Soil Microbes: The Unseen World Beneath our Feet

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American Farmland Trust

Soil School

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Saving the Land that Sustains Us

West Multnomah Soil & Water Conservation District

Tualatin Soil and Water Conservation District

Conservation is for everyone.

What If I Said My Team Could Do The Following…

- We can take nitrogen out of our atmosphere and make it into a form your plants can use
- We can hold soil particles together to resist the erosive forces of wind and water
- We can create channels in the soil to help rain and irrigation water get into the soil to be used by the plant, recharge groundwater, and not run-off your field
- We can prey and release an arsenal of weaponry on pests and pathogens that are trying to attack your plants
- We can convert that plant residue you leave on the field into organic matter and during the process, release nutrients
- And oh yeah, that organic matter helps keep nutrients and water on your field is our home

What Do We Ask For in Return?

- We need to be fed
- We need you to protect our home (that btw, we built)

What would you reply?

Do we have a deal?

Who Are We?

- We are carpenters, plumbers, and electricians
- We are bankers and investors
- We are world-class chefs
- We are the military coming to your defense
- We are the chemists, the pharmacists, and the doctors managing your health

We Are Soil Life

- Soils are home to over 25% of all living species on earth!
- 1 teaspoon holds:
  - 1000s of different species,
  - Millions of individuals,
  - 300 feet of fungal networks!!

Photo source: (2016). Global Soil Biodiversity Atlas. A. Orgiazzi, et al. Luxembourg, European Commission, Publications Office of the European Union**: 176p.**

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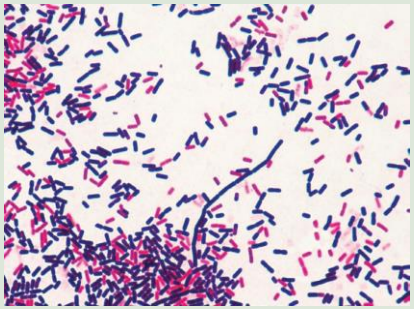
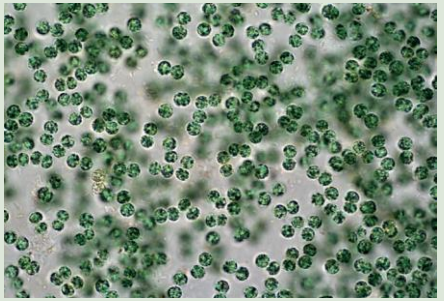
We Are Trillions of Microscopic Bacteria and Archaea in Every Shovelful of Healthy Soil



One teaspoon holds as many bacteria as there are people on Earth.
1000s of different kinds
~ 1 cow per acre

- World-class chefs
- Recyclers
- Biochemists
- Pharmacists
- Military
- Perfume makers



For every 1% SOM:
10,000 lb C
1000 lb N (50 lb MBN)
100 lb P (5 lb MBP)

Mineralization
Ammonium (NH_4^+)
Sulfate (SO_4^{2-})
Phosphate (PO_4^{3-})

Photo source: (2016). Global Soil Biodiversity Atlas. A. Orgiazzi, et al. Luxembourg, European Commission, Publications Office of the European Union: **176p.**

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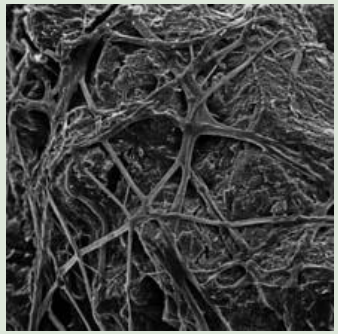
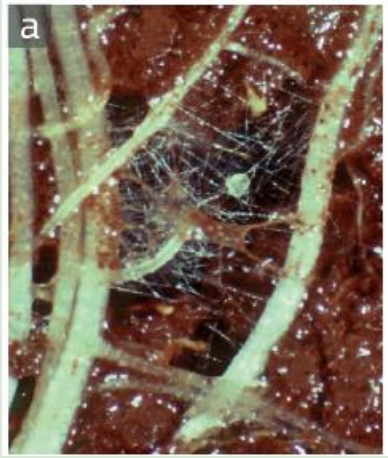
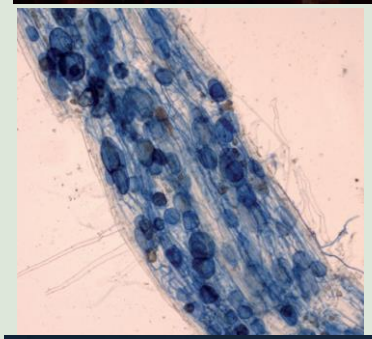
We Extend are Millions of Fungi and our threadlike hyphae extend for many feet in a cubic yard of soil







- World-class chefs
- Recyclers
- Biochemists
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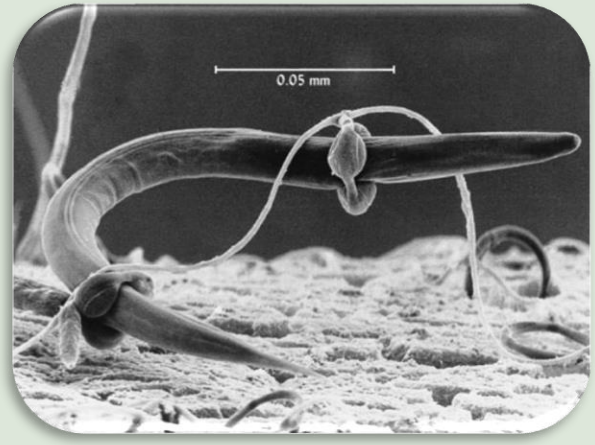
- Perfume makers



Fungi

Photo source: (2016). Global Soil Biodiversity Atlas. A. Orgiazzi, et al. Luxembourg, European Commission, Publications Office of the European Union: **176p.**

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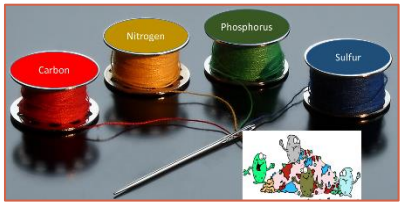
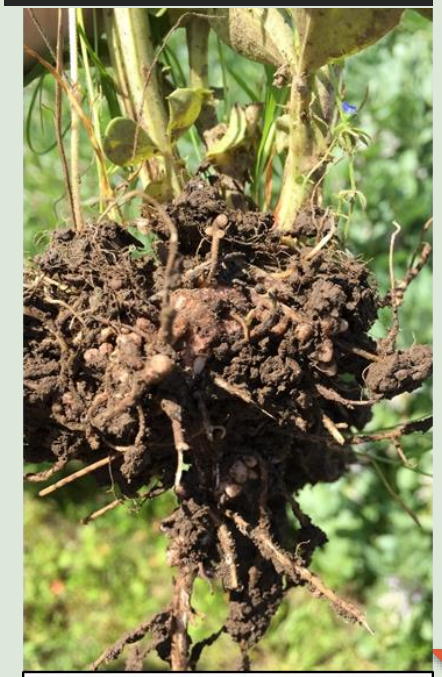
We are the Chemists Creating Nutrients and SOM



