Soil health concepts and management

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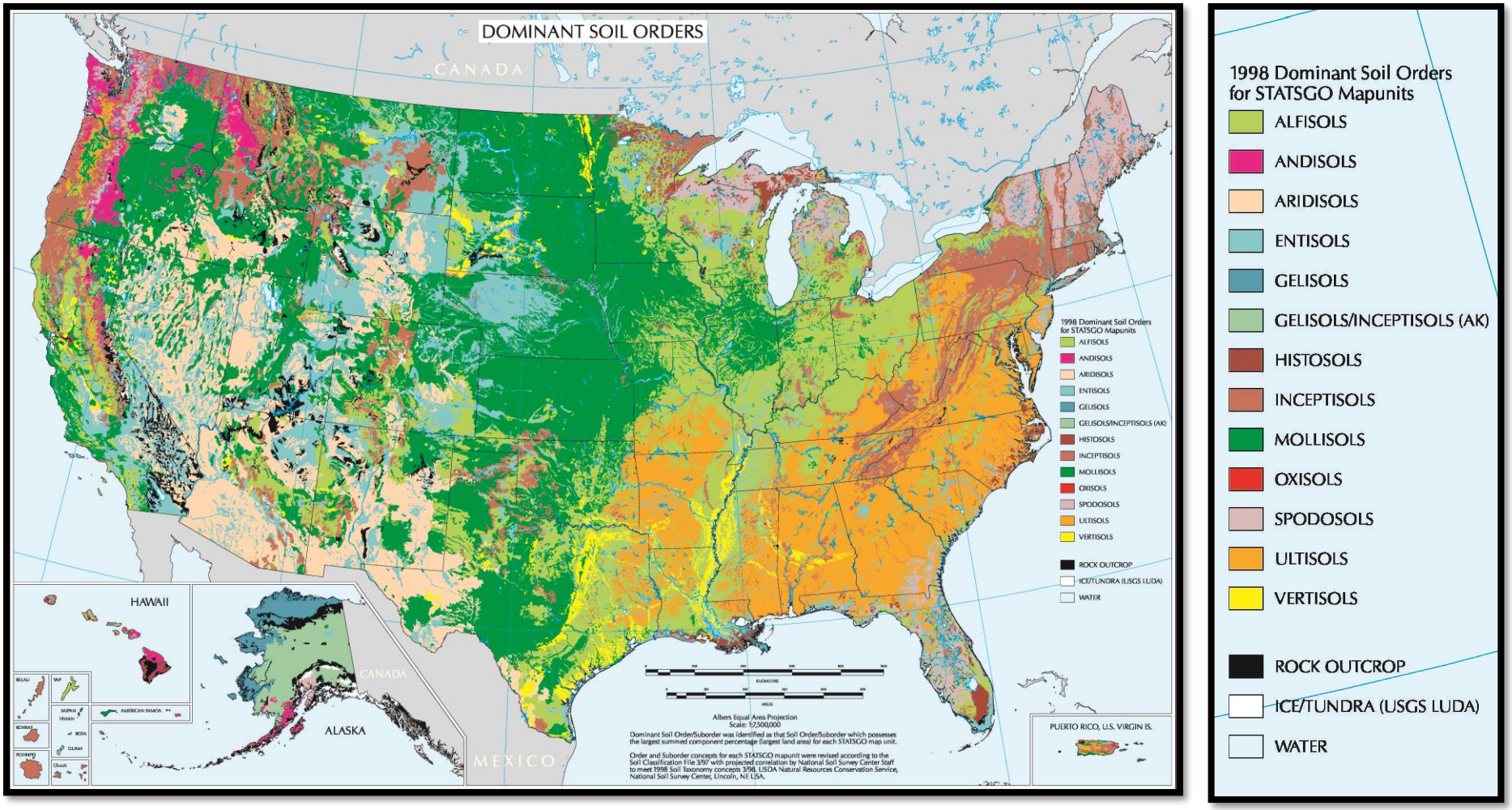
Soil diversity: National and local

United States



Source: https://www.nrcs.usda.gov/Internet/FSE_MEDIA/stelprdb1237749.pdf

Soil diversity: Western Skagit County

Entisols
38% brand new soils

Inceptisols
27% relatively new soils

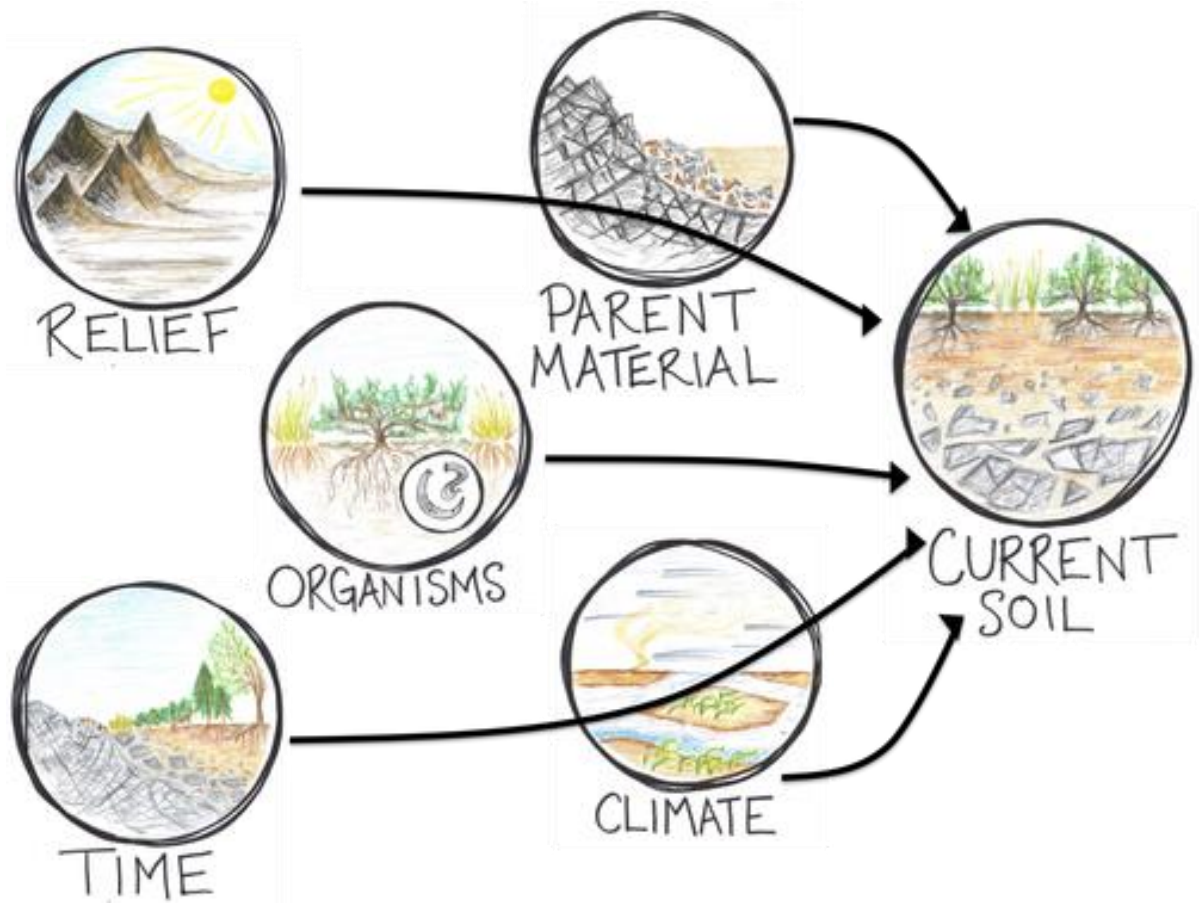
Alfisols
6% older soils

Andisols
26% volcanic

Histosols
1% peat soils

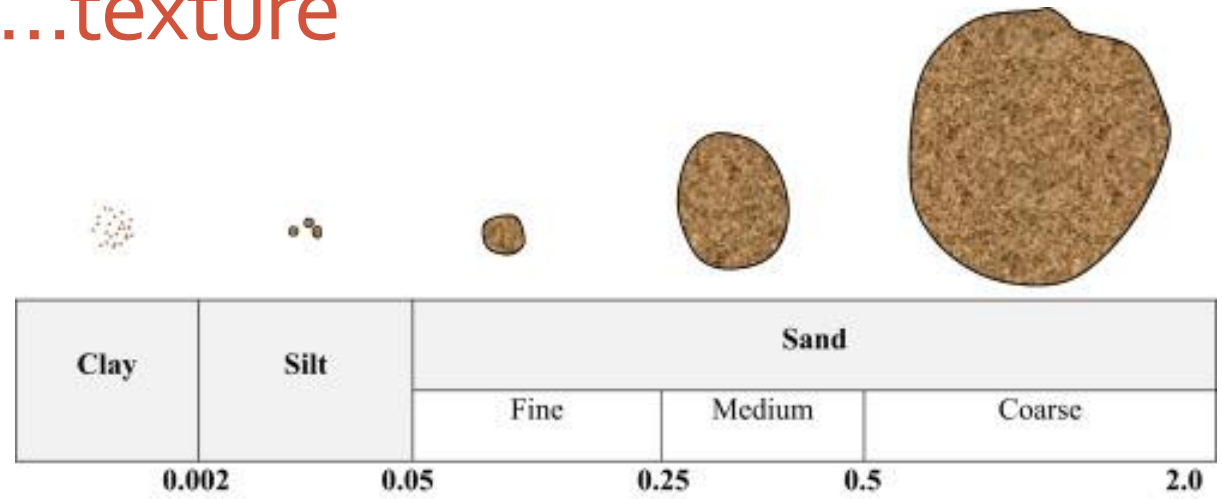
Source: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/maps/
Source: http://geo.msu.edu/extra/soilprofiles/

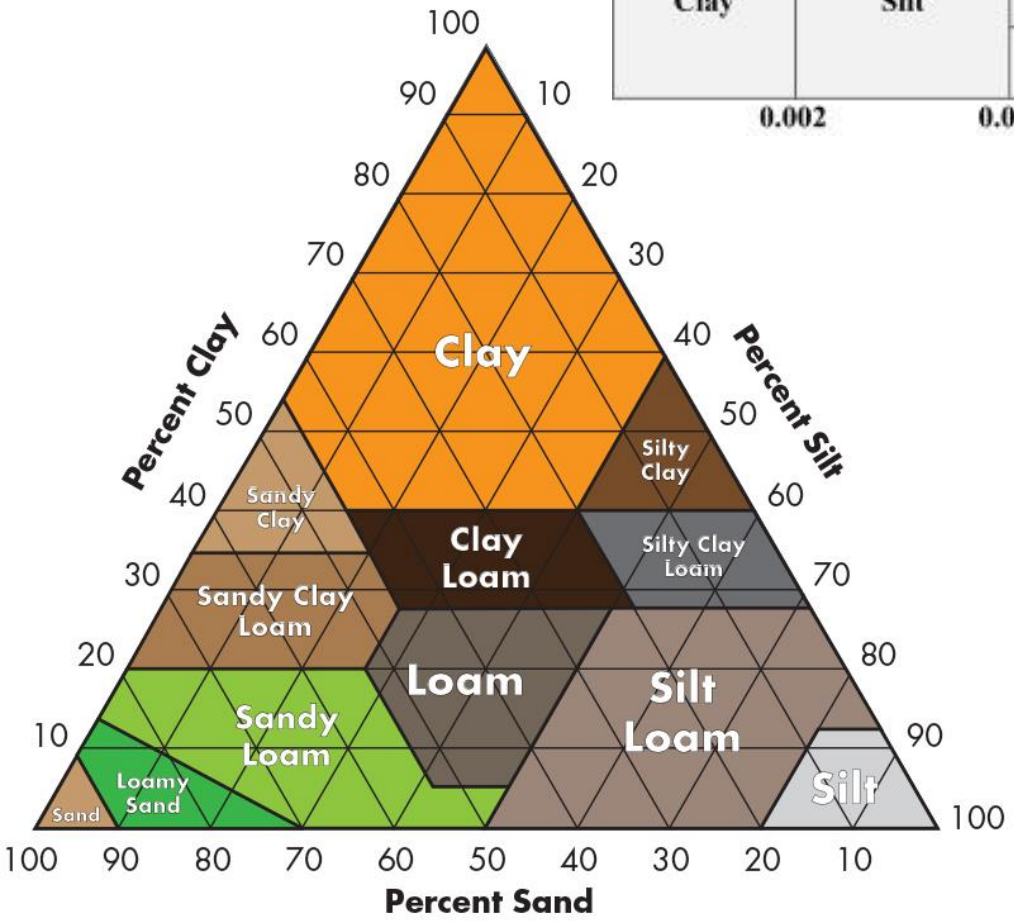
Soil forming factors: How did this diversity arise?



