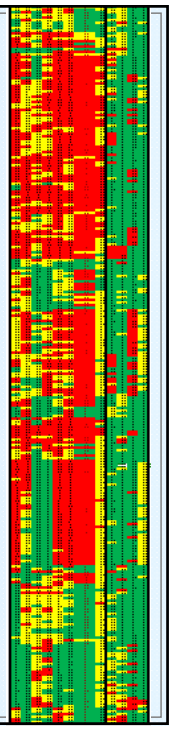
Andrew Sparda
Horizons in Soil Health

Center For Sustainability
Cal Poly
San Luis Obispo, California
May 15, 2015

Now a National Focus:
Today's soils are limited by their HEALTH

- Beyond nutrient limitations and excesses
- Biological and physical limitations:
  - Limit resilience to drought and extreme rainfall, Pests
  - Impact crop quality, yield
  - Demand expensive inputs
- Need to understand agroecosystems as systems with many interconnected parts
- Need to identify and understand constraints and manage them explicitly



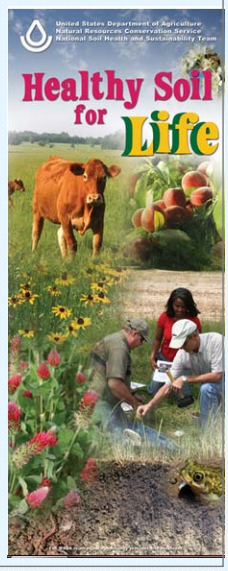
USDA - NRCS

Bianca received her Masters and Ph.D under van Es here at Cornell

New NRCS Soil Health Division with 20 specialists

Bianca Moebius- Clune

Great YouTube videos on the Science of Soil Health:http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/health/?cid=stelprdb1245890



Soil Health Sampling & Submission

http:// soilhealth.cals.cornell.edu

- Packages
- Sampling instructions
- Submission form

On-line submission form in 2015

- Soil Health Manual →

Updated edition for 2015

- Samples are sent to Cornell Nutrient Analysis Lab (CNAL)
- NY growers receive Nutrient Guidelines in ~10 days from AgroOne

CSHT Report sent out in 4 weeks

Cornell Soil Health Assessment

Publically available since 2006, revised 2014 with new indicators

Identifies soil constraints

Measures 16 indicators

- Representing agronomically important bio/phys soil processes
- Includes standard nutrient test

Guide for management decisions

- Measures interpreted with scoring functions
- Report now includes explicit written interpretations and management suggestions table

Cornell Soil Health Assessment

Bob Schindelbeck
1004 Bradfield Hall, Cornell Univ.
Ithaca, NY, 14853

Agricultural Service Provider:
Schindelbeck, Bob
Dept. of Crop and Soil Science
ris3@cornell.edu

Sample ID: L_77
Field/Treatment: CF intensely cultivated
Tillage: 7-9 inches
Crops Grown: WHT, WHT
Date Sampled: 5/7/2014
Given Soil Type: Collamer
Given Soil Texture: No Soil Texture Given
Coordinates: Coordinates Not Provided

Measured Soil Textural Class: Silt Loam Sand: 2% Silt: 83% Clay: 15%

Test Report

	Indicator	Value	Rating	Constraint
Physical	Available Water Capacity	0.14	36	
	Surface Hardness	260	15	Rooting, Water Transmission
	Subsurface Hardness	340	30	Subsurface Pan/Deep Compaction, Deep Rooting, Water and Nutrient Access
	Aggregate Stability	15.7	16	Aeration, Infiltration, Rooting, Crusting, Sealing, Erosion, Runoff
Biological	Organic Matter	2.5	22	Nutrient and Energy Storage, Ion Exchange, C Sequestration, Water Retention
	ACE Soil Protein Index	5.1	24	Organic Matter Quality, Organic N Storage, N Mineralization
	Root Pathogen Pressure	3.2	73	
	Respiration	0.53	0	Soil Microbial Abundance and Activity
	Active Carbon	288	4	Energy Source for Soil Biota
Chemical	pH	6.5	100	
	Phosphorus	20.0	100	
	Potassium	150.6	100	
	Minor Elements (Mg 131 · Fe 3.2 · Mn 12.9 · Zn 0.3)		100	
	Overall Quality Score		48	Low

