



Cornell Soil Health Program



United States Department of Agriculture

Natural Resources Conservation Service

# Practical Approach to National Comprehensive Soil Health Management and Assessment

## PROJECT SUMMARY

Conventional farming practices have been shown to degrade the physical and biological properties of soil including breakdown of soil structure, loss of soil organic matter, and decreased diversity and activity of belowground life. Degraded soil provides a less hospitable environment for plant growth, is less resilient to extreme weather events, becomes vulnerable to excessive erosion, and encourages increasing agricultural inputs. Improved soil health management decision making tools and broader adoption of these tools can help improve farm productivity while minimizing environmental impacts.

In 2015, the Cornell Soil Health Program based at Cornell University received a Natural Resources Conservation Service (NRCS) Conservation Innovation Grant to facilitate soil health adoption by developing improved comprehensive soil health assessment and management frameworks and conducting outreach to key stakeholders.

Over the last five years, our team has been a leader in the national soil health movement and we've seen tremendous growth in the awareness of soil health concepts and use of soil health assessment frameworks. We've been at the forefront of research efforts to advance a standardized and comprehensive assessment of soil health at state and national levels. Secondly, we've worked to develop tools and research to understand financial, soil health, and environmental benefits of sustainable soil and nitrogen management. Finally, we've developed and implemented numerous workshops and practical programs to promote soil health management. In the last five years, we've accomplished some significant milestones (in detail in the Results section):

- Expanded our national soil health database to over 10,000 samples (Figure 1).
- Provided scientific and technical support to many national and local soil health efforts.
- Conducted a total of 143 outreach events to a total of 10,180 stakeholders and published numerous resources.

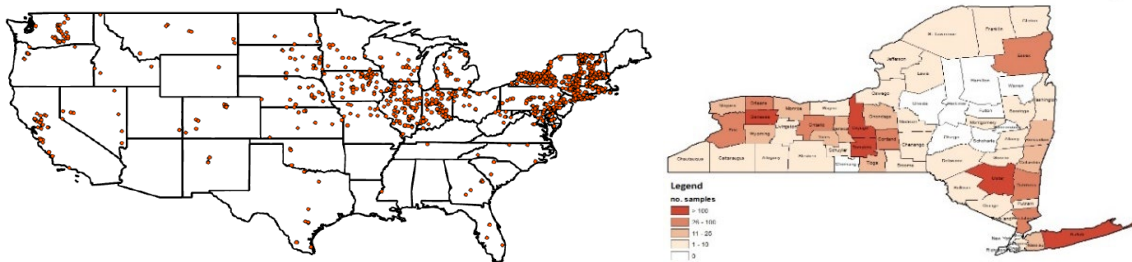


Figure 1. Maps of soil health samples at the national and state level.

## Summary of Methods

Table 1. Timeline of Practical Approach to National Comprehensive Soil Health Management Assessment CIG Project

Actions/Milestones	2016				2017				2018				2019				2020			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
<b>Objective 1 - Collaborate for the advancement of a standardized Soil Health Assessment Framework</b>																				
Guide the integration of soil health approaches																				
Facilitate quantification approach																				
<b>Objective 2 - 2. Develop a framework to enhance monetary values from soil health management</b>																				
Evaluate SSHT and Adapt-N on Yield Performance																				
Design approach for SSHT use in Land Valuation																				
<b>Objective 3 - Develop and implement workshops and practical programs to engage important audiences</b>																				
Support networking and technical assistance																				
Publish findings and recommendations																				

The Methods of the Practical Approach to National Comprehensive Soil Health Management Assessment CIG were split up into three objectives. 1) Collaborate for the advancement of a standardized Soil Health Assessment Framework. 2) Develop a framework to enhance monetary values from soil health management. 3) Develop and implement workshops and practical programs to engage important audiences (Table 1).

