Conservation Cropping Systems Initiative

Individual Site Report:

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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

Climate	
Mean Annual Temperature:	51.3°F
Mean Annual Precipitation:	38.9 in

Treatments

No-till + Cover Crops

No-till, No Cover

Neighbor (Rotational Tillage, No Cover)

Summary of DeSutter Site

The DeSutter farmer site included comparisons between long-term no-till with and without the addition of cover crops along with a neighbor's field. The neighbor did not use cover crops, but used rotational tillage with no-till soybeans and tillage occurring only prior to corn (tilled prior to 2016 samples, not before 2015), which would be considered a conservation tillage practice. In general for this site, more differences were detected between the neighbor and each of the no-till treatments than between the cover and no cover no-till treatments. Only active bacteria measured by Earthfort and the Cornell soil protein were significantly different between the cover and no cover no-till treatments. These measures are both considered to be very sensitive to management changes so it makes sense that they would show differences where the others have not. Differences between the long-term no-till treatments (with or without cover) and the neighbor included many individual measurements in one or both years, which are discussed in the results section. In most cases, the soil health measurement was greater for the no-till plots than the neighbor, but there were some exceptions (Earthfort active fungi in 2015 and aggregate stability in 2016).

Most of the commercial soil health tests evaluated in this project provide a calculated measure that is supposed to represent overall soil health, in addition to the individual measurements. None of the overall soil health indices were able to detect differences between cover and no cover no-till treatments at this site. However, both the Cornell quality score and Haney soil health calculation were greater in the cover and no cover no-till treatments compared to the neighbor in 2016.

The finding that measured differences were small or inconsistent between cover and no cover in the no-till field, but larger between the no-till field (with or without cover) and the neighbor, is not totally surprising. The no-till field was already in long-term no-till (28 yr) when the CCSI project began. Addition of a cover crop for one or two years was not enough to further improve the soil in ways that could be detected by these tests as they were used in this project. The difference between the no-till and neighbor fields reflects longer history of the different tillage management regimes. It should also be noted that the neighbor field is in essence a “rotational tillage” system, with a tillage operation once every two years. Thus although many but not all of the measures were somewhat lower in the neighbor field than in the no-till field, they are likely higher than if the field had been tilled every 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 key field soil functions. 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 subset of a soil health measures from each of the commercial soil health tests evaluated in 2015 and 2016 at the DeSutter 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—cover no-till, no cover no-till, and neighbor. We compared each of the treatments in pairs (cover/no-till vs. no cover/no-till, cover/no-till vs. neighbor, and no cover/no-till 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.

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.

Site Details—Soils, Treatments

Conservation Cropping System Experimental Plots						
% of Field	Soil Series Name	Soil Texture	Slope	Drainage Class	Native Vegetation	Parent Materials
46%	Waupecan	silt loam	0-2 %	well drained	Prairie	Loess over loamy outwash
44%	Lafayette	silt loam	0-2%	somewhat poorly drained		
10%	Waupecan	silt loam	2-6%	well drained		

Neighbor						
% of Field	Soil Series Name	Soil Texture	Slope	Drainage Class	Native Vegetation	Parent Materials
100%	Waupecan	silt loam	0-2 %	well drained	Prairie	Loess over loamy outwash

Treatment Details: DeSutter Conservation Cropping Plots: Continuous no-till since 1985 and continuous corn from 2009-2013
Neighbor: Corn/soy rotation with tillage occurring only prior to corn while soybeans are no-till.

Treatments	Summer 2013	Fall 2013	Spring 2014	Summer 2014	Fall 2014	Spring 2015	Summer 2015	Fall 2015	Spring 2016	Summer 2016	Fall 2016	Spring 2017	Summer 2017
NT+CC	CN	CR		SB	WH		12-way mix		–	CN	CR		SB
NT	CN	–		SB	WH		–			CN	–		SB
NBR	SB	–		CN	–		SB	–		CN	–		SB

NT+CC—Cover Crop No-till; NT—No Cover No-till; NBR—Neighbor using rotation tillage, no cover
Cash and Cover Crop Abbreviations: CN—Corn; SB—Soybean; CR—Cereal Rye; WH—Wheat
Cover crops are color-coded as light green.