Photosynthesis → releases sugars for bacteria



Fava Bean; Moore-Kucera, 2016

N_2 Nitrogen Fixation NH_4

Specialized bacteria convert N from atmosphere → NH_4

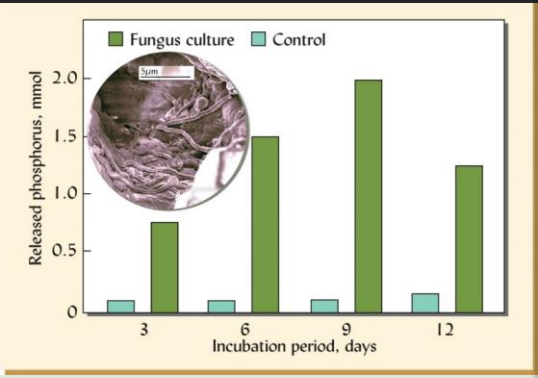
Plant Residues

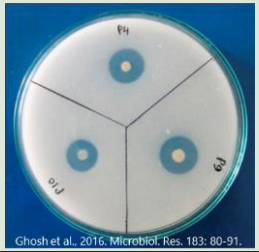
Photo courtesy of USDA-NRCS

Decomposition & Mineralization

Create soil organic matter and release ammonium, sulfate, phosphate for plants

Phosphorus bound to soil minerals





Phosphorus solubilization

Fungi & Bacteria release P bound to soil minerals in plant-available forms

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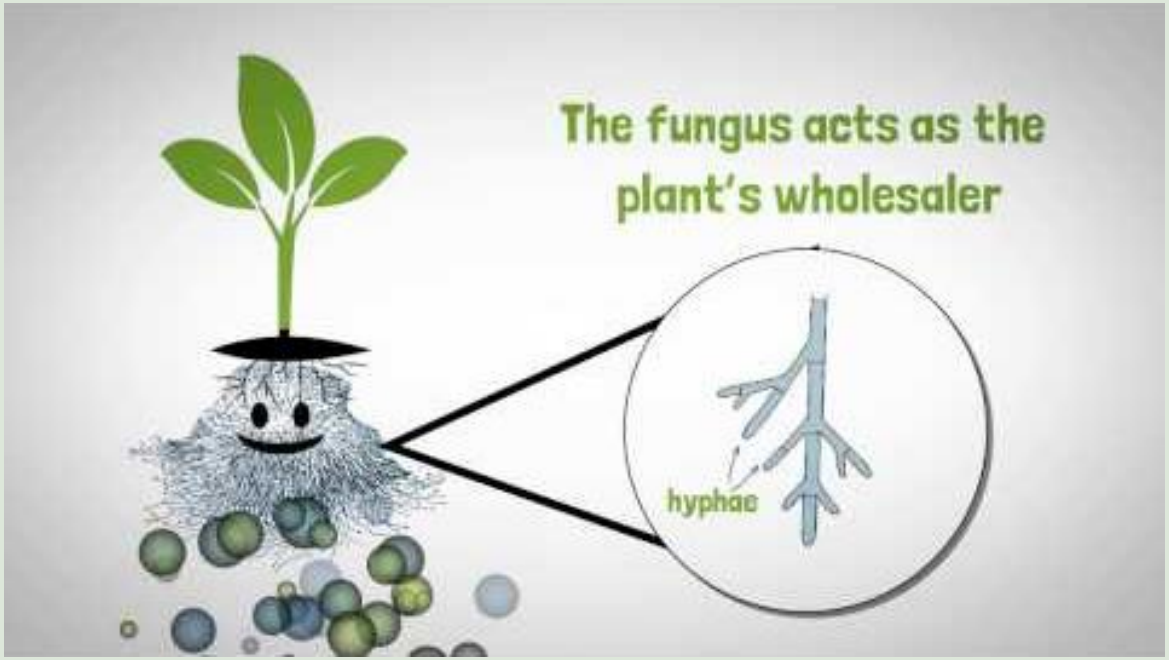
We Are Root Extensions, Plant Growth Stimulators and Protectors

Mycorrhizal Fungi
mykós = fungus ; riza = root



- Symbiosis between fungus and plants
- Biofertilizer
- Bioregulator
- Bioprotector
- Increase root surface area up to 40x

We Help Form Stable Aggregates

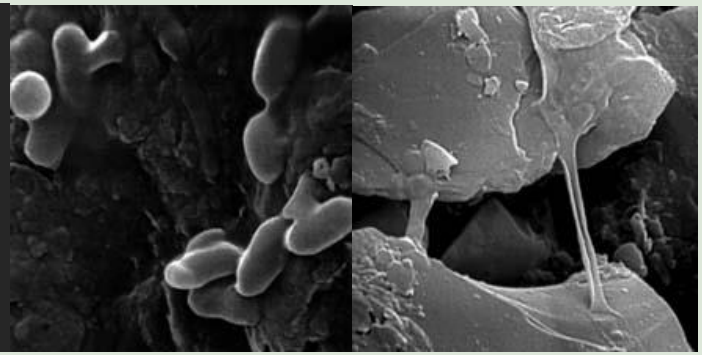
- When undisturbed, soil organisms transform residues and create SOM
- Release sticky substances that help hold soil particles together
- They build their own home
- Aggregates provide stability, nutrients, air and water flow, ‘hiding spots’

Physical Enmeshment (Fungal Hyphae & Plant Roots)

