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Soil Health Assessments

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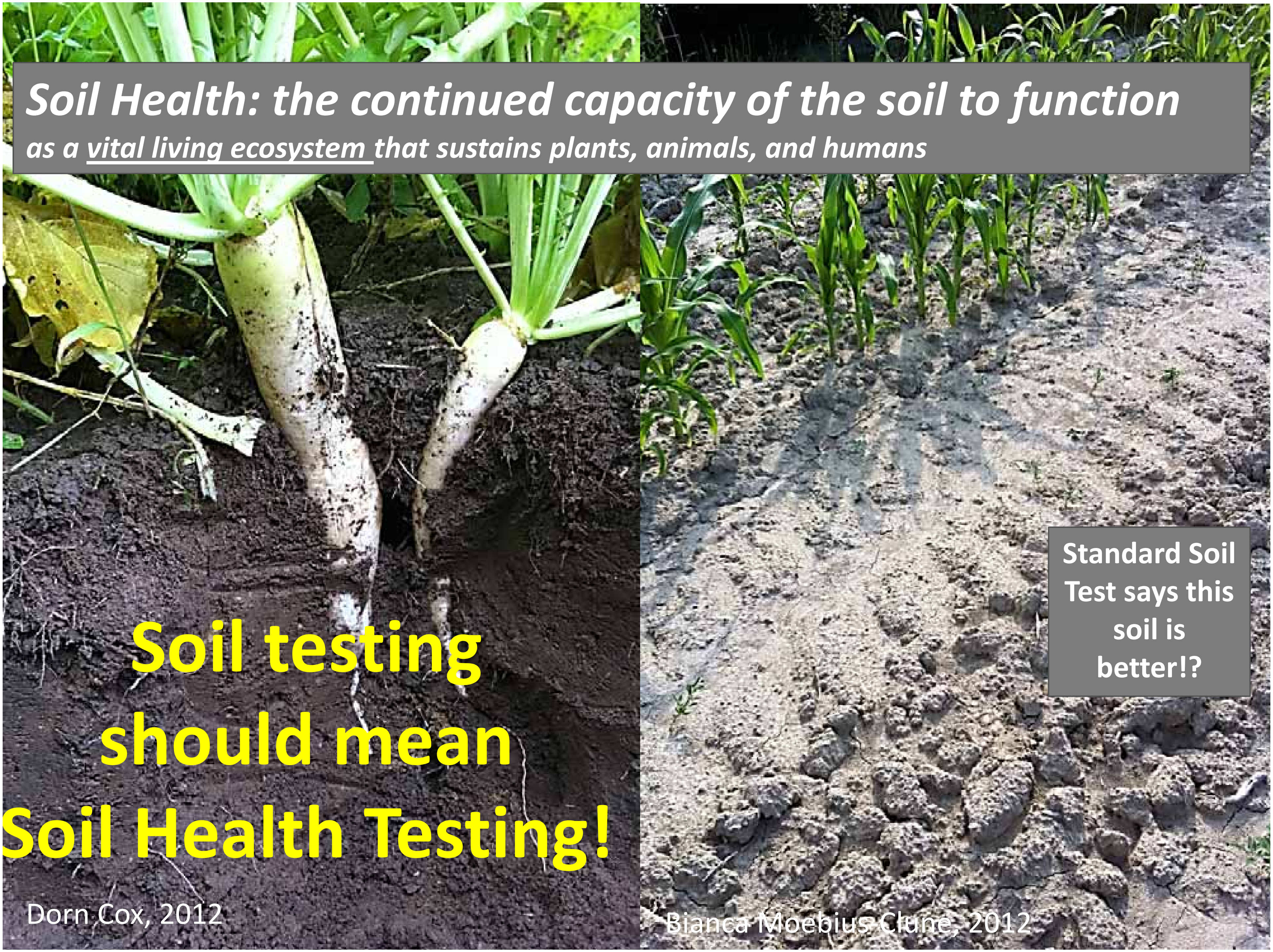
Unlocking the Secrets to Soil Health Success in Organic Systems

Aurora, Oregon

Soil Health: the continued capacity of the soil to function

as a vital living ecosystem that sustains plants, animals, and humans



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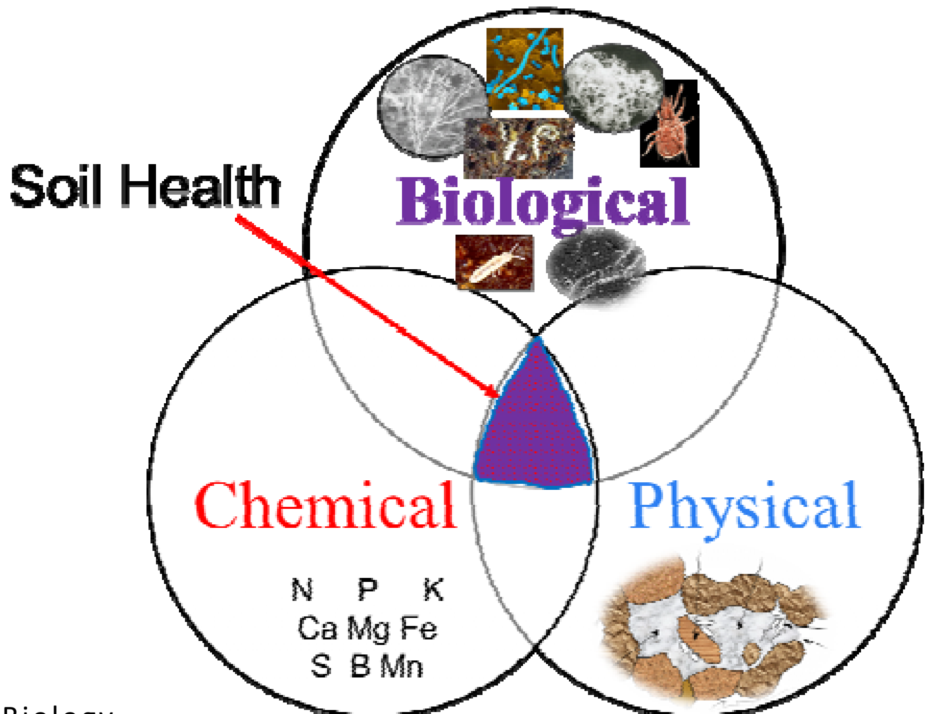
Reasons for Soil Health Testing

- **Understand constraints** beyond nutrient limitations and excesses
- **Target management practices** to alleviate those constraints
- **Measure** soil improvement or degradation from management
- **Improve awareness** of Soil Health (not just plant nutrition)
- **Enable valuation** of farmland
- **Enable assessment** of farming system risk

Assessing Soil Health Using Indicators

A soil health indicator is a measurement of a soil property that provides information about the status of specific important soil processes



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Field Indicators of Soil Health

Field Based – Use your senses

- Smell: rich, earthy smell is produced by Actinobacteria as they decompose organic materials
- Feel: Soft, crumb-like structure
- Sight: No signs of erosion, crusting, salts
- Sight: Earthworms/macrofauna typically beneficial
- Sight: White, filament networks are signs of fungi
- Sight: Deep, abundant roots; no abrupt bends, etc.

