Soil Health and Connecticut Tobacco Production

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Overview

Tobacco is a regionally important crop, grown in rich topsoils of the Connecticut River valley. Across the approximately 2,500 acres in Connecticut currently dedicated to tobacco production, fields have lost inches of topsoil and tons of organic matter because of conventional inversion tillage and frequent cultivation (Blanco-Canqui et al., 2024; Munna & Lal, 2025). With little land available and increasing pressure to produce more, farmers have fewer opportunities to rotate crops or plant cover crops—factors that have only intensified these problems.

In 2024, American Farmland Trust sampled soils from 49 tobacco fields on 11 farms in Hartford and Tolland counties to assess the current state of soil health among Connecticut tobacco farms, and help growers consider the benefits to improved soil health practices. This brief will present anonymous results and discuss trends in CT tobacco farms' soil health indicators and how they impact drought resilience, soil erosion, compaction and water infiltration, soil acidity and nutrient availability.

The Importance of Soil Health

Soil health is defined as "the capacity of soil to function as a vital living system, to sustain biological productivity, promote the quality of agricultural ecosystems, and food production for animal, and human" (Nunes et al., 2021). Traditional soil testing looks at the chemical analysis of available nutrients, but we know that soil function is really about the <u>overlap</u> of chemical interactions, biological function, and physical performance (Kabato et al., 2025; Idowu et al., 2020). All these soil indicators are related, and each indicator has an influence on the others. This analysis can point to where soil function is limited by specific indicators. Management changes can be adopted to address certain constraints (Munna & Lal, 2025).

Soil health is important because it supports both the human and non-human participants in agricultural ecosystems. Healthy soil improves crop production and resilience to weather extremes by improving water infiltration during heavy rainfall or by improving water holding capacity during drought. Organic matter is usually higher in soils with a higher soil health rating (Nunes

FIGURE 1. DIAGRAM OF SOIL HEALTH AS A CONCEPT

et al., 2021). Organic matter supports soil aggregate stability and reduces the risk of erosion, as well as increasing the biological activity of a soil (Poeplau et al., 2024; Zhang et al., 2024). This plant and soil activity can lead to more efficient nutrient cycling, fertilizer savings, and nutrient retention (Porwollik et al., 2022). Pathogen pressure and weed pressure are generally lower in healthy soils. Overall, soil health contributes to more resilience under a range of unfavorable conditions (Kabato et al., 2025).

Testing for soil health can be useful in several ways:

- <u>Snapshot</u>: How is overall soil health?
- <u>Diagnostic</u>: Does this evidence explain performance?
- <u>Risk Assessment</u>: What are the weak areas?
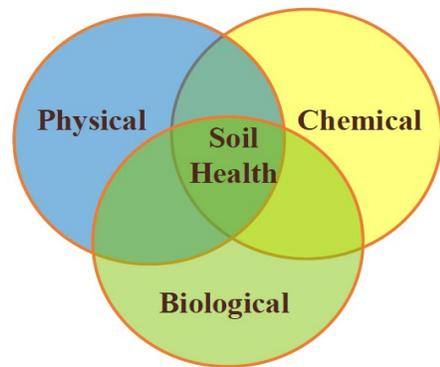- <u>Monitor Change</u>: What management practices would improve soil health?

Sampling Scope and Protocol

This project sampled soils from 49 tobacco fields on 11 farms in Hartford and Tolland counties (see Figure 2). Sixty percent of these soil samples had a sandy loam texture, which is common in the rich CT river valley farmland of this area (Figure 3). Silt loams, loams, and loamy sands were also common. These light soils have inherent characteristics with both benefits and challenges. Generally, there is good water infiltration, which is helpful during heavy or frequent rains and makes for timely planting and cultivation. However, the low proportion of clay particles, which strongly hold on to nutrients and organic matter, means that there is often low baseline fertility and biological activity in these sandy soils.
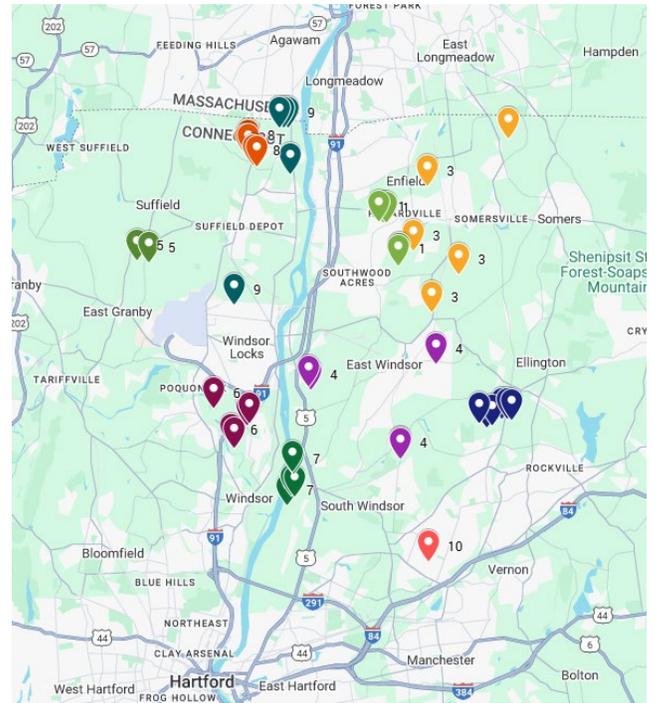

