Soil Compaction Mitigation Guide

NOFA/Mass
Northeast Organic Farming Association
Massachusetts Chapter

MDAR
MASSACHUSETTS DEPARTMENT OF AGRICULTURAL RESOURCES

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Introduction

Project Overview

Our project, funded with FY2020 Specialty Crop Block Grant Program funds from the Massachusetts Department of Agricultural Resources (MDAR), is dedicated to accelerating soil health through compaction mitigation. This resource booklet serves as a comprehensive guide to the project's objectives, methods, and outcomes.

Project Purpose

Our project aims to address a timely and crucial issue faced by Massachusetts farmers - soil compaction. In the ever-evolving landscape of agriculture, the vitality of our soil is paramount, and soil compaction presents a formidable challenge. This section provides in-depth insight into why this project is not only essential but also pivotal in the current agricultural landscape.

The Challenge of Soil Compaction

Soil compaction is an enduring obstacle that threatens the health and productivity of our agricultural lands. It occurs when the soil particles are compressed, reducing pore space and restricting the movement of air, water, and essential nutrients. While it affects farms across the nation, Massachusetts farmers, in particular, face the unique challenge of managing diverse soil types, from sandy soils prone to erosion to heavier clay soils with higher compaction risks.

A Threat to Farm Viability

The persistence of soil compaction poses a direct threat to the viability and sustainability of our farms. Compacted soils impede root growth, limiting the access of crops to vital resources and reducing yields. Inefficient water infiltration exacerbates the impact of droughts, and poor aeration promotes anaerobic conditions detrimental to beneficial soil microorganisms. Over time, these compaction-related issues can lead to decreased farm income, increased resource inputs, and, ultimately, the decline of our agricultural heritage.

Climate Change Resilience

In an era marked by the challenges of climate change, addressing soil compaction is a crucial component of building climate resilience in our farming communities. Healthy soils act as carbon sinks, sequestering carbon dioxide and mitigating the effects of greenhouse gas emissions. By improving soil structure and mitigating compaction, we not only enhance the productivity of our farms but also contribute to broader efforts to combat climate change and adapt to its impacts.

Empowering Massachusetts Farmers

Our project is rooted in the belief that knowledge is the key to overcoming challenges. By fostering a Farmer Learning Cohort and engaging project advisors, we empower Massachusetts farmers with the knowledge and tools needed to combat soil compaction effectively. Through peer-to-peer learning, data collection, and comprehensive education, we enable farmers to make informed decisions about soil management, ultimately enhancing their farm's resilience, sustainability, and profitability.

Agriculture's Vital Role

Agriculture is the bedrock of our communities, providing essential sustenance, economic stability, and a connection to our environment. Addressing soil compaction is not just about improving farm yields; it's about safeguarding our food supply, preserving our land for future generations, and fortifying the foundation of our agricultural legacy.

In summary, our project's purpose goes beyond mitigating soil compaction; it is about securing the future of Massachusetts farming by fostering resilience, sustainability, and innovation. Through collaboration, education, and the dissemination of knowledge, we aim to ensure that our farms continue to thrive in the face of evolving challenges, thereby enriching our communities and protecting the land we cherish.

Project Details

Project Background

The agricultural landscape of Massachusetts has a rich history dating back centuries, with farms playing a vital role in the development of local communities and the state's overall prosperity. Over time, these farms have adapted to changing conditions, adopting new practices and technologies to optimize crop yields and maintain soil health.

Historically, Massachusetts farms were characterized by a diverse range of crops and livestock, with many adopting traditional tillage methods. These methods, while effective in the short term, gradually led to a phenomenon that is now recognized as a critical issue in modern agriculture: soil compaction.

Soil compaction, often referred to as the silent yield robber, began to emerge as a pressing concern in the mid-20th century as farms sought to increase production to meet the demands of a growing population. As farms expanded and mechanization became commonplace, the heavy machinery used for planting, harvesting, and other activities inadvertently compacted the soil.

This compaction, which primarily affects the topsoil layers, significantly alters the soil's physical properties. It reduces pore space, restricts root growth, limits water infiltration, and hinders nutrient availability. As a result, crop yields started to plateau, and farmers faced diminishing returns on their investments.

The emergence of soil compaction as a critical issue in modern agriculture is not unique to Massachusetts; it mirrors a global trend. Farmers worldwide have grappled with the consequences of soil degradation caused by compaction, leading to decreased agricultural productivity and environmental challenges.

In the context of Massachusetts, the need to address soil compaction has become increasingly urgent due to the state's vulnerability to the impacts of climate change. Extreme weather events, such as prolonged droughts and heavy rainfall, have become more frequent, posing a threat to crop yields and farm resilience. Soil compaction exacerbates these challenges by limiting the soil's ability to retain water and withstand extreme weather conditions.