Source: https://dartmouthigert.wordpress.com/2015/01/23/an-apatite-for-kenyte/

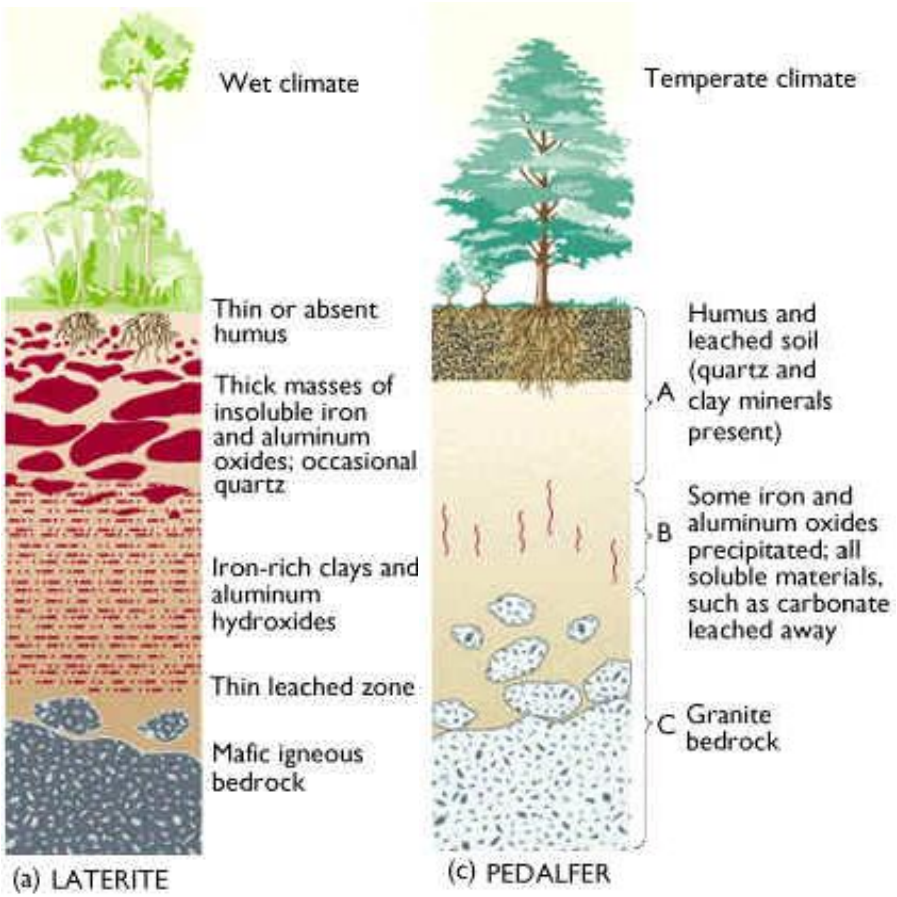
Soil type affects…texture



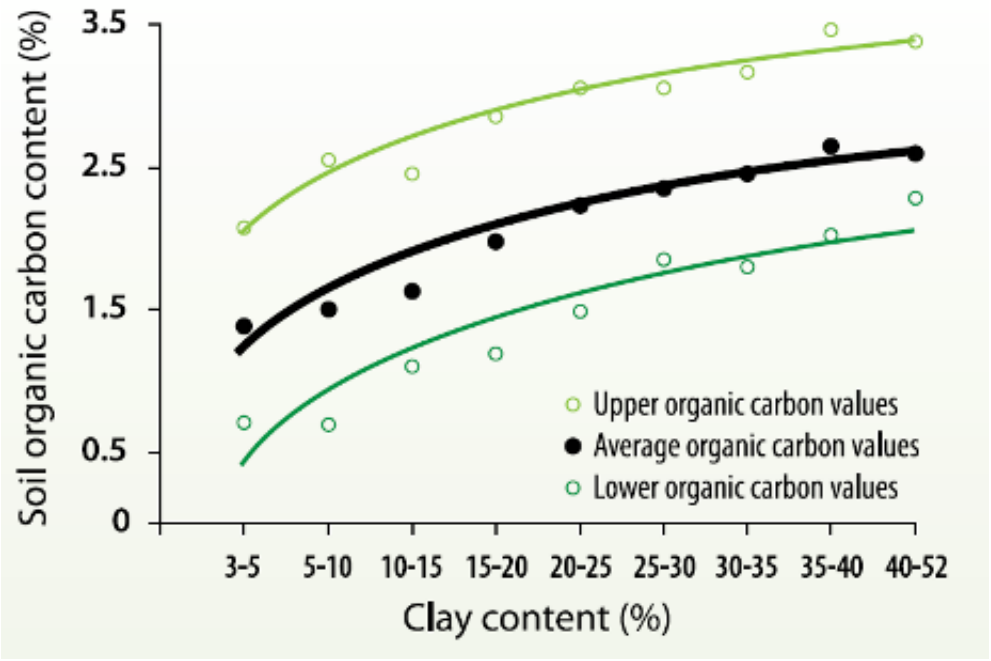


- Parent material mineralogy
- Level of weathering
- Secondary clay mineral formation

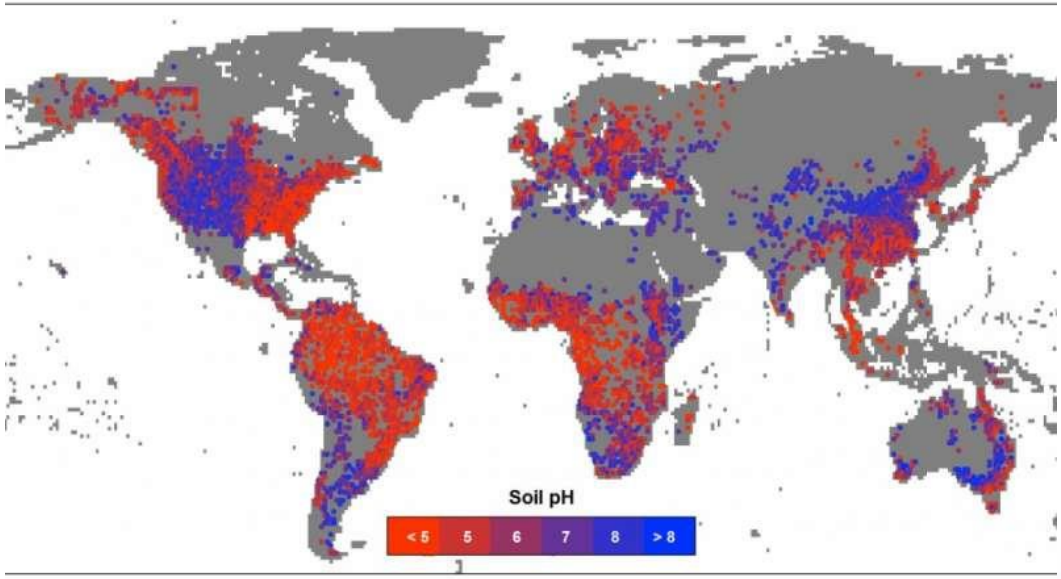
Soil type affects…organic matter content



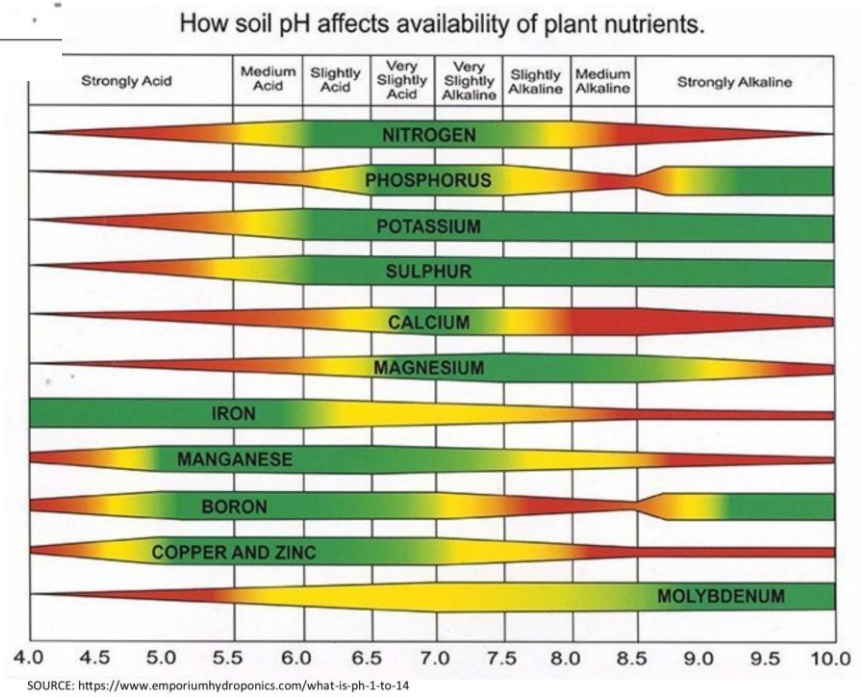
- Organic matter storage capacity
- Biological activity