Photo: Aaron Roth

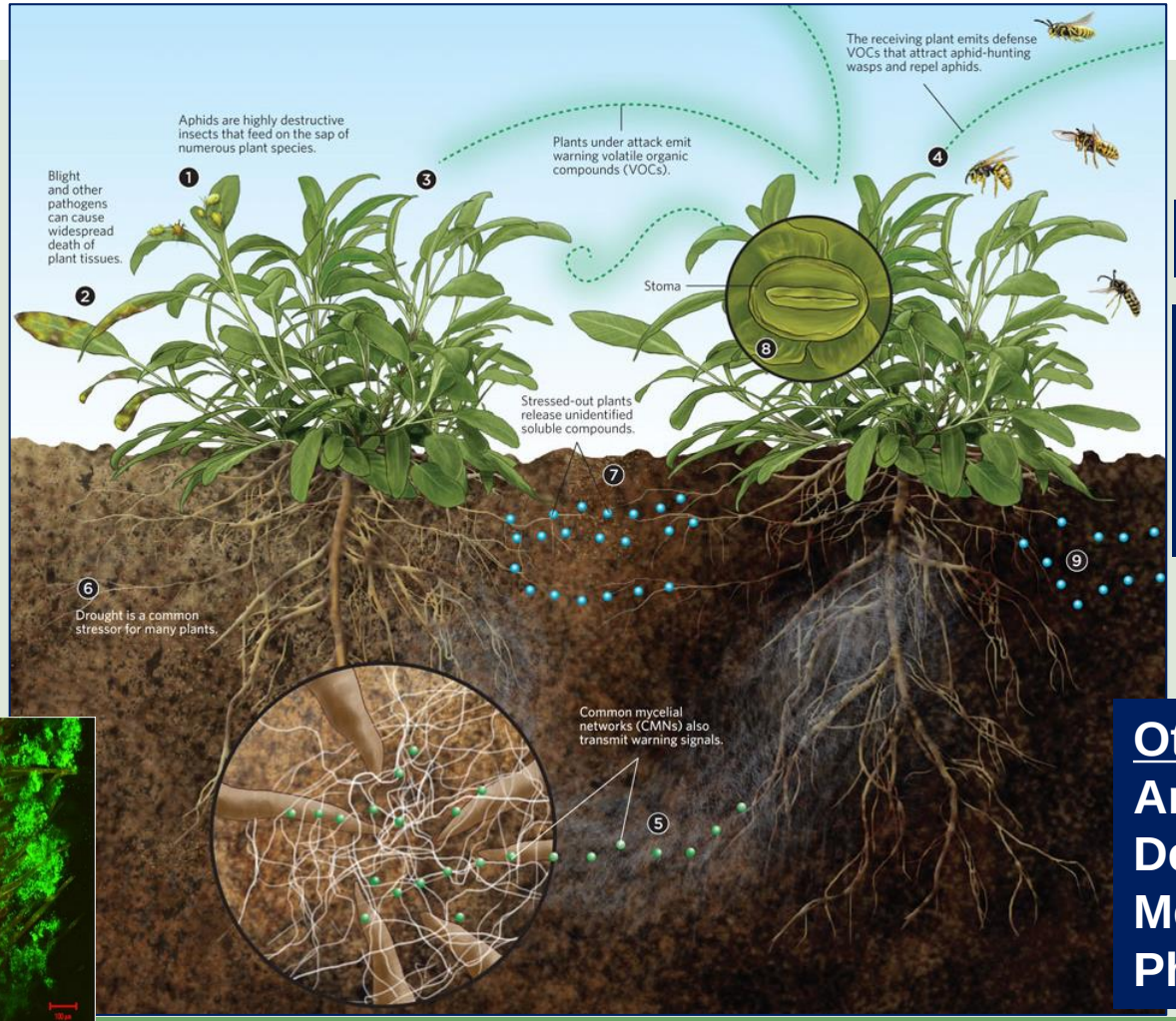
Photo: J. Moore-Kucera

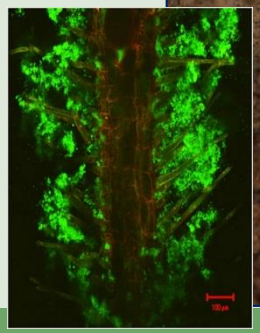
Biochemical Glues From Bacteria and Fungi



SEM photos used with permission from eickh@uni-bremen.de (http://www.microped.uni-bremen.de/SEM_index.htm)

We are the Military Coming to the Defense of Plants





Impact

↑ pest control
↓ disease
↓ pesticides
↑ resiliency

Other benefits:
Antiobiotics
Detoxification
Medicinal &
Phyto-medicinal

http://www.the-scientist.com/?articles.view/articleNo/38727/title/Plant-Talk/

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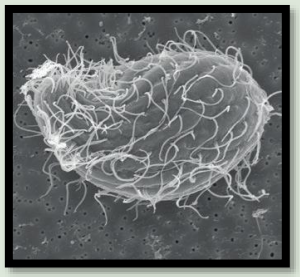
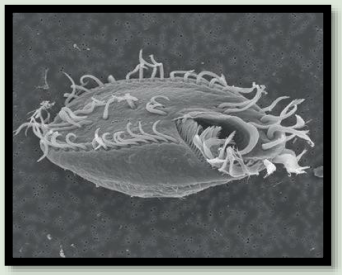
We Are 10,000 Protozoa and up to 100 Nematodes Per Gram of Soil

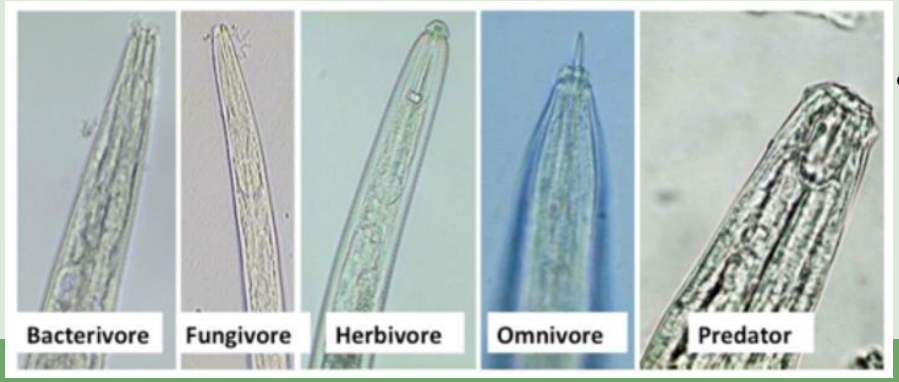




Protozoa

- One hectare (~2.5 acres) of soil contains the equivalent in weight of two sheep of protozoa.
- One protozoa can consume 100s of bacterial cells every minute!

Nematodes



- Most soil nematodes are not pathogenic
- Predation responsible for 19% of soluble N in soil
- Predation keeps populations in check

Photo source: (2016). Global Soil Biodiversity Atlas. A. Orgiazzi, et al. Luxembourg, European Commission, Publications Office of the European Union**: 176p.**

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We Are thousands of Mites, Springtails, & Other Small Invertebrates in 10ft^2

Arthropods

- **We are the predators of other small fauna and nematodes**
- **We help with population control and nutrient release**

"Every time you take a step in a mature Oregon forest, your foot is being supported on the backs of 16,000 invertebrates held up by an average of 120,000 legs." – Dr. Moldenke OSU

Photo source: (2016). Global Soil Biodiversity Atlas. A. Orgiazzi, et al. Luxembourg, European Commission, Publications Office of the European Union**: 176p.**

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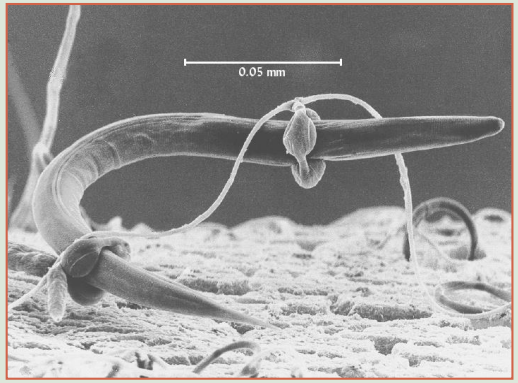
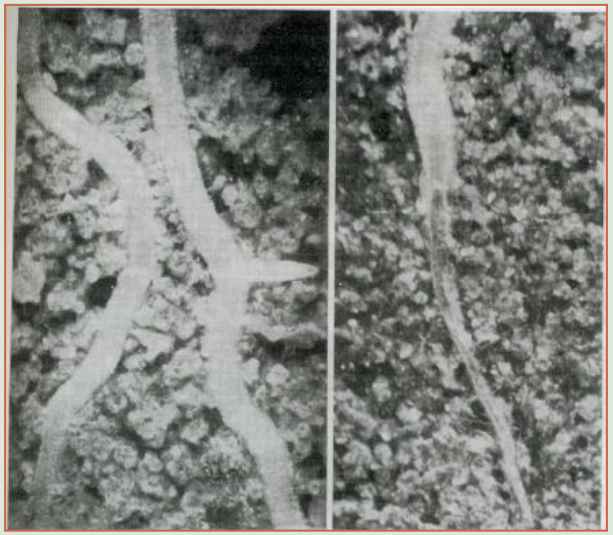
We are Fiercely Competitive and Keep Populations Under Control

Nematode-trapping Fungi



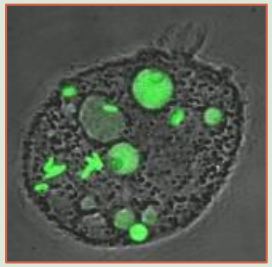
Vampyrellids (protist) eating a fungal root pathogen involved in take-all disease

Protection from *Rhizoctonia solani*



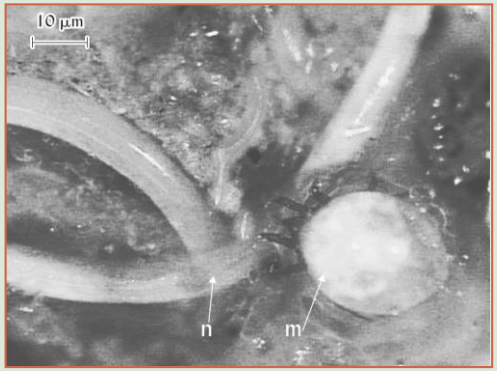
Roots with springtails

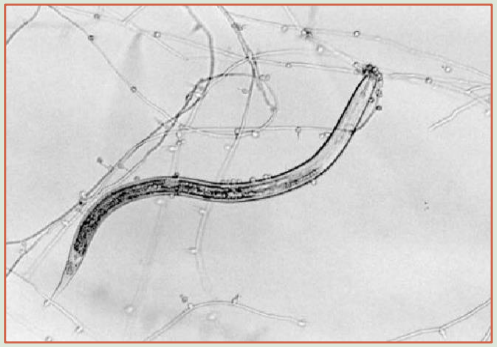
Roots without springtails



A single protozoan can eat billions of bacteria each day!