Additional Field Indicators

- Penetration resistance
- Aggregation
- Color
- Residue cover
- Infiltration
- Field respiration

>300psi can negatively impact root growth, infiltration, air exchange

Images source The Cornell Framework Manual

Important Soil Processes & Potential Indicators

Water Partitioning
- Available water capacity
- Macroaggregate stability

Soil Organic Matter Cycling
- Soil organic C (more accurate)
- Soil organic matter (typically offered; easier & cheaper)

Carbon Food Source
- Permanganate oxidizable C (Active C)

Microbial Activity
- Short-term C mineralization (respiration)
- Enzyme activities

Bioavailable N
- ACE proteins
- N mineralization

Microbial Community Composition
- Fatty acid profiling (EL-FAME)

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Soil Health Indicators - Chemical

Nutrient Availability

- NPK – Major plant nutrients
- Trace Elements

Chemical Reactivity

- pH
- Salinity / Sodicity

Nutrient Recommendations from Land Grant Universities

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Important Soil Processes & Potential Indicators

Water partitioning	• Available water capacity • Macroaggregate stability

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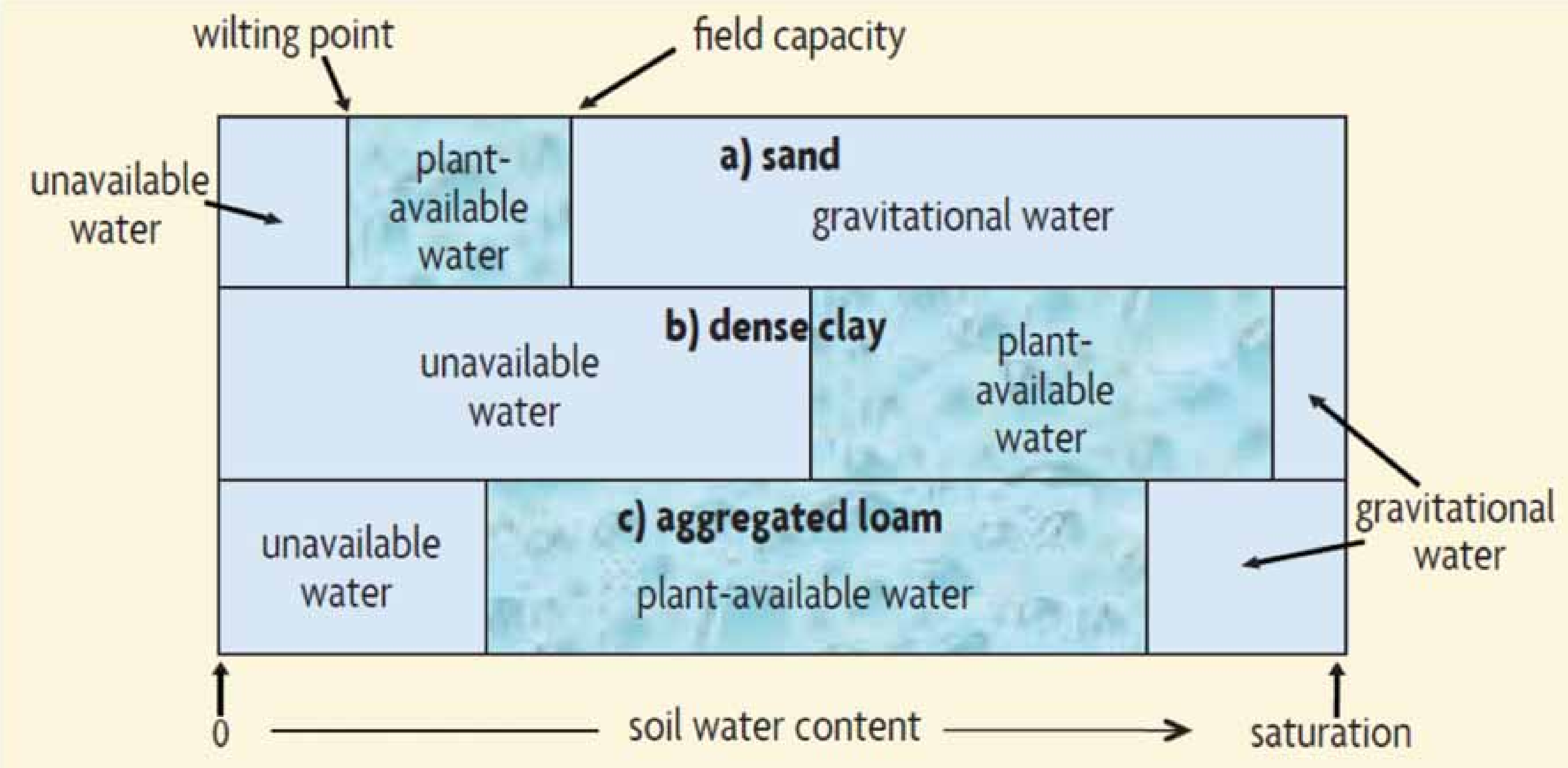
Available water-holding capacity

- Plant available
- Drought resistance
- Minimize leaching



Magdoff & van Es, 2009

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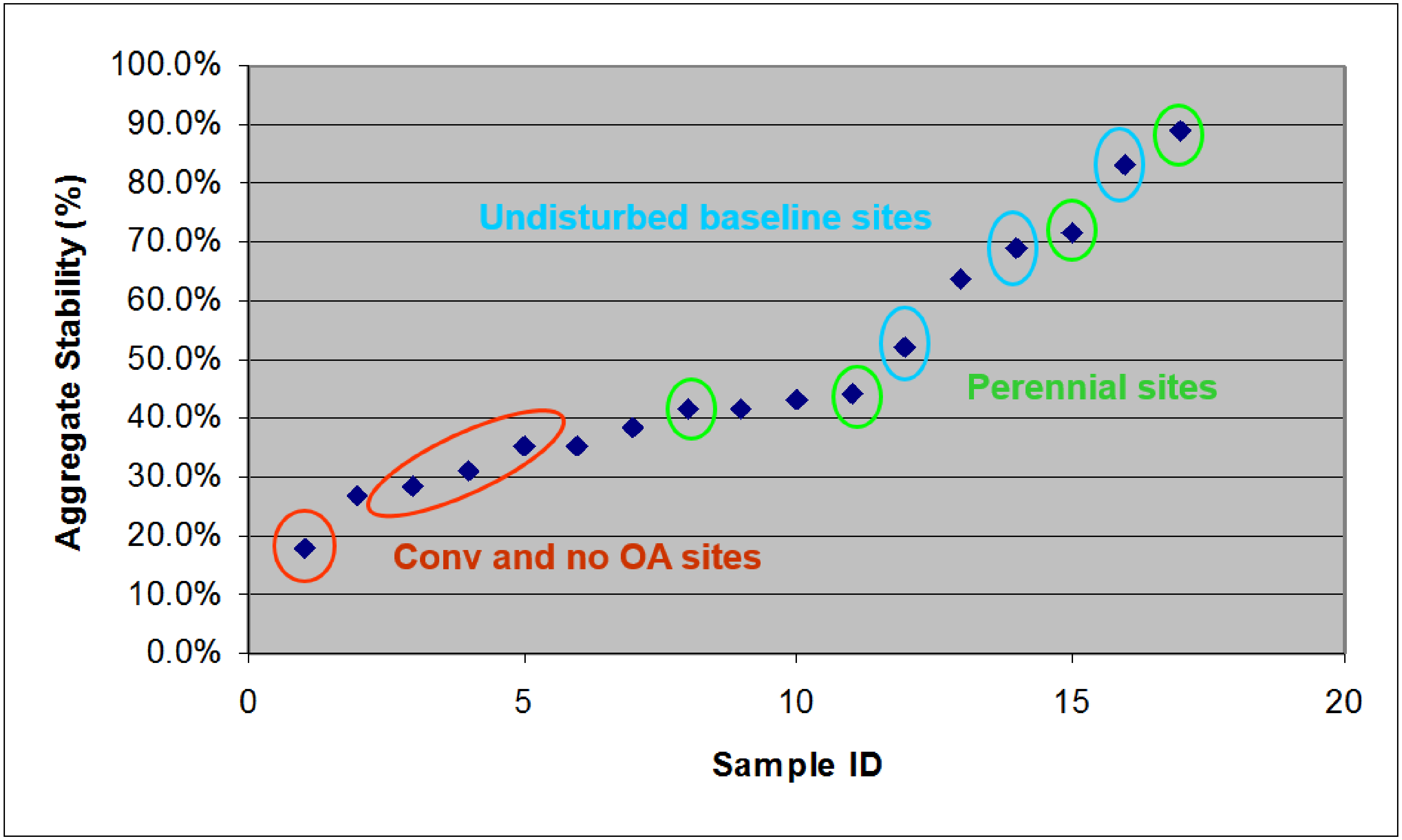
Aggregate Stability

