

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 agro-nomic 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: | 53.9°F |
| Mean Annual Precipitation: | 45.7 in |

Treatments

No-till + Cover Crop
No-till, No Cover
Neighbor (Tillage, No cover)



Summary of Villwock Site

At the Villwock farmer site, the treatments consisted of no-till cover crop and no cover comparisons along with a neighbor sampled in 2016.

There were several soil health measures that indicated greater soil health with cover crops and no-till compared to no-till only. Some of these such as greater soil respiration and larger counts of amoeba show that the microbial community and activity increases with cover crops. Several other measures that increased with cover crops indicate changes to the organic matter; these include the direct measure of organic matter as well as available water capacity which is related to both the organic matter and the soil texture. The ACE protein index was also higher with cover crops suggesting more N is in readily available forms for microbes to eat, some of which can later become plant-available. The Cornell quality score, which incorporates many of these measures was also higher with cover crops. Neither PLFA nor the Haney Soil Health Tool included any measures that were able to distinguish between the cover and no cover no-till treatments at Villwock.

The neighbor was sampled in 2016 allowing for a comparison between these conservation cropping systems and systems with tillage and no cover crops on a nearby similar soil. Although the soils were mapped as the same soil series, lab analysis showed 6% higher clay in the neighbor field, which can lead to significant differences in other soil physical properties of these coarse-textured soils. For some measures the neighbor had higher values than the no-tilled treatments; these included available water capacity, organic matter, and the overall Cornell quality score. These differences, especially available water capacity and organic matter, are probably due to the higher clay content of the neighbor as well as the applications of turkey manure on the neighbor fields. The no-till cover crop treatment did have a higher fungi:bacteria

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ratio and diversity index as measured by PLFA as well as Cornell aggregate stability compared to the neighbor. There were also complications in interpreting these results as many of the measures were highly variable for the neighbor field, making it difficult to conclude that the differences between treatments were real and repeatable and not just the product of random error.

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 a subset of a soil health measures from each of the commercial soil health tests evaluated in 2015 and 2016 at the Villwock 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 and no cover/no-till and the neighbor (2016 only). 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 the 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.

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Site Details—Soils, Treatments

| Conservation Cropping System Experimental Plots | | | | | | |
|---|-------|------------------|-----------------|-------------------------|-------------------|------------------|
| % of Field | Slope | Soil Series Name | Soil Texture | Drainage Class | Native Vegetation | Parent Materials |
| 74% | 0-1% | Lyles | loam | very poorly drained | Transition | Loamy outwash |
| 18% | 0-2% | | | | | |
| 8% | 0-2% | Ayrshire | fine sandy loam | somewhat poorly drained | Forest | Eolian sands |

| Neighbor | | | | | | |
|------------|------------------|--------------|-------|---------------------|-------------------|------------------|
| % of Field | Soil Series Name | Soil Texture | Slope | Drainage Class | Native Vegetation | Parent Materials |
| 100% | Lyles | loam | 0-1% | very poorly drained | Transition | Loamy outwash |

| | Summer 2013 | Fall 2013- Summer 2014 | | Fall 2014- Summer 2015 | | Fall 2015- Summer 2016 | |
|-----------------------------|-------------|---------------------------|------|---------------------------|------|---------------------------|------|
| Treatments | Cash | Cover | Cash | Cover | Cash | Cover | Cash |
| NT+CC (VF 1,3,5) | CN | CL/RD | CN | OA/CL/ RD/RP | SB | OA/CL/ RD/RP | CN |
| NT (VF 2,4,6) | CN | — | CN | — | SB | — | CN |
| NBR (VF 7,8,9,10) | ? | — | ? | — | ? | — | CN |

NT+CC—Cover Crop No-till; NT—No Cover No-till; NBR—Neighbor
 Cash and Cover Crop Abbreviations: CN—Corn; SB—Soybean; CL—Crimson Clover; RD—
 Radish; OA—Oats; RP—Rapeseed
 Cover crops are color-coded as light green.

| Soil Health Sampling Dates | Soil Moisture (%) | | |
|-------------------------------|-------------------|------|------|
| | NT+CC | NT | NBR |
| June 10, 2015 | 14.8 | 15.3 | — |
| June 14, 2016 | 5.0 | 4.3 | 10.8 |

