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:

VUJC
Dubois County

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Climate	
Mean Annual Temperature:	**53.0°F**
Mean Annual Precipitation:	**45.7 in**

Treatments
No-Till + Cover Crops
Conventional Tillage + Cover Crops

Summary of VUJC Site

The VUJC site has one no-till plot and one tilled plot, both planted with cover crops. Because these treatments are not replicated, we are not able to statistically analyze the data and therefore cannot definitely say whether there are differences between the two tillage practices with cover crops. Most of the soil health measures are similar between the treatments and based on the variability in these measures we saw in the other sites, likely do not differ between the plots. However a few soil health measures had very large apparent difference (PLFA total bacteria, PLFA total fungi, Earthfort amoeba), which may indicate some different results from different tillage practices.

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 VUJC 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.

Values are presented for both of the treatments at the location—no-till/cover crops and conventional tillage/cover crops. Since there is no replication at the location, we are not able to test the treatments for statistically significant differences.

Site Details—Soils, Treatments

Conservation Cropping System Experimental Plots						
% of Field	Soil Series Name	Soil Texture	Slope	Drainage Class	Native Vegetation	Parent Materials
90%	Zanesville	silt loam	1-6%	moderately well drained	Forest	Loess over loamy residuum
10%	Steff	silt loam	0-2%	moderately well drained	Forest	Acid loamy alluvium

	Fall 2012-Summer 2013		Fall 2013-Summer 2014		Fall 2014-Summer 2015		Fall 2015-Summer 2016	
Treatment	**Cover**	**Cash**	**Cover**	**Cash**	**Cover**	**Cash**	**Cover**	**Cash**
NT+ CC VUJC1 **CT+CC** VUJC2	CR/CL/RD	CN	CR	SB	OA/CL/RD	CN	OA/CL/RD	SB

NT+CC—No-till with Cover Crops; CT+CC—Conventional Tillage with Cover Crops
Cash and Cover Crop Abbreviations: CN—Corn; SB—Soybean; CR—Cereal Rye; CL—Crimson Clover; RD—Radish; OA—Oats
Cover crops are color-coded as light green.

Both plots at VUJC have the same cash and cover crop treatments, but differ in tillage practice.

Soil Health Sampling Dates
May 26, 2015
June 29, 2016

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. Measured values from 2015 and 2016 for Phospholipid Fatty Acids (PLFA) for no-till (NT+CC) and conventional tillage (CT+CC) plots at VUJC which both have cover crops. 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. **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.**

	May 26, 2015	
PLFA—Ward Laboratories	NT+CC (CN)	CT+CC (CN)
Total Microbial Biomass (ng/g)	1823	1385
Total Bacteria (ng/g)	913	707
Total Fungi (ng/g)	235	182
Mycorrhizal Fungi (ng/g)	58	45
Protozoa (ng/g)	17	19
Fungi:Bacteria Ratio	0.26	0.26
Diversity Index	1.60	1.66
	June 29, 2016	
PLFA—Missouri	NT+CC (SB)	CT+CC (SB)
Total Microbial Biomass (nmol/g)	39.1	34.7
Total Bacteria (nmol/g)	19.7	20.1
Total Fungi (nmol/g)	0.36	0.62
Mycorrhizal Fungi (nmol/g)	1.42	1.20
Protozoa (nmol/g)	0.16	0.14
Fungi:Bacteria Ratio	0.21	0.20
Diversity Index	1.35	1.32

CN—Corn; SB—Soybean

Due to the lack of replication, we are not able to statistically analyze this data to definitively determine if there are differences between treatments, but most of these measures look similar between treatments. They are not likely to be different, based on the variability in these measures we saw in the other farmer sites.

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.

- Ward Laboratories, which analyzed PLFA in 2015, has a rating system for total microbial biomass (see Appendix).
    - According to the rating system, the no-till microbial biomass are rated average and the tilled plot has slightly below average microbial biomass.

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.

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.

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.

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.

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.

- Ward Laboratories has a rating system for this measurement as well (see Appendix).
    - Based on this, the values for the 2015 measurements for both treatments are in the good category.
    - The 2016 fungi:bacteria ratios of the tilled and no-tilled cover crop plots are rated as 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.