Mite preying on a nematode





Soybean cyst nematode parasitized by the fungus *Hirsutella minnesotensis*

We Are the Earthworms, Beetles, Centipedes and Other Larger Fauna

Earthworms & Macrofauna

- We are the engineers mixing & moving residues
- We are the plumbers and carpenters creating channels and strengthening soil
- We help the microbes build organic matter

Photo sources: Beare et al. 1995. Plant & Soil 170:5-22; Kuzyakov et al. 2015. Soil Biol Biochem 83:184-199

Earthworms can turn over the top 6 inches of soil in 10-20 years.

Photo source: (2016). Global Soil Biodiversity Atlas. A. Orgiazzi, et al. Luxembourg, European Commission, Publications Office of the European Union**: 176p.**

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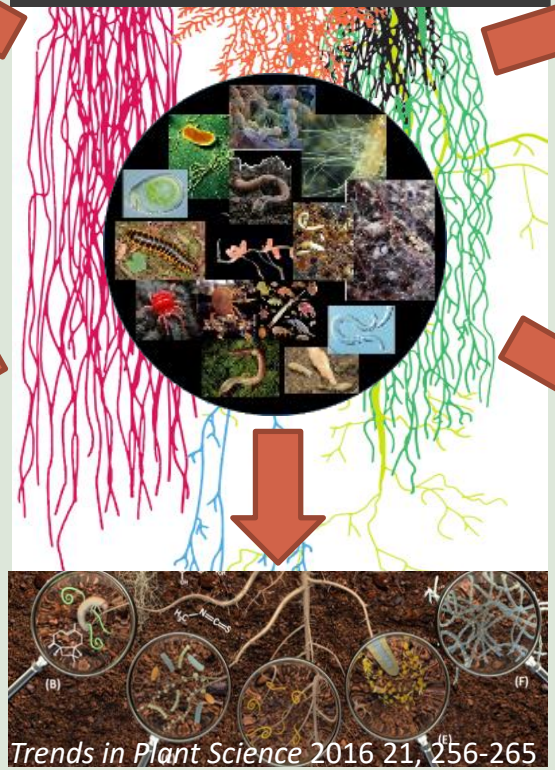
Biological Hot Spots to Optimize Function

Litter Layer

Photo source: NRCS

Rhizosphere



Trends in Plant Science 2016 21, 256-265

Root/Worm Channels

Photo source: P. Lavelle; J Moore-Kucera

Aggregate Surfaces

Photo source: J Moore-Kucera

Pore Space

Photo source: Barry Fisher, NRCS

Root cartoon and organism images: Orgiazzi , Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.; Slide design by J Moore-Kucera

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Things That Affect Us and the Jobs We Perform

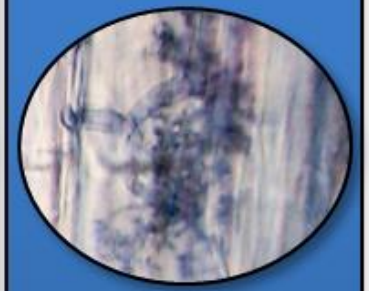
Management

- Tillage
- Planting
- Fertilizer use
- Amendments
- Cover crops
- Irrigation

Crops

- Crop type
- Cultivar
- Crop rotation
- Cover crops

Soil Biology



- Bacteria
- Fungi
- Protozoa
- Nematodes
- Earthworms
- Mammals

Soil Properties

- Soil type
- Texture
- pH
- Bulk density
- Organic matter
- Drainage

Environment

- Precipitation
- Temperature
- Humidity
- Wind
- Season length
- CO_2 levels

Lehman, R. M., et al. (2015). "Soil biology for resilient, healthy soil." Journal of Soil and Water Conservation 70(1): 12a-18a.

A Changing Climate is A Major Threat

Management

- Tillage
- Planting
- Fertilizer use
- Amendments
- Cover crops
- Irrigation

Crops

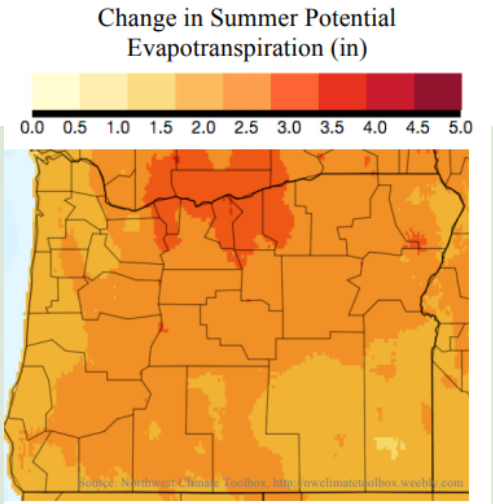
- Crop type
- Cultivar
- Crop rotation
- Cover crops

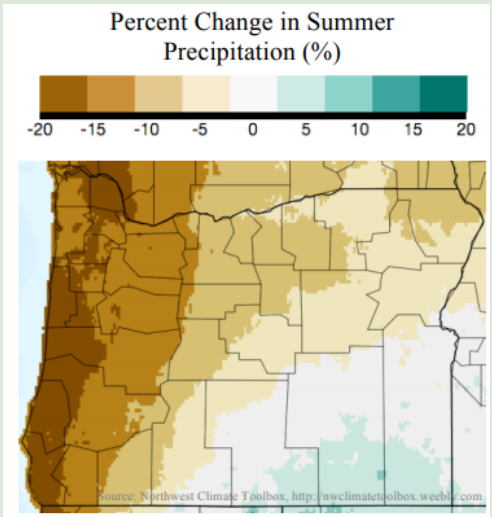
- What are some of the projected changes for Oregon?
- How might that impact Oregon agriculture?
- How can farm and ranch land combat climate change?
  - Protection from loss
  - Management strategies
  - Soil health
  - Biological hot spots
- What can you do?

Environment

- Precipitation
- Temperature
- Humidity
- Wind
- Season length
- CO_2 levels

Projected Climate Changes For OR

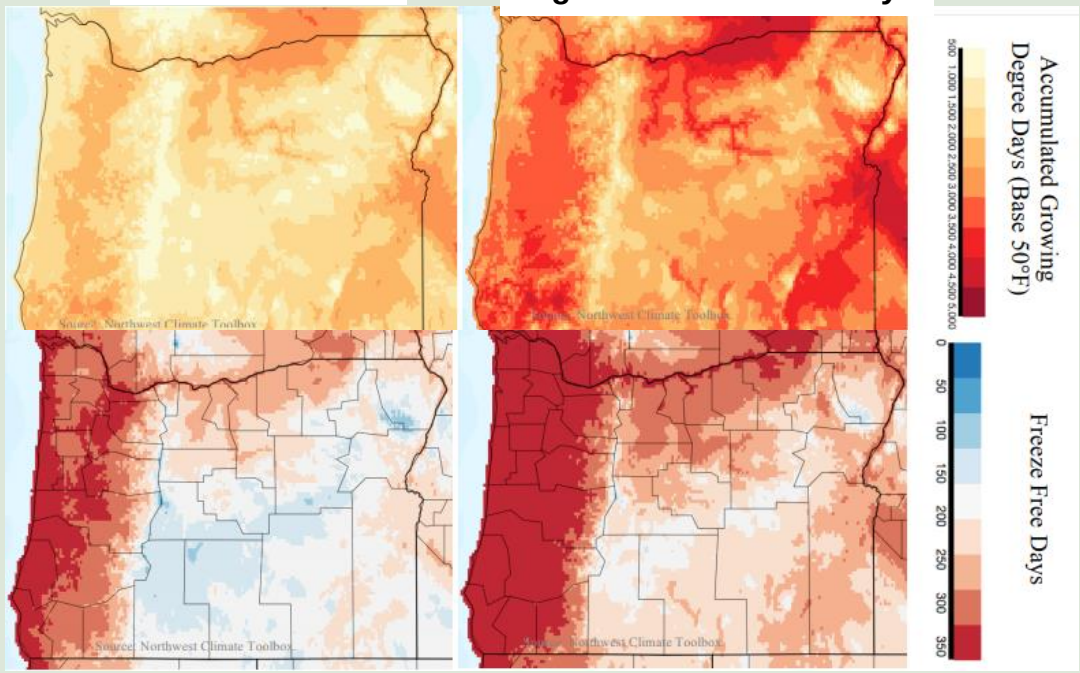




Most areas will experience at least 30 additional 'hot days' (>86F) each year (about 2x more than we have now)

