Conservation Cropping Systems Initiative

Report Structure
This report is prepared for an individual farmer cooperator, with data from commercial soil health tests taken in 2015 and 2016. The report is structured as follows:

- Goals of the soil health tests analysis
- Summary of results from this individual cooperator
- Results in detail—this section discusses in detail the individual site results that are summarized in the immediately previous section, for the cooperator and others who may want to study the results in more depth.

A short summary of the results from all cooperators is provided in a separate report. Further synthesis of all data from all sites is ongoing, and will be provided as available.

Soil Health
Soil health has been defined as "the capacity of soil to function as a vital living system to sustain biological productivity, promote environmental quality and maintain plant and animal health."[1] Developing sustainable agronomic practices is directly related to their ability to influence soil health. Any attempt to categorize an agricultural practice as sustainable must first consider the effect on the soil.

Goals of Soil Health Analyses
A key component of the project conducted by the Conservation Cropping Systems Initiative (CCSI) is the evaluation of four different commercial soil health tests—Phospholipid Fatty Acids (PLFA), Earthfort Biological Soil Analysis, Cornell Soil Health Assessment, and Haney-Soil Health Tool. The objectives of this facet of the project are to assess the usefulness and value of the different commercial tests on evaluating the health of Indiana soils as well as the ability of the soil health indicators to distinguish among different cropping practices. Each of the four commercial soil health tests contain upwards of 10 separate soil health measures and most also include a ranking or calculation of overall soil health. While each of these commercial tests includes a large number of different soil properties, they each are supposed to evaluate overall soil health. One of the main goals of this project is to assess the usefulness of these tests on Indiana soils when comparing different cropping systems.

1 Doran et al., 1996; Doran and Zeiss, 2000

Individual Site Report:

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Climate	
Mean Annual Temperature:	**53.2°F**
Mean Annual Precipitation:	**43.2 in**

Treatments

No-Till + Cover Crops

Strip-Till + Cover Crops

Neighbor (Tillage, Continuous soybean)

Summary of Wenning Site

The Wenning farmer site has treatment comparisons of cover crops with no-till, cover crops with strip-tillage and a neighbor. These were sampled during summer of 2015 and summer of 2016 for the commercial soil health tests. For phospholipid fatty acid (PLFA) test, most of the significant differences were between the no-till cover crop plot and the neighbor. The no-till cover crop had significantly higher total bacteria and mycorrhizal fungi in 2015 and higher total microbial biomass and protozoa as well as bacteria again in 2016 compared to the neighbor. For all of these measures, the average values for the strip-tilled cover crop plots were also numerically higher than the neighbor, but because of much higher variability in the strip till plots, these differences were not statistically significant. It makes sense for there to be great variation in the microbial community between the tilled strip and the undisturbed soil in the row middles of the strip till system; however, it complicates the ability to detect true differences between the strip-till system and other systems as opposed to just random variation.

The Cornell and Haney tests each showed some significant differences between the two cover crop treatments and neighbor. For Haney, significant differences were found between the two cover crop treatments and the neighbor for phosphorus and water extractable C and N. The overall Cornell quality score was higher for both strip-till and no-till cover crop treatments than the neighbor in both 2015 and 2016. However, most of the significant differences for the individual soil health indicators of the Cornell test were in 2015. This includes greater active carbon, soil protein, and soil respiration in both strip and no till cover crops than the neighbor and greater organic matter in the no-till than the neighbor. An important consideration for these results is that the neighbor grew continuous soybean while the field at

Wenning was a corn-soybean rotation with cover crops. This difference in crop rotation may partially account for the greater number of significant differences detected in 2015, when corn was growing in the no-till and strip-till cover crop plots at Wenning while the neighbor's field had soybean, compared to 2016 when all of the plots had soybean.

All of the significant differences between the two different tillage practices under cover crops were found in 2015 with higher total fungi in strip-till vs. no-till as measured by the Earthfort test, higher organic matter and 96 hour soil respiration from the Cornell test in no-till vs. strip-till and higher water extractable organic C from the Haney Soil Health Tool in no-till vs. strip-till. While the Cornell and Haney tests indicate higher soil health under no-till than strip-till, it may be only temporary as none of these were significant the following year.

