



NEW YORK SOIL HEALTH

ROADMAP

2 0 1 9

New York Soil Health for Healthy Food, Profitable Farms, and Protection of Natural Resources

TAKE CARE OF THE LAND AND THE LAND WILL TAKE CARE OF YOU . . .

SOIL CONSERVATION PIONEER HUGH HAMMOND BENNETT, 1947

Message from project leadership

Interest in soil health has expanded greatly in recent years and New York has been at the forefront of the soil health movement. Today many farmers, government and non-government organizations, and researchers are finding that maintaining healthy soils not only can increase farm profitability, but also protects our soil and water resources, builds resilience to extreme weather events, and can contribute to climate change mitigation.

As a key objective of the New York State Soil Health Initiative (NYSH), we have brought the many interested stakeholders together to produce a soil health roadmap for New York. The core of the Roadmap is a section that includes a vision statement, and key goals—outlining specific research, outreach, and policy priorities for pursuing those goals.

The final document is presented here, and will also be made available in an interactive format at our www.newyorksoilhealth.org website (along with a shorter executive summary). The Roadmap includes a background section briefly reviewing the state of knowledge on soil health, historical and current soil health efforts within and beyond New York, and key stakeholders and organizations involved.

CONTRIBUTORS

Farmers and Farmer Organizations | Researchers | Agriculture Service Providers | Policymakers | Representatives of state and federal agencies: NYS Dept. of Agriculture & Markets, NYS Dept. of Environmental Conservation, USDA - Natural Resources Conservation Service | Non-profit organizations: New York Farm Viability Institute, American Farmland Trust, The Nature Conservancy, New York Farm Bureau

STAKEHOLDER INPUT AND DEVELOPMENT OF THE SOIL HEALTH ROADMAP



FRONT & INSIDE COVER ILLUSTRATIONS

Front: New York state outline with photo inset of Branton Farms in Stafford, NY

Inside: NYS Agricultural Districts as certified through January 2018. This graphic was created at Cornell IRIS using the NYS Agricultural District shapefile data available through the Mann Library CUGIR website (<https://cugir.library.cornell.edu/>). Data was created from certified Agricultural District maps, on behalf of the NYS Department of Agriculture and Markets.

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ROADMAP

INTRODUCTION

Historical land use and intensive agriculture with poor soil management have led to an alarming loss of organic matter in agricultural soils worldwide.¹ The profitability and sustainability of many New York farms are vulnerable to this trend. The importance of organic matter to soil health cannot be overstated.² Soils with low levels of organic matter have less resilience to drought and flooding, and during heavy rainfall events are more prone to soil erosion and runoff of sediment, chemicals, and nutrients into surface waters. Low organic matter soils are also more likely to become compacted, with negative impacts on crop growth and yield.^{3,4}

Organic matter is the energy source for the soil food web and essential to supporting a diverse, robust, and beneficial population of soil organisms. Many of these, from microbes to earthworms, play a crucial role in the recycling and availability of essential plant nutrients, while others help to suppress weeds, plant disease, and insect pests. Equally important, soil organisms leave behind sticky substances that help to hold soil aggregates together, the key for an optimum soil structure that promotes root growth, and improves water holding capacity and drainage.

Farmers in New York, and the agriculture service providers, government agencies, non-governmental organizations, and researchers who support them, have been at the forefront of what many are now considering a worldwide “soil health revolution”.⁵ This shift in farming techniques emphasizes building organic matter in degraded soils, and takes an ecological approach to management that recognizes the importance of the biological, as well as physical and chemical, components of soils. Managing for healthy soils not only benefits farmers directly, but has significant off-farm benefits for the environment and the general population, such as ensuring a sustainable supply of healthy, affordable food and safe drinking water, and contributing to climate change mitigation.

SOIL HEALTH FIELD DAYS AND WORKSHOPS

Throughout New York state farmers and agriculture professionals gather to learn about maintaining healthy soil.



Photo: Matt Ryan

LIFE IN THE SOIL

THE SOIL FOOD WEB

There are many groups of soil-dwelling organisms, which range in size from those that are easy to see, such as earthworms and arthropods, to those that are microscopic, such as bacteria. Understanding these organisms and their needs, and how they influence soil functioning, can help us improve soil health.⁶



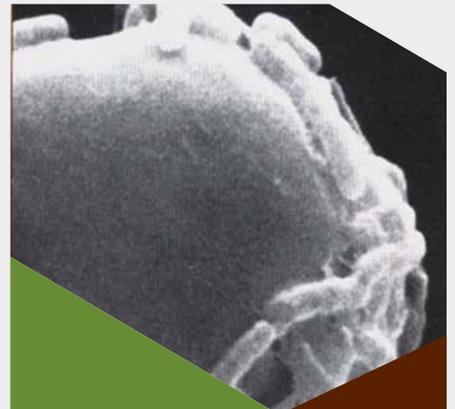
NEMATODE
mouth of bacterial feeder

Nematodes are an abundant and diverse group of tiny, mostly microscopic worm-like creatures found in all soils. A few are parasitic to plants, but by far the majority are beneficial, such as the one shown here.



EARTHWORM

Earthworms are “biological blenders” of the underground, and play an important role in nutrient cycling and soil structure.



RHIZOBIUM
attached here to soybean root hair

Rhizobia are important soil bacteria that make nitrogen available to legume plants.



“ IN A HANDFUL OF TYPICAL HEALTHY SOIL THERE ARE MORE CREATURES THAN THERE ARE HUMANS ON THE ENTIRE PLANET. ”

DAVID W. WOLFE | TALES FROM THE UNDERGROUND⁷

DEFINING SOIL HEALTH

Defining soil health and determining how to measure it have become increasingly important as we attempt to remediate degraded soils and monitor our progress. We will rely in this report on the widely accepted and succinct definition of soil health proposed by the USDA Natural Resources Conservation Service (NRCS):

“THE CONTINUED CAPACITY OF SOIL TO FUNCTION AS A VITAL LIVING ECOSYSTEM THAT SUSTAINS PLANTS, ANIMALS, AND HUMANS.”

SOURCE: www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/

MORE THAN "NPK"

Establishing an approach to measure soil health in relation to desired benefits has proven more complex than originally thought. However, it is important for everyone from farmers to policy-makers to be able to quantify baseline soil health status, and monitor changes over time in relation to crop and soil management.⁸ As we entered the 21st century, it became apparent that more than the standard soil “NPK” (the macronutrients Nitrogen, Phosphorus, and Potassium) test, which was relied upon for many decades and focuses primarily on soil chemistry, was needed. Research groups at USDA-NRCS⁹, Cornell University¹⁰, and others began evaluating approaches that integrated soil chemical properties with biological and physical measurements relevant to soil health (Fig. 1, Fig. 2).

Images from the May 15-17, 2018, NRCS Soil Health Planner Certification Course. 1. Attendees learning strategies to integrate grazing into soil health management systems. 2. Cedric Mason, NYSH research support specialist and Paul Salon, soil health specialist for the northeast region at USDA-NRCS. 3. Bob Shindelbeck, Cornell Soil Health Lab director.



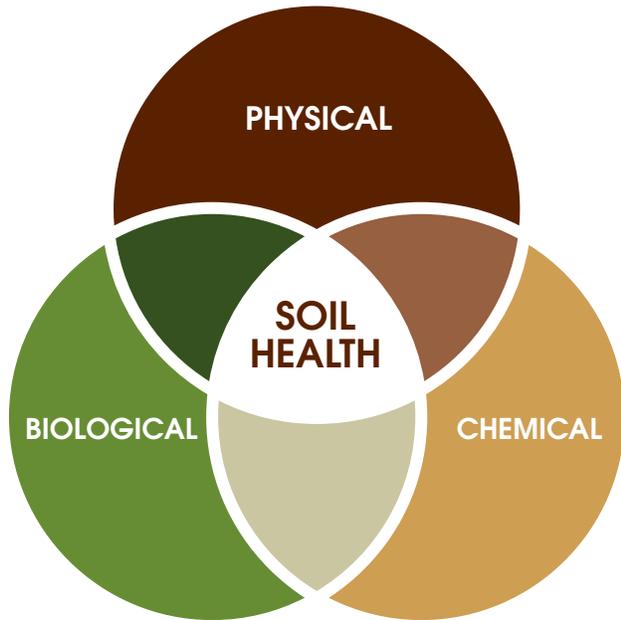
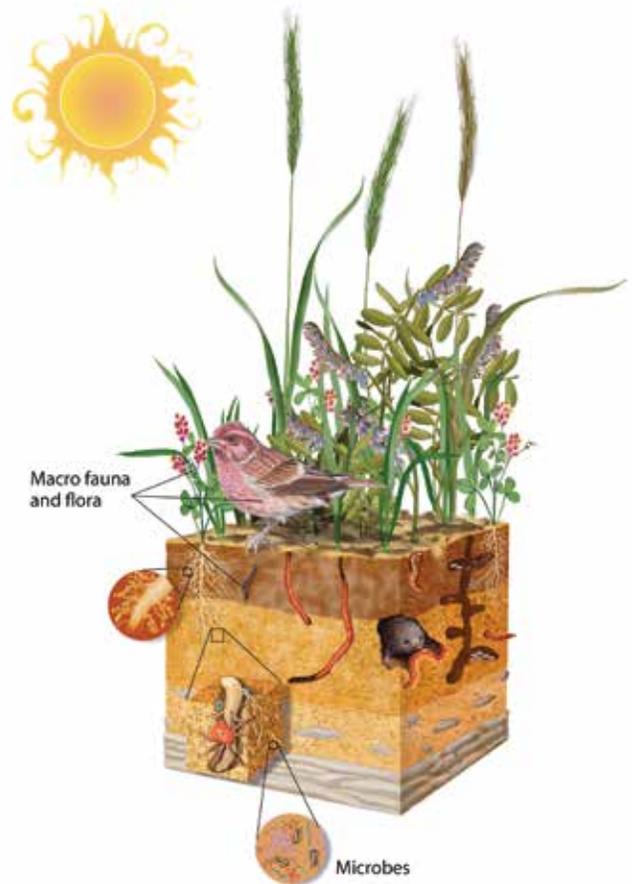