Soil Health Sampling Dates	Soil Moisture (%)		
	NT+CC	NT	NBR
June 2, 2015	24.8	26.6	26.4
June 8, 2016	19.2	20.9	20.0

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 no-till (NT+CC) and no cover no-till (NT) plots at DeSutter as well as neighbor (NBR). 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 2, 2015					
	Average Values			Significant Differences		
PLFA—Ward Laboratories	NT+CC (WH)	NT (WH)	NBR (SB-NT)	NT+CC vs NT	NT+CC vs NBR	NT vs NBR
Total Microbial Biomass (ng/g)	1602	2159	981		**	**
Total Bacteria (ng/g)	890	1203	515		**	**
Total Fungi (ng/g)	92.9	181.8	49.9			
Mycorrhizal Fungi (ng/g)	18.1	39.9	4.9			
Protozoa (ng/g)	6.1	16.0	0.5			
Fungi:Bacteria Ratio	0.10	0.14	0.10			
Diversity Index	1.30	1.36	1.27			
	June 8, 2016					
PLFA—Missouri	NT+CC (CN)	NT (CN)	NBR (CN-Tilled)	NT+CC vs NT	NT+CC vs NBR	NT vs NBR
Total Microbial Biomass (nmol/g)	69.0	73.5	54.9			**
Total Bacteria (nmol/g)	37.1	38.9	28.9			**
Total Fungi (nmol/g)	0.51	0.49	0.81			
Mycorrhizal Fungi (nmol/g)	2.68	2.62	1.45		**	***
Protozoa (nmol/g)	0.34	0.42	0.75			
Fungi:Bacteria Ratio	0.19	0.19	0.18			
Diversity Index	1.31	1.31	1.32			

WH—Wheat; SB-NT—No-tilled soybean; CN—Corn

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.

- While no significant difference between cover and no cover treatments was detected, both of these no-till systems had greater microbial biomass in both 2015 and 2016 than in the neighbor.
- Ward Laboratories, which analyzed PLFA in 2015, has a rating system for total microbial biomass (see Appendix).
  - According to the rating system, both cover and no cover at DeSutter fall in the average category while the neighbor has a poor rating for 2015.

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.

- As with total microbial biomass, the bacterial community was larger in the cover and no cover no-till treatments than in the neighbor, both years.

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, there were no significant differences between treatments. However, there was a definite trend towards greater mycorrizhae in the cover and no cover no-till soils compared to the neighbor.
  - Although the differences between the neighbor and the conservation cropping systems plots may seem large, the lack of significant differences is likely due to high variability in the data.
- In 2016, there were significantly greater mycorrhizal fungi found in the cover and no cover no-till plots than in the soils at the neighbor.
  - Mycorrhizal fungi are better able to survive in no-till soils because they can stay near the surface in root channels and quickly recolonize the new roots of the crop hosts. Tillage disturbs the soil and damages the mycorrhizal hyphae, reducing their ability to colonize the new crop roots.

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 either year.

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.

- There were no significant differences between either of the conservation cropping systems or the neighbor in either year.
- Ward Laboratories has a rating system for this measurement as well (see Appendix).
  - Based on this, the values for the 2015 measurements for all treatments fall in the slightly below average category while in 2016 all treatments were in the average category.

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.

- Ward Laboratories provided a rating system for this calculation as well (see Appendix).
  - The diversity index for cover and no cover no-till soils for both 2015 and 2016 were in the slightly above average category.
  - The neighbor value was in the average category in 2015 and in the slightly above average category in 2016.
- There were no significant differences between any treatments in either 2015 or 2016.

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 no-till (NT+CC) and no cover no-till (NT) plots at DeSutter as well as neighbor (NBR). Statistical differences within pairs of treatments are indicated as significant at <0.01 by ***, at <0.05 by ** and at <0.10 at *.