Recognizing the historical significance of agriculture in Massachusetts and the emerging threat of soil compaction, this project aims to empower farmers with the knowledge and tools needed to combat this issue. By delving into the historical context and tracing the evolution of farming practices that contributed to soil compaction, we can better understand the urgency of addressing this issue and preserving the agricultural heritage that has shaped the state.

Project Significance

The significance of this project extends far beyond its immediate goals. It addresses critical issues that resonate with the broader context of agriculture, climate resilience, and the pivotal role of farms in Massachusetts.

Climate Resilience

In an era marked by climate change and unpredictable weather patterns, the resilience of agricultural systems is paramount. Massachusetts, like many regions globally, is experiencing more frequent and severe weather events, such as droughts, storms, and temperature extremes. These conditions place tremendous stress on farmers who must adapt to maintain crop yields and sustainability.

Soil compaction exacerbates the challenges posed by climate change. Compacted soils have reduced water-holding capacity, making them less capable of withstanding prolonged droughts. Additionally, compacted soils struggle to absorb heavy rainfall, leading to increased runoff and erosion. This not only affects crop productivity but also contributes to water pollution and sedimentation of water bodies.

By addressing soil compaction and promoting practices that improve soil structure and health, this project contributes significantly to climate resilience in Massachusetts agriculture. Resilient soils can better retain moisture during droughts and drain excess water during heavy rainfall, reducing the risks associated with extreme weather events. Moreover, healthy soils sequester carbon, mitigating greenhouse gas emissions and contributing to climate change mitigation efforts.

Role of Agriculture in Massachusetts

Agriculture has deep roots in Massachusetts' history, culture, and economy. Beyond its vital role in providing fresh, locally grown food, agriculture plays a pivotal role in shaping the character of rural communities and preserving open spaces. Farms in Massachusetts contribute to tourism, heritage preservation, and the overall quality of life for residents.

However, the viability of Massachusetts agriculture is at risk. Rising land prices, changing consumer preferences, and the aforementioned challenges of climate change and soil compaction threaten the sustainability of farms across the state. By addressing soil compaction and enhancing soil health, this project directly supports the longevity and success of farms in Massachusetts.

The project also aligns with the state's broader agricultural and environmental goals, including initiatives to reduce greenhouse gas emissions, improve water quality, and promote sustainable land management. It contributes to the state's vision of a vibrant and resilient agricultural sector that can thrive in the face of evolving challenges.

In summary, the significance of this project goes beyond addressing soil compaction; it encompasses climate resilience, the preservation of agricultural heritage, and the realization of broader state objectives. By promoting sustainable soil management practices and equipping farmers with the knowledge and tools needed to combat soil compaction, this project stands as a beacon of progress in ensuring the future sustainability of agriculture in Massachusetts.

Project Advisors

This section introduces the esteemed project advisors who bring a wealth of knowledge and expertise to guide and support our soil compaction mitigation project. Each advisor plays a crucial role in shaping the project's direction and ensuring its success.

Maggie Payne - Resource Soil Scientist, MA NRCS

Maggie Payne is a prominent figure in the field of soil science and resource management. As a Resource Soil Scientist with the Massachusetts Natural Resources Conservation Service (NRCS), her role in the project is indispensable. Maggie specializes in understanding soil structure and physical properties, making her a valuable asset for evaluating soil health-related practices. Her deep understanding of NRCS programs and resources for farmers adds a crucial layer of expertise to our project. Maggie actively participates in quarterly calls, serves as a guest expert and educator, and shares insights that directly contribute to the project's success.

Kate Parsons - Resource Conservationist, MA NRCS
Kate Parsons brings her extensive experience as a Resource Conservationist with the Massachusetts NRCS to the project. Her active involvement in quarterly calls, as a guest expert, and as an educator enhances our project's educational components. Kate's primary focus lies in promoting soil health practices and reducing tillage. Her deep knowledge of NRCS programs and resources for farmers is instrumental in guiding our project participants toward sustainable soil management practices.

Laura Maul - Environmental Analyst, Conservation & Technical Assistance
Laura Maul, an Environmental Analyst specializing in Conservation & Technical Assistance, plays a unique role in our project. Her role involves contributing to a statewide perspective on farmer practices and equipment for soil health improvement. Laura is a regular participant in our quarterly calls, demonstrating her keen interest in understanding what works best for farmers. Her affiliation with the *Massachusetts Department of Agricultural Resources (MDAR)* ensures that our project aligns with state-level initiatives. Laura's insights help inform our ACRE grant narrative, proposal evaluation, and outreach efforts.