**Objective 1:** The goals for the first objective were to:

- Conduct 960 Standard Soil Health Assessments from across the United States to develop a nationwide soil health database.
- Develop new indices combining information from different indicators and new predictive models for indicator prediction.
- Analyze the Cornell Soil Health Database to come up with regional scoring functions, interpretation frameworks.
- Evaluate the relative utility of the Standard Soil Health test vs. the Basic test to improve soil health testing packages measuring fewer soil health indicators.

**Objective 2:** The goals for the second objective were to:

- Integrate soil health indicator data with the Adapt-N tool to enhance nitrogen mineralization prediction.
- Implement Adapt-N on 4,000 acres and collect yield data from field trials.
- Correlate multi-year yield data with soil health indicator data to identify soil health indicators that affect crop productivity.

One significant unforeseen challenge with completing some of the tasks under this objective was that in 2014, Adapt-N was licensed to Agronomic Technology Corporation (ATC), and then in 2017, YARA International acquired ATC. These changes to Adapt-N were unanticipated at the time the proposal was written and changed the scope of Adapt-N needs. But Adapt-N use has expanded significantly to over one million acres.

**Objective 3:** The goals of the third objective were to:

- Provide intensive workshops on soil health principles and testing.
- Present at professional meetings, field days, and scientific conferences on the Cornell Soil Health Testing Framework

## Results

The Cornell Soil Health Team has accomplished the above objectives and has made tremendous progress in advancing soil health research and outreach in the last five years. As part of this, we've:

### Objective 1:

- Expanded our national soil health database to over 10,000 samples with 16 biological, physical, and chemical soil properties measured on each sample. Significant effort was taken to validate GPS coordinates for a large subset of this database (n=7,200) to extract site inherent information (soil taxonomy and climate information). This database has been essential to our leading and contributing to research that will enable a standardized national soil health assessment framework (Figure 1).
- Processed 960 composite soil samples with known farmer and field management information through the Standard Comprehensive Assessment of Soil Health (CASH) package from across 40 U.S. states. 455 of these samples were analyzed for beta-glucosidase and mid-infrared (MIR) reflectance at the USDA-NRCS Kellogg Lab in Lincoln, NE.
- In 2017, we completed the first national and regional analysis comparing the suite of CASH soil health indicators across the Northeast, Mid-Atlantic, and Midwestern regions. The analysis established new scoring functions by region and soil texture group. A counterintuitive result of the research was the soil health in the top six inches was greater in the Northeast and Mid-Atlantic than in the Midwest. This can be explained by a greater diversity of cropping systems in the Northeast and Mid-Atlantic that receive greater quantities of organic matter inputs, contain rotations with perennial crops, or are organic cropping systems compared to the Midwest (Fine et al., 2017).
- Collaborated with NRCS Soil Health Division and USDA Agricultural Research Service scientists on a large project to integrate two prominent soil health frameworks (SMAF and CASH) and provide a standardized national framework to interpret soil health indicators from any location in the continental United States. This framework is being called the Soil Health Assessment Protocol and Evaluation or SHAPE (Nunes et al., 2020a and 2020b).
- Conducted research on effects of sustainable soil management strategies on soil health indicator benefits and change. We studied the long-term effects of tillage practices, residue management, and cropping system diversification practices on CASH indicators at long-term cropping experiments in New York and North Carolina (Nunes et al., 2018; van Es and Karlen, 2019). One useful finding was that cover crop effects were greater under No-Till than Plow-Till, illustrating that cover crop effects are better preserved in a No-Till environment (Nunes et al., 2018).
- Characterized soil health across New York State by soil type and cropping system. These reports and manuscript document the effects of soil texture and cropping system groups. Furthermore, this analysis provides the data necessary to develop scoring functions and aspirational soil health goals or targets based on soil type and cropping system (Amsili et al., 2020).
- Compared soil health profiles between remnant tallgrass prairie and adjacent agricultural land to use as benchmarks for future restoration (Kurtz, 2020).