FIGURE 1. THE COMPLEXITY OF MEASURING SOIL HEALTH

Cornell’s Comprehensive Assessment of Soil Health (CASH) protocol includes not only a standard soil test that focuses on soil chemistry, but also integrates this with physical and biological indicators of soil health.

FIGURE 2. HEALTHY SOIL ECOSYSTEM

Healthy soil ecosystem, with organisms living within and above the soil surface. Illustration credit: Carlyn Iverson and USDA-SARE.



Images from the 2018 Empire Farm Days, the largest outdoor agricultural trade show in the Northeastern U.S. 1. Cover crop trials. 2. A panel of farmers discuss the strategies that they use to improve soil health on their farms. 3. Paul Salon, soil health specialist for the northeast region at USDA-NRCS giving a tour of the cover crop trials planting.



MEASURING SOIL HEALTH

IDENTIFYING USEFUL BIOLOGICAL INDICATORS OF SOIL HEALTH HAS BEEN THE BIGGEST CHALLENGE.



(Left) Cornell Orchards Summer interns learn about soil health assays from Cornell Soil Health Lab staff: Kirsten Kurtz, Lab Manager and Bob Schindelbeck, Lab Director. Photo: Gregory Peck
(Below) Soil sampling. Photo: David Wolfe

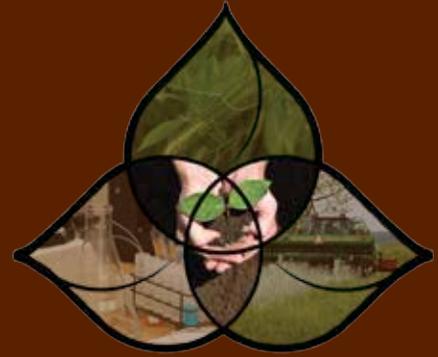


Relying on actual counts or estimates of abundance of specific soil organisms can quickly become prohibitively expensive, and interpreting these data in terms of impacts on crop productivity or other desired benefits are often impossible. With cost being an important criterion for a farmer-oriented soil health test, researchers at Cornell have focused on relatively low-cost indicators of biological activity or function, such as soil respiration rate, and available forms of carbon and nitrogen to support the soil food web.

These comprehensive assessments of soil health are now available through the Cornell Soil Health Lab on a fee-for-service basis for farmers throughout the Northeast U.S. and other regions. The CASH protocol continues to improve as needs arise and new techniques become available.

THE CORNELL “COMPREHENSIVE ASSESSMENT OF SOIL HEALTH” (CASH) PROTOCOL IS THE RESULT OF ALMOST TWO DECADES OF EFFORT ANALYZING THOUSANDS OF SOIL SAMPLES COLLECTED FROM COMMERCIAL AND RESEARCH FARMS, AND EVALUATING NUMEROUS SOIL HEALTH INDICATORS.⁶

More info: <http://soilhealth.cals.cornell.edu>



The CASH protocol includes:

field measurement of soil compaction (penetrometer readings)

several measures of soil physical characteristics (e.g., aggregate stability and water holding capacity)

several indicators of soil biological activity (e.g., soil respiration rate and microbial available “active” carbon)

a modified version of the standard soil (chemical) test for acidity, organic matter, and nutrients

21,000

Cornell Soil Health Lab  conducts about 21,000 soil health tests every year.

"REPORT CARD"

Farmers receive an interpretive “report card” indicating in green, yellow, or red, those aspects of soil health that range from optimum (green) to problematic (red). Most importantly, the report provides recommendations for addressing soil constraints that could negatively affect farm profits or the environment.

Measured Soil Textural Class: **silt loam**

Sand: **2%** - Silt: **83%** - Clay: **15%**

Group	Indicator	Value	Rating	Constraints
physical	Available Water Capacity	0.14	37	
physical	Surface Hardness	260	12	Rooting, Water Transmission
physical	Subsurface Hardness	340	35	
physical	Aggregate Stability	15.7	19	Aeration, Infiltration, Rooting, Crusting, Sealing, Erosion, Runoff
biological	Organic Matter	2.5	28	
biological	ACE Soil Protein Index	5.1	25	
biological	Soil Respiration	0.5	40	
biological	Active Carbon	288	12	Energy Source for Soil Biota
chemical	Soil pH	6.5	100	
chemical	Extractable Phosphorus	20.0	100	
chemical	Extractable Potassium	150.6	100	
chemical	Minor Elements Mg: 131.0 / Fe: 1.2 / Mn: 12.9 / Zn: 0.3		100	

Excerpt of an example summary report page from a soil health assessment using the CASH protocol.

IMPROVING SOIL HEALTH

FOUR APPROACHES

The agricultural literature is filled with strategies for improving soil health, and most can be fit into one of the four categories described here.



EXPAND THE USE OF FALL/WINTER COVER CROPS

This increases the total annual plant uptake of carbon dioxide through photosynthesis, which significantly increases soil organic matter compared to leaving land fallow during the fall to early spring period.

The roots of cover crops help hold the soil in place and thus provide resilience to soil erosion during heavy wind or rainfall events. Some cover crops have deep and extensive root systems that move carbon deep into the soil profile, and can break up compacted soil layers to improve infiltration and drainage.

Over the past two decades we have learned that plant roots can be quite “leaky”, releasing sugars and other substances that can build up populations of beneficial soil organisms for themselves or the following crop. Some plant species also release trace amounts of allelopathic substances that can suppress weeds, insects and/or soil-borne disease organisms.

PHOTOS

1. Fall cover crop
2. Soybean emerging through mulch.
3. Seeding into mulch.
4. Johannes Lehmann with biochar & biomass examples

Photos 1-3: Matt Ryan
Photo 4: Jason Koski, Cornell Brand Communications



DIVERSIFY WITH CROP ROTATIONS

This breaks pest cycles, adds nutrients or organic matter, maximizes soil biodiversity, and provides other benefits.

A classic example of crop rotation that farmers have been using for centuries is growing nitrogen-fixing legume plants (e.g., soybeans) in alternation with non-legumes (e.g., corn). When possible, integration of perennial or semi-perennial (e.g. alfalfa) plants into a cropping system, where and when possible, is an effective strategy for reducing soil disturbance and remediating degraded soils.



CORNELL UNIVERSITY WILLBORO RESEARCH FARM. PHOTO: CEDRIC MASON



RESOURCES

—
 Cornell's *Comprehensive Assessment of Soil Health*⁶

*Building Soils for Better Crops*¹¹

Websites:

USDA-NRCS (nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/)

New York Soil Health (newyork-soilhealth.org)

And many other sources



03

REDUCING TILLAGE

—
 This practice slows the pace of organic matter decomposition so that nutrient release happens gradually, matching crop nutrient needs.

Excessive tillage not only breaks up soil aggregates and exposes more of the soil organic matter to decomposition, but also pumps excessive amounts of oxygen into the soil, accelerating microbial decomposition activity. Excessive tillage as a means of remediating soil compaction can lead to a chronic soil compaction problem³, a result of decreased organic matter, poor aggregate stability, and increased plow layer compaction.



04

USING COMPOST, MANURE, BIOCHAR OR OTHER SOIL AMENDMENTS

—
 This is a way of utilizing high organic matter and carbon-rich "waste" materials for soil health benefits.

