Summary of CCSI Farmer Site Results

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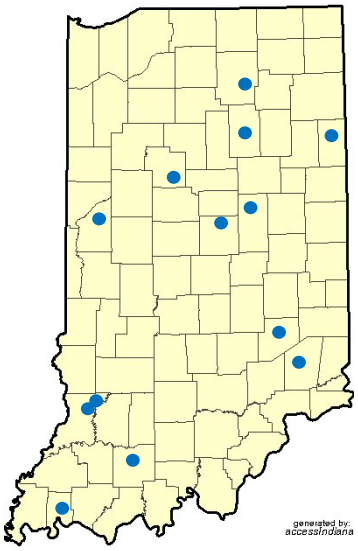
Report Structure

This report is prepared as a summary of results from all 14 CCSI farmer sites, 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
- Executive Summary
- Detailed Summary of Soil Health Test Results
  - Effect of cover crops
  - Comparison of tillage practices with cover crops
  - Effect of nitrogen rate in combination with no-till and cover crops



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

Executive Summary

Overall, the results from 2015 and 2016 show that these commercial soil health tests were not able to successfully detect many differences between treatments at the farmer sites. Few of the soil health indicators were able to distinguish between no-till with and without cover crops, but this may be a product of the short-term addition of cover crops compared to the long-term no-till system that had been in place at most sites prior to the implementation of the CCSI plots. There were a few more differences detected between the conservation cropping system plots and the conventional neighbors, which may indicate again that the long-term no-till system had already improved soil health. Longer duration of the cover crop treatments may be necessary for these soil health indicators to improve to a detectable degree. The soil health indicators that showed the greatest potential to distinguish between treatments were primarily related to carbon cycling and soil organic matter; these included active carbon, water extractable organic carbon, and soil respiration.

The biological tests—PLFA and Earthfort, showed only a few significant differences between treatments across all of the sites. Because of the high variability generally found in these measurements, detecting statistically significant differences requires much larger numerical differences than might be expected. While more time in the soil health system may be necessary for the differences between treatments to become large enough to detect, changing the timing of the sampling or the depth of sampling may also be necessary.

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.

Detailed Summary

Selected soil health indicators from each of the commercial soil health tests are summarized from the 14 farmer sites. All of the results shown are from 2016, except for Earthfort measures, which are from 2015. For each soil health indicator, data are shown from a few sites to highlight the general results for that measurement across all of the sites. The majority of the sites had comparisons between no-till with and without cover crops, along with some different cover crop treatments. A few other sites had tillage comparisons, and one site had three different nitrogen rates with no-till and cover crops.

Cover Crop Results

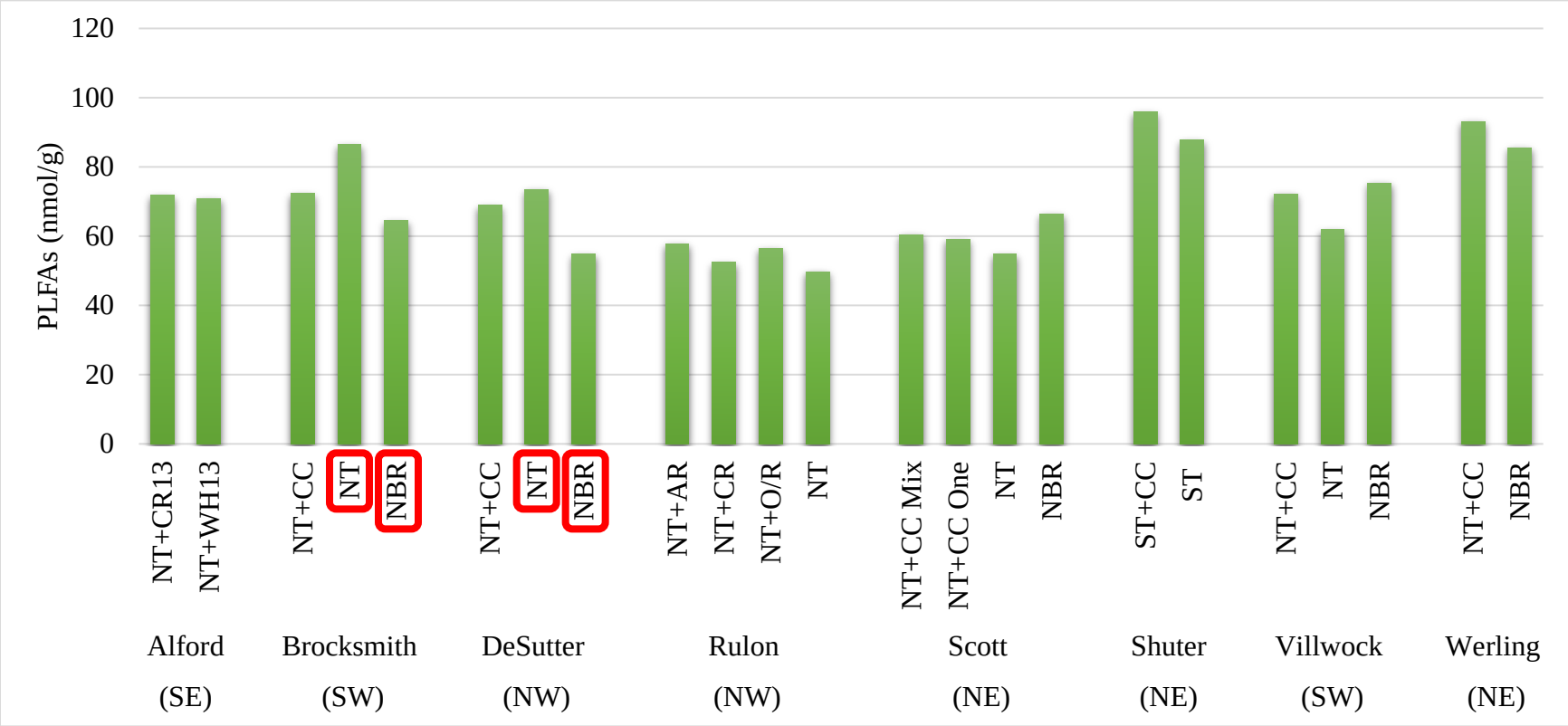
Table 1. List of treatment descriptions and abbreviations for each of the farmer sites that included treatment comparisons with and without cover crops sorted by region of Indiana.

