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Evaluation of Soil Health Tests

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What is soil health?

- Indicator of environmental health
- Assessment of a given soil's fitness to function:
  - Provide suitable medium for plant growth
  - Regulate and partition water flow through the environment
  - Serve as an environmental buffer

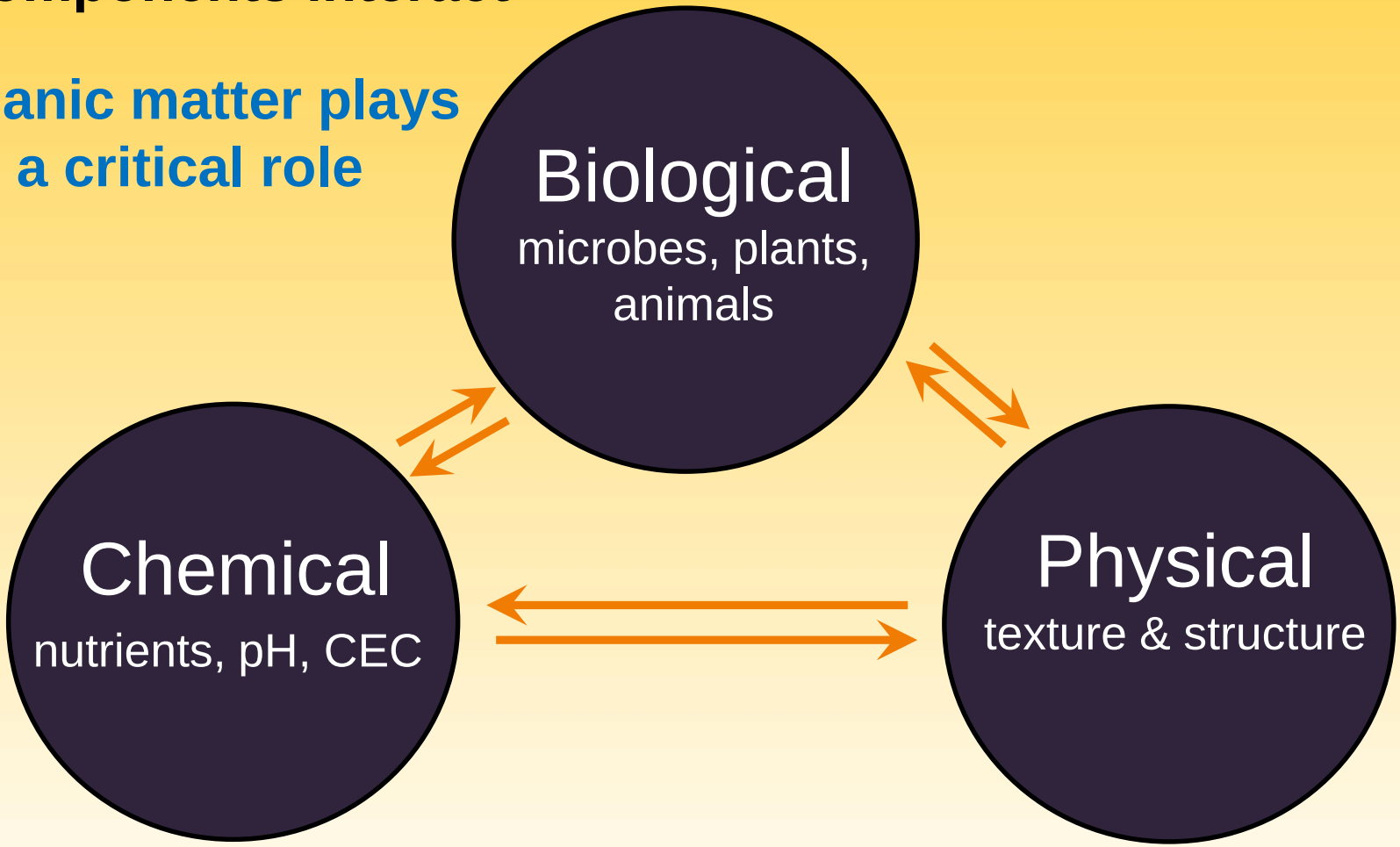
Soil quality vs soil health

- Farmers like the term soil health
  - Conveys whether soil is a robust or ailing resource
  - Soil as a *living dynamic entity* that functions in a *holistic* way, not an inanimate entity with a value that depends on its innate characteristics and intended use
- Scientists like the term soil quality
  - Defined by the interactions of a particular soil's measurable chemical, physical, and micro-biological properties
  - These properties can be *managed* and *adjusted* by farmers and *measured* to determine direction of change