These amendments tend to improve soil structure, water and nutrient retention, water infiltration rate and drainage, and can promote beneficial soil organisms. Biochar is a highly stable carbon substance produced by burning biomass or organic wastes at low oxygen in a pyrolysis unit. Energy can be captured and utilized during pyrolysis, and the biochar can be added to soil to sequester carbon and improve soil structure and function.

SOIL HEALTH ECONOMICS

FARM-LEVEL INCENTIVES AND BARRIERS

The approaches to maintaining and improving soil health described on pages 10-11 seem straightforward, but many farmers are not yet adopting these strategies. Understanding the costs and benefits from the farmer's perspective will be essential for expanding adoption. A partial budget analysis approach has been used to establish a detailed accounting of costs and benefits for individual farms. However, partial budget analyses can miss some of the resilience or avoided cost benefits included in Table 1, which only become apparent after many years, or in years with drought, flooding, or other environmental challenge. More work is needed to expand the economic factors included in soil health analyses, and translate economic data into decision-tools for farmers and policy-makers, such as exploring the use of optimal control models¹².



DAIRY FARMER DAVE MAGOS

See references for economic case study farmer profiles.^{15, 16}

THERE ARE SOME BARRIERS TO ADOPTION THAT ARE NOT EASILY CAPTURED IN STRICTLY ECONOMIC TERMS, SUCH AS:^{13, 14}

- MANAGEMENT COMPLEXITY
- LACK OF TECHNICAL ASSISTANCE
- POLICY DISINCENTIVES

LOGISTICAL CONSTRAINTS ARE ANOTHER ISSUE, SUCH AS:

- DIFFICULTY ESTABLISHING A FALL-WINTER COVER CROP WITHIN A RELATIVELY SHORT GROWING SEASON
- REDUCING TILLAGE IN ORGANIC CROPPING SYSTEMS WHERE HERBICIDE USE IS NOT AN OPTION FOR CONTROLLING WEEDS

CASE STUDIES

In order to capture some of these other issues, the USDA-NRCS and others have developed case studies with data and input from individual farmers in New York,^{15,16} and elsewhere, who have had several years or more experience with soil health practices. These can reveal successful approaches for overcoming barriers to adoption, and subtle factors that influence management decisions and investments over time. These case studies, which may or may not include a partial budget analysis, can be very effective farmer-to-farmer training tools.

Table 1. Farm-Level Costs and Benefits of Adoption of Soil Health Practices

FARM-LEVEL COSTS AND BENEFITS OF ADOPTION OF COVER CROPS AND/OR NEW ROTATION SEQUENCES			
POTENTIAL COSTS		POTENTIAL BENEFITS	
ANNUAL VARIABLE	FIXED CAPITAL	ECOLOGICAL/ ENVIRONMENTAL	ECONOMIC BENEFITS
Seed and other input costs for new crops	New seeding or harvesting equipment	Maximized vegetation, root growth, and residue cover year-round	Reduced farm soil erosion and vulnerability to soil compaction, less need for sedimentation repairs
Labor, herbicide, and fuel, costs for management (e.g., planning, planting, mowing, termination)	Purchase of rollers, crimpers for cover crop termination (organic systems)	Cover crops preventing weed growth; root exudates suppressing weeds, insects, soil-borne pathogens	Reduced fuel and chemical use for weed, pest, disease control
Reduced revenue (lost opportunity cost) when some cash crop acreage devoted to soil-building cover crops or lower-value cash crop		Breaking weed, insect, or soil-borne disease cycles; biodiversity, more resilient and healthier ecosystems	Drought and flooding resilience. Avoided costs for irrigation or drainage systems, less need for sedimentation repairs
		Increased soil organic matter; improved soil aggregate stability, better water holding capacity and drainage, retention of nutrients	Reduced fertilizer expenditures
		Nitrogen contribution with legume cover crops or rotation crops	
FARM-LEVEL COSTS AND BENEFITS OF ADOPTION OF NO-TILL OR REDUCED TILLAGE			
POTENTIAL COSTS		POTENTIAL BENEFITS	
ANNUAL VARIABLE	FIXED CAPITAL	ECOLOGICAL/ ENVIRONMENTAL	ECONOMIC BENEFITS
Herbicide and/or labor costs for weed management	No-till planters for planting into crop residue	Reduced soil disturbance maintains soil organic matter, improves aggregate stability, better water holding capacity and drainage	Drought and flooding resilience. Avoided costs for irrigation or drainage systems
Risk of problems with compaction and/or lower yields in first years of transition if not managed properly	Strip tillage or other types of specialized field preparation equipment	Improving nutrient retention, and supporting soil biota involved in nutrient cycling	Reduced vulnerability to soil compaction over the long term
			Reduced fertilizer expenditures
FARM-LEVEL COSTS AND BENEFITS OF ADOPTION OF COMPOSTS, MANURES, OTHER SOIL AMENDMENTS			
POTENTIAL COSTS		POTENTIAL BENEFITS	
ANNUAL VARIABLE	FIXED CAPITAL	ECOLOGICAL/ ENVIRONMENTAL	ECONOMIC BENEFITS
Labor cost for management and spread of amendments	Purchase of spreaders or other specialized equipment	Direct additions of organic matter with benefits for improved soil structure, water holding capacity and drainage, nutrient retention	Drought and flooding resilience. Avoided costs for irrigation or drainage systems
Fuel costs for import and application of amendments			Reduced fertilizer expenditures

SOIL HEALTH ECONOMICS

STATEWIDE FARMER SURVEY



FARMER SURVEY OF SOIL HEALTH ECONOMICS: COSTS & BENEFITS

During 2017-2018 NYSH conducted a survey of 182 New York farmers from 46 NY counties.

60%

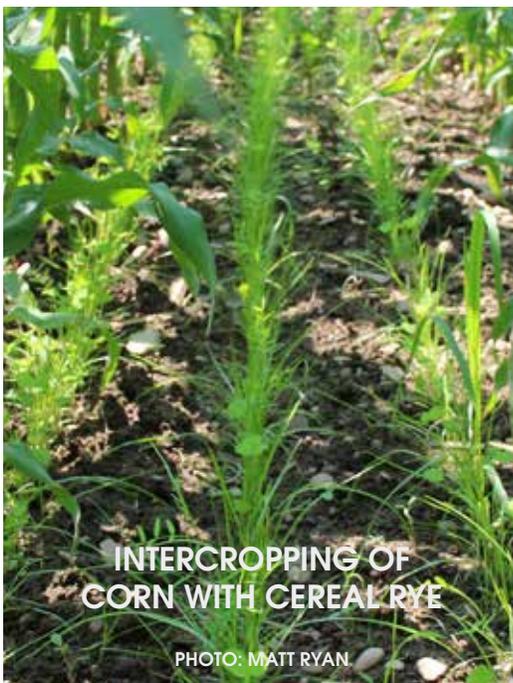
REPORTING RESILIENCE BENEFITS

More than 60% of farmers using reduced tillage or cover crops reported increased resilience to drought and flooding.

The costs and benefits of adoption of soil health practices vary by geographic region, cropping system, and year-to-year variability in weather and other environmental factors. Lack of clarity on the timeline for reaping benefits from investment in soil health practices is a barrier for many farmers. While soil health partial budget analyses and case studies have been conducted in New York by USDA-NRCS^{15,16} and others, these are limited to a small number of farms, regions, cropping systems, and years.

To address this knowledge gap, NYSH conducted a survey of 182 New York farmers that encompassed all major agricultural counties in the state, and included field, vegetable, forage, and perennial fruit crop growers.¹⁷ More than 60% of farmers using reduced tillage or cover crops reported increased resilience to drought and flooding (Fig. 3a).

The survey revealed some important distinctions between costs and benefits for vegetable compared to field crop and forage crop growers.¹⁸ It also provided some new insights into the timeline of benefits. For example, contrary to the popular notion that soil health benefits only occur after many years of investment, results indicated that some benefits, such as reduced erosion with cover crops (Fig. 3b) and reduced labor and fuel costs with less tillage, were realized within the first five years of adoption. In contrast, other benefits such as higher yields can take longer in many cases (Fig. 3c).



INTERCROPPING OF CORN WITH CEREAL RYE

PHOTO: MATT RYAN

AN EXPANDED VIEW OF SOIL HEALTH BENEFITS HAS LED TO SEVERAL STATE PROGRAMS AND POLICIES FOCUSED PARTICULARLY ON SOIL HEALTH, SUCH AS THE NEW YORK SOIL HEALTH INITIATIVE (WWW.NEYORKSOILHEALTH.ORG), AS WELL AS MORE FORMAL POLICY ACTIONS IN CALIFORNIA, MARYLAND, AND ELSEWHERE.¹⁹

WEATHER RESILIENCE

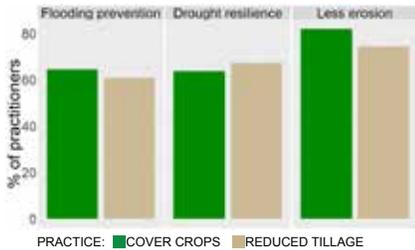


Figure 3a. More than 60% of farmer respondents to the New York soil health survey felt that adoption of soil health practices (cover crops or reduced tillage) improved resilience to flooding, drought, and soil erosion.

