WASHINGTON STATE UNIVERSITY EXTENSION

Building Soils for Better Crops

2016 CONFERENCE

November 29th, Moses Lake, WA
Big Bend Community College, ATEC Building

8:30 a.m. – 9:00	***Check-in and On-site Registration***
9:00 – 9:05	**Welcome** Andy McGuire, WSU CSANR
9:05 – 9:55	**Nutrient Placement in Strip-till and No-till** Fabian Fernandez, University of Minnesota
9:55 – 10:45	**Emerging Soil amendments: Promises, Potential, and Pitfalls** Kristin Trippe, USDA-ARS, Corvallis OR
10:45 – 11:00	***Break***
11:00 – 11:50	**Humic Substances, Uses and Abuses** Mir M Seyedbagheri, University of Idaho (retired)
11:50 – Noon	***Discussion and questions***
Noon – 12:40	***Lunch***
12:40 – 1:20	**Practical Insights from the Current Views of Soil Organic Matter** Andy McGuire, WSU CSANR
1:20 – 2:10	**Soil Acidification, Liming on Western soils** Haiying Tao, WSU
2:10 – 2:25	***Break***
2:25 – 3:05	**Soil Health at NRCS** Jennifer Moore Kucera, NRCS Soil Health Division, West Regional Team Leader
3:05 –3:35	**Economics of Soil Building** Eric Williamson, Grower, George WA
3:35 – 4:15	**Results of Soil Improvement practices in Columbia Basin** David Granatstein, WSU CSANR
4:15 – 4:30	***Questions and wrap-up***

Moderators: David Granatstein and Andy McGuire

CCA credits: Soil & Water Management: 3, Nutrient Management: 1

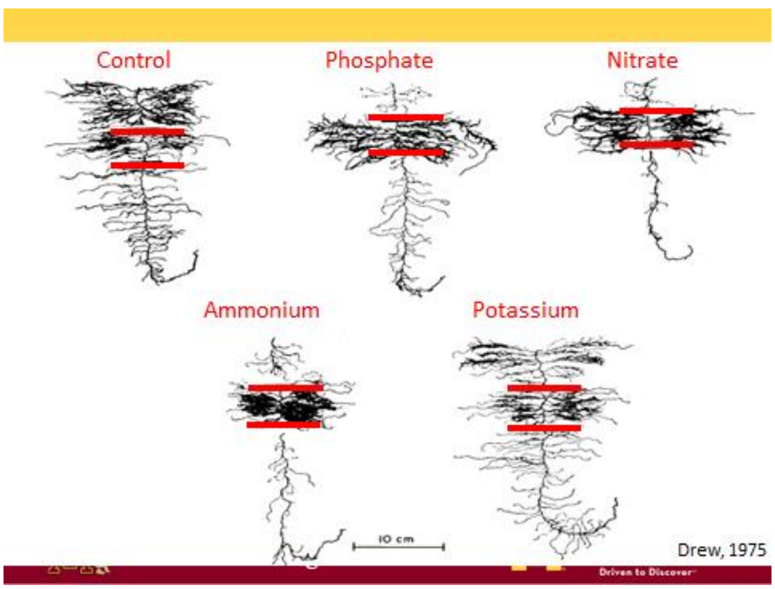
This conference supported with funds from:
The WSU Center for Sustaining Ag and Natural Resources BioAg program

Understanding Nutrient Placement in No-till and Strip-till

Fabián Fernández, University of Minnesota, St. Paul, MN

1) Understand three pathways of nutrient movement to roots
   a) Mass flow – nutrient moves with the water absorbed by the plant
   b) Diffusion – nutrient moves from higher to lower concentration in soil water
   c) Root interception – root grow to a nutrient location
2) Pathway importance differs by nutrient
   a) Nitrogen – 79% mass flow, 20% diffusion
   b) Phosphorus – 93% diffusion, 5% mass flow
   c) Potassium – 80% diffusion, 18% mass flow

1) Two key questions for nutrient placement: Where are the active roots? Where is the water?
   i) Root density in corn and soybean less impacted by nutrient addition and more impacted by soil depth
      (a) Most roots in top 4" of soil



1) More root density at surface 0-2" with no-till than strip-till
   i) Was 17,000 miles more roots/acre for no-till, but root development is an energy cost to the plant, so may be affecting yield
   ii) Strip-till appears more efficient for taking up P and K; more uptake between rows versus in row, thus banding in row is placing fertilizer in the wrong location (slide Efficiency)

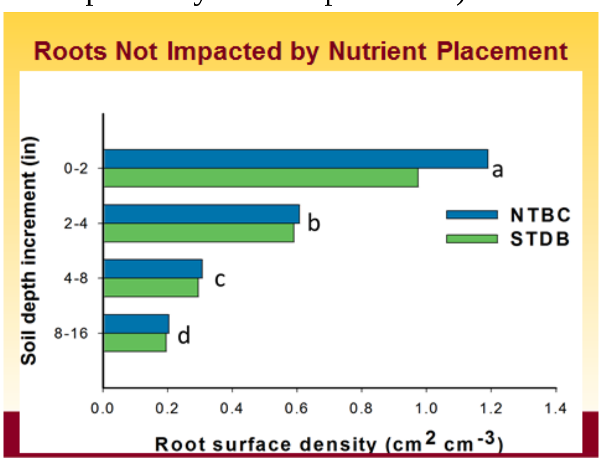
Efficiency

Tillage/fert. placement	RSD	Apparent uptake rate P	Apparent uptake rate K
	$cm^2\ cm^{-3}$	—$mg\ m^{-2}\ day^{-1}$—	
NTBC	0.47a	3.02b	26.58b
STDB	0.40b	3.74a	32.67a

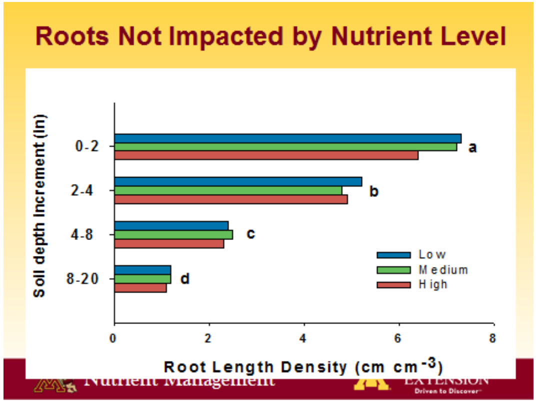
Nutrient Management — University of Minnesota Extension, Driven to Discover

1) Higher yields in strip-till led to higher soil organic matter than in no-till due to greater residue return
   a) New roots are most active in taking up water and nutrients
2) Diffusion distances can be short during growing season when soil is drying; thus nutrients can be “stranded” from the roots

1) Placement appears to have little effect on where roots take up nutrients (slide Roots not impacted by nutrient placement)

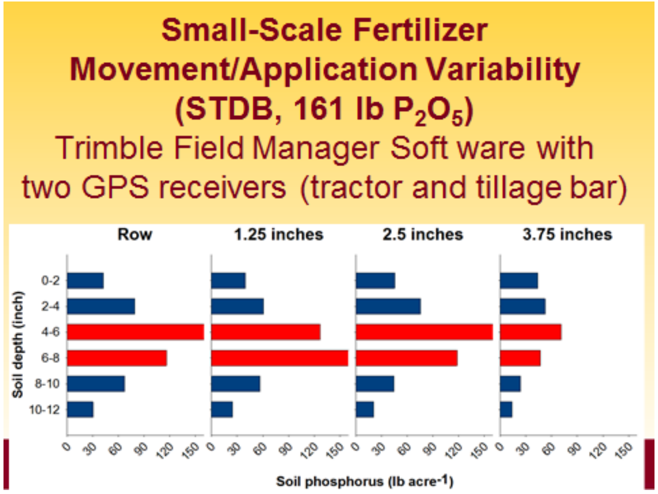


1) Greatest uptake of K was from between row position at 0-2” depth,
2) Root length density was highest in 0-2” depth of soil and unaffected by fertility level (slide roots not impacted by nutrient level)



1) Less water in-row with strip-till versus no-till, which can affect root uptake activity; may not be the case in irrigated systems where soil moisture is controlled

1) How to soil test in systems with zonation (vertical or horizontal)
   i) Limitations
      (a) Soil test value only indicates available P and K, not the fertilizer needed
      (b) Need field calibration of test results and fertilizer additions with yield to interpret results
      (c) Use fertilizer recommendations from your state – the process can differ from state to state
   ii) Taking a soil sample
      (a) Better to take fewer samples (to be separately analyzed) and more cores to be sampled (all mixed together)
      (b) Suggest 10-20 cores per composite sample in something like a 10' radius of a marked GPS point; mix well and remove amount to go to lab
      (c) In a banded system, go to 20-100 cores per composite
      (d) Also, may have to sample for stratification of nutrients
   iii) Soil sampling with precision planting and banding
      (a) Need to take at least 2 samples between crop rows for each sample taken in the crop row to deal with horizontal variability
      (b) Can be large nutrient variability at 1-2" distances horizontally and vertically (slide Small scale fertilizer…)



If spatial nutrient variability not accounted for high likelihood to either under- or over-fertilize rather than putting on the appropriate amount

Take home messages

- Don't take shortcuts when soil sampling; get a representative and useful sample
- Adequate P and K levels are more important than fertilizer placement
- Tillage - not P and K placement - had an important effect on corn and soybean yields; strip-till had a positive benefit on soil properties
- No evidence P and K rates can be reduced when banding fertilizer
- If banding P and K; for each soil sample taken in the crop row (where the band is), take 2 or 3 samples away towards the inter-row
- Recommends broadcast for P and K; unless the soil is a high fixer of P or K; or for avoiding possible P loss in surface runoff or erosion

Emerging Soil Amendments: Promise, Potentials, and Pitfalls

Kristin Trippe, USDA-ARS, Corvallis, OR

1) Three primary types of inputs into soil – fertilizer, amendments, mulch
   i) Have different purposes, impacts

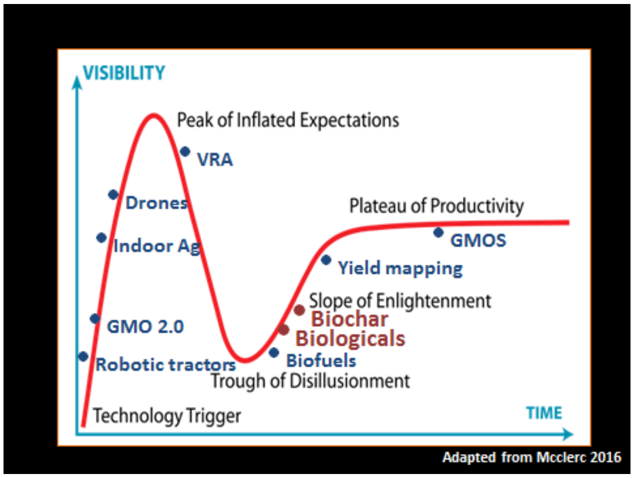
Definitions and Examples

Substrate	Nutrient content and availability	Benefit	Application rate
Fertilizer *	High	Nutrients	Low
Amendment	Low	Organic matter pH, water	High
Mulch	Negative	Weeds and water	High

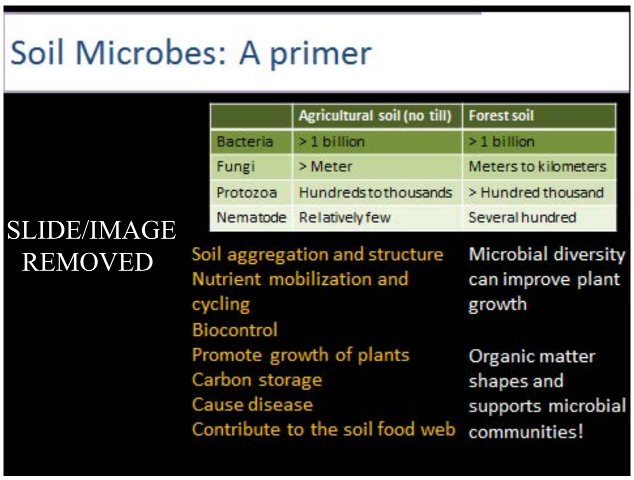
1) Soil amendments
   i) Generally are organic (carbon) based materials
   ii) Goal – provide a better environment for roots and improve nutrient uptake
   iii) Potential benefits
      (a) Physical
         1. Add organic carbon
         2. Improve nutrient release
         3. Improve soil structure
         4. Improve bulk density
         5. Improve water retention or permeability
      (b) Chemical
         1. Adjust pH (up or down)
         2. Improve water permeability
      (c) Biological – many unknowns
         1. Increase biological activity
         2. Extensive experience with manures, composts, crop residues

1) Current situation
   i) Many novel soils amendments and inoculants being offered to growers
   ii) Many are following the “Hype’ curve of new technology
      (a) Can quickly reach a ‘peak of inflated expectations’ to be followed by a ‘trough of disillusionment’
      (b) Need to continue innovating to move out of the trough to ‘plateau of productivity’ and more widespread adoption and success

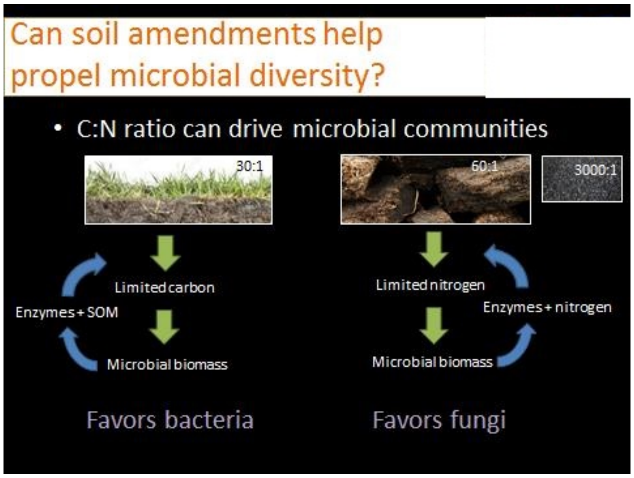
(c) Biochar, biological inoculants are just moving up from the bottom of the trough; extensive research on biochar is a factor



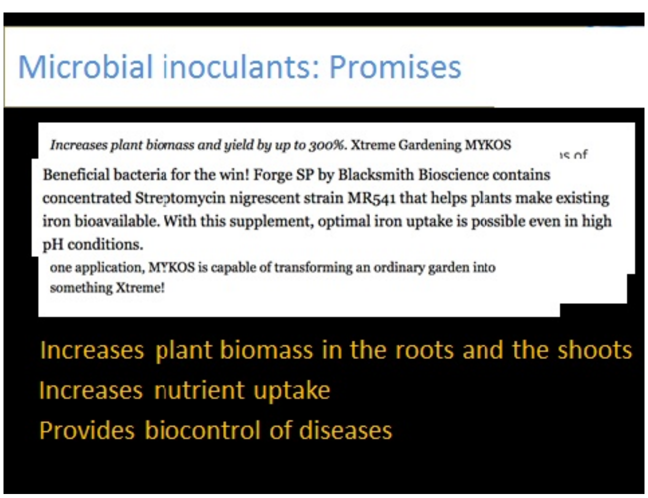
1) Soil microbes - a primer
   i) Lots of biology in the soil
   ii) Many important functions performed by soil microbes



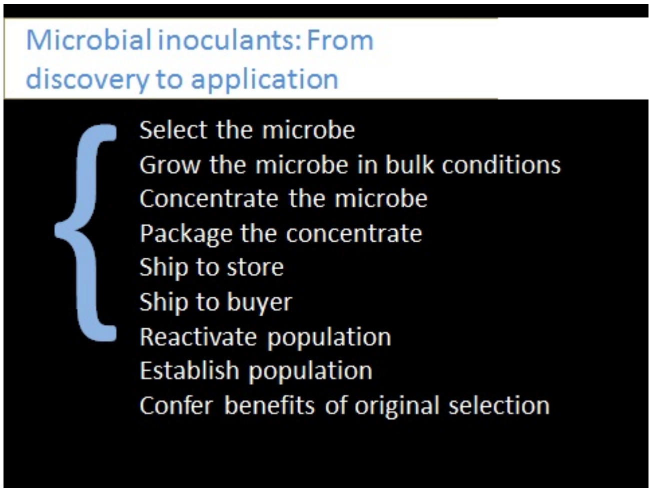
Amendments can shape soil biology



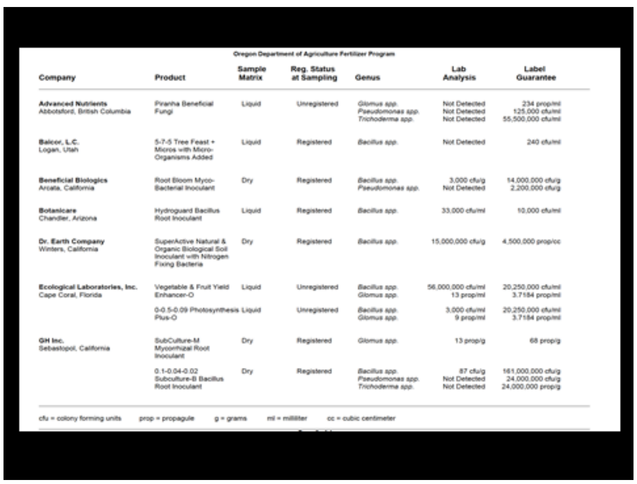
1) Microbial inoculants
   i) Many promises – what's on the label?
      (a) Regulation of label varies by state, so the information does as well
         1. WA – no requirement for laboratory validation of the microbial content
         2. OR – OR Dept. Agr. has strict requirements; publishes testing results (http://www.oregon.gov/ODA/programs/Pesticides/Fertilizers/Pages/ReportsPublicationsForms.aspx)
            i. Bacillus species – 75% of products with this claim failed
            ii. Pseudomonas species – 100% failed
            iii. Glomus species (mycorrhizae) – 80% failed
            iv. Trichoderma species (100% failed)
         3. Is there evidence for the claims on the label? Under what circumstances were any tests done, and do they apply to your situation?