Components of a Healthy Soil

All components interact

Organic matter plays a critical role



Producers describe soil health

Producers generally describe soil health subjectively, using words related to how the soil looks, feels, and smells. Asked in a U.S. survey to describe healthy soils, producers said that they

- are deeper and darker
- easier to plow
- work up more easily in the spring
- sponge up and hold more water
- dry out sooner
- break down crop residues more rapidly in the fall
- have higher organic matter and less erosion
- have greater numbers and more varieties of earthworms
- have a sweet, fresh-air smell.

They also observed that, on healthy soils,

- fuel costs are way down
- there is less wear and tear on machinery
- the tractor pulls more easily
- less fertilizer is required
- crop yields are higher
- there is a greater variety of weeds
- there are fewer problems with insects and disease
- the feed-crops produced are of better quality, and veterinary bills of animals eating this feed are lower.

What's the key to Soil Health? Organic Matter !!!

- Nutrient Cycling
  - Increases nutrient holding capacity (CEC)
  - Builds nutrient pools
  - Chelates nutrients (reduces P sorption)
  - Feeds organisms that release nutrients

- Water dynamics
  - Improves infiltration
  - Decreases evaporation
  - Increases water holding capacity
  - Improves drought resistance

and more benefits…..

- Structure
  - Reduces crusting
  - Encourages extensive root growth
  - Improves aggregation
  - Reduces erosion
  - Prevents compaction
  - Easier to work

- Other effects
  - Soil may warm more quickly
  - Enhances microbial activity (feeds the organisms that cycle nutrients)
  - Improves resistance to pests

NRCS Soil Quality Indicators

- Physical:
  - aggregate stability
  - available water capacity
  - bulk density
  - infiltration
  - slaking
- Chemical:
  - reactive carbon
  - soil electrical conductivity
  - soil nitrate
  - soil pH
- Biological:
  - earthworms
  - particulate organic matter
  - potentially mineralizable nitrogen
  - soil respiration
  - total organic carbon

Cornell University's Soil Health Assessment Manual

- soil texture
- aggregate stability
- available water capacity
- field penetration resistance
- organic matter (LOI)
- active carbon (POxC)
- potentially mineralizable nitrogen (7-d anaerobic incubation)
- root health assessment
- chemical analysis (pH, nutrients, toxic elements)

Soil carbon pools at VICMS,

long term cropping systems trial at Lamberton

rotation	system	TOC	POM-C	PMC	MBC
		g C kg^{-1} soil			
2 yr	LPI	27.6 a	2.06 b	0.96 b	0.47 a
	HPI	24.6 a	1.36 c	0.64 c	0.34 b
	ORG	27.1 a	3.29 a	1.63 a	0.36 ab
4 yr	LPI	28.4 ab	1.76 b	0.79 b	0.40 ab
	HPI	27.1 b	1.45 b	0.78 b	0.38 b
	ORG	29.8 a	2.49 a	1.23 a	0.45 a

Background for Solvita Project

- Solvita – a newly commercialized test kit.
- 24 Hour CO_2-Burst – microbial activities and potential C and N mineralization

Figure 1. General procedure of Solvita CO_2-Burst test. http://solvita.com/soil

Cost of different soil tests

	Solvita	Organic Matter	Extractable N	Standard Aerobic Incubation
Cost	$$	$	$	$$$
Labor Intensive	-	-	-	++
Time period	1 day	1 day	1 day	64 – 128 day
In season estimation of N pool	Yes	Yes	Yes	No