COVER CROPS

LESS EROSION OR SEDIMENTATION REPAIR

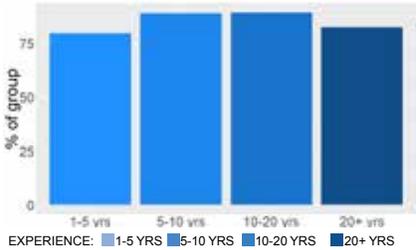


Figure 3b. Based on survey results, the benefit of less erosion with use of cover crops occurred within the first five years for more than 75% of farmer respondents.

COVER CROPS

GREATER YIELDS OF CASH CROPS

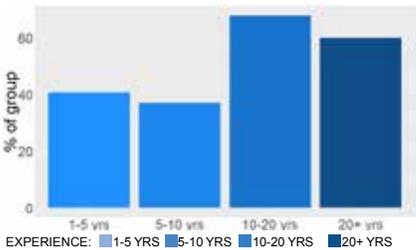


Figure 3c. A benefit of cover crops on cash crop yields was reported by only about 40% of farmers who had been using cover crops for less than 10 years, but was reported by more than 60% of farmers using cover crops for 10-20 years or longer.

OFF-FARM WATER QUALITY, CLIMATE CHANGE MITIGATION, AND OTHER ENVIRONMENTAL BENEFITS

Environmental and other off-farm benefits of soil health are becoming more widely recognized.²⁰ Some of these are summarized in Table 2. One important example is the intersection of soil health with water quality. Implementation of good soil health practices on working lands will minimize sedimentation and nutrient and chemical losses into our lakes, streams, and groundwater. This is closely linked with maintaining a supply of safe drinking water and current concerns about Harmful Algal Blooms (HABs) in New York lakes.

TABLE 2. OFF-FARM ENVIRONMENTAL AND ECONOMIC BENEFITS OF HEALTHY SOILS	
ECOLOGICAL OR ENVIRONMENTAL EFFECTS	ECONOMIC BENEFITS
Water quality: Reduced herbicide, pesticide, fertilizer, manure runoff or leaching into waterways	<ul style="list-style-type: none"> - Avoided taxes for water treatment costs - Sustainable and affordable safe drinking water - Recreational value for streams, ponds, lakes is maintained
Water quality: Reduced sedimentation of waterways	<ul style="list-style-type: none"> - Avoided taxes for costs of dredging ditches, streams, ponds - Avoided taxes for repairing flood damage to public and private lands
Biodiversity, more resilient and healthier ecosystems	<ul style="list-style-type: none"> - Recreational value of public areas is maintained - Maintained or increase in land and home values
Sustainable, productive local food production	Sustainable supply of healthy, affordable food for communities, holds communities together.
Climate change mitigation: soil carbon sequestration	Avoided taxes to repair weather damage exacerbated by climate change

Other important off-farm values indicated in Table 2 include those associated with climate change adaptation and mitigation. Maintaining high organic matter, a cornerstone of good soil health management, stores carbon in soils (organic matter is often more than 60 percent carbon) that otherwise would be in the air as the greenhouse gas, carbon dioxide. In this way, building healthy soils is a natural geoengineering approach for carbon capture and sequestration that can slow the pace of climate change (mitigation), while also improving resilience to some of the uncertainties of weather in a changing climate, such as increased risk of drought or flooding.²¹ Recent global and national analyses^{22,23,24} suggest that natural climate solutions which include agroforestry as well as better soil and crop management, could potentially compensate for up to a third of human greenhouse gas emissions.

ENVIRONMENTAL BENEFITS

WHAT'S IT WORTH?



\$226 MILLION IN SOCIAL/ ENVIRONMENTAL BENEFITS

For each 1% of U.S. acres of corn-soy-wheat adopting soil health practices.



OFF-FARM ECONOMIC BENEFITS

This would potentially include lower food and water prices, and an increase in property values.

Putting a dollar value on soil health's environmental and human health benefits remains challenging, and is an area where more research is needed. An ambitious study organized by The Nature Conservancy²⁵ gathered soil health economic-oriented information from a wide variety of sources for three important field crops: corn, soybean, and wheat. They estimated that for each 1% of U.S. acres of corn-soy-wheat adopting soil health practices, the annual economic benefits would amount to \$226 million of societal value through increased water capacity, reduced erosion and nutrient loss, and reduced greenhouse gas emissions. An analysis along these lines for the major crop groups of New York, that might include important vegetable and fruit crops as well as field crops, would be useful.

In Table 2 we indicate some complex, second-order economic factors that are particularly difficult to quantify, yet potentially significant in the valuation of environmental soil health benefits. This would include avoided tax increases associated with costs for water treatment, dredging sediment from waterways, flood control, and repairing damage from extreme weather events exacerbated by climate change. Other potential off-farm economic benefits of good soil health management include lower food and water prices, increase in land and home values, and maintaining recreational value of public and private land and water bodies.



(PHOTO LEFT) DONN BRANTON OF BRANTON FARMS ILLUSTRATES THE CONNECTION BETWEEN WATER QUALITY AND SOIL HEALTH BY SHOWING TWO SAMPLES OF WATER, ONE CLOUDY WITH SEDIMENT FROM THE CREEK ENTERING HIS PROPERTY AND THE OTHER WITH CLEAR WATER THAT EXITS HIS FARM. PHOTO: KITTY GIFFORD



FLOODED CABBAGE FIELD

These New York cabbage fields flooded due to poor drainage. This not only reduces crop yield, but can also lead to soil erosion and runoff into nearby streams.

PHOTO: David Wolfe



HARMFUL ALGAL BLOOMS

Harmful algal blooms may make the water look bright green or like pea soup. These algae can produce toxins that can be harmful to people and animals.

When farmers build up organic matter in the soil this helps to reduce the harmful runoff that can contribute to toxic algae.

PHOTO: Myers Point on Cayuga Lake by Bill Foster



SOIL HEALTH AND FOOD

Healthier soils can help farmers manage the stresses of climate change. Consumers benefit from a more reliable food supply and lower prices.

Consumers can play a role by asking farmers about their soil health practices, and communicating to elected officials about soil health issues.



CARBON SEQUESTRATION

Maintaining high organic matter stores carbon in soils.

Organic matter is often more than 60% carbon that otherwise would be in the air as the greenhouse gas carbon dioxide. Building healthy soils is a natural geoengineering approach for carbon capture and sequestration that can slow the pace of climate change.

ACTIVITIES IN NEW YORK PAST AND CURRENT*

NEW YORK SOIL HEALTH

The statewide New York Soil Health initiative, which began in 2017, has provided a communication and collaboration framework to encompass the full diversity of interests, events, resources, and priorities of the many stakeholder groups involved in the soil health movement (Fig. 4). New York Soil Health is funded by the NYS Environment Protection Fund, administered by the NYS Department of Agriculture and Markets (NYS-DAM), and coordinated by personell at Cornell University.

In July, 2018, New York Soil Health organized the first statewide Soil Health Summit held in Albany. About 140 attended the event, with farmers, policymakers, and over 35 organizations represented. The summit brought together for the first time the full swath of those working on soil health issues. There was sharing of interests and accomplishments of the various organizations, as well as a breakout session focused on gathering input on goals and priorities for this Roadmap document (for details see: www.newyorksoil-health.org/summit).

FARMER ORGANIZATIONS

Many innovative conventional as well as organic New York farmers have been at the forefront of the soil health movement. Farmers of the Northeast Organic Farmers Association (NOFA) have been working for many years on soil health issues, and provide resources for their members (<https://www.nofany.org>). They hold farmer-to-farmer trainings, and operate an online discussion group.

In many ways the soil health movement in New York has evolved as a complex collaboration with local agribusinesses and consultants, university researchers and educators, and government and non-governmental agencies. About twenty years ago a wide range of field and vegetable crop growers began working with Cornell University researchers and Cornell Cooperative Extension (CCE) educators on soil health issues, and formalized into a Soil Health Program Work Team. One outcome of this collaboration was the development of the CASH framework and measurement protocol.¹⁰

Other grower-led soil health groups have formed in recent years, such as the Western New York Soil Health Alliance, and the New York State Soil Health Workgroup, currently coordinated by USDA-NRCS. There has been considerable farmer, agribusiness, university, and government and non-government organization participation in all of these groups, and cross fertilization among them.

*SEE APPENDIX FOR MORE DETAILS ON ORGANIZATIONS MENTIONED HERE.