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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 Villwock from 2015 and 2016 along with the neighbor (NBR) from 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 10, 2015 | | | | | |
|----------------------------------|----------------|---------|-------------|-------------------------|--------------|-----------|
| | Average Values | | | Significant Differences | | |
| | NT+CC (SB) | NT (SB) | | | | |
| PLFA—Ward Laboratories | | | | | | |
| Total Microbial Biomass (ng/g) | 668 | 1055 | | | | |
| Total Bacteria (ng/g) | 334 | 413 | | | | |
| Total Fungi (ng/g) | 16 | 73 | | | | |
| Mycorrhizal Fungi (ng/g) | 0 | 10 | | | | |
| Protozoa (ng/g) | 0 | 3 | | | | |
| Fungi:Bacteria Ratio | 0.04 | 0.16 | | | | |
| <i>Diversity Index</i> | 1.11 | 1.33 | | | | |
| | June 14, 2016 | | | | | |
| | Average Values | | | Significant Differences | | |
| | NT+CC (CN) | NT (CN) | NBR (CN-CT) | NT+CC vs NT | NT+CC vs NBR | NT vs NBR |
| PLFA—Missouri | | | | | | |
| Total Microbial Biomass (nmol/g) | 72.2 | 61.9 | 75.3 | | | |
| Total Bacteria (nmol/g) | 40.2 | 34.5 | 40.5 | | | |
| Total Fungi (nmol/g) | 1.29 | 1.13 | 1.17 | | | |
| Mycorrhizal Fungi (nmol/g) | 2.96 | 2.36 | 2.48 | | | |
| Protozoa (nmol/g) | 0.63 | 0.53 | 0.46 | | | |
| Fungi:Bacteria Ratio | 0.22 | 0.21 | 0.18 | | ** | |
| <i>Diversity Index</i> | 1.38 | 1.36 | 1.29 | | ** | |

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

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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 any of the treatments were detected in either 2015 or 2016.
- Ward Laboratories, which analyzed PLFA in 2015, has a rating system for total microbial biomass (see Appendix).
 - According to the rating system, the microbial biomass of the cover crop/no-till treatment is rated as poor while the no cover/no-till microbial biomass is rated as slightly below average in 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.

- No significant difference between treatments was detected in either year.

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.

- No significant difference between treatments was detected in either year.

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 in either 2015 or 2016 between the cover and no cover no-till treatments.
- In 2016, the fungi:bacteria ratio of the cover crop/no-till treatment was higher than the neighbor, which is a good sign for improvement of soil health with conservation cropping systems.
- Ward Laboratories has a rating system for this measurement as well (see Appendix).
 - Based on this, the values for the 2015 measurements for cover crop/no-till fall in the very poor category while the no cover/no-till fungi:bacteria ratio is rated as average.
 - In 2016, the fungi: bacteria ratios of both the cover and no cover no-till plots are considered slightly above average while the neighbor is 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.

- Similar to the fungi:bacteria ratio, no differences between cover and no cover no-till treatments either year, but the diversity index of the no-till cover crop plots is significantly higher than the neighbor.
- Ward Laboratories provided a rating system for this calculation as well (see Appendix).
 - The diversity index of the cover crop/no-till plots in 2015 falls in the slightly below average category and the no cover/no-till plots have a slightly above average diversity index.
 - For the 2016 measurements, the diversity index of both cover and no cover no-till treatments are slightly above average while the neighbor has an average diversity index.

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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 Villwock. 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 10, 2015 | | |
|-----------------------------------|----------------|---------|-------------------------|
| | Average Values | | Significant Differences |
| | NT+CC (SB) | NT (SB) | |
| Active Bacteria (µg/g) | 43 | 48 | |
| Total Bacteria (µg/g) | 1445 | 1541 | |
| Active Fungi (µg/g) | 33 | 26 | |
| Total Fungi (µg/g) | 659 | 661 | |
| Protozoa--Flagellates (µg/g) | 8182 | 3737 | |
| Protozoa--Amoeba (µg/g) | 452001 | 74954 | ** |
| Protozoa--Ciliates (µg/g) | 240 | 156 | |
| Total Fungi: Total Bacteria Ratio | 0.45 | 0.48 | |

SB—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 the treatments for either total or active bacteria.

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 or active fungi in 2015.

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.

- More amoeba were detected in the cover crop/no-till plots than in the no cover/no-till plots, which can be beneficial as the amoeba feast on bacteria and release excess nutrients into the soil.
- There were no significant differences between cover and no cover no-till treatments for flagellate and ciliate types of protozoa.

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.

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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). 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 measurement 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 no-till (NT+CC) and no cover no-till (NT) plots at Villwock from 2015 and 2016 along with the neighbor (NBR) from 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.

| Cornell Soil Health Assessment | June 10, 2015 | | | June 14, 2016 | | | | | |
|---------------------------------|----------------|---------|-------------------------|----------------|---------|-------------|-------------------------|--------------|-----------|
| | Average Values | | Significant Differences | Average Values | | | Significant Differences | | |
| | NT+CC (SB) | NT (SB) | | NT+CC (CN) | NT (CN) | NBR (CN-CT) | NT+CC vs NT | NT+CC vs NBR | NT vs NBR |
| <i>Quality Score</i> | 45.1 | 38.0 | ** | 61.8 | 57.8 | 69.3 | | * | ** |
| Aggregate Stability (%) | 20.1 | 18.5 | | 36.5 | 38.3 | 26.5 | | ** | |
| Available Water Capacity | 0.12 | 0.11 | | 0.13 | 0.12 | 0.16 | ** | ** | ** |
| Surface Hardness (psi) | 500 | 467 | | — | — | — | | | |
| Subsurface Hardness (psi) | 483 | 533 | | — | — | — | | | |
| Organic Matter (%) | 1.47 | 1.40 | | 1.83 | 1.57 | 2.96 | * | *** | *** |
| Active Carbon (ppm) | 406 | 347 | | 427 | 387 | 517 | | | |
| ACE Soil Protein Index | 3.73 | 3.47 | | 4.50 | 4.01 | 4.82 | * | | |
| Soil Respiration-96 hours (ppm) | 300 | 250 | | 470 | 390 | 470 | *** | | |

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

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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 70 are optimal, while values below 30 are considered a constraint and indicate the soil functions are limited. Values between 30 and 70 are considered sub-optimal.