Objectives

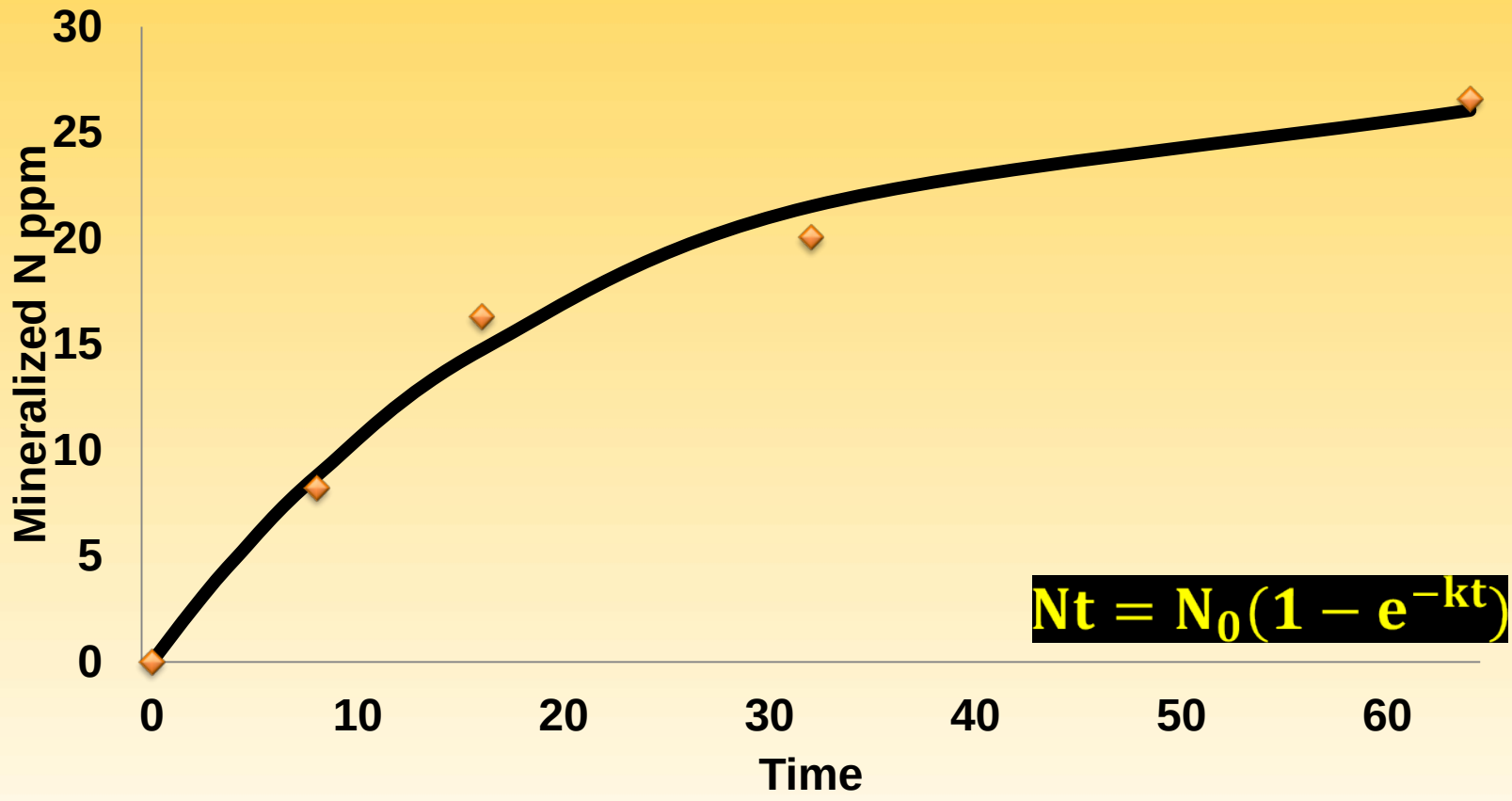
1) **Compare Solvita test with standard aerobic incubation**
2) **Does Solvita test measure N supply better than SOM?**
3) **Can fertilizer N recommendations be improved using the Solvita test?**
4) **Test repeatability**

Lab tests performed

- Solvita test
- Soil Organic Matter (LOI)
- KCl extractable N
- 64 day aerobic incubation
- Permanganate Oxidizable Carbon (POXC) – a quick test for active C

Estimation of N_o from lab incubation (PMN)

Stanford and Smith (1972)



Methods

All samples taken in spring from control plots of corn response trials (4 reps). Dried at 40 C and ground to 2 mm.

