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2017 SOIL HEALTH BENCHMARK STUDY
Example Results

Thank you for participating in PASA's 2017 Soil Health Benchmark Study. In 2017, 28 farms (24 organic vegetable farms and 4 no-till row crop farms) contributed to this citizen-science research project. Together, we are documenting that PASA farmers are forging new frontiers in the art and science of growing healthy soils.

HOW TO USE THIS REPORT

1. Review the "benchmark" graphs to see what's typical, and possible, for soil health outcomes among your peer farmers.
2. Review the results of your Cornell Soil Health tests. These tests identify the strengths and constraints of your soils and also provide general management recommendations.
3. Connect with a learning community. This research will guide a series of PASA field days, webinars, and conferences that will bring farmers together to share insights and develop new management ideas. The farmers contributing to this research are a tremendous resource, and through this project, PASA can help connect you with a peer farmer who is tackling similar challenges.
4. Share the infographic marketing resources with your customers and help them understand the great work you are doing for soil health and sustainable farming.

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METHODS

This research draws from two data sources: 1) field soil samples and 2) farm management records. Our methods were developed in August 2016 with input from participating farmers and scientists at PASA, Penn State University, and Cornell University.

PASA staff consulted with participating farmers to choose three study fields that spanned typical rotation practices on that farm. For instance, if a farmer practices a three-year vegetable rotation involving fall brassicas in one year, to tomatoes and peppers in the next year, to a full year of cover crops, we would choose one field in each of these phases for sampling. We also chose fields that represented typical soil types and topographic positions on each farm.

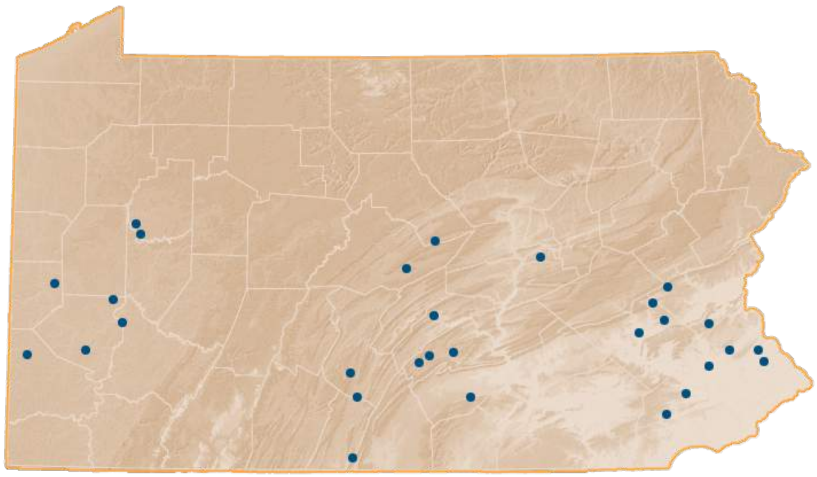
In October of 2017, PASA staff visited each farm and collected soil samples from each field. We collected subsamples from six locations in each field, homogenized the samples, and submitted them to the Cornell Comprehensive Assessment of Soil Health. Cornell runs a battery of tests, evaluating ten different physical, biological, and chemical indicators of soil health.

Throughout the growing season, participating farmers maintained logs of farm operations in the selected fields, either using template excel spreadsheets provided by PASA, farm management software, or failsafe paper notebooks. Records included: 1) tillage, cultivation, planting, and any farm operations involving soil disturbance; 2) planting and termination dates for crops and cover crops, and 3) application dates and quantities for all fertilizers and soil amendments.

In December 2017 and January 2018, participating farmers shared their soil management records with PASA. PASA staff scientists organized these data and generated three additional management indicators: 1) days of living cover, 2) tillage intensity, and 3) organic inputs. These indicators provide a snapshot of some of the farm management practices that most influence soil health.

Direct-market, sustainable vegetable farmers are the core of PASA’s membership, so this project began with a focus on organic vegetable operations. We advertised this project through PASA’s email newsletter and direct outreach to member farms, with an aim to gather a representative sample of geography and farm sizes. Different farms take different approaches to building soil health. To draw insights from a diversity of farming systems and build connections across Pennsylvania’s farming communities, we also involved a pilot group of row crop farmers from the PA No Till Alliance in this project. Combined, we worked with 24 organic vegetable farms and 4 row crop farms. In 2018, we expect to expand the project to include 30 organic vegetable farms, 8 conventional vegetable farms, 8 no-till row crop farms, and 8 grass-based dairies.