Region	Farmer Site	County	Abbreviation	Treatment Description
Northeast	Scott	Kosciusko	NT+CC Mix NT+CC One NT NBR	No-till + Cover Crop Mix No-till+Single Species Cover Crop No-till, No Cover Neighbor (Tillage, No cover)
	Shuter	Madison	2015: NT+CC NT	2015: No-till + Cover Crops No-till, No Cover
			2016: ST+CC ST	2016: Strip-till + Cover Crops Strip-till, No Cover
	Wabash SWCD	Wabash	NT + CC Large NT + CC Small	No-till + Cover Crop-Large Mix No-till + Cover Crop-Small Mix
	Werling	Adams	NT+CC NBR	No-till + Cover Crops Neighbor (Tillage, No cover)
Northwest	DeSutter	Fountain	NT+CC NT NBR	No-till + Cover Crops No-till, No Cover Neighbor (Tillage, No cover)
	Rulon	Hamilton	NT+AR NT+CR NT+OR NT	No-till + Annual Ryegrass No-till + Cereal Rye No-till + Oats/Daikon Radish No-till, No Cover
Southeast	Alford	Dearborn	NT+CR13 NT+WH13	No-till + Wheat Cover in 2013 No-till + Cereal Rye Cover in 2013
Southwest	Brocksmith	Knox	NT+CC NT NBR	No-till + Cover Crops No-till, No Cover Neighbor (Tillage, No cover)
	Stahl	Warrick	NT+CC NT	No-till + Cover Crops No-till, No Cover
	Villwock	Daviess	NT+CC NT NBR	No-till + Cover Crops No-till, No Cover Neighbor (Tillage, No cover)

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.

Figure 1. Total microbial biomass in 2016 as measured by phospholipid fatty acids (PLFAs) for some of the farmer sites that had cover crop treatment comparisons. Statistically significant differences between treatments at a location are indicated by red boxes around treatment names.

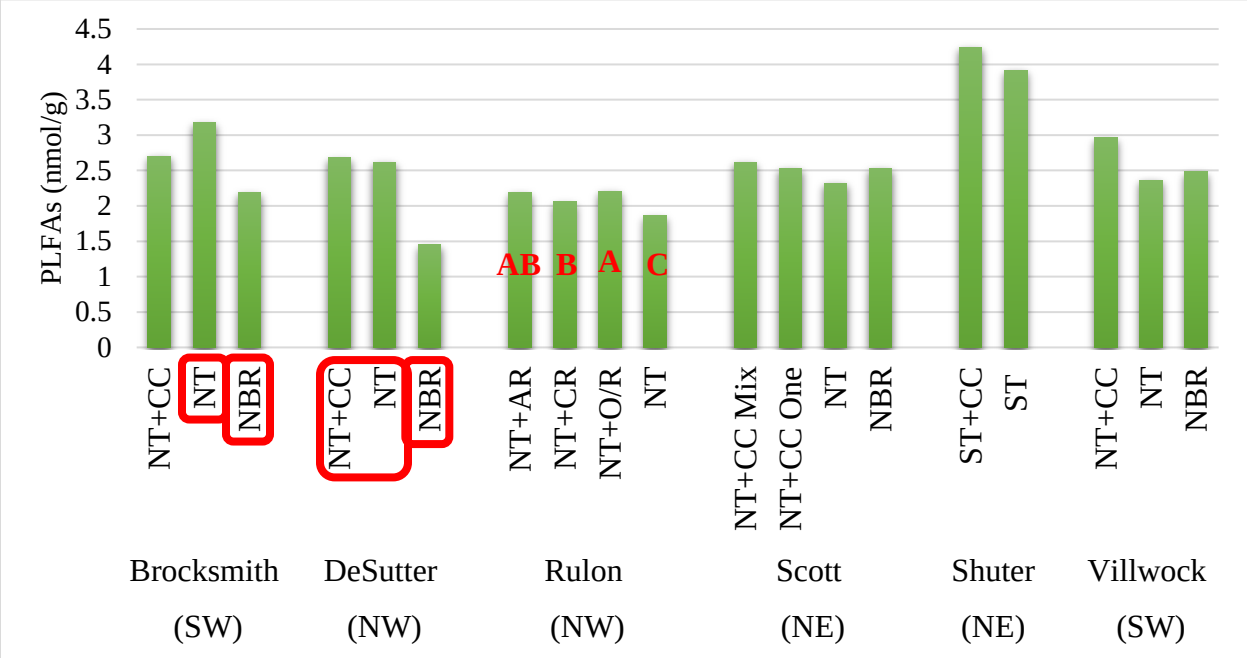


Total Microbial Biomass

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.

- Both Brocksmith and DeSutter's no-till treatments without cover crops had greater microbial biomass than the conventional neighbors.
- In contrast, while not statistically significant, both Scott and Villwock showed a trend of higher microbial biomass at the neighbor.
    - However, this was likely due to the presence of a living crops at Scott's neighbor while only wheat stubble was present at the time of sampling at the Scott CCSI plots in July.
    - Villwock's neighbor also had much higher clay content than the Villwock CCSI plots, which affected organic matter and therefore may also have led to the slightly higher microbial biomass.
- Overall, there were no significant differences between treatments with and without cover crops at the CCSI plots. This is probably due to short-term establishment of cover crops compared to the relatively long-term duration of no-till on these fields.

Figure 2. Mycorrhizal fungi as measured by phospholipid fatty acids (PLFAs) in 2016 for some of the farmer sites that had cover crop treatment comparisons. Statistically significant differences between treatments at a location are indicated by different letters or by red boxes around treatment names.