1) There are many spots from production to application of microbial inoculants where things can be different than expected



Thus, having quality assurance test results is important



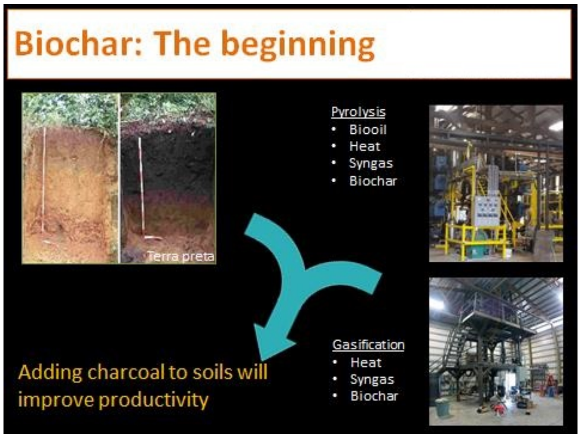
Oregon Department of Agriculture Fertilizer Program

Company	Product	Sample Matrix	Reg. Status at Sampling	Genus	Lab Analysis	Label Guarantee
Advanced Nutrients Abbotsford, British Columbia	Piranha Beneficial Fungi	Liquid	Unregistered	*Glomus spp.* *Pseudomonas spp.* *Trichoderma spp.*	Not Detected Not Detected Not Detected	234 prop/ml 125,000 cfu/ml 55,500,000 cfu/ml
Balcor, L.C. Logan, Utah	5-7-5 Tree Feast + Micros with Micro-Organisms Added	Liquid	Registered	*Bacillus spp.*	Not Detected	240 cfu/ml
Beneficial Biologics Arcata, California	Root Bloom Myco-Bacterial Inoculant	Dry	Registered	*Bacillus spp.* *Pseudomonas spp.*	3,000 cfu/g Not Detected	14,000,000 cfu/g 2,200,000 cfu/g
Botanicare Chandler, Arizona	Hydroguard Bacillus Root Inoculant	Liquid	Registered	*Bacillus spp.*	33,000 cfu/ml	10,000 cfu/ml
Dr. Earth Company Winters, California	SuperActive Natural & Organic Biological Soil Inoculant with Nitrogen Fixing Bacteria	Dry	Registered	*Bacillus spp.*	15,000,000 cfu/g	4,500,000 prop/cc
Ecological Laboratories, Inc. Cape Coral, Florida	Vegetable & Fruit Yield Enhancer-O	Liquid	Unregistered	*Bacillus spp.* *Glomus spp.*	56,000,000 cfu/ml 13 prop/ml	20,250,000 cfu/ml 3.7184 prop/ml
	0-0.5-0.09 Photosynthesis Plus-O	Liquid	Unregistered	*Bacillus spp.* *Glomus spp.*	3,000 cfu/ml 9 prop/ml	20,250,000 cfu/ml 3.7184 prop/ml
GH Inc. Sebastopol, California	SubCulture-M Mycorrhizal Root Inoculant	Dry	Registered	*Glomus spp.*	13 prop/g	68 prop/g
	0.1-0.04-0.02 Subculture-B Bacillus Root Inoculant	Dry	Registered	*Bacillus spp.* *Pseudomonas spp.* *Trichoderma spp.*	87 cfu/g Not Detected Not Detected	161,000,000 cfu/g 24,000,000 cfu/g 24,000,000 prop/g

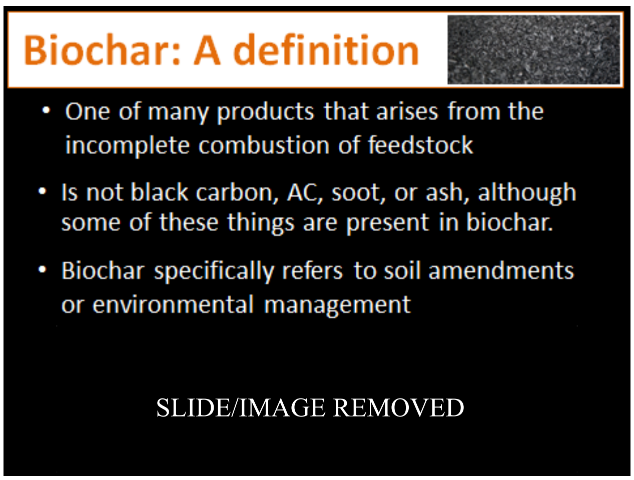
cfu = colony forming units prop = propagule g = grams ml = milliliter cc = cubic centimeter

1) Once you know the product contains what it is supposed to, then it is the time to look at its efficacy for its purported benefits
2) Remember that soil organic matter shapes and supports microbial communities
3) Other practices such as residue management and tillage can also have a big effect

1) Biochar – another emerging soil amendment
   i) What is biochar?
      (a) Biochar is a kind of charcoal
      (b) Was discovered in Amazonian soils where it changed the soil from very low crop productivity to highly productive (see photo below left); these soils are called Amazonian dark earths, or Terra Preta

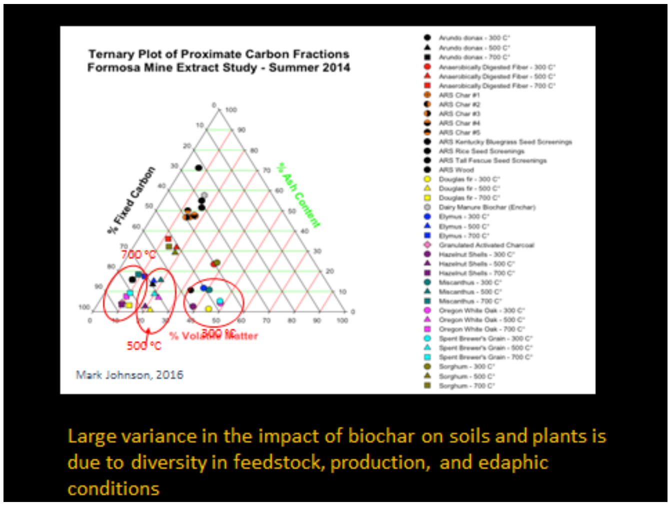


Made from heating biomass feedstocks in the absence of oxygen; combustion does not occur; this process can be pyrolysis, gasification



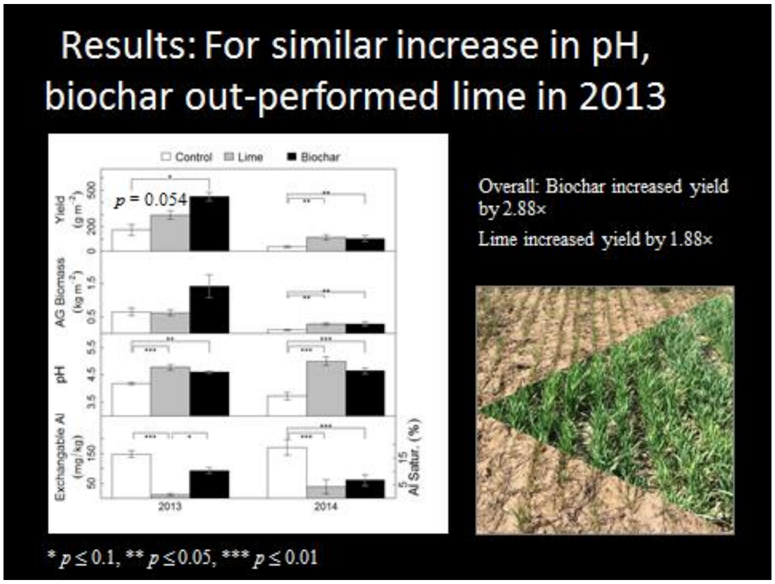
1) What does it do? Many examples from research studies
   a) Builds healthy soil
   b) Sequesters carbon
   c) Reduced acidity
   d) Increases soil water holding capacity
   e) Retains nutrients
   f) Increases soil microbial abundance
   g) Makes plants more resistant to disease

1) Results have been highly variable and inconsistent
   i) Biochar properties vary with feedstock, production process, and then interact with different soil types and climates

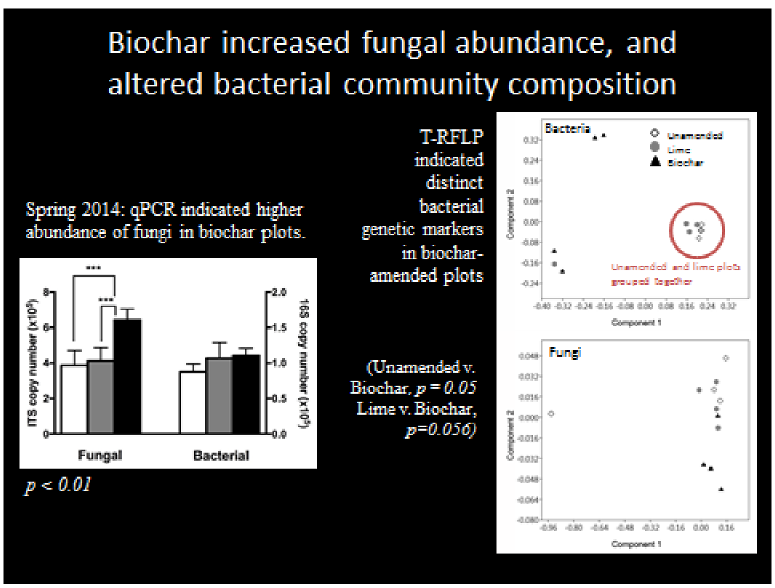


1) Biochar case study in eastern WA – few examples of use on larger commercial farms
    i) Gady family built a gasifier system to process grass seed cleaning waste

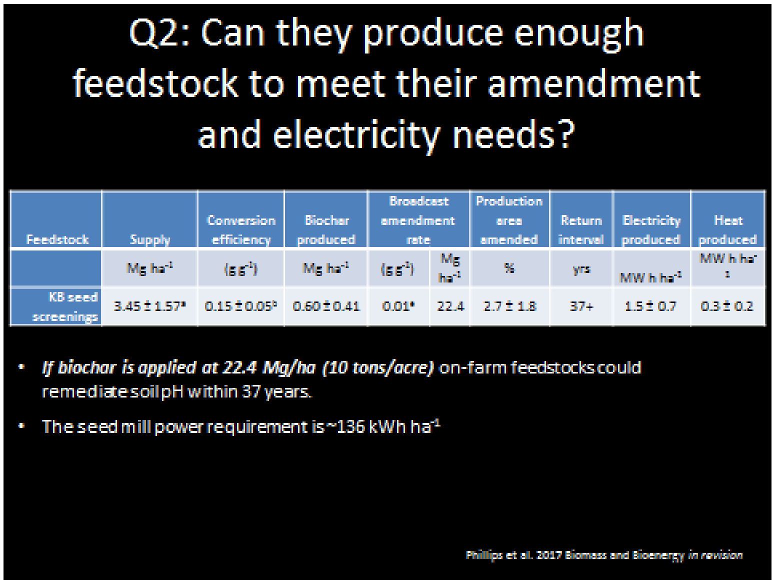
1) Biochar from the process was used on the fields. Interest in its role as a liming agent. Soil pH dropping significantly in this region from N fertilizer use.
2) Research questions: *Is on-farm biochar production feasible for a large-scale farm? Is the Gady's biochar a good match for their soil needs? (does it increase pH, increase water holding capacity, microbial populations, soil fertility, and yield?) Can they produce enough feedstock to meet their amendment and electricity needs?*
    i) Winter wheat field trials – Goal to increase pH from 4.5 to 5.5, 0-10 cm soil depth
        (a) Wheat yield with biochar did better than with lime, or control in 2013



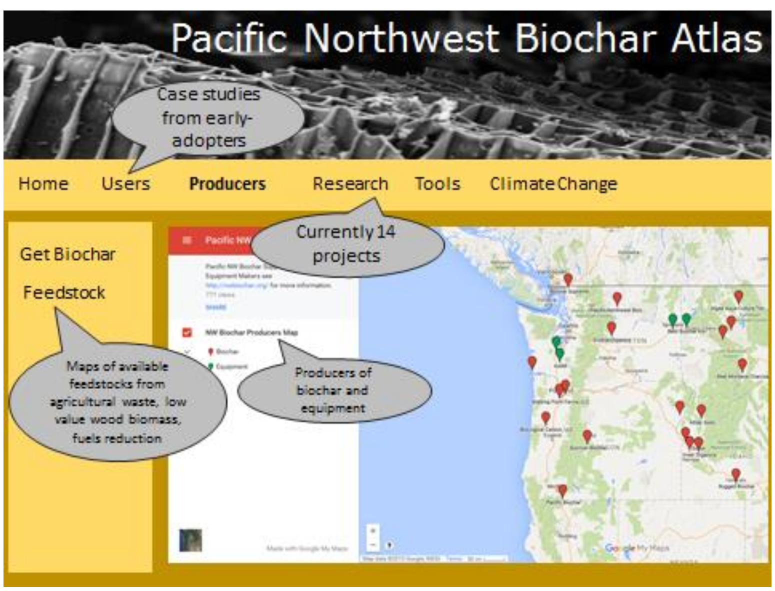
1) Benefits of biochar were less evident in 2014; conditions were drier overall
2) Biochar increased soil P and K; probably no yield benefit since levels were already high
3) Biochar did immobilize some N
4) Biochar increased fungal abundance and altered bacterial community

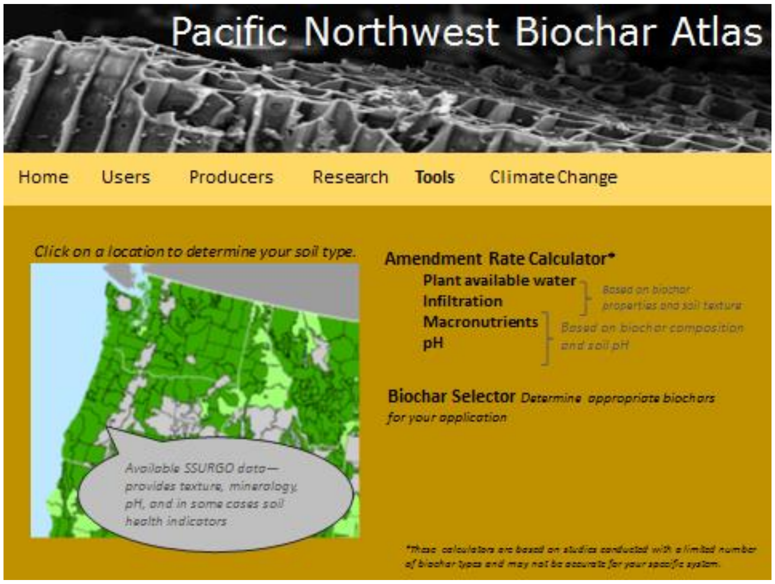


1) Answers to research questions:
   i) Biochar is a good fit for their soils; saw a yield response
   ii) Biochar production would more than meet farm needs for electricity and heat
   iii) If biochar applied at 10 tons/ac, can only cover 2-3% of acres each year; would take 37 yr to return to the same field; is this often enough to control pH?