More work is needed to further evaluate the potential usefulness of these commercial tests for characterizing differences in soil health as found in Indiana cropland. The commercial tests as performed in this project, were often unable to distinguish between treatments that appear in the field to show differences. This may reflect a lack of sensitivity of the tests to important characteristics of field soil functioning. Please refer to the separate overall summary report for further discussion of overall questions, further analyses planned, and questions for future research on soil health assessment methods.

Results

Results are presented in the following tables with a subset of a soil health measures from each of the commercial soil health tests evaluated in 2015 and 2016 at the Wenning farmer site. The selected variables were chosen based on preliminary analysis that indicated that these soil parameters had the greatest potential to be sensitive to conservation cropping practices and allow us to distinguish between treatments.

Average values are presented for each of the treatments at the location—strip till and no-till with cover crops as well as the neighbor. We compared each of the treatments in pairs (strip till/cover vs. no-till/cover, strip till/cover vs. neighbor, and no-till/cover vs. neighbor) to evaluate them for statistically significant differences. These are found for each year in three columns to the right of the averages and degree of significance is indicated by the number of asterisks. Three asterisks (***) indicates a very strong statistical significance while comparisons with fewer asterisks are less statistically significant. Lower significance or lack of significant differences between treatments could be because of a smaller (or no) difference between treatments, but could also be due to greater variability within the measure so we are less confident that the apparent differences between treatments are real.

Brief Statistics Primer—Statistically Significant Differences

Here is an example from one of our farmer cooperators of the highly variable numbers we are analyzing. The average total fungi for four strips of no-till with cover crops was 195 ng/g compared to the neighboring field with an average of 51.5 ng/g of total fungi. These seem like those numbers are very different, but the difference between them is NOT statistically significant, but the difference between them is NOT statistically significant.

How in the world can these two numbers not be different? The no-till cover crop is 4x larger than the other, why do the statistics say they aren't different? Statistical analysis tries to determine how confident we can be that this difference is real and would occur again. It's not based just on how large the difference is. We compare how different the two fields are to the amount of variation within each field.

Example

Treatment	Rep #1	Rep #2	Rep #3	Rep #4	Average
No-Till + Cover Crops	98	38	390	254	**195**
Neighbor	32	85	33	56	**51.5**

To make sense of this, we need to look to the numbers that go into the averages. For the no-till, cover crop field, we have numbers that are kind of all over the place with some lower values—38 and 98, but also two very high numbers—254 and 390. For this field, the average is much higher than the average of the neighbor, but there is a high amount of variability in this measure as well. With so much variability in the measure, we can't be confident that this treatment is truly different from the neighbor.

As an example, if you have a field that has a lot of variability in it, you could randomly select a few different spots to check for yield. Depending on what spots you check, you may think you could have record yields or that it's going to turn out to be a disappointing harvest. In this case, eventually you will harvest the whole field and so you know what your true yield is. For the soil health indicators we are looking at, we can only estimate these measures based on the 3 or 4 replicated plots in each field. When there is high amounts of variability, we have no way of knowing what the true average is so we need to be cautious in declaring these differences to be real. If we were to repeat this experiment with four different plots in those fields, we might get a very different average and the difference between the no-till cover crop and the neighbor might end up being much smaller.

The soil health measurements tend to be much more variable than standard soil fertility tests, as the soil biology can be very patchy with microbes clustering near cover and cash crop roots and residues. Wheel tracks can reduce pore space in the soil, affecting water and oxygen availability for microbes. We try to reduce this problem by collecting 20-30 soil cores from each strip to get a more representative sample, but high variability still remains. Soil biology can also change dramatically throughout the summer as moisture and temperature change so these tests only provide a snapshot of these measures at the time of sampling. Ultimately, these issues complicate our ability to detect significant differences even when there are large numerical differences between the treatments.

Conservation Cropping Systems Initiative

Site Details—Soils, Treatments

Conservation Cropping System Experimental Plots						
% of Field	Slope	Soil Series Name	Soil Texture	Drainage Class	Native Vegetation	Parent Materials
85%	0-2%	Xenia	silt loam	moderately well drained	Forest	Loess under loamy till
15%	2-4%					

Neighbor						
% of Field	Soil Series Name	Soil Texture	Slope	Drainage Class	Native Vegetation	Parent Materials
100%	Xenia	silt loam	0-2 %	moderately well drained	Forest	Loess under loamy till

Treatment Details:
Conservation cropping system plots had the same cash and cover crop treatments, but differed in tillage practices. The neighbor had no cover and conventional tillage.