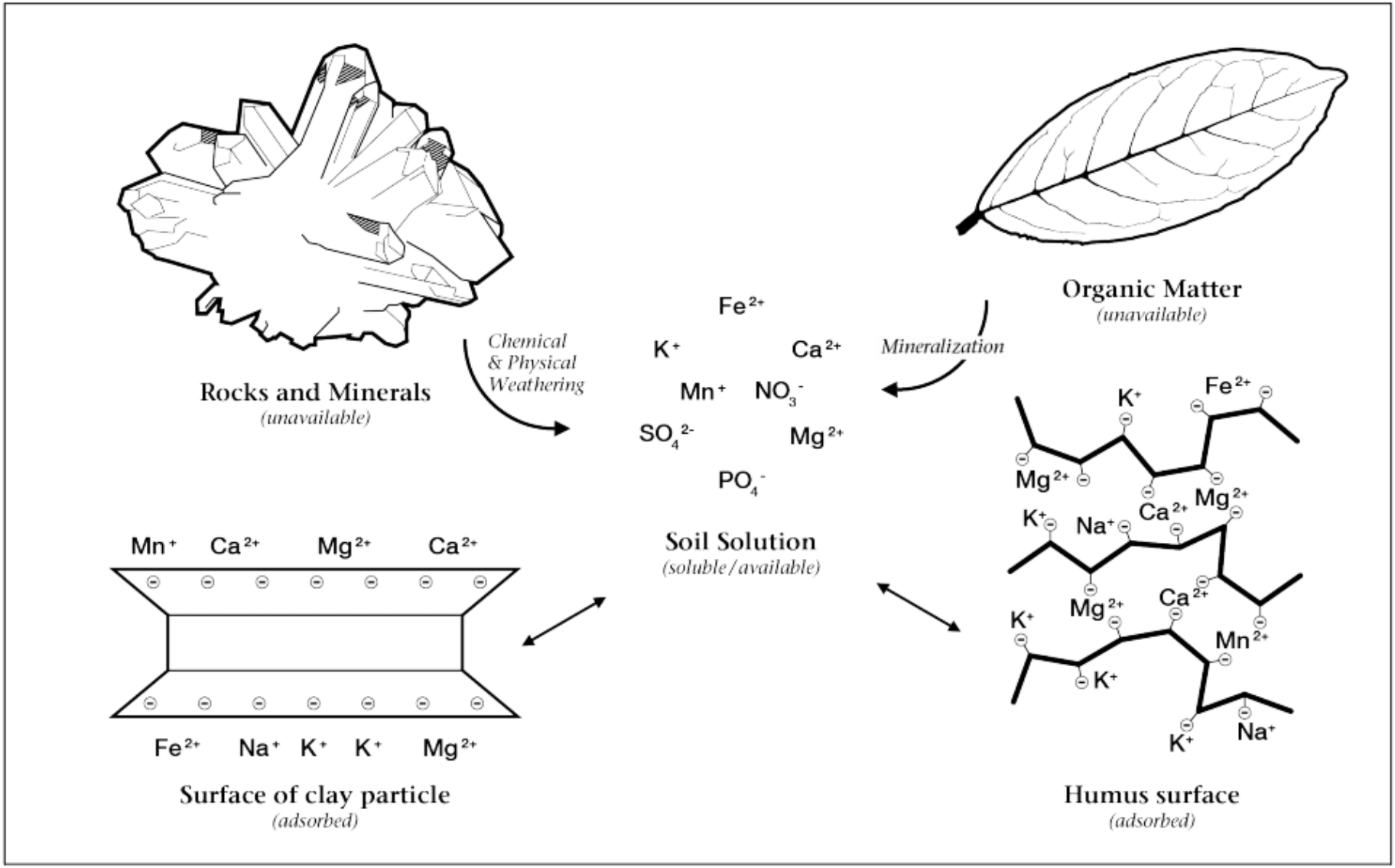
Soil type affects…soil pH



Slessarev et al., 2016

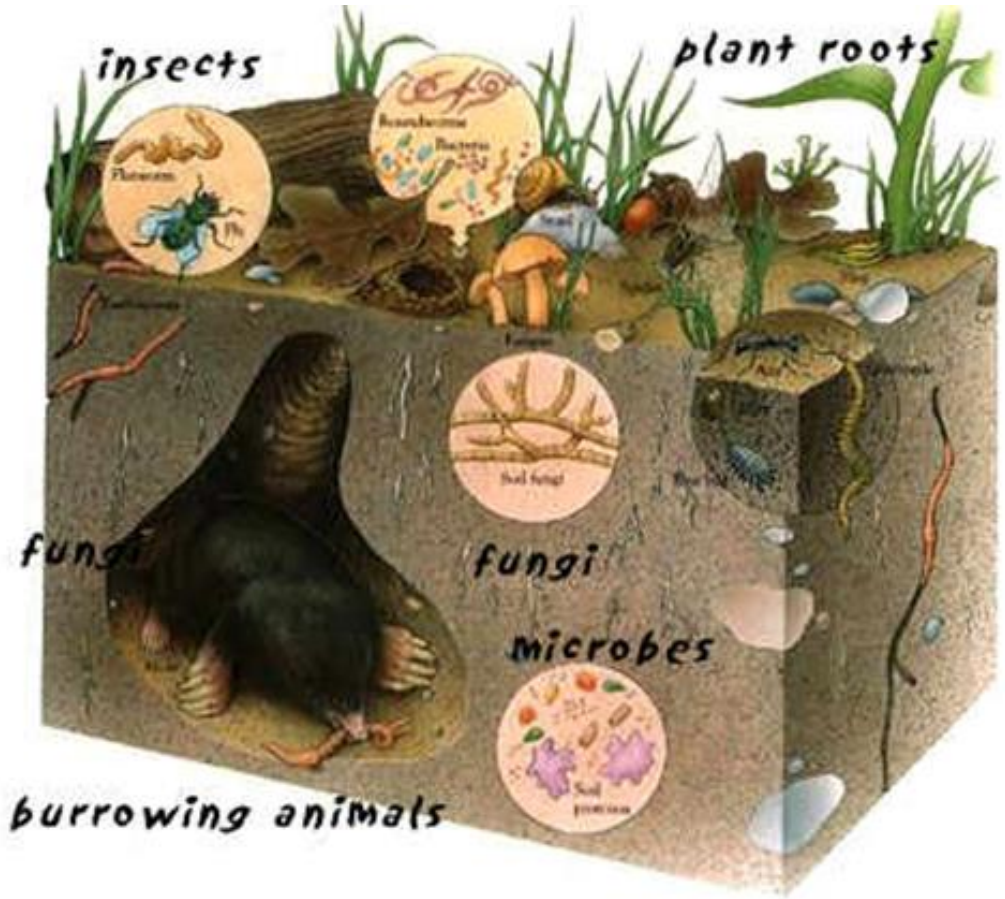


Soil nutrient cycling



Ref: Collins, Cogger, Miles, Koenig, WSU Exension

Soil organisms and their role in soil formation & functioning

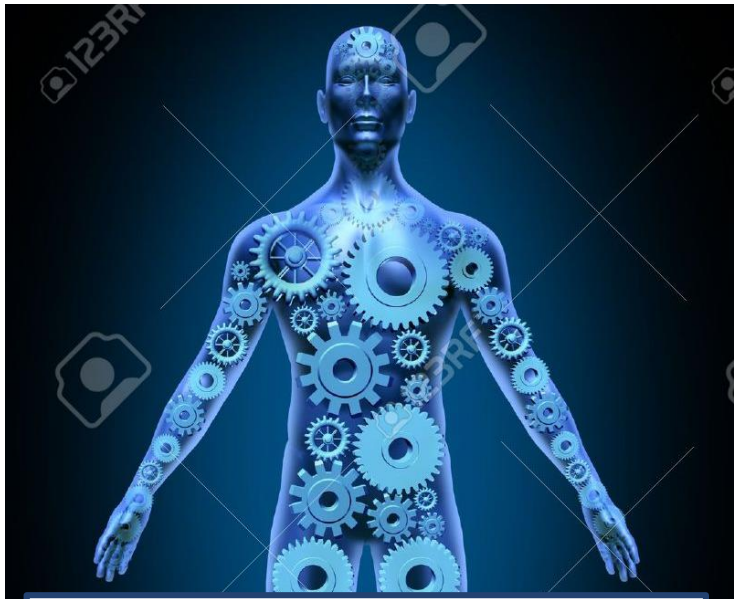


What is "soil health"?

"The continued capacity of the soil to function as a **vital, living ecosystem** that sustains plants, animals, and humans."

- Natural Resources Conservation Service

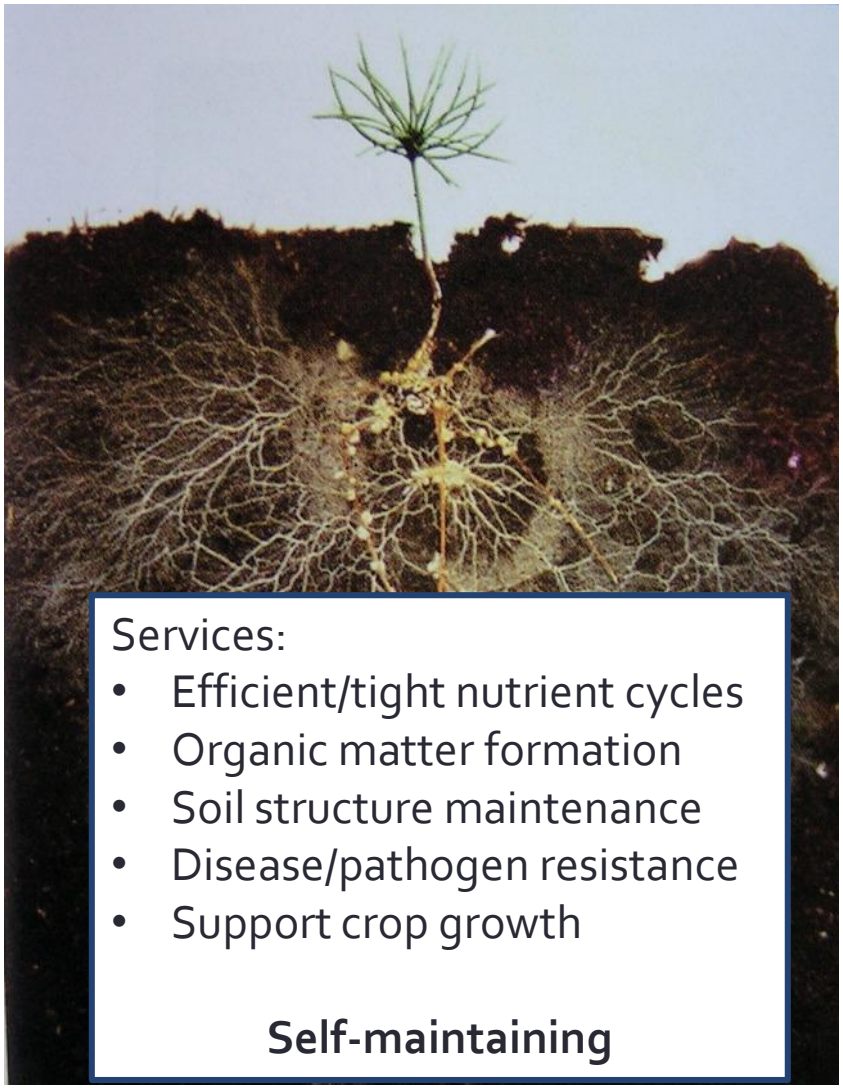
What is a healthy soil?



Services:

- Efficient nutrient use
- Building and regeneration
- Strong skeleton/musculature
- Disease prevention
- Support growth

Self-maintaining



Services:

- Efficient/tight nutrient cycles
- Organic matter formation
- Soil structure maintenance
- Disease/pathogen resistance
- Support crop growth

Self-maintaining

www.theatlantic.com/health/archive/2013/06/healthy-soil-microbes-healthy-people/276710/

What is an *un*healthy soil?

Challenges

Erosion/Run-off

Organic matter loss

Contamination

Sealing/Crusting

Compaction

Biodiversity loss

Modified from Bünemann et al., 2018

Challenges ⟷ Processes

Challenges	Processes
Erosion/Run-off	Soil aggregation
Organic matter loss	Nutrient cycling
Contamination	Water cycling
Sealing/Crusting	Carbon storage
Compaction	Decomposition
Biodiversity loss	Habitat for roots/ organisms

Modified from Bünemann et al., 2018

Challenges	Processes	**Services**
Erosion/Run-off	Soil aggregation	Crop production
Organic matter loss	Nutrient cycling	Water quality
Contamination	Water cycling	Disease control
Sealing/Crusting	Decomposition	Carbon storage
Compaction	Organic matter formation	Resilience
Biodiversity loss	Habitat for roots/ organisms	Climate regulation

Modified from Bünemann et al., 2018

Challenges ⟷ Processes ⟷ **Services**

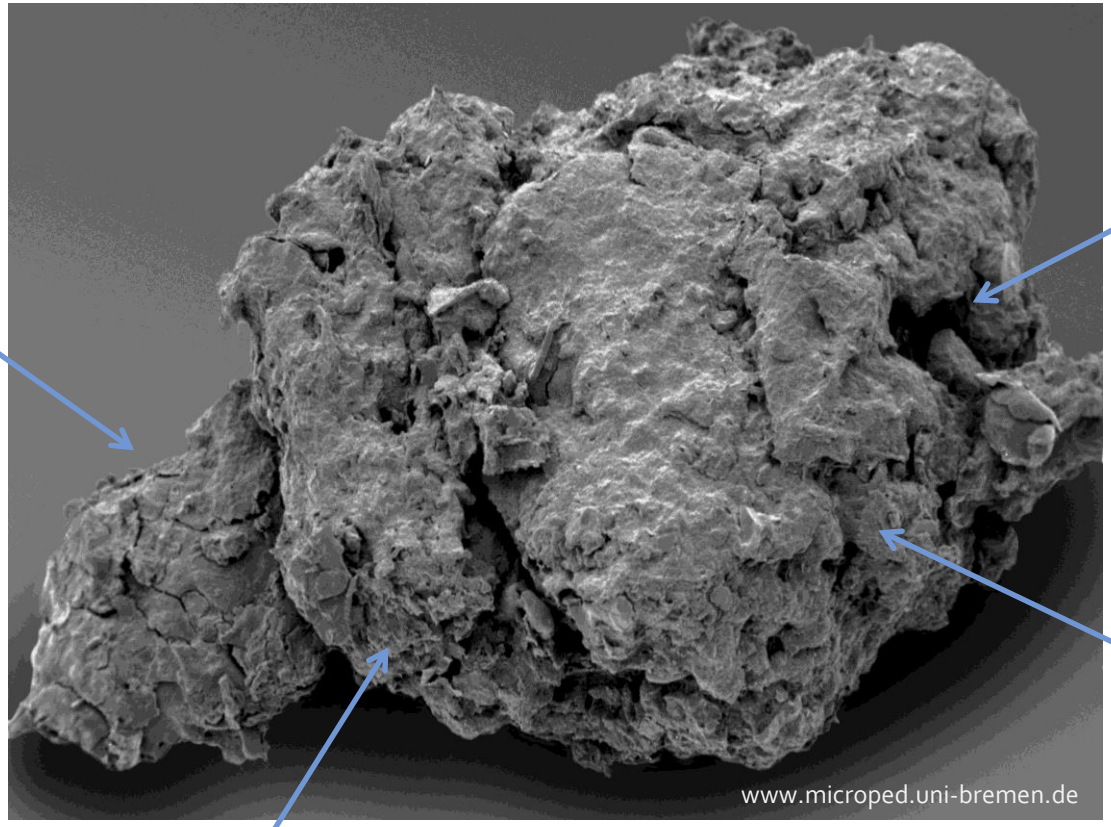
Poor drainage

Loss of soil health services:

- Reduced crop growth
- Loss of soil structure
- Loss of nutrients
- Disease pressure

Improved drainage: Soil aggregation

What is an aggregate?



Soil particles (silt & clay) bound together with organic matter

Pores for air and water

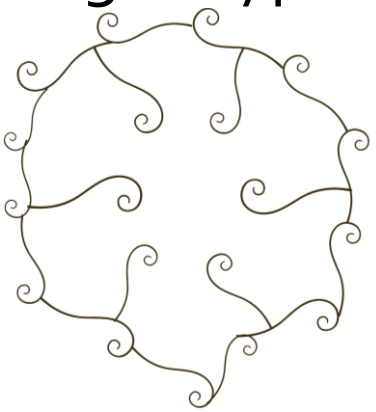
Protects organic matter inside

Living space for good bacteria and fungi

Soil Particles + Microbial "Glues" + Fungal Hyphae

+

+



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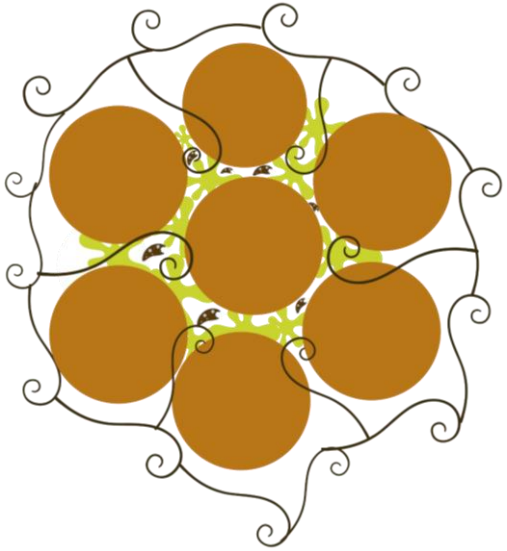
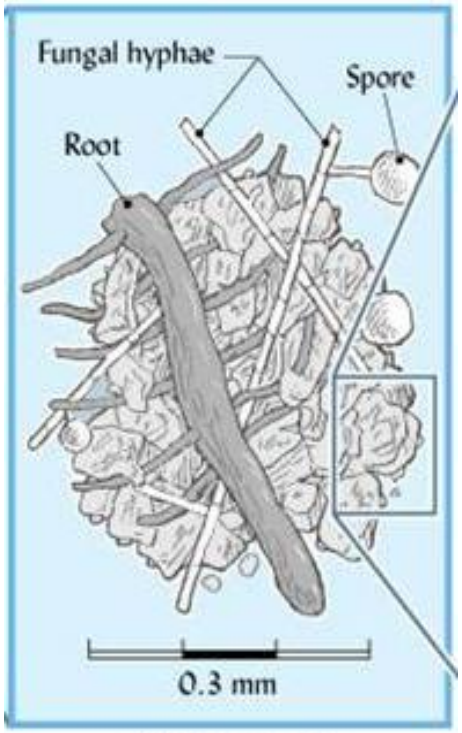


