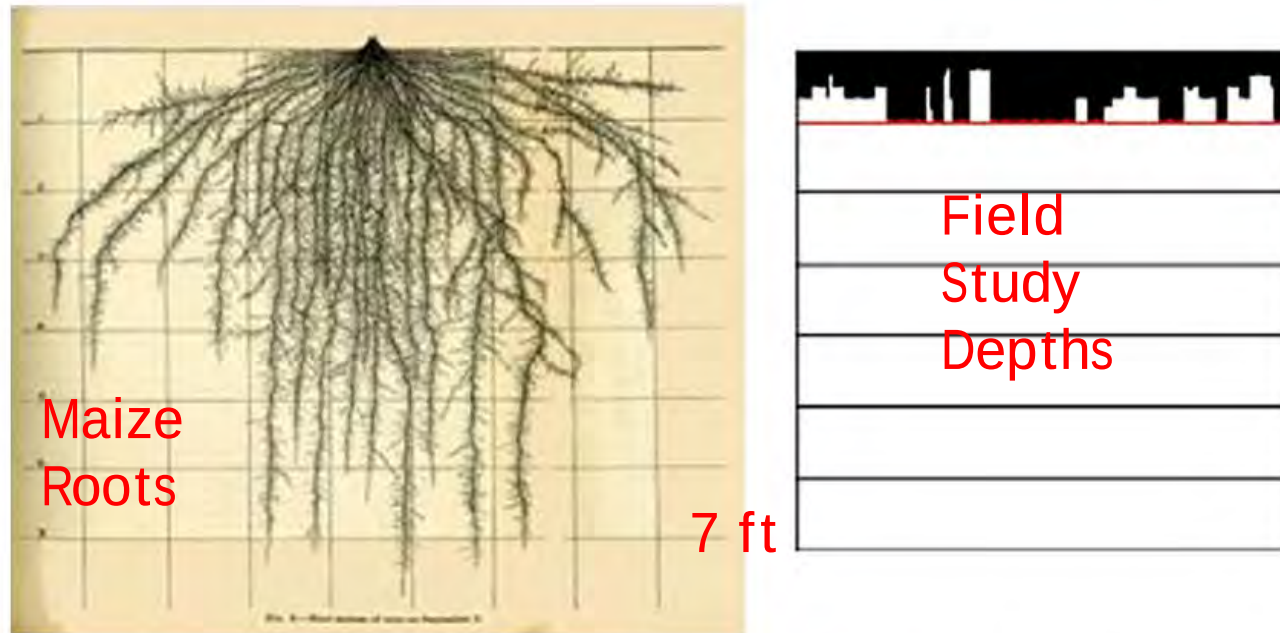


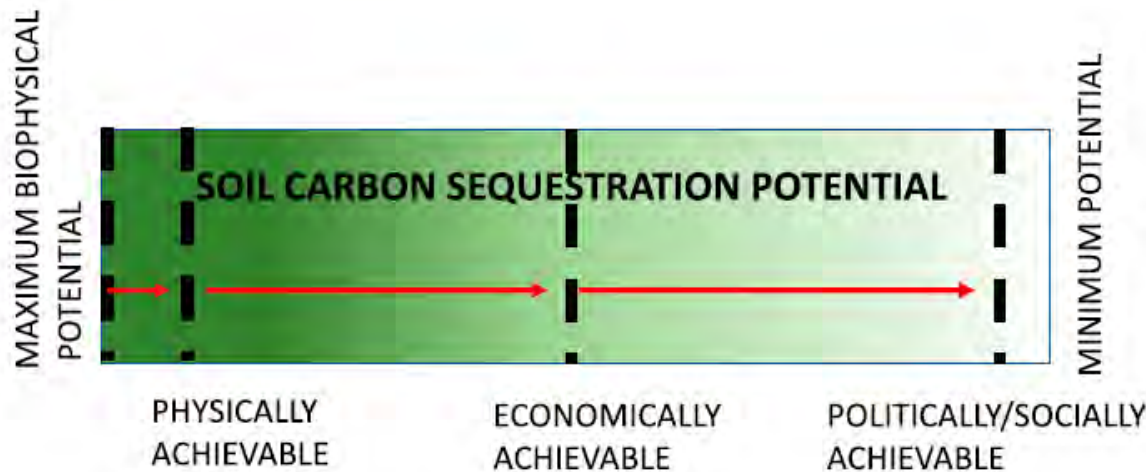
Fig. 1. The root system of a corn plant, drawn during field excavation by Weaver and colleagues, reprinted with permission of the Carnegie Institution, Washington, DC (8). The scale on the left, denoting depth below the soil surface, is in feet. The plot on the right shows the sampling depths, to the same scale, employed in 140 comparative studies of tillage impacts on soil carbon (7).

Baker, John M., et al. "Tillage and soil carbon sequestration—What do we really know?." *Agriculture, ecosystems & environment* 118.1-4 (2007): 1-5.

Achievable?

OPINION

Soil carbon sequestration is an elusive climate mitigation tool



Amundson, Ronald, and Léopold Biardeau. "Opinion: Soil carbon sequestration is an elusive climate mitigation tool." *Proceedings of the National Academy of Sciences* 115.46 (2018): 11652-11656.

Questions?

Is this what I said?

Regenerative Agriculture; good for soil and water, good for farmers, and good for consumers"

An agricultural revolution is happening based on an old idea that farmers who pay attention to soil health will produce healthier crops and animals, use fewer herbicides and pesticides, improve water quality, and increase profit per acre. Researchers and major food companies are investigating how to pay farmers to switch to regenerative agriculture practices in grazing and cropping systems using carbon offsets and other market incentives. Join rookie-ag-scholar David Harbor from W&L Geology to learn about soil erosion, soil health and regenerative agriculture practices and principles, see what his research students have started exploring, and explore examples of practices already being adopted here in Rockbridge County