University of Massachusetts Amherst

Office of Pre-Award Services

January 31, 2024

Massachusetts Executive Office of Energy and Environmental Affairs
Thomas Anderson
Thomas.Anderson@mass.gov

Subject: UMass Proposal No. 10399
Entitled: Demonstration and Education to Increase Soil Health Adoption on Massachusetts Cropland

Dear Mr. Anderson:

Attached for your consideration is the subject proposal submitted on behalf of Professor Wharton C. Clay of the Extension Department.

Please note that the appropriate contracting instrument between MA state agencies is the Interdepartmental Service Agreement (ISA) and not the Standard State Contract. If this proposal results in an award, the Interdepartmental Service Agreement (ISA) should be sent to the following contact person in the Office Post-Award Management at opam@umass.edu:

Alene Denson, Ed.D., Director
Office of Pre-Award Management
University of Massachusetts
Mass Venture Ctr, 100 Venture Way, Suite 201
Hadley, MA 01035

If you have questions on technical aspects of the proposal, please contact the UMass Principal Investigator directly. Administrative concerns may be directed to the Office of Pre-Award Services, at (413) 545-0699 or via email at pre-award@umass.edu.

Sincerely,

Kimberly A. Lowney
Pre-Award Research Administrator

Demonstration and Education to Increase Soil Health Adoption on Massachusetts Cropland

UMass Extension Agriculture Program | 230 Stockbridge Rd. Amherst MA 01003
Challenge Grants Implementing the Commonwealth's Healthy Soils Action Plan
Commbuys Bid #BD-24-1042-ENV-ENV01-96064 | RFR ID: ENV 24 DCS 08

Project Description

Goals and Objectives

Our project's goal is to increase both understanding of soil health and adoption of agricultural practices that promote it. While tillage reduction and cover cropping have been proven to broadly improve soil health in agricultural systems, gaps in knowledge and resources are actively inhibiting the effective adoption of soil health best management practices and subsequent soil functioning. Without scientific knowledge and communication, no-till management practices may not be adopted at all, or their adoption may fall short of the potential to achieve carbon sequestration goals. Our project objectives and associated methods are designed to take advantage of the resources that UMass Extension possesses to achieve real advances in knowledge and proven approaches to adoption:

Objective 1: Support simple and regular on-farm soil health evaluation that can be used by 100 farmers on 6,000 acres during the grant period.

Laboratory testing is a critical component of an effective statewide soil health effort, but some parameters can be observed repeatedly over time on the farm at modest cost and with great benefits to the farm. Educating farmers about the tools, techniques, and underpinning science – as well as the limits of interpretation – has potential to complement other forms of analysis and education and serve as an empowerment and engagement tool.

Objective 2: Demonstrate no-till and cover crop adoption that enables 300 farmers to understand effects on soil pH, microbial activity, and short-term carbon storage and reduces barriers to adoption.

Demonstrations are a highly effective tool, used frequently by UMass Extension and other Extension organizations, for bridging between scientific research and adoption of practices, building trust in science, and facilitating peer-to-peer learning. Providing rigorous data gathering along with side-by-side demonstrations of relevant practices, farmers can observe differences directly, but also absorb the significance of the data and analysis. In order to build knowledge and confidence in these techniques, we will document the local impact of no-till and cover cropped systems on chemical and biological indicators of soil health.

Objective 3: Incorporate Massachusetts-specific knowledge into soil health management tools that can be used by the more than 5,000 farmers and other residents using the UMass Extension Soil and Plant Nutrient Testing Lab annually.

The UMass Soil Testing Lab is a key asset in the Commonwealth's healthy soils efforts. It recently benefited from legislative investments in equipment (one of the HSAP recommendations) and is expanding services and related education. Farmers and other land managers ultimately rely on soil test results for many key management practices, particularly addition of lime to correct low pH and addition of macro and micronutrients and organic matter through amendments and cover crops. Test results with recommendations provide customized and applicable knowledge in the moment when farmers need it most. Incorporating new soil health knowledge generated through the demonstrations and from the literature, particularly how agricultural input application methods and quantities should be adjusted when using no-till methods and cover crops, will permit customers to better use the lab's results to adopt healthy soils practices without compromising crop productivity.

To maximize agricultural soil health in Massachusetts, many individual growers must buy into making many specific decisions on their land. Farmers and land managers will be more inspired to use no-till and cover cropping techniques to improve their soil health if they can tangibly understand and assess the land's soil health and adjust their lime and fertilizer applications to new sustainable systems with the support of Extension resources. While laboratory-based soil health tests are available, they are expensive and interpretation of results is both complex and context-specific. Thus, educational programming and resources are needed in the areas of soil management and soil health testing.

UMass Extension is uniquely positioned to address these needs because growers already rely on information through factsheets and routine soil test recommendations for fertilizer and lime inputs, as well as our staff and faculty expertise and the availability of our research farms.

These efforts are needed to ensure that Massachusetts farmers and land managers can begin reducing tillage and increasing cover cropping on their land while remaining confident in their agricultural productivity and economic sustainability. This project will promote soil health by helping land managers to confidently reduce tillage and increase cover cropping by providing science-based recommendations for adjusting inputs like fertilizer and lime, engaging with diverse communities about these methods through public education events and demonstration trials, and supporting on-farm measurement of the impacts of sustainable land management.

Project alignment with the Massachusetts Healthy Soils Action Plan

Soil health across all land uses is essential to the future of Massachusetts for climate change mitigation and environmental quality. The importance of farmland in particular is derived from its large area, its great potential for soil health improvement, and the key role that farmers play in providing food, cultural amenities, and environmental services to the Commonwealth. Over half a million acres are owned by Massachusetts farmers, with over 250,000 acres classified as agricultural by use. Unfortunately, the soils of many farms are degraded from long-term intensive tillage and lack of living root presence during several months of the year. However, this condition provides an opportunity to make significant changes since large improvements in soil health are possible and can increase ecological services like carbon sequestration while maintaining agricultural yields. The Massachusetts Healthy Soils Action Plan (HSAP) identifies approximately 70,000 acres of cultivated cropland that typically experience annual tillage under current management as an important target for adoption of healthy soils practices. (HSAP, pp. 67)

The HSAP identifies seven broad "Healthy Soils Strategies," three of which are addressed in this proposal:

- "Enhance the functional capacity of soils across all land covers."

- "Expand technical, financial, educational, and material support for land managers of all types to employ soil-smart practices."
- "Enhance the analytical capacity for measuring and monitoring soil health in Massachusetts." (HSAP, p.7)

In addition, the Plan identifies six highest-priority Health Soils Actions, two of which are relevant to this proposal:

- "Enroll 50% of existing agricultural production acres in the implementation of soil health plans by 2030."
- "Eliminate technical and knowledge barriers to adoption of practices which increase soil health."

Finally, the Soil and Land Management portion of the recommendations in the Agriculture section includes these additional relevant suggestions: (HSAP, p. 78)

- Identify and study healthy soils practices for each subclass of agriculture that provides unequivocal financial benefit to farmers.
- Enhance the analytical capacity for measuring soil health in Massachusetts through purchase of additional equipment at the State Soil Laboratory.
- Increase support for educational programs, technical service, and targeted outreach efforts on the benefits, costs, and details of implementing healthy soils practices.
- Ensure that sufficient resources are provided to institutions and organizations that provide technical, educational, and other support to farmers in healthy soil practices including Agricultural Extension, Conservation Districts, private non-profits such as NOFA, and proven private consultants.
- Encourage farmer-to-farmer events, including "twilight talks", that promote use of best practices.

These recommendations arise from the fact that the HSAP's analysis projects that the vast majority of potential improvements in soil organic carbon (SOC) in its three modeled agricultural scenarios would be derived from either "modest" or "ambitious" adoption of best management practices (BMP's), particularly those labeled as "Conservation Agriculture." (HSAP, p. 75) The major principles of soil health in agricultural systems include reduced soil disturbance, vegetative cover of the soil, increased duration of living roots, and increased diversity. These four tenets are embedded in two key management practices for cropland: reduction of tillage and integration of cover crops into farming systems. Indeed, the HSAP's section on Conservation Agriculture highlights the incentives offered by NRCS for four practices that align with these overall management approaches. (HSAP, p. 73)

The three project objectives described above and the methods, outcomes, and deliverables described below are all closely linked to one or more of the recommendations highlighted here. This project will make significant strides in identifying soil health practices that optimize benefits for farmers, improving the availability of technical support for farmers and reducing barriers to adoption, and increase opportunities for farmer-to-farmer knowledge sharing in a science-oriented context. It will also support one of the key farmer support institutions mentioned in the HSAP (UMass Extension) and contribute to our ongoing effort to enhance our analytical and advisory capacity in the soil health realm, and create potential for UMass to play a key role in development of a support system for soil health management plans.