		Summer 2013	Fall 2013-Summer 2014		Fall 2014-Summer 2015		Fall 2015-Summer 2016		Fall 2016-Summer 2017	
Treatments	**Tillage**	**Cash**	**Cover**	**Cash**	**Cover**	**Cash**	**Cover**	**Cash**	**Cover**	**Cash**
ST + CC (RW 1,3,5,7)	ST	CN	AR/CL/OA/RP	SB	AR/CL/RP*	CN	CR	SB	3-way mix	CN
NT + CC (RW 2,4,6,8)	NT									
NBR (RW 9,10,11,12)	CT	?	–	SB	–	SB	–	SB	–	SB

ST + CC—Cover Crop Strip-till; NT + CC—Cover Crop No-till; NBR—Neighbor
Cash and Cover Crop Abbreviations: CN—Corn; SB—Soybean; AR—Annual Ryegrass; CL—Crimson Clover; OA—Oats; RP—Rapeseed; BW—Buckwheat; CR—Cereal Rye
Cover crops are color-coded as light green.
*Poor stand from fall seeding; reseeded with "Shopvac Mix" of AR, CL, RP, BW, OA on March 1, 2015

Soil Health Sampling Dates	Soil Moisture (%)		
	ST+CC	NT+CC	NBR
June 23, 2015	NA	NA	NA
June 20, 2016	23.7	21.9	18.7

Phospholipid Fatty Acids (PLFA)

Phospholipid fatty acids are found in the cell membrane of all cells. Each microbial group also has specific fatty acids only found in the cell membrane of that certain group of microbes—these are called biomarkers. The amount of biomarker fatty acids measured in the soil tell us how large each of these microbial groups are within the soil sample.

- In soils, we look at total microbial biomass as well as several microbial groups—bacteria, fungi, mycorrhizal fungi, and protozoa.
- The PLFA tests in 2015 and 2016 were analyzed by two different commercial laboratories so the units between years are different and make comparisons between 2015 and 2016 difficult.

Table 1. Average values for Phospholipid Fatty Acid (PLFA) for cover crop/strip till (ST+CC), cover crop/no-till (NT+CC) and neighbor (NBR) from Wenning farmer site in 2015 and 2016. PLFA tests in 2015 were analyzed by Ward Laboratories and measured in ng/g while in 2016, PLFA tests were analyzed at the Missouri Soil Health Assessment Center and measured in nmol/g. Statistical differences within pairs of treatments are indicated as significant at <0.01 by ***, at <0.05 by ** and at <0.10 at *. Measurements in italics are calculations within commercial tests purported to be indicators of overall soil health. **NOTE: Different units and labs between the two years, make direct comparisons between 2015 and 2016 impossible, except for Diversity Index and Fungi:Bacteria Ratio.**

	June 23, 2015					
	Average Values			Significant Differences		
PLFA—Ward Laboratories	ST+CC (CN)	NT+CC (CN)	NBR (SB-CT)	ST+CC vs NT+CC	ST+CC vs NBR	NT+CC vs NBR
Total Microbial Biomass (ng/g)	2627	1435	1117			
Total Bacteria (ng/g)	1134	834	626			*
Total Fungi (ng/g)	305	148	103			
Mycorrhizal Fungi (ng/g)	70	48	31			*
Protozoa (ng/g)	23	11	12			
Fungi:Bacteria Ratio	0.26	0.18	0.17		**	
Diversity Index	1.61	1.48	1.50			
	June 20, 2016					
PLFA—Missouri	ST+CC (SB)	NT+CC (SB)	NBR (SB-CT)	ST+CC vs NT+CC	ST+CC vs NBR	NT+CC vs NBR
Total Microbial Biomass (nmol/g)	67.0	66.2	49.0			**
Total Bacteria (nmol/g)	35.1	35.2	26.0			**
Total Fungi (nmol/g)	1.28	0.80	0.42			
Mycorrhizal Fungi (nmol/g)	2.28	2.46	1.89			
Protozoa (nmol/g)	0.52	0.48	0.22			***
Fungi:Bacteria Ratio	0.21	0.20	0.17			
Diversity Index	1.34	1.33	1.28			

CN—Corn; SB—Soybean; CT—Conventional tillage

PLFA, cont

Total Microbial Biomass
Represents the overall size of the microbial community within the soil; larger microbial communities indicate a more favorable environment for microbial growth and a healthier soil.