- Resist erosion
- Infiltration & Aeration
- Biological habitat



Data source Teresa Matteson, Benton Co SWCD

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Important Soil Processes & Potential Indicators

Process	Potential Indicators
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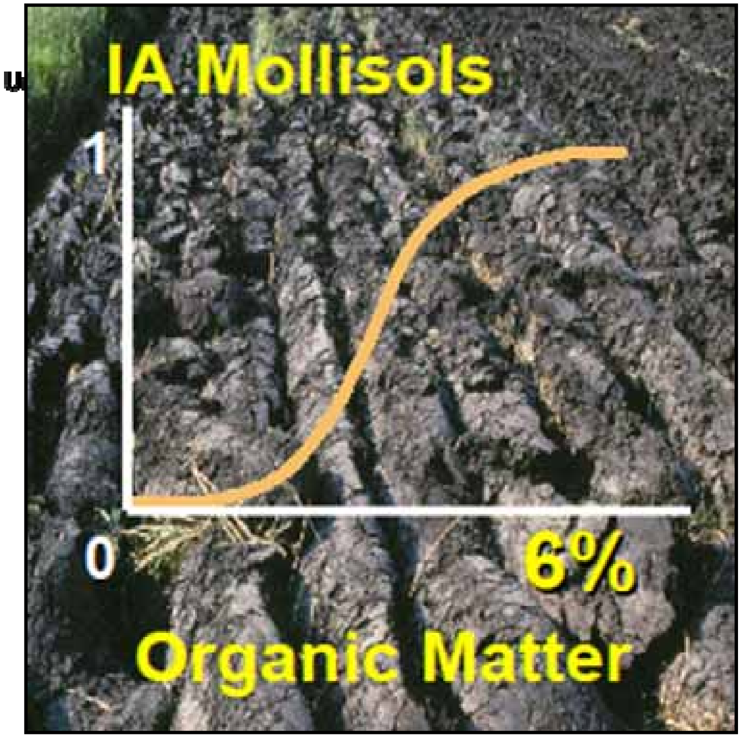
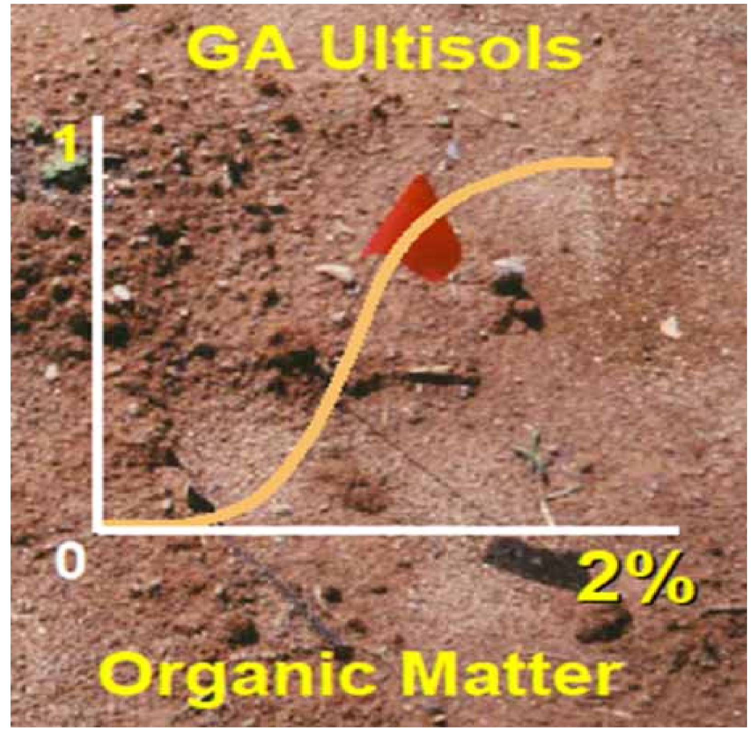
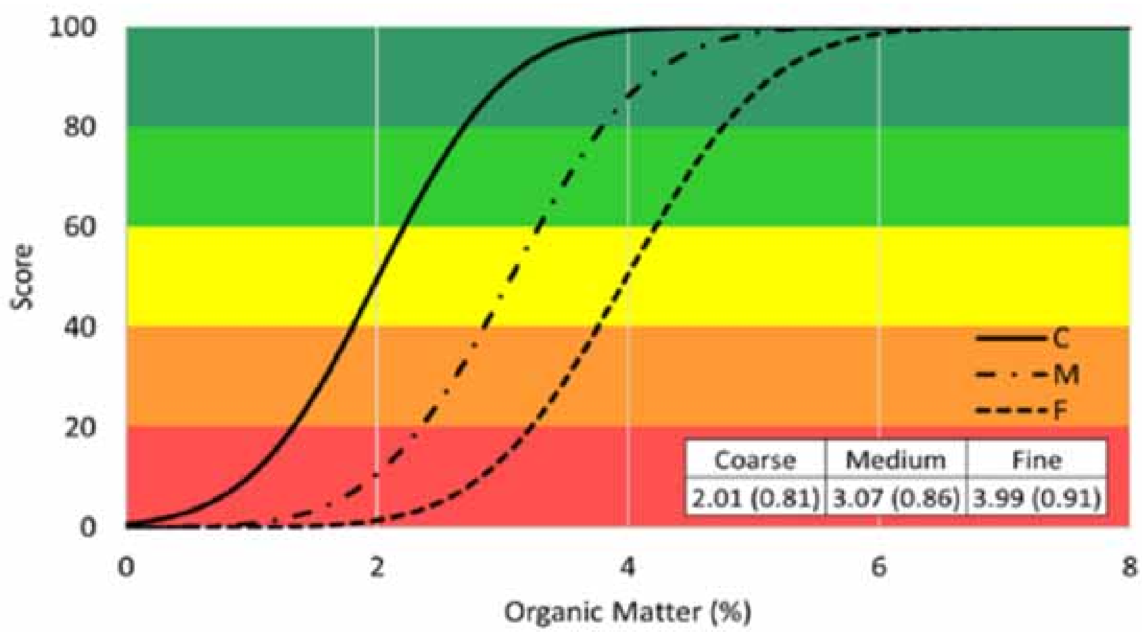

IA Mollisols
1
0
6%
Organic Matter


GA Ultisols
1
0
2%
Organic Matter


Score
100
80
60
40
20
0
0
2
4
6
8
Organic Matter (%)
C
M
F
Coarse
Medium
Fine
2.01 (0.81)
3.07 (0.86)
3.99 (0.91)