Soil Aggregate

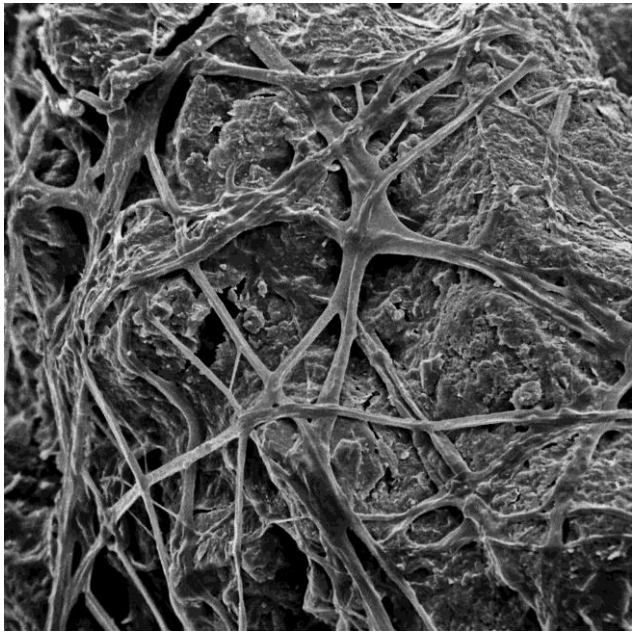
Images by Daniel Rath

Soil aggregation

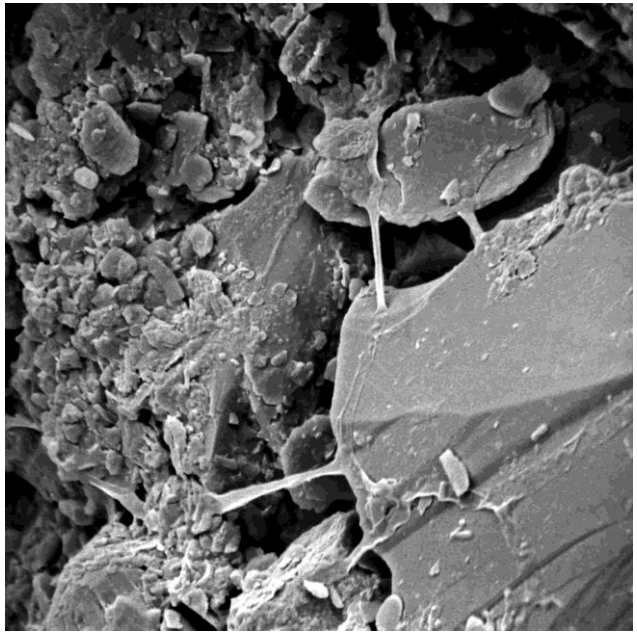
How are aggregates made?



Microaggregate



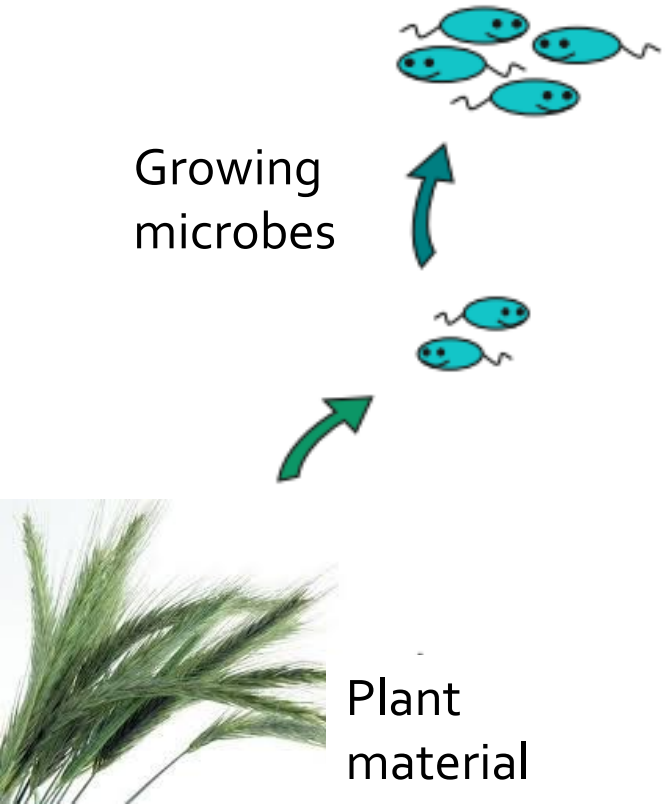
Fungal mycelia surrounding an aggregate



Bacterial filaments securing soil particles

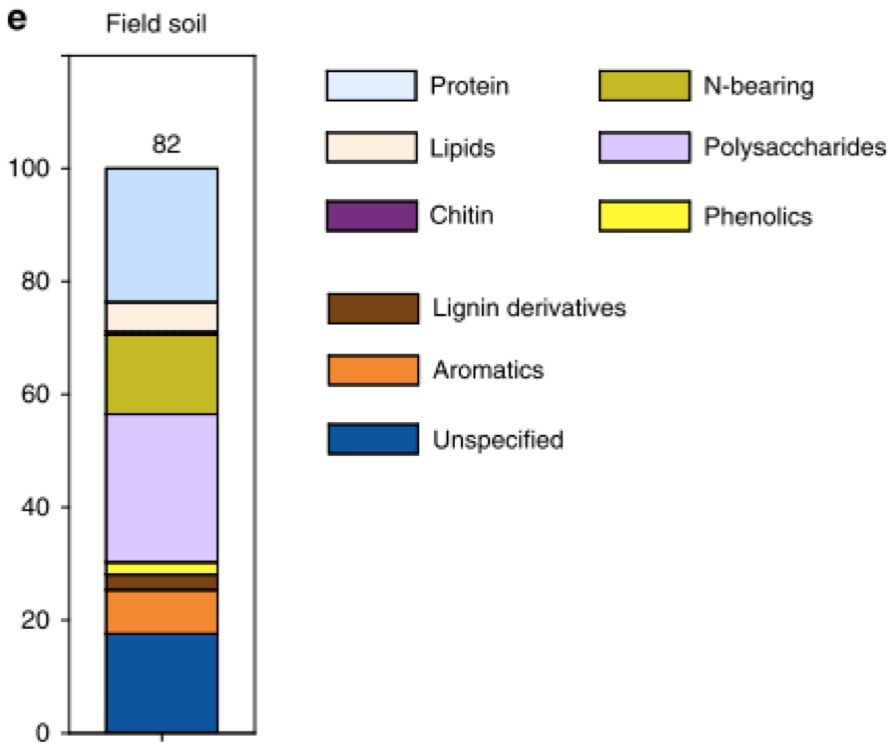
Aggregate diagram from Brady & Weil, 2008; SEM images from www.microped.uni-bremen.de

Up to ~80% of SOM can be derived from microbial biomass



Miltner et al., *Biogeochemistry*, 2008

Microbes themselves *make* soil organic matter!



From Kallenbach et al., 2016

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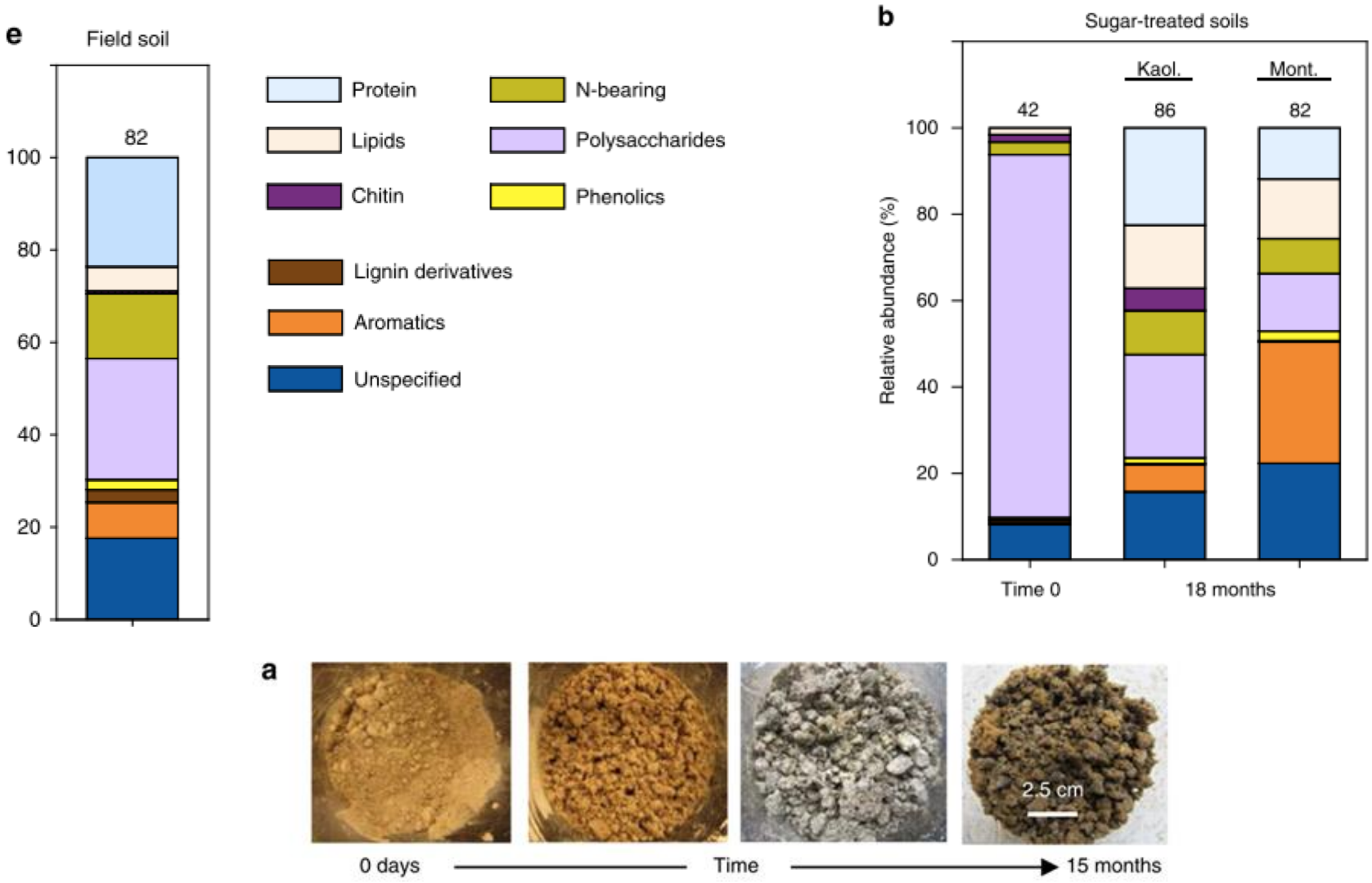
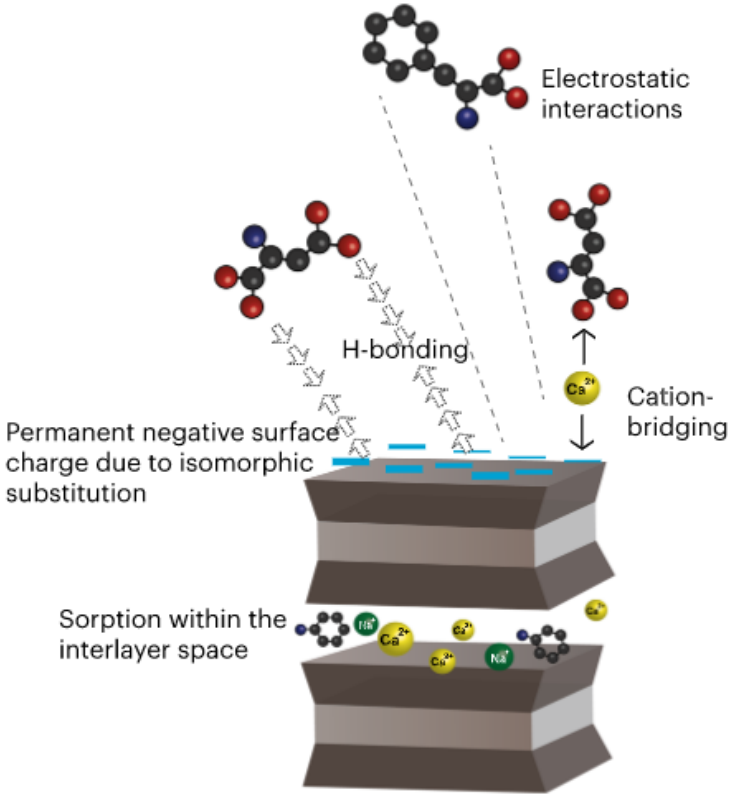
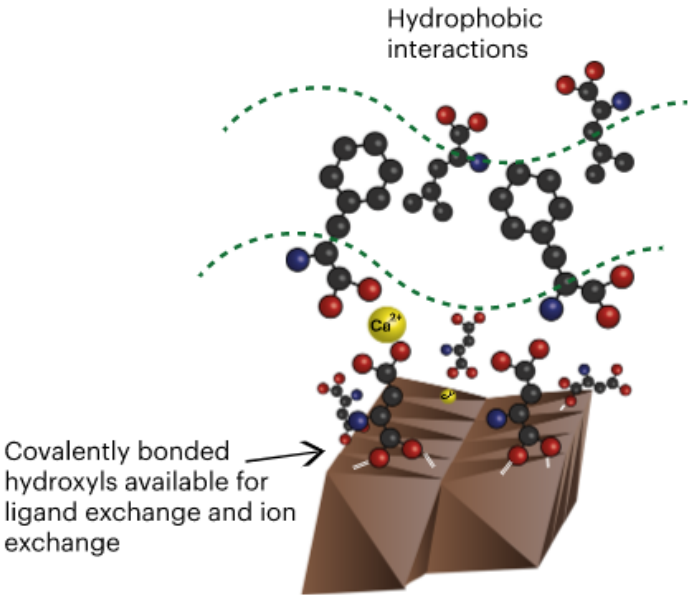