PARTICIPATING FARMS



Organic Vegetables

- Tricia Borneman & Tom Murtha, Blooming Glen Farm, Bucks County
- George Brittenburg, Taproot Farm, Berks County
- Will & Mike Brownback, Spiral Path Farm, Perry County
- Debra & Hannah Smith-Brubaker, Village Acres Farm & FoodShed, Juniata County
- Michael Ahlert & Kim Butz, Red Earth Farm, Berks County
- Jarrah Cernas, Chicano Sol, Perry County
- Timothy Derstine, Hares Valley Growers, Huntingdon County
- Deirdre & Trey Flemming, Two Gander Farm & Apiaries, Chester County
- Jeff Frank, Liberty Gardens, Lehigh County
- Tim Gebhart, Cherry Valley Organics, Beaver County
- Jennifer Glenister & Jim Crawford, New Morning Farm, Fulton County
- Aimee & John Good, The Good Farm, Lehigh County
- Jennifer Halpin & Matt Steiman, Dickinson College Farm, Cumberland County
- Dan Kemper & Drew Smith, Rodale Institute, Berks County
- Don Kretschmann, Kretschmann Family Organic Farm, Beaver County
- Frank Kurylo, Kimberton CSA, Chester County
- Daniel Lengancher, Long Acre Farm, Clarion County
- Derek Mcgeehan, Anchor Run CSA, Bucks County
- Jennifer Montgomery & Greg Boulos, Blackberry Meadows Farm, Allegheny County
- Ron Moule & Steve Tomlinson, Carversville Farm Foundation, Bucks County
- Steve & Olga Nonn, Old Tin Roof Farm, Westmoreland County
- Cameron & Audrey Pedersen, Bending Bridge Farm, Franklin County
- Tara Rockacy, Churchview Farm, Allegheny County
- Alex Smith, Living Hope Farm, Montgomery County

No Till Row Crop Farms

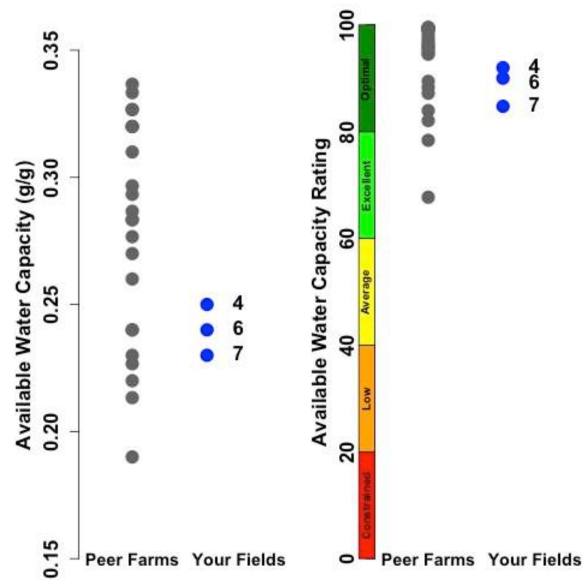
- Jim Harbaugh, Schrack Farms, Clinton County
- Dean James, Cotner Farms, Berks County
- Dave McLaughlin, Little Germany Farms, Perry County
- Joel Myers, Myers Farm, Centre County

BENCHMARKS: Cornell Comprehensive Assessment of Soil Health Indicators

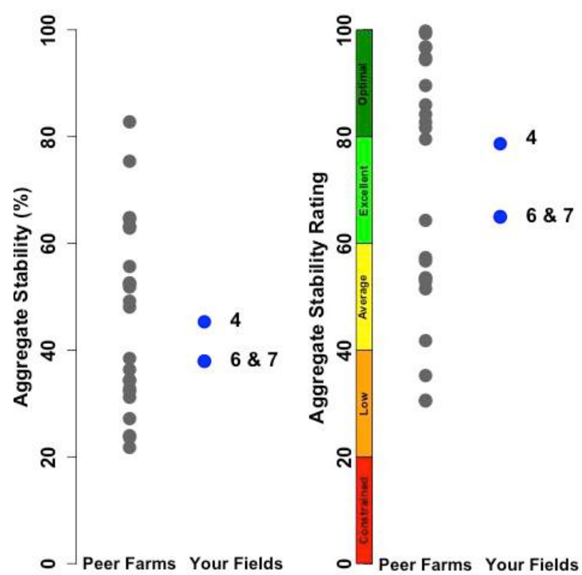
How to Read These Graphs:
For each indicator in their soil health test, Cornell returns both the measured laboratory value and a rating on a 0-100 scale. To account for inherent variation across soil types, Cornell uses a database of thousands of samples to score each indicator relative to soil samples with similar soil textures. The following series of graphs shows both the measured values and relative ratings for your three fields, compared to the farm-scale averages for the set of 24 PASA organic vegetable farms.