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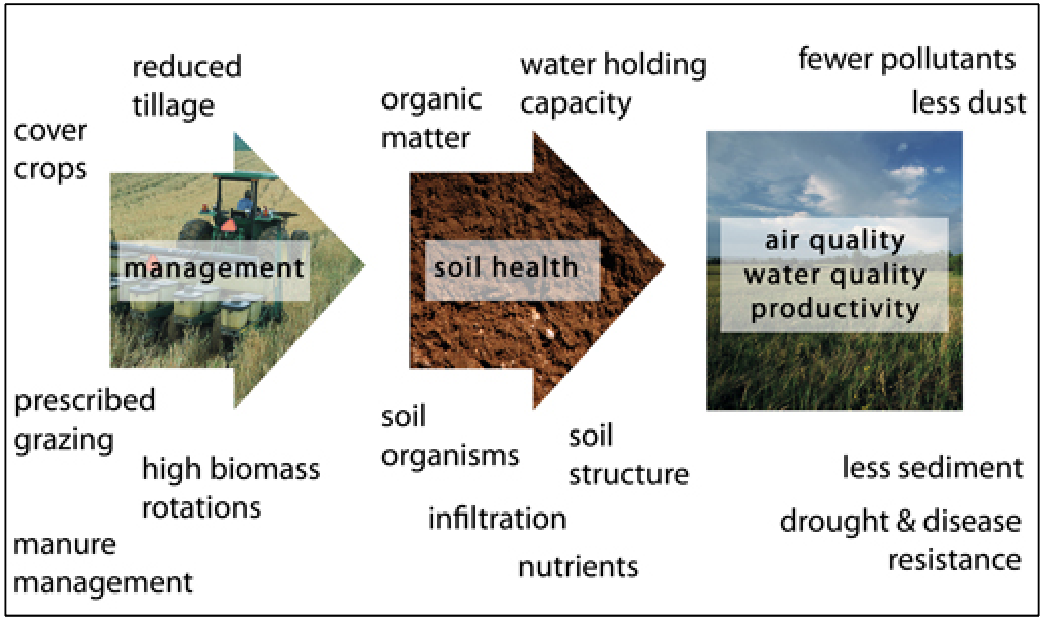
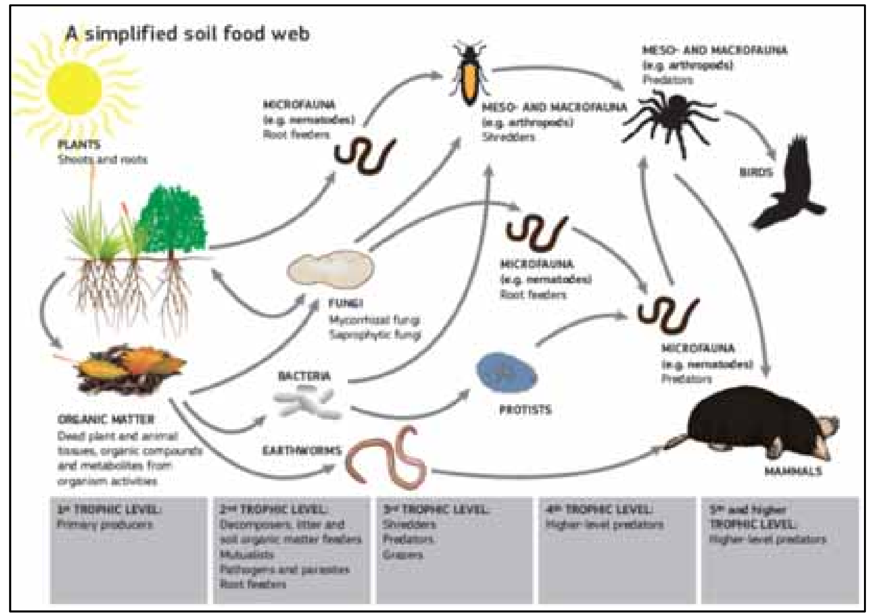
Managing SOM key to air/ H_2O quality & soil health

Carbon is the currency of soil





"Carbon can be collected (photosynthesis), spent (traded to soil organisms), saved (SOM), and is universally desired by all members of the economy." -Keith Berns

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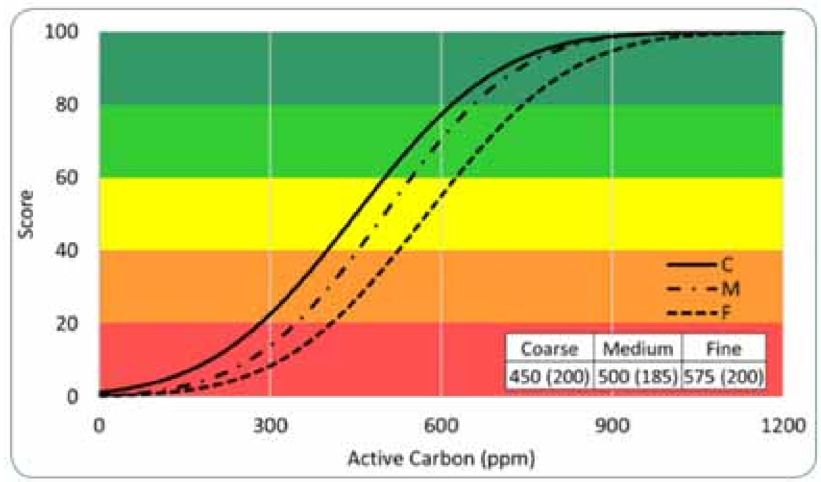
Active Carbon

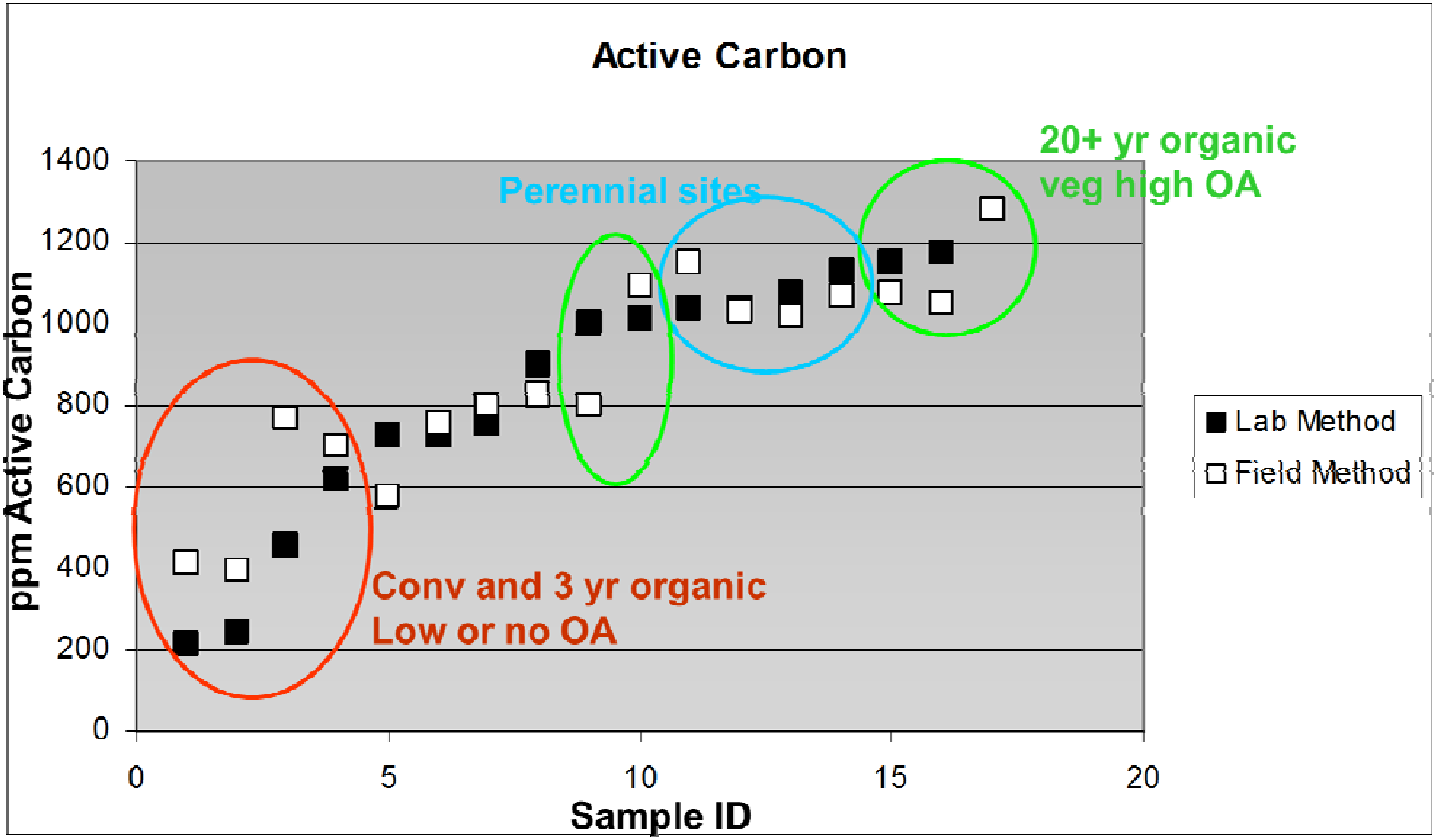
- Labile C pool
- Microbial energy source
- Early indicator of SOM +/-