1) Project conclusions:
   i) The Gady Farm is an example of a large that is producing and using biochar produced from grass seed residuals.
   ii) Farm-scale production is physically feasible, but not agronomically feasible over short time frames.
   iii) Nevertheless, business as usual is not sustainable and changes in farming practices will eventually be required.
   iv) If biochar benefits are persistent, the amendment could be economically feasible over longer (40+ year) timeframes.
   v) Feasibility is limited by availability of feedstock
2) Other tools: PNW biochar atlas – online map of biochar research; online amendment calculator linked to soils database





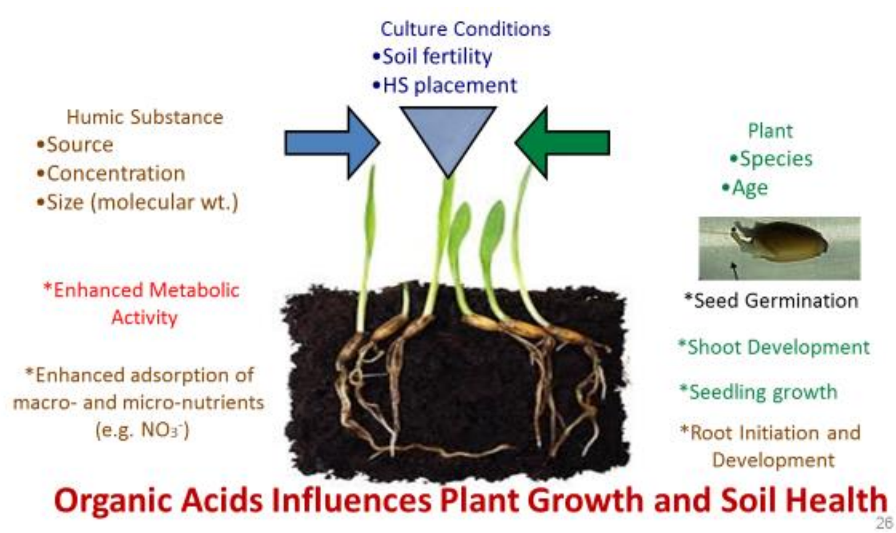
For more information, contact Kristin.Trippe@ARS.USDA.GOV, Tel. 541-738-4180

Humic Substances (HS), Uses and Abuses

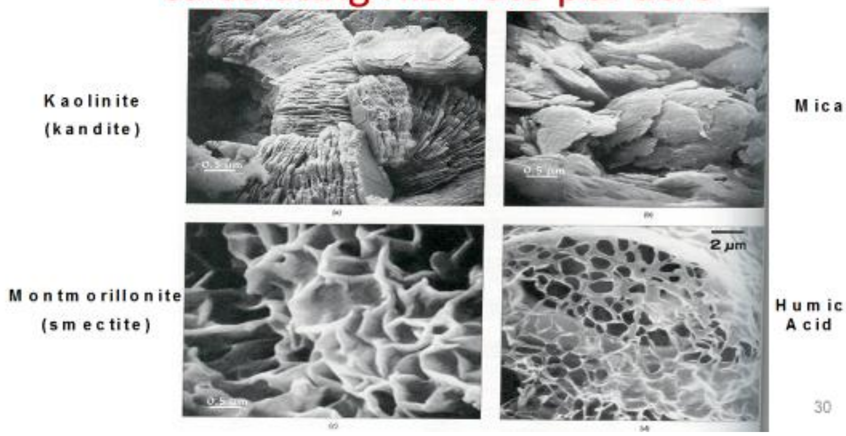
Mir M Seyedbagheri, University of Idaho (retired)

1. *Many factors lead us to this conclusion:* ***We must enhance soil health and its sustainability.***
2. *Historical background*
    a. *Leonardite, North Dakota has the biggest mine*
    b. *How it is processed makes a significant difference*
3. *Raw humate*
    a. Ineffective; unprocessed ore
    b. Low solubility
4. Humate processed through wet chemistry
    a. Effective
    b. Higher solubility
5. Humic Acids are "super-mixtures."
    a. *We do not know the exact molecular structure of humic substances*
        i. *So, testing of varying materials is required*
6. *How do they work?*
    a. *Functional groups (*Carboxyl, Phenol, Hydroxyl, Ketone, Ester, Ether, Amine) increase
        i. CEC
        ii. Buffering
        iii. Chelation
        iv. Complexation
7. Effects in physical properties
    a. Humates increase micro-pores
        i. *Roots*
        ii. *Water*
        iii. *Nutrient uptake*
    b. *Macropores*
        i. *Oxygen*

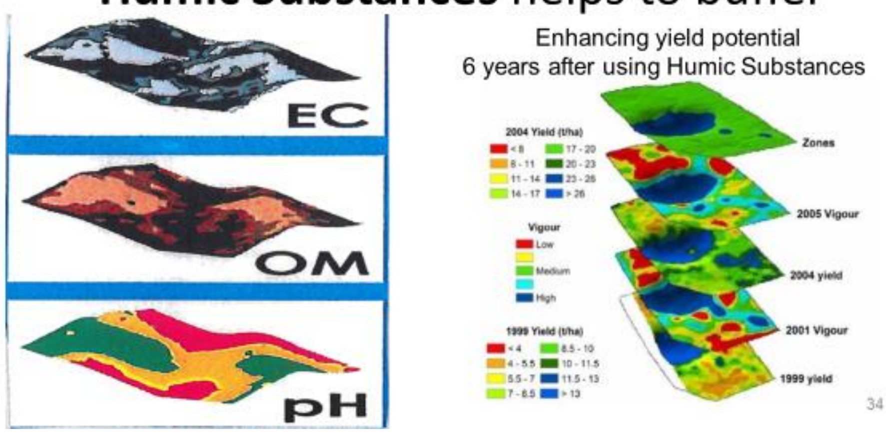
8. *Five R's of Nutrient Stewardship*
    a. *Right fertilizer*
    b. *Right rate*
    c. *Right time*
    d. *Right place*
    e. *Right humic, fluvic, or humin chemistry*
9. *Different chemistry for different purposes*
    a. *Humic*
        i. *Soil conditioning*
    b. *Fulvic*
        i. *Foliar and side-dressing*
    c. *Humin*
        i. *New research, not yet determined*



Understanding Soil Mineralogy is a must for calculating H.S. rate per acre

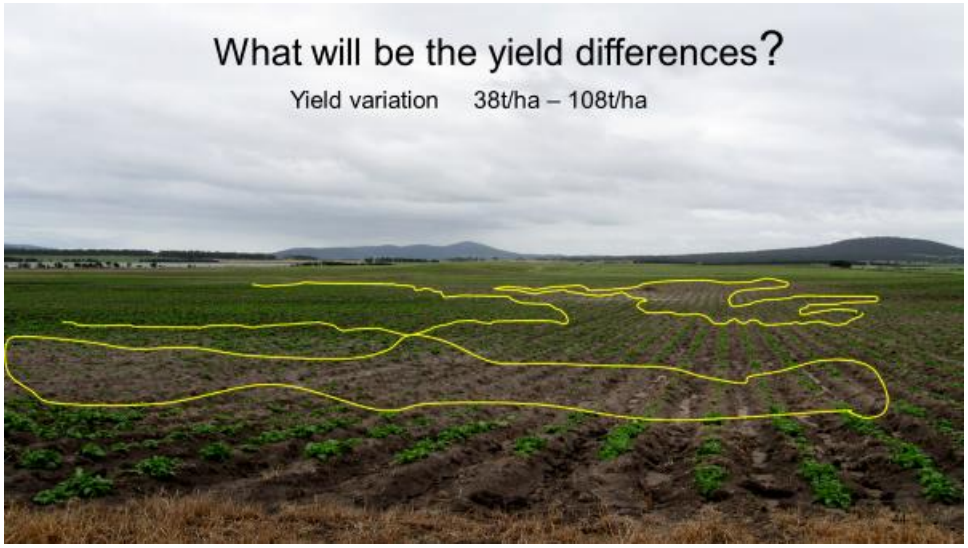


Variations in soil fertility & how **Humic Substances** helps to buffer

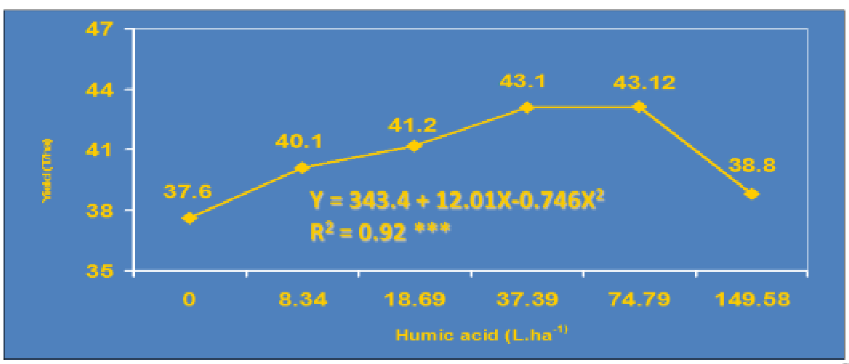


Influence of H.S. on P Availability

10. *What is the end effect on crop yield?*



Effects of Humic Acid Rate on Potato Yield at Three Sites



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2014 Field Potato Research

- Variety: Norkotah
- Soil Texture: Sandy Loam
- Ph 7.9
- Organic matter 1.4%
- Plot design: randomized plots
- Four replications of each treatment:

1. Control: farmers usual fertility application
2. 1X = 37.39 Liters/ha
3. 2X = 74.78 Liters/ha
4. 3X = 112.17 Liters/ha

Hand-harvested and graded on Aug. 5, 2014

51

Effect of H.S. on Plant Growth

Corn at 6-8th vegetative leaf stage

61

Our field test plots showed H.S. increased yield up to 30%

62

11. Research findings on the effects of HS on soil and plant metabolism

a. Solubilization of Micro (e.g. Fe, Zn, Mn) and
b. Some Macronutrients (e.g. K, Ca, P)
c. Buffers salts, reducing burning
d. Forms a bond with fertilizer preventing "Tie-up"
e. Increase crop production by 10-40%
f. Enhance plant nutrient translocation
g. Accelerate the ripening period 5-10 days
h. Enhance soil & plant health
i. Increase water sequestration by 11%
j. Decrease the content of nitrates and other harmful substances in fruit & improves nutritional quality
k. Increased plant's resistance to disease, frost damage, and drought

Practical Insights from Current Views of Soil Organic Matter

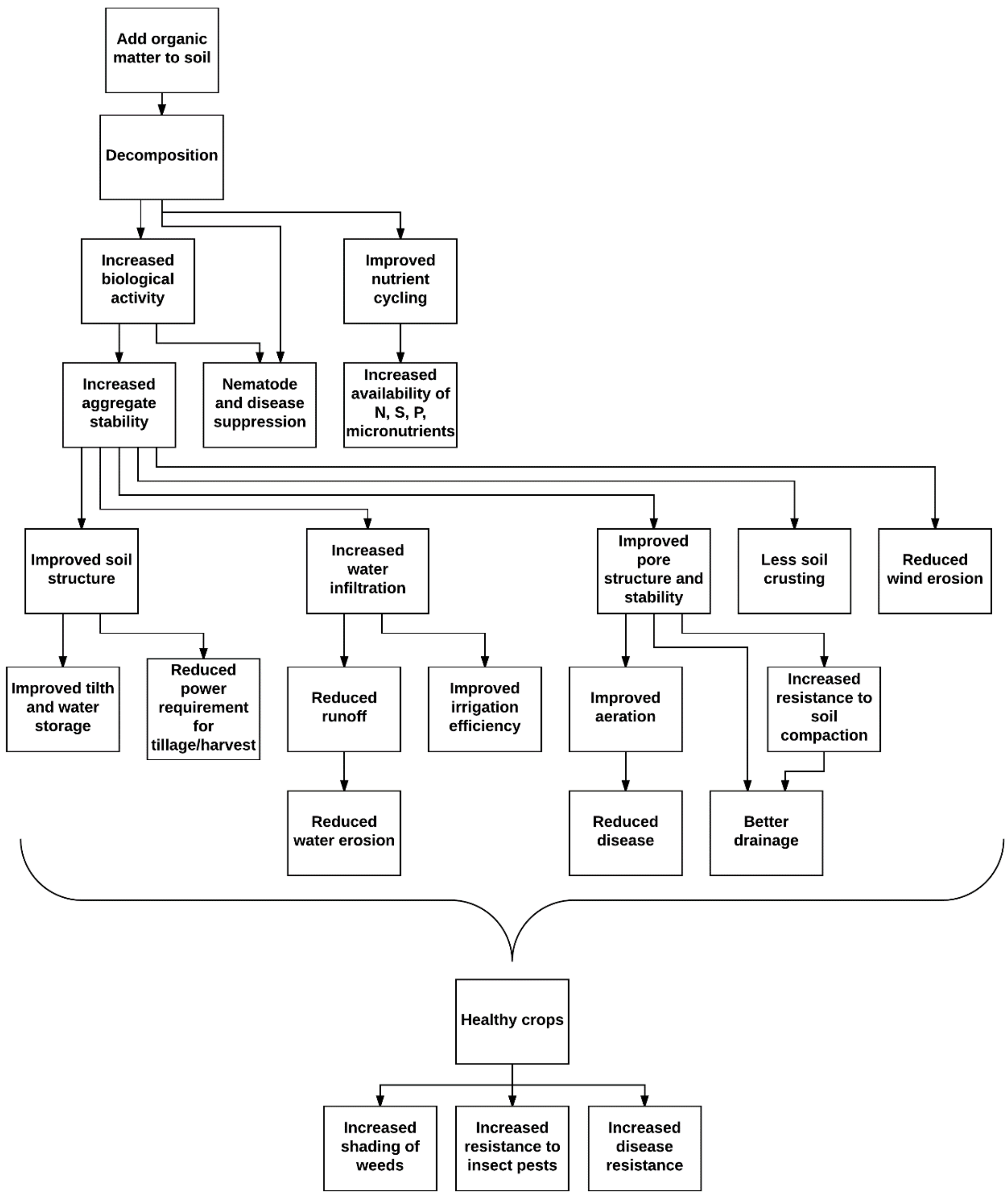
SOIL ORGANIC MATTER IS A COMPLEX TOPIC, but researchers are getting a better idea of what happens when organic materials are added to the soil. This handout covers their latest views, important factors, and what it all means for us here in the Columbia Basin of Washington.

Castellano, M. J., Mueller, K. E., Olk, D. C., Sawyer, J. E., & Six, J. (2015). Integrating plant litter quality, soil organic matter stabilization, and the carbon saturation concept. Global Change Biology, 21(9), 3200–3209. https://doi.org/10.1111/gcb.12982

Grandy, A. S., & Neff, J. C. (2008). Molecular C dynamics downstream: The biochemical decomposition sequence and its impact on soil organic matter structure and function. Science of The Total Environment, 404(2–3), 297–307. https://doi.org/10.1016/j.scitotenv.2007.11.013

The cascade of benefits from increased soil organic matter

The first thing to remember is that building soils is essentially a matter of building soil organic matter levels, because soil organic matter (SOM) affects nearly all aspects of soil quality. The cascade of benefits from increased soil organic matter:



WHY DO YOU NEED to know more than this? First, because your soil texture affects how organic matter is stabilized. In the Columbia Basin, the difference between sands and those soils with more silt and clay is important. Second, this tells us why the *quantity* of amendments matters. It also shows us how the *quality* of amendments can matter, for example manure vs. crop residues vs. a green manure crop. Finally, it shows why soil management decisions are important.

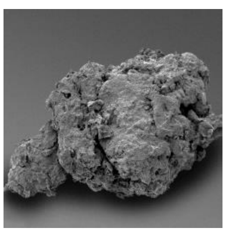
Sand-sized, particulate organic matter, or POM

PLANTS CAPTURE SUNLIGHT and store it in their leaves, stems and roots, known as their "biomass". When the plant dies, this biomass begins to decompose, faster in warm wet conditions such as an irrigated soil in the summer, slower in cold or dry conditions.

In the soil, many organisms are involved in decomposition, earthworms, mites, all the way down to bacteria and fungi. Decomposition starts with breaking up large pieces of biomass into smaller pieces. When these pieces get to be about the size of sand particles, they begin to produce some of the effects that we attribute to soil organic matter. The composition of these pieces, however, still resembles the plants they came from. Researchers call this particulate organic matter or POM. POM can either be naked or can be protected within a soil aggregate. Being exposed to everything in the soil, naked POM decomposes at twice the rate of POM in aggregates.