- Ward Laboratories provided a rating system for this calculation as well (see Appendix).
    - For 2015, both the no-till and tilled plots have excellent diversity based on this rating scale.
    - In 2016, the diversity of both tilled and no-tilled cover crop plots were rated as slightly above average.

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. Measured values for Earthfort Biological Analysis in 2015 for no-till (NT+CC) and conventionally tilled (CT+CC) cover crop plots at VUJC.

	May 26, 2015	
Earthfort	NT+CC (CN)	CT+CC (CN)
Active Bacteria (µg/g)	62	95
Total Bacteria (µg/g)	805	2224
Active Fungi (µg/g)	55	35
Total Fungi (µg/g)	1072	745
Protozoa--Flagellates (µg/g)	3381	5549
Protozoa--Amoeba (µg/g)	338120	55493
Protozoa--Ciliates (µg/g)	169	16
Total Fungi: Total Bacteria Ratio	1.33	0.33

CN—Corn

Earthfort, cont.

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.

- The total bacteria for the no-till with cover crop plots seems low compared to the results from other sites.

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.

- The total fungi of the no-till cover crop plot is a little higher than expected compared to the results from other sites

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.

- The difference in the number of amoeba type of protozoa under no-till compared to the tilled plot is rather large, and is comparable in size to significant differences in this measure at other sites.

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.

- The fungi:bacteria ratio for the no-till cover crop plot is extremely high and we are not confident that this is real. It is likely the results of the low bacteria and high fungi measures, which were both outside the range we would expect.

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 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.

Cornell, cont.

Table 3. Measured values for Cornell Soil Health Assessment in 2015 and 2016 and for no-till (NT+CC) and conventional tillage (CT+CC) cover crop plots at VUJC. Measurements in italics are calculations within commercial tests purported to be indicators of overall soil health.

Cornell Soil Health Assessment	May 26, 2015		June 29, 2016	
	NT+CC (CN)	CT+CC (CN)	NT+CC (SB)	CT+CC (SB)
Quality Score	46.6	40.4	45.7	42.7
Aggregate Stability (%)	NA[#]	15.2	8.8	15.1
Available Water Capacity	0.26	0.26	0.25	0.27
Surface Hardness (psi)	300	300	304	321
Subsurface Hardness (psi)	300	300	341	334
Organic Matter (%)	1.90	1.90	1.61	1.77
Active Carbon (ppm)	387	343	268	238
ACE Soil Protein Index	3.79	3.37	3.00	3.22
Soil Respiration-96 hours (ppm)	240	240	211	207

[#]The number provide for aggregate stability of the NT+CC treatment in 2015 is out of line with the measurement of the following year as well as all other aggregate stability measures.
CN—Corn; SB—Soybean

Due to the lack of replication, we are not able to statistically analyze this data to definitively determine if there are differences between treatments, but most of these measures look similar between treatments. They are not likely to be different, based on the variability in these measures we saw in the other farmer sites.

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.

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

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.

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

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.

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.

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.

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.

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. Measured values for the Haney Soil Health tool in 2015 and 2016 and for no-till (NT+CC) and conventional tillage (CT+CC) cover crop plots at VUJC. Measurements in italics are calculations within commercial tests purported to be indicators of overall soil health.

	May 26, 2015		**June 29, 2016**	
Haney-Soil Health Tool	NT+CC (CN)	CT+CC (CN)	NT+CC (SB)	CT+CC (SB)
Nitrogen (N lb/A)	116	59	33	33
Phosphorus (P_2O_5 lb/A)	30	27	29	29
Soil Respiration-24 hours (ppm)	34	32	34	34
Water Extr. Organic C (ppm)	187	165	282	282
Water Extr. Organic N (ppm)	17.7	18.5	20.3	20.3
Carbon: Nitrogen Ratio	10.5	8.9	13.9	13.9
Soil Health Calculation	7.1	6.6	8.3	8.3

CN—Corn; SB—Soybean

Due to the lack of replication, we are not able to statistically analyze this data to definitively determine if there are differences between treatments, but most of these measures look similar between treatments. They are not likely to be different, based on the variability in these measures we saw in the other farmer sites.

Haney, cont.

Nitrogen and Phosphorus Nutrient Content
These are measures of N and P currently in the soil.

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

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.

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.

Photo Credit: Jennifer Woodyard

June 13, 2016. Tilled strip surrounded by no-till field.

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