Historical Period 1971-2000

Future Period 2040-2069 High Emissions Pathway



Less snowfall results in increased warming where snow disappears; earlier snowmelt (more flooding potential; less water available in summer)

Source: Third Oregon Climate Assessment Report (2017)
http://www.occri.net/media/1048/6ocar3_final_agriculture.pdf

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Impacts of Climate Change on Oregon Agriculture

Grains, oilseeds, dried beans, and dried peas ($570M; 2012)

- Wheat yields may increase but other pressures may offset benefits

Fruits, tree nuts, berries ($517M)

- Negative yield impacts due to increased heat and drought stress, changes in precip and chilling requirements; pests, pollinator dynamics, etc.

Vegetables, melons, potatoes, and sweet potatoes ($492M)

- Susceptible to water depletions and thus yields declines
- Potato yield expected to decline

Beef and Dairy Cattle ($894M)

- Increased heat stress & decrease fertility, increase infections, decrease growth & milk production
- Reductions in forage quantity and quality and increased variability

Source: Third Oregon Climate Assessment Report (2017)
http://www.occri.net/media/1048/6ocar3_final_agriculture.pdf

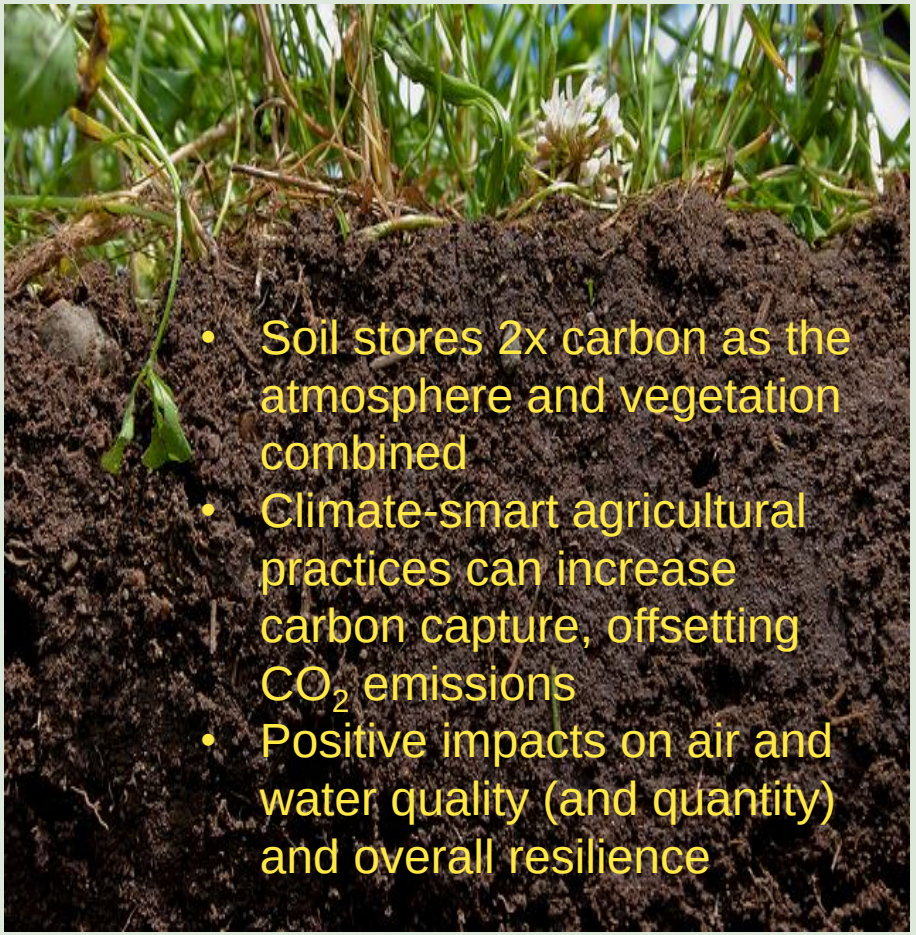
Farmland Protection
Productive, Versatile, Resilient

- Lost farmland not only reduces the amount of land available to grow food and provide environmental services, but the potential harm to environment is magnified
- Ag and ranch land can help meet needs of increased food demands AND help mitigate climate changes by rebuilding soil and sequestering CO_2

AFT's Farmers Combat Climate Change Initiative

Accelerate adoption of climate smart agriculture

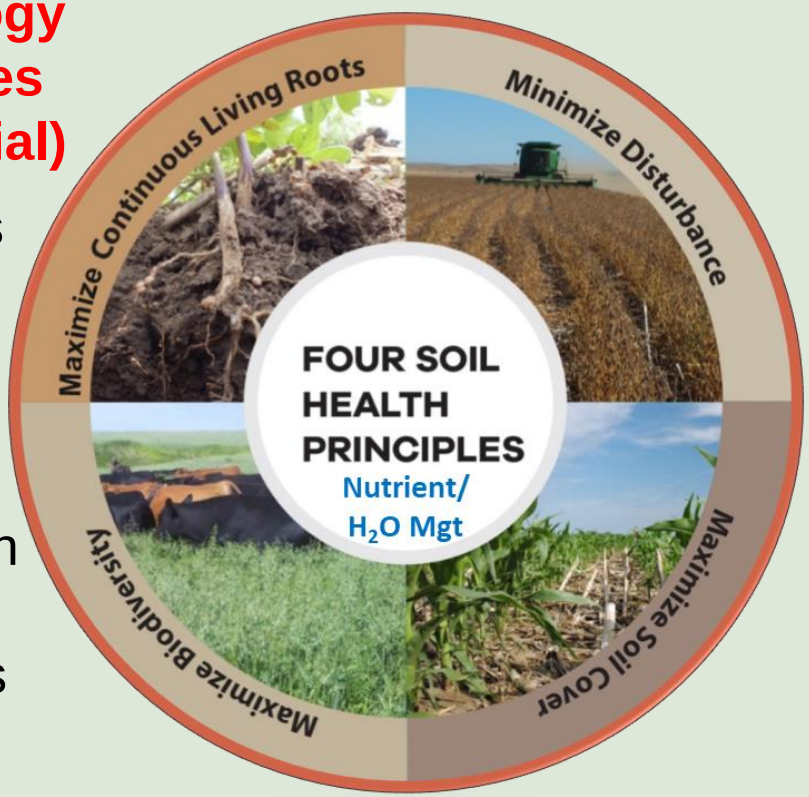
- Soil health practices and carbon farming can help absorb CO_2 from the atmosphere and store it in the soil.
- Farm conservation practices are among the least costly & most immediate actions that can help reduce emissions & protect air & water quality.