Methodology (Activities and Outputs for each Objective)

Objective 1: Support simple and regular on-farm soil health evaluation that can be used by 100 farmers on 6,000 acres during the grant period.

In the spring of 2024, materials will be purchased to assemble 10 on-farm soil health testing kits. The kits will include materials and instructions to measure many indicators of soil health, including soil aggregate stability, compaction (penetrometer), water infiltration, pH, and soil biology using a variety of accessible methods. The test kits will be distributed to agricultural non-profits and other entities willing to loan them to local farmers, including Conservation Districts, Buy Local groups, and satellite Extension offices in Newton and East Wareham. UMass Extension has already created a **Soil Health Kit Guidebook** which complements the soil health test kits (see Supplement). Hands-on, educational events will be held in tandem with each partner organization to demonstrate the methods, build interest in soil health testing, and discuss soil health with community members. Soil health test kit events will begin in the spring of 2024 with the UMass Extension Soil Health Mini-School and continue until the early summer of 2025.

Objective 2: Demonstrate no-till and cover crop adoption that enables 300 farmers to understand effects on soil pH, microbial activity, and short-term carbon storage and reduces barriers to adoption.

Also in the spring of 2024, two demonstrations will be installed at the UMass Crop and Animal Research Farm in South Deerfield to show different no-till and cover cropping methods to farmers. Both sets of demonstrations will provide tangible field production-scale examples of no-till and cover cropping methods commonly used to promote soil health in comparison to intensive tillage and bare fallows. Both experiments will use winter squash because it is an important cash crop in Massachusetts which is suitable for all investigated cropping systems

The first demonstration (No-till and Cover Crop Mixes) will consist of three tillage treatments (conventional tillage, reduced tillage, and no-till) with four cover crop treatments in each tillage type (no cover crop, late-planted winter annual rye, early-planted winter-killed mix, and early-planted overwintering mix). This demonstration will show the relationship between tillage and cover crop biomass on early indicators of soil carbon sequestration and crop growth.

The second demonstration (No-till and pH Stratification) will consist of two tillage treatments (conventional tillage and no-till), two cover crop treatments (no cover crop, tillage radish), two lime treatments (incorporated and surface applied), and two nitrogen source treatments (acidifying ammonium sulfate and non-acidifying composted manure) (Figure 2). This demonstration will focus on methods to reduce pH depth stratification on no-till farms such - organic nitrogen sources and cover cropping with tillage radish - and how the soil pH affects early indicators of soil carbon sequestration and different soil depths. This demonstration will be replicated in order to better scientifically inform adjustments to routine soil test recommendations.

Three field events will be held at the demonstrations to show farmers the effects of these systems at key moments in the season and host discussions about how soil health impacts production agriculture. These events will be in August 2024, October 2024, and April 2025. Demonstration results will also be presented at the 2025 UMass Extension Soil Health Mini-School in the winter of 2025.

Please note that additional detail describing the design and implementation plan for each demonstration is provided in a Supplement at the end of this proposal.

Objective 3: Incorporate Massachusetts-specific knowledge into soil health management tools that can be used by the more than 5,000 farmers and other residents using the UMass Extension Soil and Plant Nutrient Testing Lab annually.

The data collected from the two sets of demonstrations will be combined with the scientific literature to create a series of five educational factsheets on soil health. These will describe how to adapt soil test recommendations to cropping systems which use no-till and cover cropping to promote soil health as well as other topics based on grower interests. While the specific topics will be finalized based on farmer input, these factsheets will cover topics like: Soil sampling in no-till fields, Choosing the right nitrogen source for no-till farming, Bio tillage with radishes, and Promoting soil health using cover crop mixes. While not customized to the individual customer's soil test results, these resources will empower progressive farmers to make adjustments that are supported by science and that may reduce input costs or nutrient runoff while enhancing carbon sequestration.

In addition, the UMass Soil Testing Lab will contract with a database consultant to develop a plan for how to include updated recommendations for no-till and cover cropped fields in standard soil-test-based input recommendations from the Soil Testing Lab. The database and its recommendation engine are complex, containing not only tens of thousands of customer records, but hundreds of individual recommendations for unique combinations of crops grown and test results obtained. Soil health recommendations may require adjustments based on user input regarding past or planned practice. A database upgrade is planned over the next two years, and these grant resources will allow us to incorporate more sophisticated approaches to soil health recommendations in that project than would otherwise be possible. It is unlikely that the final results of this investment will be available before the end of the grant period, but planning documents and related contracts can be considered outputs.

Expected Outcomes and Deliverables

The deliverables and outcomes described below have also been discussed in the previous section. The relevant objectives are listed in brackets.

200 people discuss and learn how to use and have easy access to the soil health test kit (10 hands-on events state-wide). These may include host organizations, agricultural service providers, and farmers. We anticipate that at least 100 farmers producing on at least 6,000 acres will make use of the kit on their farms. [Objective 1]

100 people see first-hand the effects of different no-till and cover crop management strategies (3 research demonstration field events in South Deerfield). [Objective 2]

2 research reports are published describing the demonstration results. [Objective 2]

5 factsheets are published about various aspects of adapting soil testing to no-till and cover cropped fields. Fact sheets are publicized in UMass Extension farmer newsletters reaching at least 3,000 subscribers, and links to relevant fact sheets are provided with soil test results. Customer surveys indicate that at least 200 customers gained knowledge that may affect practices. [Objectives 2, 3]

1 plan in place for updating the UMass Soil Testing Lab database to incorporate updated input recommendations into standard soil test recommendations.

Taken together, we believe the overall outcome will be meaningful and measurable progress toward our goal to increase both understanding of soil health and adoption of agricultural practices that promote it. In the language used in HSAP, we expect that as a result of these efforts, intelligent use of Soil Health analysis and Conservation Agriculture practices will begin to increase soil function on high-priority cultivated cropland.

Budget

Please see budget table by budget period (state fiscal year) below, followed by explanatory narrative for each category. Please note that because this project is embedded within UMass Extension's overall soil health programming, there are valuable contributions to the project's outcomes that are not documented as match or in-kind in the budget. Notably, these include use of the UMass Research Farm in South Deerfield and the use of unfunded staff time that would have otherwise been directed to a different set of soil health activities, but will be used to accomplish proposed project goals.

Budget Table by State Fiscal Year with Matching Funds

	03/01/2024 – 06/30/2024	07/01/2024 – 06/30/2025	Total Funding Request	Matching Funds
PI Clem Clay				
Arthur Siller Salary	$4,747.80	$819.00	$5,566.80	
Fringe benefits	$2,230.04	$384.68	$2,614.72	
Samantha Glaze-Cororan Salary	$2,127.29	$6,381.86	$8,509.15	
Fringe benefits	$47.86	$143.59	$191.45	
Hourly Technician Wages	$5,000.00	$15,000.00	$20,000.00	
Fringe benefits	$112.50	$337.50	$450.00	
Classified Farm Staff Salary	$225.00	$675.00	$900.00	
Fringe benefits	$105.68	$317.05	$422.73	
Travel reimbursement	$670.00	$670.00	$1,340.00	
Test Kits	$15,000.00		$15,000.00	
Demonstration Input Supplies	$8,150.00		$8,150.00	
Internal Facility User Fees	$7,740.00		$7,740.00	
External Soil Testing	$576.00	$3,456.00	$4,032.00	
Consulting Services	$0	$5,000.00	$5,000.00	
Indirect Costs	$0	$0	$0	
Unrecovered Indirect Costs				$20,778.39
TOTAL	$46,732.17	$33,184.68	$79,916.85	

Table 1. Budget by Period with Match

Budget Justification: University of Massachusetts Amherst

Senior Personnel: $14,075.95

PI Clem Clay will oversee grant administration throughout the project and supervise personnel.

Arthur Siller, UMass Extension Soil Health Educator IV, (0.72 calendar month in budget period 1; and 0.12 calendar month in budget period 2 = $5,566.80) will lead educational programming and manage research and demonstration projects. Arthur will assemble, distribute, and demonstrate the Soil Health Kits around the state, manage demonstration installation, maintenance, and sampling, and write extension factsheets. Arthur has managed research and educational programs on agronomy and cropping systems at UMass as a PhD student over the last 5 years.