Earthfort	June 2, 2015					
	NT+CC (WH)	NT (WH)	NBR (SB-NT)	NT+CC vs NT	NT+CC vs NBR	NT vs NBR
Active Bacteria (µg/g)	46	35	47	**		
Total Bacteria (µg/g)	1800	1802	1386			
Active Fungi (µg/g)	17	19	30		**	*
Total Fungi (µg/g)	447	322	308			
Protozoa--Flagellates (µg/g)	22475	3568	2726			
Protozoa--Amoeba (µg/g)	372786	168150	191528			
Protozoa--Ciliates (µg/g)	180	81	145			
Total Fungi: Total Bacteria Ratio	0.26	0.19	0.23			

WH—Wheat; SB-NT—No-tilled soybean

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 total bacteria, but there were greater levels of active bacteria in cover no-till soils than the no cover no-till plots.
- When looking at total bacteria, there was a trend for greater levels for cover and no cover no-till soils compared to the neighbor.
    - The lack of significant differences is likely due to high variability within the measurements.

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 total fungi, but there was a trend toward greater total fungi under cover no-till plots compared to the other treatments.
- Active fungi was greater in the neighbor than both of the conservation cropping systems.
    - This is an unexpected result, but may be due to greater available food source throughout the full 8 inches of the soil that were sampled. In no-till soils, fungi are mainly supported near the surface while in tilled soils, plant residues are distributed to a greater depth so fungi can grow in that greater depth of the soil.

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.
- The trend across all three protozoa types was towards greater numbers under cover crop than no cover or the neighbor.
    - While the differences in average between these measures were fairly large, these values were also highly variable, which is likely why the differences were not statistically significant.

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 in 2015 and 2016 and for cover crop no-till (NT+CC) and no cover no-till (NT) plots at DeSutter as well as neighbor (NBR). 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 2, 2015						June 8, 2016					
	Average Values			Significant Differences			Average Values			Significant Differences		
Cornell Soil Health Assessment	NT+CC (WH)	NT (WH)	NBR (SB-NT)	NT+CC vs NT	NT+CC vs NBR	NT vs NBR	NT+CC (CN)	NT (CN)	NBR (CN-Till)	NT+CC vs NT	NT+CC vs NBR	NT vs NBR
Quality Score	52.8	55.0	49.1				58.7	60.6	47.0		**	**
Aggregate Stability (%)	15.6	18.0	14.1				16.4	16.6	23.0		**	*
Available Water Capacity	0.28	0.29	0.29				0.31	0.34	0.34			
Surface Hardness (psi)	314	317	264		*	**	334	325	322			
Subsurface Hardness (psi)	488	494	414		**	**	347	354	345			
Organic Matter (%)	3.0	3.4	3.0				3.1	3.3	3.0			
Active Carbon (ppm)	547	592	410		***	*	525	576	354		**	***
ACE Soil Protein Index	4.67	5.13	5.97				4.91	5.33	5.22	**		
Soil Respiration-96 hrs (ppm)	370	390	350				320	340	250		*	*

WH—Wheat; SB-NT—No-tilled soybean; CN—Corn

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.

- While there were no significant differences in 2015, both cover and no cover no-till soils had significantly higher quality scores than the neighbor in 2016, indicating the soil health was greater in the conservation cropping systems.

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 in 2015, but there was a trend towards high aggregate stability under the cover and no cover treatments than the neighbor.
- In contrast, aggregate stability was significantly greater in the neighbor in 2016 than either the cover or no cover no-till treatments.
    - This is very surprising as it is very different from the previous year and typically tillage causes decreases in aggregate stability. The neighbor tills prior to the corn crop so tillage would have occurred between the 2015 and 2016 sampling.
    - This result may also be related to differences in cash crop residues from the previous year as the previous crop in the neighbor was soybean, which can break down fairly rapidly causing a temporary increase in aggregate stability.

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-textured soils. However, for a specific soil texture, more organic matter can increase available water capacity.

- There were no significant differences between any treatment for either year.
- As the soil textures are all the same, the lack of differences indicates very little difference in soil organic matter as well.