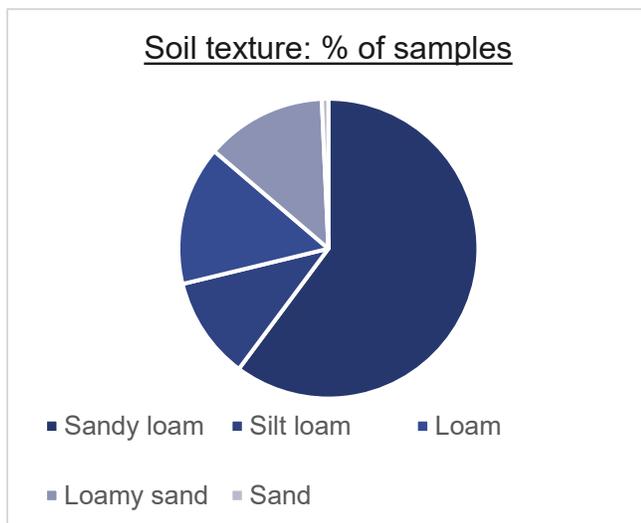**FIGURE 2. TOBACCO FIELDS SAMPLED IN 2024**

FIGURE 3. SOIL TEXTURE FOR ALL SAMPLES

Sampling was done according to the protocol recommended by Cornell Soil Health Lab (Moebius-Clune BN et al., 2016) which can be found here:

https://soilhealthlab.cals.cornell.edu/testing-services/soil-sample-collection/

Soil Health Testing Method

We used the **Cornell Comprehensive Assessment of Soil Health (CASH) test** to assess the health of soils in these fields. The CASH package includes a suite of chemical, physical, and biological analyses that assess the overall health of the soil. Results from each of the soil health analyses are reported as values, which are assigned a rating from 1 to 100 based on the optimal range of values for each indicator (accounting for the influence of soil texture). The test also provides an overall score for the sample which combines the ratings for each of the soil analyses. This CASH test is widely used for research across the United States, with scores that are calibrated for the Northeast (Bowman & Wood, 2022). It highlights the primary indicators that influence soil function and crop production for each sampled field, as seen in the CASH report example below.

Measured Soil Textural Class: **sandy loam**
Sand: **70%** - Silt: **23%** - Clay: **6%**

Group	Indicator	Value	Rating	Constraints
physical	Predicted Available Water Capacity	0.15	62	
physical	Surface Hardness	434	0	Rooting, Water Transmission
physical	Subsurface Hardness	399	18	Subsurface Pan/Deep Compaction, Deep Rooting, Water and Nutrient Access
physical	Aggregate Stability	26.7	28	
biological	Organic Matter Soil Organic Carbon: 0.85 / Total Carbon: 0.87 / Total Nitrogen: 0.08	1.6	30	
biological	Predicted Soil Protein	3.60	14	Organic Matter Quality, Organic N Storage, N Mineralization
biological	Soil Respiration	0.2	12	Soil Microbial Abundance and Activity
biological	Active Carbon	243	15	Energy Source for Soil Biota
chemical	Soil pH	5.9	72	
chemical	Extractable Phosphorus	14.9	100	
chemical	Extractable Potassium	182.4	100	
chemical	Additional Nutrients Ca: 293.5 / Mg: 65.0 / S: 2.9 Al: 31.1 / B: 0.01 / Cu: 0.18 Fe: 1.5 / Mn: 1.1 / Zn: 0.4		77	