Dr. Sam Glaze-Corcoran, UMass Extension Soil and Plant Nutrient Testing Lab Manager, (0.27 calendar month in budget period 1 and 0.80 calendar month in period 2 = $8,509.15) will supervise the field demonstration and educational program and be directly responsible for working with a database consultant to integrate demonstration results into the UMass Soil and Plant Nutrient Testing Lab database to provide updated input recommendations for no-till and cover cropped cropland. Dr. Glaze-Corcoran is an expert in cropping systems and soil analysis and has successfully managed numerous extension projects with UMass Extension for the last 10 years.

Other Personnel: $20,900.00

Hourly Technician (800 hours x $25/hour = $20,000) will be hired to assist Dr. Glaze-Corcoran and Arthur Siller with project activities in the field and educational activities.

Classified Farm Staff (30 hours x $30/hour = $900) will operate machinery to install and maintain demonstration experiments including tillage, planting, lime and nutrient application, and harvesting activities. The University of Massachusetts, being a non-profit, public institution of higher education, pays the faculty and staff on an appointed salary base and not an hourly rate. Therefore, any converted hourly rate is for budget information only. All salaries will be paid consistent with University policies and procedures which have been designed in accordance with the requirements of the Uniform Guidance 2 CFR 200.

Fringe Benefits: $3,678.90

Fringe benefits are calculated at University negotiated blended rate of 46.97% on professional and classified staff salary including 43.20% + 0.14 worker's compensation + 2.11% UI, UHI, MTX, PFML + 0.52% sick leave bank plus$ $16.50 weekly for health & welfare; and 2.25% on non-benefitted hourly technician wages including 0.14 worker's compensation + 2.11% UI, UHI, MTX, PFML.

Domestic Travel: $1,340.00

Mileage reimbursement is requested in the amount of $1,340 at a rate of 67/cents per mile x anticipated 2,000 miles over the two budget periods.

Materials & Supplies: $23,150.00

(10) Test Kits x $1,500 = $15,000. Each test kit contains the following items intended to enable a variety of in-field soil health assessments: spade, soil probe, penetrometer, aggregate stability test kit, sieve, jar, earthworm ID booklet, measuring cup, mustard powder, infiltration ring, graduated cylinder, wood block. Costs are based on PI prior experience.

Demonstration Inputs = $8,150 include cash crop seed ($1,000), fertilizer ($1,000), lime ($1,000), herbicides ($500), shipping costs ($150), cover crop seed ($500), and bulk density slide hammers (2 @ $2,000 each). Costs are based on PI prior experience.

Other Direct Costs: $16,772.00

Internal Facility Fees = $7,740 for routine soil tests (150 @ $18 = $2,700); soil tests with organic matter (100 @ $23.40 = $2,340); pH tests (270 @ $10 = $2,700). Rates at https://ag.umass.edu/sites/ag.umass.edu/files/pdf-doc-ppt/prepaid_kits_recharge_082418.pdf and https://ag.umass.edu/services/soil-plant-nutrient-testing-laboratory/lab-services

External Soil Testing = $4,032 and includes active carbon (56 @ $30), soil respiration (56 @ $30), microbial biomass (56 @ $12) from Cornell Soil Health Lab and UMaine Soil Testing Service. Rates at soilhealthlab.cals.cornell.edu/testing-services/individual-soil-analyses and umaine.edu/soiltestinglab/wp-content/uploads/sites/227/2023/04/23-soil-price.pdf.

(200) hours Consulting Services x $250 = $5,000. An example of a consultant is the entity that developed the current database. This company was Schroth Systems but has been spun off as Ag Stars (https://www.agstars.us/). Based on PI prior experience their last quote for similar work was in 2020 at rates of $175-$200/hour for the level of consultants required for this project. We are projecting that the current rate for a consultant is ~$250/hour based on annual 5% cola.

Total Direct Costs: $79,916.85

Indirect Costs: $0

Indirect costs are not included in the budget per sponsor guidelines.

Matching Funds: $20,778.39

Unrecovered indirect costs at the Commonwealth of Massachusetts negotiated rate of 26% MTDC are included as cost-share. Direct cost base = $79,916.85

TOTAL FUNDING REQUEST: $79,916.85

Organizational Capacity

The UMass Center for Agriculture, Food, and the Environment is the administrative home for both UMass Extension and the Massachusetts Agricultural Experiment Station. It manages four research farms, including the Crop and Animal Research and Education Farm in South Deerfield where the proposed demonstrations will be established. The farm supports faculty research and both Extension Faculty and professional Extension Educators working in many disciplines and with many agricultural and commercial horticulture audiences, including vegetable and fruit growers as well as hay, dairy, and field crop producers. Fee-based services include the UMass Plant Diagnostic Lab and the UMass Soil and Plant

Nutrient Testing Lab, which processes 13,000 routine soil tests for 5,000 customers in a typical year. The Stockbridge School of Agriculture and other UMass departments employ numerous faculty with research programs in various aspects of soil health. Taken together, UMass Amherst likely generates more knowledge relevant to the topic of soil health than any other Massachusetts institution.

UMass Extension has a long history of producing in-person and written educational programing and installing research demonstrations to effectively communicate scientific knowledge in agriculture to the public. The principal investigators of this project have laid the groundwork for success by securing land for demonstrations, creating the first Soil Health Kit and Guidebook, and making connections with local agricultural organizations as partners for education and outreach.

Dr. Sam Glaze-Corcoran, UMass Extension Soil and Plant Nutrient Testing Lab Manager, will supervise the project, organize the overall field demonstration and educational program, and be directly responsible for working with a database consultant to integrate demonstration results into the UMass Soil and Plant Nutrient Testing Lab database to provide updated input recommendations for no-till and cover cropped cropland. Dr. Glaze-Corcoran is an expert in cropping systems and soil analysis and has successfully managed multiple laboratories and numerous Extension projects with UMass Extension and other farmer-based organizations for the last 10 years.

Arthur Siller, UMass Extension Soil Health Educator, will lead educational programming and research demonstration management for this project. Arthur will assemble, distribute, and demonstrate the Soil Health Kits around the state, manage demonstration installation, maintenance, and sampling, and write Extension factsheets. Arthur has managed research and educational programs on agronomy and cropping systems at UMass as a Ph.D. student over the last 5 years.

Clem Clay, UMass Extension Agriculture Program Director, will guide the project and ensure overall project success by overseeing grant administration and interfacing with partner organizations.

Dr. Masoud Hashemi, UMass Extension Professor, will support the project by consulting on methodology and participating in the education and outreach program. Dr. Hashemi has is an internationally known expert in cover cropping and soil health.

To supplement permanent staff capacity during this project, seasonal staff will also be hired to assist Dr. Glaze-Corcoran and Arthur Siller with project activities in the field and educational activities.

Project Timeline

Major activities are listed by time period, with date-specific milestones in *italics*.

- **March - June 2024**
    - Purchase and assemble Soil Health Kits
    - Begin Soil Health Kit distribution and education

  - UMass Extension Soil Health Mini-School (already planned, but will incorporate test kit)
  - Layout demonstration trials at UMass Crop Research Farm in South Deerfield
  - Initial field preparation and soil sampling
  - Plant squash cash crop
- ***6/30/24 Milestones:***
  - *All Soil Health Test Kits purchased, 3 Trainings offered.*
  - *Demonstration plots planted.*
  - *FY24 budgeted funds expended (see budget section).*
- **July - August 2024**
  - Continue Soil Health Kit distribution and education
  - Maintain demonstration trials
  - Host in-field educational event in August at demonstration trials
  - Analyze initial soil samples for mineral nutrient content, pH, and soil carbon parameters
  - Research database consultant services
- **September - November 2024**
  - Complete Soil Health Kit distribution and education
  - Harvest squash in demonstration trials
  - Plant cover crops in demonstration trials
  - Sample soil for pH in the No-till and pH Stratification trial
  - Host in-field educational event in October at demonstration trials
- ***November 30, 2024 Milestones:***
  - *10 Soil Health Test Kit trainings completed.*
  - *Demonstration plots prepared for winter with all 2024 season; all data gathered.*
  - *1 in-field educational events featuring demonstration plots held.*
- **December 2024 - March 2025**
  - Analyze soil samples for pH
  - Write factsheets on adapting soil test results to no-till and cover cropped soils
  - Consult with database professional
  - UMass Extension Soil Health Mini-School (already planned, but will incorporate demo plot lessons)
- **April - June 2025**
  - Sample soil in both demonstrations for soil health analysis
  - Host in-field educational event in April at demonstration trials
  - Analyze soil samples for mineral nutrient content, pH, and soil carbon parameters
  - Write plan for updating input recommendations in the Soil Testing Lab database for no-till and cover cropped soils
  - Write factsheets to communicate demonstration trial results