Surface and Subsurface 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, while subsurface hardness measures 6-18 inches. 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.

- For 2015, both surface and subsurface hardness were lower at the neighbor than in either cover or no cover no-till plots. No significant differences were detected in 2016.
    - The difference in 2015 may reflect the differential root growth of the two different cash crops. The no-till field had a wheat crop, probably headed out, whereas the neighbor had still young soybeans. The roots of the nearly mature wheat would have provided greater strength and resistance to penetration than would young soybean roots.

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.

- There were no significant differences between treatments either year.

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 both years, active carbon was greater in both cover and no cover no-till plots compared to the neighbor.

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.

- No significant difference in protein content in 2015.
- In 2016, there was greater protein content under no cover no-till plots compared to the cover crop plots.
    - While this result is unexpected, it may be related to the high amount of volunteer wheat in the no cover no-till plots. In addition, the cover crop plots were planted to a 12-way mix in fall 2015, most of which winterkilled so the no cover plots may have ended with greater plant biomass in the spring as a result of the volunteer wheat. Unfortunately, spring 2016 biomass samples were not collected so this cannot be confirmed.

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.

- There were no differences between any of the treatments in 2015.
- In 2016, soil respiration was greater in the cover and no cover no-till systems than from the neighbor.

Haney-Soil Health Tool

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

Nitrogen and Phosphorus Nutrient Content

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

- No significant differences were detected in 2015 for either N or P.
- In 2016, N was much higher in the neighbor field compared to either of the conservation cropping system fields, but this is likely due to side-dress N application in the neighbor prior to sampling.
- Phosphorus was greater in 2016 in the no cover plots compared to the neighbor, which may also be due to different fertilizer application timings.

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.

- In 2015, no cover was significantly greater than the neighbor. The values for cover also trended higher than the neighbor, but were not significantly different.
- For 2016, both cover and no cover had greater soil respiration compared to the neighbor.

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.

- For carbon, the only significant difference was in 2015 with greater water extractable organic C in the neighbor field compared to the cover crop plot.
- No significant differences were found for N.

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.

- No differences were detected between treatments in 2015, but in 2016, the values for both cover and no cover no-till were greater than the neighbor.
- The soil health calculation for all three treatments increased from 2015 to 2016, but to a greater degree in the cover crop no-till soils.

Photo Credit: Lee Schweitzer, Purdue University

Dan DeSutter and Eileen Kladivko (foreground) in a 12-way cover crop blend following wheat. Fall 2015

Photo Credit: Eileen Kladivko, Purdue University

Biomass sampling of 12-way cover crop blend following wheat crop. Fall 2015

Haney Cont.

Table 4. Average values for the Haney Soil Health tool in 2015 and 2016 and for cover crop no-till (CC) and no cover no-till (NC) plots at DeSutter as well as neighbor (NBR). 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 2, 2015						June 8, 2016					
	Average Values			Significant Differences			Average Values			Significant Differences		
Haney-Soil Health Tool	NT+CC (WH)	NT (WH)	NBR (SB-NT)	NT+CC vs NT	NT+CC vs NBR	NT vs NBR	NT+CC (CN)	NT (CN)	NBR (CN-Till)	NT+CC vs NT	NT+CC vs NBR	NT vs NBR
Nitrogen (N lb/A)	45.4	49.9	39.6				74.5	83.0	180.6		***	***
Phosphorus (P_2O_5 lb/A)	66.1	71.7	50.0				53.3	54.6	35.2			**
Soil Respiration-24 hrs (ppm)	68.3	69.9	40.9			*	124.9	131.0	82.1		*	**
Water Extr. Organic C (ppm)	303	305	325		*		255	265	245			
Water Extr. Organic N (ppm)	19.5	20.5	18.6				23.5	24.5	24.1			
Carbon: Nitrogen Ratio	15.6	14.9	17.4			***	10.9	10.8	10.3			
Soil Health Calculation	11.8	12.1	9.2				17.4	18.2	13.1		*	***

WH—Wheat; SB-NT—No-tilled soybean; CN—Corn

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