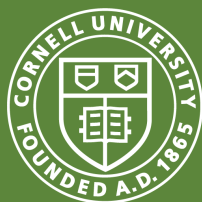




# Status of Soil Health on Long Island Farms



Cornell **CALS**  
College of Agriculture and Life Sciences

# Status of Soil Health on Long Island Farms

## Key Messages

- **Cropping system and soil texture impact the soil health status of Long Island farms.**
- **Mixed Vegetable, Pasture, and Perennial Fruit systems maintain the best overall soil health across soil type.**
- **The impact of sandier soils and a warmer climate supports the need for a regional characterization of soil health on Long Island.**
- **Management practices such as reduced tillage, cover cropping, and use of organic amendments can be utilized to build soil health levels.**

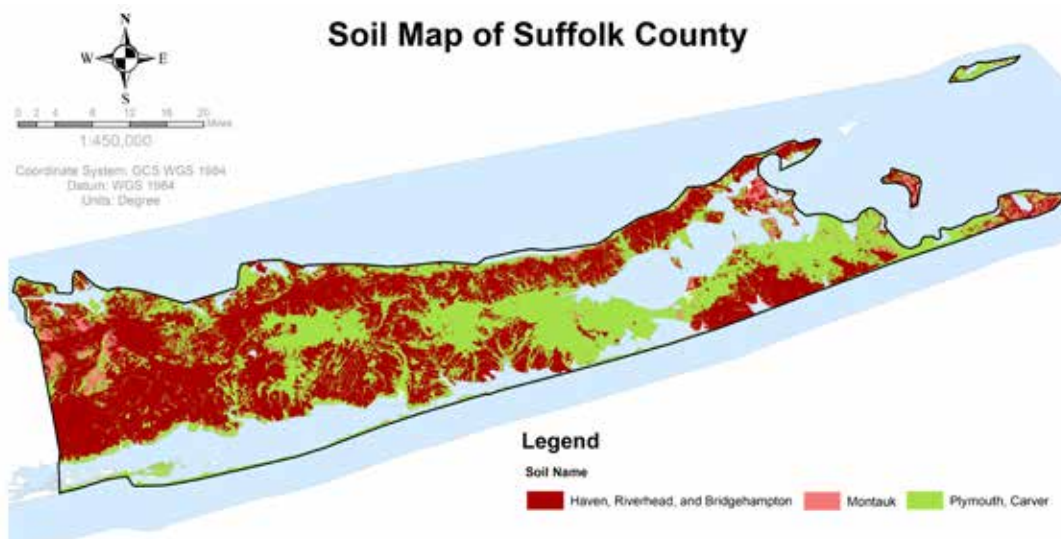
## Introduction

Interest in soil health concepts, practices, and testing has grown rapidly across the United States as farmers, researchers, and the general public increasingly *recognize* the central role of soils in food production, water quality, environmental sustainability, and climate adaptation and mitigation. Soil health, sometimes referred to as soil quality, or soil tilth, can be defined as “the capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans” (USDA-NRCS, 2020). Healthy soil is critical for the long-term productivity and sustainability of agricultural systems and is impacted by both natural and anthropogenic factors. Inherent soil properties, such as soil texture, are shaped by the five soil forming factors: parent material, climate, biology, topography, and time. Human activities have intensified in the last century and impact soil properties at a much faster rate than natural timescales. However, it is well known that farmers and land owners have a tremendous capacity to either degrade or improve the health of the soil through decisions related to the types of crops and animals they raise, and how they are managed.

The New York Soil Health Initiative published a report and a peer-reviewed paper (Amsili et al., 2020;

Amsili et al., 2021) that characterized soil health by soil type and cropping system across New York State (NYS). This work emphasized that both cropping system and soil texture shape soil health outcomes. A more recent analysis comparing soil health between Long Island with the rest of NYS highlighted the need for smaller regional scale analyses within the state so that farmers can compare their soil health to similar nearby production environments and meet more realistic aspirational soil health goals (Amsili et al., 2022). Such characterizations are especially important for regions of New York that have very distinct production environments (i.e., soils, climate, and cropping systems), which is the case for Long Island. This report is the first regional characterization effort and documents our current knowledge of soil health on farmland in Suffolk County, Long Island.

Suffolk County, the eastern two-thirds of Long Island, is home to over 550 farms that are integral to the region’s identity and agritourism based economy. Most of the remaining commercial agricultural production occurs on the East End, within the towns of Riverhead, Southampton, Southold, Shelter Island, and East Hampton. This region hosts a great diversity of agriculture



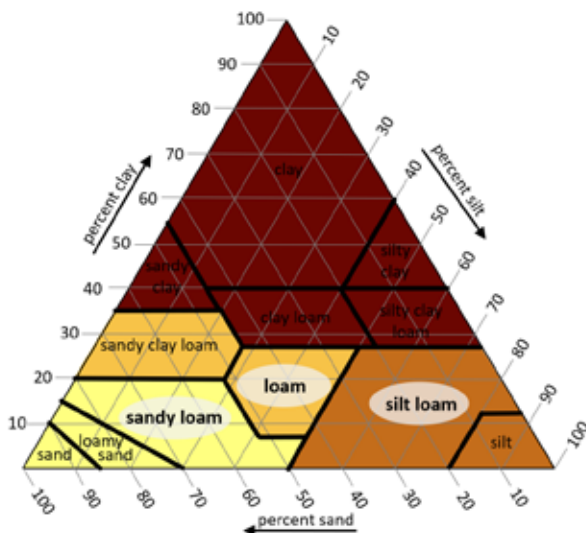
**Figure 1.** Map of taxonomic subgroups and their associated soil series in Suffolk County.

and remains the state's top producer of nursery crops, certain vegetable crops (pumpkins and tomatoes), and perennial fruits (grapes and peaches). There are also many small-scale diversified vegetable farms that largely grow fresh market vegetables and several pastured livestock operations. The high value of land, warmer climate, and higher proportion of coarse-textured soils (high sand and low clay contents) create much different conditions for agricultural production compared to the rest of NYS. These soils developed from sorted sand and gravel glacial outwash parent materials that are characteristic of the southern edge of the Pleistocene glaciers and are deep well-draining soils ideal for crop production, indicated by the Plymouth and Carver soil series (Figure 1; Warner et al. 1975). However, they also show more susceptibility to nutrient and pesticide leaching, low organic matter content, and poor structure. As a result, inputs from agriculture, nutrients and pesticides, as well as other sectors (commercial, residential, and industrial), have contributed to the adverse impacts on the surface and ground waters of the region (Zaki et al., 1982; Gobler et al., 2012; Fisher et al., 2021). Further, warming temperatures, increased saltwater intrusion, and more extreme and variable weather patterns are already impacting agricultural production in Suffolk County. Identifying and implementing practices that improve soil health on farms is critical for protecting the environment, increasing the resiliency of farms to climate-related risks, and maintaining an economically viable agriculture industry on Long Island.

## Methods

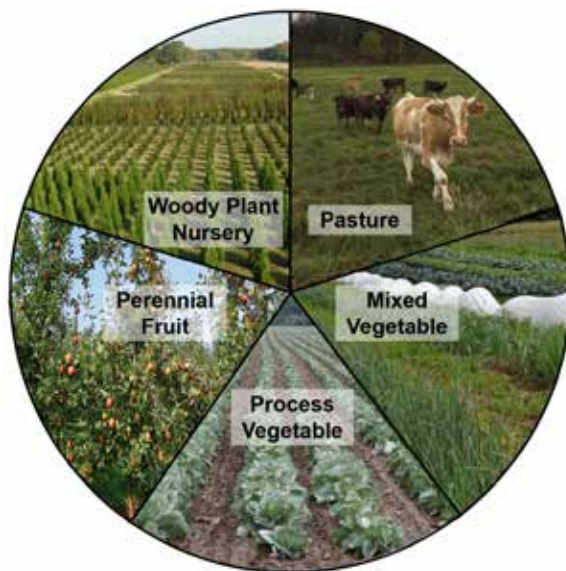
This report summarizes results from 304 soil samples collected from commercial farms across Suffolk County between 2014-2021. Some were collected as part of the soil health testing program initiated in 2018 by the Cornell Cooperative Extension of Suffolk County - Agricultural Stewardship Program and the Suffolk County Soil and Water Conservation District.