From Kallenbach et al., 2016

Microbial products bind to clay minerals



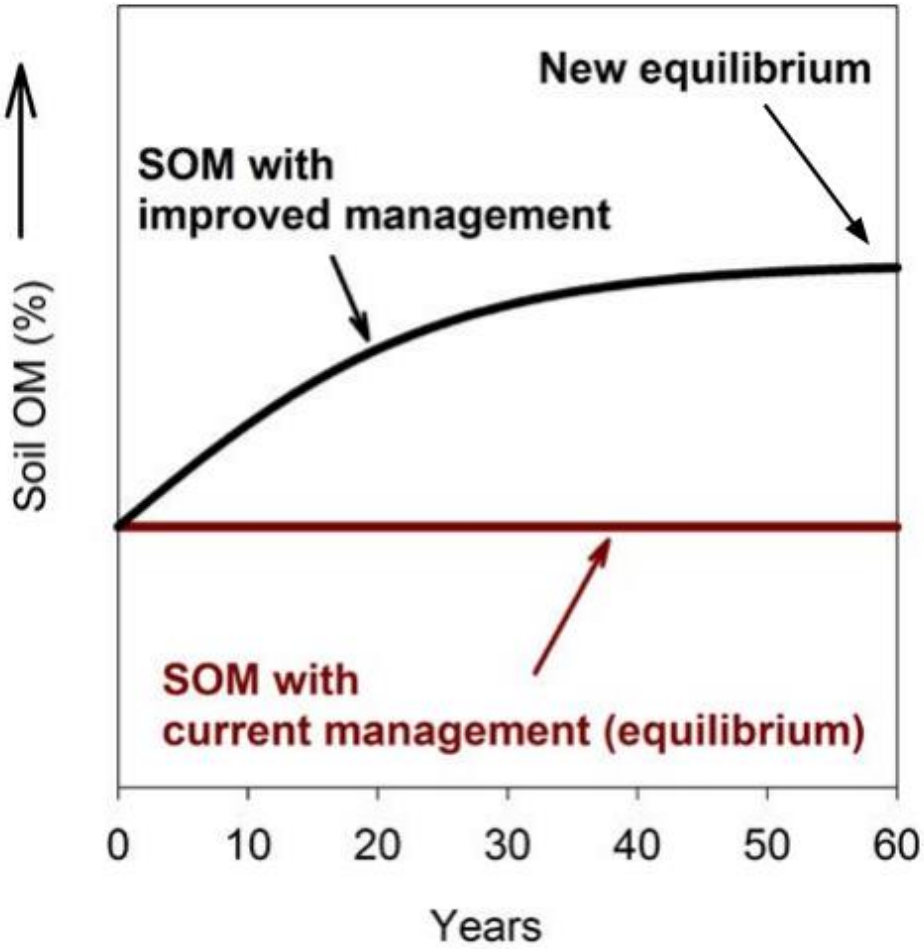
Layer Silicate Clays
- e.g. smectite



Metal Oxides and Hydroxides
-e.g. goethite

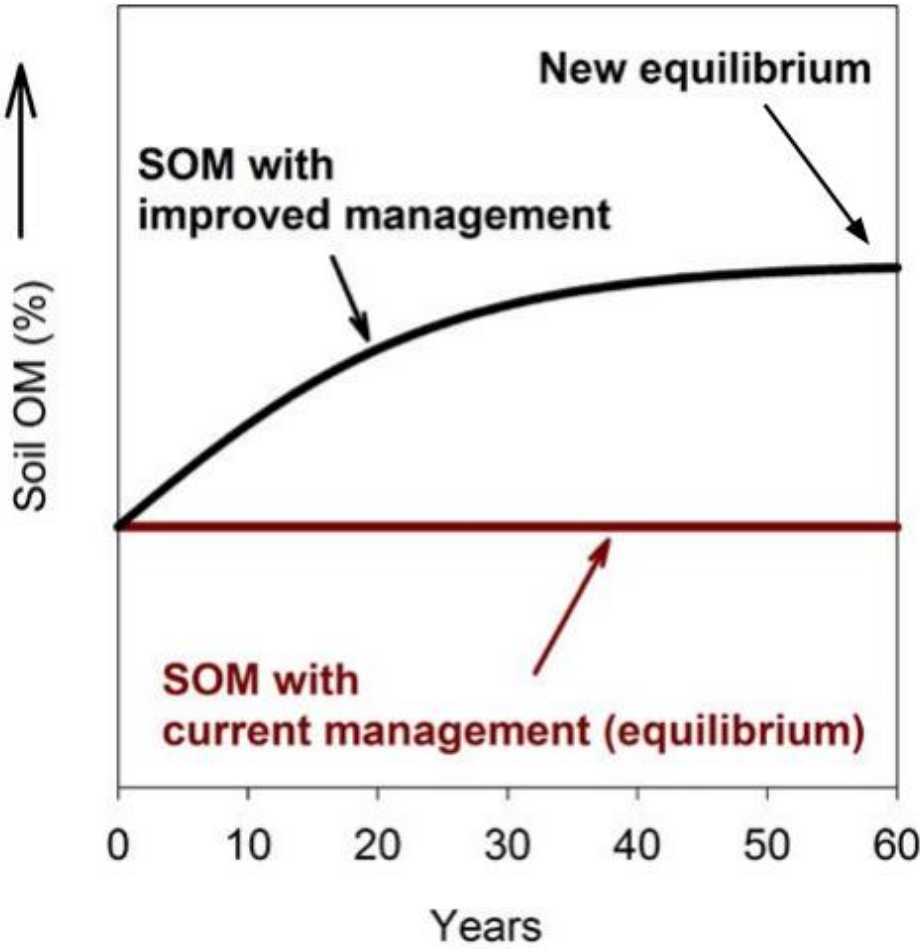
Jilling et al., 2018

Total soil organic matter vs Active carbon

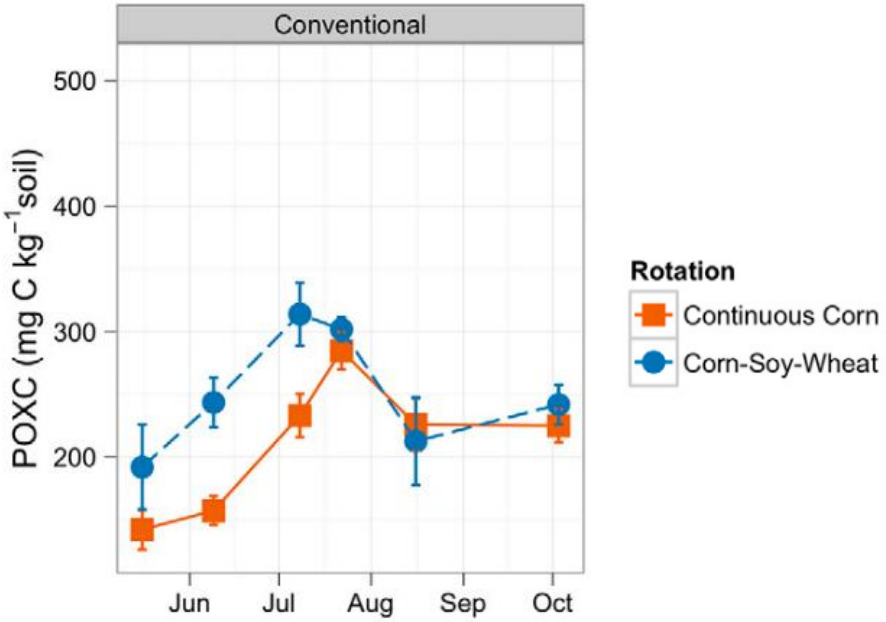


Sullivan, Moore, Brewer, 2019, OSU Extension

Total soil organic matter vs Active carbon



- **Active C:** The food that is available to microbes
- Faster to change
- More sensitive to management



Sullivan, Moore, Brewer, 2019, OSU Extension

Culman et al., 2013

Total soil organic matter vs Active carbon

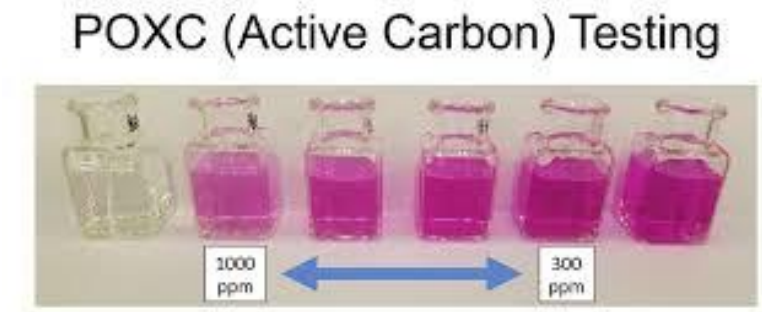


Image: AgVise

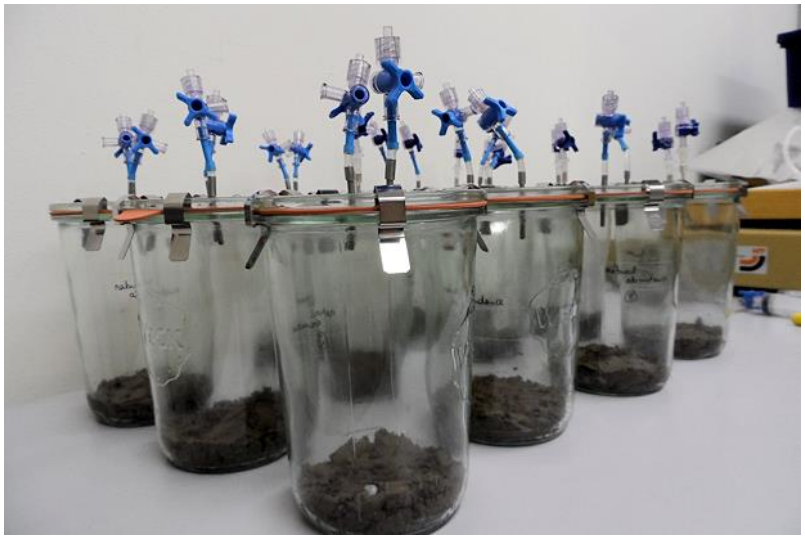
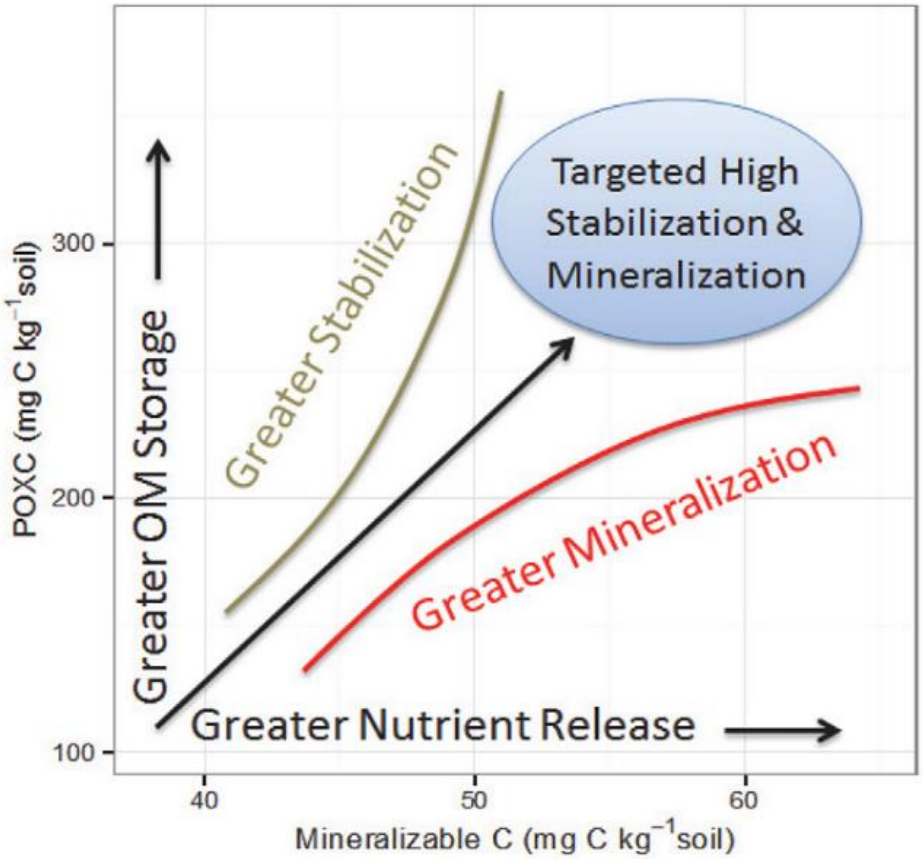
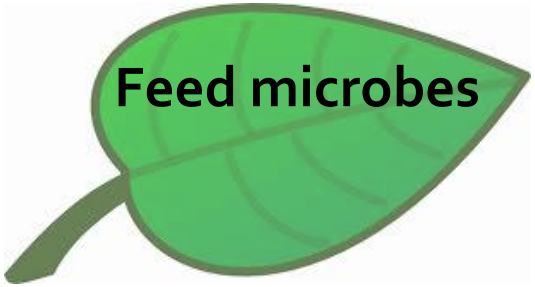