More detail on how each indicator is measured, and potential management approaches to remedy constraints, is included in your Cornell reports. The Cornell Soil Health manual is also an excellent resource for deeper learning about this soil health test (https://soilhealth.cals.cornell.edu/training-manual/).

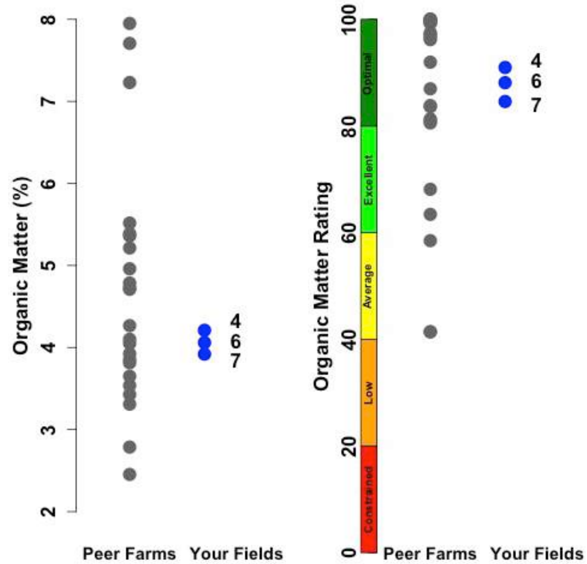
Available water capacity is a measure of the amount of water accessible to plant roots relative to the total amount of water the soil can hold under saturated conditions. Soils with greater available water capacity allow plants to perform better under drought conditions.



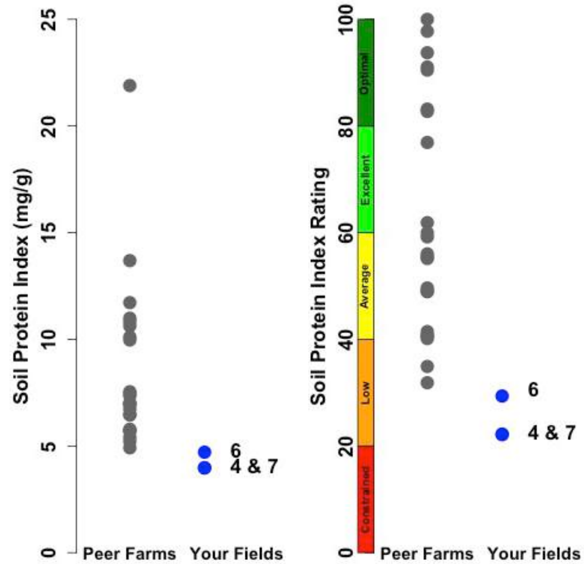
Aggregate Stability is a measure of the extent to which soil structure can hold up to wind, rain, and other stresses. Aggregate stability is measured as the percentage of soil aggregates that hold together through a standardized rainfall simulation. Good aggregate stability helps promote germination and root growth.



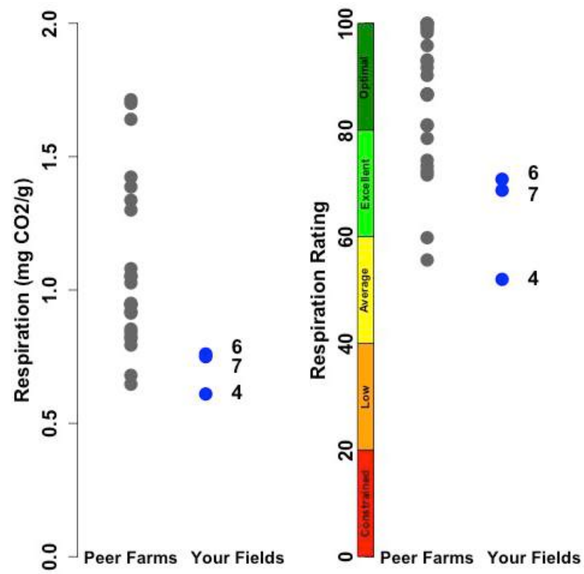
Organic matter is measured as the percent of total soil mass that contains carbon compounds derived from living or once-living biomass. Organic matter is a core measurement of soil health. Organic matter is the foundation of soil life, contributes to the formation of stable soil aggregates, helps to improve available water capacity, and provides a slow-release supply of nutrients.