Potassium permanganete ($KMnO_4$) oxidation:

- Provides an indication of the portion of organic matter that provides food and energy to soil microbes.
- Related to microbial biomass and other (more complex) measures of labile C
- More responsive than total organic C



Adapted from: Weil, R. 2005. Laboratory Manual for Introductory Soils, 7th Ed.



Data source Teresa Matteson, Benton Co SWCD

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Important Soil Processes & Potential Indicators

Process	Potential Indicators
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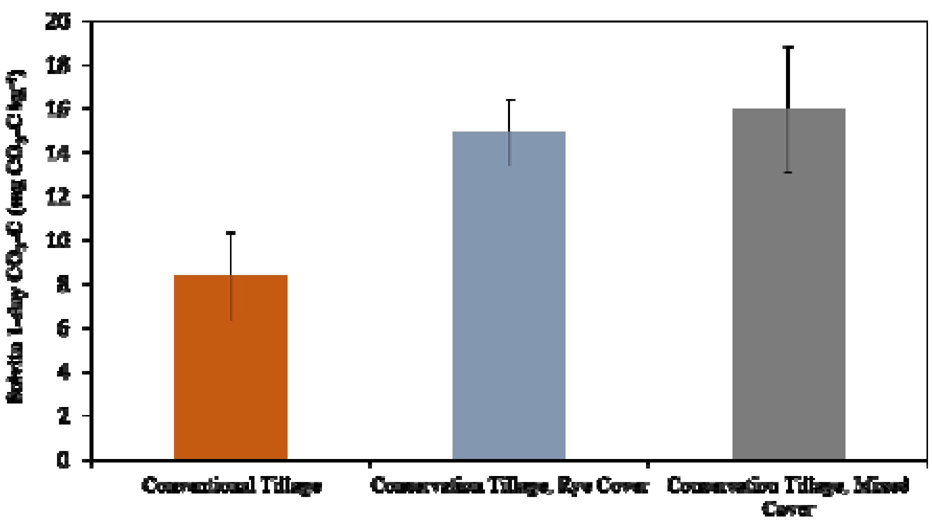
Microbial Activity	• Short-term C mineralization (respiration) • Enzyme activities
Bioavailable N	• ACE proteins • Potentially mineralizable nitrogen

Carbon Mineralization

- Biological activity
- Decomposition
- Nutrient cycling

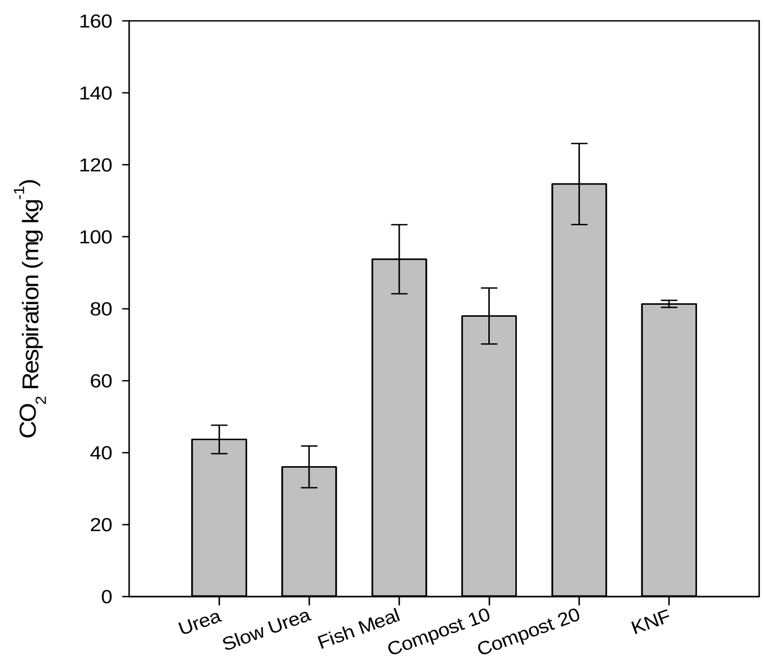
Reduced till treatments with cover had <u>~2x higher CO_2 burst levels</u> than conventional till cotton systems



Mixed Cover includes: hairy vetch (*Vicia villosa* Roth), radish (*Raphanus sativus* L.), Winter pea (*Pisum sativum* L.), and rye (*Secale cereal* L.)

Ongoing Texas research, unpublished data; J. Burke and K. Lewis

Organic amendments had <u>~2-3x higher CO_2 burst levels</u> than conventional N fertilizers



Ongoing Hawaiian research, unpublished data; J. Deenik and S. Crow

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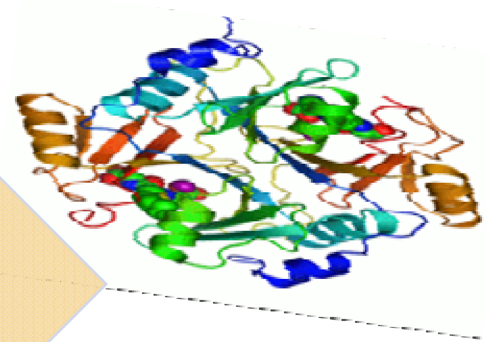
Enzyme activities

- Biological activity
- Decomposition
- Nutrient cycling



Enzyme activities: extractions of enzymes excreted by soil microbes are responsible for transforming nutrients and forming soil organic matter

Carbon cycling
Breakdown of cellulose, chitin, and other C-containing compounds release sugars and carbohydrates that fuel microbes

Nitrogen cycling
Release of ammonium, amino-sugars from the breakdown of organic N compounds (urea, amides, proteins, amino acids, etc.)