ACE Soil Protein Index

Soil Protein Measurement

- 3g soil shaken with 24ml extractant
- 20 mM sodium citrate buffer, pH 7.0
- Autoclaved 30 min @ 121 °C, 15 p.s.i
- Total protein in extract quantified using BCA assay

Why Measure Protein?

- Organic Matter in soil comes from biomass (plant, fungal, bacterial, and some animal)
- Biomass composed of cellulose, cellular proteins, chitin, carbohydrates, lipids and some other materials
- Of these, Proteins highest in organically bound N
- Measured (stored) protein reveals nitrogenous reserves (organic matter "quality")
- Microbial activity can mineralize this N, making it plant available

Soil Microbial Activity: Respiration

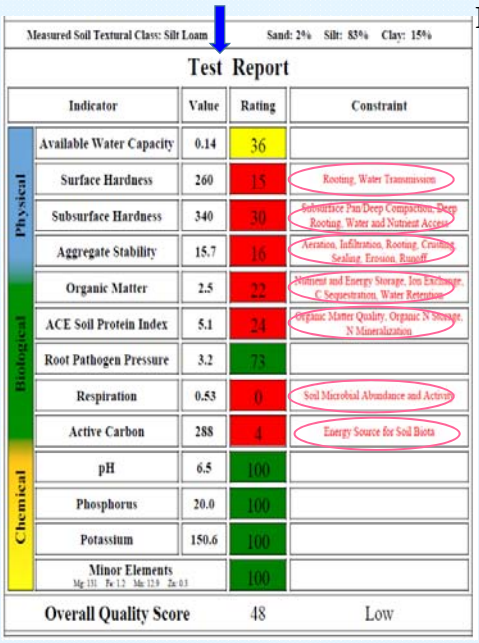
Sealed Chamber Alkali Trap Respirometry

- 20g air dried soil
- Rewet by capillary action
- 9ml 0.5M KOH -- traps released CO_2 as CO_3^{2-}
- Trapped CO_3^{2-} quantified by conductivity drop in KOH

Why Measure Respiration?

- Respiration is a measure of the <u>metabolic activity</u> of the soil microbial community
- Microbial activity important functionally
  - Cycling of nutrients into and out of soil OM pools
  - Solubilization and transport
  - Most N transformations
  - Breakdown of incorporated residues
- Soil biological activity influences key physical characteristics
  - OM accumulation
  - Aggregate formation and stabilization

Cornell Soil Health Assessment



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Chemical	pH	6.5	100	
	Phosphorus	20.0	100	
	Potassium	150.6	100	
	Minor Elements (Mg 131 Fe 1.2 Mn 12.9 Zn 0.1)		100	
	Overall Quality Score		48	Low

Page 1

- **Assesses soil chemical, physical and biological functioning**
- **Process oriented**
- **Measures indicators**
- **Uses scoring functions (see page 2)**
- **Overall score**
- **Targeted management suggestions (see pages 9-10)**

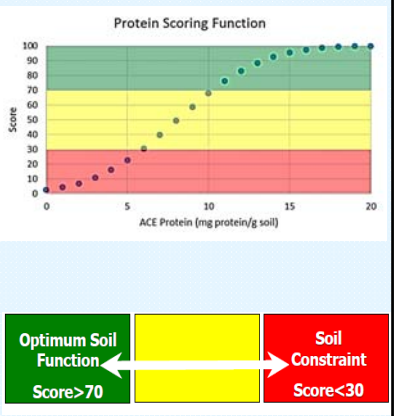
Cornell Soil Health Assessment Page 2

Measured Soil Health Indicators

The Cornell Soil Health Test measures several indicators of soil physical, biological and chemical health. These are listed on the left side of the report summary, on the first page. The "value" column shows each result as a value, measured in the laboratory or in the field, in units of measure as described in the indicator summaries below. The "rating" column interprets that measured value on a scale of 0 to 100, where higher scores are better. Ratings in red are particularly important to take note of, but any in yellow, particularly those that are close to a rating of 30 are also important in addressing soil health problems.

