

Healthy Soil, Healthy Plants, Healthy Planet




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Source: Modern Farmer

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Deep roots of prairie plants built rich topsoil of Midwest

- Deep, dense roots hold the soil & prevent erosion
- good infiltration of stormwater
- more than half the organic matter is gone after 150 yrs of tillage and conventional agriculture
- from 4' of topsoil to 6"

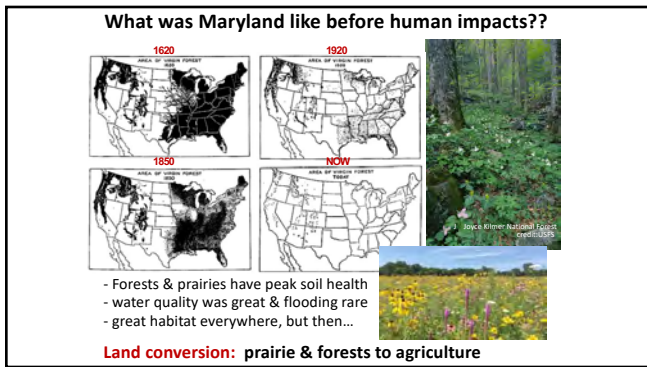


Dr. Jerry Glover w/
 Compass plant,
 Big Bluestem,
 Indiangrass

National Geographic 2015

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What was Maryland like before human impacts??



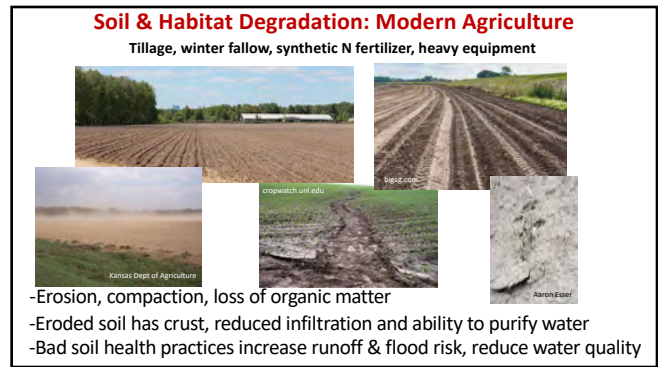
- Forests & prairies have peak soil health
- water quality was great & flooding rare
- great habitat everywhere, but then...

Land conversion: prairie & forests to agriculture

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Soil & Habitat Degradation: Modern Agriculture

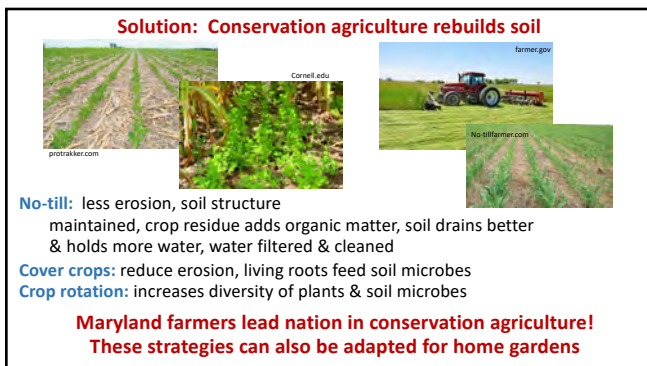
Tillage, winter fallow, synthetic N fertilizer, heavy equipment



- Erosion, compaction, loss of organic matter
- Eroded soil has crust, reduced infiltration and ability to purify water
- Bad soil health practices increase runoff & flood risk, reduce water quality

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Solution: Conservation agriculture rebuilds soil



- No-till:** less erosion, soil structure maintained, crop residue adds organic matter, soil drains better & holds more water, water filtered & cleaned
- Cover crops:** reduce erosion, living roots feed soil microbes
- Crop rotation:** increases diversity of plants & soil microbes

**Maryland farmers lead nation in conservation agriculture!
 These strategies can also be adapted for home gardens**


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Soil is Earth's 2nd largest ecosystem

Healthy soil performs crucial ecosystem functions:

- **Physical support of plants**
- **Water storage, filtration & cycling:** Stable soil aggregates resist erosion, drain & hold water
- **Nutrient cycling:** Soil organisms make nutrients available to plants
- **Provides habitat for biodiversity:** Healthy soil is diverse, & diversity stabilizes ecosystems

90% of ecosystem functions are driven by soil organisms!