  - Write research reports
- ***June 30, 2025 Milestones:***
  - *All demonstration plot samples collected and analyzed.*
  - *5 fact sheets completed and disseminated to UMass Extension audiences including farmers, service providers, and soil test customers.*
  - *2 research reports completed.*
  - *3 in-field educational events featuring demonstration plots held.*
  - *Plan for soil test database recommendations completed.*
  - *All budgeted funds expended (see budget section).*

Project Evaluation and Monitoring

The project will be quantitatively evaluated using participation in educational programs and the production of written educational materials as outlined in the *expected outcomes and/or deliverables* section. Participants will provide feedback on the knowledge they gained and their expectations and intentions regarding implementation. UMass Extension regularly conducts similar evaluations on its programs. Results will be included in grant reporting. Due to the time limitations, we do not believe it is feasible to quantify the on-the-ground impact of knowledge gained, as the best-case scenario would include new practices being adopted by fall of 2024, with 2025 crop and soil performance results not known by farmers prior to the end of the grant period.

Sustainability Plan

Field demonstration and educational programming will be complete by the end of the grant time period, but additional funding may be sought to continue the demonstrations and/or use them as a basis for establishing long-term trials. The Healthy Soils Action Plan grant will fund the specific aspects of the Soil Testing Lab database update described above; other funds have been set aside or will be sought for the other aspects of the upgrade. This aspect of the project will be continued by Dr. Sam Glaze-Corcoran following the end of the HSAP grant. Additionally, both Dr. Glaze-Corcoran and Arthur Siller will continue to be publicly available as UMass Extension staff to continue educational programs on the Soil Health Kit, managing agricultural inputs in no-till and cover cropped fields, and on soil health in Massachusetts broadly. Both will participate in the NRCS State Technical Committee's Soil Health Subcommittee and engage as appropriate in discussions about future soil health management plan support. Relationships with many organizations interested in soil health are already in place, and will grow into stronger partnerships during the grant period, resulting in increased opportunities for UMass Extension to inform efforts of other actors who wish to use science-based methods to help farmers improve soil health.

Risk Assessment of Project, Partners, Timeline

Because of UMass Extension's experience with this type of program and resources, this project is low risk. As with all agricultural demonstrations and in-field events, the weather is the primary risk to our project's effectiveness. Extreme rain or drought could negatively impact plant growth in demonstration trials while rain could reduce participation at in-field events. To mitigate these risks, we will reschedule educational activities around poor weather and work with partner organizations to have covered spaces available when possible. Additionally, while we do not plan to use irrigation on demonstration plots to follow the typical production practice on land farms, irrigation is available at the UMass research farm and would be used if the educational value of the experiment was threatened.

Supplement: Rationale, Design, and Implementation Plan for Two Demonstrations

Several aspects of soil health management need further investigation. Farmers must understand how pH changes over time relative to the soil depth, the negative influence of tillage on physical, chemical, and biological characteristics of the agricultural lands, use of alternative nitrogen fertilizer sources, and cover cropping. These factors determine the magnitude of both carbon sequestration and agricultural production. No-till soils can become depth-stratified in terms of acidity and nutrient levels. This can limit both microbial and plant growth which in turn reduces carbon sequestration and crop yields. The extent of this limitation and the proper strategies to alleviate it must be thoroughly understood to maximize the health and productivity of no-till fields. Specifically, it is not well understood whether either bio tillage using cover crops or minimal mechanical tillage can effectively promote the movement of lime and nutrients into the subsurface soil and how this movement affects biological activity and carbon sequestration. Secondly, lime and fertilizer are available in multiple forms and it is not known how these forms behave and interact in no-till cropping systems.

As agricultural techniques change to promote soil health, farmers need scientific recommendations on how other farming methods should be adapted. This is especially important as it relates to agricultural inputs that have a large effect on both economic and environmental sustainability. By combining this knowledge of soil acidity with the measurement of organic matter and microbial activity, recommendations will be developed to describe the specific practices that lead to more carbon sequestration and plant productivity through soil health. Finally, the implications of these techniques must be understood by farmers across the diversity of crops in Massachusetts. Thus, research demonstrations and educational programs and materials are needed to explore and communicate best management practices for promoting soil health in cropland by encouraging public participation in soil health improvements.

The first demonstration (**No-till and Cover Crop Mixes**) will consist of three tillage treatments (conventional tillage, reduced tillage, and no-till) with four cover crop treatments in each tillage type (no cover crop, late-planted winter annual rye, early-planted winterkilled mix, and early-planted overwintering mix) at two seeding rates (Figure 1). This demonstration will show the relationship between tillage and cover crop biomass on early indicators of soil carbon sequestration and crop growth.

The second demonstration (**No-till and pH Stratification**) will consist of two tillage treatments (conventional tillage and no-till), two cover crop treatments (no cover crop, tillage radish), two lime treatments (incorporated and surface applied), and two nitrogen source treatments (acidifying ammonium sulfate and non-acidifying composted manure) (Figure 2). This demonstration will focus on methods to reduce pH depth stratification on no-till farms such as organic nitrogen sources and cover cropping with tillage radish, and how the soil pH affects early indicators of soil carbon sequestration and different soil depths. This demonstration will be replicated in order to better scientifically inform adjustments to routine soil test recommendations.

In both demonstrations, soil will be sampled in early May at the start of the experiment to assess the baseline soil pH, texture, and nutrient content. Organic matter, active carbon, and microbial biomass will be measured for the surface soil (0-1 inch) and the root zone below the surface (1-10 inches). Lime and nutrients will be applied based on UMass Soil Lab recommendations. Squash will be direct-seeded and grown using IPM methods following the New England Vegetable Management Guide recommendations. Squash will be harvested in September. Conventional till plots will be disked and the various cover crop treatments will be planted using a seed drill.

Surface and subsurface pH will be measured in the No-till and pH Stratification demonstration in October 2024 and additional lime will be applied on the surface if it is recommended.

The next spring (2025), soil in both sets of demonstrations will be sampled and analyzed for pH, nutrient content, organic matter, active carbon, and microbial biomass in the same manner as in 2024. Since soil biological activity is correlated with seasonal effects, 2025 sampling will occur at the same time as the baseline samples were collected in 2024 (early May).