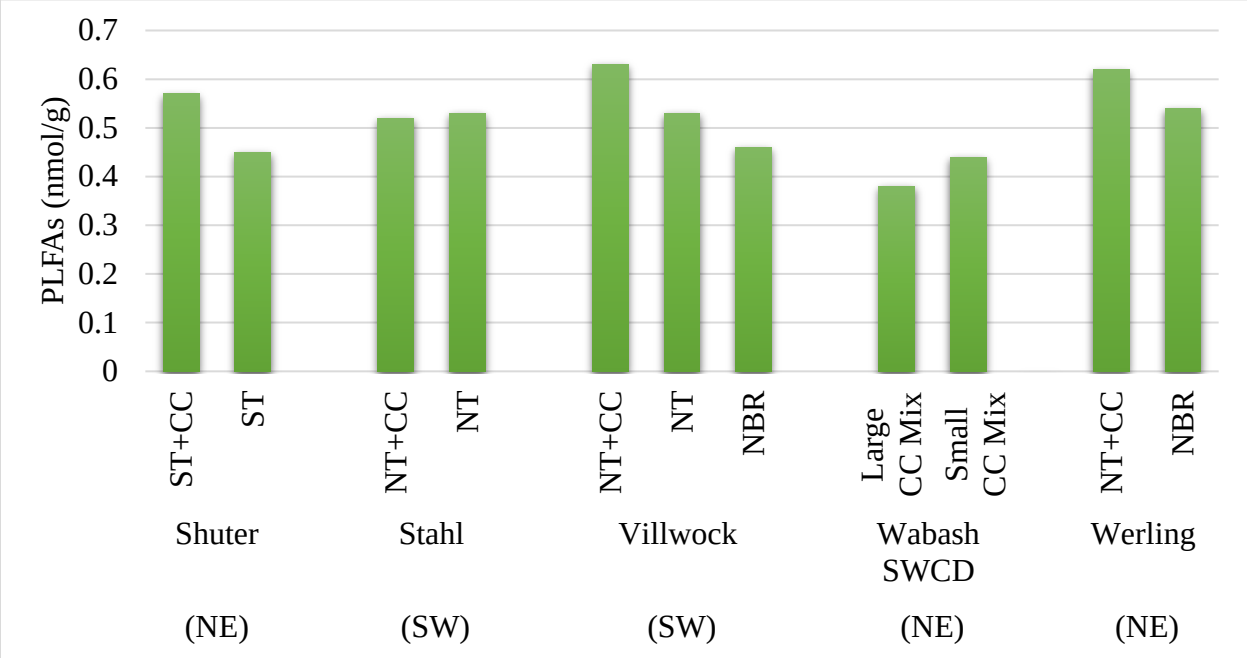


Mycorrhizal Fungi

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.

- Only one site, Rulon, show increased mycorrhizal fungi with cover crops in combination with no-till than with only no-till. This may be related to the longer-term duration of these plots since they were already in place in 2013 when the other plots were first established.
- Both Brocksmith and Desutter had greater levels of mycorrhizal fungi than their neighbor, but for Brocksmith, this was true only without cover crops, surprisingly.
- Other sites (Scott, Shuter and Villwock) showed trends of increasing mycorrhizal fungi with the addition of cover crops, but these were not significant.

Figure 3. Protozoa measured by phospholipid fatty acids (PLFAs) in 2016 for some of the farmer sites that had cover crop treatment comparisons. Statistically significant differences between treatments at a location are indicated by red boxes around treatment names.



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.

- None of the CCSI showed any significant differences between treatments with and without cover crops for protozoa PLFAs.

<u>Earthfort Biological Soil Analysis</u>

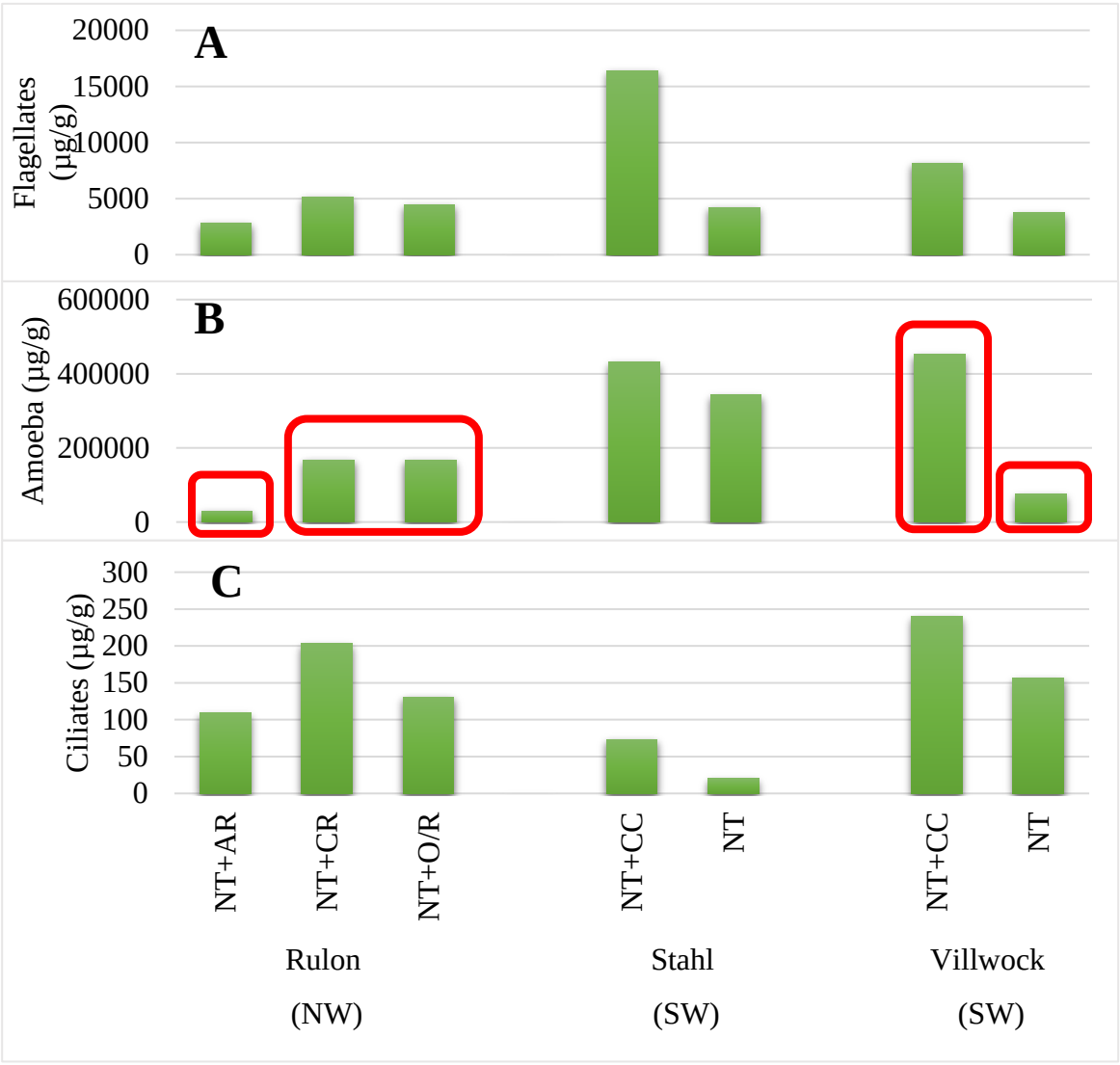
Similar to PLFA, this commercial test measures the size of various microbial groups; however, these measurements were made using microscopy, directly counting the size of these microbe groups.