- The overall quality score calculated from the Cornell test was higher with cover crops than without under no-till in 2015.
- Those same two treatments were no longer significantly different the following year, but both values were much higher. Both were significantly lower than the quality score from the neighbor, likely due in part to the lower clay content causing lower available water capacity and lower organic matter.

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 in 2015.
- In 2016, the cover crop/no-till treatment was significantly higher than the neighbor while the no cover treatment is not significantly different from the neighbor.
- These results may seem strange as the neighbor has aggregate stability 11.8% lower than the no cover/no-till plots, which is NOT significant but smaller difference of 10% compared to the cover crop/no-till plots was significant.
- Why is this?
 - This seeming contradiction is because the measured values of the three cover crop plots have less variability among them than among the three no cover plots. This means we can be more confident that the difference between the cover and conventional treatments is real and could be repeated.
 - In contrast, the difference between no cover and neighbor could be related to random errors so we cannot be as confident that this is a true difference between the 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.

- There were no significant differences between treatments in 2015.
- In 2016, the cover crop/no-till plots had slightly greater available water capacity than the no cover/no-till plots

while the neighbor had higher available water capacity than either the cover or no cover no-till plots.

- One of the strongest influences on available water capacity is soil texture. The soils of the neighbor have 6% higher clay content (16% vs 10%) than the cover and no cover no-till plots at Villwock, which can explain why the neighbor would have higher available water capacity.

Surface and Subsurface Hardness

These are measures of compaction 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

- No significant differences in surface hardness or subsurface hardness in 2015.

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 in 2015.
- In 2016, with one more year of cover crops, the cover crop/no-till treatment had higher organic matter than no cover/no-till.
- The neighbor had significantly greater organic matter than either of the no-till treatments.
 - The higher clay content of the neighbor contributed to the greater organic matter as clay particles can bind to and protect organic matter. The neighbor also had turkey manure applications that would have also increased the organic matter.
 - This difference in organic matter may also contribute to the difference in available water capacity as well.

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.

- Active carbon did not differ among treatments in 2015 or 2016.

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Cornell cont.

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 differences were found in 2015.
- In 2016, the no-till cover crop protein index was higher than the no cover plots with no-till.
 - Neither was significantly different from the neighbor, likely due to high variability in the neighbor soil samples.

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, but in 2016, cover/no-till had higher soil respiration than no cover/no-till.
 - High variability in the neighbor data again means that the no cover/no-till is not significantly different from the neighbor despite the large difference between the averages.

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 for cover crop no-till (NT+CC) and no cover no-till (NT) plots at Villwock from 2015 and 2016 along with the neighbor (NBR) from 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 10, 2015 | | | June 14, 2016 | | | | | |
|---|----------------|---------|-------------------------|----------------|---------|-------------|-------------------------|--------------|-----------|
| | Average Values | | Significant Differences | Average Values | | | Significant Differences | | |
| Haney-Soil Health Tool | NT+CC (SB) | NT (SB) | | NT+CC (CN) | NT (CN) | NBR (CN-CT) | NT+CC vs NT | NT+CC vs NBR | NT vs NBR |
| Nitrogen (N lb/A) | 49 | 42 | | 102 | 118 | 65 | | | ** |
| Phosphorus (P ₂ O ₅ lb/A) | 74 | 71 | | 78 | 68 | 100 | | | |
| Soil Respiration-24 hours (ppm) | 52 | 41 | | 72 | 50 | 86 | | | ** |
| Water Extr. Organic C (ppm) | 180 | 156 | | 217 | 188 | 226 | | | |
| Water Extr. Organic N (ppm) | 16.1 | 14.0 | | 20.7 | 18.0 | 19.6 | | | |
| Carbon: Nitrogen Ratio | 11.1 | 11.1 | | 10.7 | 10.4 | 11.6 | | | |
| <i>Soil Health Calculation</i> | 8.6 | 7.0 | | 11.4 | 8.7 | 12.9 | | | ** |

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

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Haney cont.

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 P or in 2015 for N.
- Nitrogen in the cover and no cover treatments at Villwock with no-till were not different in 2016, but the no cover/no-till treatment had significantly more N than 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 2015.
- In 2016, the only significant difference was that soil respiration from the neighbor was higher than in the no cover/no-till treatment.

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.

- No significant differences were found for either water extractable organic C or N in 2015 and 2016.

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.
- In 2016, the soil health calculation of the neighbor was higher than that of the no cover/no-till treatment. There were no significant differences between the cover and no cover treatment or between the cover and neighbor.
- The soil health calculation increased from 2015 to 2016 for the cover and no cover no-till treatments, which is an indication of improved soil health over time.

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 |

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