Figure 1. No-till and Cover Crop Mixes Trial

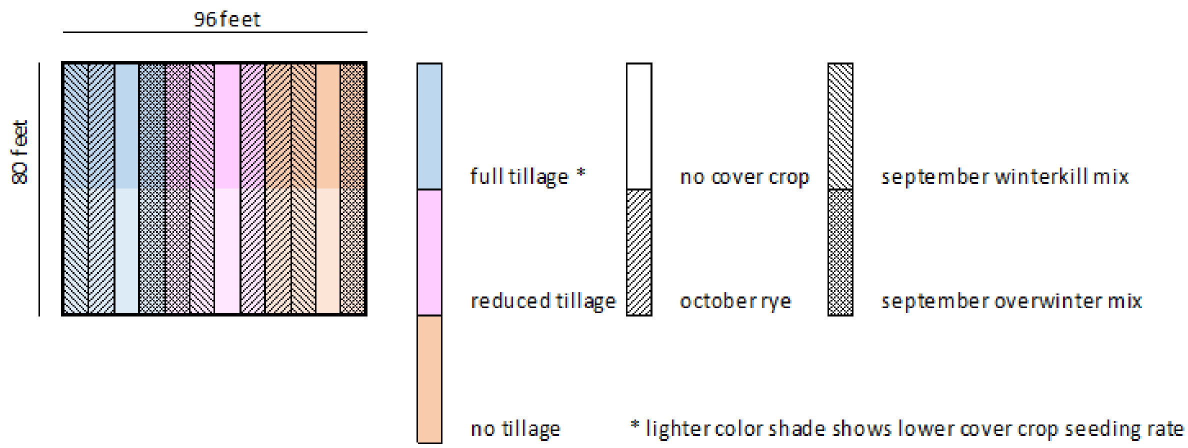
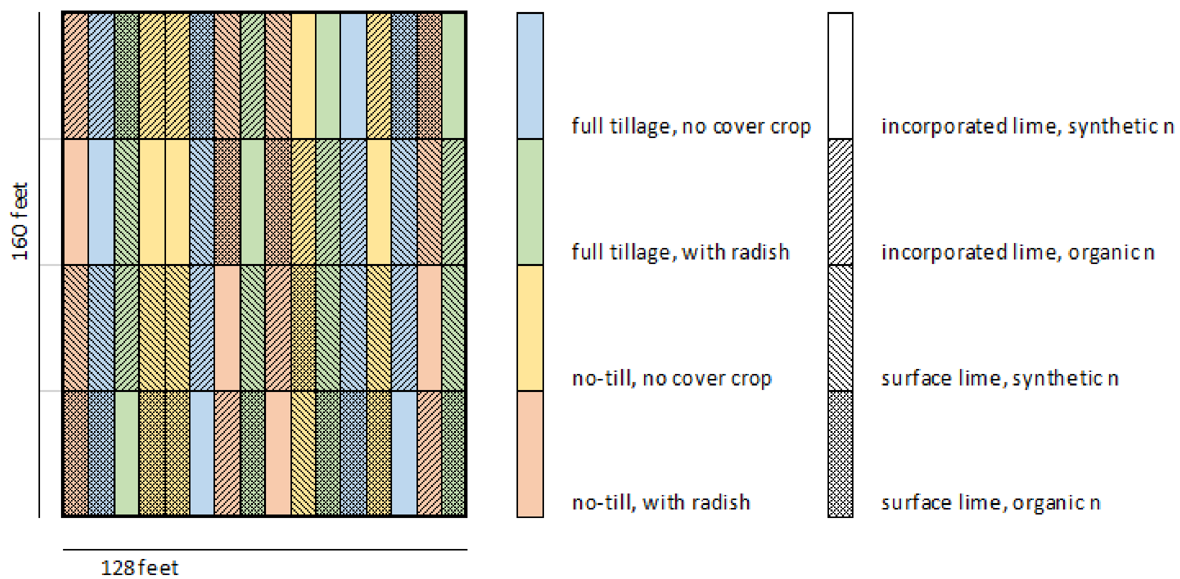


Figure 2. No-till and pH Stratification Trial



Demonstration and Education to Increase Soil Health Adoption on Massachusetts Cropland

UMass Extension Agriculture Program | 230 Stockbridge Rd. Amherst MA 01003
Challenge Grants Implementing the Commonwealth's Healthy Soils Action Plan
Commbuys Bid #BD-24-1042-ENV-ENV01-96064 | RFR ID: ENV 24 DCS 08

Supplement: Soil Health Kit Guidebook

Please see attached. This guidebook was developed for the Soil Health Kit assembled by UMass Extension in 2023 and available for use by Extension personnel and for loan to others from the Amherst campus. With grant funding, 10 kits will become available for loan in locations throughout Massachusetts, and this Guidebook will be updated over time and used as the basis for trainings.

UMass Soil Health Test Kit and Guide

This kit includes directions, general guidance, and physical materials to complete soil health assessments.

This kit does not include some simple consumables that you might need, specifically: water, cups, pens, sharpies, and sample collection bags. Check to make sure you have these items before your site visit.

> How to Use the UMass Soil Health Test Kit and Guide
>
> This resource was created to simplify soil health and make soil health more accessible for both educators and stakeholders.
>
> This kit includes items needed for popular methods of soil health assessment. This resource is not exhaustive; the emphasis is on simple, free, chemical and physical assessments. Additional information is provided about fee-for-service laboratory tests where appropriate.
>
> Guidelines are provided to help with method selection. For example, some methods are very effective for general education about soil health principles, while other methods can be used to support farm visits or collect data for on-farm trials.

This kit is designed to be a "grab-and-go" resource. Some users may find value in reviewing the complete guide for a refresher, as a decision support tool, or to build a workshop. Other users may find the most value in simply reviewing methods and borrowing the physical items.

This kit and guide are meant to be universally applicable, from vegetable farmers to community gardeners, from pasture managers to turf managers. Adapt considerations and interpretations as needed.

Prepared by: Sam Corcoran, Arthur Siller

Recommend citation: Corcoran, S. and Siller, A. UMass Soil Health Test Kit and Guide. 2023. UMass Extension. Amherst, MA, USA.

Last Updated: November, 2023
This work prepared by the support of Northeast SARE, SNE20-004-MA.

Table of Contents

Data Interpretation: Context Collection

Interpret all data in context

- Why do you and/or the land manager care about soil health at this location?
- What current conditions should you expect based on inherent soil properties and historical management?
- What changes to management and changes to soil conditions are reasonable to expect in the future?

1. Goals:

A method should always be conducted with a use in mind. If there is no use for the data, there is no reason to perform the method. “Use” is subjective. To determine the use, identify the goal.

Examples of Goals:

- Satisfy curiosity.
- Educate about soil health.
- Conduct a general assessment for informational and decision-making purposes.
- Identify risks and room for improvement.
- Diagnose a problem.
- Demonstrate the effectiveness of soil health management practices on different fields or farms.
- Quantify changes to soil over time or in response to a practice.
- Conduct research.

METHOD:

- Interview with land manager.
- Walk the land during a single visit.
- Visit the land several times throughout the season or over multiple growing seasons.
- Consider grant and stipend funds related to soil health that support farm improvement.
- Review county, state, federal, and global sustainability initiatives.

Caveat: Goals are subjective and dynamic. Data collected for curiosity or as a routine assessment in one season could be used to help diagnose a problem next season. Consider data collection with this in mind.

2. Management history:

Includes type, frequency, and depth of soil disturbance, frequency and volume of organic matter inputs (compost, mulch, manure, uncollected grass clippings), soil cover (mulch, cover crops, high tunnel over bare soil), fertilizer, soil fumigation, and irrigation.

METHOD:

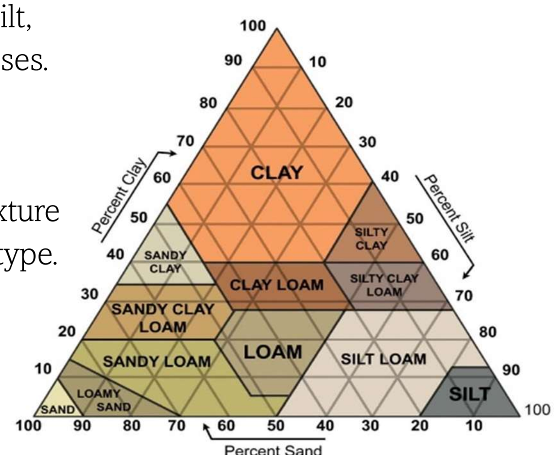
- Interview with land manager

Caveat: Management history is often approximated information. Focus on big-picture details.

3. Soil texture/Soil type:

Soil texture is defined by the proportion of sand, silt, and clay in the soil. There are twelve texture classes. Example: clay, sandy clay, sandy loam.

Soil type refers to a highly detailed, taxonomic classification of soils. It is more complex than texture but texture is a substantial factor in defining soil type.



The soil texture pyramid.

METHOD:

- Guide to texture by feel
- Mason jar texture test
- Laboratory texture test
- Web Soil Survey of soil type

Caveat: Texture by feel is free and immediate, but takes practice. A jar test takes time and has some margin for error, but is free and easy. A laboratory test costs money and is not always needed, but provides high accuracy and precision. A soil texture assessment could differ from the web soil survey soil type description due to historical management, but the Web Soil Survey is standardized, easy, free, and fast.

4. Site Characterization:

Data collected for soil health analyses are snapshots. These snapshots are affected by season, weather, and natural variation in sample collection. On a given day, soil health measurements may not reflect the typical soil condition. For instance, plant growth may be stunted in some areas due to compaction. But, if the soil is uncharacteristically wet on the day the field is sampled, compaction will be underestimated by the penetrometer.

Site-scale observations can provide a reality check for unexpected measurements.

Examples of site characteristics worth noting:

- Plant growth
- Plant stress during wet or dry weather
- Soil-borne disease
- Erosion
- Soil crusting
- Water ponding

Remember to note any spatial variation in the area. Comparisons to nearby areas can be relevant. For example, does one field or garden bed look bad but a neighboring area looks good?

Some soil health characteristics are only clearly visible under certain conditions (e.g. wind erosion, ponding) or are most easily observed through their effect on plants.

METHOD:

- Interview with land manager.
- Walk the land during a single visit.
- Visit the land several times throughout the season or over multiple growing seasons.