All soil samples were analyzed using the standard Comprehensive Assessment of Soil Health (CASH) package at the Cornell Soil Health Laboratory, which includes soil texture, four biological indicators, four physical indicators, and seven chemical indicators. It also identifies specific soil health constraints and provides both short- and long- term management recommendations. Detailed information on methods used are provided in the appendix section and available online in the Cornell Soil Health Manual (Moebius-Clune et al., 2016). The soil samples were assumed to have been collected following specific sampling guidelines, which involve the collection of at least five soil slices (0–6-inch depth) using a spade from different locations in a field to create a single representative composite sample. Soils collected encompassed a variety of soil types, cropping systems, and management practices as described below. Lawn, garden, and landscape samples were removed from the analysis to focus on agricultural soils. Samples were also removed if GPS coordinates were not available. The samples were approximately evenly split among sandy loam, loam, and silt loam texture



Texture Class	n	Sand %	Silt %	Clay %
Sandy loam	115	59.2 (7.8)	32.7 (8.3)	8.2 (2.4)
Loam	78	45.1 (3.9)	44.2 (3.3)	10.7 (2.4)
Silt loam	111	31.6 (5.9)	56.9 (5.3)	11.6 (2.7)

**Figure 2.** Soil texture triangle with the three main texture classes (sandy loam, loam, silt loam) analyzed in Suffolk County. Mean (StdDev) for percent of sand, silt, and clay in each texture class.



Cropping System	n	Crop Codes*
Processing Vegetables	42	PUM, POT, TOM, SWC, SQW, CBP
Mixed Vegetables	98	MIX
Perennial Fruit	69	APP, GPV, PCH, GPF, BLB, HPT
Pasture	35	PIT, PNT, GRT, PGT, PLE, PIE
Woody Plant Nursery	60	SAG, TRE, ALG

\*Crop codes with less than 2 samples were removed from this table.

**Figure 3.** The five cropping systems analyzed in Suffolk County (n=304).

classes (Figure 2; Table A1). The effect of cropping system was analyzed within each texture class to account for the inherent influence of soil texture on a soil’s ability to hold water, carbon, and nutrients.

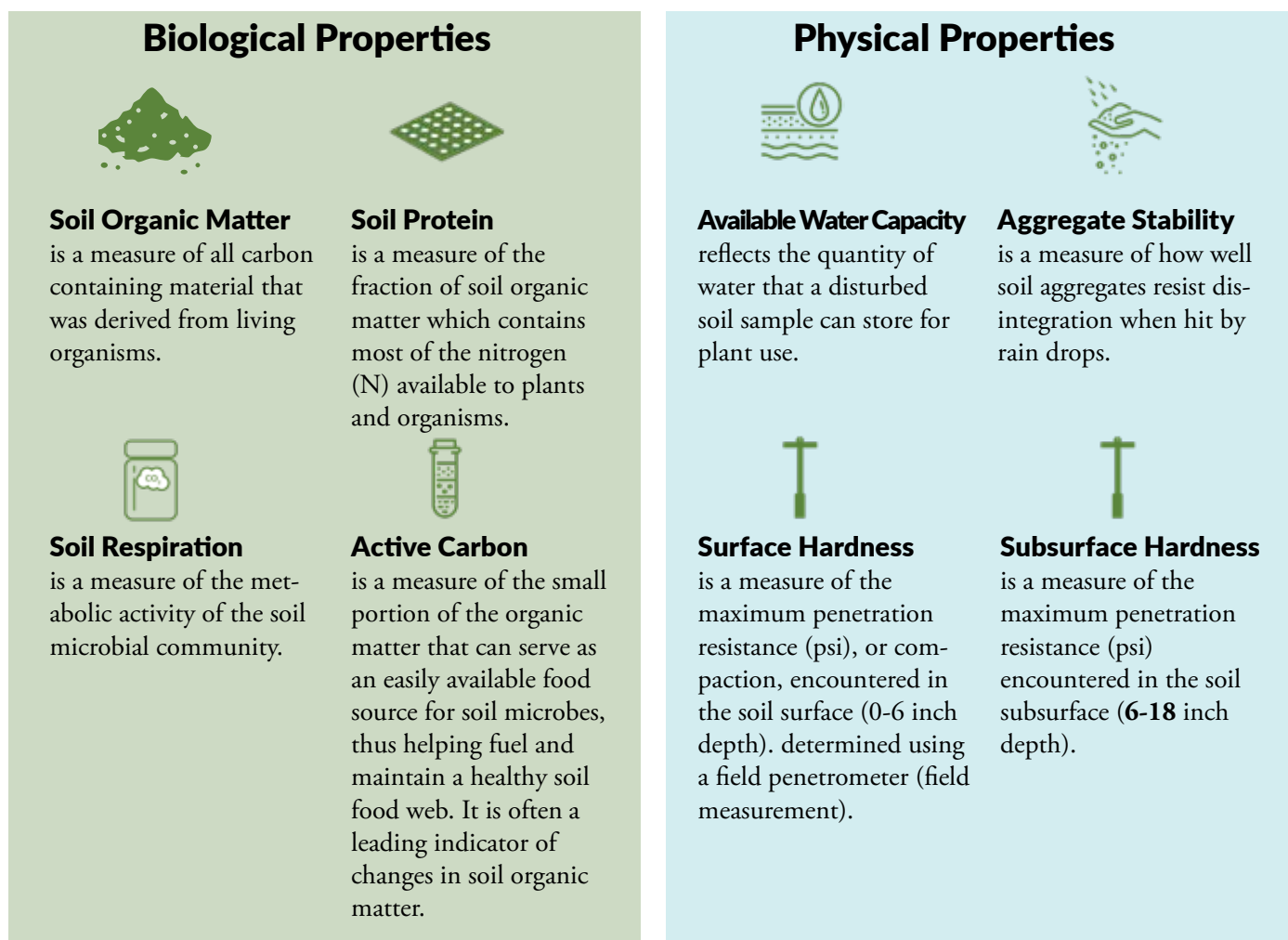
Five cropping system categories were constructed by grouping similar crops (Figure 3; Table A2-A3). The Processing Vegetable category grouped fields where crops such as pumpkins, potatoes, tomatoes, sweet corn, winter squash, and cabbage were grown. The Mixed Vegetable category consisted of fields where several different vegetable crops were grown in the same field in a single season and sold as fresh market produce at farm stands, farmers markets, or through community

supported agriculture shares. This category also tended to represent smaller (approximately 1-10 acres in size) and more diversified farms than those within the more specialized Processing Vegetable category. The Perennial Fruit category grouped all tree fruit orchards (apples, peaches, cherries, etc.), vineyards, small fruits (blueberries and brambles), and hopyards. Pastures included livestock operations with perennial forage crops and fields that had multiple years of permanent grass cover. Woody Plant Nursery included all operations producing field-grown ornamental horticulture crops (oak trees, California privet, boxwood, holly, Christmas trees, etc.).