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 require oxygen to survive. Ciliates are the largest and least common protozoa, and they are able to survive without oxygen in anaerobic conditions.

- Only amoeba had significant differences among the three types of protozoa, with greater numbers of amoeba in the no-till with cover crop treatment at Villwock compared to no-till only and more amoeba with cereal rye and oat/radish mix cover crops compared to annual ryegrass at Rulon.
- There were no significant differences for any of the sites for flagellates or ciliates.

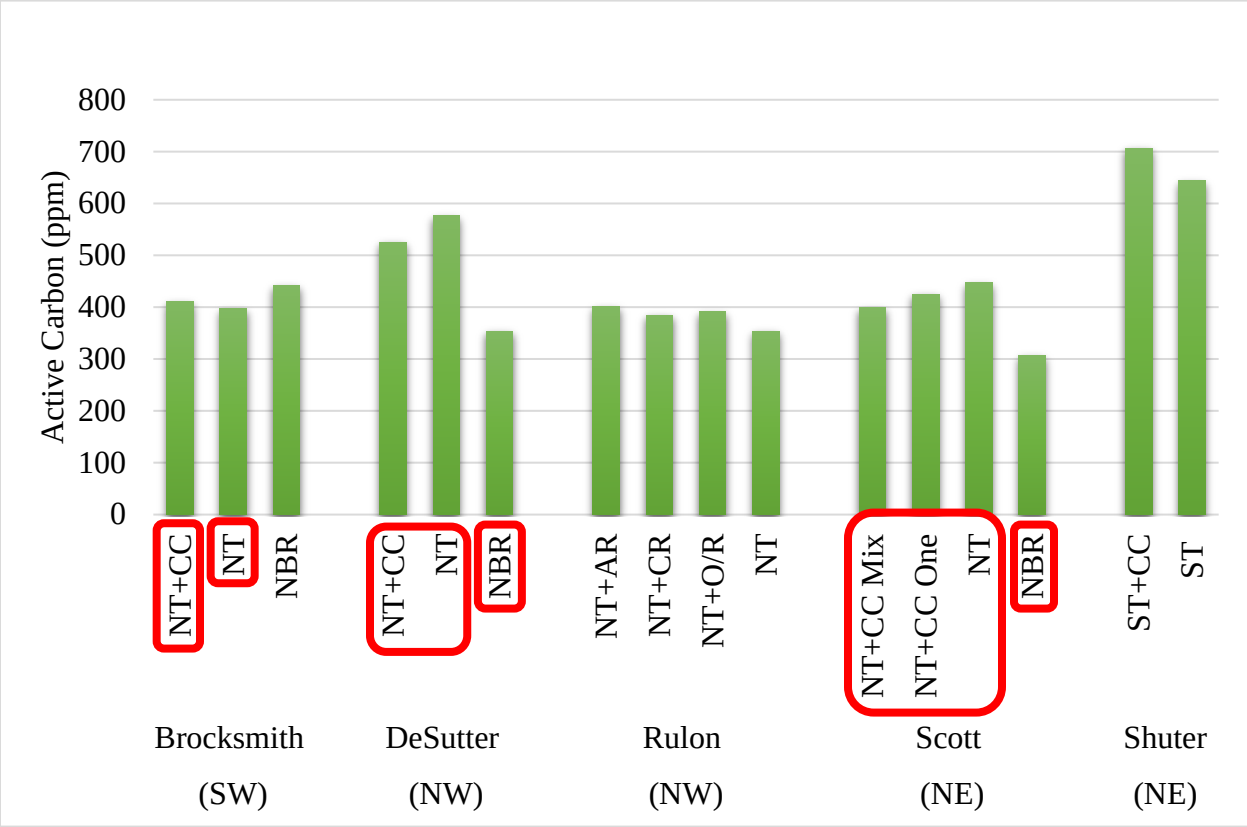
Figure 4. Protozoa measured by the Earthfort Biological Soil Analysis in 2015 for sites including cover crop treatment comparisons. The three types of protozoa—A) flagellates, B) amoeba, and C) ciliates, were all measured separately in this commercial test. Statistically significant differences between treatments at a location are indicated by red boxes around treatment names.