Caveat: Site-scale characteristics are generally the result of interactions among many factors. For example, ponding may occur simply because a spot in the field is slightly low-lying, but this ponding could be made worse because of compaction. Care must be taken in associating site characteristics with soil health tests.

Soil Health Testing Methods

<u>Method Use Key</u>

 Demonstration/Educational

 Quick Check

 Routine Check

 In-Depth Assessment

Aggregate Stability - Physical

Background

Pick up a handful of soil and observe the naturally occurring little balls that have formed; these are soil aggregates, soil particles bound together. Aggregates can be microscopic or more than an inch in diameter. Aggregates are held together by chemical bonds between negatively charged particles (clay, silt, organic matter) and positively charged elements (calcium, magnesium, potassium, sodium). Aggregates are also held together by sticky substances made by soil microbes, and by the physical reinforcement of plant roots and fungal networks.

Aggregate stability tests measure how well these balls of soil particles hold together when they are disturbed.

Disturbance can mean tillage, the impact of rainfall, or the rewetting of a dry aggregate. Aggregate breakdown is associated with soil compaction, reduced water infiltration, increased erosion, and increased surface runoff. Decreased aggregate stability is associated with decreased microbial activity due to habitat loss.

Aggregate stability is heavily impacted by soil texture. For example, sandy soil would be expected to have less aggregate stability than clay soil because sand does not have a charge and does not form chemical bonds with other soil particles.

Slake Slump Aggregate Stability Test Kit

SLAKE TEST

Items: Tap water, mason jar, wire basket.

Prep time: 48-hour aggregate airdry.
Test time: 5 minutes.

Method: Find an aggregate on the soil surface about 1 inch in diameter. Allow the aggregate to air dry for 48 hours in a warm, dry location. Do not place in an oven, this can affect the result. When aggregate is dry, place a wire basket in a mason jar. SLOWLY and GENTLY place the air-dried aggregate in the basket.

Observe how much of the aggregate breaks down and falls through the basket within 5 minutes. Can perform on just one sample or compare different soil types or different management practices. Demonstrations typically use 1 aggregate per field or management type.

Collect 5 – 10 aggregates per field, up to five acres
Record and rank aggregate breakdown according to the following chart (Table 1).

Table 1. Ranking scale for the slake test. Modified from the scale for the Aggregate Stability Test Kit.

Rank	Criteria
0	The soil immediately disintegrates and falls through the mesh.
1	50% or more of the soil falls through the mesh within the first five seconds.
2	50% or more of the soil falls through the mesh within 5 – 30 seconds.
3	50% or more of the soil falls through the mesh within 30 seconds to 5 minutes.
4	10 – 25% of soil remains in the basket at 5-minute mark.
5	25-75% remains in the basket at 5-minute mark.
6	75 – 100% remains in the basket at 5-minute mark.

Interpretation: Imagine dry soil in summer receiving rainfall. Water rushes inside the aggregates, displacing and trapping air. Internal pressure to build up. This can cause an unstable aggregate to fracture and break down. Some soils will not have any aggregates large enough for this test. The lack of large aggregates could indicate a history of soil disturbance or a sandy soil. Some aggregates will break down almost immediately. This indicates poor aggregate stability. If large aggregates are formed but don't hold together, the soil is likely low in soil organic matter. The more that the aggregate holds together, the better.

Caveat: If the aggregate holds together until the end of the test, break it open. If it is dry inside, this is a bad sign. The aggregate held together, but water was not able to enter the aggregate. This soil will have issues with compaction, water infiltration, and water retention.

SLUMP TEST

Items: Tap water, mason jar, dish strainer, splat board.

Prep time: none
Test time: 1-2 minutes

Method: Take a handful of surface soil. Crumble so any large aggregates are ½ cm diameter. Place in a dish strainer. Place the strainer in a jar of water to wet the soil for one minute. Flip strainer over onto the splat sheet.

Observe how well the soil holds the form of the strainer, and how much the base spreads out.

Interpretation: If the soil looks like pudding and

spreads out, it has poor aggregate stability. If the aggregates hold together and form a structure that looks closer to a lava cake, it has good aggregate stability.

AGGREGATE STABILITY TEST KIT

Items: Distilled water, aggregate stability test kit box, stopwatch, mist bottle for dry soils.

Prep time: 1.5 hours total. 30 minutes to collect samples and 1 hour to airdry after samples are collected.

Test time: 10 – 20 minutes.

Method:

1. Randomly collect 9 aggregate samples from the soil surface and 9 aggregate samples from the depth of typical/historical disturbance. Ideally from up to 2 acres, maximum up to 5 acres. Aggregates should be 6 – 8 mm in size (Half the width of the average pinkie fingernail; 0.6 – 0.8 cm. There are 2.5 cm in an inch.)

2. Place samples in each sieve in the first box. Allow to air dry for one hour. Best to complete this test in the field. Jostling during transportation back to the office will break aggregates.

3. Once dry, fill the second, empty box with distilled water to a depth of 2 cm.

4. Before placing samples in water, note that each sample must be observed at 5 seconds, 30 seconds, and 5 minutes using the assessment chart (Table 2). At the 5-minute mark, sieves must be dipped in and out of water five times.

To hit these time points, gently place 9 sieves with their aggregates in the cells filled with water 30 seconds apart. By the time you complete the 9th sample, it will be almost time to begin the 5 minute read on the first sample. Use values 0 – 3 on Table 2 for readings in the first 5 minutes.

5. Once the 5 minute read is collected using values 0 – 3, move each sieve up and down five times, removing it fully from the water each time. It should take 1 second to remove the sieve, and 1 second to replace the sieve, for a total of 2 seconds per up and down cycle. Be consistent. If you followed the timing, you have 30 seconds per sample to complete this step. This step is completed on all samples with greater than 10% of the original aggregate remaining.

Record the final result using values 3 – 6 on Table 2.

Table 2. Soil stability ranking table. Original table source is Herrick et al., 2001.	
Rank	Description
0	Soil too unstable to sample*
1	50% of the sample breaks down within 5 sec
2	50% of the sample breaks down in 5 -30 sec.
3	50% of the sample breaks down in 30 sec – 5 min. OR < 10% of the sample remains after 5 dipping cycles
4	10 – 25% of the sample remains after dipping cycles
5	25 – 75% Of the sample remains after dipping cycles
6	75 – 100% of the sample remains after dipping cycles.

* No aggregates large enough or that hold together even if misted with water.

Interpretation: The data from the first five minutes is nearly identical to a slake test. The difference is aggregate size and volume of samples. These small aggregates are critical for soil function, and are easier to find in soils with lower clay content and increased disturbance compared to the large aggregates used in a jar slake test. This data indicates how a dry soil will initially respond to re-wetting.

The data taken after the dipping cycle represents increased force acting on the aggregate, similar to water infiltrating and draining or water running across the surface. The aggregates are wet when this step begins, and this indicates how aggregates hold up throughout a precipitation or irrigation event.

In general, a higher rank means better aggregate stability! This test is best used to look for improvements over time after a significant management practice change is made. This test can also be interesting to compare the two fields with the same management practice on different soil types, or to compare two fields with different management practices on the same soil type.

To improve the quality and interpretation of this test, consider reviewing the Herrick paper. It is easy to read and understand.

Soil Compaction - Physical

Background

Compaction is measured in PSI, pressure per square inch. The PSI indicates structure and pore space. Fluffy, chocolate cake soil is less compact. Pudding cup soil is more compact.

Compaction is affected by soil texture and management. Clay soils are likely to be more compact than sandy soils. Small clay particles clog up soil pores, increasing compaction.

Tillage is a temporary fix for compaction. Tillage creates a fluffy structure at first, but that structure will collapse within the growing season. Tillage breaks up the components that maintain fluffy, well-structured soils: roots, channels created by roots, channels created by soil fauna, fungal hyphae, and biological glues released by fungi and bacteria.

Foot and vehicle traffic will also compact soils from the surface pressure. This includes farm equipment, vehicles, human walking paths, fields used for athletic activities, and grazing animals on pasture. Soils are more susceptible to compaction from this surface pressure when they are wet. A single, significant compaction event – such as using a wet field as a parking lot – could result in long-lasting compaction evident over 20 years or more.

Soil compaction is also connected to aggregate stability. Increased aggregate stability is associated with decreased compaction.