Overall Quality Score: **44** / Medium

FIGURE 4. CORNELL ASSESSMENT OF SOIL HEALTH REPORT SAMPLE

Overall Results

The overall total average CASH test score was "medium", 47 out of 100, which is a simple average of the ratings for all 10 indicators. The values are based on the optimal range for each indicator, accounting for the influence of soil texture. Each colored box represents 50% of the results, and the thick black line inside the colored box shows the median score. For Potassium (K) and Phosphorus (P) ratings, there is no visible box, just a vertical black line, which means that most farms had a score of 100. Black dots show data points that are outliers. Ratings for all 49 samples are represented below in Figure 5.
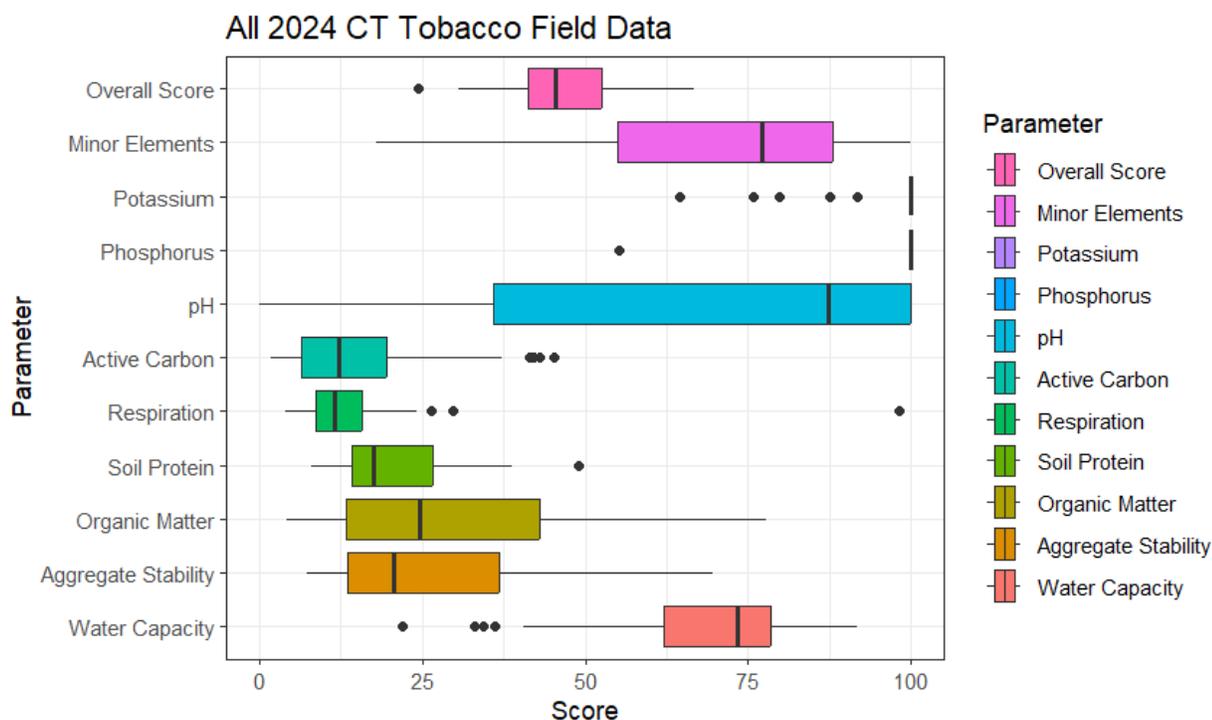

FIGURE 5. RESULTS FROM ALL CT TOBACCO FIELDS SAMPLED IN 2024.

Overall, the nutrient and soil pH ratings were high in Connecticut tobacco fields. The biological indicators were low on average, including active carbon, respiration, soil protein and organic matter. Aggregate stability, which is rated relative to soil texture, was low. Available water capacity ratings were high, especially considering the sandy texture of many samples. This pattern—strong chemical fertility with weak biological indicators—is commonly observed in intensively tilled systems (Bowman & Wood, 2022; Munna & Lal, 2025). This indicates that there are significant opportunities to improve

soil health, which would enhance crop resilience to drought, improve soil conditions, and reduce reliance on fertilizer inputs.

More detailed discussion of the results is organized in the following categories:

- **Nutrients and fertility**
- **Biological activity**
- **Drought resilience**
- **Soil erosion**
- **Compaction**
- **Influence of soil texture**

Nutrients and Fertility

Phosphorus

Excessive phosphorus (P) is a critical concern for water quality on farms and neighboring waterways, where it can cause toxic algae blooms (Porwollik et al., 2022). The average value of P for this group of samples was 14 ppm, ranging from 4 to 24 ppm (Figure 6). While the state of Connecticut does not make recommendations to limit P application on agricultural lands, other states have recommended that fields with more than 14 ppm P should not receive additional P fertilizer as it is unnecessary and an environmental concern. Growers at the higher end of this range should consider obtaining fertilizer with no- to low- P content.
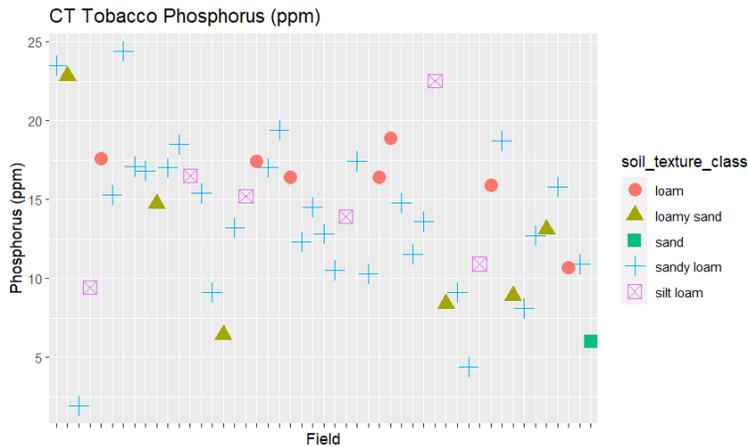
FIGURE 6. SOIL PHOSPHORUS IN PPM FOR TOBACCO FIELDS SAMPLED IN 2024.