Six soil health indicators, four biological and two physical indicators, are the focus of this report: soil organic matter, soil protein, active carbon, respiration, available water capacity, and aggregate stability (Figure 4). Surface and subsurface hardness (two physical indicators) and soil chemical properties are presented in the appendix. **Soil organic matter (SOM)** is a measure of all carbon containing material that was originally derived from living organisms (plant residues, microbes, etc.). SOM is important for soil functions including water and nutrient retention, energy storage for microorganisms, and carbon sequestration. Both the quality and quantity of SOM are important in soils and directly connected to soil texture with fine textured soils holding more organic matter than coarse textured soils. **Soil protein** is a measure of the fraction of SOM which contains most of the organic nitrogen in the soil. Microbes can then mineralize those soil proteins into plant available forms of nitrogen. **Active carbon** is a measure of the small fraction of the SOM that is an easily available

food source for soil microbes. **Soil respiration** is a measure of the metabolic activity of the soil microbial community, indicating both microbial abundance and metabolic activity. **Available water capacity** is the amount of water a soil can hold and make available for plant use. **Aggregate stability** is a measure of how well soil aggregates (group of soil particles) resist falling apart when wetted and hit by rain drops. It is important for soil processes including aeration, infiltration, surface crusting, erosion, and runoff.

The data were analyzed using ANOVA with soil texture or cropping system as fixed effects to assess differences in the biological, physical, and chemical soil parameters. Multiple comparisons were made using a Tukey adjustment at  $\alpha=0.05$ . A variance component analysis was used to evaluate how well soil texture and cropping system factors explained variance in the different indicators. All statistical analyses were run using the R statistical software (R Core Team, 2022).



**Figure 4.** The biological and physical indicators used in the soil health analyses on Long Island.

## Results

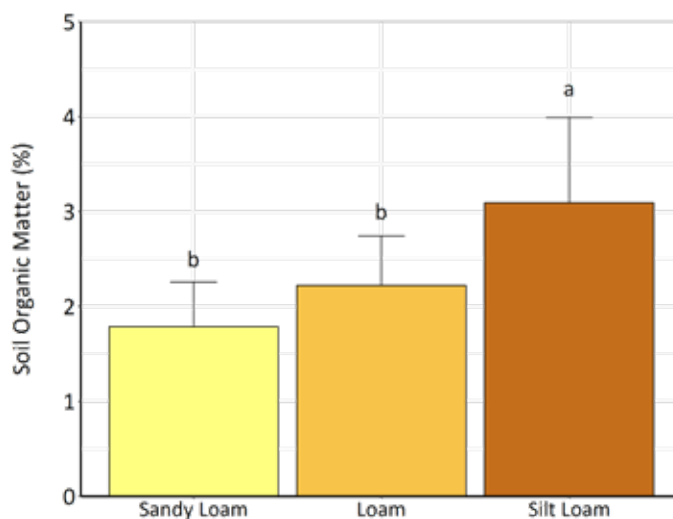
Inherent soil properties exert a strong control on the amount of storable carbon and nutrients, pH, water holding capacity, drainage, and more in a soil. Information about these inherent properties across virtually the entire United States is available through the USDA-NRCS Web Soil Survey, SoilWeb, or county level Soil Survey Reports (e.g., Soil Survey of Suffolk County, 1975). In agriculture and many other environments, however, human activities have increasingly become a force of change on the landscape. Tillage and crop rotations, as well as carbon and nutrient flows through erosion, organic amendments and crop harvesting choices have dramatically altered the biological, physical, and chemical characteristics of the soil which are superimposed onto the inherent soil properties. In this analysis, we examined the effects of soil texture and cropping system on various soil health properties.

### *Effect of soil texture on soil health indicators*

Soil texture is a dominant inherent soil property that has a significant influence on a soil's ability to retain organic matter and plant available water (soil functions). Suffolk County's soils tend to have coarser textures than soils from the rest of NYS. Specifically, the majority of agricultural soils from Suffolk County had clay contents only up to 15%, whereas soils from the rest of NYS commonly have clay content between 15-30% or more. Specifically, loam and silt loam texture classes on Long Island had 5% less clay on average than those textures from the rest of NYS.

Similar to the statewide report, we found that texture controlled the inherent amount of OM that a soil can hold. This is because soils high in silt and clay particles (fine-textured) can hold more OM than sandy (coarse-textured) soils due to the larger amount of mineral surface area that can bind with organic molecules. For both Processing Vegetables and Pastures systems that don't receive many external OM inputs, there was a clear increasing trend in SOM across sandy loam, loam, and silt loam texture classes (Figure 5). This trend was not observed in Mixed Vegetable and Perennial Fruit systems, presumably due to the high amount of variability in the amount of external OM inputs that may be applied in these systems (i.e., compost or woodchips).

The variance component analysis showed how much the biological and physical soil health indicators were affected by either soil texture or cropping system (Table A4). The analysis revealed that available water capacity was mostly impacted by soil texture whereas cropping system explained more of the variance for active carbon, respiration, and aggregate stability. Field-to-field factors were significant as a larger percentage of the variance remained unexplained. A larger dataset, more nuanced classification of cropping systems, or additional management information like OM inputs may likely have led to less unexplained variance.

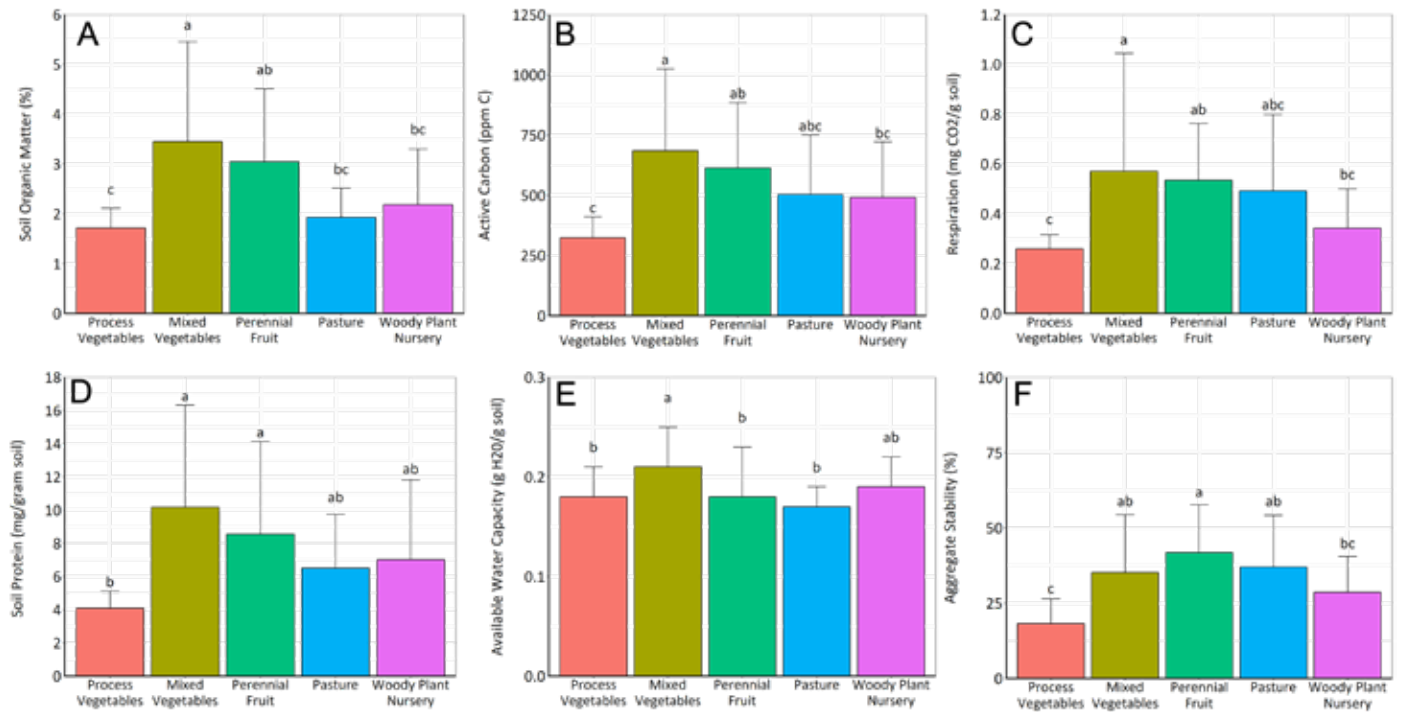


**Figure 5.** Mean soil organic matter across soil texture classes in Processing Vegetable and Pasture Cropping systems. Sandy loam (n=36), Loam (n=13), Silt loam (n=28).