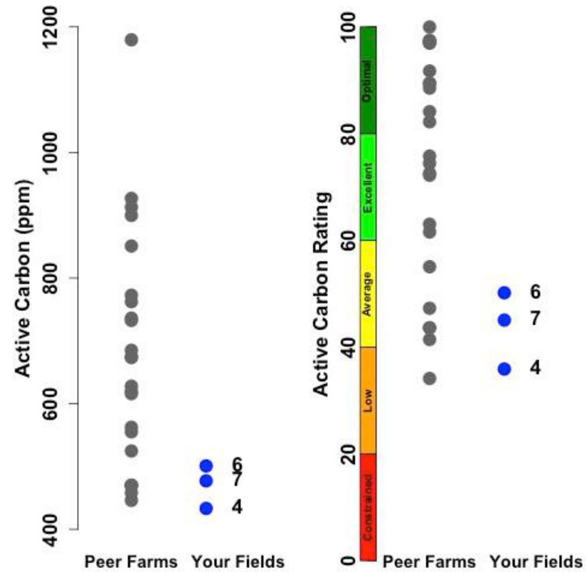
Soil Proteins are a large pool of nitrogen stored in soil organic matter. Microbes in the soil can break down these proteins and make the nitrogen available to plants. Soil protein is measured as mg protein extracted per gram of soil.



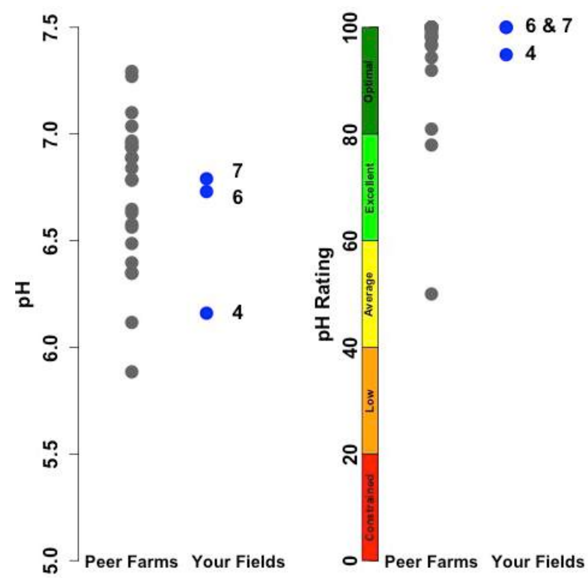
Soil Respiration measures the abundance and activity of microbial life in the soil. Soil microbes work to break down plant residues in the soil and cycle nitrogen and other nutrients from organic matter into plant-available forms. As they break down organic matter, microbes release carbon dioxide (CO_2), so microbial activity can be measured by capturing the carbon dioxide produced by soil microbes over a four-day incubation period in the lab. Respiration is expressed in units of mg CO_2 per gram of soil.



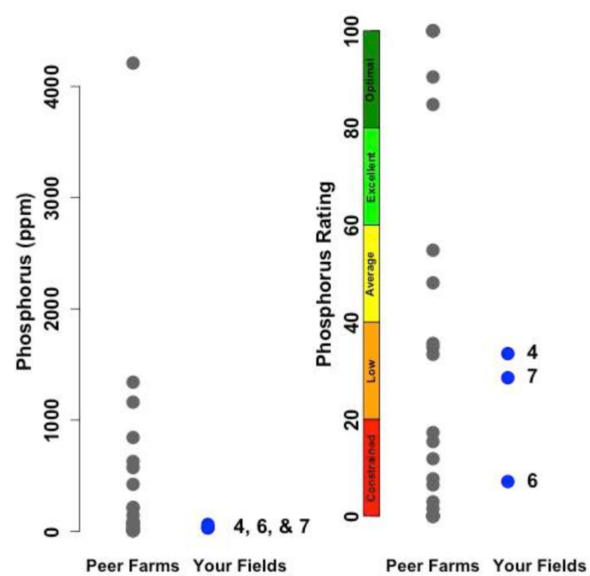
Active Carbon is a measurement of the small portion of the organic matter that can serve as an easily available food source for soil microbes, thus helping maintain a healthy soil food web. It is measured in parts per million (ppm). Active carbon is a good leading indicator of biological soil health and tends to respond to changes in management earlier than total organic matter content.