As PSI increases, compaction increases. As compaction increases:

1. Root growth decreases. Root exploration comes to a halt at or above 300 PSI. Once 300 PSI is reached, root growth will be limited to existing cracks or pores in the soil.
2. Water infiltration decreases. Water enters the soil slowly and drains slowly. The soil is more susceptible to ponding, runoff, erosion, drought, and waterlogging.
3. Soil aeration decreases, compromising roots and soil creatures who require oxygen for respiration.
4. Habitat decreases. Bacteria, fungi, earthworms, and insects struggle to live, and contribute less to soil structure, carbon storage, and nutrient availability for plants.

Wire Flag

Penetrometer

WIRE FLAG

<u>Items</u>: One wire flag

<u>Prep time</u>: None

<u>Test time</u>: 1 second

<u>Method</u>: Hold the flag at the top and push the wire into the ground until it bends. If the wire goes in easily to a depth of 12 inches, the soil is not considered to be compact. If the flag does not go in 12 inches, measure the length of the wire that does enter the ground before bending. This tells you where the compaction begins.

<u>Interpretation</u>: This test is short and sweet. Do you have compaction, yes or no. You can also ask: what depth does the compaction start? Compaction that begins 6 inches deep is not as bad as compaction that begins 2 inches deep. This gives you an immediate understanding of the conditions that plants are experiencing as they try to root. This also gives you an immediate understanding of how easy it might be for water to enter the soil. Where compaction starts, drainage slows down.

PENETROMETER

<u>Items</u>: Penetrometer, analog or digital

<u>Prep time</u>: None

<u>Test time</u>: 1 minute per sample

<u>Method</u>:
Push the penetrometer into the soil, using consistent pressure. Record the depth at which pressure above 300 PSI begins.

Record values at 3-inch intervals. The penetrometers have tick marks every 3 inches. Analog versus digital is subjective. Digital records the value as you go. Take 10 – 20 readings per field, up to 5 acres. Use the small tip for hard or rocky soils.

<u>Interpretation</u>: Compaction is ranked as good (0 – 200 PSI) elevated (200 – 300 PSI) or bad (over 300 PSI). Use these readings for detailed quantification of compaction relative to depth.

Caveat: Don't overemphasize the precise number from the digital penetrometer. Soil moisture and your personal downforce on the penetrometer will affect the precise number. To track changes over time, the digital penetrometer is better if values are assessed with the understanding that they can have a significant, but poorly defined, margin of error.

Water Infiltration - Physical

Background

Water infiltration is simply the rate at which water enters the soil, typically measured as inches per hour. If water cannot quickly and easily enter the soil, bad things happen:

- Water runs across the soil surface, eroding the soil and carrying nutrients with the water; this steals topsoil, results in less nutrients for plants, and contributes to environmental pollution.
- Less water is stored in the soil to support plant growth, so more frequent irrigation is required.
- It is easier for drought conditions to develop, and harder to reverse drought.
- Ponding is more likely to occur in low-lying areas, producing difficult wet spots that stunt plants and encourage disease.

Water Infiltration Ring

WATER INFILTRATION RING

Items: Infiltration ring, mallet, wood block, tap water, graduated cylinder, plastic wrap, stopwatch.

Prep time: 5 minutes

Test time: 1 hour

Method: Remove any large debris from the soil surface. If measuring a grass system, leave the grass. The grass and thatch will affect the infiltration rate.

Place the wood block over the infiltration ring. Hit the block with the mallet to drive the ring into the ground without bending it. Uniformly drive the ring into the ground until it is three inches deep. Gently press soil around the inside of the ring to eliminate any gabs that formed.

Drape plastic wrap over the ring, covering the soil. Using the graduated cylinder, add 444 ml of water to the ring on top of the plastic wrap. This is equivalent to adding 1 inch of water. When ready, pull the plastic wrap away letting all the water enter the ring and come into contact with the soil. Start the timer. Record how long it takes for the water to fully enter the soil.

This test is time consuming, and there can be a lot of variation. 1 test gives a nice estimate.

To increase the quality of the test, repeat it several times throughout the field.

Interpretation: Consider rain events in New England. Is the soil able to handle a summer rainstorm, a fall Nor'easter? Consider our hilly landscape. Is a pasture, cropland, golf course, or garden on a hillside extra-susceptible to runoff due to poor infiltration rates?

Measuring water infiltration is a great way to identify risks and set priorities. Poor water infiltration is associated with compacted soils, poor aggregate stability, and low soil organic matter. This information can help prioritize which fields are most in need of soil-health minded management.

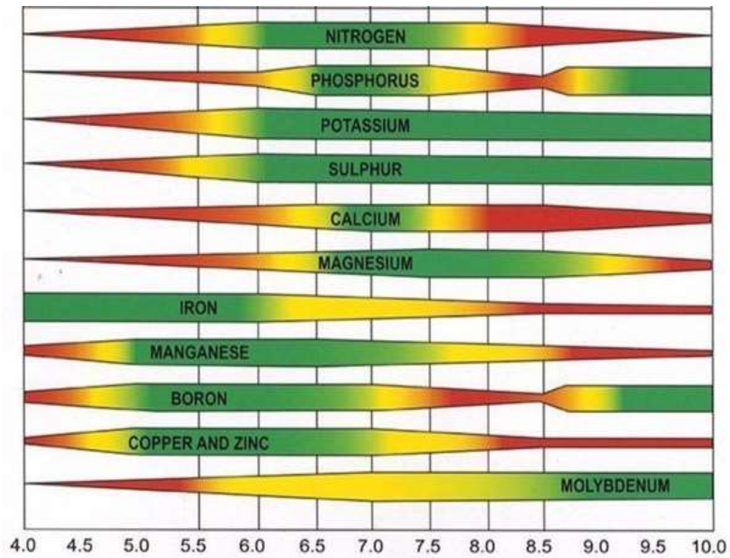
Soil type will affect infiltration rate. Sand has the largest infiltration rate potential (nearly an inch per hour) and clay has the smallest infiltration rate potential, less than 1/5th of an inch per hour. Loamy soils are in the middle, around ½ in per hour.

Caveat: Soils that are bone dry will initially have a lower infiltration rate, but the rate will improve after some water has time to work its way in. Soils that are very wet will be too saturated to accept more water, also resulting in a low infiltration rate. Consider the question you are asking. Do you want to know how a field will accept water when it is bone dry? Do you want to know if a soil is so saturated it can't accept any more water? Do you want to get an assessment of "normal" infiltration? If you want a "normal" assessment, pre-wet the area if it is excessively dry before beginning the test.

pH – Chemical

Background

Soil pH impacts plant available nutrients. For example, when we measure calcium with a laboratory test, there is far more calcium in the soil than what we measure; the laboratory test measures calcium in a form that plants can easily access.



Each plant nutrient has an optimum pH. Some plants are said to be "acid-loving", meaning they like a low pH. In fact, these plants, like blueberries and rhododendrons, like iron, which is more available at low pH.

A quick soil pH test can help identify fertility problems. But, a good pH does not mean that a soil definitely has enough nutrients. For example, a soil may have a pH of 6.5 where phosphorus and potassium are very available to plants, but the soil could still be deficient in phosphorus and potassium simply because these nutrients have not been added to the soil.

However, a low pH result is a quick indication that there is a problem to be solved. In New England, soils are naturally acidic due to rainfall and the original materials that our soils are made out of. To increase the pH, we add lime.

How much lime? You need a proper soil test for that.

Why? Some soils are more stubborn than others. Stubborn soils have more "exchangeable acidity", and it takes more lime to raise the pH of a stubborn soil. This is why two people could have a pH of 5.5 but get different lime recommendations after a laboratory soil test. Measuring exchangeable acidity requires chemicals found only in a laboratory setting.

To better understand lime and pH, review the factsheets linked at the end of this document, reach out to the UMass Soil Health Educator, or reach out to the UMass Soil and Plant Nutrient Testing Laboratory.

pH Soil Slurry & Test Strip pH Test

SOIL SLURRY & TEST STRIP pH TEST

Items: distilled water, cup, pH test strip, soil probe, bucket, ½ measuring cup.

Prep time: 25 – 45 minutes total. 10 – 30 minutes to collect a soil sample, depending on field size, plus 15 minutes for the soil slurry to sit before testing.

Test time: 5 seconds.

Method: Soil pH can be conducted on a field up to 20 acres. Randomly collect approximately 20 soil samples using a soil probe, mixing them together in a bucket as you go. Sample distinct sub areas separately. For example, uphill versus downhill, a garden bed versus a lawn area.