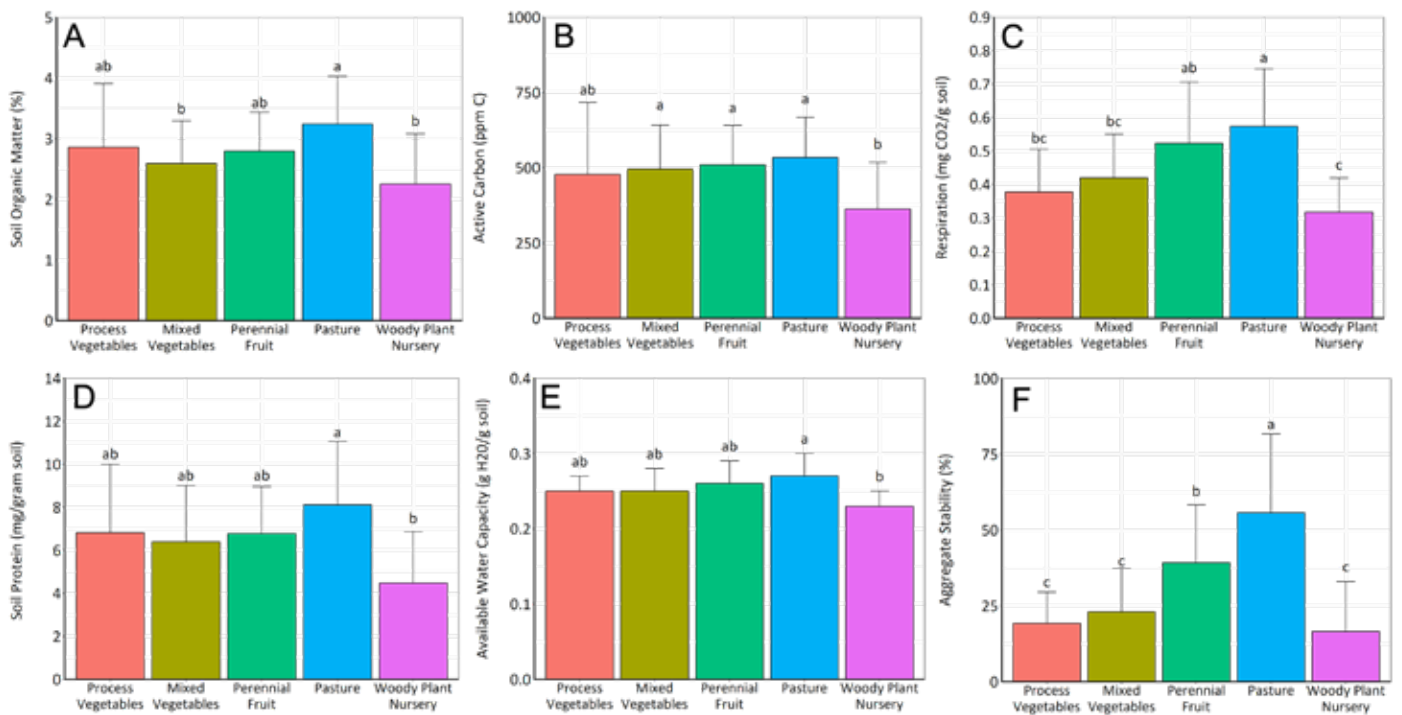
### *Effect of cropping system on soil health indicators*

#### *Biological Soil Health*

Cropping systems strongly impact the quantity and quality of SOM, which were assessed using the four biological soil health indicators (Figure 6-7, Table A7). Differences were most pronounced among cropping systems in sandy loam soils. Mixed Vegetable and Perennial Fruit systems tended to have the highest values across all biological indicators, especially compared to Processing Vegetables (Figure 6; Table A7). The higher values in the Mixed Vegetable systems are likely related to these fields often being managed organically with significant annual OM inputs through compost or intensive cover cropping. Pasture systems tended to fall in the middle in terms of soil health indicators in sandy loam and loam textured soils. But they had the



**Figure 6.** Mean soil organic matter (%) (A), active carbon (ppm C) (B), respiration (mg CO<sub>2</sub>/g soil) (C), soil protein (mg/g soil) (D), available water capacity (g H<sub>2</sub>O/g soil) (E), and aggregate stability (%) (F) across five cropping systems on sandy loam textured soils.



**Figure 7.** Mean soil organic matter (%) (A), active carbon (ppm C) (B), respiration (mg CO<sub>2</sub>/g soil) (C), soil protein (mg/g soil) (D), available water capacity (g H<sub>2</sub>O/g soil) (E), and aggregate stability (%) (F) across five cropping systems on silt loam textured soils.

highest values in silt loam soils, which is consistent with the findings from the larger statewide analysis and the fact that pastures are rarely disturbed by tillage and receive year-round organic inputs. However, while all pasture systems had perennial cover, not all operations categorized here had large ruminants on the field and therefore lacked high manure applications which may have contributed to lower biological indicator values in the coarser textured soils.

Processing Vegetable systems were detrimental to soil biology in sandy loam soils but not in silt loam soils, which may indicate that coarser textured soils are more sensitive to reduced OM inputs than medium textured soils. Perennial Fruit systems had high levels of respiration across soil types which may be attributed to the undisturbed soil habitat within these systems and in some cases the addition of woodchips to add OM, provide weed control, and protect the soil surface from erosion. Woody Plant Nurseries tended to have lower values for the biological indicators (although variable) and may be attributed to the crop type and age, and thus current field management practices, when the samples were collected. Management practices at Woody Plant Nurseries vary widely depending on the crop type and age. During field preparation tillage and herbicide applications are frequent to obtain a clean planting bed. But subsequent interseeding between the planted rows with cover crops is becoming more common to help reduce erosion, increase OM, and improve nutrient management.

#### *Physical Soil Health*

Cropping system impacted available water capacity and aggregate stability in the sandy loam and silt loam soil textural groups. Aggregate stability tended to be lowest in Processing Vegetable systems across all soil textures. This may be attributed to the typical uses of intensive tillage for field preparation and weed control, short-duration crops, and low crop residue returns. Conversely, aggregate stability was highest in Perennial Fruit and Pasture systems where plants live year-around to build and stabilize soil aggregates, and also cycle more organic plant residues.

Cropping systems that maintain higher % SOM levels can positively affect available water capacity, but this effect is variable and typically stronger in coarser textured

soils (where it is also more impactful due to drought sensitivity) than other texture groups. Subsurface soil compaction was not affected by cropping system and few differences were observed in surface compaction. However, this is difficult to interpret since samples are taken in the field and subjective to the individual collecting the data and current soil moisture conditions.

#### ***Soil health benchmarking and production environment soil health goals***

The regional soil health characterization for Suffolk County builds a robust foundation for interpreting soil health parameters and setting soil health goals that are appropriate for Long Island's unique production environment (soils, climate, and cropping systems). Suffolk County's generally coarser textured soils and warmer climate are important factors that likely contribute to lower inherent ability for soils to retain OM against decomposition. A recent analysis corroborated this hypothesis by showing that Long Island soils had on average 0.8% lower SOM concentrations compared to the rest of NYS (Table A9; Figure A1). Therefore, soil health benchmarking and production environment soil health goals must reflect these different conditions. Figure 8 illustrates how a field (Field X) on a small Mixed Vegetable Farm compares to the average Mixed Vegetable and Processing Vegetable farms in Suffolk County for the indicators of SOM and aggregate stability. This figure illustrates that farms have the potential to reach a high value if certain management practices are implemented, which in many cases is influenced by the size (acres) of the operation and the feasibility of particular practices being employed (e.g., equipment availability and labor constraints).