- No significant difference between treatments was detected in 2015.
- In 2016, neither of the cover crop plots differed from one another, but the no-till cover crop treatment had significantly higher microbial biomass than the neighbor.
- Ward Laboratories, which analyzed PLFA in 2015, has a rating system for total microbial biomass (see Appendix).
    - According to the rating system, the 2015 microbial biomass of the strip tilled cover crop treatment is rated slightly above average, the no-till cover crop is slightly below average and the neighbor is rated as poor.

Total Bacteria
Bacteria are decomposers that help break down residues and cycle nutrients and are an important part of the microbial community. However, for optimal soil health, it is important that the microbial community not be dominated by bacteria. Therefore, a high bacteria number does not indicate by itself that the soil has high soil health.

- In 2015, the two cover crop plots did not differ from one another.
- The neighbor had significantly lower bacteria than the no-till cover crop treatment, but despite a larger numerical difference between the neighbor and the strip-tilled cover crop, this difference was not statistically significant.
- Why is this?
    - This seeming contradiction is because the measured values of the no-till plots have less variability among them than among the strip-tilled plots. This means we can be more confident that the difference between the no-till/cover and neighbor is real and could be repeated.
    - However, it is also possible that the strip till is in fact more variable due to differences between the tilled soil in the strip and the undisturbed soil in row middles. The soil samples included both zones, likely in different proportions in each plot, leading to greater variability.
- In 2016, the no-tilled cover crop bacteria PLFA was higher than the neighbor. The strip-tilled cover crop treatment trended towards greater bacteria as well, but this difference was not significant, likely due to high variability in the strip till data again.

Total Fungi
Fungi, like bacteria, are decomposers, but some fungi have fairly specialized enzymes that break down residues that are more complex and difficult to break down. They are also important to soil organic matter formation and soil aggregation. This makes fungi a very valuable part of the microbial community, and high levels of fungi can be a strong indicator of soil health.

- No significant differences between any of the treatments for fungi in either 2015 or 2016.

Mycorrhizal Fungi
Mycorrhizal fungi, also known as arbuscular mycorrhizae fungi (AMF), can be beneficial to many crops as they colonize plant roots and form mutually beneficial relationships. Mycorrhizae are able to scavenge for nutrients in the soil that the plant would not otherwise be able to reach—these can be especially important for P and N.

- In 2015, no-till/cover crop had significantly more mycorrhizal fungi than the neighbor. The average value for strip-till/cover crop treatment was actually numerically higher than the no-till/cover crop but because of high variability, the strip-till/cover crop treatment was not statistically different from either the no-till/cover crop or the neighbor.
- No significant difference between treatments was detected in 2016.

Protozoa
These microbes are important to nitrogen cycling within soils. Protozoa mainly feed on bacteria and as they eat, they release excess nitrogen that is then available for crop uptake.

- No significant differences found between treatments in 2015.
- In 2016, the no-till/cover crop had significantly more protozoa than the neighbor. No significant differences between other treatments.

Fungi: Bacteria Ratio
As mentioned above, fungi can be a strong indicator of soil health so it is important to have a high ratio of fungi to bacteria.

- The fungi: bacteria ratio of the strip-till/cover crop treatment is significantly higher than the neighbor in 2015. There were no significant differences between the fungi:bacteria ratio in 2016.
- Ward Laboratories has a rating system for this measurement as well (see Appendix).
    - Based on this, the values for the 2015 measurements for the strip-tilled/cover crop plots are rated as good while the no-till/cover crop and neighbor are average.
    - The 2016 fungi:bacteria ratios of all the treatments are average to slightly above average.

Diversity Index
This measurement is calculated using the proportion of the microbial biomass that is in each of the microbial groups listed above and indicates how much diversity is found within the microbial community. High diversity is preferred as a microbial community is better able to deal with environmental stresses and able to decompose a more diverse array of residues.

- None of the treatments had significantly different diversity index either year.
- Ward Laboratories provided a rating system for this calculation as well (see Appendix).
    - The 2015 diversity index of the strip-till/cover crop treatment is rated as excellent while the no-till/cover crop and neighbor are rated as good.

Earthfort Biological Soil Analysis

Similar to PLFA, this commercial test measures the size of various microbial groups; however, these measurements were made using microscopy, directly counting the size of these microbe groups. This analysis was only completed in 2015.