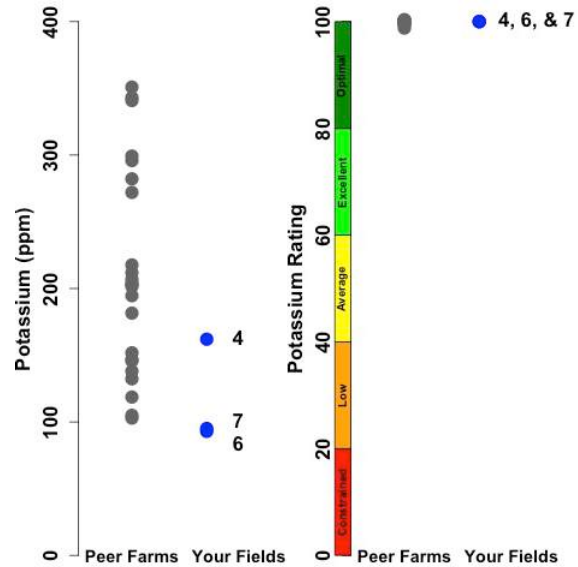
pH is a measurement of how acidic the soil is, which controls how available nutrients are to crops. If pH is too high, nutrients such as phosphorus, iron, manganese, copper and boron become unavailable to the crop. If pH is too low, calcium, magnesium, phosphorus, potassium and molybdenum become unavailable. The value is presented in standard pH units, and rated using a hump-shaped curve, with a pH between 6.2-6.8 optimal for most crops.



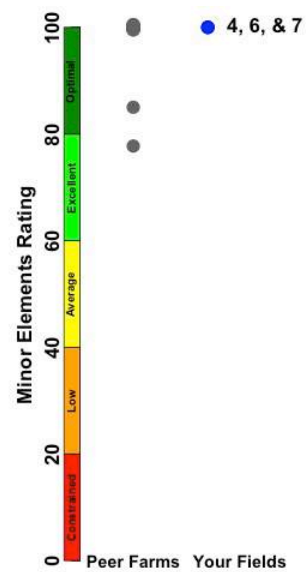
Phosphorus is an essential plant nutrient and is used by plant cells to build DNA and regulate metabolic reactions. At high levels, phosphorus can become a risk to water quality and at very high levels it can interfere with plant uptake of micronutrients including iron and zinc. Note that the Cornell scoring function for phosphorus follows a hump-shaped curve, with both low and high parts per million (ppm) values getting ratings towards zero. Optimal ppm values for phosphorus vary based on the texture and geology of individual soil types.



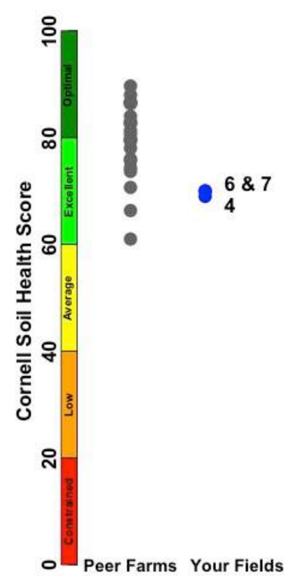
Potassium is an essential plant macronutrient that contributes to heat and cold tolerance and promotes fruit development in horticultural crops.



Minor Elements including Magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn) are essential for various plant biochemical reactions but are required in small quantities. If any minor elements are deficient, this will decrease yield and crop quality, but toxicities can also occur when concentrations are too high. The minor elements rating is an aggregate score for the four selected minor nutrients (Mg, Fe, Mn, and Zn).



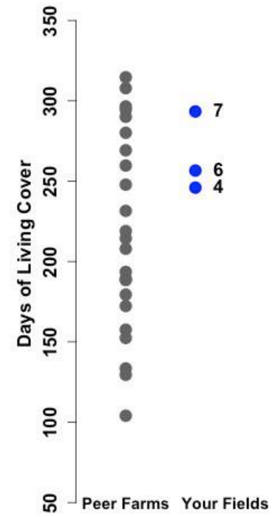
Cornell Soil Health Score is a simple average of the ratings for the set of ten chemical, biological, and physical indicators in the Cornell Comprehensive Assessment of Soil Health. The overall score can be a useful general summary, but individual indicators will be more useful in identifying strengths or management challenges for a specific field.