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).

Figure 5. Active carbon measurements from Cornell commercial soil health test for several farmer sites that had comparisons with cover crops from 2016. Statistically significant differences between treatments at a location are indicated by red boxes around treatment names.



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.

- Both DeSutter and Scott had greater active carbon with no-till with and without cover crops compared to the neighbor.
- Brocksmith was the only site that had significantly more active carbon with cover crops than without.
    - However, this difference was relatively small and is likely only statistically significant because this measurement was relatively consistent across the different replications in the field. This is in contrast to results from most other sites and soil health indicators, which tend to have high variability.

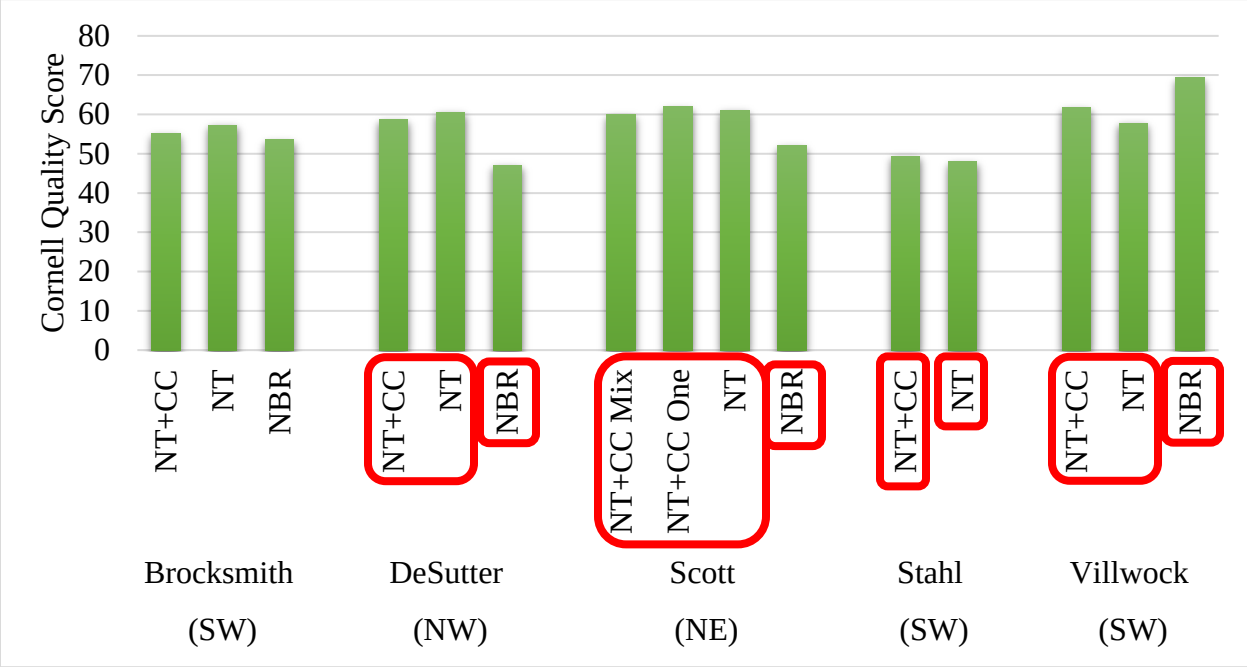
Figure 6. Soil respiration (96 hours) measurements from Cornell commercial soil health test for several farmer sites that had comparisons with cover crops from 2016. Statistically significant differences between treatments at a location are indicated by red boxes around treatment names.

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.

- The 96 hour soil respiration results from the Cornell test were relatively inconsistent across sites.
- Some sites (Brocksmith, DeSutter and Villwock) had greater respiration values with no-till and cover crops compared to a neighbor for Brocksmith and Desutter or compared to no-till without cover crops for Villwock.
- Both Scott and Stahl showed greater soil respiration values without cover crops compared to the cover crop treatments. At Scott, this may be due to lack of live roots in the wheat stubble vs. living soybean roots in the neighbor field.

Figure 7. Cornell Quality Scores for several farmer sites that had comparisons with cover crops from 2016. Statistically significant differences between treatments at a location are indicated by red boxes around treatment names.