Size, mm (•)	**Compared to sand, silt, clay**	**Ave. turnover time, yrs.**
>2	Sand sized and larger	0.5
0.2-2	Coarse sand	3
0.05-0.2	Fine sand	18
<0.05	Silt and clay sized, microscopic	63+

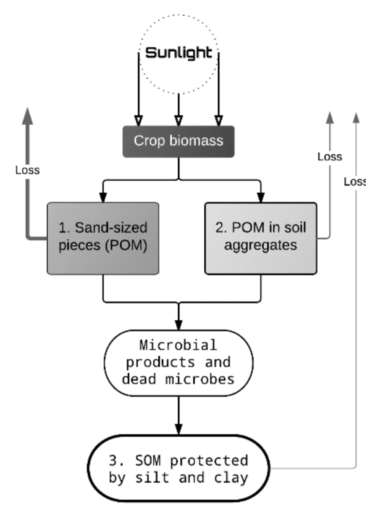
From Balesdent J. (1996). The significance of organic separates to carbon dynamics and its modeling in some cultivated soils. Eur J Soil Sci 47:485–93.



Soil aggregate: crumbs of sand, silt and clay particles, and POM held together by fungal hyphae and microbe produced "glues."

Organic matter bonded to silt and clay particles

AGGREGATES BREAK DOWN AND REFORM, allowing decomposition of the POM within them. Along with the naked POM, decomposition eventually produces very small particles that no longer resemble the plant material they came from. Microbes of all types contribute to this process producing waxes, lipids and proteins, all of which are organic matter. When they die, microbe bodies add large complex, stable molecules to this organic matter pool. At some point, some of this micro-produced material chemically bonds to silt and clay particles. The silt and clay protect this pool of organic matter even better than aggregates. Because it is protected, this is the largest and oldest pool of soil organic matter, often called humus.



Different pools of organic matter have different effects

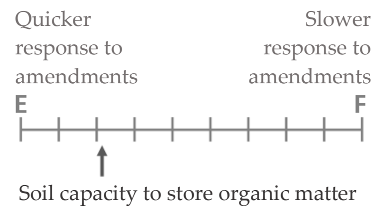
EACH OF THESE THREE POOLS of soil organic matter, naked POM, POM in aggregates, and humus on silt and clay, produce different benefits in the soil.

- Naked POM: nutrient cycling, disease suppression
- Aggregate POM: soil structure/tilth, soil pore stability, water relations
- Humus: cation exchange capacity, micro-aggregation

Limitations on the size of organic matter pools

Each pool also has different limitations on its size. The amount of naked POM depends on the amount of inputs (crop residues and amendments) vs. the rate of decomposition. Increasing inputs or slowing decomposition (reducing tillage for example) can increase this pool. Aggregate POM also depends on inputs and decomposition rates, but it does not change as quickly as naked POM in response to management.

The amount of silt and clay in a soil - its texture - determines the upper limit on the amount of humus it can hold. When the sites on all silt and clay particles are filled with humus, the soil is at capacity and further amendments will not increase this pool. Climate (water and temperature effects on decomposition rates) and management (tillage and crop rotation) can then further reduce the potential size of the humus pool.



The speed of changes in organic matter levels is also related to how close a soil is to its capacity. Soil organic matter levels in a soil with lots of spare capacity (closer to empty) can be increased more rapidly than when one that is nearly full, and with less biomass input.

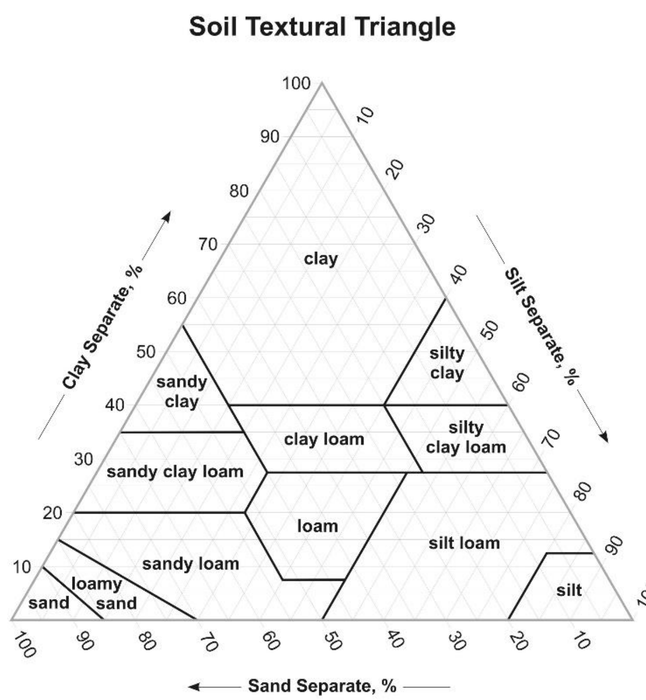
Effects of amendment quality

THE QUALITY OF ORGANIC AMENDMENTS affects the speed of decomposition. Materials high in lignin or with high Carbon:Nitrogen or C:Phosphorus ratios are more difficult for microbes to break down and so slower to decompose. This results in lower amounts of organic matter being bonded to silt and clay particles. Research suggests that adding fertilizer to increase the N and P of these materials can increase the retention of organic matter, but not speed up the process. Materials low in lignin and with low C:N and C:P ratios decompose more quickly, produce more microbe numbers, and result in more organic matter that is attached to silt and clay particles.

ORGANIC AMENDMENTS: manures, composts, vegetable processing wastes, green manures and crop residues including cover crops

Effects of soil texture

The texture classifications in the soil texture triangle show where the relevant changes occur between texture types. The protection of organic matter by silt and clay particles is a large factor in separating texture classes. These smaller soil particles have greater effects on overall soil function than do the larger sand particles. As little as 10-20% silt or clay can change a texture classification, so a "clay" requires only 40% clay particles, while a silt requires 80% silt particles, and a sand, 90% sand particles. Our loam soils, which are often considered the best overall texture for farming, can still be 66% sand. Because of these disproportional effects of silt and clay, you should avoid loss of these particles by wind or water erosion.



What this means for building soils

The measurement problem

Although researchers have come up with this system for thinking about soil organic matter, measuring these different pools is difficult. Commercial labs measure only total soil organic matter, the combination both POM pools and humus. Therefore, you must manage without knowing how close your soil is to capacity, or how much naked POM you have. This can be done by looking at your soil texture, your overall amendment rate, and factoring in tillage levels and crop rotation.

Management recommendations

In the Columbia Basin, we can divide our soils into sands and soils with silt and clay; loamy sands, sandy loams, silt loams and loams.

SANDS: These soils have very little silt and clay. Adding tillage, warm climate, and irrigation results in low soil organic matter levels. Naked POM may be over 50% of your soil organic matter. Your main strategy is to reduce decomposition rates by minimizing tillage, and increase amendment rates through rotations with high residue crops and regular inputs of manures, composts, or cover crops. Lower quality amendments (woody or high C:N) will work because you want to slow decomposition in these soils. Regular inputs (every year or two) will be crucial if you produce low-residue, high-tillage crops like potatoes or onions. Finally, reduce wind erosion losses of silt and clay. Even though your soil's organic matter capacity is limited, experience has found that you can still increase total organic matter levels to near 1% in sands.

SOILS WITH SILT AND CLAY: In our region, these soils, especially those with higher amounts of silt, will probably have moderate to high levels of spare capacity for storing organic matter. This means that both low- and high-quality amendments can increase organic matter levels. The limiting factor will be tillage in many situations – consider high residue farming where practical. There is higher potential for aggregation and associated soil structure in these soils, so regular amendments are important to maintain the POM that drives these processes. Total soil organic matter levels of 1-2.5% are achievable.

Grant/Adams County
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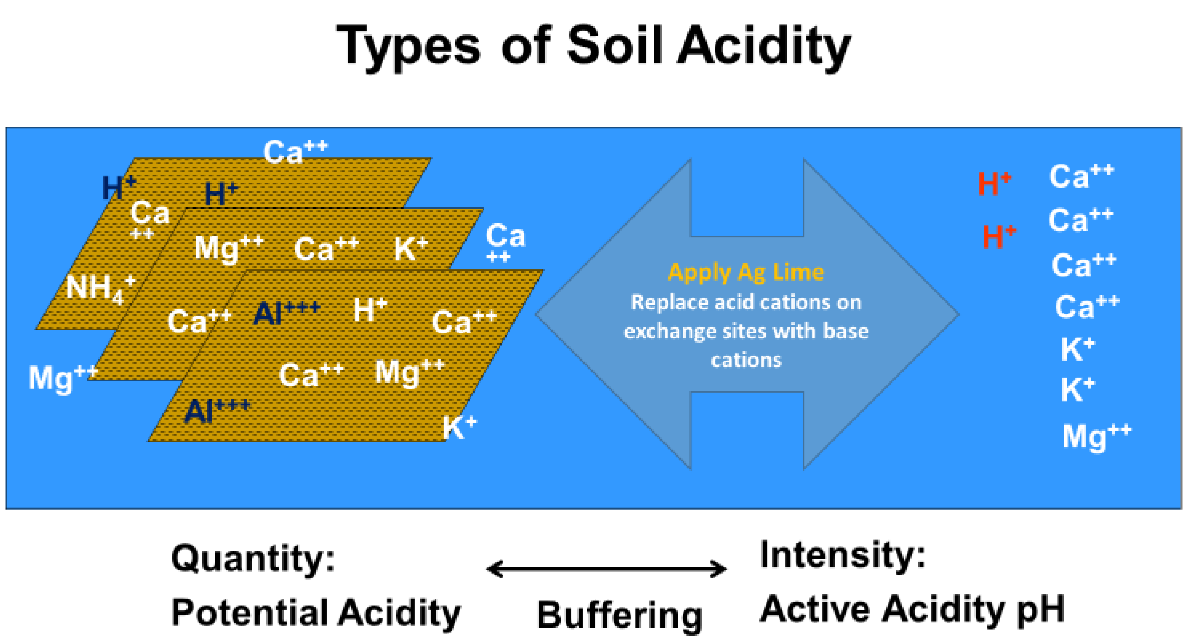
Soil Acidification, Liming on Western Soils

Haiying Tao, Washington State University

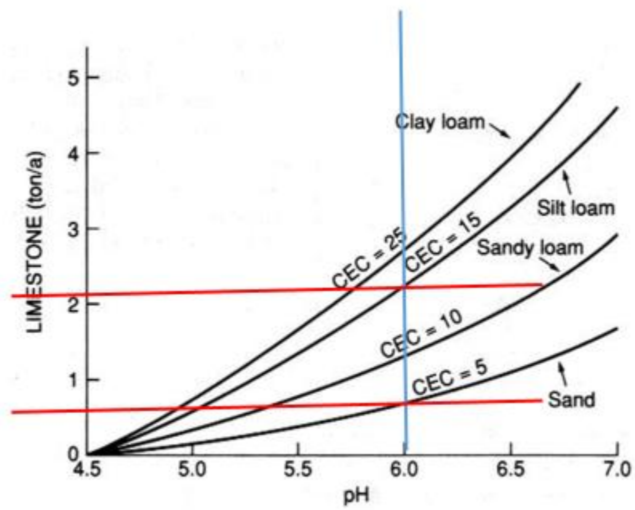
1. Outline
    a. Basics of soil acidity
    b. Current issues
    c. Soil pH in different tillage systems
    d. Lime requirement determination
    e. Liming studies
2. **Types of Soil Acidity**
    a. Active acidity: pH
        i. [H+] in soil solution
        ii. measured with a pH meter
        iii. pH controls chemical properties
        iv. pH affects both biological and physical properties
    b. Exchangeable acidity: buffer pH
        i. Amount of Al3+, H+, and some Fe3+ that occupies exchange sites on clays, soil aggregates, and organic matter
    c. Residual acidity
        i. Not readily available
        ii. Bound Al and H ions in clay minerals and soil aggregates



3. Soil Buffering Capacity

a. Resistance to change in pH.
b. Buffering capacity increases as CEC increases.
c. High clay and/or organic matter greater buffering, Sandy soils have lower buffering capacity.
d. Al in soil buffers pH change.

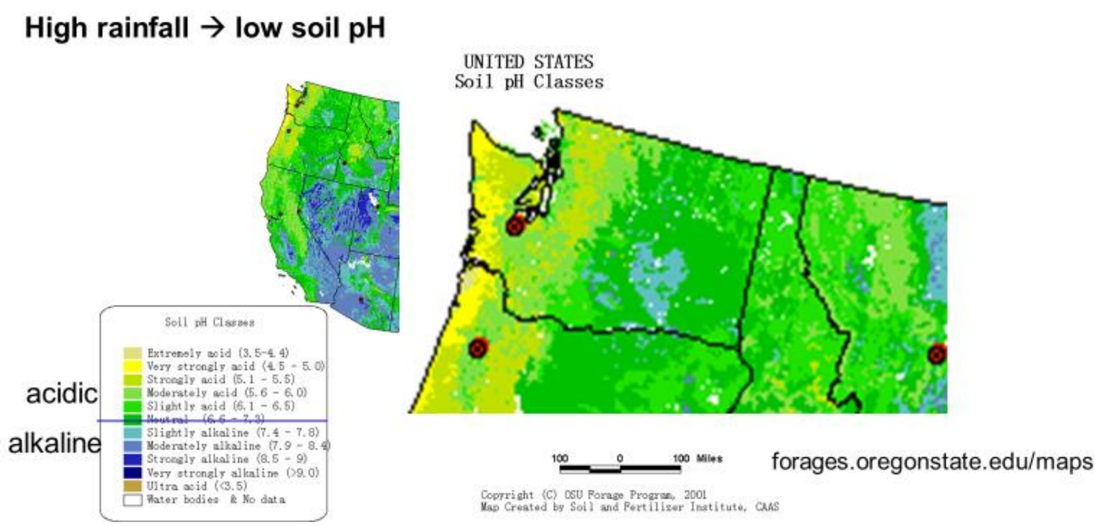
Soil pH Buffering Capacity as Affected by Soil Minerals and CEC



Approximate limestone (ton/a) required to raise soil pH (7-inch depth) of soil of four textural classes with typical CEC (meq/100 g soil).