Table 2. Average values for Earthfort Biological Analysis in 2015 for cover crop/strip till (ST+CC), cover crop/no-till (NT+CC) and neighbor (NBR) from Wenning farmer site. Statistical differences within pairs of treatments are indicated as significant at <0.01 by ***, at <0.05 by ** and at <0.10 at *.

	June 23, 2015					
Earthfort	ST+CC (CN)	NT+CC (CN)	NBR (SB-CT)	ST+CC vs NT+CC	ST+CC vs NBR	NT+CC vs NBR
Active Bacteria (µg/g)	42	45	42			
Total Bacteria (µg/g)	1117	1197	1554		**	
Active Fungi (µg/g)	14	17	22			
Total Fungi (µg/g)	563	347	418	**		
Protozoa--Flagellates (µg/g)	1318	2245	1882			
Protozoa--Amoeba (µg/g)	303367	414960	226999			
Protozoa--Ciliates (µg/g)	41	86	87			
Total Fungi: Total Bacteria Ratio	0.26	0.19	0.23			

CN—Corn; SB—Soybean; CT—Conventional Tillage

Total and Active Bacteria

As mentioned above, bacteria are decomposers, but are not considered strong indicators of soil health. While some bacteria may be dormant or dead, active bacteria gives an indication of how many bacteria are able to actually cycle nutrients and contribute to decomposition of residues at the time of soil sampling.

- There were no differences between any of the treatments for active bacteria.
- The neighbor had significantly more total bacteria than the strip-tilled cover crop treatment.

Total and Active Fungi

Fungi are also decomposers, but because of their contributions to soil aggregation and soil organic matter, it is preferred to have high fungi levels and have a fungal dominated microbial community. Again, the active fungi gives a better indication of how many fungi are currently able to contribute to nutrient cycling.

- There were no significant differences between treatments for active fungi in 2015.
- The strip-tilled cover crop had more total fungi than the no-till cover crop treatment.

Protozoa

As mentioned above, protozoa eat bacteria and release excess nitrogen, which is now plant available. The Earthfort analysis measures the amounts of three different types of protozoa. Flagellates and amoebae are aerobic protozoa that require oxygen to survive. Ciliates are the largest and least common protozoa, and they are able to survive without oxygen in anaerobic conditions.

- There were no significant differences between any of the treatments for any of the protozoa types.

Total Fungi: Total Bacteria Ratio

Fungal dominated microbial communities are a strong indicator of soil health so higher values of the fungi: bacteria ratio are preferred.

- No significant differences were found between any of the treatments.

Cornell Soil Health Assessment

This commercial soil test consists of twelve different measures of different aspects of the soil, which are all rated and then combined together to form an overall quality score (out of 100). The chemical tests of soil pH, P, K and minor elements are not shown in this report as they were not different between treatments, but they are included in the calculated quality score. In general, most of the chemical tests were in the optimal range, reflecting long-term good soil fertility practices.

Note on Rating System:
The ratings in the Cornell Soil Health Assessment are determined by scoring functions for each soil property. The scoring functions used in this report are specific to the Midwest region and some differ based on the soil texture (sandy soils would be rated differently than finer soils). These scoring functions were developed based on a large database of measurements collected from throughout the region. Certain soil measurements rate higher for higher values (Aggregate Stability, Available Water Capacity, Organic Matter, ACE Protein, Soil Respiration, and Active Carbon). Surface and Subsurface hardness are rated higher with lower measured values. Others, such as pH and phosphorus, are rated closer to 100 when within an optimum range; above and below that range are rated lower.

Table 3. Average values for Cornell Soil Health Assessment for cover crop/strip till (ST+CC), cover crop/no-till (NT+CC) and neighbor (NBR) from Wenning farmer site in 2015 and 2016. Statistical differences within pairs of treatments are indicated as significant at <0.01 by ***, at <0.05 by ** and at <0.10 at *. Measurements in italics are calculations within commercial tests purported to be indicators of overall soil health.