Quality Score

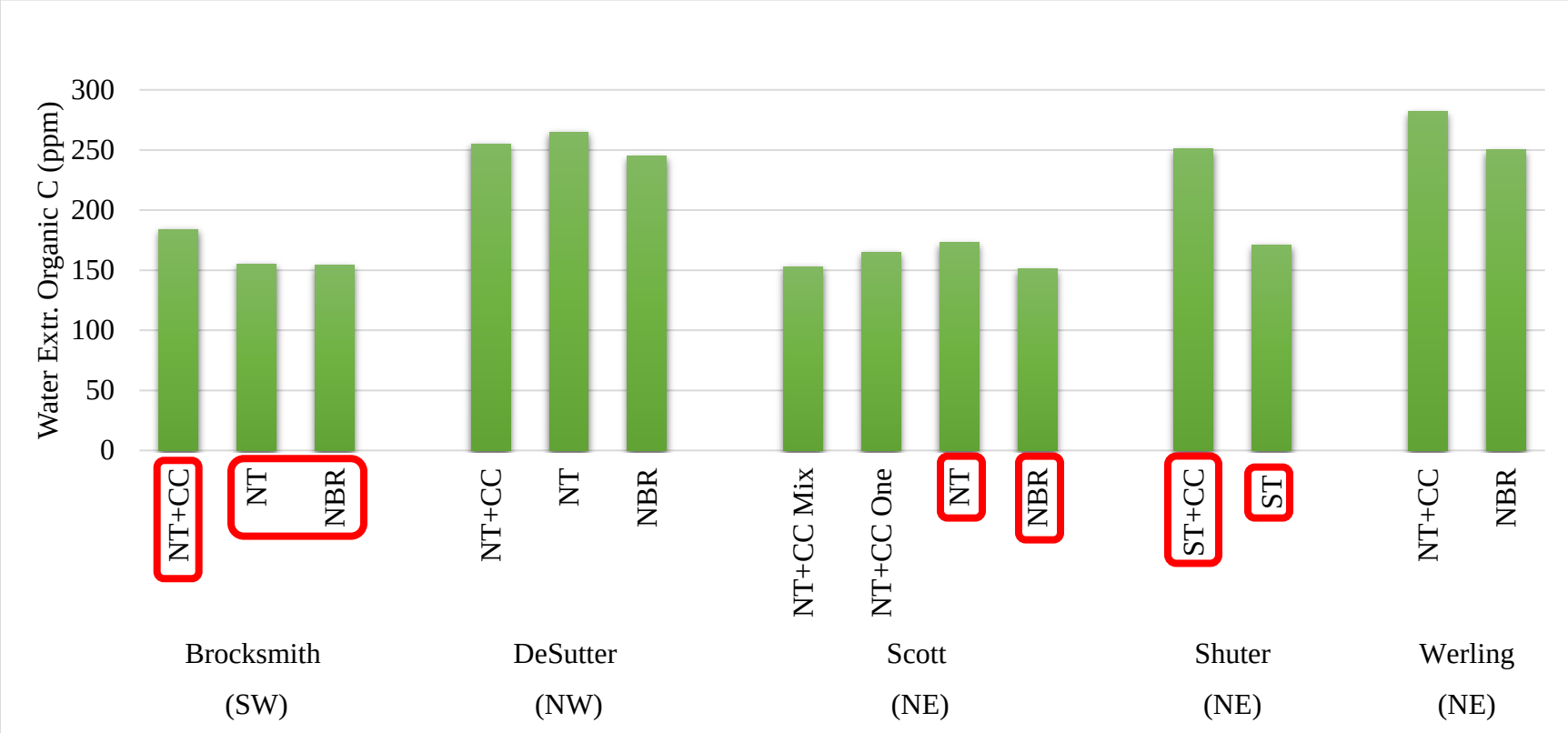
This is calculated based on the rating for each of the 12 different soil measures within this commercial soil health test. It is supposed to indicate overall soil health and values above 60 are considered excellent. Quality scores between 40 and 60 are rated medium and indicate soil health could still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

- Both DeSutter and Scott had higher overall quality scores for all no-till treatments with and without cover crops compared to the neighbor.
- In contrast, Villwock's neighbor had higher a quality score than both no-till treatments at Villwock. This is likely due to the 6% higher clay content at the neighbor, which also resulted in higher organic matter content at the neighbor.
- Stahl was the only site that had a significantly higher quality score with cover crops compared to the no cover treatment.

<u>Haney-Soil Health Tool</u>

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.

Figure 8. Water extractable organic C from the Haney Soil Health Tool for several farmer sites that had comparisons with cover crops from 2016. Statistically significant differences between treatments at a location are indicated by red boxes around treatment names.