Julie Fine - Crop Scientist (M.S.) specializing in cover crops for soil health; Sales representative for Johnny's Selected Seeds
Julie Fine is a seasoned Crop Scientist with a master's degree specializing in cover crops for soil health. Her dual role as a sales representative for Johnny's Selected Seeds further enhances her expertise in practical applications. Julie actively participates in our quarterly calls, where she serves as a guest educator in conferences, webinars, and events. Her deep knowledge of cover crop applications for compaction mitigation, especially in low-till systems, enriches our project's educational components.

These project advisors, with their diverse backgrounds and extensive expertise, provide invaluable guidance and support. Their active involvement in the project ensures that we are equipped with the latest insights and resources to effectively combat soil compaction and promote soil health among Massachusetts farmers. Their contributions not only enhance the project's outcomes but also foster a collaborative environment where knowledge sharing and innovation thrive.

Introduction to the Cohort

At the heart of our soil compaction mitigation project lies the **Farmer Learning Cohort**. This section serves as a captivating gateway into the essence of our cohort, introducing its members, their backgrounds, and the diverse tapestry of farms they steward across the picturesque landscapes of Massachusetts.

Our Farmer Learning Cohort is a dynamic assembly of agricultural visionaries, each with a unique story and a shared commitment to enhancing soil health and resilience. Within this cohort, we find a tapestry of experience, knowledge, and passion that collectively propels our project forward.

Simple Gifts Farm, Amherst - Jeremy Barker-Plotkin:
Jeremy, a dedicated farmer, cultivates a vibrant tapestry of vegetables, beef, pork, and eggs. His farm boasts an array of tools and practices, including the 3-point hitch subsoiler, plow, perfecta, and a grazed pasture fallow rotation every three years.

Many Hands Organic Farm, Barre - Julie Rawson:
Julie oversees a thriving ecosystem of vegetables, poultry, beef, pork, eggs, and fruit. Her farm implements innovative practices like the ripper/shallow chisel plow, intercropped cover crops, and wood chip mulching.

Woven Roots Farm, Tyringham - Jen Salinetti:
Jen is a passionate grower of vegetables, employing techniques such as broadforking, tilther, and sheet mulching to enrich her farm's soil.

Just Roots Farm, Greenfield - Meryl Latronica:
Meryl focuses on cultivating vegetables and is in the midst of transitioning into a no-till system with mulching. Her farm utilizes tools like the chisel plow, disc harrow, and perfecta harrow.

Appleton Farm, Hamilton/Ipswich - Andrew Lawson:
Andrew manages a diversified farm, encompassing vegetables, dairy, beef, and hay. His arsenal of tools includes the farmet high-speed disc/softer harrow, chisel plow, and a no-till drill.

Global Village Farm – Ulum Pixan:
Ulum's farm thrives with vegetables, fruit trees, and eggs, where she practices sheet mulching on permanent beds.

Freedom Food Farm, Raynham - Chuck Currie:
Chuck tends to a variety of vegetables, beef, lamb, and pork, using innovative techniques such as roller-crimped cover crops and a grain drill.

As readers delve into the profiles of each cohort member and their respective farms, a vivid tapestry emerges—a tapestry woven with dedication, diversity, and a shared commitment to combatting soil compaction. These farmers are the architects of change, leading the charge towards healthier, more resilient soils and a sustainable future for Massachusetts agriculture. Their stories, experiences, and dedication form the bedrock of our project, and their collective wisdom promises to illuminate the path forward for soil health improvement in the region.

Cohort Objectives

The Farmer Learning Cohort is a dynamic and purpose-driven group, bound together by a shared commitment to address the critical issue of soil compaction. To achieve this mission, our cohort has meticulously outlined specific objectives that encompass both data collection and educational events, forging a comprehensive approach to tackling soil health challenges in Massachusetts.

Project Objectives

The following objectives were developed as a part of the original project proposal and underscore the dedication by NOFA/Mass and the Farmer Learning Cohort to holistic soil health improvement. By combining data-driven research with educational outreach, the cohort aimed to drive positive change in Massachusetts agriculture, fostering healthier soils, greater resilience, and sustainable farming practices.

Objective 1: Observe soil hardness, density, and infiltration rate on a diverse set of farms, with the goal of tracking which practices result in the greatest improvement in soil structure over three years.

The primary focus of this objective revolved around data collection. The Soil Health Technical team at NOFA/Mass recorded and monitored crucial soil parameters such as hardness, density, and infiltration rate. Over a span of three years, this data was accumulated and analyzed meticulously to uncover the most effective practices that lead to a tangible improvement in soil structure and health.