Phosphorus cycling
Release of phosphate from organophosphates

Sulfur cycling
Sulfatases release sulfate from organosulfates

Degradation of organic contaminants
– oxidases and hydrolases

Degradation of lignin/ complex SOM– phenol oxidases and peroxidases

Images source The Cornell Framework Manual

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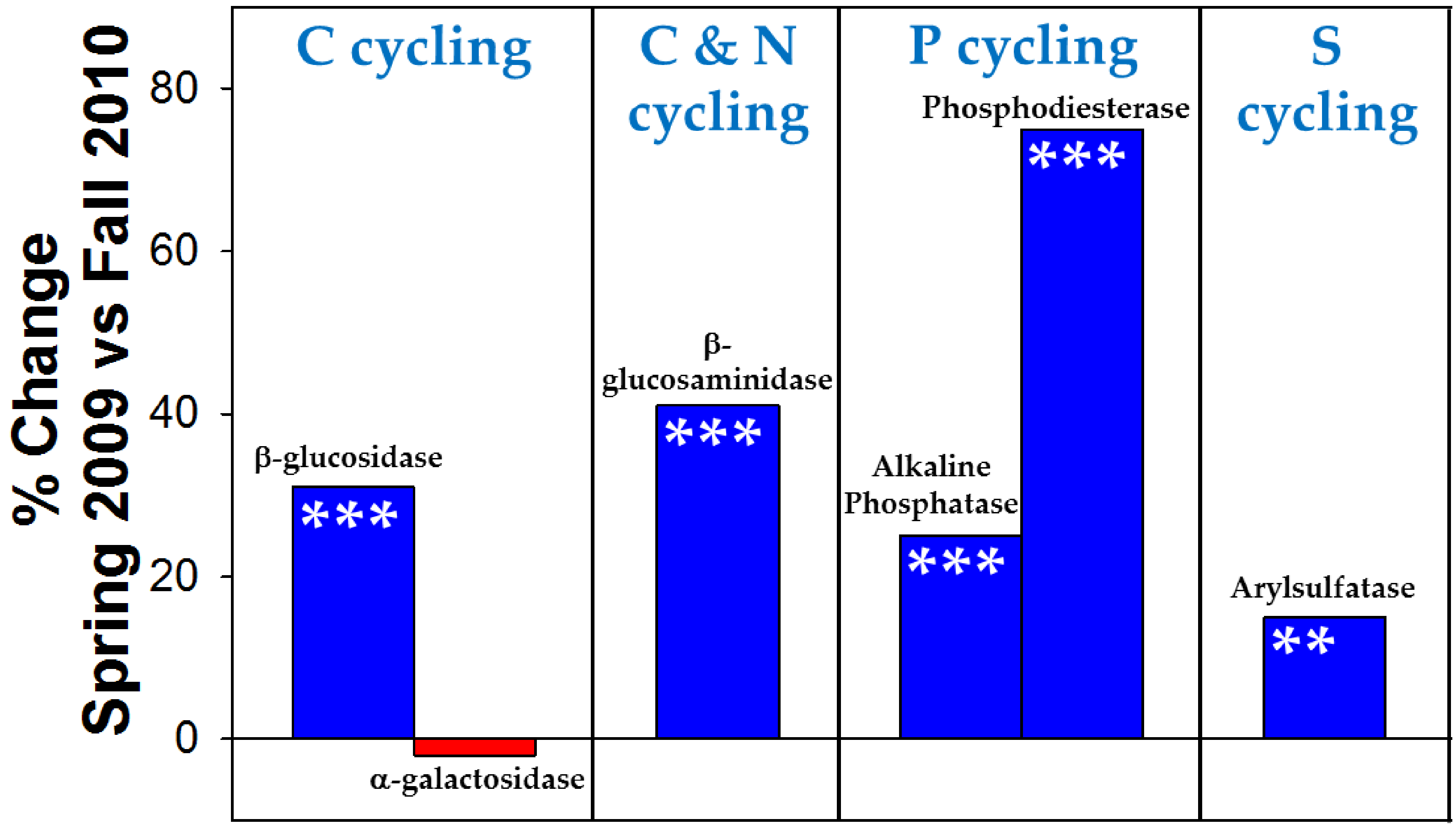
Enzyme activities increased 17-75% following transition from cotton to biofuel sorghum (after only 1 year)



Cotton et al., 2013. Biol Fert Soils 49:403-413

Soil protein

- Labile N pool
- Microbial energy source
- N cycling

		Soil organic matter (%)	Active Carbon (ppm)	Soil protein (mg/g)	Soil Respir. (mg/g)
All Practices Combined (9 paired fields)	**With**	2.2	461	5.3	0.5
	Without	1.8	374	4.0	0.4
	Effects and potential	☺	☺	☺	☺
Organic Amendments	**With**	2.6	566	6.4	0.6
	Without	2.2	480	4.6	0.4
	Effects and potential	☺	😐	☺	☺
Green Manures	**With**	1.9	364	4.6	0.4
	Without	1.5	329	3.6	0.3
	Effects and potential	☺	😐	☺	😐

Effects on soil

☺ **Positive effect (P < 0.05 probability level)**

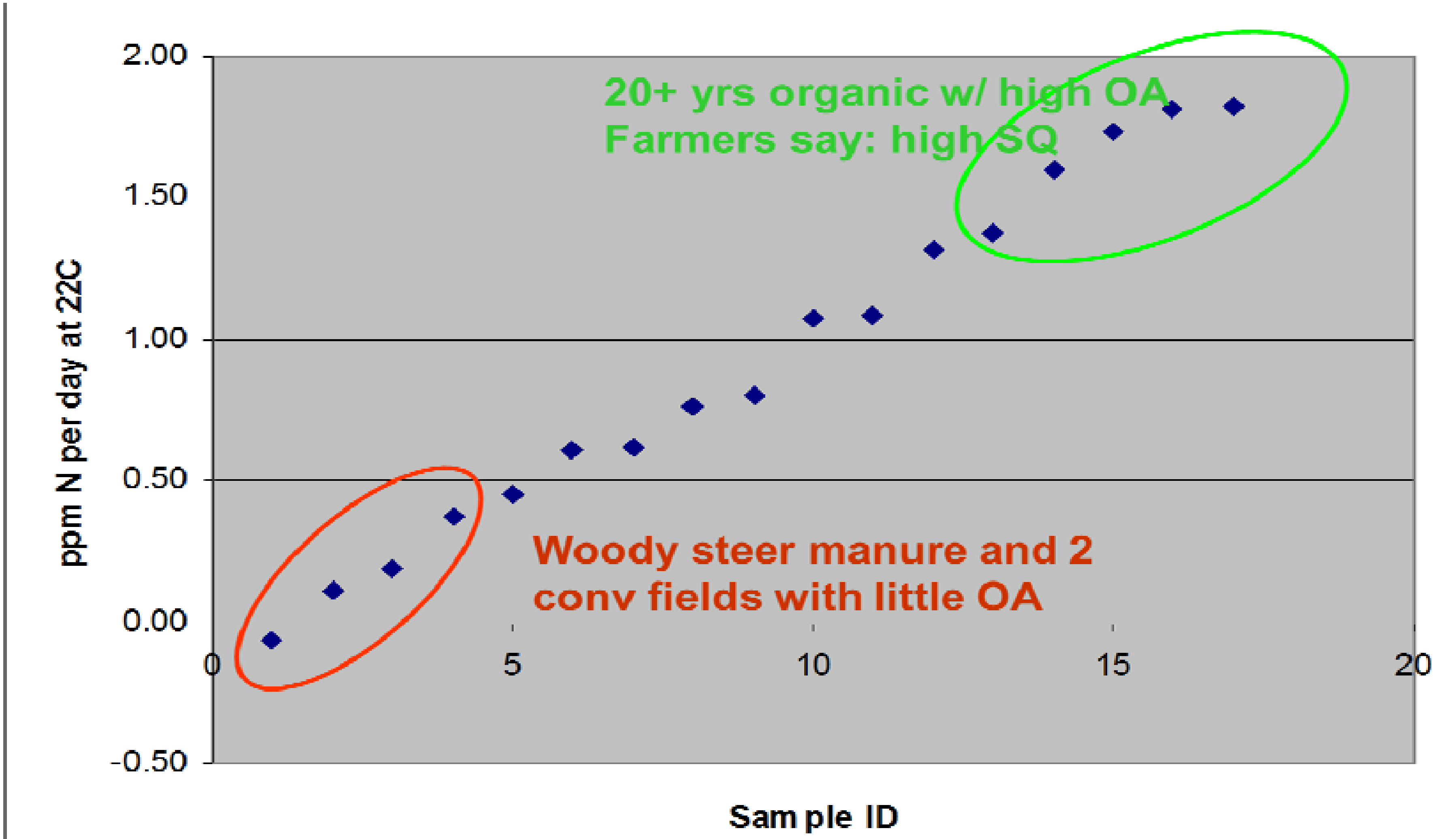
😐 **No effect**

Data courtesy David Granatstein, WSU

Images source The Cornell Framework Manual

Potentially mineralizable N

- Conversion organic N to plant available forms
- Biological activity
- N release