- Evaluated several soil organic matter quality indices. Simple indices such as active carbon/soil organic matter and protein/soil organic matter were more useful than more complex indices that were explored.
- Determined that organic matter and active carbon were the best predictors of total soil health score. This indicates that organic matter and active carbon are good targets for a basic package. In 2020, the Cornell Soil Health Laboratory shifted to using active carbon instead of respiration in the basic test to reflect this change in understanding.
- Developed two robust machine learning models to predict available water capacity and soil protein, the two most time-intensive and costly indicators to measure in the CASH test. The available water capacity and protein prediction were made available in 2019 and 2020 by the Cornell Soil Health Laboratory.
- Incorporated total carbon and total nitrogen into the CASH framework. Total carbon and nitrogen are more accurate measurements of the total organic matter pool and will allow greater comparison between different methods.

### Objective 2:

- Studied integration of Cornell Comprehensive Assessment of Soil Health with Adapt-N.
- Researched best soil health indicator predictors of nitrogen mineralization through a greenhouse trial and found that soil respiration and protein provide additional value for predicting nitrogen mineralization than organic matter alone.
- Incorporated a cover crop module and a soil productivity factor into Adapt-N to improve the prediction of nitrogen requirements when cover crops precede corn planting.

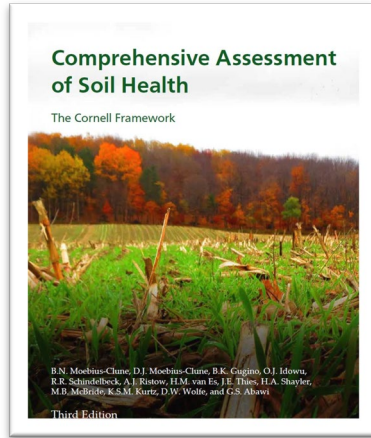
- Demonstrated that labile organic matter indicators, and particularly soil protein and active carbon, were good predictors of corn yield in a long-term research experiment in North Carolina (van Es and Karlen, 2019).

### Objective 3:

- Provided scientific and technical support to three major national soil health efforts and three local ones - The NRCS Soil Health Division, the [Soil Health Institute](#), the [Soil Health Partnership](#), an interagency [New York Soil Health Working Group](#), the Cornell led [New York Soil Health Initiative](#), and the [PASA Soil Health Benchmark Study](#). Additionally, we've offered support to several major corporations that have sustainability initiatives for their farm suppliers, including Danone.
- In 2019-2020, the Cornell Soil Health Laboratory processed 2,000 samples from the Soil Health Institute's "North American Project to Evaluate Soil Health Measurements" for the standard CASH package and bulk density.
- Completed major updates for two widely-read soil health publications: Building Soils for Better Crops (4<sup>th</sup> Ed), and the Comprehensive Assessment of Soil Health: The Cornell Framework Manual (3rd Ed).
- Conducted a total of 143 outreach events (winter meetings, field days, trainings, workshops, webinars, international meetings, conferences, and public outreach events to a total of 10,180 farmers, ag service providers, policy makers, and other stakeholders. This included the 2016 and 2020 SWCS Annual Conferences.
- We completed the [User Guide to the Soil Water Holding Capacity Demo Kit](#) and have distributed 35 demonstration kits.

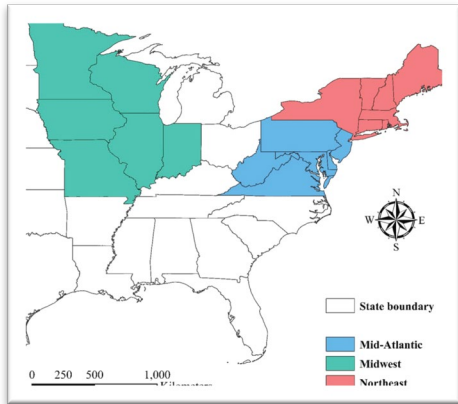


# Products



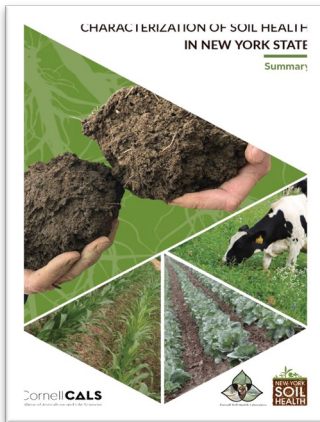
## Comprehensive Assessment of Soil Health: The Cornell Framework Manual and Manual Series Fact Sheets