Objective 2: Increase farmer awareness and understanding of persistent soil compaction, its relation to water infiltration rate, and its variability over time.

Beyond data collection, our cohort recognized the paramount importance of education. This objective aimed to elevate farmer awareness and understanding of the complex issue of soil compaction. Farmers gained insights into the relationship between compaction and water infiltration rates, as well as the variability of compaction over time. This knowledge empowers farmers to make informed decisions about their land management practices.

Objective 3: Educate farmers about tools and methods for evaluating soil structural issues.

Education is a cornerstone of our cohort's mission. Farmers were equipped with the practical knowledge of tools and methods to evaluate soil structural issues. They gained proficiency in assessing soil health, enabling them to identify areas of concern and make informed adjustments to their farming practices.

Objective 4: Educate farmers about practices that are effective in alleviating compaction and improving soil structure.

Building on the foundation of understanding and evaluation, the cohort delved into actionable solutions. Farmers were educated on practices with proven effective in mitigating compaction and enhancing soil structure. The objective was to empower farmers with a toolkit of practices that can be implemented on their farms, fostering long-term soil health improvement.

Objective 5: Disseminate the Compaction Mitigation Resource Booklet to a wide audience of growers, to increase awareness of soil structural issues and the effectiveness of different implements and practices to improve soil structure over time.

Our cohort is committed to spreading knowledge far and wide. The culminating project outcome is this Compaction Mitigation Resource Booklet that encapsulates the insights gained from data collection, education, and real-world experiences. This booklet serves as a beacon of information, distributed to a wide audience of growers, to raise awareness about soil structural issues and provide practical guidance on the effectiveness of various implements and practices for soil improvement.

Understanding Soil Compaction

What is Soil Compaction?

Soil compaction refers to the compression and reduction of pore spaces within the soil, resulting in increased soil density. This condition occurs when external forces, such as heavy machinery, livestock traffic, or even natural processes like rainfall, press down on the soil, causing the soil particles to come closer together. Soil compaction can have significant implications for agricultural productivity and overall soil health. Key points to understand about soil compaction include:

• Impact on Soil Structure: Soil compaction alters the natural structure of the soil, reducing the space available for air and water movement. This, in turn, affects the soil's ability to support plant growth and nutrient uptake.

• Reduction in Infiltration: Compacted soils have reduced infiltration rates, meaning they struggle to absorb and retain water efficiently. This can lead to water runoff, eutrophication, erosion, and increased vulnerability to drought.

• Impact on Root Growth: Compacted soils restrict root penetration and growth. This limitation hampers the ability of plants to access nutrients and water from deeper soil layers.

• Affects Microbial Activity: Soil compaction can negatively impact the soil's microbial communities, which play a crucial role in nutrient cycling and overall soil health.

• Management Challenges: Farmers often face challenges in managing compacted soils. Traditional tillage practices can exacerbate compaction, leading to a vicious cycle of increased tillage and compaction, ultimately leading to yield reductions and environmental degradation.

Common Misconceptions

To effectively address soil compaction and its mitigation, it's essential to dispel common misconceptions that can hinder progress, which include the following:

Misconception 1: It's Only a Surface Issue

One common misconception is that soil compaction only affects the top layer of soil. In reality, compaction can extend much deeper into the soil profile, impacting root growth and nutrient availability in subsurface layers.

Misconception 2: Compaction is Irreversible

While severe compaction can be challenging to remediate, it's not always irreversible. There are effective strategies and practices, such as deep tillage, cover cropping, and organic matter incorporation, that can gradually improve soil structure over time.

Misconception 3: All Equipment Causes the Same Compaction

Different farm equipment exerts varying levels of pressure on the soil. It's a misconception to assume that all machinery will lead to the same degree of compaction. Understanding the specific impacts of equipment and managing their use accordingly is crucial.

Misconception 4: Compaction is Only an Issue for Large Farms

Soil compaction can affect farms of all sizes, from small-scale operations to large commercial farms. The extent of the problem may vary, but the principles of compaction mitigation apply universally.

Misconception 5: Compaction Can Be Ignored

Some farmers may underestimate the long-term consequences of soil compaction and choose to overlook it. Ignoring compaction can lead to decreased yields, increased input costs, and reduced overall farm resilience.

Addressing these common misconceptions is essential for raising awareness about the seriousness of soil compaction and encouraging farmers to take proactive steps toward mitigation and improved soil health.