Image: Thunen-Institut/AK



Culman et al., 2016

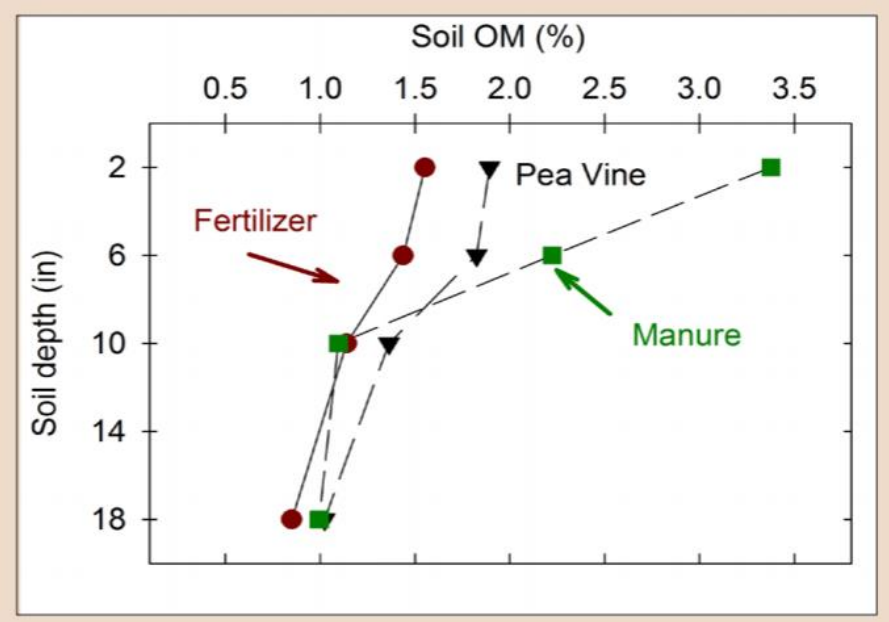
What can we do to manage soils for soil health?



- More **carbon** inputs to soil
  - Organic matter inputs
  - Cover crops
  - Intercropping
  - Crop residues
  - Living roots
  - Increase crop biomass

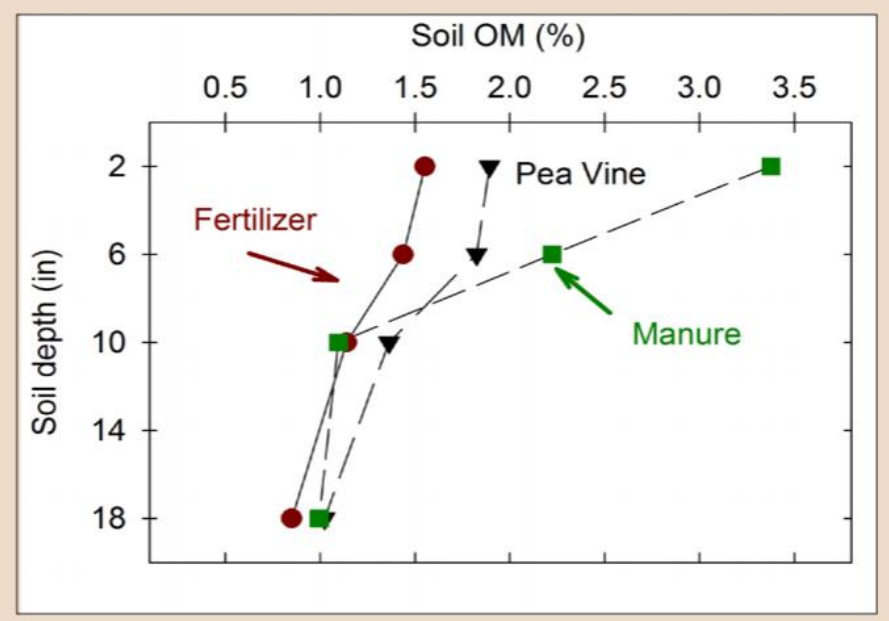
- Create conditions that favor **aggregate** formation
  - Reducing tillage
  - Timing of tillage
  - Weight of equipment

Examples



Published in Sullivan et al., 2019; Adapted from Ghimire et al., 2015

Examples



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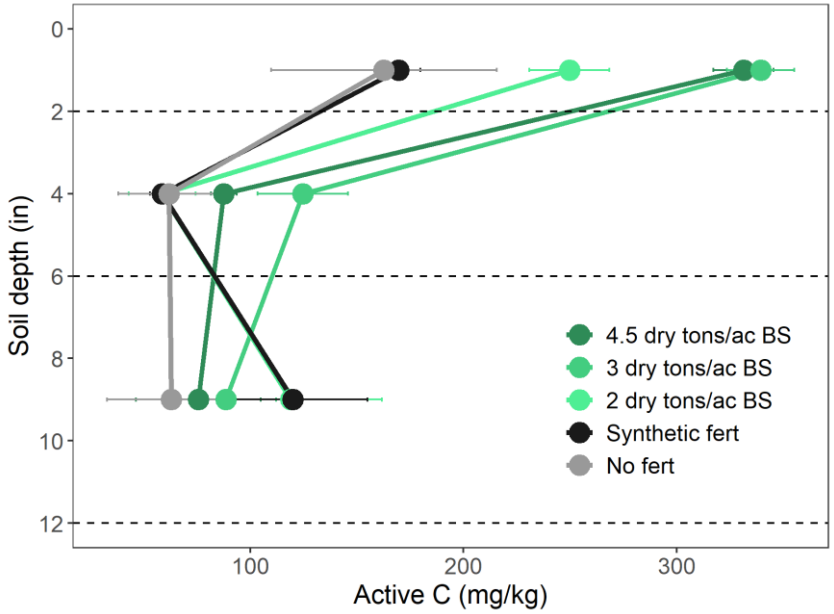
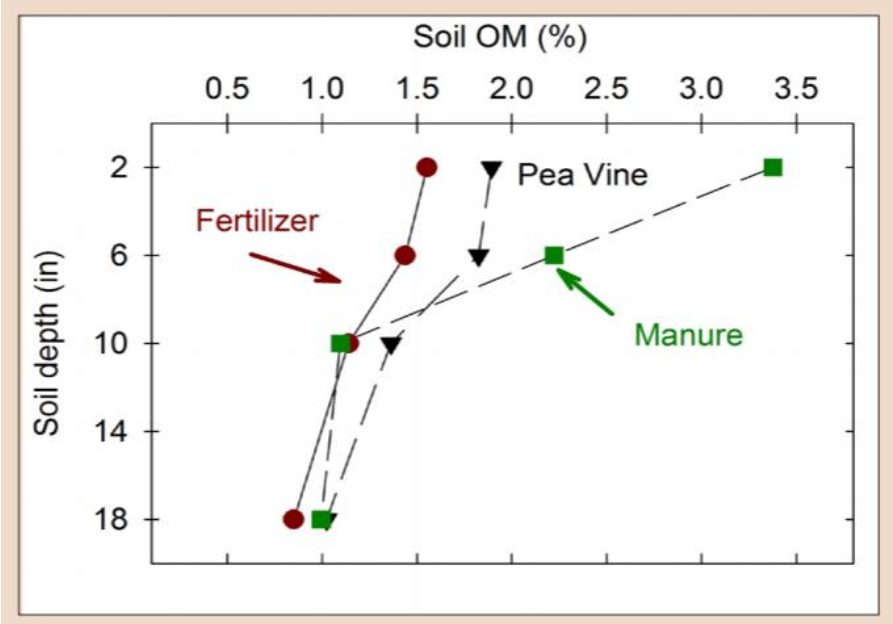


Griffin LaHue et al., unpublished data

Examples



Published in Sullivan et al., 2019; Adapted from Ghimire et al., 2015

Collins et al., 2016

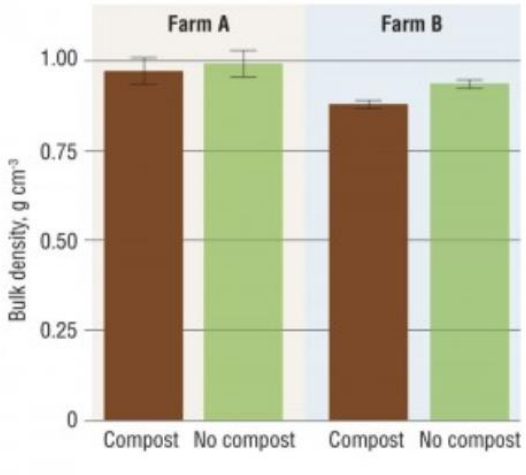
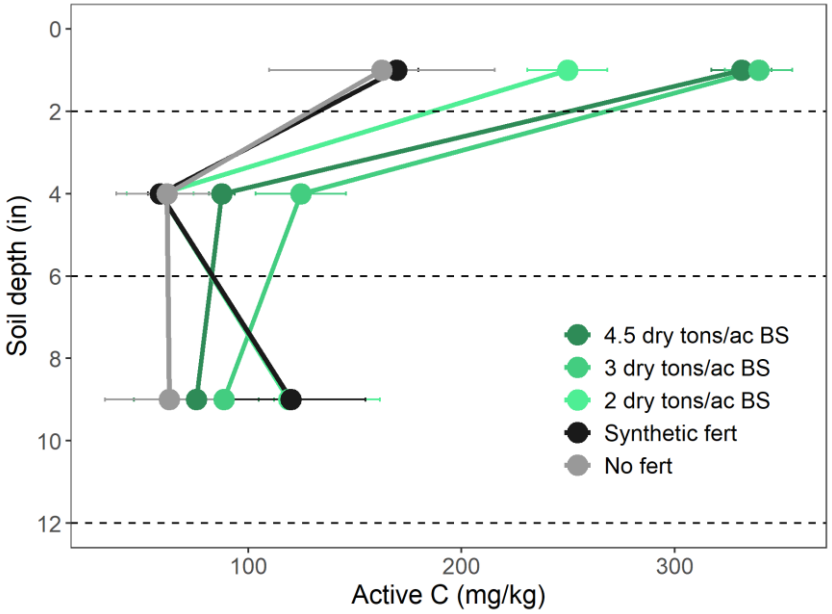


Figure 2. Bulk density with and without compost application, 2015



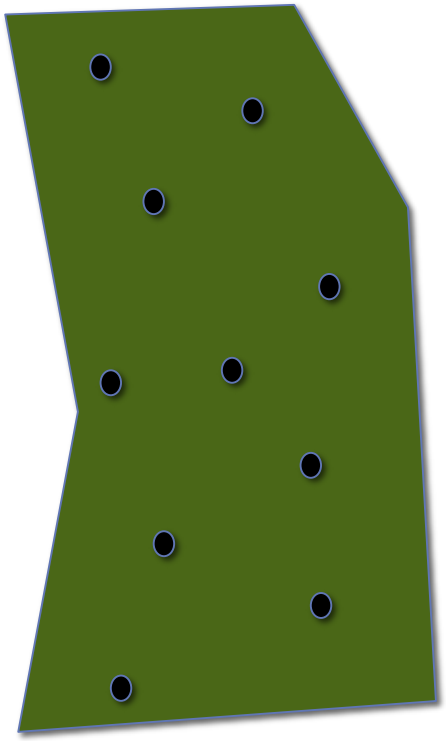
Griffin LaHue et al., unpublished data

Testing for soil health

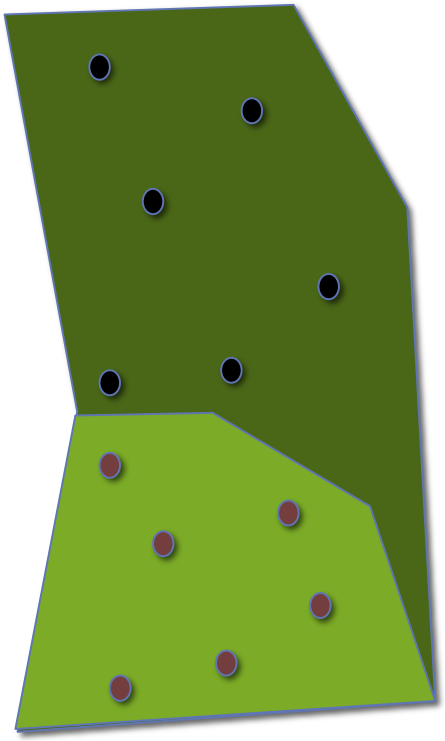
Group	Indicator
physical	Available Water Capacity
physical	Surface Hardness
physical	Subsurface Hardness
physical	Aggregate Stability
biological	Organic Matter
biological	ACE Soil Protein Index
biological	Soil Respiration
biological	Active Carbon
chemical	Soil pH
chemical	Extractable Phosphorus
chemical	Extractable Potassium
chemical	Minor Elements Mg: 1813.2 / Fe: 0.7 / Mn: 5.1 / Zn: 0.4

Solvita CO_2 Burst Test

How/when should I take samples?



Take ~10 samples from random locations and consolidate in a bucket.