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Healthy soil, healthy ecosystem

A healthy soil ecosystem requires a diverse food web



What are the most abundant soil organisms??

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Microbes!





Friendly microbes battle the unfriendly ones.

Microbes are
- crucial for healthy body & healthy soil

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The secret life of soil




- 1t soil contains >1 BILLION microbes
- **Plants give** up to 40% of the sugar they make from photosynthesis to bacteria & fungi
- **Plants get** nitrogen, water, nutrients, protection from diseases, predators & abiotic stress

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Bacterial Allies: N-fixation by *Rhizobium*

- Bacteria take N_2 from air, make ammonia (NH_3)
- Mostly in legumes, some freeliving
- Symbiosis evolved ~2.2B years ago

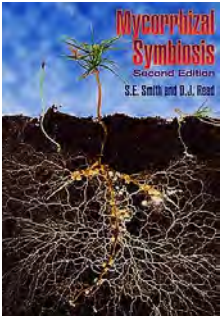

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Mycorrhizae: Fungi that colonize plant roots

Aid plants in water, nutrient uptake

But mycorrhizae also

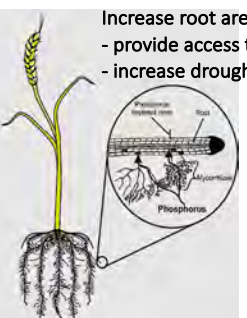
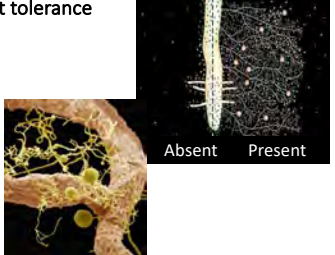
- Fight disease
- Combat plant stress
- Act as predators!
- Link plants, even different species

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Up to 90% of all plants have mycorrhizae

- Increase root area x 700
- provide access to water & nutrients,
- increase drought tolerance

Absent Present

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Plants and Symbionts Call to Each Other

N-fixing bacteria (2.2 BYA):

Mycorrhizae (~ 500 MYA):

Nature Reviews | Microbiology

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Other microbial feats:

Endosymbiotic fungi in roots and leaves
 increase tolerance to insect pests, salt, heat and disease

Soil bacterium (*Pseudomonas*) attacks pathogenic fungus (*Pythium* = root rot)

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Mix of soil bacteria protects cucumber from drought stress

With bacterial inoculation **Control**
 No water for 13 days

Wang et al. 2012. PLoS One. 7, e52565

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Build healthy soil so that naturally occurring bacteria & fungi can promote plant growth, fight pathogens & moderate stress

In unhealthy soil, need synthetic nitrogen fertilizer, pesticides, fungicides, irrigation

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What makes "healthy soil"??

50% water and air!

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Healthy soil is crumbly w/ stable aggregates built by soil organisms


Stable soil aggregates:

- roots & their exudates
- mycorrhizae & "glue"
- other sticky material from soil organisms

Aggregates are crucial habitat, increase resilience to floods, drought, disease

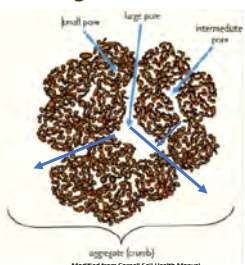
Source: Cornell Soil Health Manual
 aggregate (crumb)

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Healthy soil reduces climate risk from increased flooding

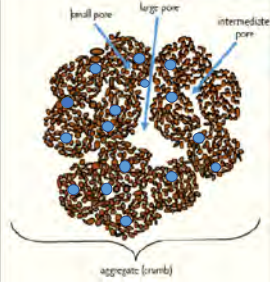

In healthy soil, aggregates are stable in water & pores allow good drainage



aggregate (crumb)
Modified from Cornell Soil Health Manual

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Healthy soil reduces climate risk from drought




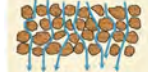

small pore large pore intermediate pore
aggregate (crumb)

- water held within aggregates in small pores reduces drought risk

Soil health is the top "no regrets" strategy for climate resilience

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Visualizing Healthy vs Unhealthy Soil



stable in water
water infiltrates, is held
high in organic matter
need few inputs

falls apart in water → erosion
erosion crust forms, little infiltration
low organic matter
need fertilizer & chemicals


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What can we do to restore soil?