- A rating of 30 or less indicates a *Constraint* and is color-coded red. This indicates a problem that is likely limiting yields, crop quality, and long-term sustainability of the agroecosystem. In several cases this indicates risks of environmental loss as well. The "constraint" column provides a short list of soil processes that are not functioning optimally when an indicator rating is red. It is particularly important to take advantage of any opportunities to improve management that will address these constraints.
- A rating between 30 and 70 indicates *Suboptimal* functioning and is color-coded yellow. This indicates that soil health could be better, and yield and sustainability could decrease over time if this is not addressed. This is especially so if the condition is being caused, or not being alleviated, by current management. Pay attention particularly to those indicators rated in yellow and close to 30.
- A rating of 70 or greater indicates *Optimal or near-optimal* functioning and is color-coded green. Past management has been effective at maintaining soil health. It can be useful to note which particular aspects of management have likely maintained soil health, so that such management can be continued. Note that soil health is often high, when first converting from a permanent sod or forest. In these situations, intensive management quickly damages soil health when it includes intensive tillage, low organic matter inputs, bare soils for significant parts of the year, or excessive traffic, especially during wet times.

Scoring Function strategy



Cornell Soil Health Assessment Pages 3-8

- Defines the processes each indicator represents
- Relationship to soil management

Aggregate Stability is a measure of how well soil aggregates or crumbs hold together under rainfall or other rapid wetting stresses. Measured by the fraction of dried aggregates that disintegrate under a controlled, simulated rainfall event similar in energy delivery to a hard spring rain, the value is presented as a percent, and scored against a distribution observed in regional soils with similar textural characteristics. A physical characteristic of soil, Aggregate Stability is a good indicator of soil biological and physical health. Good aggregate stability helps prevent crusting, runoff, and erosion, and facilitates aeration, infiltration, and water storage, along with improving seed germination and root and microbial health. Aggregate stability is influenced by microbial activity, as aggregates are largely held together by microbial colonies and exudates, and is impacted by management practices, particularly tillage, cover cropping, and fresh organic matter additions.

- Interpretation of each test score
- Management prioritization

Your measured Aggregate Stability value is **15.7%**, corresponding with a score of **16**. This score is in the **Low** range, relative to regional soils with similar texture. **Aggregate Stability should be given a high priority in management decisions based on this assessment, as it is likely to be an important constraint to proper soil functioning and sustainability of management at this time.** Please refer to the management suggestions table at the end of this document.

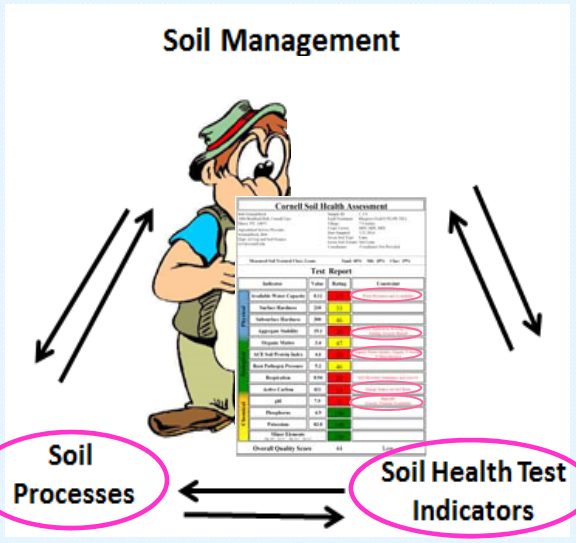
Cornell Soil Health Assessment Pages 9-10