Nitrogen

Nitrogen (N) fertilizer application and yield were reported by most tobacco farmers in this CT project. On average, growers apply 290 lbs. N/acre, split between pre-plant application and side-dress. With one exception, farmers reported a tobacco yield of 1900 to 2100 lbs./acre. Despite similar yields, N application ranged from 245 to 385 lbs. N/acre among participating farmers (Figure 7). Higher rates of N application did not necessarily result in higher production. Research from the University of Kentucky in 2019 suggested that the ideal total N for CT broadleaf production should be between 150 and 175 lbs. N/acre (Bailey and Pearce, 2020). Recommendations from CAES average 250 lbs. N/acre, depending on soil test results.
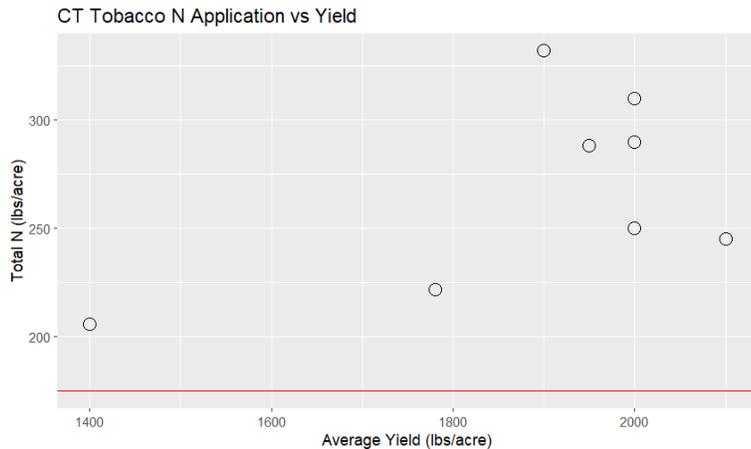
FIGURE 7. RELATIONSHIP BETWEEN REPORTED NITROGEN (N) FERTILIZER AND 2023 TOBACCO YIELD.

For growers applying more than 250 lbs. N/acre, trialing an appropriate reduction of N application may result in cost savings while maintaining crop yield. Reduced N applications can also improve surrounding water quality and greenhouse gas emissions. Any trial should be conducted on a small section of a good field with appropriate soil moisture.

Predicted Soil Protein

Soil protein is the largest pool of soil organic N. The rate at which it breaks down limits soil N cycling and reflects the ability of soils to supply N to crops. The average of the 49 samples was 4 mg per gram of soil, which is rated at 20 of 100, indicating that soil protein levels are generally low. Improvements to soil protein levels will increase N cycling and availability to crops, improving plant vigor. Reducing tillage and rotating in a legume cover crop will improve soil protein levels.

Soil Acidity

Soil acidity, measured by pH, is essential for managing nutrients and fertility. The average across these 49 samples was 6.1, which is the ideal for tobacco production, although there was a wide range from 5.1 to 7.0. Eight fields had a pH below 5.5, which is considered toxic for plant growth, because essential nutrients are not available at that pH. Managing fields for appropriate soil pH is an important aspect of soil health.

Micronutrients

Several fields showed a deficiency in sulfur or boron, which are both important for tobacco growth. This can be associated with low pH (below 5.5), but not necessarily. Ensuring sufficient micronutrient availability will contribute to both plant and soil health.

Biological Activity

Soil is a living entity, and biological indicators help assess overall soil health. **Respiration and active carbon** are markers of biological activity and carbon cycling in soil. Medium to high values of respiration and active carbon indicate conservation of organic matter and carbon contributions to a healthy soil sponge that retains water for times of drought.