First year (2013-14)

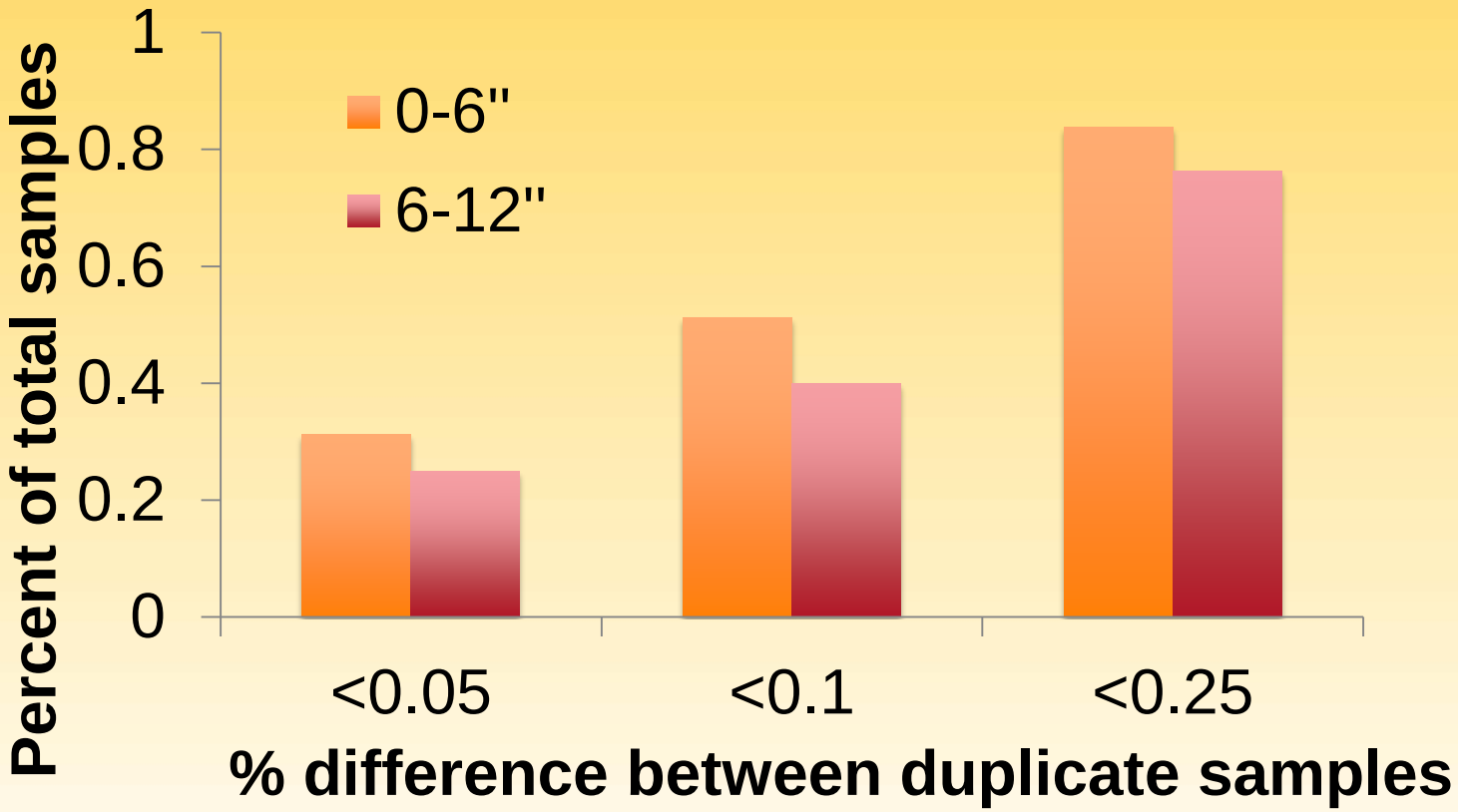
- 80 samples, 5 sites, 2 depths (0-15 and 15-30 cm, n=160).

Second year (2014-15)

- 148 samples, 26 sites, 2 depths (0-15 cm, 15-30 cm, n=296).
- Three types of previous crops (alfalfa, corn, and soybean)
- Six different soil texture classes (clay, silt clay, silt clay loam, clay loam, silt loam, and loamy sand).