Management Suggestions for Physical and Biological Constraints

Constraint	Short Term Management Suggestions	Long Term Management Suggestions
Available Water Capacity Low	• Add stable organic materials, mulch • Add compost or biochar • Incorporate [illegible]	• Reduce tillage • Rotate with sod crops • Incorporate high biomass cover crop
Surface Hardness High	• Perform some [illegible] (strip till, aerators, [illegible]) • Use shallow-rooted [illegible] • Use a living mulch or interseed cover crop	• Shallow-rooted cover/rotation crops • Avoid traffic on wet soils, monitor • Avoid excessive traffic/tillage/loads • Use controlled traffic patterns/lanes
Subsurface Hardness High	• Use targeted deep tillage (subsoiler, yeomans plow, chisel plow, spader.) • Plant deep rooted cover crops/radish	• Avoid plows/disks that create pans • Avoid heavy loads • Reduce traffic when subsoil is wet
Aggregate Stability Low	• Incorporate fresh organic materials • Use shallow-rooted cover/rotation crops • Add manure, green manure, mulch	• Reduce tillage • Use a surface mulch • Rotate with sod crops and mycorrhizal hosts
Organic Matter Low	• Add stable organic materials, mulch • Add compost and biochar • Incorporate high biomass cover crop	• Reduce tillage/mechanical cultivation • Rotate with sod crop • Incorporate high biomass cover crop
Soil Protein Index Low	• Add N-rich organic matter (low C:N source like manure, high N well-finished compost) • Incorporate young, green, cover crop biomass • Plant legumes and grass-legume mixtures • Inoculate legume seed with Rhizobia & check for nodulation	• Reduce tillage • Rotate with forage legume sod crop • Cover crop and add fresh manure • Keep pH at 6.2-6.5 (helps N fixation) • Monitor C:N ratio of inputs
Root Pathogen Pressure High	• Use disease-suppressive cover crops • Plant on ridges/raised beds • Monitor irrigation • Biofumigate	• Use disease-suppressive cover crops • Increase diversity of crop rotation • Sterilize seed and equipment • Improve drainage/monitor irrigation
Respiration Low	• Maintain plant cover throughout season • Add fresh organic materials • Add manure, green manure • Consider reducing biocide usage	• Reduce tillage/mechanical cultivation • Increase rotational diversity • Maintain plant cover throughout season • Cover crop with symbiotic host plants
Active Carbon Low	• Add fresh organic materials • Use shallow-rooted cover/rotation crops • Add manure, green manure, mulch	• Reduce tillage/mechanical cultivation • Rotate with sod crop • Cover crop whenever possible

Constrained and Suboptimal indicators are flagged in the Report management suggestions table

Soil Health Management Planning begins with grower questions..



- Where is my soil strong or weak?
- What can I do to address these issues?
- How can I "put it all together" to make a sound soil management plan?
- Can someone help me with this?

SH Management Planning Process Overview

1. Determine farm background and management history — Grower strengths

Compile background info: history by management unit, farm operation type, equipment, access to resources, situational opportunities or limitations.

2. Set goals and sample for soil health — Grower goals, soil sampling

Determine number and distribution of soil health samples needed according to operation background and goals.

3. For each management unit: identify and explain constraints, prioritize — Evaluate results

Soil Health Report identifies constraints, guides prioritization. Explain results based on background, and adjust priorities.