BENCHMARKS: PASA Management Indicators

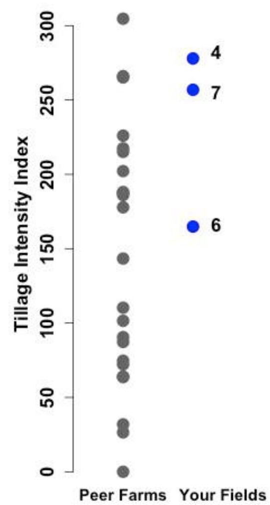
Days of Living Cover

Living vegetation protects soil from wind and water erosion while also supplying the soil with fresh organic matter. Linking together crops and cover crops to maximize days of living cover is a fundamental soil building practice. The "Days of Living Cover" score is the days between crop or cover crop seeding (or transplant) and termination (or winter kill). For each field, we weighted the days of living cover for different crops and cover crops by the area planted and then summed over all the crops and covers crops.



Tillage Intensity Index

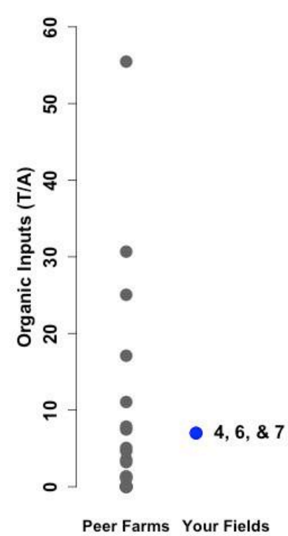
Tillage can degrade soil structure and organic matter, but it can also be a valuable tool for weed management and incorporating cover crops. The tillage intensity index uses data from a Natural Resources Conservation Service soil erosion model to assign a soil disturbance score to all farm operations that can compact or disturb soil (see inset table). We weighted the cores for each machinery operation based on the area covered and then summed over the season.



Implement	Tillage Index
Roller Crimper	0.1
Grain Drill	2.4
Waterwheel Transplanter	3.1
Perfecta Harrow	10.2
Rototiller	18.2
Disc Plow	39.0
Moldboard Plow	65.0

Organic Inputs

Organic inputs including composts, manures, and straw mulches can jump-start the formation of soil organic matter, add microbiology to the soil, and supply macro and minor nutrients. However, continuous inputs can also contribute to soil health challenges, such as excessive phosphorus levels. This organic input score shows the total organic inputs (composts, manures, and mulches) into each field, in units of tons per acre.



INSIGHTS: Comparing Farm Systems

Our 2017 data set includes a mix of both organic vegetable farms and no-till row crops, which allows us to make some broad comparisons across these farming systems. Although the sample for no till farms is small, these data indicate that both organic vegetable and no-till row crop systems have examples of optimal soil health and that **different farms can apply different strategies for growing soil health** (see Table on page 9)**.**

For instance, both systems had great overall Cornell Soil Health scores and "optimal" organic matter levels. This organic matter has been established over time using very different production and management strategies. The row crop farms had minimal soil disturbance and achieved nearly continuous living cover by planting cash crops (corn, soybeans, and small grains) into green cover crops and then terminating the cover crops with a selective herbicide. In contrast, the organic vegetable farms had intensive soil disturbance and fewer days of living cover on average, but they also tended to have more complex crop rotations and more organic inputs (compost, manures, or mulches).

Both systems tended to have different soil constraints. The no till farms had much lower soil protein levels, which is an indicator of nitrogen "banked" for slow release from the soil organic matter. This could suggest that nitrogen supplied from inorganic fertilizers on these farms is discouraging the production of organic nitrogen (i.e., soil proteins) by legumes in the rotation. In contrast, the most consistent problem on the organic vegetable farms was excessive to very excessive levels of phosphorus, typically the result of supplying nitrogen with off-farm manures or compost that also contain a lot of phosphorus.

As this project continues, this data set will provide an enormous resource for identifying management practices that can remedy these problems on working farms.