**Comprehensive Assessment of Soil Health**

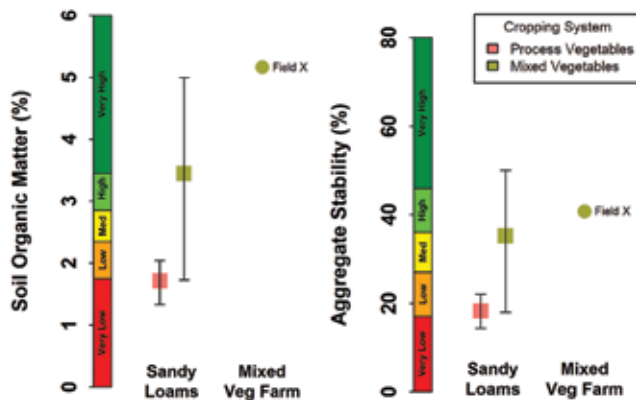
From the Cornell Soil Health Laboratory, Department of Soil and Crop Sciences, School of Integrative Plant Science, Cornell University, Ithaca, NY 14853. <http://soilhealth.cals.cornell.edu>

Measured Soil Textural Class: **sandy loam**  
Sand: **65%** - Silt: **23%** - Clay: **10%**

**Field X-Mixed Veg**

Group	Indicator	Value	Rating	Constraints
physical	Predicted Available Water Capacity	0.23	91	
physical	Surface Hardness	118	70	
physical	Subsurface Hardness	281	56	
physical	Aggregate Stability	40.7	70	
biological	Organic Matter Total Carbon: 3.67 / Total Nitrogen: 0.28	5.2	99	
biological	ACE Soil Protein Index	16.9	99	
biological	Soil Respiration	0.7	64	
biological	Active Carbon	986	99	
chemical	Soil pH	6.8	100	
chemical	Extractable Phosphorus	14.7	100	
chemical	Extractable Potassium	43.6	65	
chemical	Minor Elements Mg: 78.3 / Fe: 1.0 / Mn: 4.1 / Zn: 1.5		100	

Overall Quality Score: **84 / Very High**



**Figure 8.** From CASH report to soil health benchmarking figures for a Mixed Vegetable farm in Suffolk County for both soil organic matter and aggregate stability. Cropping system values are the mean and the lower and upper whiskers represent the 25th and 75th percentile for the sandy loam soil texture class.

### Conclusions

This Long Island regional analysis reinforces the findings from the statewide analysis that soil texture and cropping system are dominant factors contributing to the overall soil health on farms. The different agricultural management practices associated with the various cropping systems analyzed overall had a large impact on soil

health status. These differences often reflect important differences in total carbon and nutrient balances (e.g., perennial vs. annual systems, cover crops, and organic amendments) and the degree of disturbance from tillage. Mixed Vegetable, Pasture, and Perennial Fruit systems maintained the best overall soil health. In the case of Mixed Vegetable systems (often organically grown), this is likely because of the utilization of various soil amendments such as compost to supplement fertility and build OM, crop rotations, diversity of crops grown and residues returned, and a high degree of cover cropping. Pasture and Perennial Fruit systems are largely undisturbed and have year-round living vegetation. Pasture systems receive continuous root and shoot inputs, and some Perennial Fruit systems additionally receive wood-chip mulch. This permanent cover further protects the soil from losses due to wind and water erosion.

In contrast to Mixed Vegetable systems, Processing Vegetables are more intensively managed, and although they often practice cover cropping, they typically don't receive sufficient organic inputs to replace the OM that is lost annually from tillage and other management activities. Typically, 40-80% of the carbon and nutrients in the aboveground biomass are exported off the farm as crop harvests, which must to be counterbalanced with soil management practices like cover cropping and organic amendment application to maintain and build soil health. The impact of Woody Plant Nurseries on soil health were more variable, which may be linked to the diversity of crop species, size, and age grown on farms.

Regardless of cropping system and soil texture, certain management practices are known to promote improvements in soil health. These include implementing no-till or conservation tillage, cover cropping, utilizing crop rotations, perennial vs. annual crops, keeping crop residues on fields, practicing integrated pest management, using organic-based fertilizer such as manures and compost, and substituting herbicides for mulching or other cultural practices for weed control. While every farm is different and management practices vary, incorporating as many of these practices as possible will build greater soil health over time.

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## Appendix

Available water capacity (AWC) is a measure of the amount of plant available water a soil can store. AWC is measured as the difference between water content at field capacity and water content at the permanent wilting point. Saturated soil subsamples were equilibrated to pressures of -10 kPa (field capacity) and -1500 kPa (permanent wilting point) on porous ceramic pressure plates in pressure chambers (Soil Moisture Equipment Corp., Goleta, CA).

Additionally, the lab recommends that surface (0-6 in) and subsurface (6-18 in) penetrometer measurements are taken at the time of soil sampling to assess compaction in the field. Surface soil compaction limits infiltration, rooting, and proliferation of soil organisms, which can lead to increased runoff, erosion, and poor water storage, while subsurface compaction leads to poor drainage, aeration, and deep rooting. Research has indicated that most plant roots cannot readily penetrate soil with penetrometer readings above 300 psi.

### *Chemical Soil Health Indicators*

Seven chemical measurements, including soil pH and Modified Morgan Extractable phosphorus (P), potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), and zinc (Zn) are measured in the soil health test. Soil pH was measured in a 1:2 soil:water slurry. Modified Morgan Extractable nutrients were extracted with a Modified Morgan solution (ammonium acetate plus acetic acid, pH 4.8) and then run using inductively coupled plasma optical emission spectrometry (SPECTRO Analytical Instruments Inc., Mahwah, NJ). All nutrient contents were reported in units of mg kg<sup>-1</sup> soil (ppm). Soil chemical properties such as pH and major macronutrients (P and K) have been thoroughly studied across NYS and robust interpretations exist for most crops. A total heavy metal screening is available as an add-on to the standard assessment if heavy metals are thought to be a concern (especially in urban environments).

### **New York State Soil Health Dataset Background Information Tables**

**Table A1.** The number and percentage of total samples belonging to different soil taxonomic subgroups and their associated soil series in each soil texture class.