Data source Teresa Matteson, Benton Co SWCD

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Bioavailable N	• ACE proteins • N mineralization
Microbial Community Composition	• Fatty acid profiling (EL-FAME)

Microbial community

- Overall microbial biomass (MB)
- Fungi:Bacteria
- Broad taxonomic groups

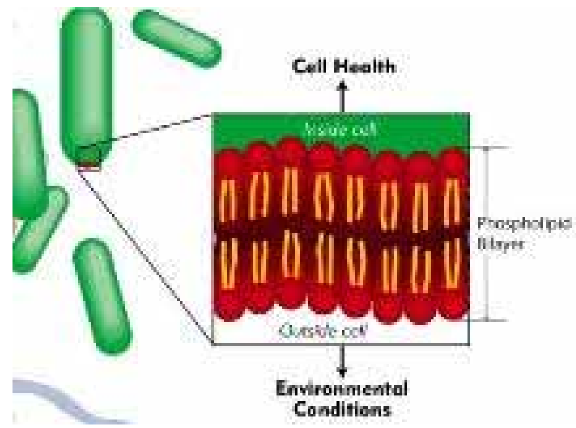
- MB makes up to 5% of total SOC
- MB holds up to 50 lb N/ac
- Very sensitive to management changes
- Single measurements difficult to interpret but trends over time provide insights to management effects on microbes
- Different microbial groups provide indication of functional shifts due to management

Microbial community

- Ester-linked fatty acid methyl ester profiling
- (EL-FAME)

What are fatty acids?

- Essential cellular components that help form a protective layer around cells.
- All organisms except Archaea have ester-linked fatty acids
- Different types of 'tails' are biomarkers of different microbial groups



Total & Bacterial FAME Biomarkers & Interpretation

Microbial Group	Generalizations for interpretation
Total PLFA	Proxy for total microbial biomass (C flow)
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

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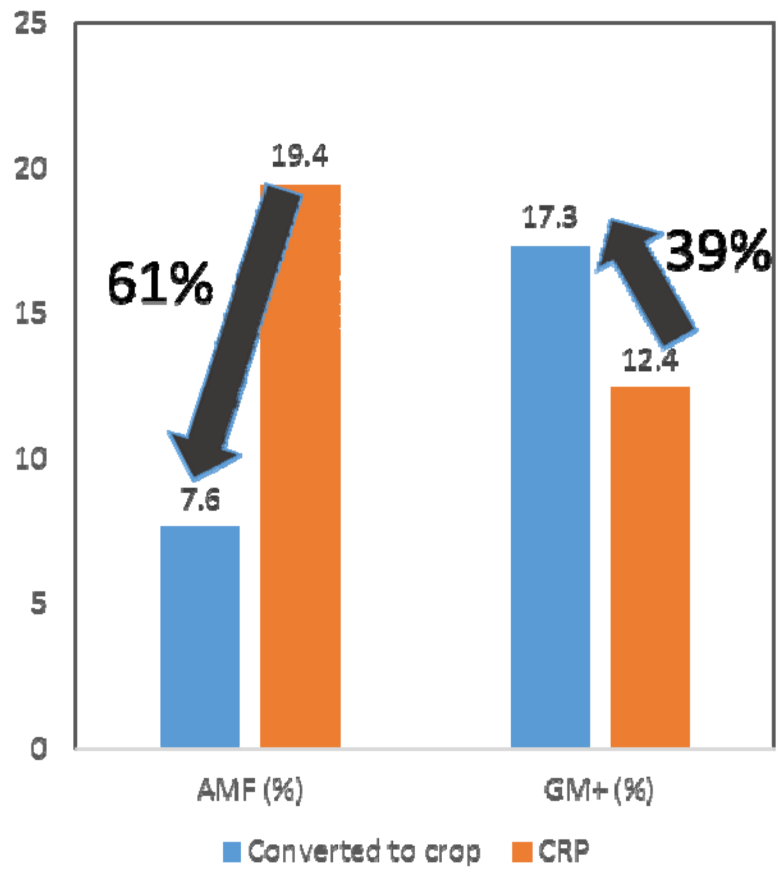
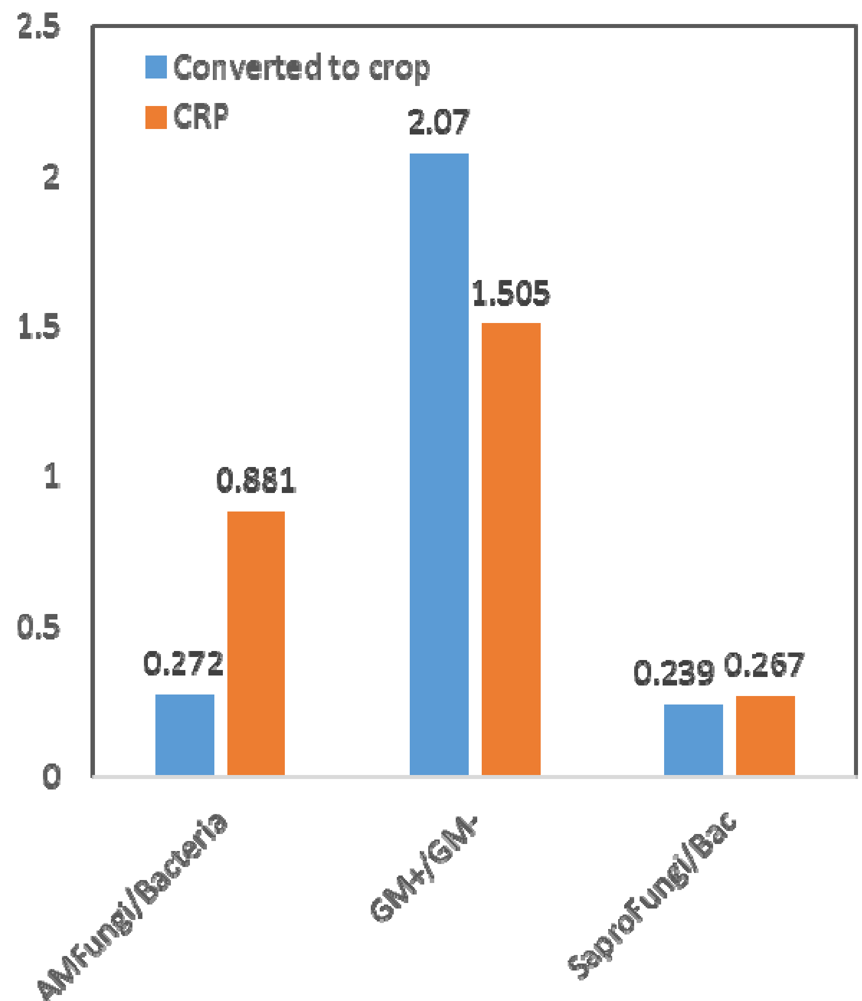
Fungal & Protozoan FAME Biomarkers & Interpretation

Group	Generalizations for interpretation
Saprophytic fungi	Associated with high organic matter; complex SOM decomp; low pH;
Ectomycorrhizae	Associated with woody species; Same biomarkers as saprophytic fungi so ecosystem type important for interpretation
Arbuscular mycorrhizae	Higher in less (physically) disturbed lands; important for aggregation, P, H_2O uptake, plant protection
F:B ratio	Higher values generally associated with greater functional benefits and less soil disturbance
Protozoa (possibly also nematodes)	N mineralization; population control

Within 5 years following conversion of CRP to cropland, AMF ↓61%, 39% ↑ GM+





Li, C. et al. (unpublished data)