Data Collection and Analysis

In our Farmer Learning Cohort, data collection is the bedrock upon which our journey towards improving soil health is built. We understand the significance of gathering accurate, meaningful data to drive informed decision-making. This section provides valuable insights into our data collection process, encompassing the tools and methods employed to observe soil conditions across our diverse set of farms.

Data Collection Tools

Our data collection efforts are supported by an array of tools designed to capture information about soil health in a general sense but more precisely compaction. These tools have been meticulously selected to ensure accuracy and consistency in our observations. They include:

Soil Hardness Tool: Penetrometer

The penetrometer is an indispensable instrument in our data collection toolkit, serving as a primary tool for assessing soil hardness and compaction levels within the Farmer Learning Cohort. Soil hardness, often referred to as soil resistance or penetrometer resistance, is a key parameter in understanding the physical condition of the soil and its ability to support healthy crop growth. Here, we will provide an in-depth look at the penetrometer, its functionality, and its role in our data collection efforts.

A penetrometer is a handheld device designed to measure the resistance encountered when a probe is inserted into the soil. This resistance is a direct indicator of soil compaction, as compacted soils tend to offer higher resistance to penetration. The penetrometer typically consists of the following components:

The penetrometer features a slender, pointed probe or rod that is inserted into the soil. This probe is equipped with a sharp tip designed to penetrate the soil surface.

Attached to the probe is a pressure gauge or digital display that registers the force required to push the probe into the soil. This measurement is recorded in units such as pounds per square inch (psi) or pascals (Pa).

The handle of the penetrometer allows the user to apply downward force on the probe while ensuring it is held vertically during insertion.

How the Penetrometer Works

The operation of the penetrometer is relatively straightforward:

• Probe Insertion: The pointed probe is inserted vertically into the soil at a controlled speed. The user applies downward pressure to overcome soil resistance and advance the probe into the ground.

• Resistance Measurement: As the probe penetrates the soil, it encounters resistance from compacted layers or hardpan. This resistance is

Application in Data Collection
In the context of our Farmer Learning Cohort, penetrometers are used to collect essential data on soil hardness and compaction levels. Soil technicians regularly employ penetrometers to assess the state of their soils at varying depths. Here's how the penetrometer fits into our data collection process:

Baseline Assessments
During the initial baseline data collection phase, technicians use penetrometers to gauge soil hardness at specified depths across their fields. This establishes a starting point for monitoring changes over time.

Periodic Measurements
Technicians conduct subsequent measurements at regular intervals, typically seasonally, to track the evolution of soil compaction. This data allows us to observe trends and identify the effectiveness of soil health practices.

Comparative Analysis
By analyzing penetrometer data collectively, we can identify patterns of compaction across different farms and management practices. This information guides our educational efforts and recommendations for compaction mitigation.

Benefits of Penetrometer Data

Penetrometer data provides several key benefits within our cohort:

• Objective Assessment: Penetrometer readings offer an objective and quantitative assessment of soil hardness, eliminating subjective judgments.

• Early Detection: Changes in soil compaction can be detected early, enabling timely interventions to prevent long-term damage to soil structure.

• Data-Driven Decision-Making: The data generated by penetrometers serve as a foundation for data-driven decision-making, helping farmers adopt practices that improve soil health.

• Educational Tool: Penetrometer data is a valuable educational tool, facilitating knowledge sharing among cohort members and fostering a deeper understanding of soil compaction issues.

In summary, the penetrometer is a vital instrument in our data collection efforts, providing tangible insights into soil hardness and compaction levels. Its ease of use, accuracy, and ability to generate quantitative data make it an essential component of our comprehensive approach to addressing soil compaction challenges faced by Massachusetts farmers.

Soil Density Assessment by Core Sampling

Assessing soil density through core sampling is an essential component of our data collection strategy aimed at comprehensively understanding and addressing soil compaction issues within the Farmer Learning Cohort. Soil density, often referred to as bulk density, is a crucial parameter in evaluating soil compaction, as it directly reflects the degree of soil particles' packing within a given volume. In this section, we'll provide a detailed overview of the core sampling method, its functionality, and its role in our data collection efforts.

Core Sampling Equipment

Core sampling involves extracting cylindrical soil cores from the field for analysis. The core sampling equipment consists of the following components:

• Soil Core Sampler: This is a specialized tool designed to extract intact soil cores from the ground. It typically includes a hollow tube with a cutting edge and a handle for insertion.

• Hammer or Mallet: A hammer or mallet is used to drive the core sampler into the soil, ensuring that a complete and undisturbed core is collected.

• Core Extractor: This tool helps to extract the soil core from the sampler tube without damaging its structure.

• Measuring Tape: A measuring tape is used to record the depth at which each core sample is collected.