Respiration

Among all samples, the average CASH rating for **respiration** was 15 out of 100, which generally indicates a reduced population of the bacteria and fungi that decompose organic materials, bind soil aggregates, and release soil-bound nutrients (Figure 8). Reduced biological activity impacts many aspects of soil function, from nutrient cycling to organic matter levels to soil aggregate stability.
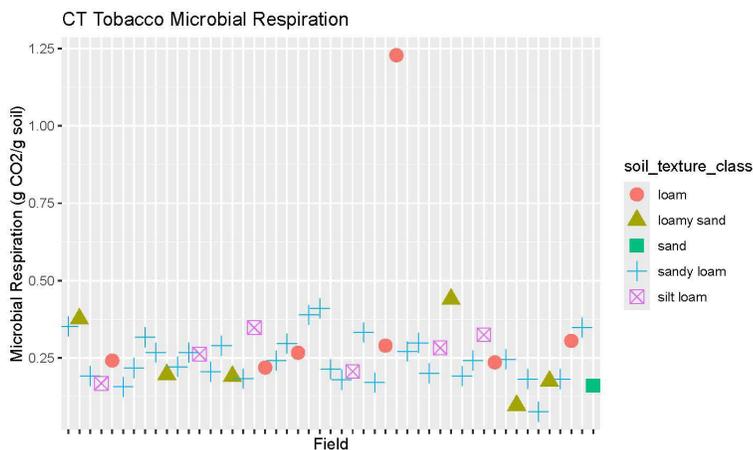

FIGURE 8. MICROBIAL RESPIRATION VALUES IN G CO_2/G FOR ALL TOBACCO FIELDS SAMPLED IN 2024.

Active Carbon

Active carbon functions as a food source for soil biological organisms. A value of less than 400 pm active carbon indicates restricted soil function. Most of the 49 samples fell in this medium to low functioning category, with an average rating of 15 out of 100 (Figure 9). We can infer that some of the low respiration values are due to a lack of carbon-based food for the soil microbiome. The recommendations section at the end of this report will address this constraint in more detail.
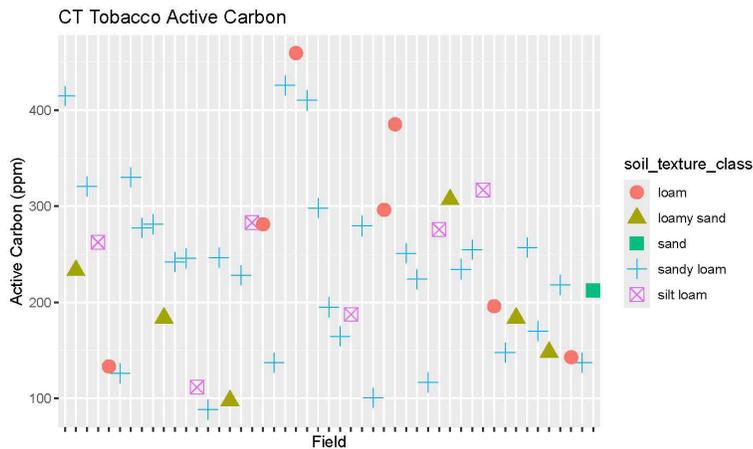

FIGURE 9. ACTIVE CARBON VALUES FOR ALL TOBACCO FIELDS SAMPLED IN 2024.

Drought Resilience

The soil health indicators that influence drought resilience that we measured are organic matter, predicted available water capacity, and subsurface hardness.

Organic matter

Organic matter (OM) in soil acts as a sponge to absorb and release water and nutrients in the soil profile; it consists of carbon-based material derived from decomposed plant and animal biomass. Of the 49 tobacco fields sampled, the average OM was 1.7% (Figure 10). Although this represents a low percentage of organic matter compared with the typical 1 to 6% found in annual cropping systems, it is considered low to moderate for sandy soils. Among all fields sampled, the average OM rating was 29 out of 100.
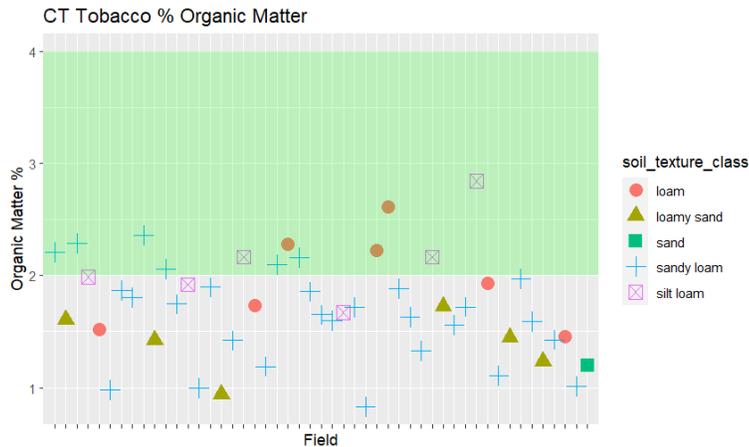
FIGURE 10. PERCENT SOIL ORGANIC MATTER FOR ALL FIELDS SAMPLED IN 2024.

Subsurface Hardness

Soil Compaction influences the ability of water to infiltrate the soil and for plant roots to grow. Compacted soil holds less water, reduces plant root biomass and depth, and limits root access to air, water, and nutrients. It is important to consider compaction at several depths in the soil profile. Surface compaction can be an issue for transplants and small seeded crops. In the fields sampled for this project, some had already been tilled and cultivated, while others were still undisturbed all winter/spring, so it was difficult to make comparisons of surface (0 to 6" deep) compaction.