Management Principles To Increase Resiliency By Supporting Soil Biology

Feed & Fuel Soil Biology with diverse C sources (plant, animal, microbial)

- Break disease cycles
- Stimulate microbial diversity
- Increase SOM and nutrient cycling
- Enhance plant growth
- Increase predator & pollinator populations



Protect Microbial Habitat

- Protect soil organic matter and soil aggregates
- Reduce erosion & runoff risk
- Buffer temperature
- Reduce evaporation

*Modified from USDA –NRCS-Principles for High Functioning Soils Factsheet

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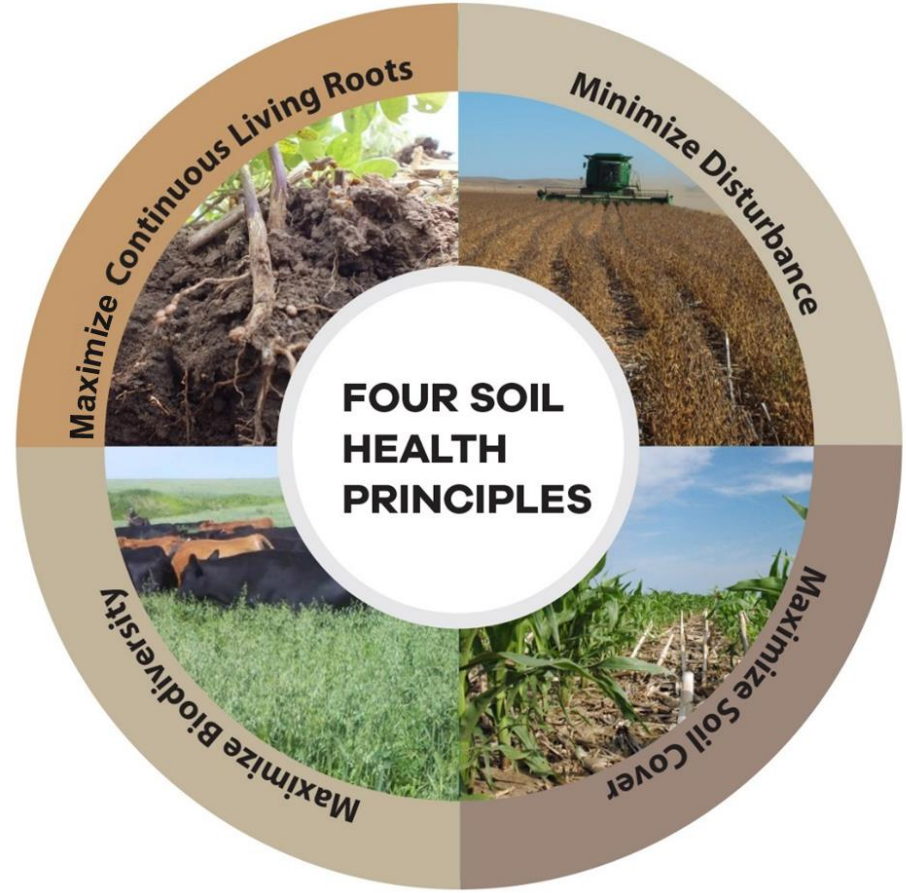
Management Practices To Increase Resiliency By Supporting Soil Biology

Soil Health Practices

- **Cover Cropping*****
- Reduced-till/No-till
- Crop Rotations
- Soil Amendments
- Precision Management
- Rotational Grazing
- Crop/livestock integration
- Agroforestry



We Are A Team…But We Work Best Together…See us in Action!

15 week time lapse

** The featured video clip has been removed to save file space.
You can view it at https://vimeo.com/222168889 **

Made by: Wim van Egmond
https://vimeo.com/222168889

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Signs of Soil Health You Can Look For In Your Field or Garden

Surface Indicators

Surface

Surface Cover

Surface Crusting

Residue Breakdown

Ponding

✓Absence of crusting, ponding, erosion

Soil Physical Indicators for Soil Health

Soil Physical

Penetration resistance

Soil Structure & Color

Aggregate Stability

Erosion

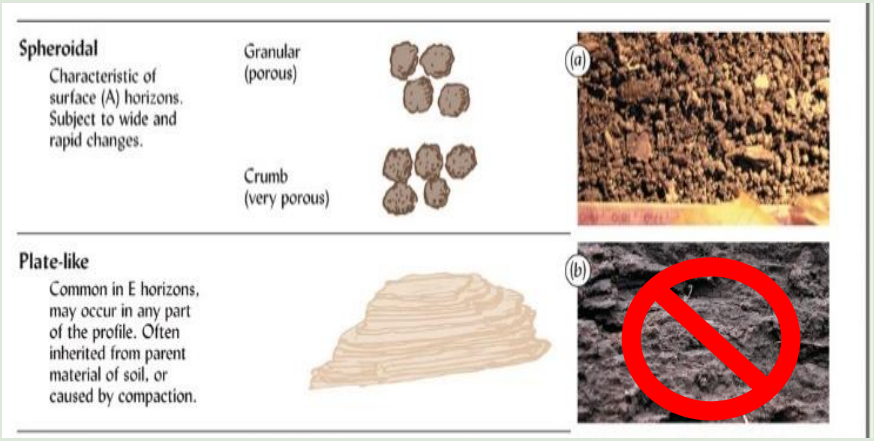
✓Wire flag or penetration resistance meter goes easily into soil to at least 10”

Soil Physical Indicators of Soil Health


Source: Moore-Kucera


Source: Chessm


Source: Moore-Kucera



Soil structure examples extracted from The Nature and Properties of Soil, 15 e, R.R. Weil & N.C. Brady

- ✓ Residues mixed by biological activity into surface layers
- ✓ Dark soil color (deeper the better)
- ✓ Soil has granular structure (absence of platy structure)

Soil Physical Indicators of Soil Health

Source: NRCS

Source: B. Smith

✓Soil maintains structure during slake or slump test

Soil Biological Indicators

Soil Biological

Biopores

Root Depth & Distribution

Biological Activity

- ✓ Visible soil organisms (e.g., worms, beetles, millipedes, ants, etc.)
- ✓ Or signs of organism activity (e.g., earthworm channels or casts, fungal hyphae)

Photo sources: NRCS; Global Soil Biodiversity Atlas; midden picture; lowalearningfarms.wordpress.com

Step 6: Soil Biological Field Indicators

Example of rhizosheaths (left), and J-rooting (middle and right). Photo source: B. Fisher (left); D. Lamm (middle), C. Thomas (right), NRCS-SHD.