The [Third Edition](#) provides a substantial update and contains information on soil health concepts, individual soil health indicators, a guide to our soil health management framework, and more. Furthermore, the manual now exists as a series of factsheets



## Manuscripts that Advance a Standardized National Soil Health Assessment Framework

Three manuscripts have been published that advance our national ability to appropriately interpret soil health data across regions, soil type (soil texture and taxonomy), and climate. These references are bolded in the [complete list](#).



## Characterization of Soil Health in New York State Reports

The Characterization of Soil Health in NYS Reports provides the first attempt to define soil health scoring functions and aspirational soil health goals that consider both soil type and cropping system. Both [Technical](#) and [Summary](#) Reports were published.

**All Products:** We've published 37 peer-reviewed publications, new editions of the *Comprehensive Assessment of Soil Health*, *The Cornell Framework Manual* and *Building Soils for Better Crops*, 35 extension articles, and have been featured in over 50 third party media outlets. For a complete list of peer-reviewed publications, extension articles, and third-party news sources see:

<http://blogs.cornell.edu/healthysoil/resources/references-for-usda-nrcs-cig-2015-2020/>

## Looking Ahead

The Cornell Soil Health Program is positioned to continue to be leader in the advancement of a standardized national soil health assessment framework and adoption of soil health assessment and management frameworks.

### Advancing a Standardized National Soil Health Assessment Framework

Since 2019, the Cornell Soil Health Program has collaborated with the NRCS Soil Health Division and USDA Agricultural Research Service scientists to merge data from the Cornell Soil Health Laboratory National Dataset, the largest of its kind, with data from published sources, and data from the Kellogg National Laboratory. These efforts have already yielded two useful manuscripts:

- Nunes, M.R., H.M. van Es, K.S. Veum, J.P. Amsili and D.L. Karlen. 2020a. Anthropogenic and Inherent Effects on Soil Organic Carbon across the U.S. *Sustainability* 12: 5695.
- Nunes, M.R., K.S. Veum, P.A. Parker, S.H. Holan, D.L. Karlen, J.P. Amsili, H.M. van Es, et al. 2020b. The soil health assessment protocol evaluation applied to soil organic C. *Soil Sci. Soc. Am. J. In Press.*

Next steps will include similar analyses and development of interpretive soil health metrics for the remaining soil health indicators included in CASH: active carbon, respiration, protein, available water capacity, and aggregate stability. For the first time, these new interpretative soil health metrics will enable farmers, agricultural professionals, and researchers to have a standard to assess soil health results against the backdrop of differences in soil type (taxonomy and texture) and climate for any location in the continental U.S.

## Outreach

In addition to next steps in research, it remains essential to continue to train agricultural professional in soil health assessment and management frameworks and understanding the linkages between sustainable soil management strategies (reduced tillage, cover cropping, organic amendments, crop-livestock integration) and soil health outcomes. Over the last five years, we've developed countless resources to train agricultural professionals working in the public, non-profit, and private sectors. Resources developed for the:

- [2018-2020 Soil Health Specialist Training.](#)
- [September 2019 Intensive Soil Health Workshop from Historical 1890/1994 land grant institutions.](#)
- [New York Soil Health video resources section.](#)

These will provide a strong foundation for future soil health curriculum and workshop development.

We are inspired by efforts like the PASA group that has applied the Cornell soil health assessment and management framework to a cohort of innovative PA growers where more detailed information can be collected on cropping system type, and new metrics such as “days of living cover” and tillage intensity. We believe this type of information is necessary to develop interpretive metrics that are cohort based as well.



### Cornell Soil Health Program

Learn more about the Cornell Soil Health Program and Laboratory:

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