However, subsurface hardness can be measured even after a field has been recently tilled. Heavy equipment and frequent tillage contribute to the creation of hard pans; to assess compaction in this hard pan zone, a penetrometer is used to measure the resistance of soil to penetration between 6-18". Among all fields sampled, the average ranking was 14 out 100 (Figure 11). Subsurface hardness above 300 psi is considered to limit plant root growth, because there is simply too much resistance for new plant roots to push through easily.
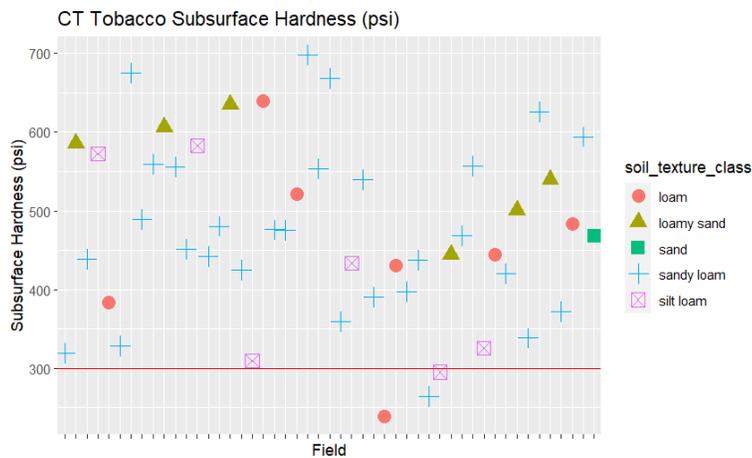
FIGURE 11. SUBSURFACE HARDNESS IN PSI FOR ALL FIELDS SAMPLED IN 2024.

Influence of Soil Texture

Available water capacity and aggregate stability are both particularly influenced by soil texture. Sandy soils, also known as coarse textured soils, have large pore spaces which allow water to drain quickly. Soils with more clay particles hold more water because the many small pores hold water through capillary action. Stable soil aggregates provide more pore space for water to enter, increasing infiltration and water holding capacity.

Available water capacity

Available water capacity (AWC) is an assessment of how much water your soil can hold by weight. Sandy soils inherently store less water than finer textured soils and organic matter content strongly influences available water capacity. CASH tests use a predictive model to provide values for AWC based on soil texture. In this group of samples, the average rating was 68 out of 100.
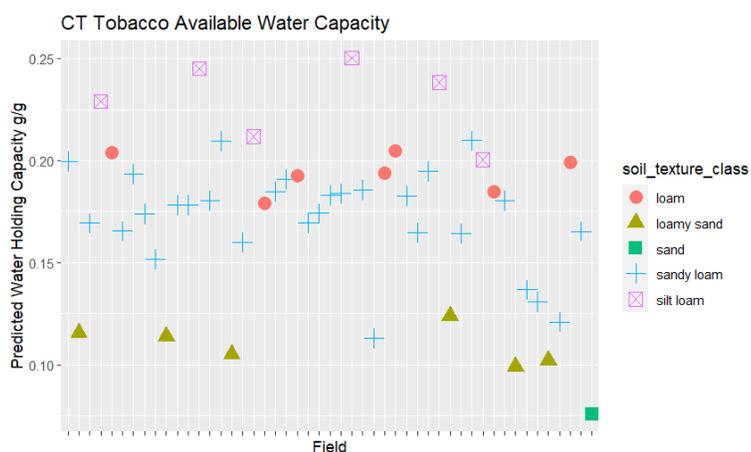
FIGURE 12. PREDICTED AVAILABLE WATER CAPACITY IN G WATER/G SOIL FOR ALL FIELDS SAMPLED IN 2024.

In Figure 12, soil textural class was observed to be strongly related to AWC. To examine this relationship, we analyzed the interaction of AWC with soil texture grouped as coarse, moderately coarse, and medium textures (Figure 13).

General terms	**Basic class names**
Coarse textured	Sand, loamy sand
Moderately coarse	Sandy loam
Medium	Silt loam, loam