✓ **Abundant, deep roots not inhibited by restrictive layers; well-branched**

Linking What you See in the Field to Actions you Can Take

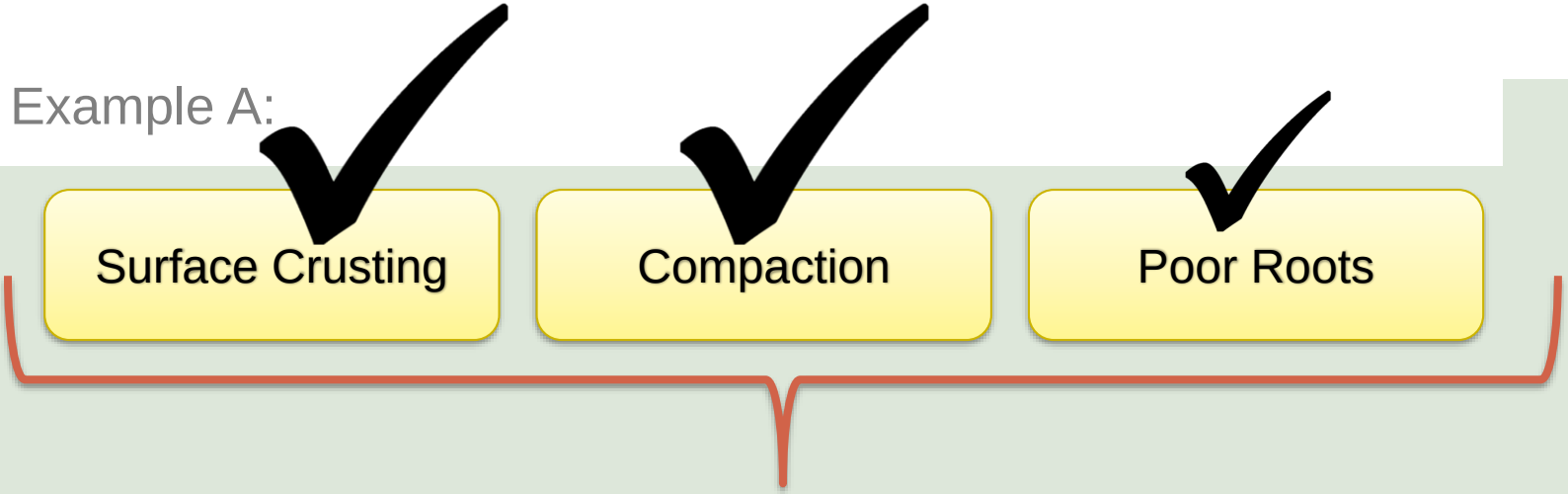
- Example A:

Linking What you See in the Field to Actions you Can Take

- Example A:

Linking What you See in the Field to Actions you Can Take

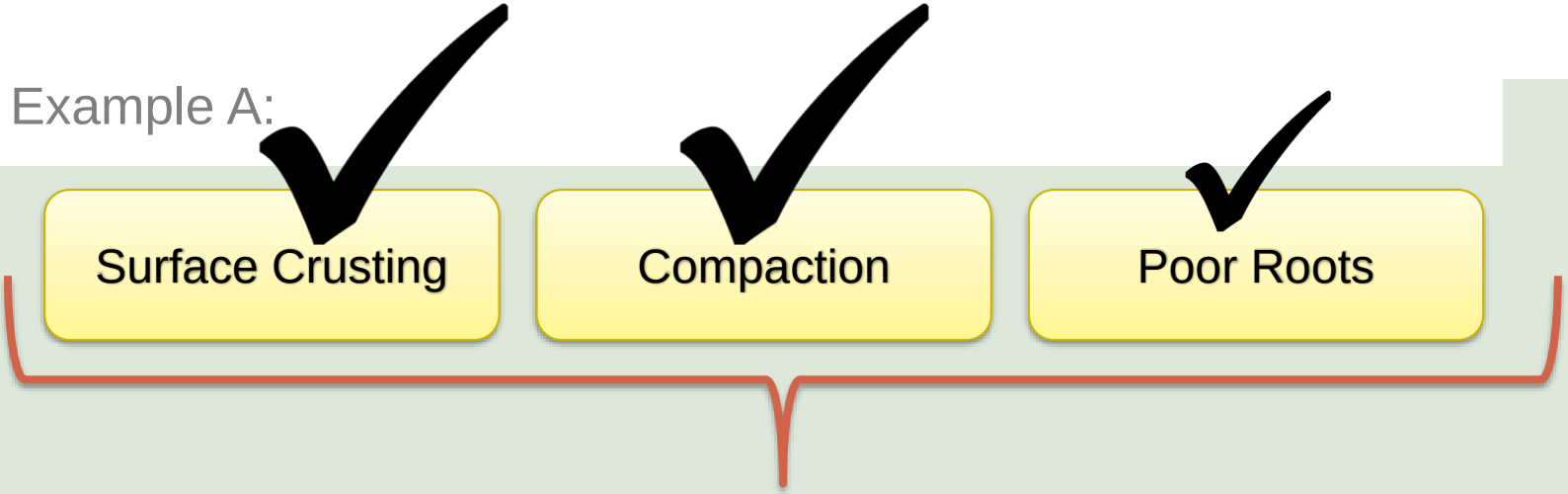
- Example A:



- **Your soil is distrubed enough that there is a physical barrier to roots having access to the full soil profile**
- **Your soil is at risk for erosion and runoff**

Linking What you See in the Field to Actions you Can Take

- Example A:

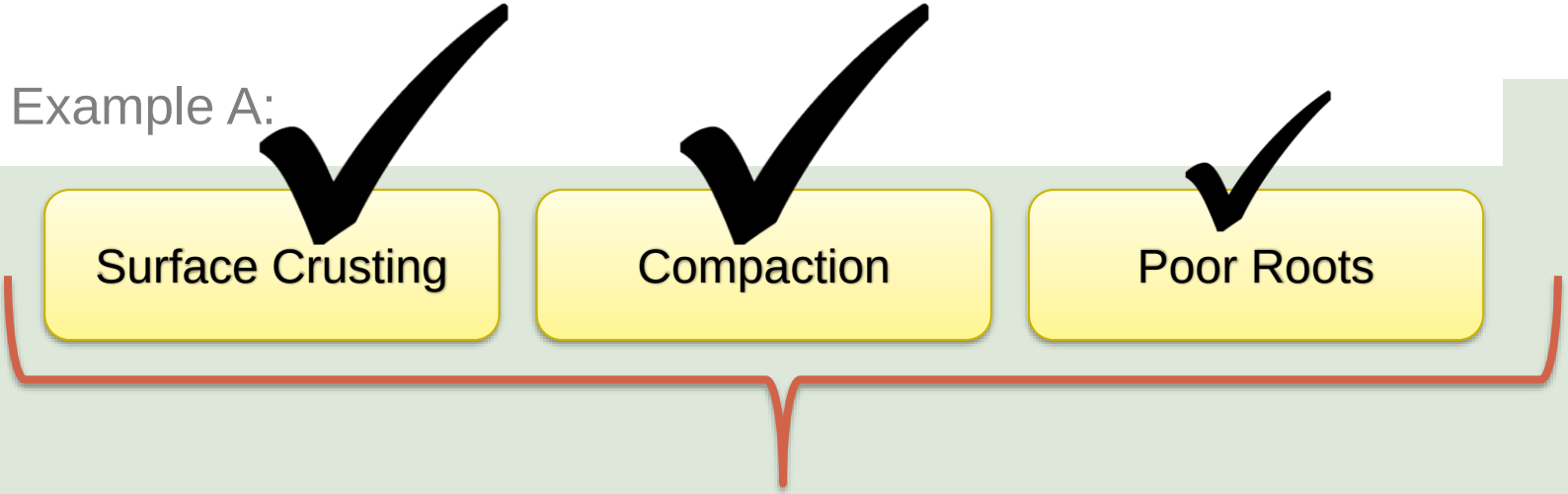


- **Your soil is distrubed enough that there is a physical barrier to roots having access to the full soil profile**
- **Your soil is at risk for erosion and runoff**

NEED TO ADD PROTECTION

Step 7: Connect Assessment with Principles to Inform Action

- Example A:



- **Your soil is distrubed enough that there is a physical barrier to roots having access to the full soil profile**
- **Your soil is at risk for erosion and runoff**

NEED TO ADD PROTECTION

- **Review your tillage practices and consider a cover crop species that will help break up compaction and add residue.**