	June 23, 2015						June 20, 2016					
	Average Values			Significant Differences			Average Values			Significant Differences		
Cornell Soil Health Assessment	ST+CC (CN)	NT+CC (CN)	NBR (SB-CT)	ST+CC vs NT+CC	ST+CC vs NBR	NT+CC vs NBR	ST+CC (SB)	NT+CC (SB)	NBR (SB-CT)	ST+CC vs NT+CC	ST+CC vs NBR	NT+CC vs NBR
Quality Score	53.1	54.3	42.5		**	***	54.7	54.9	42.9		***	***
Aggregate Stability (%)	8.1	8.6	10.7				16.7	14.0	14.9			
Available Water Capacity	0.28	0.28	0.28				0.24	0.25	0.27			
Surface Hardness (psi)	233	207	200		*		267	253	288			
Organic Matter (%)	2.30	2.43	2.17	*		**	2.27	2.23	2.18			
Active Carbon (ppm)	367	389	211		**	**	376	381	315			
ACE Soil Protein Index	3.70	3.80	2.97		*	**	3.66	3.11	2.73			
Soil Respiration-96 hours (ppm)	360	390	280	***	**	**	300	290	250			

CN—Corn; SB—Soybean; CT—Conventional Tillage

Cornell, cont.

Quality Score
This is calculated based on the rating for each of the 12 different soil measures within this commercial soil health test. It is supposed to indicate overall soil health and values above 60 are considered excellent. Quality scores between 40 and 60 are rated medium and indicate soil health could still be improved. If the values are less than 20, this is considered a constraint and needs to be addressed.

- In both 2015 and 2016, the strip-till and no-till cover crop treatments had higher Cornell quality scores than the neighbor.

Aggregate Stability
This measures how well the soil aggregates stay together and can be a strong indicator of how well the soil is able to resist erosion. High aggregate stability can prevent crusting and increase water infiltration

- No significant differences were found between treatments.

Available Water Capacity
This measures how much water the soil holds between field capacity and permanent wilting point, which is the amount of plant-available water the soil can store. Available water capacity is dependent on the soil texture as coarse texture soils are able to store much less water than finer soils. However, for a specific soil texture, more organic matter can increase available water capacity.

- No significant differences in available water capacity in either year.

Surface Hardness
These are measures of strength of the soil and is an indication of the physical structure of the soil. High levels of surface and subsurface hardness can restrict root growth and influence water infiltration. Surface hardness is measured in the top 6 inches, and these measures can also be affected by soil moisture at the time of sampling. These numbers were taken with a cone penetrometer at the time of the field sampling

- The surface hardness of the strip-tilled cover crop was higher than the neighbor in 2015.
- There were no significant differences in surface hardness in 2016.

Organic Matter
Soil organic matter is one of the most important indicators of soil health due to its relationship with many other aspects of the soil, including water infiltration and holding capacity, aggregate stability, and nutrient cycling. However, the limitation of this measure is that it can take several years to significantly alter organic matter.

- In 2015, the no-till plots had more organic matter than the strip-tilled cover crop plots and the neighbor.
- There were no significant differences between treatments in 2016.

Active Carbon
This measures the portion of organic matter that is most easily decomposed by soil microbes. High active carbon is an indicator of good soil health and is much more sensitive to management changes than organic matter as a whole.

- In 2015, both cover crop treatments had higher active carbon than the neighbor.
- None of the treatments were significantly different in 2016.

ACE Soil Protein Index
This is similar to active carbon as it represents the most easily cycled part of organic matter, but measures nitrogen. Proteins are readily broken down by microbes, which mineralizes N into plant-available forms.

- In 2015, both cover crop treatments had a greater soil protein index than the neighbor.
- None of the treatments were significantly different in 2016.

Soil Respiration
Soil respiration measures the amount of carbon dioxide released by soil microbes over a certain period of time. For Cornell, it is measured over 96 hours so the measure is able to stabilize and is more consistent than measures over a short period of time. This measures how active the soil microbes are.

- In 2015, all three of the treatments were significantly different from one another with the highest soil respiration for no -till cover crop followed by strip–tilled cover crop with the lowest soil respiration for the neighbor.
- None of the treatments were significantly different in 2016.

Haney-Soil Health Tool

Like the Cornell commercial soil health test, the Soil Health Tool consists of many different tests that evaluate different aspects of the soil. The tests focus on nutrient availability and microbe activity.

Table 4. Average values for the Haney Soil Health tool in 2015 and 2016 for cover crop/strip till (ST+CC), cover crop/no-till (NT+CC) and neighbor (NBR) from Wenning farmer site. Statistical differences within pairs of treatments are indicated as significant at <0.01 by ***, at <0.05 by ** and at <0.10 at *. Measurements in italics are calculations within commercial tests purported to be indicators of overall soil health.