How Core Sampling Works

The core sampling process involves the following steps:

• Selection of Sampling Locations: Farmers identify specific locations within their fields for soil density assessment. These locations are often strategically chosen based on factors such as crop types, compaction concerns, or management practices.

• Core Sampling: Using the core sampler, technicians drive the tube into the soil at the predetermined depth. The tube's cutting edge ensures that a complete soil core is collected without disturbing the surrounding soil.

• Core Extraction: Once the core sampler is removed from the ground, the core extractor is used to gently push the collected soil core out of the tube.

• Data Collection: Technicians record key information for each core sample, including the depth at which it was collected, its location within the field, and any relevant soil characteristics.

Application in Data Collection

Core sampling plays a crucial role in our data collection process within the Farmer Learning Cohort:

• Density Assessment: Soil cores collected from various depths provide insights into soil density variations. Bulk density is calculated by weighing the extracted core and measuring its volume.

• Depth Profiling: By collecting cores at different depths within the soil profile, we create density profiles that reveal compaction trends and variations over time.
• Comparative Analysis: Data from core samples are analyzed collectively to identify areas of high or low soil density. These findings help farmers make informed decisions regarding compaction mitigation practices.

• Seasonal Monitoring: Soil technicians collect core samples periodically, allowing us to track changes in soil density over the course of the project. This longitudinal data is invaluable for assessing the effectiveness of compaction mitigation strategies.

Benefits of Core Sampling Data

Core sampling data offers several key benefits within our cohort:

• Objective Density Measurements: Core sampling provides objective and quantitative measurements of soil density, eliminating subjectivity in compaction assessment.

• Informed Decision-Making: Farmers and cohort members can make informed decisions about compaction mitigation strategies based on real-time soil density data.

• Compaction Identification: High-density areas can be pinpointed, allowing for targeted mitigation efforts where they are needed most.
•
Longitudinal Tracking: By collecting samples at multiple time points, we gain insights into compaction trends and the effectiveness of soil health practices.

• Educational Tool: Core sampling data serves as an educational tool, enhancing farmers' understanding of soil density and its implications for crop production.

In summary, the core sampling method for assessing soil density is a fundamental component of our data collection strategy. It provides valuable insights into soil compaction issues, guides data-driven decision-making, and supports the educational objectives of our project within the Farmer Learning Cohort.

Soil Infiltration Rate Assessment Method

The assessment of soil infiltration rate is an integral part of our data collection strategy aimed at comprehensively understanding and addressing soil compaction within the Farmer Learning Cohort. Infiltration rate measures how quickly water penetrates the soil, a parameter closely related to soil compaction. In this section, we'll provide a detailed overview of the infiltration method, its functionality, and its role in our data collection efforts.

Infiltration Tool

The infiltration rate is typically measured using a simple tool called an infiltration ring or infiltrometer. This tool consists of the following components:

• Infiltration Ring: The infiltration ring is a cylindrical device that is gently inserted into the soil. It is open at the top and closed at the bottom. The ring's diameter and height are standardized to ensure consistent measurements.

• Stopwatch or Timer: A stopwatch or timer is essential for recording the time it takes for water to infiltrate into the soil within the ring.

• Water Source: A container with a predetermined amount of water that equals 1 inch of rainfall is used to supply the ring with water.

How Infiltration Assessment Works

The infiltration rate assessment process involves the following steps:

• Selection of Sampling Locations: Farmers choose specific locations within their fields for infiltration rate measurements. These locations are typically chosen based on factors such as compaction concerns, drainage issues, or management practices.

• Installation of Infiltration Ring: The infiltration ring is gently inserted into the soil at the predetermined location and depth. Care is taken to ensure that the ring is level and snugly fitted into the soil to prevent water from bypassing the ring.

• Water Application: A controlled amount of water is poured into the infiltration ring, filling it to a specified depth. The level of water is carefully monitored, and the stopwatch is started as soon as water is added.

• Measurement of Infiltration: Observers record the time it takes for the water level to drop to a predetermined depth or until no further significant drop is observed.

• Data Collection: Key information is recorded for each infiltration measurement, including the location, soil type, initial water level, time of measurement, and any relevant soil characteristics.

Application in Data Collection

Infiltration rate assessment plays a crucial role in our data collection process within the Farmer Learning Cohort:

• Compaction Evaluation: Infiltration rate is closely linked to soil compaction. Slower infiltration rates often indicate compacted soils, as they struggle to absorb water quickly.

• Comparative Analysis: Data from infiltration rate measurements are analyzed collectively to identify areas with poor infiltration, helping farmers make informed decisions regarding compaction mitigation practices.