Table: 2017 comparisons of soil health indicators for organic vegetable and no till row crop farms

		Organic Vegetables (n=24)			No-Till Row Crops (n=4)		
		Median	**Min**	**Max**	**Median**	**Min**	**Max**
Cornell Ratings	Available Water Capacity	96	68	100	91	86	100
	Aggregate Stability	75	30	100	87	70	93
	Organic Matter Rating	90	41	100	84	71	87
	Soil Protein	56	25	100	31	26	52
	Respiration	87	56	100	81	66	97
	Active Carbon	75	34	100	64	46	72
	pH	100	50	100	100	90	100
	phosphorous	20	0	100	77	0	100
	potassium	100	99	100	100	100	100
	minor elements	100	78	100	100	71	100
	Cornell Soil Health Score	80	61	90	78	73	86
PASA Indicators	Days in Living Cover	217	104	315	350	340	364
	Tillage Index	161	0	305	7	5	9
	Organic Inputs (T/A)	4.1	0	133	2.0	0	6.7

Cornell Rating Codes: Constrained (0-20) | Low-Level (20-40) | Average (40-60) | Excellent (60-80) | Optimal (80-100)

MARKETING RESOURCES:

Healthy soils improve air and water quality, grow more nutritious products, and help ensure an abundant food supply for future generations. Farmers that practice excellent soil stewardship therefore deserve a better price and bigger markets for their products. We designed the customized infographic include in this report to help you tell your customers and stakeholders about the important work you are doing to improve and protect your soil resources.

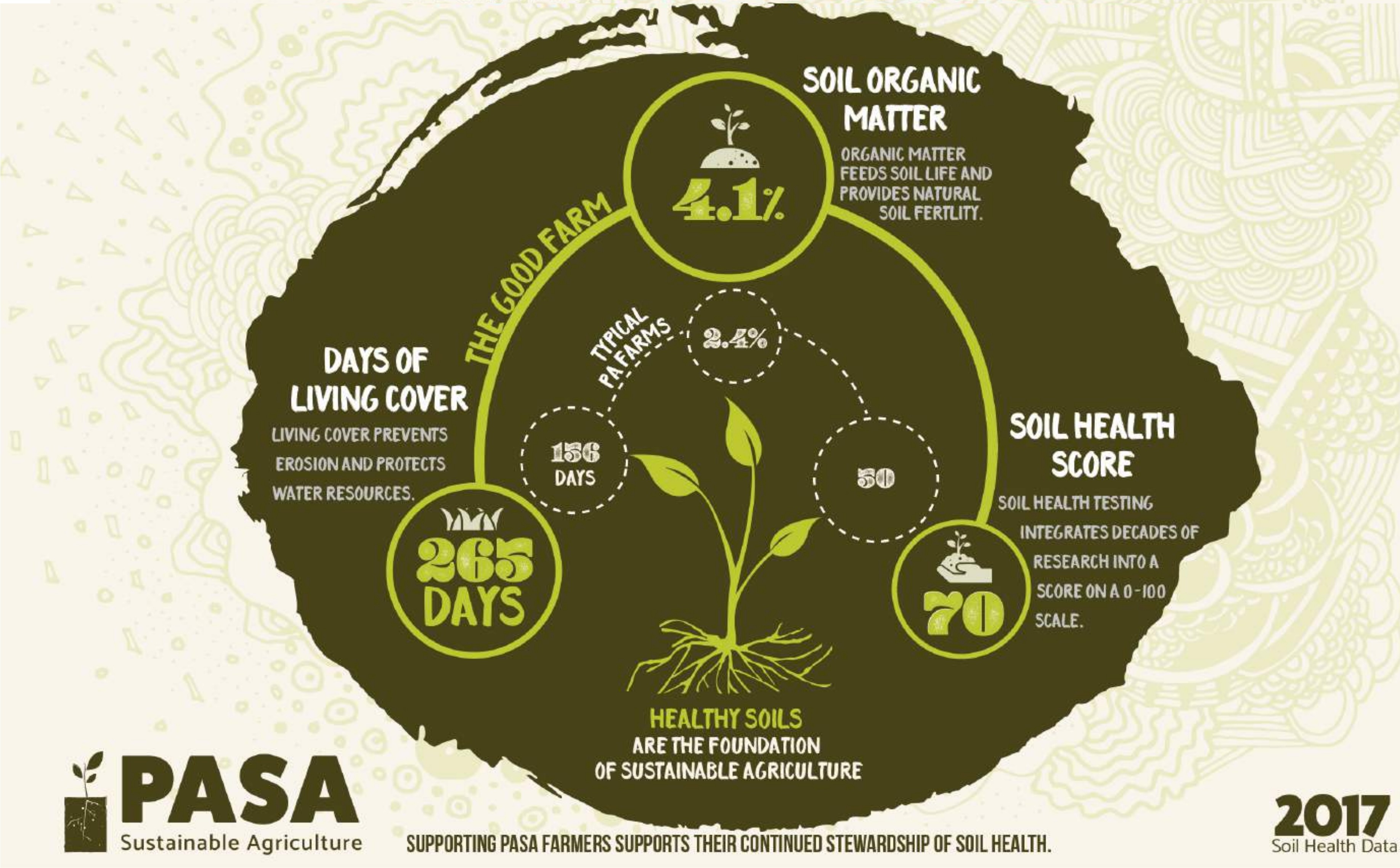
Each infographic has been tailored to your farm's soil health data, and shows your farm averages for three key statistics:

1. **Days of Living Cover**, compared to a Pennsylvania benchmark for a corn and soybean rotation planted without cover crops. Estimates for corn and soybean days of living cover were taken from planting and harvest dates reported by the National Agricultural Statistics Service (NASS). Recent estimates from Penn State University report that only 22-37% of PA corn acres receive a cover crop, so the benchmark of no cover crops is a fair assessment of the status quo.
2. **% Organic Matter**, compared to the % organic matter estimated by the NRCS Soil Survey for the soil types sampled on your farm.
3. **Cornell Soil Health Scores**, compared to the average soil health score for all soils in the Cornell database, which is set to 50 in their scoring system.

The infographic also contains a one-page summary that explains our research and soil health principles, with a general public audience in mind.

You can add these infographics to your farm's website, or share print copies with your wholesale buyers, at your farm stand, or in CSA boxes. These marketing resources are a new experiment for PASA. If you do share your farm's infographics with your customers, please let us know if you have suggestions for how we can improve them or create additional resources to support you in marketing your soil health stewardship to your customers.

PENNSYLVANIA ASSOCIATION FOR SUSTAINABLE AGRICULTURE
FARMERS IMPROVE THEIR SOIL



The soil below our feet is a living, breathing ecosystem. Healthy soils protect our air and water resources and ensure a bountiful harvest of nutritious food.
At PASA, we know that many families support our member farms because they believe in the work these farmers are doing to steward a more sustainable environment.
That's why we're working to scientifically-document the beneficial environmental outcomes our farmers achieve and to help chart a course for continuous improvement. In 2016, we began a benchmark study of soil health on organic vegetable farms, combining state-of-the art laboratory soil tests with inventories of farm management practices. We found that our farmers are practicing great soil stewardship:

Organic Matter

Soil organic matter is formed as plant roots and leaves decay, and it provides the engine for long-term soil health. As plants grow, they breath in carbon dioxide (the primary greenhouse gas causing climate change) and store it in the soil as organic matter. Organic matter helps soil rapidly absorb rainfall during storms and then slowly discharge water to crops during dry periods. Organic matter also provides a natural storehouse of plant nutrients that helps crops thrive with less fertilizer. PASA farmers maintain 4.1% soil organic matter, which is 1.9 times higher than values under typical Pennsylvania agricultural practices.

Days in Living Cover

Living vegetation continuously adds organic matter to the soil. A thick green canopy of leaves intercepts rainfall and prevents storms from carrying topsoil downstream. Below ground, living plant roots hold soil together and feed a complex food web of beneficial microbes and insects. Through diverse vegetable crop rotations and by growing "cover crops" over the fall and early spring, PASA farmers keep their soil covered in living vegetation for 240 days of the year. In contrast, typical Pennsylvania corn and soybean crops only maintain 156 days of cover, leaving the soil barren and vulnerable to erosion for half of the year.

Cornell Soil Health Score

The Cornell University Comprehensive Assessment of Soil Health system integrates decades of soil science research to build a holistic picture of soil health. Cornell soil health scores combine measurements of twelve different biological, chemical, and physical attributes into a 0-100 scale. Scores around 50 are typical, while PASA farms averaged 80, which is considered an "optimal" rating.

Supporting PASA organic vegetable farms supports their continued stewardship of soil health.
For more information on PASA and soil health, contact info@pasafarming.org; 814-349-9856.