North American Soils Before Europeans

- Native soils in forests & prairies -- peak soil health
- High organic matter, deep roots, good soil structure
- Great water infiltration & water quality, flooding & erosion rare
- Very high biodiversity in the soil
- Soil ecosystem in balance

Then came the Europeans....

The Dust Bowl (1930s)
A major wake-up call about unsustainable behavior

- Agriculture w/o understanding of how soil & water interact
- Continuous tillage & winter fallow left soil unprotected from erosion
- Some modifications made under the New Deal (1940s), but...

Modern agriculture continued to damage soil

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 increases runoff & flood risk, reduces water quality

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

We can apply the same ideas to gardening & landscaping
Soil is Earth’s second 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 decompose dead things to 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!

Which organisms are the most abundant?

Microbes!

Mother Jones 2014. Kharlamova

Friendly bacteria & fungi battle the unfriendly ones.

Microbes are
- crucial for healthy body
  AND healthy soil

The secret life of soil

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

Nitrogen-fixing Bacteria
- Some bacteria can take N₂ from air, make ammonia (NH₃)
- In legumes, make root nodules
- First N-fixing bacteria evolved about 2 billion years ago

Mycorrhizae:

Fungi that colonize plant roots

Aid plants in water, nutrient uptake - evolved at the same time as land plants (450 MY ago)

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

Up to 90% of all plants have mycorrhizae

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

Absent

Present
Plants and Symbionts Call to Each Other

Supporting the microbes is costly to plant, so interaction reduced if there is already enough N,P in soil.

Other ways soil bacteria help plants:

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

Mix of soil bacteria protects cucumber from drought stress

With bacterial inoculation

Control

No water for 13 days

Other fungal feats:

- Endosymbiotic fungi in roots increase plant tolerance to:
  - insect pests,
  - disease
  - salt,
  - heat

If we build healthy soil:

- Naturally occurring bacteria & fungi can promote plant growth,
  - fight pathogens & moderate stress

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

What makes “healthy soil”??

50% water and air!
Soil aggregates:
- roots & their exudates
- mycorrhizae & “glue”
- other sticky material from soil organisms

Aggregates are stable in water and provide crucial habitat.

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

Healthy soil reduces climate risk from increased flooding:
- aggregates are water-stable
- pores allow good drainage of stormwater.

In healthy soil,

Healthy soil reduces climate risk from drought:
- water held within aggregates in small pores reduces drought risk.

Soil health is the top “no regrets” strategy for climate resilience.

Healthy soil co-benefit:
- protects water quality
- helps control stormwater.

Healthy soil reduces climate risk from drought:
- water held within aggregates in small pores reduces drought risk.

Soil health is the top “no regrets” strategy for climate resilience.

What can we do to restore soil?

Mimic Nature!

1. Limit disturbance & inputs
2. Keep the soil covered
3. Increase diversity, rotate crops
4. Maintain live roots all year
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**USDA Natural Resources Conservation Service (NRCS) principles: All about the microbes**

- Feed & Diversify the Soil Biota*
- Protect Soil Aggregates & Organic Matter

modified from Dennis Chessman NRCS Kentucky

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)

2. Limit physical disturbance through compaction
Soil compaction from machinery or foot traffic reduces aeration and infiltration & crushes soil habitat

3. 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 N₂O emissions
- Synthetic fertilizer production very energy intensive

Chemicals & other additives
- impacts on microbes still uncertain
- even additives approved for organic can have an impact
- limit runoff into waterways

4. 2. Keep soil covered to prevent erosion from rain and wind
- ~20 mph
- Can use plant residue or cover crops

5. 3. Increase plant diversity with crop rotation and cover crop mixtures
Helps manage nutrients, pests & diseases

More plant diversity, more microbial diversity
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 healthy plants and more carbon sequestered

Multiple agricultural & ecosystem co-benefits from soil health practices

Healthy soils fight climate change by storing carbon

Contact me anytime with questions or comments!

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July 1: Regenerative Gardening!