4. Processes that Cause Soil Acidity
   a. Rainfall

Sources of Soil Acidity - *Rainfall*



b. Decomposition of organic matter (OM)

c. Plant uptake
d. Leaching of cations
e. Fertilizer applications
   i. Oxidation of nitrogen (nitrification)
   ii. Oxidation of sulfur
   iii. Acidic phosphate fertilizers

5. Sources of Soil Acidity – OM
   a. OM contains compounds that act like weak acid: it releases H+ when crop residues decompose
   b. Organic acids contribute to soil acidity: humic and fulvic acids
   c. SOM serves as pH buffer
   d. Acts as both H+ donor and H+ acceptor
   e. Buffering capacity of soil increases with increasing SOM content
   f. Humus has higher CEC than most clay minerals
   g. SOM binds Al3+

Sources of Soil Acidity –
Nutrient Transformation & Plant Uptake

Process	Reaction	pH Effect		
Nitrogen		mole H^+ per mole of N or S		
Mineralization	$R\text{-}NH_2 + H^+ + H_2O \leftrightarrow R\text{-}OH + NH_4^+$	Consume H+ or release OH-	-1	Raises pH
Denitrification	$2NO_3^- + 2H^+ \leftrightarrow N_2 + 2\frac{1}{2}O_2 + H_2O$		-1	
Urea hydrolysis	$(NH_2)_2CO + 3H_2O \leftrightarrow 2NH_4^+ + 2OH^- + CO_2$		-1	
NO_3^- uptake	$NO_3^- + 8H^+ + 8e^- \leftrightarrow NH_2 + 2H_2O + OH^-$		-1	
SO_4^{-2} uptake	$SO_4^{-2} + 8H^+ + 8e^- \leftrightarrow SH_2 + 2H_2O + 2OH^-$		-2	
Immobilization	$NH_4^+ + R\text{-}OH \leftrightarrow R\text{-}NH_2 + H^+ + H_2O$	Consume OH- or release H+	+1	Lowers pH
Nitrification	$NH_4^+ + 2O_2 \leftrightarrow NO_3^- + H_2O + 2H^+$		+2	
Volatilization	$NH_4^+ + OH^- \leftrightarrow NH_3 + H_2O$		+1	
NH_4^+ uptake	$NH_4^+ + R\text{-}OH \leftrightarrow R\text{-}NH_2 + H^+ + H_2O$		+1	
S Mineralization	$R\text{-}S + 1\frac{1}{2}O_2 + H_2O \leftrightarrow SO_4^{-2} + 2H^+$		+2	

6. Sources of Soil Acidity - Fertilizers

Sources of Soil Acidity - *Fertilizers*

- **Ammonium-based fertilizers:**
  nitrification process: $2NH_4^+ + 4O_2 \rightarrow 2NO_3^- + 2H_2O + 4H^+ + energy$

  - *anhydrous ammonia* $NH_3 + 2O_2 \leftrightarrows NO_3^- + H_2O + H^+$
  - *urea* $(NH_2)_2CO + 4O_2 \leftrightarrows 2NO_3^- + 2\,H^+ + CO_2 + H_2O$
  - *ammonium nitrate* $NH_4NO_3 + 2O_2 \leftrightarrows 2NO_3^- + 2\,H^+ + H_2O$
  - *ammonium sulfate* $(NH_4)_2SO_4 + 4O2 \leftrightarrows 2NO_3^- + 2SO_4^{-2} + 4\,H^+ + H_2O$
  - *monoammonium phosphate*
    $NH_4H_2PO_4 + O_2 \leftrightarrows 2NO_3^- + 2\,H^+ + H_2PO_4^- + H_2O$
  - *diammonium phosphate*
    $(NH_4)_2HPO_4 + O_2 \leftrightarrows 2NO_3^- + 3\,H^+ + H_2PO_4^- + H_2O$

- **Other fertilizers:**

  - *elemental S* $2S + 3O_2 + H_2O \leftrightarrows 2SO_4^{-2} + 4\,H^+$
  - *ammonium thiosulfate*
  - $(NH_4)_2S_2O_3 + 6O_2 \leftrightarrows 2SO_4^{-2} + 2NO_3^- + 6\,H^+ + H_2O$

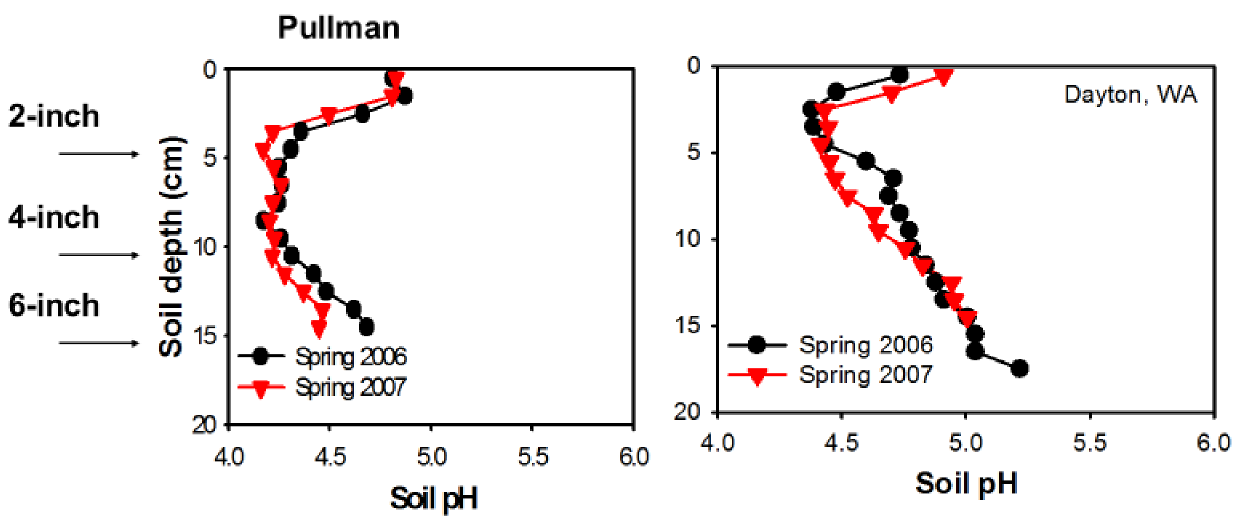
7. Importance of Soil pH
   a. Many plants have optimum pH's for growth
   b. Affects the availability of plant nutrients.
   c. Reduces nutrient use efficiency
   d. Reduce cation exchange capacity (CEC)
   e. Affects fate and activity of pesticides.
   f. Affects biological activity – mineralization, nitrification, N fixation ...
   g. Affects soil-borne pathogens
      i. Fungal pathogens favored at low pH
      ii. Bacterial pathogens favored at high pH

Minimum soil pH values recommended for crops – Oregon State University Extension

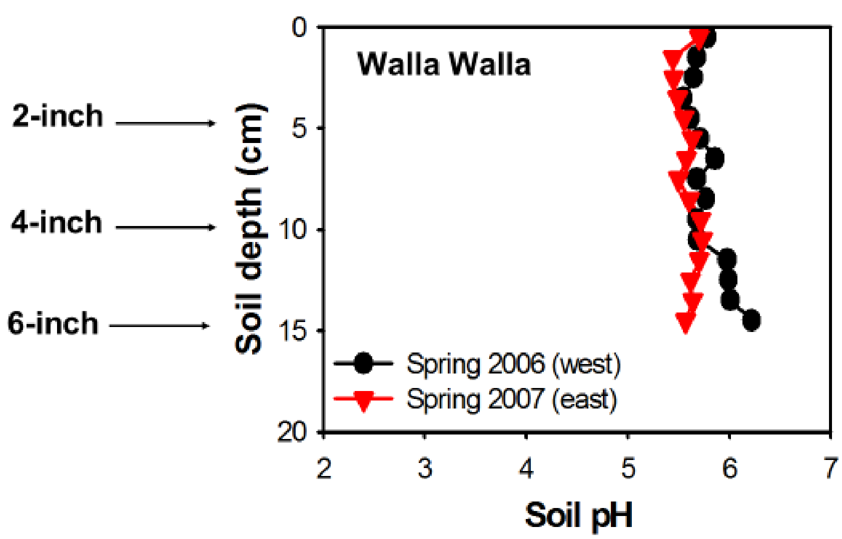
	Crop	Optimal pH Range
	Alfalfa	6.5 - 8.4
	Asparagus	6.5 - 9.0
	Beans and cucurbits	5.8 - 8.1
	Blueberries, cranberries	4.5 - 5.5
	Cereals or small grains	5.5 - 8.4
Corn	Corn grain or silage	5.5 - 8.4
	Sweet corn	>5.8
Forage and seed legumes	Crimson/subterranean clovers, vetch	5.5 - 6.0
	Red clover for forage or seed	>6.0
	White clover for forage or seed	>5.8
	Garlic	6.5 - 8.4
	Peppermint	>5.6
	Hops	>5.7
	Potatoes	5.0 - 8.4
	Pasture and turf grass	5.5 - 8.0
	Fruit trees	6.0 - 8.0
Vegetables	Brassica (broccoli, etc.)	6.3 - 8.2
	Other vegetables	6.5 - 8.2

8. A Growing Issue - Soil Acidification in PNW
    a. 60% have seen increasing soil acidity in the last 6-10 years
    b. 32% said that soil acidity is decreasing yields
    c. 6% have pH < 5
    d. 52% are managing problem with crop rotations and tillage
    e. 19% have tried liming

Soil pH Stratification in No-till Soil



Soil pH Distribution in Tilled Soil



9. Managing Acid Soils
    a. Add OM: Chelates Al^{3+}, Fe^{2+} /Fe^{3+} , and Mn^{+}
    b. Breeding: Al Tolerant Variety
    c. Alternative crops
    d. Liming: Raises soil pH
        i. Determining Lime Requirement (LR)
        ii. Bandaids
10. Determining Lime Requirement
    a. Field determination with lime
    b. Titration in the laboratory
    c. Incubation in the laboratory
    d. Buffer tests methods
        i. Shoemaker-McLean-Pratt (SMP)
        ii. Adams-Evans
        iii. Woodruff
        iv. Mehlich
        v. Modified Mehlich
        vi. Sikora

Example of buffer test result:

1:1 pH = 5.0
$CaCl_2$ pH=4.3
KCl Al = 44.2 mg/kg

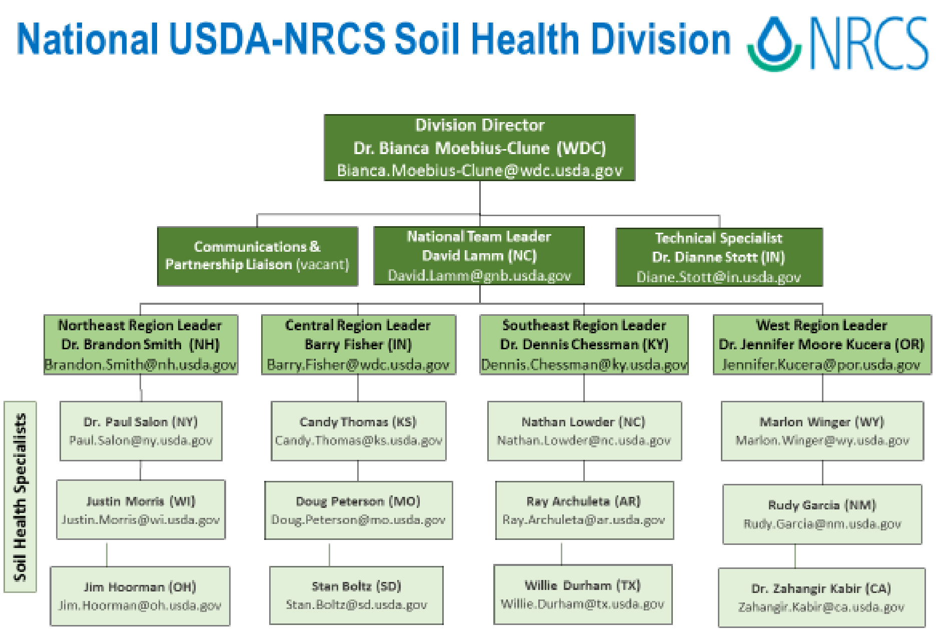
Lime Req		Tons/Acre	3.7
Buffer pH	SMP		5.7
Cation Exchange	CEC	meq/100g	15.0
Total Bases	NH4OAc	meq/100g	8.3
Base Saturation	NH4OAc	%	55.2

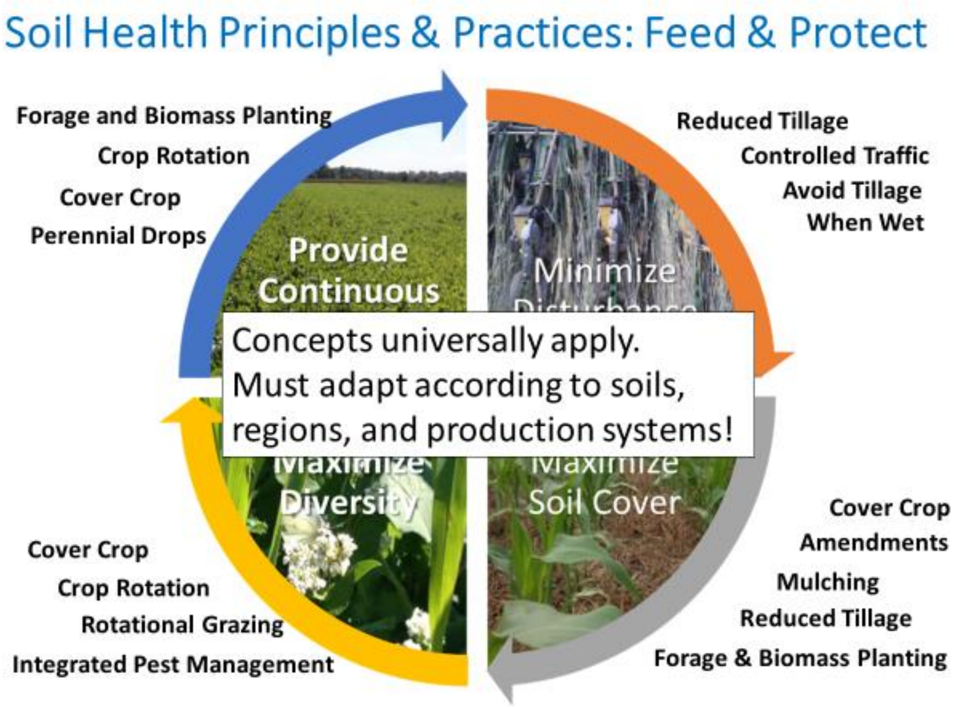
11. Take Home Message
    a. Different crops have different tolerance to low soil pH
    b. Liming becomes necessary when soil pH is lower than minimum required soil pH by a crop
    c. Exchangeable Al^{3+} content will increase dramatically at pH≤4.8
    d. Ammonium-containing fertilizer acidifies soils
    e. Clay content, SOM, CEC are primary factors determines pH buffering
    f. Sandy soils with low pH buffering can be acidified quicker but require less lime to correct pH
    g. Lime requirement should be determined by appropriate method that is calibrated for local soils

Soil Health at NRCS

Jennifer Moore Kucera, Ph.D., West Region Team Leader, Soil Health Division USDA-NRCS

1. *History, goals, and actions*
    a. Agency born out of the Dust Bowl
    b. Meet national challenges via Soil Health Principles, Practices, and Partnerships
    c. Bridge to external **partners** for soil health science & technology acquisition
    d. Develop training materials/workshops to build NRCS staff technical capacity
    e. **Provide soil health assessment interpretation guidance**
    f. Develop conservation tools & design soil health management systems
    g. Better integrate soil health into agency policy, tools, programs





2. *Measuring soil health*
    a. *Criteria for indicators (*(Doran et al., 1994; Larson and Pierce, 1991; Mausbach and Seybold, 1998; Moebius et al., 2007; Bastida et al., 2008; Moebius-Clune 2010)
        i. Scientific, agronomic, environmental relevance
        ii. Represent diverse processes
        iii. Sensitive to agricultural management
        iv. Ability to show short term change
        v. Standardized methods that use the best currently available technology
        vi. *Easy and inexpensive to sample & measure*
        vii. *Repeatable*
        viii. *Minimal infrastructure/investment*
        ix. *Interpretations accessible to many users*
        x. ***Actionable:*** *ability to provide science-based indicator-informed recommendations for management*
3. 3 Tiers of Soil Health Indicators
    a. Tier 1
        i. Effective indicator
        ii. Defined regionally and by soil groupings across nation
        iii. Have thresholds to at least indicate "Poor", "Adequate“, "Good" that are outcome based (i.e. yield, environmental…)
        iv. Management can be suggested to improve soil functioning
    b. *Tier 2*
        i. Effective indicator

ii. *Know* the trends/directionality, may have a good idea of potential ranges in some regions, but not nationally
iii. Do *not* know thresholds for adequate functioning in a healthy soil in various regions
iv. Have some idea of which management practices can change indicator

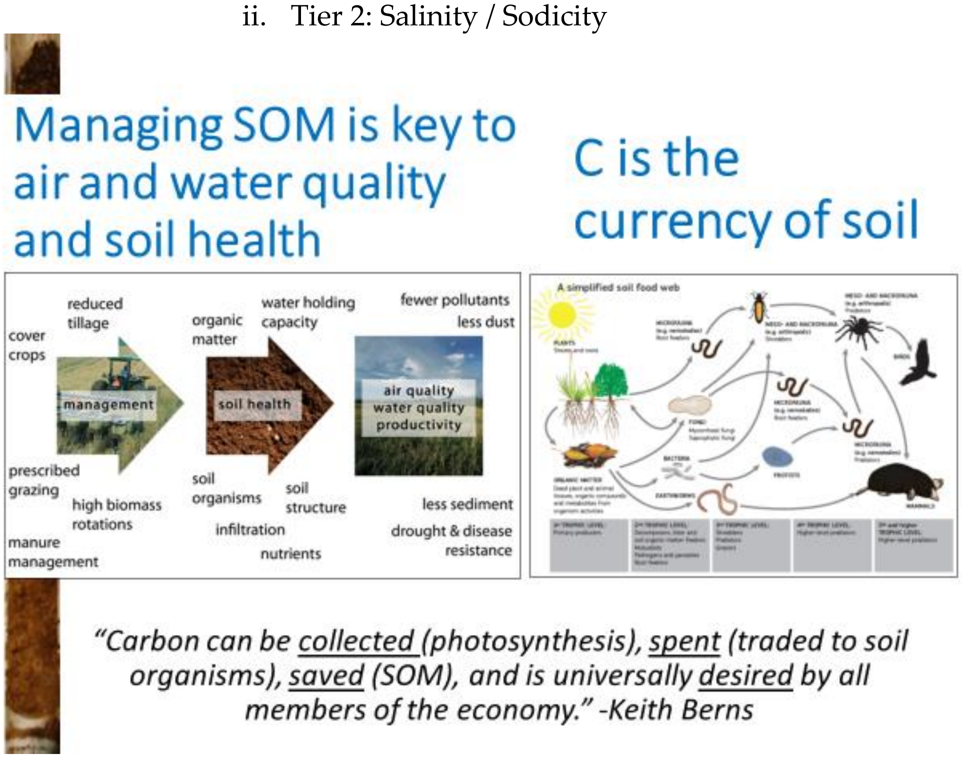
c. *Tier 3*
i. Has potential to add significant information if we learn more
ii. Is somewhat effective
iii. Still needs a lot of work for production laboratory implementation, interpretation, understanding regionality, management impacts.