	June 23, 2015						June 20, 2016					
	Average Values			Significant Differences			Average Values			Significant Differences		
Haney-Soil Health Tool	ST+CC (CN)	NT+CC (CN)	NBR (SB-CT)	ST+CC vs NT+CC	ST+CC vs NBR	NT+CC vs NBR	ST+CC (SB)	NT+CC (SB)	NBR (SB-CT)	ST+CC vs NT+CC	ST+CC vs NBR	NT+CC vs NBR
Nitrogen (N lb/A)	56	44	36				46	41	41			
Phosphorus (P_2O_5 lb/A)	107	97	13		**	***	138	85	25		**	**
Soil Respiration-24 hrs (ppm)	38	29	24				75	64	49			
Water Extr. Organic C (ppm)	258	277	223	**	**	***	198	182	133		**	
Water Extr. Organic N (ppm)	18.5	21.7	16.8			**	18.5	17.1	12.4		*	
Carbon: Nitrogen Ratio	14.0	12.9	13.3				10.7	10.8	10.8			
Soil Health Calculation	8.3	7.8	6.4		**		11.4	10.0	7.5			

CN—Corn; SB—Soybean; CT—Conventional Tillage

Nitrogen and Phosphorus Nutrient Content

These are measures of N and P currently in the soil.

- No significant differences were detected in either year for N.
- During both years, P was higher for the two cover crop/ conservation tillage treatments than for the neighbor.

Soil Respiration

As for the Cornell soil respiration, this measures the amount of microbial activity by measuring the amount of carbon dioxide released. For this test, it is measured over 24 hours. Since this is such a short time period, these measures can be highly variable.

- No differences between treatments in either year for the 24 hour soil respiration measure.

Water Extractable Organic Carbon and Nitrogen

Like active carbon and protein in the Cornell commercial test, water extractable organic C and N are supposed to measure the amount of carbon and nitrogen in organic matter that is readily available to soil microbes.

- In 2015, all treatments had significantly different water extractable organic C with the most in the no-till cover crop, followed by the strip-tilled cover crop and the least at the neighbor.
- In 2016, the only significant difference was that the strip-tilled cover crop had higher organic C extracted than the neighbor.
- For N, in 2015, no-till cover crop had significantly greater organic N than the neighbor; however in 2016, it was the strip-tilled cover crop that was significantly more than the neighbor.

Soil Health Calculation

This is calculated from the 24 hour soil respiration as well as the water extractable organic carbon and nitrogen. It is supposed to represent the overall soil health and can range from 0 to over 30. While the Soil Health Tool does not provide a rating system, they do suggest that good management practices that improve soil health will cause this calculation to increase over time.

- In 2015, the soil health calculation was greater for strip-tilled cover crop than the neighbor, but no significant differences were detected between treatments in 2016.
- The soil health calculation increased from 2015 to 2016, which is an indication of improved soil health over time.

Photo Credit: Roger Wenning

May 1, 2016: In adjacent Wenning cover crop field, Annual Ryegrass – Crimson Clover – Rape cover crop. Annual ryegrass chemically terminated 2 weeks prior to photo.

Photo Credit: Roger Wenning

May 13, 2016: In adjacent Wenning cover crop field, Crimson Clover – Rape cover crop allowed to grow after annual ryegrass termination.

Appendix

The rating system provided by Ward Laboratories for Total Biomass, Fungi: Bacteria Ratio and Diversity Index.

Rating	Total Biomass (ng/g)	Fungi: Bacteria Ratio	Diversity Index
Very Poor	< 500	< 0.05	< 1.0
Poor	500+ - 1000	0.05+ - 0.1	1.0+ - 1.1
Slightly Below Average	1000+ - 1500	0.1+ - 0.15	1.1+ - 1.2
Average	1500+ - 2500	0.15+ - 0.2	1.2+ - 1.3
Slightly Above Average	2500+ - 3000	0.2+ - 0.25	1.3+ - 1.4
Good	3000+ - 3500	0.25+ - 0.3	1.4+ - 1.5
Very Good	3500+ - 4000	0.3+ - 0.35	1.5+ - 1.6
Excellent	> 4500	> 0.35	> 1.6