Repeatability with Fixed Volume Method (2013-2014)

n(0-6")=80 n(6-12")=80



Three wetting methods

- Fixed volume method
  - 20mL water:40g soil (standard method)
- 50% Water filled pore space (WFPS) method
  - Measure soil volume, add water according to calculated pore space
  - (V – 40g/2.65) * 50%
- Quantitative soil saturation method
  - Saturate 28g soil to glistening, then add 12 more g soil & mix
  - (28g/40g)= 0.70, or 70% saturation

Results of wetting test - sandy soil

Hubbard Loamy Sand			
	Quantitative Soil Saturation	50% WFPS	Fixed Volume
Mean of Solvita Results ppm	41.54	31.67	9.44
Standard Deviation	19.76	17.82	3.50
Coefficient of Variation	0.48	0.56	0.37

Results of wetting test – clay loam soil

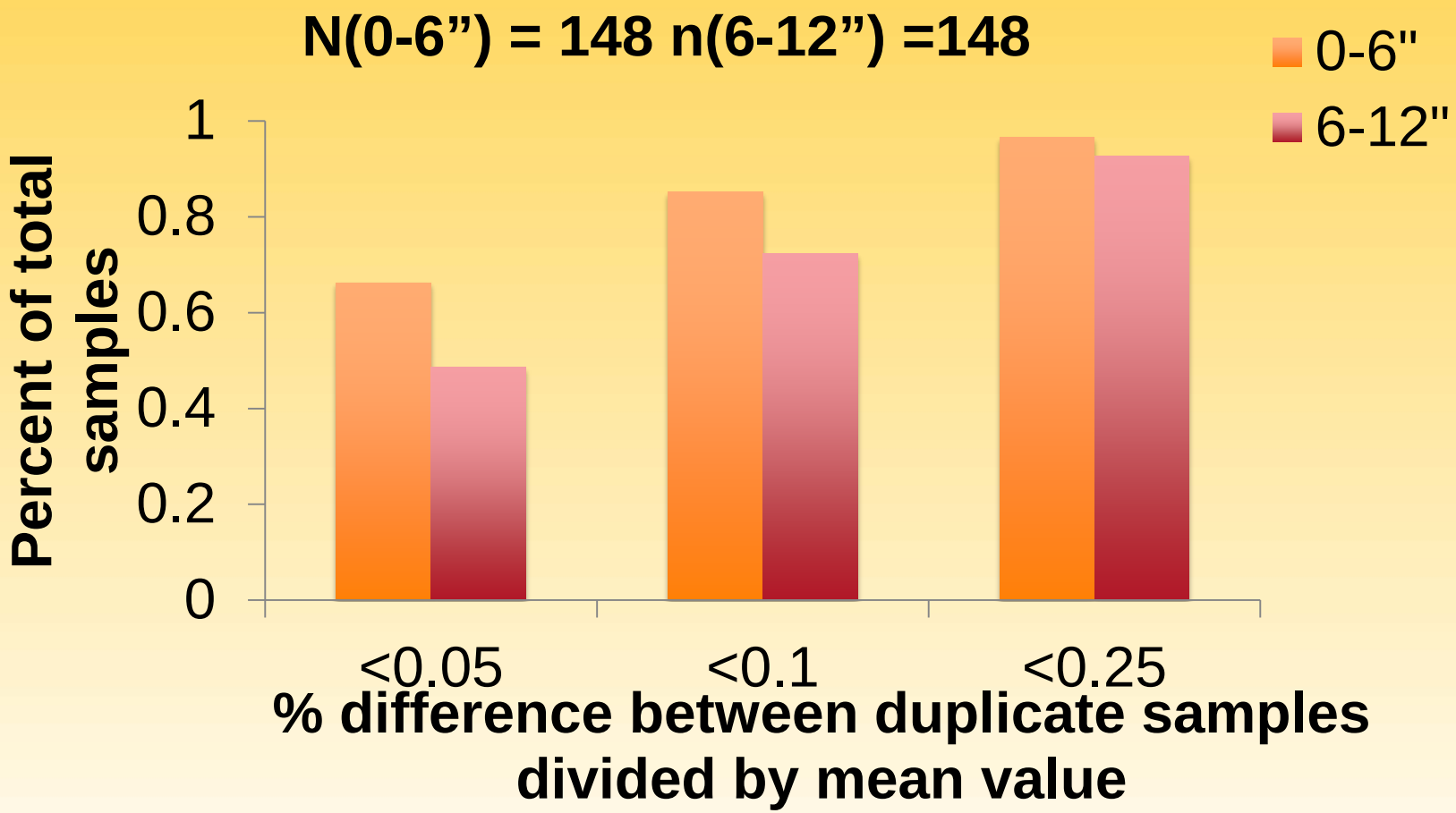
Webster Clay loam		
Quantitative Soil Saturation	50% WFPS	Fixed Volume
87.86	97.28	75.71
8.43	1.58	9.73
0.10	0.02	0.13