NEW YORK SOIL HEALTH PROVIDES A PLATFORM FOR COMMUNICATION

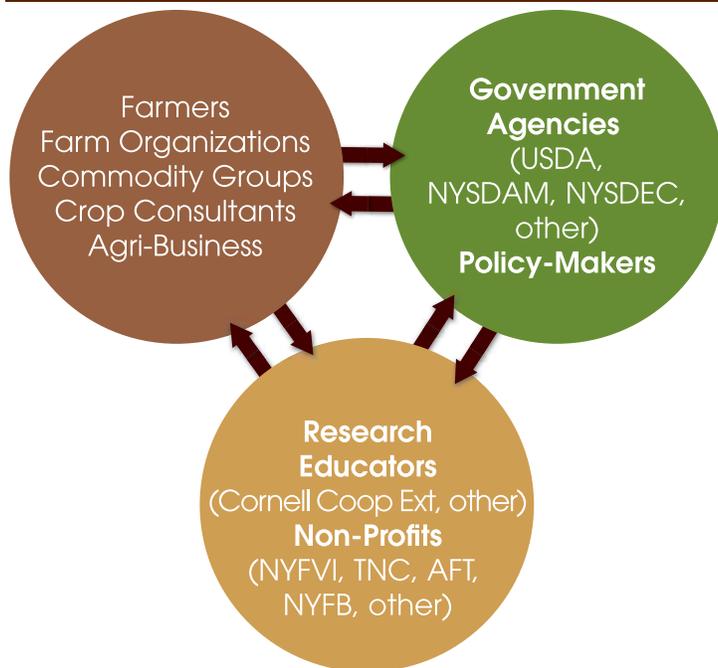


Figure 4. New York Soil Health provides a platform for communication and collaboration among the many individuals and organizations working on soil health in New York State.

RELEVANT NATIONAL AND REGIONAL EFFORTS BEYOND NEW YORK

The national **USDA-NRCS Soil Health Program** (<https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/>)

Soil Health Institute
(www.soilhealthinstitute.org)

US Climate Alliance- Natural and Working Lands Challenge (New York is one of 17 states part of this initiative)
(www.usclimatealliance.org/nwlchallenge)

California Healthy Soils Initiative
(<https://cdfa.ca.gov/healthysoils>)

Maryland Healthy Soils and Cover Crops Programs
(https://mda.maryland.gov/resource_conservation/Pages/cover_crop.aspx)

Soil Health Partnership
(<https://www.soilhealthpartnership.org/>)

See appendix for more details on these efforts.

OTHER NON-PROFIT ORGANIZATIONS

A growing number of other non-profit organizations are contributing to the advancement of soil health in New York in significant ways.

- For many years now the New York Farm Viability Institute (www.nyfvi.org), funded by the state and led primarily by New York farmers, has provided grants for research, outreach and on-farm implementation of soil health practices.
- The New York Farm Bureau (www.nyfb.org) provides support for farmers to link with policy-makers on soil health issues.
- The Nature Conservancy (www.nature.org) has become very active in soil health at the international and national level, and the New York chapter has been an important contributor to the New York Soil Health program in recent years, bringing in a perspective that links soil health with water quality and nutrient management, including the emerging “4R Plus” nutrient management program.
- The American Farmland Trust (www.farmland.org) is also quite active in the soil health realm, has developed some useful resources and farm case studies for the region, and most recently has obtained a USDA-NE SARE grant for an intensive soil health curriculum for professional agricultural service providers.

SOIL HEALTH IN NEW YORK

UNIQUE FEATURES

New York has been at the forefront of the soil health movement from the beginning, and now has an ambitious level of activity on multiple fronts.

CHALLENGES AHEAD

One challenge has been capitalizing on this momentum, and fully developing opportunities for collaboration and synergy among the many groups involved. The recent New York Soil Health (www.newyorksoilhealth.org) effort has been a start, but more efficient and comprehensive organization, planning, and establishment of communication channels between stakeholders and policy-makers is needed.

Another challenge is addressing barriers to adoption of soil health practices by farmers and other land managers. These range from economic concerns, to lack of appropriate equipment or technology for some cropping systems and practices, and lack of education and technological support. New York farmers also are constrained by our relatively short growing season, which can make establishment of fall-winter cover crops a challenge.

RESEARCH CHALLENGES

Much of the research on soil health, particularly at the national level, has focused on conventional corn-soybean systems prevalent in the Midwest. While these are important crops in New York, mixed animal-crop dairy farms dominate our agricultural landscape, and acreage and economic importance of fruit and vegetable farms are also substantial. Our soil health policy, research, and outreach efforts need to be expanded to reach these and other underserved audiences and regions, such as apple and grape growers, organic farmers, and managers of grasslands, pastures, forests, and urban landscapes.





DAIRY FARM OPPORTUNITIES

Dairy farms in New York can serve as positive examples of coupled animal and crop production. While manure is often viewed as an inherent environmental problem, this dairy waste is rich in organic matter and nutrients. New York has a unique opportunity for developing and demonstrating ways in which manure handling and land application can be optimized to minimize negative environmental impact and improve soil health. New York can also lead the way in exploring potential for energy generation from manure waste, and innovative processing of excess manure for value-added manure products for application to degraded soils.



ROADMAP DISCUSSIONS AT NEW YORK SOIL HEALTH SUMMIT



CORNELL UNIVERSITY WILLSBORO RESEARCH FARM - ROLLER CRIMPER DEMONSTRATION

POTENTIAL BENEFITS

We have reached a point where the full suite of potential benefits are being realized by some of the pioneer farmers in our region (Fig. 3a-3c). This has expanded interest among the farming community, but more effort is needed to increase adoption of soil health practices where appropriate from an economic and environmental perspective. Initial efforts in New York have focused primarily on sustainable food production and farm profitability, but in recent years a more broad landscape perspective has revealed the many environmental and human health benefits as well (Table 2).

WHAT'S NEXT?

There are policy, as well as research and outreach needs for better integrating soil health with other environmental issues of concern to all citizens of New York, such as climate change resiliency and mitigation, and water and nutrient management. These and other issues indicated above are addressed in the Roadmap Goals and Priorities.

(PHOTO LEFT) Patrick Hooker, New York deputy secretary for food and agriculture, delivered the morning remarks at the NYSH summit.



THE HISTORY OF SOIL HEALTH IN NEW YORK HAS BEEN AN IMPRESSIVE EXAMPLE OF COLLABORATION BETWEEN

INNOVATIVE:
FARMERS RESEARCHERS
EDUCATORS AGRIBUSINESS
GOVERNMENT & NON-PROFITS



VISION NY SOIL HEALTH ROADMAP

New York State is a recognized leader in soil health research, outreach, and policy, with effective stakeholder partnerships and demonstrated success at promoting a strong and dynamic agricultural and forest economy, protecting natural resources and biodiversity, improving resilience to extreme weather, and contributing to climate change mitigation.

GOALS & PRIORITIES

NY SOIL HEALTH ROADMAP

(1) Institutionalize a stakeholder network and organizational framework for soil health collaboration, communication, and priority setting

POLICY

- Institutionalize the “New York Soil Health” effort, which has been coordinated by Cornell CALS as New York State’s land grant partner, to provide a platform for sharing the full diversity of interests, resources, events and priorities of the many stakeholders involved in soil health
- A key role of this statewide program will be to establish a direct communication channel with policymakers and bring attention to and speak with one voice regarding specific soil health goals, and policy priorities to meet those goals

RESEARCH & OUTREACH

- Seek consensus where possible and promote a consistent message on soil health goals, and strategies to reach those goals, including research, and outreach priorities
- Identify and capitalize on opportunities for research and outreach synergy across groups with similar goals and/or activities, including farmer-to-farmer training

Images from the July 18, 2018, New York Soil Health Summit in Albany, NY. 1. David Wolfe, Cornell professor of plant and soil ecology and program lead for New York Soil Health. 2. Stakeholders discussing the Roadmap at the Summit. 3. Rebecca Benner, New York State science director for The Nature Conservancy.