FIGURE 13. SOIL TEXTURAL CLASSES

There was statistically significant difference in AWC according to soil texture, with medium textured soils having the highest AWC and coarse textured soils the lowest (Figure 12). While soil texture cannot be changed, management practices can greatly improve AWC with increased soil organic matter and reduced soil disturbance.
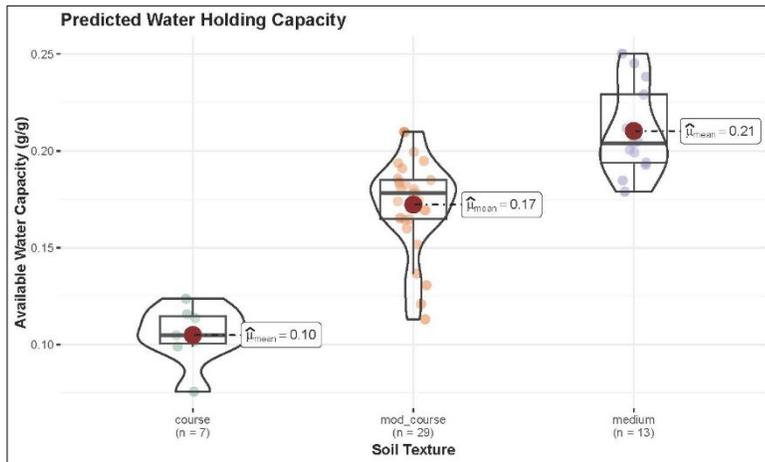
FIGURE 14. STATISTICALLY DIFFERENT VALUES IN PREDICTED WATER HOLDING CAPACITY ACCORDING TO SOIL TEXTURE.

Aggregate stability

Aggregate stability is a good indicator of how well soil crumbs or aggregates hold together under the force of rain and irrigation. The Cornell CASH test measures this according to the fraction of dried aggregates that disintegrate under a controlled, simulated rainfall event in the lab. Good aggregate stability enhances water infiltration, deep soil water percolation, and nutrient exchange (Poeplau et al, 2024; Zhang et al., 2024). A higher percentage of aggregation helps prevent soil crusting and improves aeration to plant roots and beneficial soil microbes. Low aggregate stability indicates vulnerability to soil loss, erosion, surface crusting, and decreased water infiltration and retention.

The average aggregate stability rating among all fields samples was 26 out of 100, taking into account soil texture. However, there were significant differences in aggregate stability by soil texture (Figure 13). Coarse soils had a significantly higher soil aggregation compared to moderately coarse and medium soil textures.
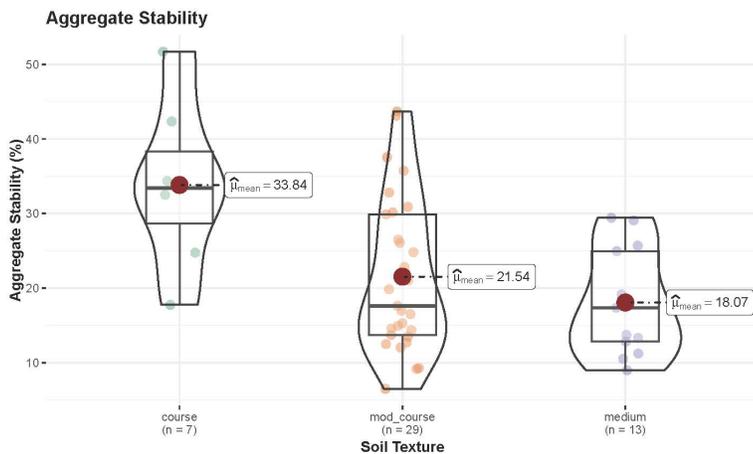
FIGURE 15. AGGREGATE STABILITY ACCORDING TO SOIL TEXTURE RATING FOR ALL FIELD SAMPLES TAKEN IN 2024.

Recommendations

Soil health is most profoundly influenced by the following factors: organic matter, soil pH, sufficient nutrients, living roots, and limited disturbance. There are clear opportunities to improve soil health by increasing organic matter (using cover crops or manure), managing soil pH (usually with lime applications), maximizing the number of days with living roots (by extending cover crop growth), and limiting soil disturbance (by reducing the frequency, intensity, or depth of tillage).

In annual tobacco production there are inherent challenges in adopting these healthy management strategies. Tobacco is a low residue crop that relies heavily on tillage and cultivation. This means that crop residue is minimal, so there's not a lot of biomass to be turned in the soil after the crop is harvested, and there is intense primary tillage and cultivation. Alternative sources of organic matter are manure or cover crops, without which it is difficult to feed the soil and maintain or increase soil organic matter.

Like human health, there are baseline recommendations that improve soils across the board. For example, eat well (feed your soil) and get enough sleep (reduce tillage). Famers should be planting cover crops as soon as possible after the crop is harvested, although this can be challenging as there is a simultaneous demand for attention with the tobacco crop curing and management. On the other end of the season, leaving spring cover crops growing as long as possible is another way to add organic matter and maximize days of living roots.

Most farmers and extension professionals interviewed agreed that zone tillage, also referred to as strip tillage, seems to be the most promising strategy for improving soil health in Connecticut tobacco production. Zone tillage equipment utilizes a deep shank to open a furrow, followed by a roller or basket to create a plantable zone. This limits primary tillage to 8 inches out of a 40 inch row. This practice can conserve soil carbon, decrease soil compaction, prevent soil erosion, and maximize both water infiltration and retention, especially if utilized in conjunction with a winter cover crop.