What This Means

- Problems with fixed volume test
  - High variability in fine-textured soils
  - Very low readings for coarse-textured soils

- 50% WFPS was chosen
  - Lowest variability in medium textured soils
  - More realistic numbers for coarse-textured soils

Repeatability with 50% WFPS Method (2014 - 2015)



Solvita vs. SOM
Crop History

Previous Crop	**n**	**Correlation coefficient (r)**	**P value**
Alfalfa	56	0.28	0.036*
Corn	44	0.11	0.49
Soybean	48	0.12	0.41
All samples	148	0.22	0.007**
*, ** = Significant at 5%, 1% level			

Solvita vs. SOM
Soil Texture

Texture	n	Correlation Coefficient	P value
Silty Clay and Clay	16	0.16	0.55
Silty Clay Loam and Clay Loam	104	0.23	0.017*
Silt Loam and Loamy Sand	28	0.85	<0.0001**
All samples	148	0.22	0.007**

Solvita vs. Extractable N
Crop History

Previous Crop	**n**	**Correlation coefficient**	**P value**
Alfafa	56	-0.10	0.49
Corn	44	0.60	<0.0001**
Soybean	48	0.47	0.0008**
All samples	148	0.43	<0.0001**
*,** = Significant at 5%, 1% level			

Solvita vs. Extractable N
Soil Texture

Texture	n	Correlation Coefficient	P value
Silty Clay and Clay	16	0.68	0.0041**
Silty Clay Loam and Clay Loam	104	0.33	0.0005**
Silt Loam and Loamy Sand	28	0.73	<0.0001 **
All samples	148	0.43	<0.0001 **

Correlation coefficients (r) for subset of 40 samples

	Solvita	SOM	Extractable N	PMN
Solvita	--			
SOM	0.55**	--		
Extractable N	0.58**	0.58**	--	
PMN	0.36*	0.46**	0.27++	--
Yield	0.32*	0.38*	0.44**	0.36*

Correlation coefficient and significance. ++, *, ** = Significant at 10%, 5%, 1% level.

Conclusions

- **Fixed volume wetting method yields highly variable results and artificially low values for coarse textured soils**
- **The Solvita CO_2-Burst test:**
  - **Significant (but not strong) correlation with SOM for soils with previous crops of alfalfa and for most soil textures.**
  - **No correlation with SOM for clay soils (although number of samples was low) or for previous history of corn and soybean.**

Conclusions

- **Is Solvita a better predictor of PMN than SOM?**
  - **2013-14:**
    - **PMN more related to Solvita than SOM (r=0.54 vs 0.34, n=19),**
  - **2014-15:**
    - **PMN more related to SOM than Solvita (r=0.46 vs 0.36, n=45).**
- **Results so far do not suggest that Solvita is a better indicator of PMN than SOM.**

Conclusions

- **Based on findings for clay soils and previous alfalfa crop, we conclude that the Solvita CO_2-Burst test is measuring a pool of active, labile C.**
- **Our final test, currently underway, will compare Solvita results with the POxC test (also called Cornell test).**
- **Solvita likely works best where organic matter is being added to the soil as compost, manure, green manure, cover crops, or other amendments.**

Correlation coefficient (r) for soil measures with mineralizable N (7 day anaerobic incubation)

	Mineralizable N	Total N	Total C	Soil Organic Matter
Total N	**0.819**			
Total C	**0.805**	0.965		
SOM	**0.781**	0.942	0.781	
24 h CO2 flush	**0.686**	0.747	0.722	0.708

35 temperate grassland soils
McDonald et al., 2013. SSSAJ 78: 1051

Haney Soil Health Test

"Uses nature's biology and chemistry" because soil analysis is performed using:

- a soil microbial activity indicator
- a soil water extract (nature's solvent)
- H3A extractant, which mimics organic acids produced by living plant roots

Haney Procedure Outline:

- Sample dried at 50° C, ground to pass a 2 mm sieve and weighed into two 50 ml Erlenmeyer flasks (4 g each) and one 50 ml plastic beaker (40 g) perforated to allow water infiltration.
- 40 g soil sample is analyzed with Solvita test at 25°C.
- One 4 g sample is extracted with 40 ml of DI water; the other with 40 ml of H3A. Samples are shaken for 10 min, centrifuged for 5 min, and filtered.
- Water and H3A extracts are analyzed on a Lachat for NO3-N, NH4-N, and PO4-P.
- Water extract is also analyzed on a C: N analyzer for water-extractable organic C and total N.
- H3A extract is also analyzed on an ICP for Al, Fe, P, Ca, and K.