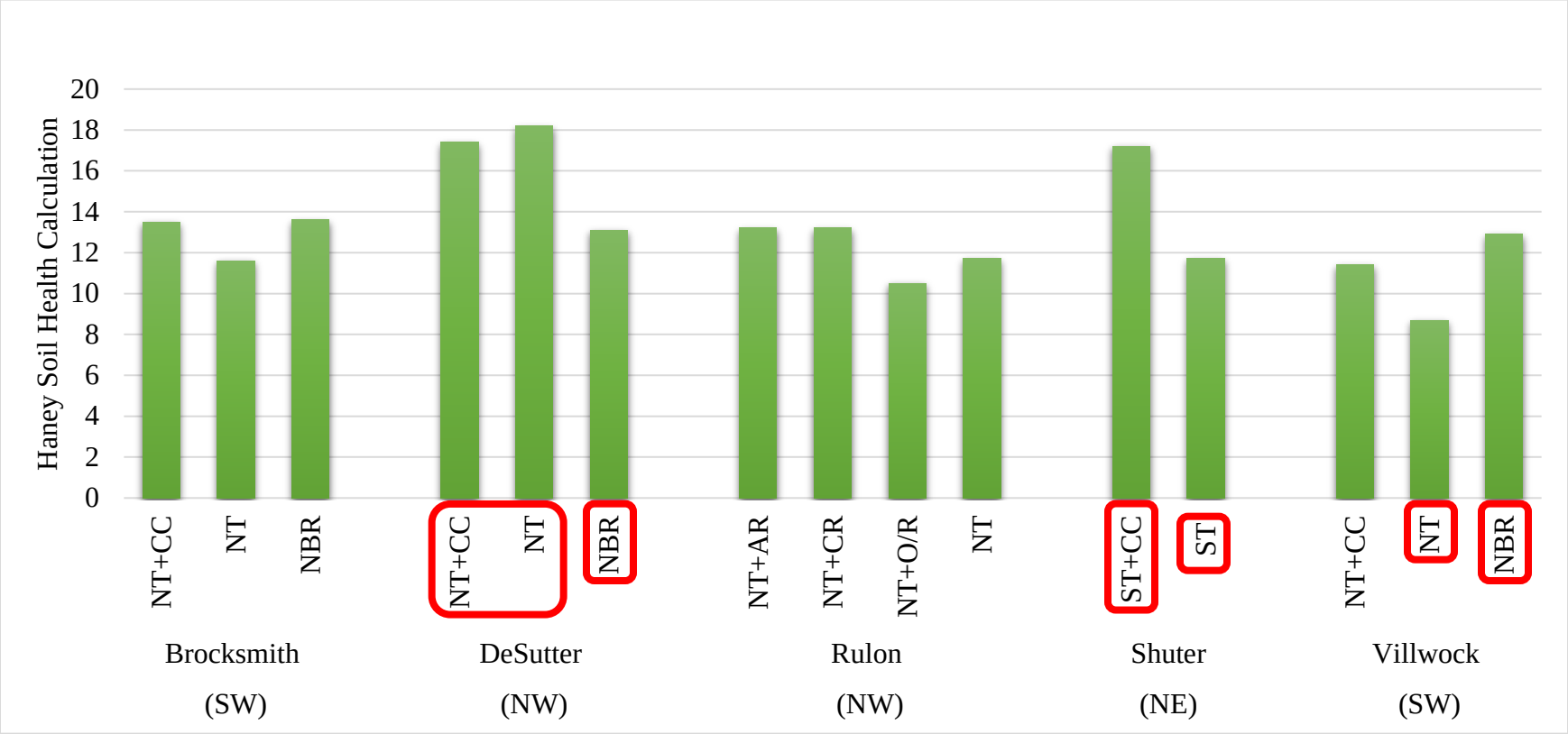


Water Extractable Organic Carbon

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

- At both Brocksmith and Shuter sites the cover crops treatment had higher water extractable organic C than the treatments without cover crops.
- The water extractable organic C was higher in no-till without cover crops at Scott than the neighbor, while the two cover crop treatments were in the middle and not significantly different from the treatments without cover crops.

Figure 9. Soil health calculation from the Haney Soil Health Tool for several farmer sites that had comparisons with cover crops from 2016. Statistically significant differences between treatments at a location are indicated by red boxes around treatment names.



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.

- The soil health calculation from DeSutter was greater for no-till with and without cover crops compared to the neighbor while at Shuter the cover crops led to a higher soil health calculation than with no cover crops.
- The soil health calculation of Villwock's neighbor was higher than the no-till, no cover treatment at Villwock, again possibly related to the difference in clay content and organic matter between the two fields.

Tillage Results

Table 2. List of treatment descriptions and abbreviations for each of the farmer sites that included treatment comparisons of tillage practices with cover crops sorted by region of Indiana.

Region	Farmer Site	County	Abbreviation	Treatment Description
Southeast	Huffmeyer	Ripley	CT+CC ST+CC NBR	TurboMax Tillage + Cover Crops Strip-tillage + Cover Crops Neighbor (Tillage, No Cover)
	Wenning	Decatur	NT+CC ST+CC NBR	No-till + Cover Crops Strip-tillage + Cover Crops Neighbor (Tillage, No Cover)
Southwest	VUJC	Dubois	NT+CC CT+CC	No-till + Cover Crops Conventional Tillage + Cover Crops **Non-replicated**

Phospholipid Fatty Acids

Microbial Biomass

- The no-till with cover crop treatment at Wenning had significantly higher microbial biomass than the neighbor. The strip-till with cover crop average was actually slightly higher than the no-till average, but was not significantly different from the neighbor due to the high amount of variability among the strip-till replications.

Mycorrhizal Fungi

- Both of the cover crop treatments at Huffmeyer had greater amounts of mycorrhizal fungi PLFAs than the neighbor.

Cornell Soil Health Assessment

Active Carbon

- At Huffmeyer, the cover crop treatments had greater active carbon than the neighbor, but only the TurboMax tilled strips were significantly higher than the neighbor.

Quality Score

- The cover crop treatments at Wenning had significantly higher quality score than the neighbor.
- A similar trend was seen at Huffmeyer although this was not significant.

Haney Soil Health Tool

Water Extractable Organic C

- Wenning had higher water extractable organic C with the strip-till cover crops treatment compared to the neighbor.

Soil Health Calculation

- The soil health calculation was the only soil health indicator that differentiated between two tillage practices with high soil health calculation with strip-till compared to the conventional tillage. However, the neighbor also had a higher soil health calculation than the conventionally tilled cover crops treatment.

Figure 10. Phospholipid fatty acids values for A) total microbial biomass and B) mycorrhizal fungi for farmer sites with cover crops and different tillage practices from 2016. Statistically significant differences between treatments at a location are indicated by red boxes around treatment names.