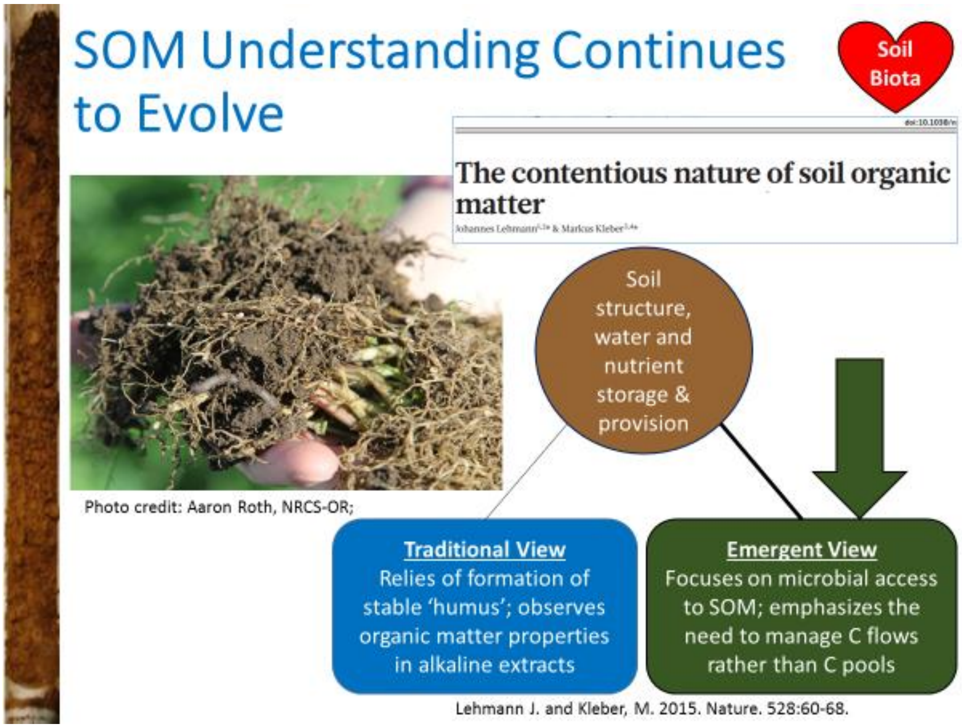
4. **Soil Health Tests are Intended to be Supplemental to Traditional Soil Tests**
5. **Soil Health Processes**

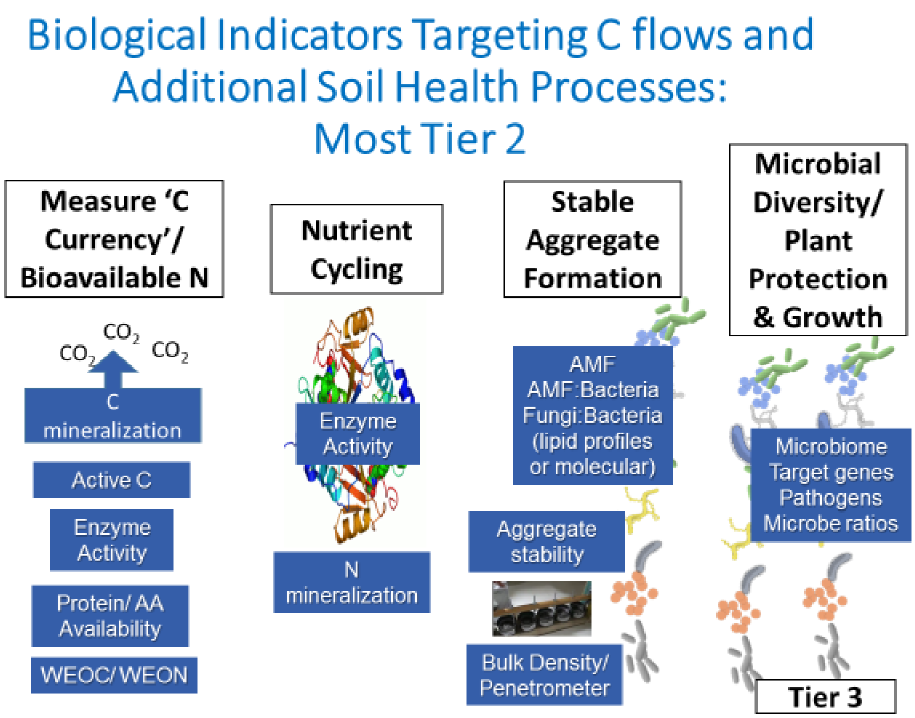
a. **Soil Organic Matter Accumulation**
i. Critically important for nutrient storehouse, soil structure, and support of the underground biota, among other impacts
ii.
iii. Tier 1: Soil Organic Carbon (dry combustion)
iv. Tier 2: Loss on Ignition

b. **Nutrient Availability**
i. Tier 1: NPK – Major plant nutrients
ii. Tier 2: Trace Elements

c. **Chemical Reactivity**
i. Tier 1: pH
ii. Tier 2: Salinity / Sodicity







6. **Soil Health Assessment Initiative**
    a. How well do current assessments do beyond the regions they were originally designed for?

i. Develop regionally based scoring functions
ii. Include β-glucosidase and microbial community structure (PLFA)

b. Cornell, U. Missouri, NRCS Kellogg Lab + Haney
c. LTAR's (Long-term Ag Research sites)
d. 300-350 samples on-farm this fall
    i. Wide range of soil health conditions
    ii. Key LRA's and benchmark soils

7. *Scoring functions for soil health assessment*

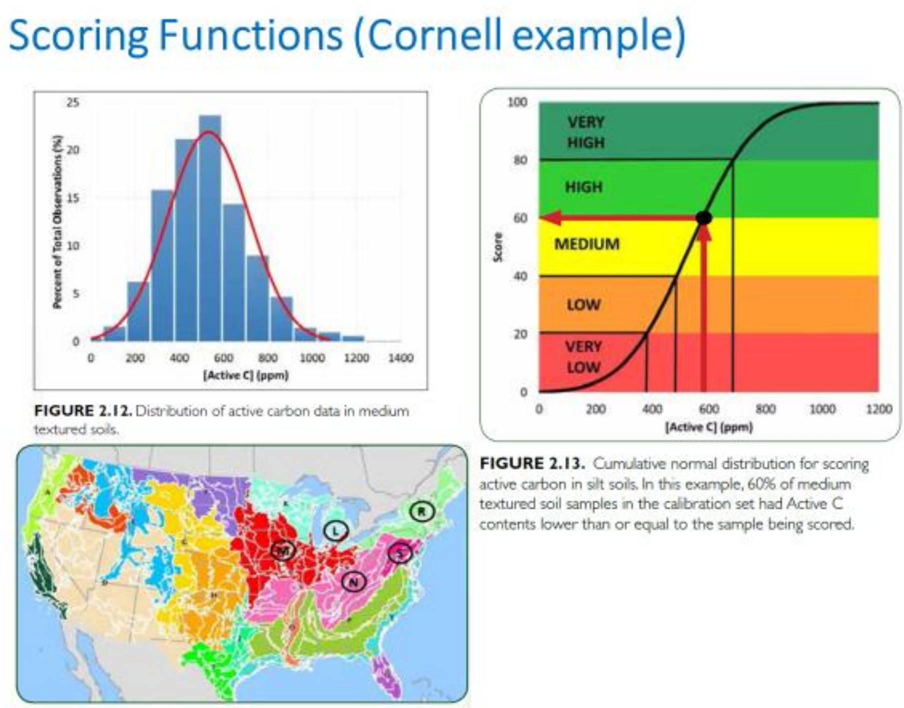


FIGURE 2.12. Distribution of active carbon data in medium textured soils.

FIGURE 2.13. Cumulative normal distribution for scoring active carbon in silt soils. In this example, 60% of medium textured soil samples in the calibration set had Active C contents lower than or equal to the sample being scored.

8. **Indicator of C Flow: Active Carbon**
    a. Potassium permanganete ($KMnO_4$) oxidation:
    b. Provides an indication of the portion of organic matter that provides food and energy to soil microbes.
    c. Related to microbial biomass and other (more complex) measures of labile C
    d. More responsive than total organic C

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9. **Indicator of C Flow & Microbial Activity: Short-term C Mineralization**
    a. Measure of metabolically active soil microbes
    b. Greater amounts
    reflect a larger, more active population
    c. Increased decomposition and breakdown of OM
    d. May be associated with release of nutrients

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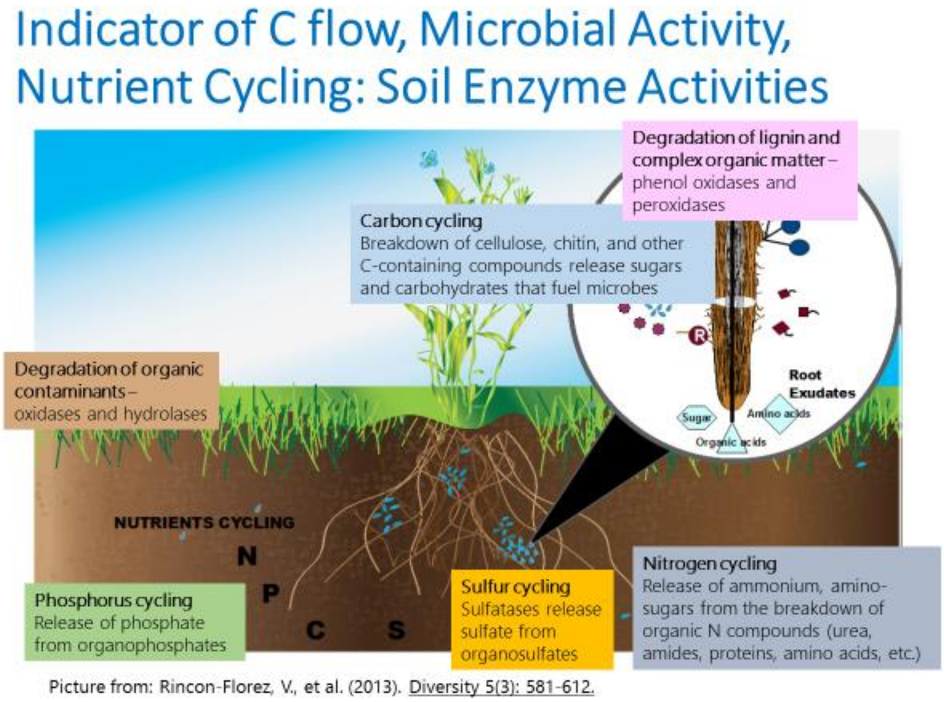
10. **Indicator of C flow, Microbial Activity, Nutrient Cycling: Soil Enzyme Activities**



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11. **Indicator of Bioavailable N and Nutrient Cycling: Org-N and Mineralization**

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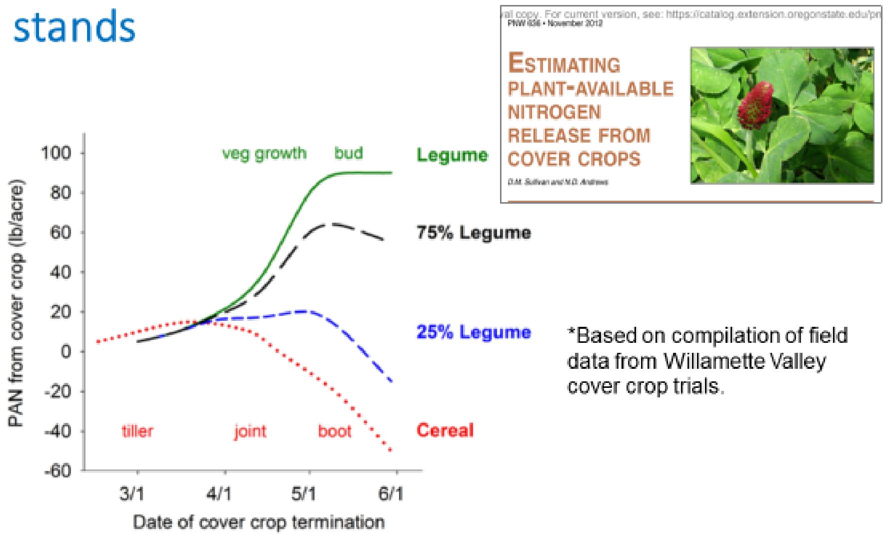
12. **Organic N and N Mineralization Laboratory Tests**
    a. Estimated by SOM (most soil labs)
        i. Roughly 2% of organic N from organic matter is expected to be mineralized each year
    b. Estimated from WEON (Haney approach)
    c. Estimated from C mineralization (CO_2 release)
    d. SLAN (soil labile amino nitrogen) from Solvita
    e. Soil proteins (new approach offered by Cornell)
    f. Potentially mineralizable N
        i. 7d anaerobic incubation
        ii. 28d aerobic incubation

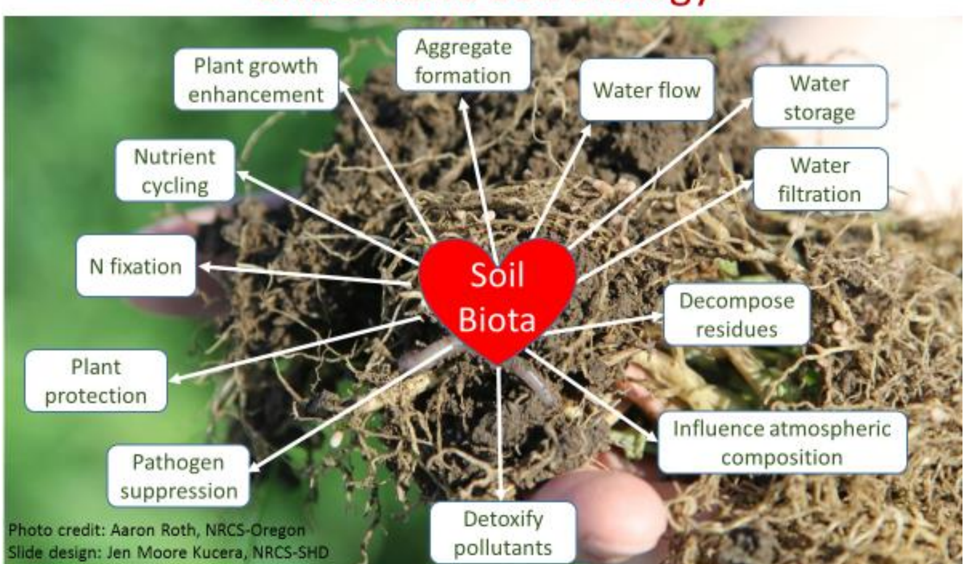
Effect of kill date on typical plant-available N (PAN) release from cereal, legume, or mixed stands



*Based on compilation of field data from Willamette Valley cover crop trials.

Sullivan, D. M. and N. Andrews (2012). Estimating plant-available nitrogen release from cover crops: Oregon State University Extension Service.