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Example using Cornell Assessment for Soil Health

Measured Soil Textural Class: **silty clay loam**

Sand: **6%** - Silt: **66%** - Clay: **27%**

chemical	Soil pH	**6.4**	**100**
chemical	Extractable Phosphorus	**7.0**	**100**
chemical	Extractable Potassium	**359.9**	**100**
chemical	Minor Elements Mg: 482.7 / Fe: 1.7 / Mn: 9.6 / Zn: 2.9		**100**

Measured Soil Textural Class: **silty clay loam**

Sand: **8%** - Silt: **60%** - Clay: **30%**

chemical	Soil pH	**6.7**	**100**
chemical	Extractable Phosphorus	**3.4**	**96**
chemical	Extractable Potassium	**364.8**	**100**
chemical	Minor Elements Mg: 545.7 / Fe: 1.1 / Mn: 8.6 / Zn: 0.5		**100**

Soil Health Management Planning Process Overview

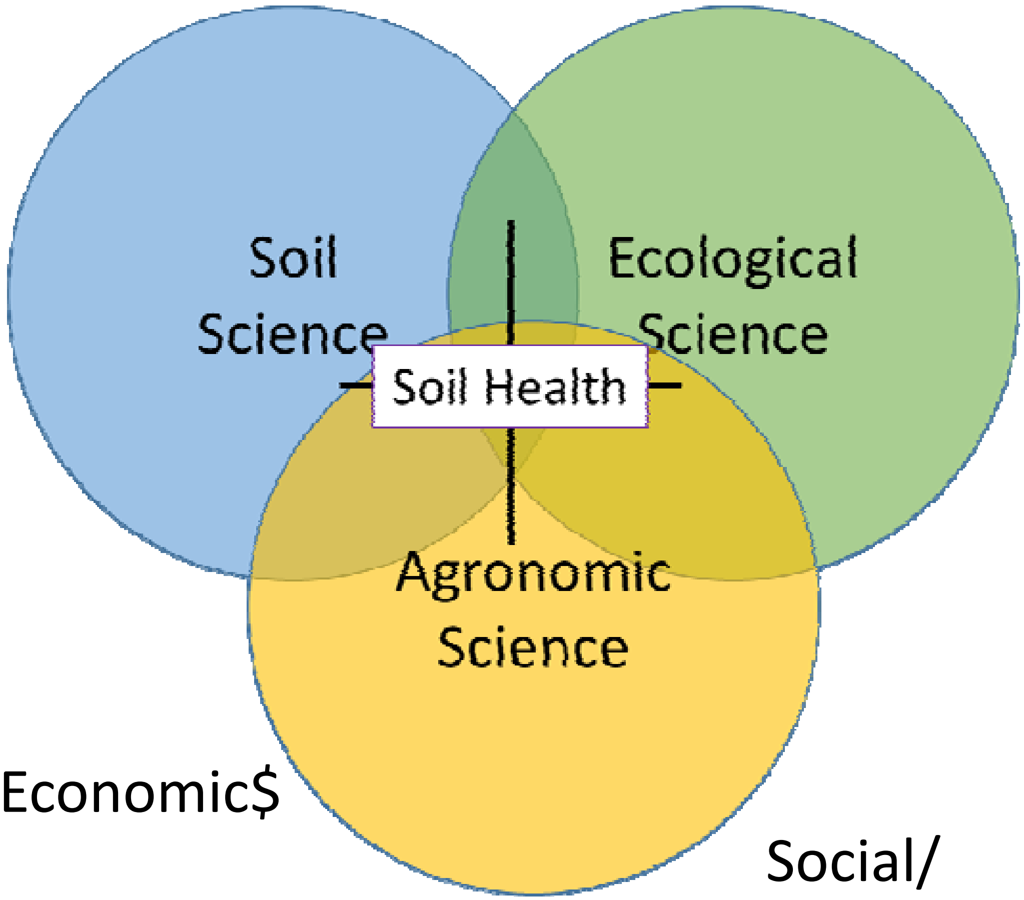
1. Determine farm background & management history
2. Set goals and sample for soil health
3. For each management unit: identify and explain constraints, prioritize
4. Identify feasible management options
5. Create short and long term soil health management plan
6. Implement, monitor, and adapt

Management Strategies

Table 5. Suggested management strategies for addressing soil health constraints

	Suggested Management Practices	
	Short term or intermittent	Long term
Physical Concerns		
Low aggregate stability	Fresh organic materials (shallow-rooted cover/rotation crops, manure, green clippings)	Reduced tillage, surface mulch, rotation with sod crops
High surface density	Limited mechanical soil loosening (e.g. strip tillage, aerators); shallow-rooted cover crops, bio-drilling, fresh organic matter	shallow-rooted cover/rotation crops; avoid traffic on wet soils; controlled traffic
High subsurface density	Targeted deep tillage (zone building, etc.); deep rooted cover crops	Avoid plows/disks that create pans; reduced equipment loads/traffic on wet soils
Biological Concerns		
Low organic matter content	Stable organic matter (compost, crop residues high in lignin, biochar); cover and rotation crops	Reduced tillage, rotation with sod crops
Low active carbon	Fresh organic matter (shallow-rooted cover/ rotation crops, manure, green clippings)	Reduced tillage, rotation
Low mineralizable N (Low PMN)	N-rich organic matter (leguminous cover crops, manure, green clippings)	Cover crops, manure, rotations with forage legume sod crop, reduced tillage
Low mineralizable N (Low PMN)	N-rich organic matter (leguminous cover crops, manure, green clippings)	Cover crops, manure, rotations with forage legume sod crop, reduced tillage
Chemical concerns	See also soil fertility recommendations	
Unfavorable pH	Liming materials or acidifier (such as sulfur)	Repeated applications based on soil tests
Low P, K and Minor elements	Fertilizer, manure, compost, P-mining cover crops, mycorrhizae promotion	Application of P, K materials based on soil tests; increased application of sources of organic matter; reduced tillage

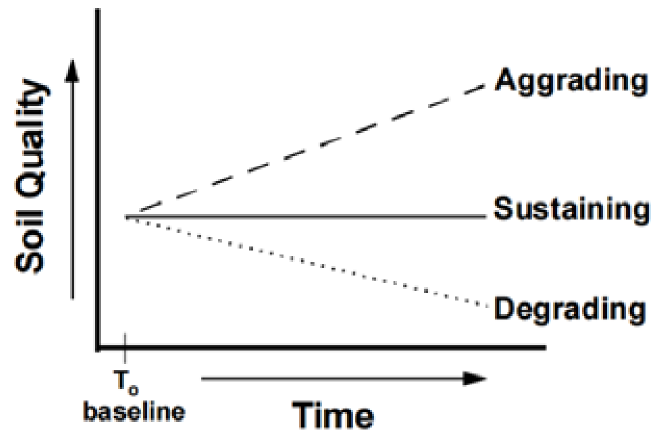
Diverse Skillset Necessary for Proper Interpretation



$Economic$

Local/ regional/ global

Social/ Cultural



Adapted from Seybold et al., 1998.

Soil Health Assessments and Soil Health Management Plans

- Soil health assessments provide greater insights to management impacts on how the overall system functions compared to traditional soil tests.
- Soil biological indicators are very sensitive but further standardization is needed to improve interpretations.
- Need comprehensive Soil Health Management Planning and Adaptive Implementation for Progress in Soil & Water Conservation

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National and Local Efforts

- National and local/regional efforts underway to improve scoring functions/ interpretations…
- National Soil Health Assessment Initiative (NRCS-SHD)
- Teresa Matteson led Benton County Soil Quality Project beginning in 2009
- Expanded this past year in collaboration with NRCS and OSU-CAL to identify soil health assessments and interpretations and develop a database specific for this region

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Thank You!

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