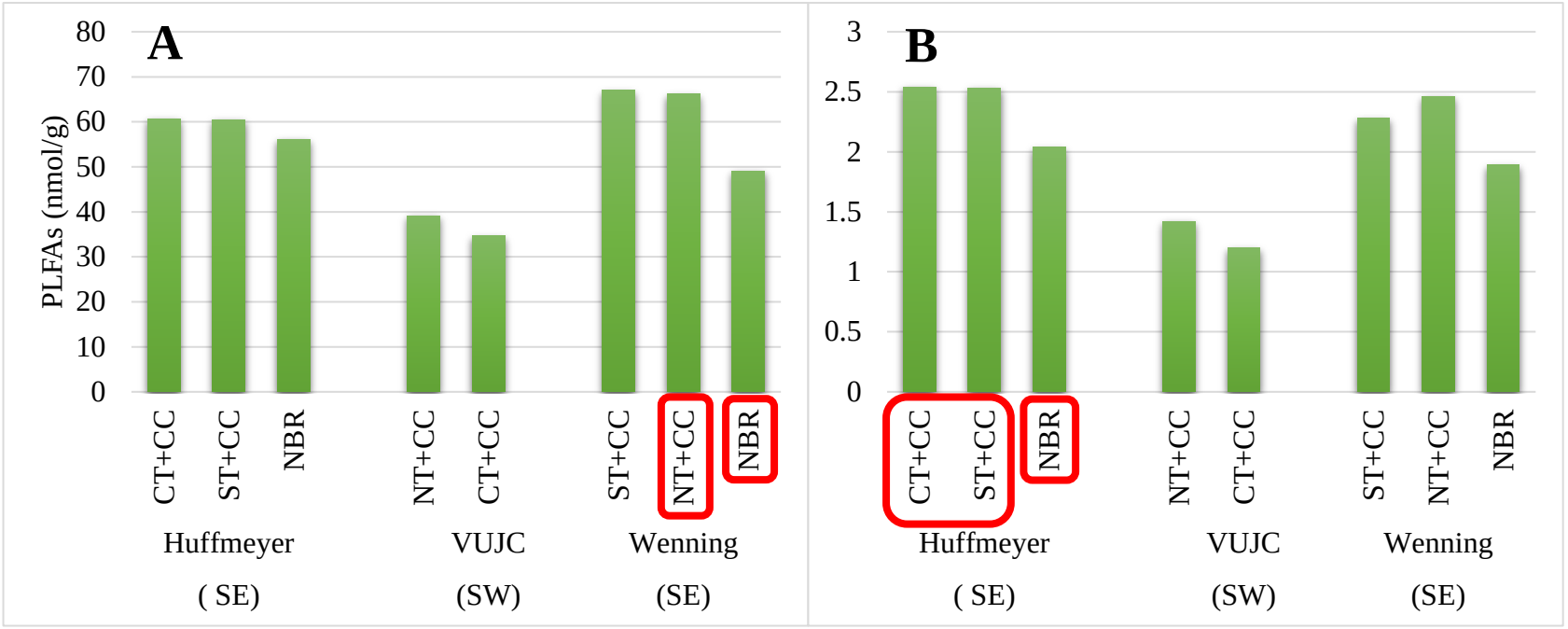
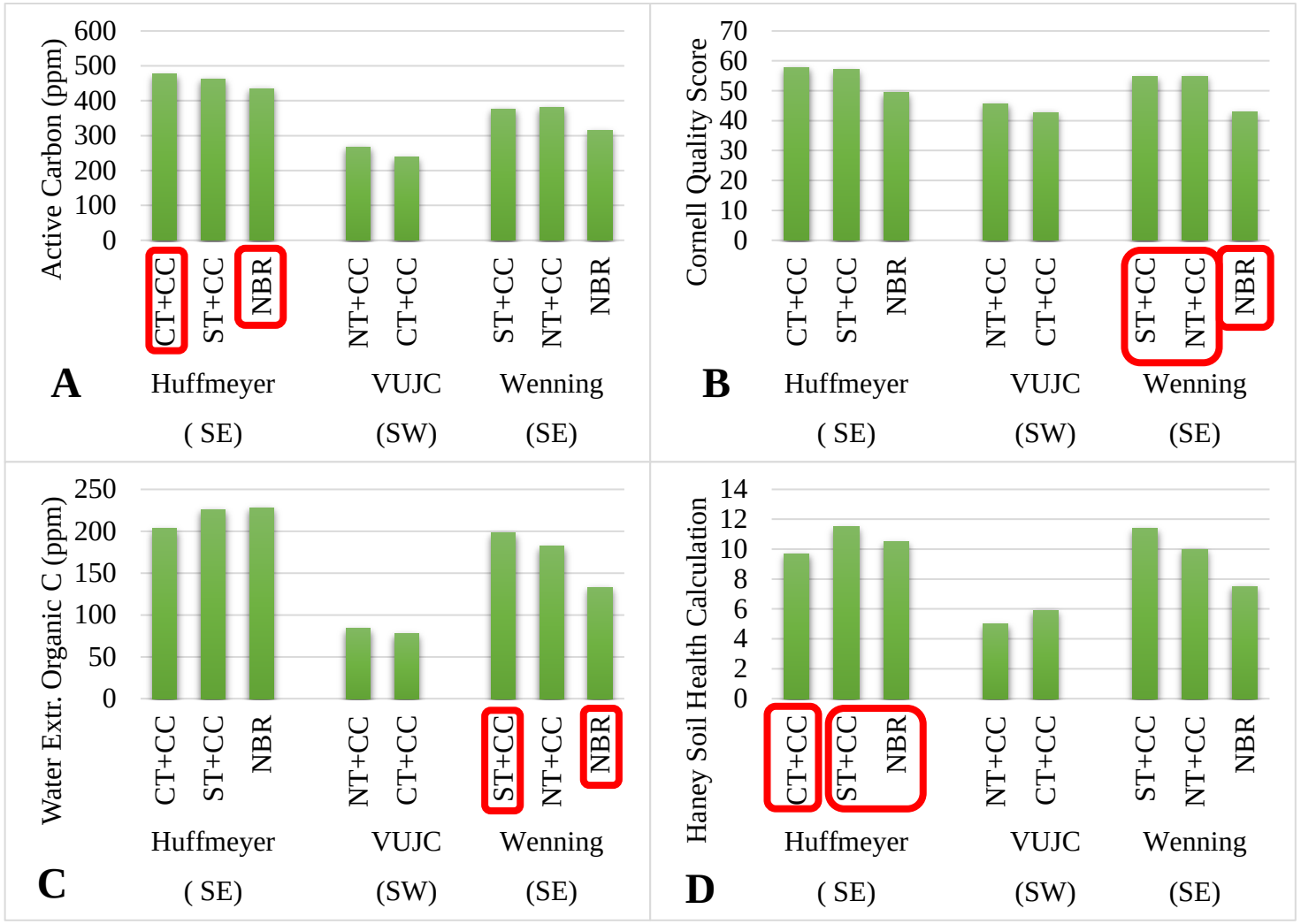


Figure 11. Results from 2016 for some Cornell and Haney soil health indicators for sites with tillage practice treatments in combination with cover crops. From the Cornell test, this includes A) Active Carbon and B) Quality Score while C) Water Extractable Organic C and D) Soil Health Calculation are from the Haney Soil Health Tool. Statistically significant differences between treatments at a location are indicated by red boxes around treatment names.



Nitrogen Rates Results

The Mills farmer site was the only location that had different nitrogen rates, in combination with cover crops and no-till. Differences in N rates affected total microbial biomass, total bacteria and total fungi measures, with all of these being significantly higher in the low and medium N rates compared to the high N rate. Organic matter was also significantly higher under the low N rate. However, these were all short-term changes during the year of fertilization, as they were not different the following year when soybean was being grown.

Figure 12. Soil health test results for A) PLFA microbial biomass and B) organic matter for three different nitrogen rates at the Mills site in 2015 during corn growing season. Statistically significant differences between treatments are indicated by different letters.