4. Identify feasible management options — Define options

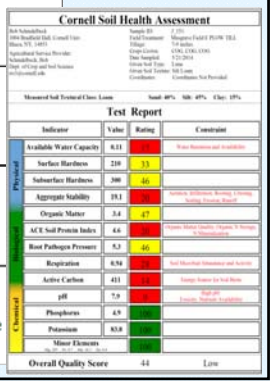
Management suggestions table available as part of Soil Health Report, or online with NRCS practice linkages

5. Create short and long term Soil Health Management Plan — Refine options

Integrate agronomic science of 2-4 with grower realities of 1 to create a specific short-term schedule of management practices for each management unit and an overall long-term strategy

6. Implement, monitor, and adapt — Implement, refine

Implement and document management practices. Monitor progress, repeat testing, and evaluate outcomes. Adapt plan based on experience and data over time.


Cornell Soil Health Assessment

Test Report

Indicator	Value	Rating	Constraint
Available Water Capacity	0.11	19	
Surface Hardness	210	33	
Subsurface Hardness	300	46	
Aggregate Stability	19.1	28	
Organic Matter	3.4	47	
ACE Soil Protein Index	4.6	28	
Root Pathogen Pressure	5.2	46	
Respiration	0.94	28	
Active Carbon	411	34	
pH	7.9	28	
Phosphorus	4.9	100	
Potassium	83.8	100	
Minor Elements		100	
Overall Quality Score		44	Low

BASIC Soil health package $50. (3-week turn-around)

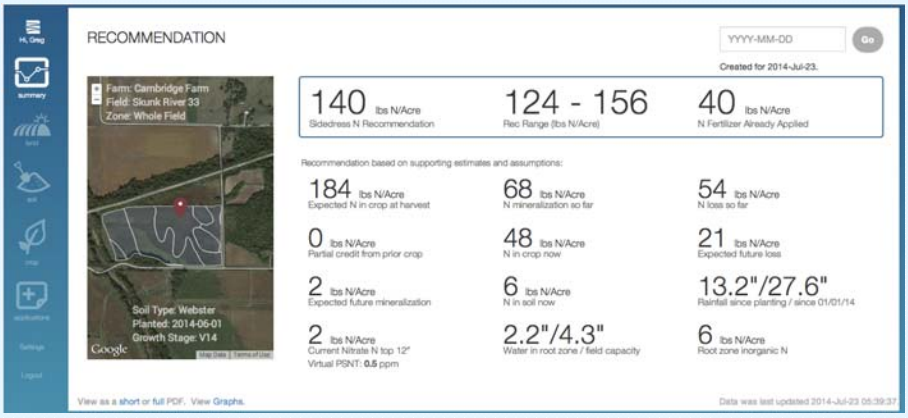
Aggregate stability- soil crumb structure related to crusting, runoff. Influenced by tillage, cover crops, OM additions

Soil hardness evaluation- collect data with field penetrometer

Respiration- a direct biological activity measurement. Affects N transformations , decomposition of residues

Nutrient analysis and OM- availability of essential nutrients

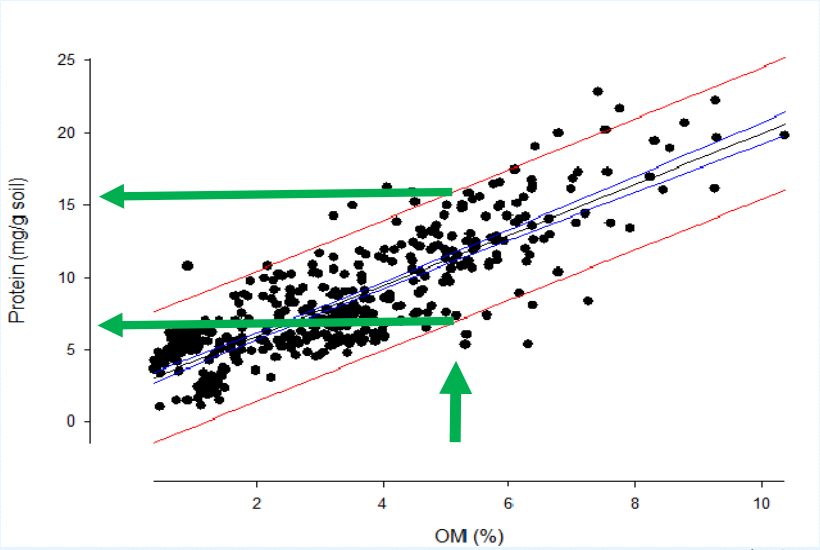
Linking Soil Health Info with Adapt-N, a cloud-based N recommendation tool



What factors does *Adapt-N* include in making a recommendation?