<b>Sandy loam</b>			
<b>Soil Subgroup</b>	<b>Associated soil series</b>	<b>n</b>	<b>% Total</b>
<b>Oxyaquic Dystrudepts</b>	Montauk	6	5
<b>Typic Dystrudepts</b>	Haven, Riverhead, Bridgehampton	85	74
<b>Typic Quartzipsamments</b>	Plymouth, Carver	24	21
<b>Loam</b>			
<b>Soil Subgroup</b>	<b>Associated soil series</b>	<b>n</b>	<b>% Total</b>
<b>Oxyaquic Dystrudepts</b>	Montauk	2	3
<b>Typic Dystrudepts</b>	Haven, Riverhead, Bridgehampton	63	81
<b>Typic Quartzipsamments</b>	Plymouth, Carver	13	17
<b>Silt Loam</b>			
<b>Soil Subgroup</b>	<b>Associated soil series</b>	<b>n</b>	<b>% Total</b>
<b>Oxyaquic Dystrudepts</b>	Montauk	7	6
<b>Typic Dystrudepts</b>	Haven, Riverhead, Bridgehampton	101	91
<b>Typic Quartzipsamments</b>	Plymouth, Carver	3	3

## Appendix

**Table A2.** Mean (StdDev) for the percent of sand, silt, and clay in each cropping system by soil texture class.

<b>Sandy Loam</b>				
<b>Cropping System</b>	<b>n</b>	<b>Sand %</b>	<b>Silt %</b>	<b>Clay %</b>
Processing Vegetables	24	54.3 (8.8)	38.1 (9.0)	7.6 (1.5)
Mixed Vegetables	36	59.3 (7.1)	33.0 (7.9)	7.7 (2.5)
Perennial Fruit	18	62.3 (6.4)	28.3 (6.3)	9.4 (2.1)
Pasture	12	66.0 (6.3)	26.2 (7.0)	7.8 (3.1)
Woody Plant Nursery	25	58.0 (6.2)	33.4 (6.3)	8.6 (2.6)
<b>Loam</b>				
<b>Cropping System</b>	<b>n</b>	<b>Sand %</b>	<b>Silt %</b>	<b>Clay %</b>
Processing Vegetables	7	46.3 (3.7)	44.4 (3.4)	9.3 (1.7)
Mixed Vegetables	24	45.2 (2.8)	44.9 (3.6)	9.9 (1.9)
Perennial Fruit	24	43.3 (5.0)	44.7 (3.0)	12.0 (3.2)
Pasture	6	47.0 (3.5)	41.9 (4.0)	11.1 (2.8)
Woody Plant Nursery	17	46.3 (3.0)	43.4 (2.7)	10.4 (1.0)
<b>Silt Loam</b>				
<b>Cropping System</b>	<b>n</b>	<b>Sand %</b>	<b>Silt %</b>	<b>Clay %</b>
Processing Vegetables	11	30.0 (6.5)	58.8 (5.6)	11.2 (3.3)
Mixed Vegetables	38	32.5 (7.2)	56.7 (5.7)	10.8 (2.5)
Perennial Fruit	27	30.3 (4.7)	56.9 (5.0)	12.8 (2.1)
Pasture	17	30.0 (4.7)	58.8 (4.5)	11.1 (3.7)
Woody Plant Nursery	18	34.1 (4.7)	54.0 (4.6)	12.0 (1.8)
<b>All</b>				
<b>Cropping System</b>	<b>n</b>	<b>Sand %</b>	<b>Silt %</b>	<b>Clay %</b>
Processing Vegetables	42	46.6 (12.9)	44.5 (11.6)	8.8 (2.6)
Mixed Vegetables	98	45.4 (13.3)	45.1 (12.1)	9.5 (2.7)
Perennial Fruit	69	43.2 (13.8)	45.2 (12.4)	11.6 (2.9)
Pasture	35	45.3 (17.1)	44.7 (15.8)	10.0 (3.6)
Woody Plant Nursery	60	47.5 (11.2)	42.4 (10.0)	10.1 (2.5)

## Appendix

**Table A3.** The number and percentage of total samples belonging to different soil taxonomic subgroups and their associated soil series in each cropping system.

<b>Processing Vegetables</b>			
<b>Soil Subgroup</b>	<b>Associated soil series</b>	<b>n</b>	<b>% Total</b>
<b>Typic Dystrudepts</b>	Haven, Riverhead, Bridgehampton	33	79
<b>Typic Quartzipsamments</b>	Plymouth, Carver	9	21
<b>Mixed Vegetables</b>			
<b>Soil Subgroup</b>	<b>Associated soil series</b>	<b>n</b>	<b>% Total</b>
<b>Oxyaquic Dystrudepts</b>	Montauk	12	12
<b>Typic Dystrudepts</b>	Haven, Riverhead, Bridgehampton	83	85
<b>Typic Quartzipsamments</b>	Plymouth, Carver	3	3
<b>Perennial Fruit</b>			
<b>Soil Subgroup</b>	<b>Associated soil series</b>	<b>n</b>	<b>% Total</b>
<b>Oxyaquic Dystrudepts</b>	Montauk	1	1
<b>Typic Dystrudepts</b>	Haven, Riverhead, Bridgehampton	62	90
<b>Typic Quartzipsamments</b>	Plymouth, Carver	6	9
<b>Pasture</b>			
<b>Soil Subgroup</b>	<b>Associated soil series</b>	<b>n</b>	<b>% Total</b>
<b>Oxyaquic Dystrudepts</b>	Montauk	2	6
<b>Typic Dystrudepts</b>	Haven, Riverhead, Bridgehampton	24	69
<b>Typic Quartzipsamments</b>	Plymouth, Carver	9	26
<b>Woody Plant Nursery</b>			
<b>Soil Subgroup</b>	<b>Associated soil series</b>	<b>n</b>	<b>% Total</b>
<b>Typic Dystrudepts</b>	Haven, Riverhead, Bridgehampton	47	78
<b>Typic Quartzipsamments</b>	Plymouth, Carver	13	22

**Table A4.** Variance components analysis percentages for eight soil health indicators.

<b>Variance Components</b>	<b>SOM</b>	<b>ActC</b>	<b>Protein</b>	<b>Resp</b>	<b>AgStab</b>	<b>AWC</b>	<b>Surface H</b>	<b>Subsurface H</b>
	%	%	%	%	%	%	%	%
<b>Texture</b>	0	0.6	1.2	0	0	47	0	0.5
<b>Cropping System</b>	2	11	6	13.5	20	2	8	3.6
<b>Texture x System</b>	16	8	10	3.5	10	6	4	0.8
<b>Unexplained</b>	82	80	83	83	70	45	88	95

# Appendix

## Biological Soil Health Indicators

For the first time, we had a dataset with complete observations of soil taxonomic information (soil type), but due to an uneven sample size across soil types and instances where the soil type and cropping system effects could not be separated, we weren't able to conclude anything about the inherent effects of soil type on soil health parameters. For example, soils with poorer inherent soil quality such as the Montauk soil that is more poorly drained than other soil types, tend to only have Mixed Vegetable or Pasture systems located on them since they would not be economical for Processing Vegetables, Perennial Fruits, or Woody Plant Nurseries to be located on.

**Table A5.** Mean values of biological soil health indicators (1 standard deviation in parentheses) by soil type and associated soil names (series).

Soil Subgroup	Associated soil series	n	SOM %	ActC mg kg <sup>-1</sup>	Protein mg g <sup>-1</sup>	Resp mg CO <sub>2</sub> g <sup>-1</sup> 4 days <sup>-1</sup>
<b>Oxyaquic Dystrudepts</b>	Montauk	15	4.4 (1.9)	807 (310)	12.9 (6.1)	0.84 (0.60)
<b>Typic Dystrudepts</b>	Haven, Riverhead, Bridgehampton	249	2.5 (1.0)	478 (198)	6.4 (3.3)	0.40 (0.17)
<b>Typic Quartzipsamments</b>	Plymouth, Carver	40	2.4 (1.2)	489 (254)	6.4 (4.5)	0.43 (0.24)

## Appendix

**Table A6.** Mean values of biological soil health indicators (1 standard deviation in parentheses) by cropping system and soil texture. Mean values followed by superscripted letters are significantly different at the 0.05 error level and no letters indicate no significant differences.