Mimic Nature!

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Soil organisms know how to build soil— let them work!

1. Limit disturbance & inputs
2. Keep the soil covered
3. Increase diversity, rotate crops
4. Maintain live roots all year

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1. Limit disturbance: Tilling

- breaks soil aggregates, destroys habitat
- increases runoff, water & nutrients lost
- increases water & wind erosion
- exposes protected organic matter to microbial decomposition (aerobic erosion)




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No-Till for vegetable/organic farms

Possible strategies

- roll cover crops for dead mulch
- flail mow, plant into mowed mulch
- strip till, fertilize just before planting
- plant cover crops between rows as living mulch

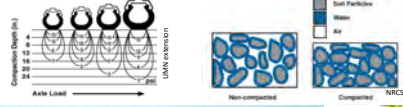


Credit: Corruzi Hooks

These strategies can also be used in gardens!

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Limit physical disturbance through compaction

Soil compaction from machinery or **foot traffic** reduces aeration and infiltration & crushes soil habitat

Larriland Farms u-pick strawberries: Tillage radishes planted between rows in fall to reduce compaction from foot traffic

Credit: Roy Wolf

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Use fertilizer & chemicals judiciously to protect microbes and the environment

Fertilizer can limit microbial action

- too much P: inhibits mycorrhizae
- too much N: inhibits N-fixers
- Excess N leads to N_2O emissions, NO_3 runoff
- Synthetic fertilizer production very energy intensive




Chemicals & other additives

- impacts on microbes still uncertain
- even additives approved for organic impact microbes
- serious runoff into surface waters

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2. Keep soil covered to prevent erosion from rain and wind





<http://www.ecosystems.org/your-farm/crops/>


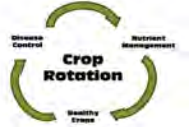
<https://www.wdrainagecontractor.com/>

Can use cover crops or plant residue (try mulched leaves in gardens)

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3. Increase plant diversity with crop rotation and cover crop mixtures

Helps manage nutrients, pests & diseases

More plant diversity, more microbial diversity
 Also important in gardens

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No-till & cover crops for vegetable/organic farms

- Plant your crop right into the killed cover crop
- Try "strip-till", and hoe a 10" strip to plant in
- Fertilize only in the strip
- Can be modified for gardens

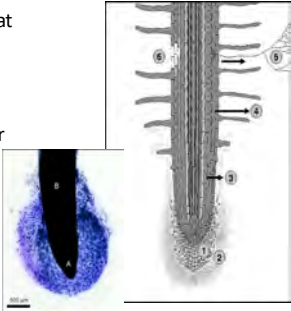



Credit: E. Rensburg

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4. Maintain live roots to feed microbes


- Roots exude sugars & proteins that feed microbes
- If no live roots over winter, microbial populations decrease
- Winter cover crops preferred over crop residue (or straw,leaves)
- More diverse & healthier microbes means more healthier plants and more carbon sequestered




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Healthy vs unhealthy: Lawn

Healthy soil: long term pasture



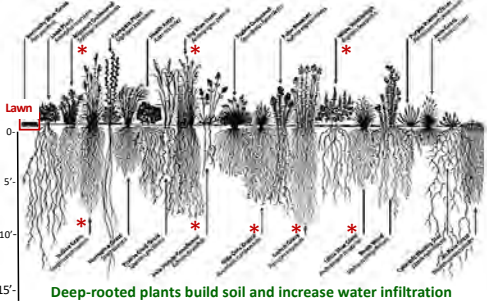
Marginal soil: mowed lawn





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Why lawn doesn't make good soil



Deep-rooted plants build soil and increase water infiltration

Conservation Res. Inst. 1995

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Native Meadow Plants:

Combined climate and watershed benefits

Use deep-rooted native plants in beds, swales, raingardens & median strips to control flooding, boost pollinators and sequester carbon



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Using deep-rooted grasses etc to stabilize streambanks

- Mowing right up to bank causes rapid erosion
- Stop mowing 4-6' out
- Plant deep-rooted grasses, i.e. Virginia wild rye - OK in shade, Northern sea oats, meadow mixes



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Email me with questions or to join my mailing list: svia@umd.edu
Webinar videos and climate resources: www.climatecorner.org
Soil carbon sequestration report: <https://www.iwla.org/soils-agriculture/soilhealthreport>

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