Collect samples from problem areas or different management areas separately

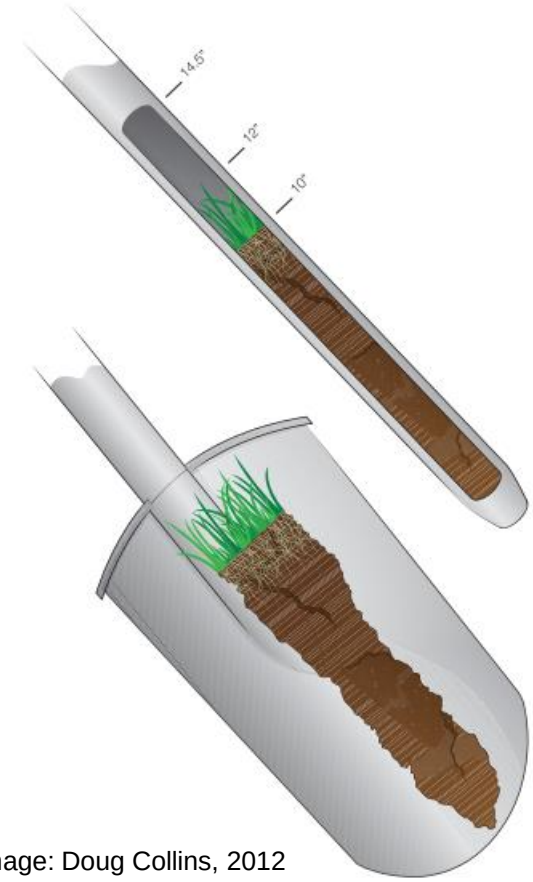
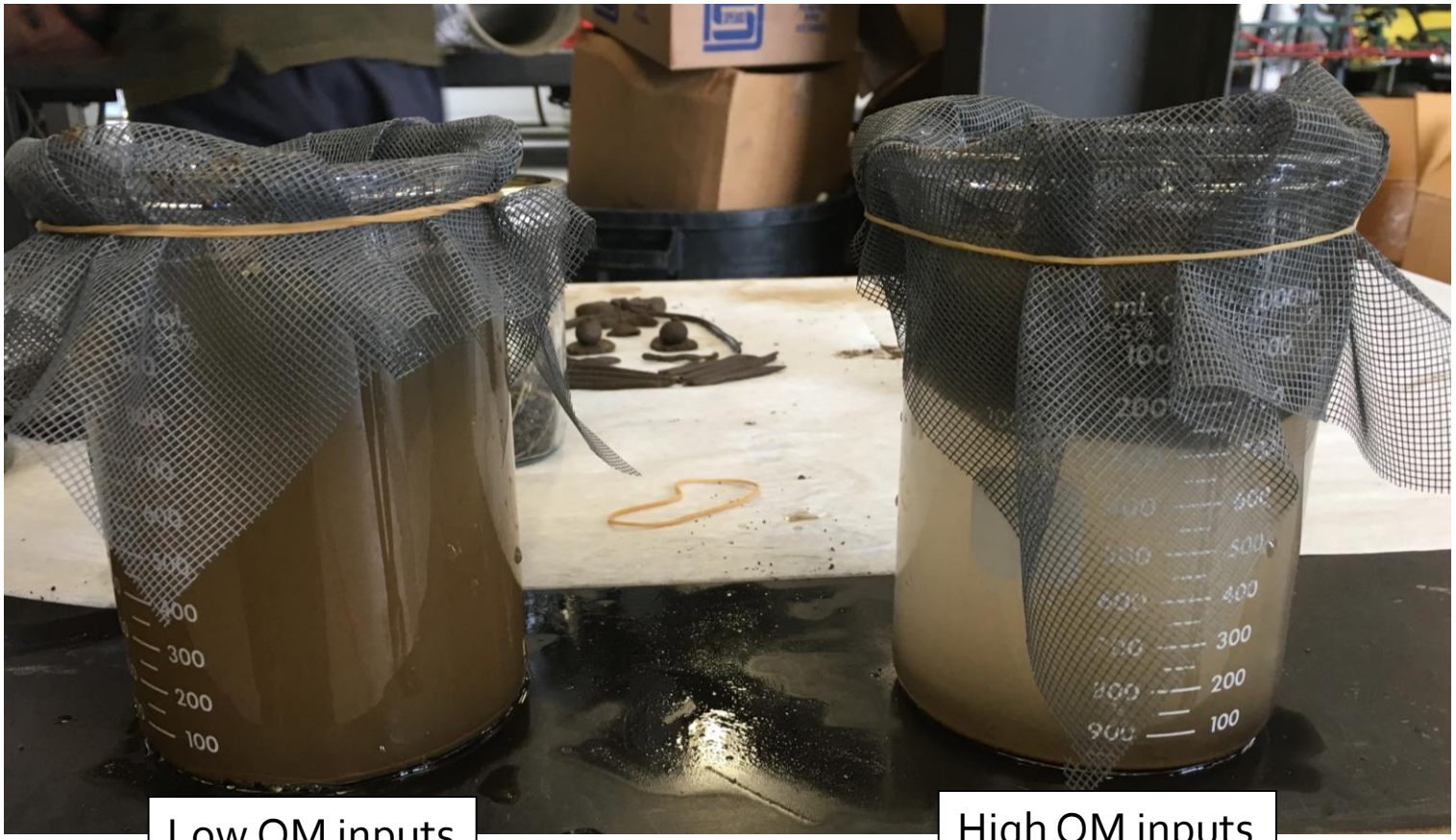


Image: Doug Collins, 2012

Using a long spade or a probe, take a sample to the depth of your plow layer or root zone (~6-10").

Visual measurements

Slake test for aggregate stability



Visual measurements

Test for microbial activity

Visual in-field measurements

SOIL—Questions refer primarily to the plow layer

Descriptive Properties	Score

1. EARTHWORMS[3]
- 0 Little sign of worm activity
- 2 Few worm holes or castings
- 4 Worm holes and castings numerous

2. EROSION[4]
- 0 Severe erosion, considerable topsoil moved, gullies for
- 2 Moderate erosion, signs of sheet and rill erosion, som topsoil blows
- 4 Little erosion evident, topsoil resists erosion by water wind

3. TILLAGE EASE[5]
- 0 Plow scours hard, soil never works down
- 2 Soil grabs plow, difficult to work, needs extra passes
- 4 Plow field in higher gear, soil flows, & falls apart, mell

4. SOIL STRUCTURE[7]
- 0 Soil is cloddy with big chunks, or dusty and powdery
- 2 Soil is lumpy or does not hold together
- 4 Soil is crumbly, granular

Descriptive Properties	Score

8. DRAINAGE[6]
- 0 Poor drainage, soil is often waterlogged or oversaturated
- 2 Soil drains slowly, slow to dry out
- 4 Soil drains at good rate for crops, water moves through

9. WATER RETENTION[14]
- 0 Soil dries out too fast, droughty
- 2 Soil is drought prone in dry weather
- 4 Soils holds moisture well, gives and takes water easily

10. DECOMPOSITION[16]
- 0 Residues and manures do not break down in soil
- 2 Slow rotting of residues and manures
- 4 Rapid rotting of residue and manures

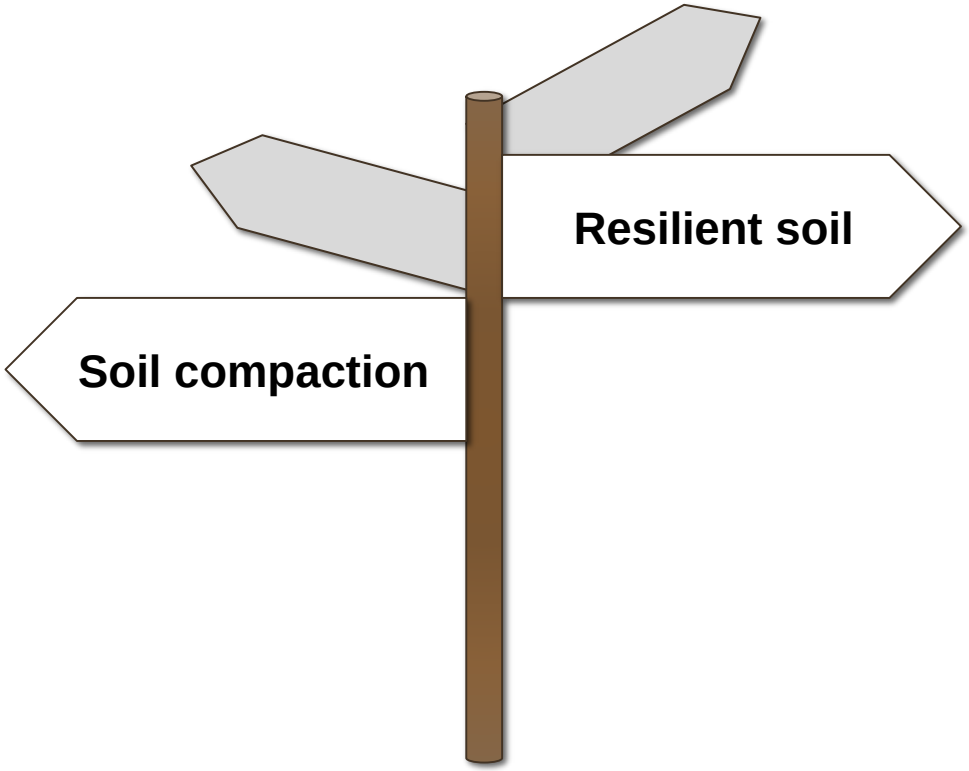
11. SOIL FERTILITY[20]
- 0 Poor fertility, nutrients do not move, potential is very low
- 2 Fertility not balanced, needs help
- 4 Fertility is balanced, nutrients available, potential is high

12. FEEL[21]
- 0 Soil is mucky, greasy, or sticky
- 2 Soil is smooth or grainy, compresses when squeezed
- 4 Soil is loose, fluffy, opens up after being squeezed

Reference values and benchmarks

Soil challenges → Soil processes → Soil services

We need to know where we started from, what the objective is, and where we are.



Take-home messages

What is a healthy soil?

- Resilient
- Regenerating
- Strong structure
- Living!

Challenges, processes, and services

- Start with the challenge you want to address and identify what processes/practices will fix it.

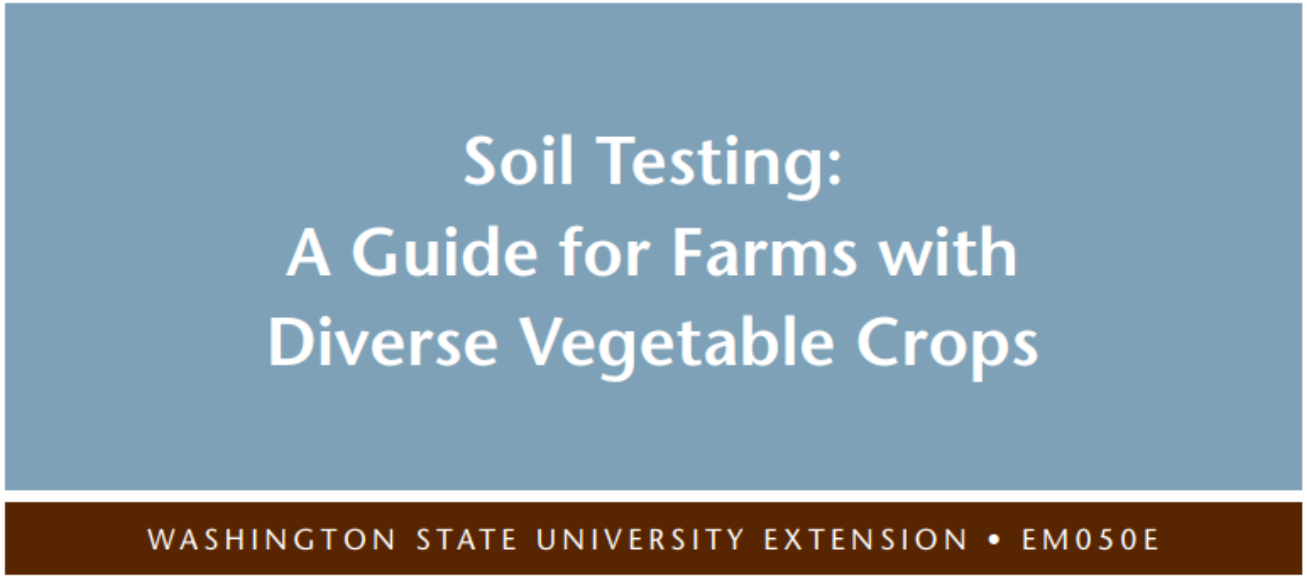
Example: Soil compaction & aggregation

- Promote soil aggregation by feeding microbes and reducing disturbance

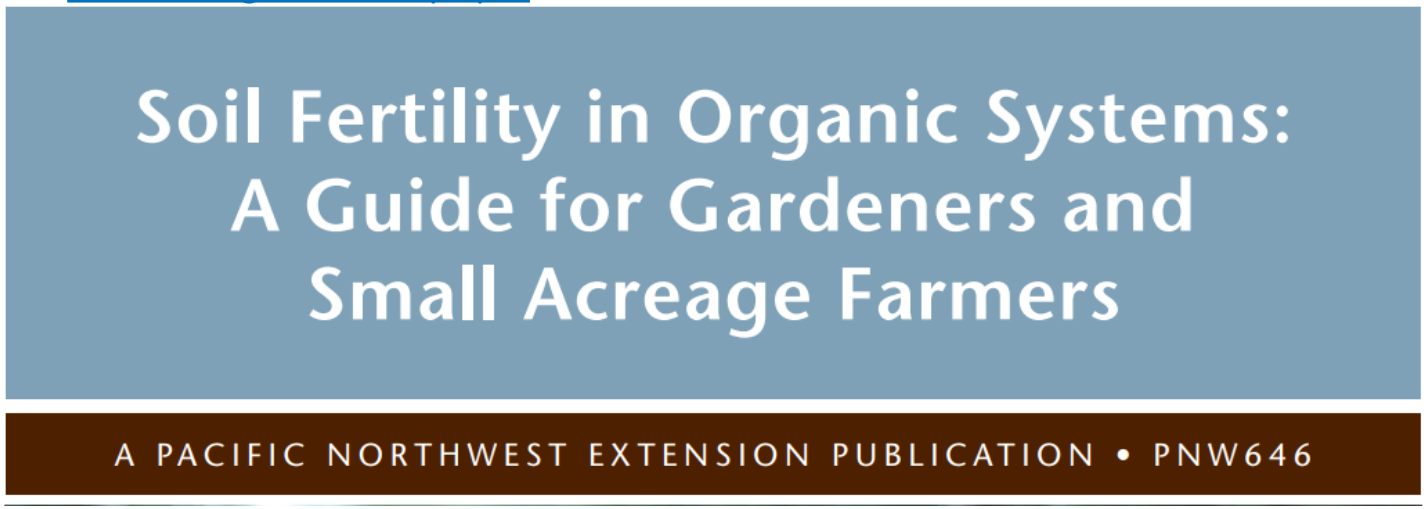
How do I measure soil health?