To Understand Soil Health We Must Understand Soil Biology



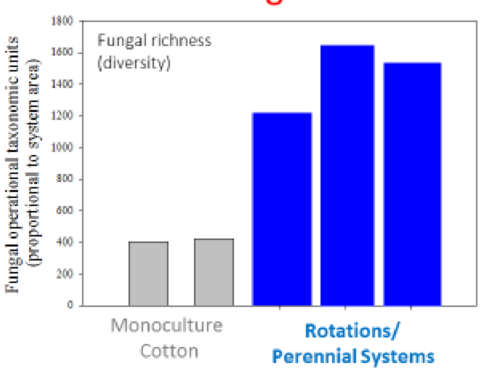
Indicator of Microbial Groups Related to Important Soil Functions: PLFA

Microbial Group	Generalizations for interpretation
Total PLFA	Proxy for total microbial biomass (C flow); combine with SOC, C min, or Enzyme Activities for enhanced interps
Gram negative (GM-)	Respond rapidly to fresh inputs; Increase with increased SOM; Sensitive to H_2O stress;
Gram positive (GM+)	More resistant to environ stress; Degrade complex SOM
Actinobacteria	Degrade complex SOM; aid in aggregation via filaments; tolerant of salt, high pH
GM+:GM- ratio	High ratios common in cultivated soils (low C; low OM inputs) compared to grasslands
Arbuscular mycorrhizae	Higher in less (physically) disturbed lands; important for aggregation, P, H_2O uptake, plant protection
Fungi:Bacteria ratio or AMF:Bacteria	Higher values generally associated with greater functional benefits and less soil disturbance

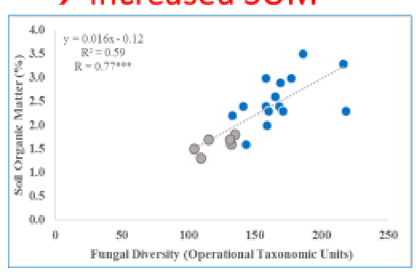
Indicator of Microbial Groups Related to Important Soil Functions: Molecular Tools

Converting part or all of the field to rotation or perennial-based agroecosystems ....

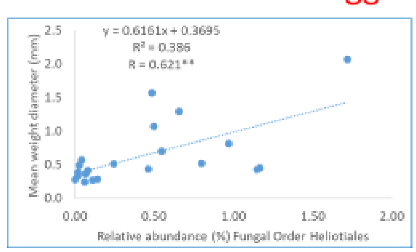
Increased Fungal Richness



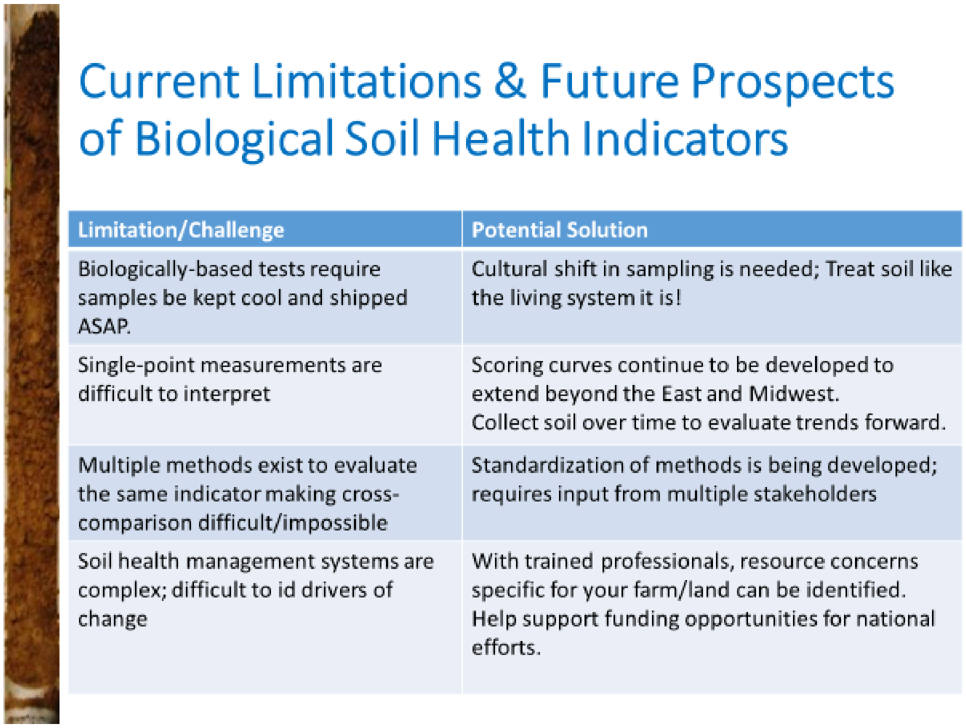
→ Increased SOM



→ Increased Stable Aggs



Davinic, M. 2014, Ph.D. Dissertation



Current Limitations & Future Prospects of Biological Soil Health Indicators

Limitation/Challenge	Potential Solution
Biologically-based tests require samples be kept cool and shipped ASAP.	Cultural shift in sampling is needed; Treat soil like the living system it is!
Single-point measurements are difficult to interpret	Scoring curves continue to be developed to extend beyond the East and Midwest. Collect soil over time to evaluate trends forward.
Multiple methods exist to evaluate the same indicator making cross-comparison difficult/impossible	Standardization of methods is being developed; requires input from multiple stakeholders
Soil health management systems are complex; difficult to id drivers of change	With trained professionals, resource concerns specific for your farm/land can be identified. Help support funding opportunities for national efforts.

13. *The goal:*

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Economics of Soil Building

Eric Williamson, George, WA

1. Main Soil Building Practices
    a. No or Reduced Tillage/High Residue
    b. Cover Crops
    c. Manure and Compost
2. High Residue Farming Economics
    a. Pros
    b. Reduced machinery Costs
        i. Lower overall investment in machinery
        ii. Less depreciation, interest, taxes
        iii. Lower fuel, repairs, labor
    c. Possibly higher yields
    d. Cons
        i. Possibly lower yields from:
            1. Weed competition
            2. Reduced stands
                a. Planting efficiency
                b. Poor seed to soil contact
                c. Cooler soils in spring increase time to emergence
            3. Shading
3. Cover Crop Economics
    a. Additional Costs of Using Cover Crops
        i. Land Prep
        ii. Planting
        iii. Seed
        iv. Fertilizer
        v. Weed Control
        vi. Water and Power
        vii. Incorporation
    b. Can be $30-100 per acre vs no cover crop
    c. Economic Benefits
        i. Many accrue to the subsequent crops
        ii. Water Infiltration and Water Holding Capacity
        iii. Soil protection from wind and water erosion
        iv. Improve Carbon to Nitrogen ratio
        v. Biofumigation
        vi. Increase in soil microorganisms
        vii. Improved bioavailability of some nutrients
    d. Some Cash Benefits too:

i. Grazing
ii. Hay/Silage sales
iii. Hunting
iv. Bees

e. Nutrient Removal from Harvested Feed
  i. Wheat Example
    1. 0.3% Phosphorous = .69% P2O5 = 13.8 lbs/ton
    2. 2.57% Potassium = 3.34% K2O = 66.8 lbs/ton
    3. (Can get removal estimates from "Crop Nutrient Removal Calculator" app)
  ii. Recent Prices
    1. P2O5 $0.46/lb of nutrient
    2. K20 $0.38/lb of nutrient
  iii. $6.35 of P2O5 removed per ton (DM) of feed
  iv. $25.38 of K20 removed per ton (DM) of feed
  v. $31.73 total P and K removal per ton of DM

f. Grazing vs Harvesting Forage

Grazing vs Harvesting Forage

Cost	Grazed	Harvested
Seed	$15	$15
Planting	$20	$20
Fert/Chem	$24	$47
Harvesting	$0	$110
Nutrients Removed	$4.76	$31.73
Total Costs	$63.76	$223.73
Yield	100 grazing days	2.5 tons/ac
Value/Unit	$0.50/day	$80/ton
Total Value	$50	$200
Net Value	-$13.76	-$23.73

  i. Benefits of Grazing
    1. Returns 85-90% of organic material to soil
    2. Minimal nutrient removal
    3. Plants can regrow and be grazed multiple times
    4. Helps recover costs of establishing cover crops while still maintaining most of the benefits

5. Deep-rooted plants pull nutrients from lower levels and bring to the surface
6. Residue load is decreased to allow for easier planting
7. Weeds can be grazed to prevent going to seed

ii. Other Grazing Factors to Consider

1. Manage to avoid compaction
2. Match type of livestock to crop to be grazed and season
3. Feeding and watering areas

g. Planting vs Grazing Dates

Crops	Planting Dates	Grazing Dates	AUDs
Winter Cereals	August 1-August 25	October 15-March 31	100
Winter Cereals	After August 25	April 1-June 15	125
Spring Cereals	August 1- August 25	October 15-December 15	90
Spring Cereals	August 25-September 15	November 1-December 15	75
Brassicas	August 1-August 20	October 15-December 31	90

4. Manure Economics

a. What is manure worth?

i. Know Thy Manure:

1. Proper sampling
2. Dig into pile and remove a small shovel full from 1-2 feet deep into the pile and put in a bucket
3. Do this in 15-20 random spots around the pile
4. Mix the contents of the bucket and then send a subsample to the lab for analysis
5. Follow lab instructions for liquid manure samples

b. Manure Sample Results

i. Moisture/Dry Matter

ii. 100-Moisture = Dry Matter

iii. 100-Dry Matter = Moisture

c. Drier manure a better value per ton but sometimes has less nitrogen

   d. Other Value Considerations
      i. Organic Matter
      ii. Secondary and Micronutrients
      iii. Sodium
      iv. pH
      v. Type of manure (pen scrapings, manure separator solids, compost, etc)
      vi. Bedding
      vii. Hauling and Spreading Costs

Valuing Manure/Compost

	Sample 1	Sample 2
Moisture	67%	38%
Dry Matter	33%	62%
P2O5 (as received)	7.5 lbs/ton	18.9 lbs/ton
K20 (as received)	14.0 lbs/ton	44.4 lbs/ton
N (as received)	8.8 lbs/ton	13.3 lbs/ton
N available in Year 1	50% (4.4 lbs/ton)	50% (6.7 lbs/ton)
N available in Year 2	25% (2.2 lbs/ton)	25% (3.3 lbs/ton)
Commercial N,P,K prices	$0.44N, $0.46P, $0.38K	$0.44N, $0.46P, $0.38K
Value/ton 1 Year Program	$10.71	$28.51
Value/ton 2 Year Program	$11.67	$29.97
Plus Other Components	??	??

5. Magic Bullet?
   a. Anecdotal evidence of better yields
   b. Could be many things
      i. Overcoming field variability
      ii. Overcoming suboptimal applications
      iii. Organic matter additions
      iv. Hidden hunger satisfied
      v. Increased biological activity (the claim that launched a thousand products!)
6. Field Variability
   a. Somewhat related to soil texture and field topography
   b. The average nutrient level is only part of the equation – you must also know the variability
   c. 2 sets of core samples (15 samples each)
      i. 12,15,18,13,17,14,16,15,11,19,15,13,18,14,16
      ii. 1,3,5,7,9,11,13,15,17,19,6,8,27,30,54

    d. Both average 15 ppm
7. Cropping Considerations
    a. Legume crops may not benefit from N in manure so valuation should reflect that
    b. May cause unwanted vine growth in podded legumes due to excess N fertility
    c. Timing of N release can be unpredictable so intensive soil N monitoring and/or commercial early season N may be warranted for non-legume crops
    d. Weed seeds depending on type of product
8. Incorporation
    a. The earlier the incorporation, the more nutrients will be available to next crop
    b. The fall prior to spring planting works well
    c. Can work with no-till but…
    d. May lose benefit of significant amounts of N
    e. Takes time to enter the root zone and be available to crops. Probably won't see benefit until subsequent crop
    f. Immediate water incorporation may help
    g. Very light tillage (i.e. turbo till) may help
    h. Soil injection works very well
9. Summary
    a. Know your field/soil
    b. Know your manure/compost
    c. Match to cropping system
    d. Proper incorporation
    e. Large applications are longer term investment

Soil Improvement Results: Columbia Basin

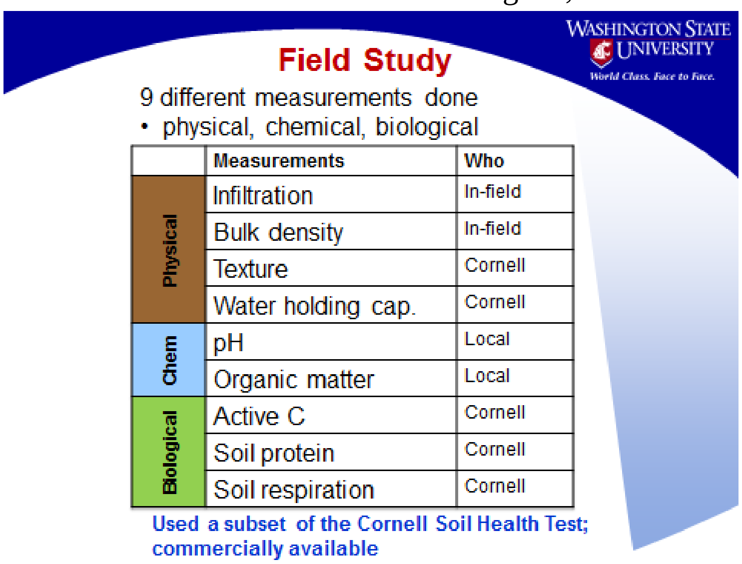
David Granatstein and Andy McGuire, WSU Extension

Conducted a study of adjacent fields with same soil type but different soil management (with and without soil improvement practice) in February 2015.

3 pairs – with and without organic amendments (compost, mint slugs)
4 pairs – with and without mustard green manure
2 pairs – with and without hi-residue farming (strip-till; no-till)

In each field had 5 sampling locations; 5 soil cores per location, 0-6” depth, composited.

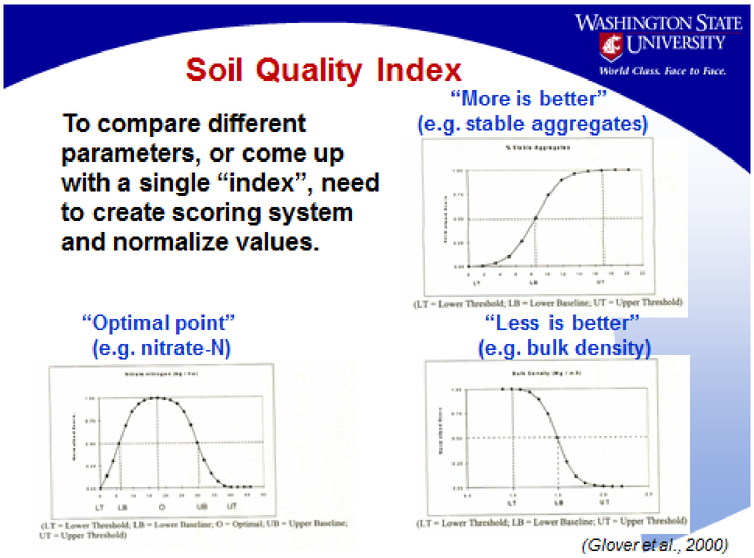
Chose tests to measure different physical, chemical, and biological soil quality characteristics. Some sent to Cornell Soil Health testing lab, some done locally. Infiltration done in-field.



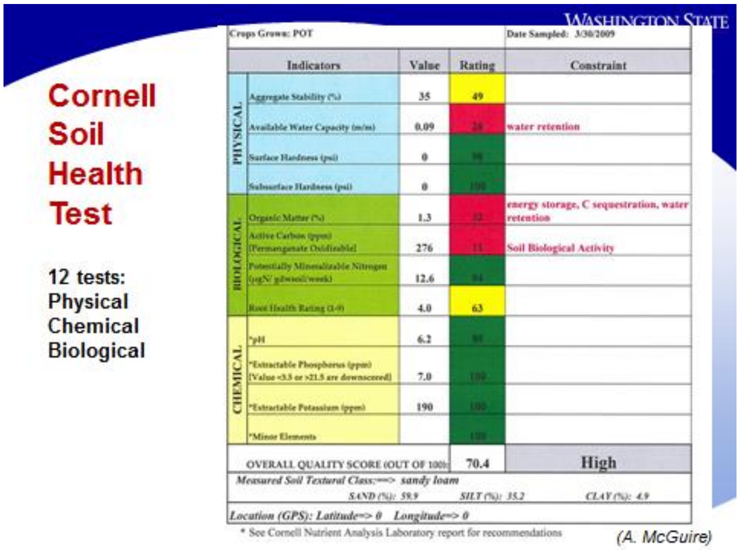
	Measurements	Who
Physical	Infiltration	In-field
	Bulk density	In-field
	Texture	Cornell
	Water holding cap.	Cornell
Chem	pH	Local
	Organic matter	Local
Biological	Active C	Cornell
	Soil protein	Cornell
	Soil respiration	Cornell

An example of sampling in the field, using metal rings to measure water infiltration.