GOALS & PRIORITIES

NY SOIL HEALTH ROADMAP

(2) Identify and take steps to overcome barriers to wider adoption of soil health practices

POLICY

- Update New York State Soil and Water Conservation Districts Law to explicitly support soil health practices for attaining agricultural and environmental goals
- Facilitate communication among all county, state and federal agencies regarding the integration of soil health with broader environmental goals, programs, and policies
- With input from stakeholders, identify specific soil health goals and priorities
- Increase support for soil health programming within existing state agencies
- Ensure regulatory consistency across agencies to facilitate reaching soil health goals
- Facilitate agribusiness ventures and farm credit opportunities that provide low cost loans, technical assistance, equipment rental, or related soil health services to farmers
- Evaluate the potential for farmers to gain a reputational benefit from adoption of soil health practices, for example by marketing a “Soil Health Grown” label
- Provide grant opportunities for basic and applied soil health research and outreach

RESEARCH & OUTREACH

Develop an intellectual and practical knowledge base for research and outreach planning based on:

- A quantitative soil health assessment in agricultural, urban, and natural areas across the state, and identify key regional and sector challenges and opportunities
- Economic and feasibility analyses for expanded adoption of soil health practices for specific land uses, regions, soil types, etc.
- Research on best methods to incentivize adoption of soil health practices
- Identified needs and opportunities in technology and farm equipment
- Fundamental soil biology and ecology research

GOALS & PRIORITIES

NY SOIL HEALTH ROADMAP

RESEARCH & OUTREACH (GOAL 2, CONTINUED)

Develop research and outreach agendas specifically for:

- Underserved areas of the state and underserved land managers/owners such as apple, grape, organic, and other farmer groups, and managers of grasslands, pastures, forests, and urban landscapes
- Developing and evaluating new cover crop varieties and species mixtures, novel rotation schemes, agroforestry, and perennial grain crops
- Integrating cover crops and/or double crops into cash crop systems
- Technical support for transitioning to new soil health practices, including “work-books”, mobile phone apps, etc.
- Ground cover management for perennial fruit crops
- Optimizing soil health for weed, disease, and insect pest management
- Improvement and expanded use of quantitative measurements of soil health, such as Cornell’s CASH protocol (<http://soilhealth.cals.cornell.edu>)
- On-farm demonstrations, educator-farmer and farmer-to-farmer training

1: Cultivated plots on the left and mulched plots on the right in an organic weed/soil health apple orchard project managed by Dr. Greg Peck. 2: Dr. Matt Ryan conducts research on the impacts of no-till cover crop rotation systems. 3. Western New York Soil Health Alliance held a Soil Health Workshop on no-till practices and benefits in 2018.



GOALS & PRIORITIES

NY SOIL HEALTH ROADMAP

(3) Integrate climate change adaptation and mitigation research, outreach, and policy with soil health programming

POLICY

- Integrate soil health programming with climate change policy initiatives, such as the “natural and working lands” component of the U.S. Climate Change Alliance, and expand support for the Climate Resilient Farming component of the state Agricultural Environmental Management (AEM) framework
- Provide grant or cost-share support to focus on soil health management for meeting New York climate change resiliency and mitigation goals

RESEARCH & OUTREACH

- Develop statewide education programming regarding the benefits of soil health for climate change mitigation and resiliency of our food system
- Expand research and outreach for supporting adoption of soil health practices for:
 - Resilience to drought, flooding, and erosion
 - Reducing emissions of nitrous oxide and methane, as well as carbon dioxide
 - Soil carbon sequestration, including:
 - ◇ Establishing soil carbon baselines and potential for sequestration at farm, regional, and state levels
 - ◇ Developing low-cost approaches to monitoring soil carbon change
 - ◇ Supporting basic research on factors leading to long-term carbon storage
 - ◇ Scaling up production and use of biochar for carbon sequestration

GOALS & PRIORITIES

NY SOIL HEALTH ROADMAP

(4) Integrate water and nutrient management research, outreach, and policy with soil health programming

POLICY

- Further integrate soil health programming within conservation planning and cost-share opportunities of the state AEM framework, including nutrient management planning for Concentrated Animal Feed Operations (CAFO) regulated by NYSDEC
- Fund and create incentives to support research and new business ventures focused on developing value-added soil amendments, including composts, biochar and other products, from manure and other sources
- Work with NYSERDA and other state programs to expand research, policies, and incentives to encourage on-farm energy generation from manure waste

RESEARCH & OUTREACH

- Address unique soil health challenges and opportunities for dairy and other mixed crop-animal production systems with expanded research and outreach for:
 - Optimized seasonal distribution of manure waste on crop lands
 - Quality control and scaling up production of manure products such as compost and nutrient-enriched biochar
 - New approaches to commercialize manure distribution (e.g., manure banks)
 - Reducing investment and management costs for anaerobic digesters
- Integrate soil health with optimized management of nitrogen and other nutrients, including the emerging “4R Nutrient Stewardship” program
- Establish a research and outreach program focused on soil health economic benefits related to water quality and management, including (but not limited to):
 - Nutrient loading to waterways and harmful algal blooms (HABs)
 - Soil erosion and sedimentation of waterways
 - Drainage and flood control
 - Reduced irrigation needs on healthy soils
- Develop statewide education programming regarding the benefits of soil health for maintaining water quality for recreational use and a safe drinking water supply

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Graduate student Ann Bybee-Finley (Dr. Matt Ryan's research group at Cornell University) discussing her summer annual forage crops research at Aurora Musgrave Research Farm in Aurora, NY.

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APPENDIX ORGANIZATIONS

The number of individuals, organizations, and projects focused on soil health in New York is expanding every year. Many of these contributed to this Roadmap report. The list below is not intended as a comprehensive inventory of all soil health efforts in the state. Additional details of some of the activities of these organizations are found in the Introduction/Background section of the Roadmap. We also have included at the end of this Appendix a few national soil health efforts, organizations, and state government activities beyond New York that have relevance.

Government Agencies

New York State Department of Agriculture and Markets (NYSDAM)

(<https://www.agriculture.ny.gov/>)

Much of NYSDAM's soil health-related work is implemented through the Agricultural and Environmental Management (AEM) framework (<https://www.nys-soilandwater.org/aem/>). The AEM framework has been in place for nearly two decades in New York and, with participation from a third of all farms in the state, has strong support in the agricultural community. Most (approximately 50) agricultural counties in New York conduct AEM programs, with the local Soil and Water Conservation District as the lead.

AEM provides incentives in the form of technical assistance and competitive cost-share funding to help farmers implement conservation plans and practices that can improve farm viability and environmental conservation. Such practices directly related to soil health include, but are not limited to, nutrient management, cover crops, conservation crop rotation, conservation tillage including no-till, prescribed grazing, composting, and buffers to name a few.

Specifically, the AEM Base Funding Program supports District efforts to work with farms through the AEM Tiers to assess, plan, implement, and evaluate soil health practice systems. The Agricultural Non-Point Source Abatement and Control Grant Program (www.nys-soilandwater.org/aem/nonpoint.html) is in its 25th year in 2019 and provides approximately \$16 million of competitive, annual cost share funding through SWCDs to address water quality resource concerns, as well as other ecological services.

The Climate Resilient Farming Program (www.nys-soilandwater.org/programs/crf.html) through SWCDs is in its fourth year in 2019 and provides competitive cost-share funding to address multiple ecosystem services, including farm adaptation to climate change and/or greenhouse gas mitigation, as well as soil health, water quality, soil conservation, and farm resilience.

Given the variety of AEM projects encouraged within the Climate Resilient Farming Program, the roughly \$2.5 million annual opportunity is offered across three separate tracks: manure storage cover and flare systems, water management systems, and one specifically focused on soil health systems. Through the Agricultural Non-Point Source Abatement and Control Grant Program (last 10 years) and Climate Resilient Farming Program (last 3 years), over 135,000 acres of soil health practice systems, including cover crops, conservation tillage, crop rotation, and contour farming, have been supported by \$4 million in State cost share funds and \$2.5 million in farmer contributions.

In addition to cost share opportunities from NYS, Districts collaborate with multiple stakeholders and pursue other local, State, and federal grants to deliver on significant soil health outreach and training events, touching thousands of farmers over the last several years.

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New York State Department of Environmental Conservation (NYSDEC)

(<http://www.dec.ny.gov/>)

The NYSDEC intersects with soil health in multiple ways, particularly the agency's oversight of the Environmental Conservation Law (ECL), Clean Water Act (CWA), and the State Pollutant Discharge Elimination System (SPDES) permits for Concentrated Animal Feed Operations (CAFOs). New York has one of the most robust CAFO permitting programs in the nation with more than 500 CAFOs across the state, the majority of which are dairy farms with 300 or more cows and associated crop and livestock operations. Many of the NYSDEC activities related to soil health are in collaboration with NYSDAM, SWCDs, and other partners involved in soil, nutrient, water, crop, and animal management within the framework of the state's Agricultural Environmental Management (AEM) program. New York requires AEM Certified Planners to work with CAFO dairy farmers to develop Comprehensive Nutrient Management Plans (CNMP). AEM planning can include practices that promote soil health, such as use of cover crops, conservation crop rotations, organic matter additions through manure application, buffers, and conservation tillage.

USDA-Natural Resources Conservation Service (NRCS)

(<https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/>)

Among its many responsibilities, the NRCS provides technical and financial assistance to help farmers manage their soils, to improve soil function, productivity, and sustainability, while addressing air and water quality concerns.

In New York the NRCS field office staff provide direct assistance to agricultural producers to develop conservation plans. These plans evaluate alternatives to improve soil health and other on-farm resource concerns and provide guidance through conservation practice standards and specifications to implement the producer's objectives. NRCS administers several conservation financial assistance programs to help incentivize implementing conservation practices and soil health management systems.