- DIY field tests & lab analyses
- Know where you started and what progress you're making

Online resources



https://s3.wp.wsu.edu/uploads/sites/2073/2014/09/Soil-Testing-for-Farms-with-Diverse-Vegetable-Crops.pdf



https://s3.wp.wsu.edu/uploads/sites/2074/2019/01/Soil-Fertility-in-Organic-Systems-1.pdf

Online resources

Cover Crops
for Home Gardens
West of the Cascades

WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS111E

OREGON STATE UNIVERSITY EXTENSION SERVICE

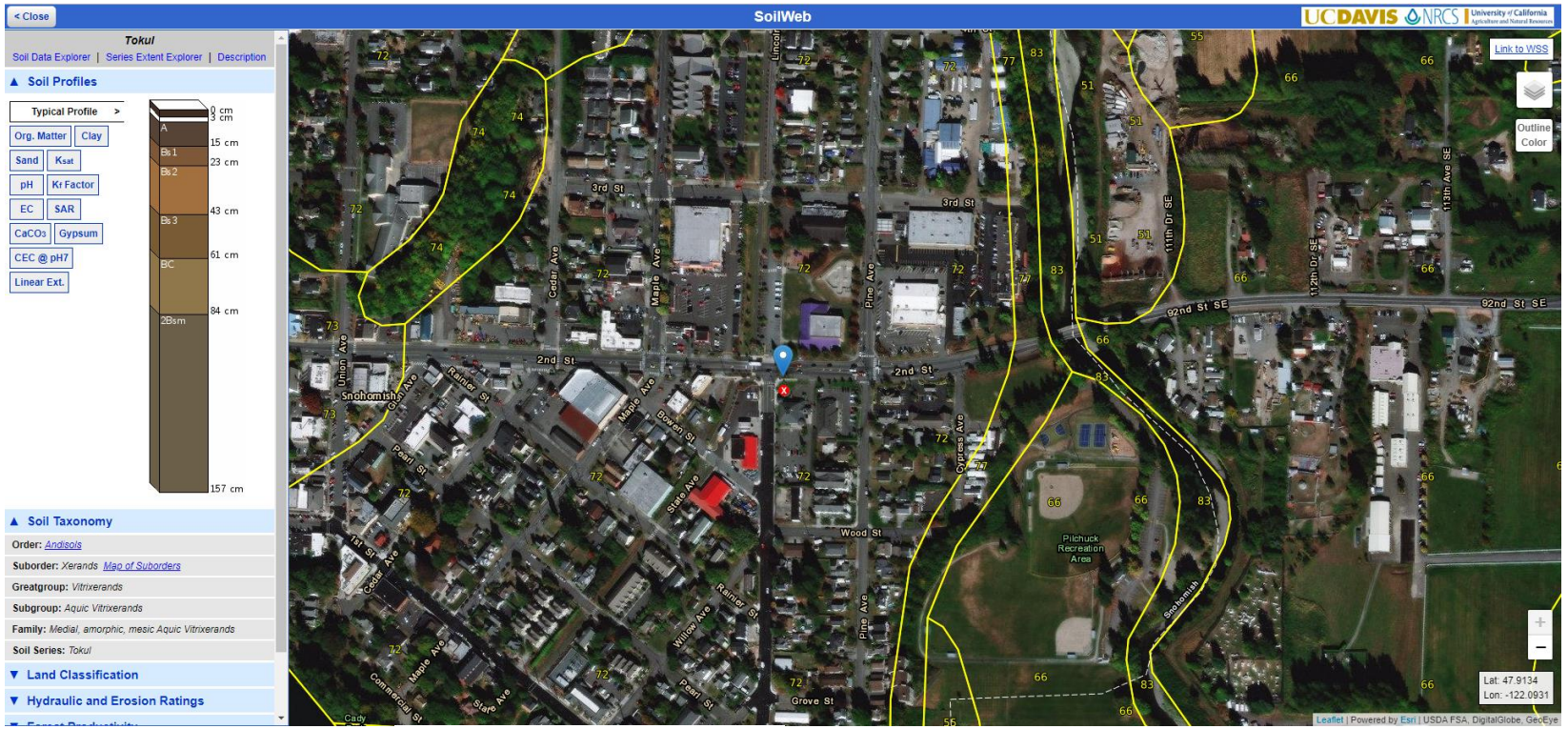
Soil organic matter as a soil health indicator: Sampling, testing, and interpretation

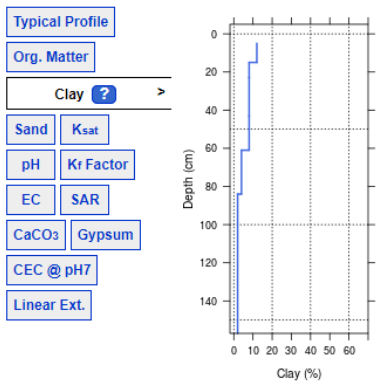
D.M. Sullivan, A.D. Moore, and L.J. Brewer

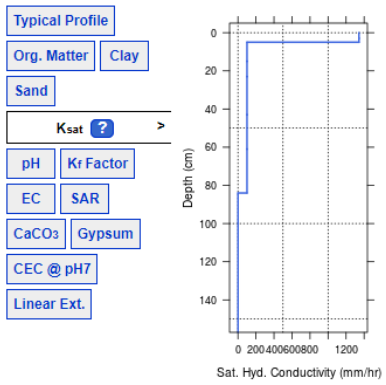
https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9251.pdf

Online resources: Learn about your soil

SoilWeb







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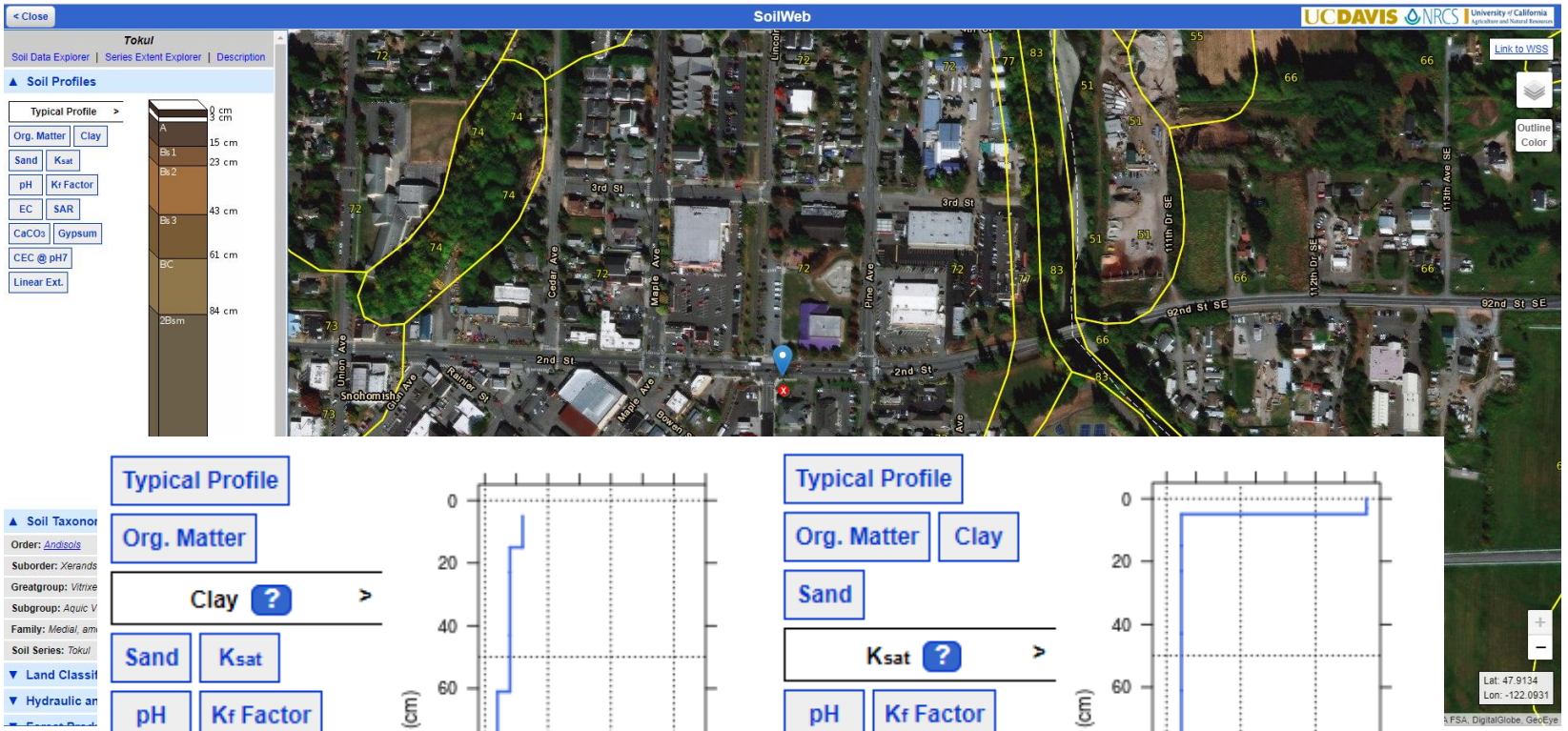
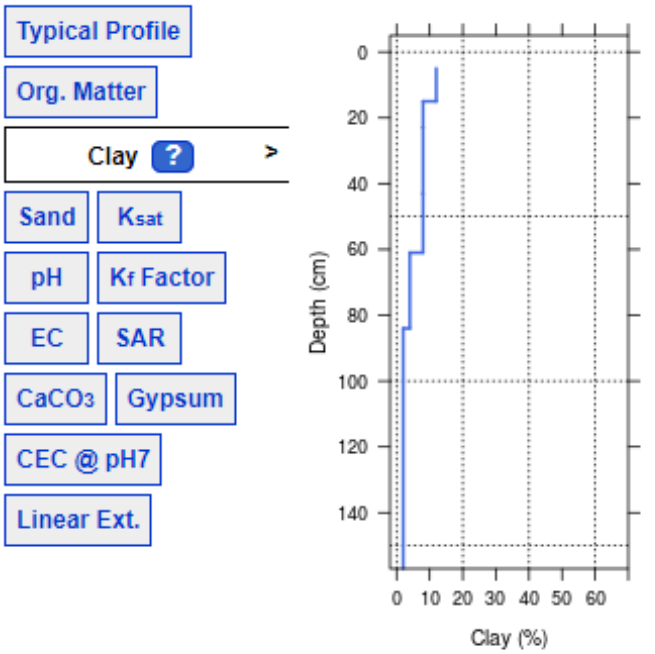
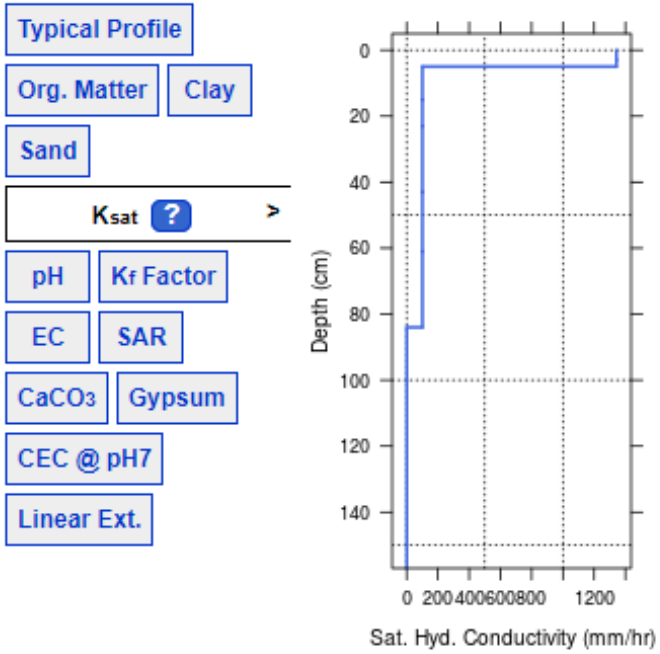




View Source Data



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Questions?