<b>Sandy Loam</b>					
<b>Cropping System</b>	<b>n</b>	<b>SOM</b> %	<b>ActC</b> mg kg <sup>-1</sup>	<b>Protein</b> mg g <sup>-1</sup>	<b>Resp</b> mg CO <sub>2</sub> g <sup>-1</sup> 4 days <sup>-1</sup>
<b>Processing Vegetables</b>	24	1.7 <sup>c</sup> (0.4)	324 <sup>c</sup> (87)	4.1 <sup>b</sup> (1.0)	0.26 <sup>c</sup> (0.06)
<b>Mixed Vegetables</b>	36	3.4 <sup>a</sup> (2.0)	685 <sup>a</sup> (340)	10.2 <sup>a</sup> (6.1)	0.57 <sup>a</sup> (0.47)
<b>Perennial Fruit</b>	18	3.0 <sup>ab</sup> (1.5)	614 <sup>ab</sup> (271)	8.5 <sup>a</sup> (5.6)	0.53 <sup>ab</sup> (0.23)
<b>Pasture</b>	12	1.9 <sup>bc</sup> (0.6)	504 <sup>abc</sup> (247)	6.5 <sup>ab</sup> (3.2)	0.49 <sup>abc</sup> (0.31)
<b>Woody Plant Nursery</b>	25	2.2 <sup>bc</sup> (1.1)	492 <sup>bc</sup> (230)	7.0 <sup>ab</sup> (4.8)	0.34 <sup>bc</sup> (0.16)
<b>All</b>	115	2.6 (1.5)	538 (288)	7.6 (5.2)	0.44 (0.33)
<b>Loam</b>					
<b>Cropping System</b>	<b>n</b>	<b>SOM</b> %	<b>ActC</b> mg kg <sup>-1</sup>	<b>Protein</b> mg g <sup>-1</sup>	<b>Resp</b> mg CO <sub>2</sub> g <sup>-1</sup> 4 days <sup>-1</sup>
<b>Processing Vegetables</b>	7	2.3 (0.3)	392 <sup>b</sup> (109)	5.4 (1.0)	0.31 <sup>b</sup> (0.07)
<b>Mixed Vegetables</b>	24	2.6 (0.9)	562 <sup>a</sup> (244)	6.7 (3.8)	0.40 <sup>ab</sup> (0.12)
<b>Perennial Fruit</b>	24	2.3 (0.7)	431 <sup>ab</sup> (133)	6.3 (2.6)	0.45 <sup>a</sup> (0.16)
<b>Pasture</b>	6	2.1 (0.7)	372 <sup>b</sup> (59)	4.6 (1.3)	0.37 <sup>ab</sup> (0.06)
<b>Woody Plant Nursery</b>	17	2.1 (0.4)	391 <sup>b</sup> (91)	4.8 (1.2)	0.32 <sup>b</sup> (0.07)
<b>All</b>	78	2.3 (0.7)	454 (177)	5.9 (2.7)	0.39 (0.13)
<b>Silt Loam</b>					
<b>Cropping System</b>	<b>n</b>	<b>SOM</b> %	<b>ActC</b> mg kg <sup>-1</sup>	<b>Protein</b> mg g <sup>-1</sup>	<b>Resp</b> mg CO <sub>2</sub> g <sup>-1</sup> 4 days <sup>-1</sup>
<b>Processing Vegetables</b>	11	2.9 <sup>ab</sup> (1.0)	477 <sup>ab</sup> (239)	6.8 <sup>ab</sup> (3.2)	0.38 <sup>bc</sup> (0.13)
<b>Mixed Vegetables</b>	38	2.6 <sup>b</sup> (0.7)	496 <sup>a</sup> (146)	6.4 <sup>ab</sup> (2.6)	0.42 <sup>bc</sup> (0.13)
<b>Perennial Fruit</b>	27	2.8 <sup>ab</sup> (0.6)	510 <sup>a</sup> (131)	6.8 <sup>ab</sup> (2.2)	0.52 <sup>ab</sup> (0.18)
<b>Pasture</b>	17	3.2 <sup>a</sup> (0.8)	534 <sup>a</sup> (133)	8.1 <sup>a</sup> (3.0)	0.57 <sup>a</sup> (0.17)
<b>Woody Plant Nursery</b>	18	2.2 <sup>b</sup> (0.8)	362 <sup>b</sup> (156)	4.5 <sup>b</sup> (2.4)	0.32 <sup>c</sup> (0.10)
<b>All</b>	111	2.7 (0.8)	482 (160)	6.5 (2.8)	0.45 (0.17)

# Appendix

## Physical Soil Health Indicators

**Table A7.** Mean physical soil health indicators (1 standard deviation in parentheses) by cropping system and soil textures. Mean values followed by superscripted letters are significantly different at the 0.05 error level and no letters indicate no significant differences. Note that surface and subsurface hardness measurements have slightly smaller samples sizes than AgStab and AWC.

Sandy Loam						
Cropping System	n	AgStab %	AWC g H <sub>2</sub> O g <sup>-1</sup> soil	n	Surface H psi	Subsurface H psi
Processing Vegetables	24	18.2 <sup>c</sup> (8.2)	0.18 <sup>b</sup> (0.03)	23	180 <sup>ab</sup> (65)	265 (40)
Mixed Vegetables	36	35.2 <sup>ab</sup> (19.2)	0.21 <sup>a</sup> (0.04)	34	184 <sup>a</sup> (41)	287 (41)
Perennial Fruit	18	41.8 <sup>a</sup> (15.9)	0.18 <sup>b</sup> (0.05)	17	179 <sup>ab</sup> (77)	274 (67)
Pasture	12	37.1 <sup>ab</sup> (17.1)	0.17 <sup>b</sup> (0.02)	8	146 <sup>ab</sup> (57)	299 (57)
Woody Plant Nursery	25	28.6 <sup>bc</sup> (11.9)	0.19 <sup>ab</sup> (0.03)	22	135 <sup>b</sup> (57)	283 (35)
All	115	31.5 (16.9)	0.19 (0.04)	104	169 (60)	299 (57)
Loam						
Cropping System	n	AgStab %	AWC g H <sub>2</sub> O g <sup>-1</sup> soil	n	Surface H psi	Subsurface H psi
Processing Vegetables	7	15.7 (8.0)	0.18 <sup>c</sup> (0.05)	7	148 (39)	245 (52)
Mixed Vegetables	24	23.7 (16.6)	0.22 <sup>a</sup> (0.02)	23	173 (65)	296 (43)
Perennial Fruit	24	29.7 (17.2)	0.22 <sup>ab</sup> (0.03)	24	166 (86)	285 (43)
Pasture	6	27.5 (17.8)	0.20 <sup>abc</sup> (0.02)	6	218 (61)	285 (43)
Woody Plant Nursery	17	21.4 (8.7)	0.20 <sup>b</sup> (0.02)	16	143 (39)	291 (42)
All	78	24.6 (15.2)	0.21 (0.03)	76	166 (68)	289 (45)
Silt Loam						
Cropping System	n	AgStab %	AWC g H <sub>2</sub> O g <sup>-1</sup> soil	n	Surface H psi	Subsurface H psi
Processing Vegetables	11	19.2 <sup>c</sup> (10.3)	0.25 <sup>ab</sup> (0.02)	10	180 <sup>ab</sup> (30)	300 (33)
Mixed Vegetables	38	23.0 <sup>c</sup> (14.4)	0.25 <sup>ab</sup> (0.03)	35	173 <sup>b</sup> (65)	289 (42)
Perennial Fruit	27	39.2 <sup>b</sup> (19.1)	0.26 <sup>ab</sup> (0.03)	23	186 <sup>ab</sup> (63)	288 (52)
Pasture	17	55.7 <sup>a</sup> (26.0)	0.27 <sup>a</sup> (0.03)	12	239 <sup>a</sup> (56)	309 (29)
Woody Plant Nursery	18	16.5 <sup>c</sup> (16.5)	0.23 <sup>b</sup> (0.02)	18	139 <sup>b</sup> (38)	278 (35)
All	111	30.5 (22.1)	0.25 (0.03)	99	179 (62)	291 (42)

# Appendix

## Chemical Soil Health Indicators

**Table A8.** Mean chemical soil health indicators (1 standard deviation in parentheses) by cropping system and soil texture. Mean values followed by superscripted letters are significantly different at the 0.05 error level and no letters indicate no significant differences.