With the increasing farmer, rancher, and landowner interest in soil health across the country, NRCS has responded by creating a nationally recognized soil health campaign, followed by the creation of the Soil Health Division (SHD) within the agency's structure in 2014. The SHD provides leadership for strategy, standards, tools, training, direct assistance, and policy related to soil health. NRCS has been collaborating with soil health experts within the public and private sectors to develop a set of current best available standard indicators and associated laboratory procedures to standardize soil health assessment.

The NRCS Big Flats Plant Materials Center in NY has conducted cover crop demonstration trials and an annual field day for more than ten years, fostering professional, academic and farmer soil health collaboration and networking. In 2013 the Northeast NRCS Soil Health Specialist, in cooperation with farmers, agribusiness, state agencies, Cornell University, SUNY Ag & Tech colleges and other stakeholders, organized the New York State Soil Health Workgroup (for more details see Appendix- Non-profit Organizations).

Since 2013 NRCS has awarded five Conservation Innovation Grants (CIG) for soil health projects in New York. These included support for: Cornell's work on the Comprehensive Assessment of Soil Health (CASH) protocol; Cornell's work to quantify and incorporate soil health lab indicator inputs into the Adapt-N tool for improved nitrogen management; a Delaware County cooperative extension cover

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crop and soil health outreach project; and projects with the American Farmland Trust and the Upper Susquehanna Coalition supporting on farm demonstrations, workshops and farmer case studies.

USDA-Northeast Sustainable Agriculture Research and Education (NE SARE)

(<https://www.nesare.org/>)

NE SARE is a regional program of the nationwide SARE effort. SARE offers competitive grants for research and education projects that address key issues affecting the sustainability and economic viability of agriculture. NE SARE was one of the first funding agencies to recognize the strategic importance of soil health, and supported some of the first soil health projects in New York, which were organized by farmers, Cornell University and Cooperative Extension, and others in the early 1990s. SARE's support has continued, such as a 2016 partnership grant, spearheaded by the NYS Soil Health Workgroup, to develop state teams to organize demonstration and other outreach projects. Most recently, NE SARE has funded the New York "Advanced Soil Health Training for Ag Service Providers" curriculum project spearheaded by the American Farmland Trust.

Farmer Organizations

Northeast Organic Farming Association, New York chapter (NOFA-NY)

(<https://www.nofany.org/>)

Soil health is a top priority for organic farmers and for NOFA-NY. They operate under the premise that healthy soils produce healthy crops, and people and animals who eat these crops will be healthy. They collaborate with other chapters in the Northeast, with other non-profits such as Earth Justice (www.earthjustice.org), and most recently with New York Soil Health coordinated by Cornell University. For many years NOFA-NY has featured soil health at winter conferences, held farmer round-tables where farmers share their practices, questions, discoveries with one another, and organized field days on farms with outstanding practices.

NOFA-NY, in cooperation with the 6 other NOFA chapters in neighboring states, has been engaged in a multi-year project to identify farmers who are doing outstanding work in carbon farming and then to share those innovations with other farmers. The Fall 2007 issue of *The Natural Farmer* focused on climate change and soil health. The NOFA initiative includes an on-line discussion group for farmers, a data base of farmer practices, and a white paper – *Soil Carbon Restoration: Can Biology do the Job?* by Jack Kittredge.

Western New York Soil Health Alliance

(www.wnysoilhealth.com)

The Western New York Soil Health Alliance was incorporated in 2016 as a farmer led group to promote good soil health practices on farms. The Alliance envisions a future where farmers use soil health systems to reduce agriculture's negative impacts on the environment, while improving the long-term productivity of our soils, efficiency of local farming practices and profitability of our farming enterprises. It promotes and supports the successful application of good soil health practices through shared ideas, experience, education and new technology, working to ensure that the tradition and culture of farming in Western New York can be carried on to future generations. A key objective is to develop a farmer-to-farmer network to promote local farm trials and share the results to educate producers and the general public on the benefits of good soil health practices, while serving as a collective voice for

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issues affecting soil health production practices for crop, dairy and livestock producers in Western New York.

Other Non-Profit Organizations

American Farmland Trust (AFT)

(<https://www.farmland.org/our-work/where-we-work/new-york>)

The American Farmland Trust launched in 2018 an “Advanced Soil Health Training for Ag Service Providers” curriculum in New York. This was funded by USDA-NE SARE and involves partnership with the Cornell University New York Soil Health program, the USDA-NRCS, and others. This multi-year training course will provide participants with the knowledge to understand the physical, biological and chemical characteristics of soil and the management systems that farmers can employ to improve soil health.

The first cadre of trainees (cover crop specialists, farm managers, agricultural retailers, crop consultants, etc.) have now completed the first two of five planned workshops. Training themes include the basic principles of soil health, cropping systems and cover crops, adaptive nutrient management for soil health, eliminating reducing or modifying tillage for soil health, and customizing soil health systems to the farm and farmer. Trainees will receive a certificate upon completion of advanced soil health training. This project is intended to be a pilot program and will be completed by the fall of 2020.

4R Nutrient Stewardship Program

(<https://www.nysaba.com/4r-ny>)

The “4Rs” refer to: right place, right source, right time and right rate for fertilizer applications. While this approach sounds straightforward, its implementation can be challenging under the complexity of real production environments. The 4R management strategy is closely linked with goals for improved soil health, crop resiliency, decreased environmental pollution, and protection of biodiversity. This approach considers economic, social and environmental dimensions of nutrient management and is essential to sustainability of agricultural systems.

The 4R Program is being adopted across North America, with measurable success. What is new about this program is the leadership from the fertilizer industry, in particular the Fertilizer Institute, and in New York the partnership with the non-profit New York State Agribusiness Association, as well as The Nature Conservancy, Cornell University, and others.

New York Farm Bureau (NYFB)

(<https://www.nyfb.org/>)

The NYFB is a non-profit organization that serves as the key liaison between the agricultural industry and New York policy-makers. The NYFB can provide unique expertise in identifying political actions to support farmer adoption of soil health practices. Also, the NYFB provides assistance in developing strategies to highlight the importance of soil health for a legislative audience, including communication with urban legislators unfamiliar with the benefits of soil health for agricultural sustainability and protection of natural resources.

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New York Soil Health (NYSH) (www.newyorksoilhealth.org)

The statewide New York Soil Health initiative, which began in 2017, has provided a communication and collaboration framework to encompass the full diversity of interests, events, resources, and priorities of the many stakeholder groups involved in the soil health movement. This Roadmap document is one product of the NYSH collaboration among stakeholders. NYSH is funded by the NYS Environment Protection Fund, administered by NYSDAM, and coordinated by CALS Cornell, the state's land-grant partner. It supports innovative research projects, as well as outreach efforts such as workshops, field days, and a website for communication and sharing of resources.

In July, 2018, NYSH organized the first statewide Soil Health Summit held in Albany. About 140 attended the event, with farmers, policy-makers, and over 35 organizations represented. It brought together for the first time the full swath of those working on soil health issues. There was sharing of interests and accomplishments of the various organizations, as well as a breakout session focused on gathering input on goals and priorities for this Roadmap document (for details see: www.newyorksoilhealth.org/summit).

New York State Soil Health Workgroup (NYSSHGW)

This Workgroup was assembled in 2013 and has been coordinated by the Northeast NRCS. It is made up of representatives from NRCS, SWCD, farmers, Ag & Markets, agriculture service providers, state government agencies, NGO's, SUNY Ag & Tech colleges, Cornell university educators and researchers, Cornell Cooperative Extension, and others. The Workgroup is the recognized advisory committee on soil health to the NRCS State Technical Committee, and meets approximately quarterly to identify statewide priorities and needs.

The Workgroup is actively involved in soil health workshops and field days at the local level to promote conservation tillage, cover cropping, grazing and nutrient management strategies. Since 2014 the Workgroup has planned and coordinated a three-day soil health program at Empire Farm Days, including presentations, cover crop field plantings for demonstration, and farmer panels. This Workgroup played an important role in the 2016 formation of the farmer-led Western New York Soil Health Alliance (for more details see Appendix- Farmer Organizations).

New York Farm Viability Institute (NYFVI) (<http://www.nyfvi.org/>)

The New York Farm Viability Institute's mission supports applied research and education projects that will increase farm profitability and support the sustainability of New York farmers. This is achieved through a farmer-driven grant making process connecting farmer-identified needs to practical research and education solutions. NYFVI has funded and completed over 300 projects overall since 2005. During that time, the board approved funding for 45 projects that directly address soil health as part of the project's deliverables.