Mix the 20 samples together very well in the bucket. Using the ½ measuring cup to scoop up some well-mixed soil and place it in a cup. Fill the ½ measuring cup with water and add it to the soil to create a 1:1 ratio. Mix well. A stick, pen, pencil, or finger are all acceptable mixing tools. Allow the mixture to sit for 15 minutes.

After 15 minutes, the soil particles will settle to the bottom of the cup. Dip a soil pH strip into the liquid and determine the pH using the color chart on the pH strip box.

Interpretation: A pH of 6.5 - 7 is considered ideal for most crops (excluding iron-lovers, like blueberries and azaleas). A pH of 6 indicates that lime will be needed, but pH is probably not a major, limiting factor. A pH below 6 indicates that pH is a significant limiting factor for plant growth. The lower, the more problematic.

Soil with a pH below 6 is in need of lime, and a soil test is recommended to provide specific guidelines.

Caveat: Could you apply lime without a lab test and recommendation? Sure. In some case,s it might even be a good idea to get a jump start. But there is nuance, and too much lime creates new problems. Ask the UMass soil health educator or the UMass testing laboratory for help if you think applying lime before/without getting a soil test might make sense (i.e. pH is very low).

For iron-loving plants, a pH of 4.5 is ideal. Lowering pH is an easier approach than raising pH. You don't need to know reserve acidity, and if you take a good soil sample, you could skip the lab test. If pH needs to be lowered, follow the sulfur application recommendations found here:

https://ag.umass.edu/sites/ag.umass.edu/files/fact-sheets/pdf/spttl_3_adjusting_soil_ph_0.pdf

Soil Critters - Biology

Background

Soil biology affects many processes in the soil ecosystem including nutrient dynamics, disease, and soil structure. Bacteria and fungi are responsible for decomposition of organic residues, transforming organic and mineral nutrients into plant-available forms and promoting soil aggregation through the release of various organic glues, among their many other activities. On the other hand, microbes can also release greenhouse gases into the air, cause plant disease, and compete with plants for resources. Additionally, diverse microbial ecosystems are difficult to directly observe. While there are research-focused lab tests which can usefully distinguish between management induced soil health differences *in the same soil*, there are not yet standard biological benchmarks for a healthy soil.

Instead, soil biological health can be qualitatively assessed by looking for visual indications of a robust soil ecosystem. Often, this means looking for evidence of larger animals which feed on microbes rather than the microbes themselves.

Caveat: Soil life is highly sensitive to environmental conditions. It's very important to understand soil biological observations as a snapshot of the soil. Additionally, soil life must be thought of in the context of a soil's function. For instance, the same earthworms in a forest soil may cause excessive decomposition of surface residues while they could serve an important role in tilled fields by creating macropores for water movement and root growth.

EARTHWORM SAMPLING AND IDENTIFICATION

Items: Shovel, magnifying glass, earthworm identification book, tap water, mustard powder.

Prep time: 10 minutes

Test time: 10 minutes

Method: Dig a one square foot hole 12 inches down. Collect the soil from the hole on a tarp. Mix 2 tablespoons of mustard powder into one half gallon of tap water. Pour water and mustard into the bottom of the hole. Count and identify the worms from the removed soil as well as any that came into the hole after mustard application.

Interpretation: Finding more than 10 worms likely means that there is a fairly health soil ecosystem. While in many cases a high worm population is indicative of a healthy soil, almost all earthworms in New England are introduced species that are not necessary for biological soil health. In fact, some can even be very disruptive in forest ecosystems. If you don't find many worms but the soil and larger ecosystem otherwise looks good, it's not anything to worry about.

Jumping worms (*Amynthas* spp. and *Metaphire* spp.) are of particular note currently because they are relatively new to the area and their long-term impact on New England ecosystems is unknown. They can be identified by the fact that the clitellum (the band or belt close to the head) wraps entirely around the worm's body rather than looking like a saddle on other Massachusetts worms. Jumping worms are also very wiggly and have bristles that can be seen with a magnifying glass. Detailed identification of earthworm species can be useful since different species have different soil habitats and activities.

FUNGAL OBSERVATION

Items: Shovel, magnifying glass.

Prep time: Less than one minute to collect a shovel of soil.

Test time: 5 minutes to carefully examine soil

Method: After collecting a shovel of soil, carefully break apart aggregates looking for fungal hyphae. Many soil fungi live most of their lives as networks of thread-like hyphae which often look like very fine white roots. Look near the roots of plants as many mycorrhizal soil fungi form partnerships with plants.

Interpretation: Like most soil biology, fungal hyphae are sensitive to environmental conditions and may be more or less visible depending on the time of year or soil moisture. It's not uncommon for there to be little visible fungal growth in the spring and late fall even in a healthy New England soil.

NODULATION OBSERVATION

Items: Shovel, magnifying glass, legumes.

Prep time: Less than one minute to dig up a legume.

Method: Gently remove soil from the roots of the legume. Look for pink lumps attached to the roots.

This method requires that legumes are present. The legumes could be a crop such as beans or clover, a cover crop such as field peas, or a weed such as white clover or alsike clover (note, oxalis species are commonly confused as legumes, but they are in the wood sorrel family and are not legumes).

Interpretation: The nodules are the creation of legume plants and rhizobia bacteria. Together these organisms turn nitrogen in the air into a plant-available nutrient. They are generally not found below about 50°F or when large amounts of nitrogen fertilizer or manure are applied. This test would be most useful for assessing different sections of a field where different plant growth was observed.

BIOPORE OBSERVATION

Items: Shovel, magnifying glass.

Prep time: Less than one minute to collect a shovel of soil.

Test time: 5 minutes

Method: Examine the soil surface for biopores. Looking under leaves and residue. Carefully dig up a shovel of soil and look at the soil profile for biopores. The biopores are generally one to several millimeters across and will look like small tubes going through the soil.

Interpretation: Biopores are a useful indicator of biological activity because they remain visible for some time after an animal has made them. This means that biopores are more consistent over the course of a day.

INSECT OBSERVATION

Items: Shovel, magnifying glass.

Prep time: Less than one minute to collect a shovel of soil.

Test time: 5 minutes

Method: Directly observe the soil surface looking under leaves and residue. Dig up the top few inches of soil and gently break it apart looking for invertebrates. Notable animals may be collected for further identification.

Interpretation: A warm and healthy soil will have some invertebrates in it. Finding different types of insects or spiders is a better sign that the ecosystem is functioning well than finding lots of one kind of animal. Consider that some invertebrates can cause severe damage to plants, so even though cutworms and slugs may be indicators of a robust soil ecosystem, they may still be unwelcome.

Additional Resources

Soil Test Items

Soil Probes – for collecting samples for a routine fertility test.

Spade – for conducting samples for laboratory soil health tests.

References

USDA NRCS In Field Soil Health Assessment Guide, 2019

https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=44419.wba

USDA NRCS Soil Quality Test Kit Guide, 2001

https://www.nrcs.usda.gov/sites/default/files/2022-10/Soil%20Quality%20Test%20Kit%20Guide.pdf

Guide to Texture by Feel

https://www.nrcs.usda.gov/sites/default/files/2022-11/texture-by-feel.pdf

Mason Jar Soil Texture Test

https://extension.unl.edu/statewide/lincolnmcpherson/Soil%20Texture%20Analysis%20%E2%80%9CThe%20Jar%20Test%E2%80%9D.pdf

USDA Web Soil Survey

https://websoilsurvey.nrcs.usda.gov/app/

UMass Soil and Plant Nutrient Laboratory Sample Test Forms

https://ag.umass.edu/services/soil-plant-nutrient-testing-laboratory/ordering-information-forms

Field soil aggregate stability kit for soil quality and rangeland health evaluations. Herrick et al., 2001.

https://www.ars.usda.gov/ARSUserFiles/30501000/SoilAggStabKit.pdf

UMass pH Factsheet and Directions to Lower pH

https://ag.umass.edu/sites/ag.umass.edu/files/fact-sheets/pdf/spttl_3_adjusting_soil_ph_0.pdf

Crop codes for soil tests:

https://ag.umass.edu/sites/ag.umass.edu/files/fact-sheets/pdf/spttl_10_master_crop_code_list_1.pdf

Forms

The following sleeves contain forms. Please help yourself.

Forms include:

Site visit data sheet

Aggregate Stability Test Kit data sheet

Soil Compaction (penetrometer) data sheet

Laboratory Sample: Routine Soil Test form

Laboratory Sample: Soil Texture