• Seasonal Monitoring: Periodic measurements allow us to track changes in infiltration rate over time, providing insights into the effectiveness of compaction mitigation strategies.

Benefits of Infiltration Rate Data

Infiltration rate data offers several key benefits within our cohort:

• Objective Assessment: Infiltration rate measurements provide objective and quantifiable data about soil compaction.

• Targeted Mitigation: Areas with poor infiltration can be targeted for compaction mitigation efforts.

• Progress Tracking: Longitudinal data helps track changes in soil conditions and assess the impact of soil health practices.

• Educational Tool: Infiltration rate assessments enhance farmers' understanding of soil compaction and the importance of soil structure for crop production.

In summary, the infiltration method, using tools such as infiltration rings, is a fundamental component of our data collection strategy. It provides valuable insights into soil compaction issues, guides data-driven decision-making, and supports the educational objectives of our project within the Farmer Learning Cohort.

Data Collection Methods

Precision and consistency are paramount in our data collection process. To achieve these objectives, we follow a well-defined methodology:

• Baseline Data Collection: At the outset of our project, baseline data on soil hardness, density, and infiltration rates are recorded on all participating farms. This initial assessment provides a clear starting point and allows us to track changes over time.

• Periodic Data Collection: Data collection is an ongoing process, spanning multiple years. Soil Technicians conduct regular assessments, typically on a seasonal basis, to monitor changes in soil conditions. This periodicity ensures that we capture the dynamic nature of soil health.

•Farm-Specific Variations: Our data collection methods are adaptable to farm-specific conditions. We recognize that each farm is unique, and as such, we tailor our approach to account for variations in soil types, crops, and management practices.

• Collaborative Data Sharing: Collaboration is a cornerstone of our cohort. Data collected by individual farmers are shared within the group, fostering collective learning and cross-pollination of ideas. This collaborative approach strengthens the quality of our dataset.

Data Analysis and Visualization

Beyond data collection, our cohort places a significant emphasis on data analysis and visualization. Raw data are transformed into meaningful insights through advanced analytical techniques. We create data visualizations, such as graphs and charts, to effectively communicate findings.

• Data Integration: Data from multiple farms are integrated into a cohesive dataset, allowing us to draw comparisons and identify trends across diverse agricultural settings.

• Identifying Compaction Patterns: Through rigorous analysis, we aim to identify patterns of soil compaction and its correlation with different farming practices. These insights are instrumental in guiding future soil health strategies.

Our commitment to robust data collection and analysis reflects our dedication to evidence-based decision-making. By employing cutting-edge tools and methodologies, our cohort is poised to uncover actionable insights into soil health, ultimately contributing to the betterment of Massachusetts agriculture.

Education

Workshops

The Farmer Learning Cohort hosted a series of workshops focused on soil health improvement and compaction mitigation. These workshops served as educational platforms where cohort members and other farmers could exchange knowledge and learn about effective practices. Key details included:

• Content: Workshops covered a range of topics related to soil health, compaction mitigation, and sustainable agricultural practices. This included discussions on soil structure, cover cropping, reduced tillage methods, and the use of specialized equipment.

• Format: Workshops were conducted in-person or virtually through webinars, depending on logistical considerations and the availability of participants. In-person workshops offered hands-on demonstrations and field visits to cohort farms.

• Target Audience: Workshops aimed to attract a diverse audience, including cohort members, local farmers, agricultural professionals, and anyone interested in soil health improvement.

Webinars

Webinars complemented the in-person workshops and served as a convenient way to disseminate information to a broader audience. Here are more details:

• Topics: Webinars covered a range of soil health and compaction-related topics. These included discussions on the results of soil health assessments, best practices in compaction mitigation, case studies from cohort farms, and expert presentations.

• Accessibility: Webinars were accessible online, making them convenient for farmers and stakeholders to participate in without the need for travel. They were live events with opportunities for Q&A sessions.

• Recordings: To maximize the reach and impact, webinar recordings were made available for later viewing on NOFA's YouTube Channel.

On-Farm Events

On-farm events were a crucial component of the project, allowing participants to witness soil health practices in action and engage directly with cohort farmers. Here's what happened during these events:

• Farm Visits: Participants had the opportunity to visit cohort farms where compaction mitigation practices were being implemented. These visits provided valuable insights into real-world applications and outcomes.

• Recordings: To maximize the reach and impact, some of the on-farm events were recorded and made available for later viewing on NOFA's YouTube Channel.

• Demonstrations: On-farm events included live demonstrations of equipment and techniques used to improve soil health and reduce compaction. Farmers learned firsthand how these practices worked on different farm types.