While a winter rye cover crop is commonly utilized in tobacco production, it is also often planted late (October or November) and terminated early (April), which limits biomass growth and potential to improve soil organic matter. There is potential to use staggered harvest dates to maximize seeding cover crops early, which would expand the days of living cover crop as well as increase options for multi-species cover crops. Manipulating the Carbon:Nitrogen (C:N) ratio by planting multispecies mixes and through targeted cover crop species selection can mitigate nitrogen immobilization during the cropping season by improving C:N ratio outcomes. Cover crop species should be selected with goals in mind, considering planned termination dates and cash crop planting dates to ensure appropriate nitrogen availability.

FIGURE 16. STRIP TILLAGE EQUIPMENT

Conclusion

Overall, the Connecticut tobacco fields sampled in this project had below average soil health. The strengths were in nutrient availability and aggregate stability, while biological indicators and compaction ratings showed opportunities for improvement.

Improved soil organic matter, respiration, and soil carbon could improve water infiltration, water and nutrient retention, and reduced erosion, all of which are critical strategies that support crop resilience, especially under recent climate patterns of extreme precipitation (Munna & Lal, 2025; Poeplau et al., 2024). The adoption of conservation tillage and cover crops could protect farmers from increasingly variable weather and protect water quality in the Connecticut River and its tributaries (Kabato et al., 2025; Porwollik et al., 2022).

Baseline soil health testing is useful for ongoing soil stewardship to evaluate the soil's resilience or vulnerability and help determine how to work towards healthier land and crops. As farmers try new management strategies, soil health testing can provide valuable information about efficacy.

Citations

Bailey, W. A., & Pearce, R. C. (2020). *Production of Connecticut broadleaf cigar wrapper tobacco in Kentucky and Tennessee* (AGR-258). University of Kentucky Cooperative Extension Service.

Blanco-Canqui, H., Francis, C. A., Galusha, T. D., & Shaver, T. M. (2024). Long-term cover crop impacts on soil health indicators and crop productivity in temperate humid systems. Renewable Agriculture and Food Systems, 39, e15. https://doi.org/10.1017/S174217052300021X

Bowman, M. S., & Wood, S. A. (2022). Cover crops influence soil health indicators in on-farm trials. Journal of Soil and Water Conservation, 77(2), 109–121. https://doi.org/10.2489/jswc.2022.00123

Idowu, O. J., van Es, H. M., Abawi, G. S., Wolfe, D. W., Ball, J. I., Gugino, B. K., Moebius-Clune, D. J., Schindelbeck, R. R., & Thies, J. E. (2020). Farmer-oriented assessment of soil quality using field, laboratory, and modeling approaches. Soil Science Society of America Journal, 84(1), 17–30. https://doi.org/10.1002/saj2.20002

Kabato, W., Kibret, K., Bedadi, B., & Diriba, M. (2025). Managing soil health for climate resilience and crop productivity in a changing environment: A review. Science of the Total Environment, 912, 169249. https://doi.org/10.1016/j.scitotenv.2024.169249

Nunes, M. R., Karlen, D. L., Veum, K. S., Moorman, T. B., & Cambardella, C. A. (2021). Soil health and nutrient density: Beyond organic versus conventional farming. Frontiers in Sustainable Food Systems, 5, 699147. https://doi.org/10.3389/fsufs.2021.699147

Moebius-Clune, B.N., D.J. Moebius-Clune, B.K. Gugino, O.J. Idowu, R.R. Schindelbeck, A.J. Ristow, H.M. van Es, J.E. Thies, H. A. Shayler, M. B. McBride, D.W. Wolfe, and G.S. Abawi.

2016. *Comprehensive Assessment of Soil Health – The Cornell Framework Manual*, Edition 3.0. Cornell University, Geneva, NY.

Munna, M. N. H., & Lal, R. (2025). Impacts of cover cropping and organic amendments on soil physical quality under temperate climates. Geoderma, 444, 116904. https://doi.org/10.1016/j.geoderma.2024.116904

Poeplau, C., Don, A., Six, J., Kaiser, M., & Chenu, C. (2024). Cover crops improve soil structure and carbon distribution in macroaggregate fractions. Soil, 10, 139–155. https://doi.org/10.5194/soil-10-139-2024

Porwollik, V., Müller, C., Elliott, J., Chrysanthacopoulos, J., & Pugh, T. A. M. (2022). The role of cover crops for soil carbon sequestration, nitrogen leaching, and crop yields: A global modeling study. Biogeosciences, 19, 957–975. https://doi.org/10.5194/bg-19-957-2022

Zhang, Z., Wang, J., Zhao, X., & Li, Y. (2024). Response of soil organic carbon and aggregate stability to land-use changes: A global synthesis. Scientific Reports, 14, 82300. https://doi.org/10.1038/s41598-024-82300-2