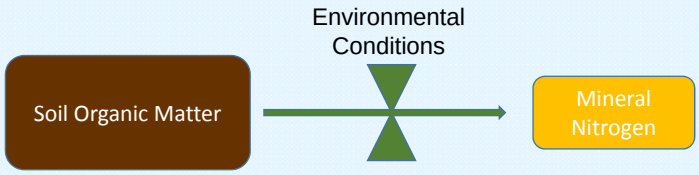
- **Weather:**
  - High resolution (4x4 km) daily P &T, and SR data
  - Irrigation amounts and dates
- **Soil:**
  - texture/soil type, slope, rooting depth**, % organic matter**
  - Tillage: fall or spring plowing; conservation tillage/residue management
  - Fertilizer and manure applications: date, rate, type, N analysis, placement
- **Crop:**
  - Cultivar; planting date, maturity class, Population and expected yield
  - Rotations: soy, corn - silage or grain, or sod - last 3 yrs, % legume, surface killed or incorporated
- **Economics**: Fertilizer and grain prices & profit loss risk

Organic matter quantity *and quality*

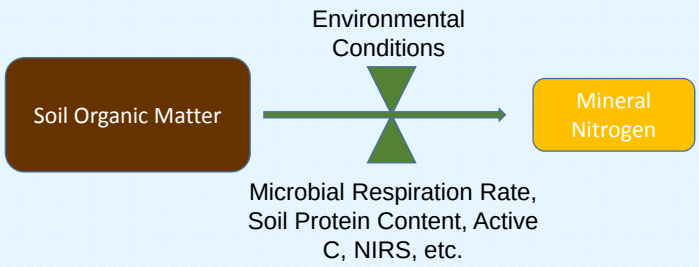


(unknown)

Adapt-N currently



Adapt-N will integrate
organic matter quality and microbial activity



How does the Cornell Assessment Compare with the Haney Test?

Potential soil health assessment complementarities

NRCS is funding a 1000+ sample study 2015-2017 where collected material will be split and set for various analyses to look for best tests to identify soil change. Meta-data analysis will look for trends of changing measured values due to soil management

Cornell Soil Health Assessment

- Physical constraints identified
- Biological constraints identified
- Bio/phys status not used to inform nutrient recs (Adapt-N does this for nitrogen)
- Various management guidelines to address constraints identified in phys/bio/chem functioning and connection to NRCS practices

Haney Soil Health Nutrient Tool

- No physical constraints
- Different, some overlapping biological constraints identified (similar respiration assay, different active C fraction)
- Bio processes inform nutrient recs for NPK
- Cover crop management recs (% legume/%grass to use) for biological functioning

Acknowledgements

The Core Development Team at Cornell University: George Abawi, Beth Gugino (now Penn State), John Idowu (now NMSU), Bianca Moebius-Clune (headed to NRCS), Dan Moebius-Clune, Bob Schindelbeck, Janice Thies, Harold van Es, David Wolfe, Many Growers and Extension Educators

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Funders:

Northern New York Agricultural Development Program

Northeast Region SARE Sustainable Agriculture Research and Education Program

NRCS Natural Resources Conservation Service

IPM Integrated Pest Management

NY farm viability INSTITUTE

USDA United States Department of Agriculture

National Institute of Food and Agriculture

Cornell University Cooperative Extension