Haney N and P results

Total N: This number is the total N from the water extract from your soil (in ppm). It contains both inorganic N and organic N sources from your soil.

Inorganic N: This is the combined amount of plant available forms of inorganic N (NO3-N plus NH4-N).

Organic N: Organic N is the total water extractable N minus the total water extractable inorganic N in ppm. This pool represents the amount of potentially mineralizable N in your soil.

Phosphate: This lists the same type of results as nitrogen but for inorganic P and organic P.

Haney Soil Health Score:

- **Solvita 1-day CO2-C:** amount of CO2-C (ppm) released in 24 hrs after drying and rewetting. Measure of microbial activity
- **Water extractable organic C (WEOC):** amount of organic C (ppm) extracted from the soil with water.
- **Water extractable organic N (WEON):** amount of total water extractable N minus the inorganic N
- **Organic C: Organic N:** ratio of WEOC to WEON. As the C: N falls, more N and P mineralization is credited.
- **Soil Health Calculation:** 1-day CO2-C divided by the organic C: N ratio plus WEOC/100 plus WEON/10 (to include a weighted contribution of WEOC and WEON).

Combines 4 independent measurements of the soil's biological properties.
Number varies from 0 to more than 50.
Goal is a number above 7 that increases over time.

Additional information reported

NO3-N Only (traditional evaluation) lbs per acre: amount of N when testing only for nitrate

Haney Test N Evaluation lbs per acre: amount of available N measured using the Haney Test.

Nitrogen Difference lbs per acre: difference in the amount of nitrogen found using the Haney Test compared to the NO3-N only approach.

Nitrogen savings per acre: amount of nitrogen saved in dollars per acre when using the Haney Test compared to traditional testing

Fertilizer Recommendations: This table provides recommended values for N, P2O5, and K2O in lbs per acre

Are “Haney Tests” Meaningful Indicators of Soil Health and Estimators of Nitrogen Fertilizer Credits?

By Dan Sullivan (Oregon State) and David Granatstein (WSU-Wenatchee)

Report from a special session at the Western Nutrient Management Conference on March 5, 2015

Dr R.O. Miller

- Problem with getting reproducible test results using a common set of soil samples.
- Concluded that Haney methodology:
  - requires standardization,
  - cross-lab validation, and
  - lab performance testing.
  - needs extensive field calibration research to confirm models

Are “Haney Tests” Meaningful Indicators of Soil Health and Estimators of Nitrogen Fertilizer Credits?

By Dan Sullivan (Oregon State) and David Granatstein (WSU-Wenatchee)

Researchers at UC Davis working with Dr Will Horwath

- Big effect of soil moisture content at time of testing.
- Relatively low values were obtained with the Haney protocol.
- Optimum soil moisture content was not the same across the soils tested.
- Soil respiration measurements were not a good predictor of measured N mineralization.

Blog by Fred Vocasek, Senior Lab Agronomist at Servi-Tech, Inc. –

the largest crop consulting and agronomic services company in the nation

"Soil health or soil quality is a **large-scale, national initiative** to maintain and improve our soil resource. The "Haney" test is being promoted as new and innovative, but actually employs concepts and techniques that are decades old. **Soil health testing may some day have a place in soil resource management.** Today there is **little or no research information to validate claims being made**. Today the soil health test number is just a number that is needed to qualify for CSP funds. A **lot more research will be needed** to determine if it is a valid tool for making better recommendations or soil management decisions."

http://fromfieldtofield.com/2015/05/21/nrcs-soil-quality-enhancement/

Conclusions

- Needs further testing, correlation and calibration for yield response to fertilizer recommendations
- Does not account for soil buffer capacity for P and K as do stronger extractants
- If NRCS continues to promote use of this test, results should be shared and evaluated by impartial researchers