Chose tests that could be done by a commercial lab, or by growers/consultants.
Cornell Soil Health lab offers a commercial service. Results from the different test have to be normalized to be able to add together for an overall soil health "score." This is done by creating scoring functions as shown below. For some parameters, more is better, but there are usually upper and lower limits. Lower numbers are better for other parameters such as bulk density. And some parameters such as nitrate have an optimal range, with less desirable conditions on either side.

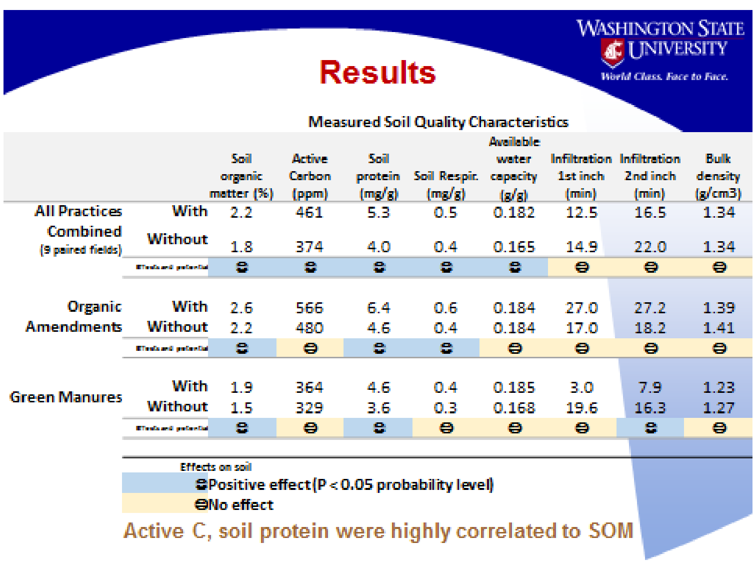


The Cornell lab has used results from multiple samples to help create their scores. They then use red, yellow, and green to indicate which parameters may be priority problems (red), borderline values (yellow), or in the desirable range (green). An overall score is given for the sample but areas that need attention are indicated, as on the report is shown below. The scoring is based on soil from the Northeast U.S. at this point in time, thus the rankings may not accurately reflect what is "good" soil quality for soils in Washington State. However, comparisons between samples with different management are very useful.



Results – expressed as difference between fields with and without soil improvement practices

- No differences for soil texture; some previous research suggests that mustard green manures do affect wind erosion and thus could impact retention of finer grained particles
- No significant differences for bulk density, water infiltration over all fields;
- Soil improvement practices significantly changed soil organic matter, active carbon, soil protein, soil respiration, available water capacity
- Active carbon, soil protein were highly correlated to soil organic matter



Measured Soil Quality Characteristics

		Soil organic matter (%)	Active Carbon (ppm)	Soil protein (mg/g)	Soil Respir. (mg/g)	Available water capacity (g/g)	Infiltration 1st inch (min)	Infiltration 2nd inch (min)	Bulk density (g/cm3)
All Practices Combined (9 paired fields)	With	2.2	461	5.3	0.5	0.182	12.5	16.5	1.34
	Without	1.8	374	4.0	0.4	0.165	14.9	22.0	1.34
	Effects on soil	Positive effect	Positive effect	Positive effect	Positive effect	Positive effect	No effect	No effect	No effect
Organic Amendments	With	2.6	566	6.4	0.6	0.184	27.0	27.2	1.39
	Without	2.2	480	4.6	0.4	0.184	17.0	18.2	1.41
	Effects on soil	Positive effect	No effect	Positive effect	Positive effect	No effect	No effect	No effect	No effect
Green Manures	With	1.9	364	4.6	0.4	0.185	3.0	7.9	1.23
	Without	1.5	329	3.6	0.3	0.168	19.6	16.3	1.27
	Effects on soil	Positive effect	No effect	Positive effect	No effect	No effect	No effect	Positive effect	No effect

Effects on soil
Positive effect (P < 0.05 probability level)
No effect

Active C, soil protein were highly correlated to SOM

- Green manure led to much higher water infiltration
- A similar 2009 study of mustard green manure showed large impacts soil organic matter and biological parameters; overall Cornell soil health score – 69 with green manure, 60 without

Orchard mulching – soil improvement strategy for tree fruit

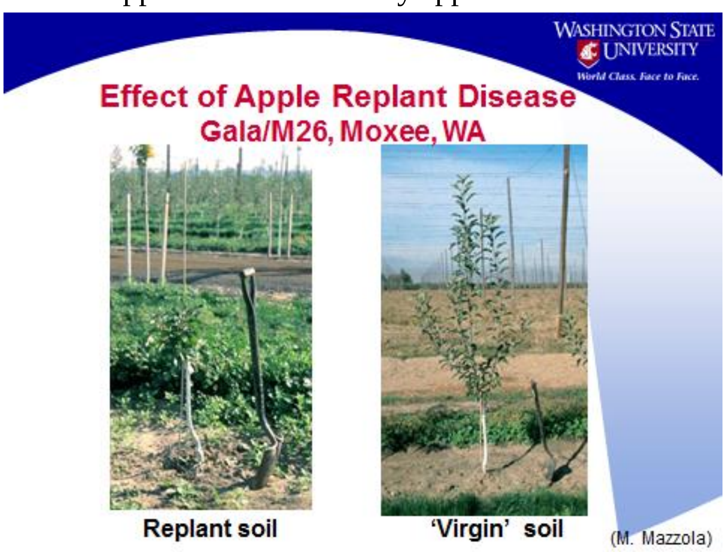
- Many studies have shown positive tree response to surface applied mulch
- Summerland, BC study – soil organic matter was significantly increased in 6th year after planting with bark mulch, while microbial biomass had changed by 4th year
- Central WA – wood chip mulch led to greater apple yield in year of application and next two years, with no change in soil organic matter; resulted in net economic gain of $4,700 over 3 years
- The Dalles, OR – wood chip mulch + compost applied to 30 yr old 'Bing' cherry in October; led to larger cherries than untreated at harvest the next July, with a net of $1,000 per acre after paying cost of mulch ($1,600/ac)
- Challenge for widespread use is availability of mulch and cost of handling; potential to generate mulch in orchard from prunings and alley vegetation (see below)

Benefit of crop rotation – biological impact

- Dryland grain study in Pullman, WA – continuous cereal versus medic-medic-wheat
- Medic-wheat rotation (no herbicide) had more weed seedlings germinate than continuous cereal (with herbicide) but less weed biomass at harvest
- Soils from plots showed the same impact when used in greenhouse growth of wheat plant plus weed seed; related to better wheat root health with rotation and more competition with weed for water and nutrients (photo below)

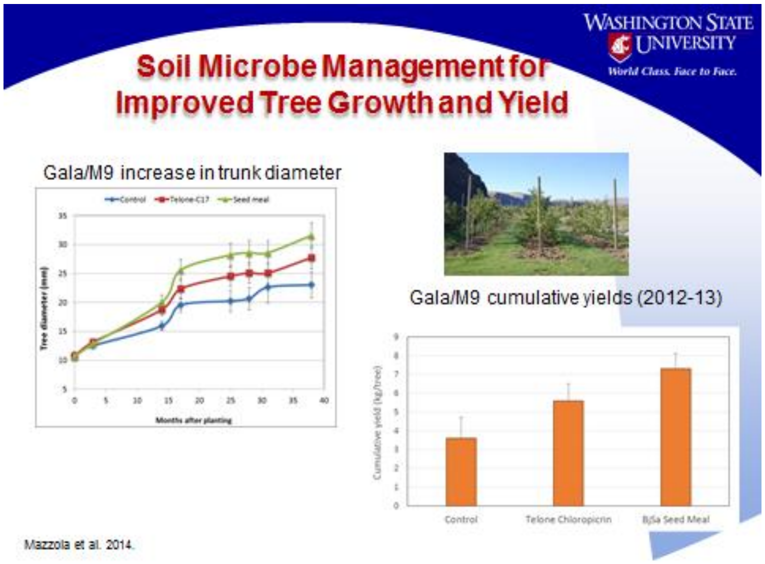
Apple replant disease

- Fungal pathogen and nematode complex
- Appears to be incited by apple root exudates themselves



An example of replant disease. Left photo: new apple tree planted into former orchard soil; very little growth. Just outside former orchard (14 ft. away) an additional row was added (no history of apple) and planted to apple. A large amount of growth (right).

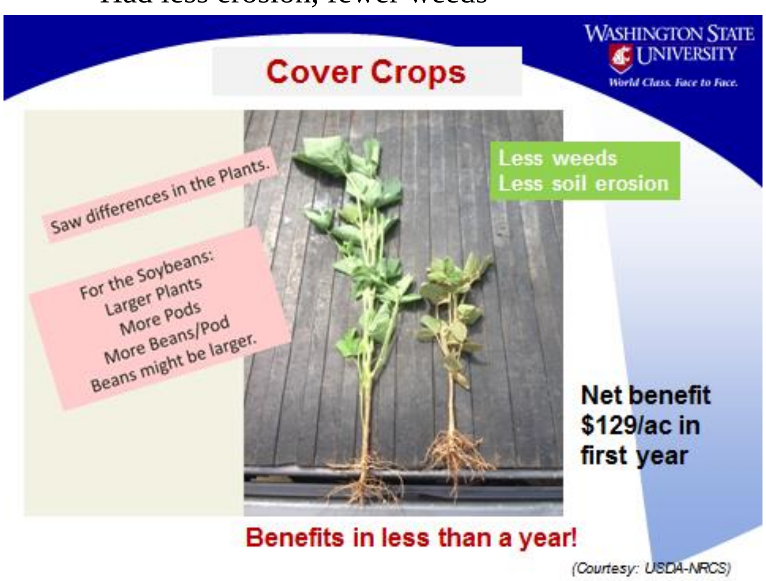
- Soil fumigation has been the common response, but still, trees do not perform as well as when on 'virgin' soil with no history of apple
- Use of Brassica seed meal mixture altered soil biology and led to greater tree growth and fruit yield than fumigation



- Seed meal treatment led to rhizosphere microbial community distinctly different from fumigated or control soil; persisted several years
- Fumigated soil biology reverted to same as control after one year

Cover crops

- Relatively inexpensive soil improvement technique
- North Carolina grower – tried cover crops for first time before soybean; goal was erosion control and weed suppression
- Saw crop response, netted $129 per acre more income with cover crops in the first year
- Had less erosion, fewer weeds



Conclusions

- Soil improvement works in irrigated CB systems
- SOM can be increased, along with related properties

- Significant differences despite not controlling for time, management, etc.
- Green manure – large impact on infiltration
- Multiple strategies, practices, tools to choose from
- Economics generally look favorable

Building Soils for Better Crops

2016 Conference

Appendix A: Copyright Permissions and References

Understanding Nutrient Placement in No-till and Strip-till

Fabián Fernández, University of Minnesota, St. Paul, MN

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- Drew, M.C. 1975. Comparison of the effects of a localized supply of phosphate, nitrate, ammonium and potassium on the growth of the seminal root system, and the shoot, in barley. New Phytol. 75: 479-490. (Adapted figure on page 2)

Emerging Soil Amendments: Promise, Potentials, and Pitfalls

Kristin Trippe, USDA-ARS, Corvallis, OR

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Citations & Photo Credits:

- Page 7 Adapted Graph- citation for Mcclerc 2016 (correction: Leclerc 2016)
    - Leclerc, R. (2016, July 5). The Next Phase For Agriculture Technology. Retrieved from Forbes.com: http://www.forbes.com/sites/robleclerc/2016/07/05/the-next-phase-for-agriculture-technology/4/#5f1dca9a219d
- Page 8 – Photo credit: Stock image provided by krisckam/123RF.COM
- Page 10 – From USDA published website by author, http://www.pnwbiochar.org/
- Page11 – Figure adapted from Mark Johnson 2016 (contact presenter for full citation)
- Page 11 – Photos by Claire Phillips
- Page 12 top Data provided from the public access Biochar atlas available at http://www.pnwbiochar.org/case-studies/farm-power/, authors Claire Phillips and Kristin Trippe (presenter). This case study data is from “Farm-power: gasifying grass residues for electricity and biochar” by Claire Phillips.
- Page 12 – Top Right “Crops amended with biochar superimposed (right) on control crops (left).” —Claire Phillips, 2017
- Page12 bottom- Presenter is Co-PI on research, contact for more information.
- Page 13 top -Phillips, C. L., Trippe, K., Reardon, C. L., Mellbye, B., Griffith, S. M., Banowetz, G. M. and Gady, D.: Physical feasibility of biochar production and utilization at a farm-scale: a case-study in non-irrigated seed production, Biomass Bioenergy, In review.
- Page 13-14 website for the Pacific Northwest Biochar Atlas: http://www.pnwbiochar.org/

Humic Substances (HS), Uses and Abuses
Mir M Seyedbagheri, University of Idaho (retired)
Pages 15-20: Have approval via email to post slides online.

Citations & Photo Credits: For more on the information from this presentation and presenter see his presentation available at this link: http://fwaa.org/wp-content/uploads/2017/02/IR-2014-01-08_9a_Influence-of-Humic-Substances_SeyedbagheriMir.pdf.

- Page 16: Photos by Kristine Nichols, USDA
- Page 18 Bottom graph: Data presented in conference paper – "30 years of research documents: the influence of Humic substances on soil health, fertilizer and water-use efficiency". https://www.researchgate.net/profile/Mir_Seyedbagheri

Fact Sheet: Practical Insights from Current Views of Soil Organic Matter
Compiled by Andy McGuire
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- Castellano, M. J., Mueller, K. E., Olk, D. C., Sawyer, J. E. and Six, J. (2015), Integrating plant litter quality, soil organic matter stabilization, and the carbon saturation concept. Glob Change Biol, 21: 3200–3209. doi:10.1111/gcb.12982
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- Page 22 Soil Aggregate Photo: Eickhorst, Thilo & Tippkoetter, Rolf. Micropedology – The hidden world of soils. University of Bremen, Germany. http://www.microped.uni-bremen.de

Soil Acidification, Liming on Western Soils
Haiying Tao, Washington State University
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- Page 26 Top, Soil pH Buffering Capacity chart:
    - Havlin, J.L., Beaton, J.D., Tisdale, S.L. and Nelson, W.L., 2005. Soil acidity and alkalinity. Soil fertility and fertilizers. 7th ed. Pearson Prentice Hall. Upper Saddle River, NJ, pp.45-96.
- Page 26 Bottom: Figure created by David Hennaway, © OSU Forage Program 2001 (soil and fertilizer institute, CAAS)
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- Page 29: Soil pH distribution in tilled soil graphs provided by Rich Koenig, Washington State University.

Soil Health at NRCS

Jennifer Moore Kucera, Ph.D., West Region Team Leader, Soil Health Division USDA-NRCS

Pages 33-43: Have approval via email to post slides online. Still awaiting specific permissions for images.

- Page 34- Figure created by Jennifer Moore Kucera, photos courtesy of NRCS.
- Page 35- the soil health figures, are they from a government publication? Please provide the citation.
  - Left: Image provided by NRCS, https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/mgnt/?cid=stelprdb1237584
  - Right: Available for educational purpose use from the Global Soil Biodiversity Atlas. Full citation is: Orgiazzi, A., Bardgett, R.D., Barrios, E., Behan-Pelletier, V., Briones, M.J.I., Chotte, J-L., De Deyn, G.B., Eggleton, P., Fierer, N., Fraser, T., Hedlund, K., Jeffery, S., Johnson, N.C., Jones, A., Kandeler, E., Kaneko, N., Lavelle, P., Lemanceau, P., Miko, L., Montanarella, L., Moreira, F.M.S., Ramirez, K.S., Scheu, S., Singh, B.K., Six, J., van der Putten, W.H., Wall, D.H. (Eds.), 2016, Global Soil Biodiversity Atlas. European Commission, Publications Office of the European Union, Luxembourg. 176 pp. Download from: https://publications.europa.eu/en/publication-detail/-/publication/c54ece8e-1e4d-11e6-ba9a-01aa75ed71a1.
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- Page 39 Top: Figure shared under CC BY-NC-SA 3.0 from the following referenced article…
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- Page 43: Bottom figure modified by presenter from a modified figure by Moebius-Clune and Cox from Building Soils for Better Crops. Original publication can be found here:
    - http://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition

Economics of Soil Building

Eric Williamson, George, WA

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Soil Improvement Results: Columbia Basin

David Granatstein and Andy McGuire, WSU Extension

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    - Photos courtesy of USDA NRCS