Over \$4 million have been invested in soil health related projects since the inception of NYFVI. Data included in final reporting showed consistent positive impacts if applicable researched management practices were applied across the state agricultural industry. NYFVI board members understand the importance of healthy soil and will continue to fund projects that have a positive impact on soil health.

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The linkages between soil health, food security and environmental quality are part of their decision making process.

The Nature Conservancy (TNC)

(<https://www.nature.org/en-us/about-us/where-we-work/united-states/new-york/>)

The Nature Conservancy (TNC) is a global conservation non-profit dedicated to conserving the lands and waters on which all life depends. Guided by science, TNC creates innovative, on-the-ground solutions to the world's greatest conservation challenges so that nature and people can thrive now and into the future. Agriculture and soil health are a global and regional priority for TNC.

In New York, TNC partnered with NYSABA (NYS Agribusiness Association) and the Fertilizer Institute to launch the 4R Nutrient Stewardship Certification Program. Outside NY, TNC has also partnered with others to promote the 4R Program in the western Lake Erie basin. As 4R certification and related practices spread in New York, water quality and soil health will improve, as will efficiencies on farms through the application of fertilizers at the right time, place, rate, and from the right source.

TNC also currently works with many partners and agricultural stakeholders in the Lake Champlain basin and the Finger Lakes region (with a plan to expand to all of New York state) to develop innovative programs that increase the adoption and effectiveness of conservation practices related to soil health.

The Conservancy's overall goals with each of these programs are to further increase the environmental and economic sustainability of farming in New York, with a parallel focus of promoting soil health practices that contribute to New York's carbon sequestration goals. TNC believes that these outcomes can be accomplished by better targeting the actions and benefits of existing programs, and through improved incentives for the ecosystem services that agriculture currently provides. TNC anticipates that improvements in these areas will yield significant benefits to water quality, food security, soil health and natural climate solutions throughout New York state.

Watershed Coalitions

(<http://www.dec.ny.gov/lands/26561.html>)

Over the last 25-plus years, several Watershed Coalitions comprised of Soil and Water Conservation Districts and other agencies have organized to protect, promote and enhance natural resources (including soil conservation) of New York's watershed regions through education, partnerships, planning and implementation. The regional coordinated approach of Watershed Coalitions in New York are nationally regarded as having an innovative, effective approach to build partnerships and advance conservation management, like soil health practices, on the ground. Their success comes from the strength of providing a network of technical experts with local tie-in to land owners while partnering with federal, state and local stakeholders. Much of this networking is facilitated by the New York Agricultural Environmental Management (AEM) framework.

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New York Higher Education and Research Institutions

New York has many higher education and research institutions which are an important resource for soil health programming now and in the future. Cornell's College of Agriculture and Life Sciences (CAL S) is the state's land grant university and has played a soil health leadership role at the state, national, and international levels since the 1990's. Cornell currently provides leadership for the statewide New York Soil Health stakeholder collaboration, and has also coordinated this New York Soil Health Roadmap effort.

In addition to Cornell, other universities within the state have faculty with interest and expertise relevant to soil health research, outreach, and/or policy, and educational programs in agricultural or environmental science or other relevant disciplines. This would include SUNY College of Environmental Science and Forestry (ESF), SUNY Cobleskill, SUNY Morrisville, SUNY Binghamton, Columbia University, the Cary Institute, and others.

Regional and National Soil Health Organizations and Activities Beyond New York

California Healthy Soils Initiative

(www.cdfa.ca.gov/healthysoils/)

California's Healthy Soils Initiative promotes practices that create healthy soils on the state's many acres of farm and rangeland. The program focuses on bolstering levels of organic matter in soils across the state to ensure the viability of California's agricultural economy, to sequester and store carbon in the soil as a climate change mitigation tactic, and to divert waste material high in organic matter from landfills. The Initiative is a collaboration between multiple state agencies and departments, providing financial assistance for implementation of soil health practices, promoting research and education efforts around soil health, and more.

Maryland Cover Crops Program and Healthy Soil Biomass Pilot Program

(https://mda.maryland.gov/resource_conservation/Pages/cover_crop.aspx)

The state of Maryland provides financial incentives to farmers to support the use of cover crops with the aim of improving soil health and reducing agricultural runoff into the Chesapeake Bay. A wide variety of cover crops can be planted in the late summer or autumn to over-winter until the following spring, and the program allows for flexible management options such as forage grazing. The Maryland Department of Agriculture also recently launched a separate, but similar, program called the Healthy Soil Biomass Pilot Program, which pays farmers to plant up to 500 acres of wheat, rye or triticale before December 1st, with the aim of accumulating soil carbon and biomass while further reducing runoff into water local waterbodies.

Pennsylvania Association for Sustainable Agriculture (PASA)

(<https://pasafarming.org/>)

Since 1992, this Pennsylvania-based association has supported farmers working for economically-just, environmentally regenerative, and community-focused food systems. PASA organizes an annual Sustainable Agriculture Conference, and operates a Soil Institute that advances sustainable farming. PASA works with a variety of stakeholders, organizes workshops and events, offers farmer training programs and supports research efforts.

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Soil Health Institute

(www.soilhealthinstitute.org)

Independent and not-for-profit, the Soil Health Institute is a collaborative organization funded by the Noble Foundation and the Farm Foundation to “safeguard and enhance the vitality and productivity of soil through scientific research and advancement.” The Soil Health Institute prioritizes fundamental and applied research, and works with a diverse group of stakeholders that includes farmers and ranchers, scientists, and consumers, to move knowledge from the laboratory to the farm field.

Recent accomplishments include the launch of the Soil Health Landscape Tool (an open-source information portal on soil health) and an Action Plan On Soil Health which outlines future goals and priorities to advance soil health. The organization is currently developing an inventory and evaluating various soil health indicators and assessment protocols for quantifying soil health (Cornell’s soil health lab and CASH protocol are involved).

Soil Health Partnership

(<https://www.soilhealthpartnership.org/>)

This effort is led by the National Corn Growers Association and currently operates in 12 states of the Midwest. A major contribution has been soil health assessments (using Cornell’s CASH protocol), and aggregation of data from over 100 commercial corn-soybean farms in the region to evaluate costs and benefits of innovative soil management. Data sharing, education, and farmer-to-farmer training are hallmarks of this multi-year effort. Key partners include: Cornell and four other universities, The Nature Conservancy, Environmental Defense Fund, USDA-ARS, USDA-NRCS, and Monsanto.

US Climate Alliance

(www.usclimatealliance.org/nwlchallenge)

New York State is one of more than a dozen states and territories to join the U.S. Climate Alliance; a coalition committed to addressing climate change and adhering to the goals of the 2015 Paris Agreement, which aims to reduce greenhouse gas emissions by 26-28% below 2005 levels by 2025. The group’s Natural & Working Lands Initiative strives to increase carbon sequestration and storage across forests, farmland, rangeland, grasslands, wetlands, and urban lands, and partners with a wide range of NGOs to develop solutions and to spur action.

APPENDIX

ABBREVIATIONS USED

AEM: Agricultural Environmental Management framework
AFT: American Farmland Trust
CAFO: Concentrated Animal Feeding Operation
CALS: College of Agriculture and Life Sciences at Cornell University
CASH: Comprehensive Assessment of Soil Health
CCA: Certified Crop Advisor
CCE: Cornell Cooperative Extension
CIG: Conservation Innovation Grant
CNMP: Comprehensive Nutrient Management Plans
CWA: Clean Water Act
ECL: Environmental Conservation Law
EDF: Environmental Defense Fund
HAB: Harmful Algal Bloom
NE-SARE: Northeast Sustainable Agriculture Research and Education (a program of the United States Department of Agriculture)
NGO: non-governmental organization
NOFA-NY: Northeast Organic Farming Association, New York chapter
NOFA: Northeast Organic Farmers Association
NPK: Nitrogen, Phosphorus, Potassium; i.e a soil “NPK” test
NRCS: Natural Resources Conservation Service
NYFB: New York Farm Bureau
NYFVI: New York Farm Viability Institute
NYSABA: New York State Agribusiness Association
NYSDAM: New York State Department of Agriculture and Markets
NYSDEC: New York State Department of Environmental Conservation
NYSEPF: NYS Environment Protection Fund
NYSERDA: New York State Energy Research and Development Authority
NYSH: New York Soil Health
NYSSHWG: New York State Soil Health Working Group
PASA: Pennsylvania Association for Sustainable Agriculture
SARE: Sustainable Agriculture Research and Education
SHI: Soil Health Institute
SPDES: State Pollutant Discharge Elimination System
SUNY: State University of New York
SWCD: Soil and Water Conservation District
TNC: The Nature Conservancy
USDA-ARS: Agricultural Research Service (United States Department of Agriculture)
USDA-NRCS: United States Department of Agriculture Natural Resources Conservation Service
USDA: United States Department of Agriculture
WNYSHA: Western New York Soil Health Alliance



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