Sandy Loam								
Cropping System	n	pH 1:2 H <sub>2</sub> O	P ppm	K ppm	Mg ppm	Fe ppm	Mn ppm	Zn ppm
Processing Vegetables	24	5.6 <sup>b</sup> (0.5)	23.9 <sup>ab</sup> (9.3)	79 (42)	72 (39)	5.1 (3.2)	2.2 <sup>b</sup> (1.2)	1.0 <sup>b</sup> (0.6)
Mixed Vegetables	36	6.2 <sup>a</sup> (0.5)	20.7 <sup>b</sup> (12.6)	92 (105)	105 (94)	3.9 (4.5)	4.0 <sup>ab</sup> (5.2)	1.4 <sup>ab</sup> (1.3)
Perennial Fruit	18	6.6 <sup>a</sup> (0.6)	18.9 <sup>b</sup> (18.8)	91 (68)	137 (127)	5.5 (5.4)	5.8 <sup>a</sup> (3.9)	2.2 <sup>a</sup> (1.8)
Pasture	12	6.1 <sup>ab</sup> (0.4)	12.2 <sup>b</sup> (8.8)	47 (37)	85 (63)	3.7 (2.7)	2.6 <sup>ab</sup> (1.7)	1.8 <sup>ab</sup> (1.7)
Woody Plant Nursery	25	6.3 <sup>a</sup> (0.4)	30.3 <sup>a</sup> (9.7)	69 (46)	113 (100)	2.8 (2.7)	2.9 <sup>ab</sup> (3.1)	1.4 <sup>ab</sup> (1.1)
All	115	6.2 (0.6)	22.3 (13.2)	80 (72)	103 (91)	4.1 (3.9)	3.5 (3.8)	1.5 (1.3)
Loam								
Cropping System	n	pH 1:2 H <sub>2</sub> O	P ppm	K ppm	Mg ppm	Fe ppm	Mn ppm	Zn ppm
Processing Vegetables	7	5.8 <sup>ab</sup> (0.3)	30.5 (12.8)	115 (88)	91 (62)	3.7 (2.0)	2.2 <sup>ab</sup> (1.2)	1.1 <sup>ab</sup> (0.8)
Mixed Vegetables	24	6.4 <sup>a</sup> (0.4)	34.6 (27.9)	116 (77)	112 (73)	2.9 (1.9)	2.8 <sup>ab</sup> (1.7)	0.9 <sup>ab</sup> (0.7)
Perennial Fruit	24	6.2 <sup>ab</sup> (0.6)	27.2 (9.6)	104 (51)	97 (54)	3.6 (1.9)	4.0 <sup>a</sup> (2.2)	1.6 <sup>a</sup> (1.3)
Pasture	6	5.7 <sup>b</sup> (0.5)	22.5 (15.8)	64 (30)	82 (42)	3.3 (1.4)	2.5 <sup>ab</sup> (0.9)	1.0 <sup>ab</sup> (0.8)
Woody Plant Nursery	17	6.0 <sup>ab</sup> (0.6)	26.0 (7.0)	82 (42)	108 (62)	3.8 (3.4)	1.9 <sup>b</sup> (1.0)	0.8 <sup>b</sup> (0.3)
All	78	6.1 (0.6)	29.1 (17.8)	101 (62)	102 (61)	3.4 (2.3)	2.9 (1.8)	1.1 (1.0)
Silt Loam								
Cropping System	n	pH 1:2 H <sub>2</sub> O	P ppm	K ppm	Mg ppm	Fe ppm	Mn ppm	Zn ppm
Processing Vegetables	11	5.8 <sup>abc</sup> (0.6)	19.0 <sup>b</sup> (8.5)	99 <sup>ab</sup> (52)	48 <sup>c</sup> (26)	4.0 <sup>ab</sup> (4.3)	2.6 <sup>b</sup> (1.1)	1.2 <sup>ab</sup> (0.7)
Mixed Vegetables	38	6.1 <sup>ab</sup> (0.5)	21.6 <sup>b</sup> (13.9)	88 <sup>b</sup> (57)	101 <sup>bc</sup> (70)	3.9 <sup>b</sup> (4.2)	2.9 <sup>b</sup> (2.1)	0.7 <sup>b</sup> (0.5)
Perennial Fruit	27	6.3 <sup>a</sup> (0.6)	33.9 <sup>a</sup> (16.1)	147 <sup>a</sup> (72)	163 <sup>a</sup> (92)	5.6 <sup>ab</sup> (5.2)	3.9 <sup>ab</sup> (2.3)	1.8 <sup>a</sup> (1.2)
Pasture	17	5.6 <sup>bc</sup> (0.5)	14.1 <sup>b</sup> (8.5)	73 <sup>b</sup> (39)	149 <sup>ab</sup> (94)	8.1 <sup>a</sup> (5.4)	5.4 <sup>a</sup> (2.9)	1.4 <sup>ab</sup> (1.3)
Woody Plant Nursery	18	5.4 <sup>c</sup> (0.6)	21.5 <sup>b</sup> (10.9)	72 <sup>b</sup> (49)	55 <sup>c</sup> (52)	3.5 <sup>b</sup> (1.8)	2.3 <sup>b</sup> (1.8)	0.9 <sup>b</sup> (0.9)
All	111	5.9 (0.6)	23.2 (14.3)	99 (63)	111 (85)	4.9 (4.6)	3.4 (2.3)	1.1 (1.0)

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### For more information:

Contact Deborah Aller at [da352@cornell.edu](mailto:da352@cornell.edu)

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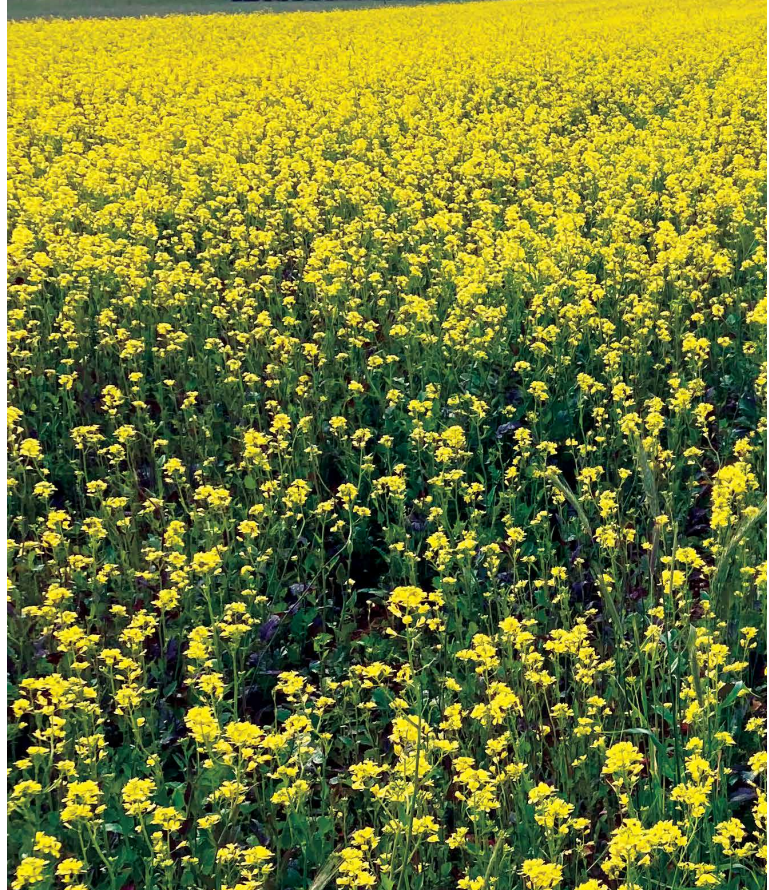


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