Linking What you See in the Field to Actions you Can Take

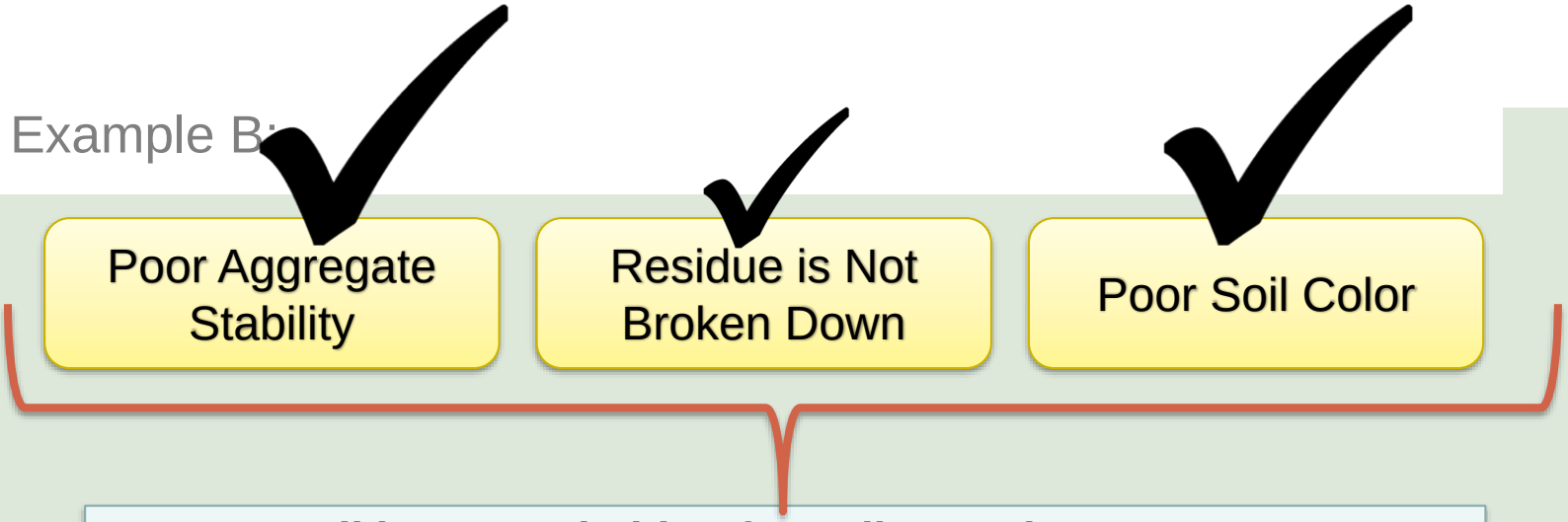
- Example B:

Linking What you See in the Field to Actions you Can Take

- Example B:

Step 7: Connect Assessment with Principles to Inform Action

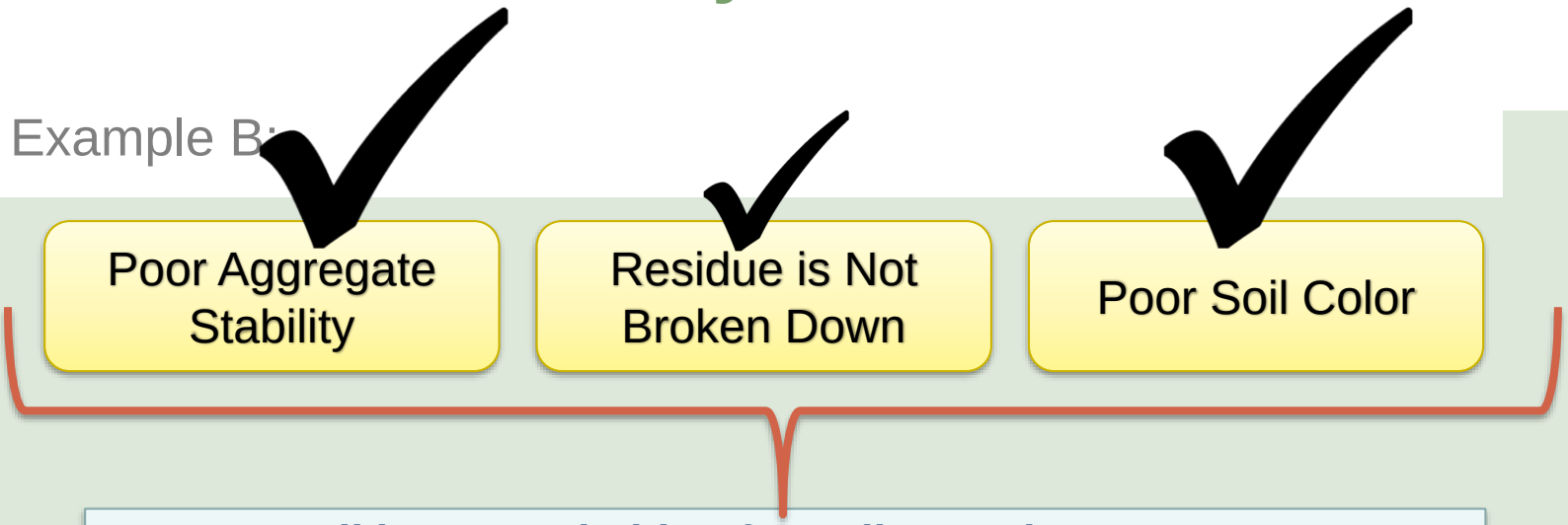
- Example B:



- **Your soil has poor habitat for soil organisms**
- **Your soil has depleted organic matter**
- **Your soil is probably had diminished water holding capacity**

Linking What you See in the Field to Actions you Can Take

- Example B:



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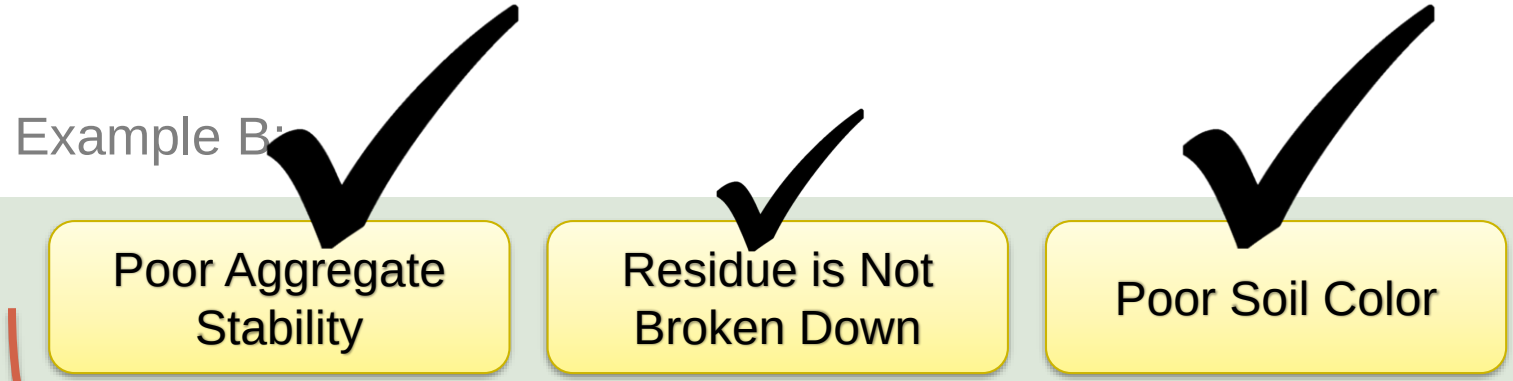
NEED TO INCREASE THE FEED

Linking What you See in the Field to Actions you Can Take

- Example B:



- **Your soil has poor habitat for soil organisms**
- **Your soil has depleted organic matter**
- **Your soil is probably had diminished water holding capacity**

NEED TO INCREASE THE FEED

- **Review your crop rotation and diversity in space and time.**
- **Look for opportunities to cover crop or add compost/mulch.**
- **Review tillage regime to increase the length of time between distrubance activities**

Thank You!

"Whether you think you can,
or you think you can't
you're right."
–Henry Ford

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Soil & Water Conservation District

Tualatin Soil and Water
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