• Networking: On-farm events promoted networking and knowledge sharing among cohort members and attendees. Participants exchanged experiences and ideas for improving soil health on their own farms.

By offering a combination of workshops, webinars, and on-farm events, the Farmer Learning Cohort ensured that education and knowledge-sharing were accessible to a wide range of participants, fostering a vibrant learning community focused on soil health and compaction mitigation.

Project Outcomes/Conclusions

After three years of dedicated research, collaboration, and knowledge sharing within the Farmer Learning Cohort, our project has yielded valuable insights and practical solutions for addressing soil compaction in Massachusetts agriculture. The journey of discovery and the collective efforts of our dedicated farmers and project advisors have led to several notable outcomes and conclusions.

Observations

In the following section, we delve into the heart of our study, presenting a comprehensive analysis of key soil health indicators collected over the course of our three-year research endeavor. These indicators include Penetrometer Readings (depth to compaction of 300 PSI), Bulk Density, and Infiltration Rates, each assessed during both spring and fall seasons. We will employ a systematic approach to analyze and interpret these datasets, aiming to provide you, our fellow farmers, with valuable insights into the state of soil compaction and its potential impact on your agricultural practices. By examining trends, variations, and noteworthy observations within these datasets, we hope to equip you with actionable knowledge to enhance your soil management strategies and foster healthier, more productive farms.

First let us look at the bulk density values acquired in this study. Some of the key trends found here are fluctuations, data limitations, recovery, and spikes.

Several farms experienced fluctuation in Bulk Density, indicating changing soil compaction levels from year to year, however, when looking at the big picture there is no significant difference across the data set in fact most of the farms remained consistent from year to year with a few outliers.

Another aspect of this data collection is data limitations. As we are conducting this testing at working farms, we encountered some limiting factors such as difficulty accessing sampling points. These included the historical rainfall of Spring 2023 where significant flooding and or high precipitation occurred or logistical timing of a certain management such as occultation prevented proper data collection.

With this specific test, it's important to note that when collecting samples at depths of 0-6 and 6-12 inches in the organic farms we're studying, there may be challenges in detecting significant changes. This is particularly true because certain dynamic tests can exhibit spatial variability. Consequently, observing changes over time using this test proves to be quite challenging.

The next test in this study involved measuring the infiltration rate at each farm. Like bulk density this is considered a dynamic test indicating that the test is spatially variable in nature so this is important to keep this in mind both when using this test to evaluate compaction and the actual analysis itself.

When comparing change over time most farms saw a reduced infiltration rate indicating that there was an improvement based on this test method. Some seasonal variability was also observed between Spring and Fall; however, this trend was not consistent amongst the farms. In other words the farms that saw better results in the Spring may not have had similar results when compared to other farms that saw an improvement in the Fall. It is not clear what the contributing factors were but seasonal variability should be considered when performing this test method to account for this.

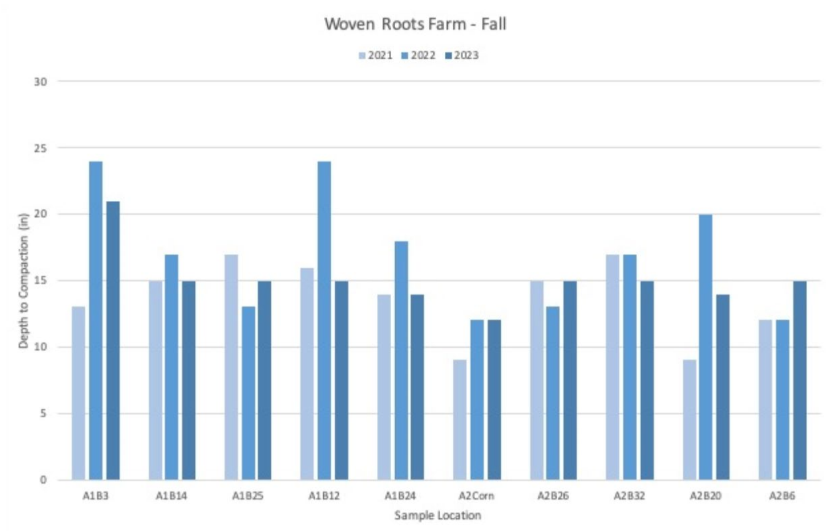
The third and final test method was the soil hardness test. This test method provided the most comprehensive view of compaction when compared to the rest of the data set. It is important to understand and make note that the penetrometer is influenced by soil moisture meaning that the higher the soil moisture the less resistance when applying pressure to the soil. However, when collecting these data the soil team was very intentional of not testing soil when saturated to mitigate to the best of our ability these potential biases.

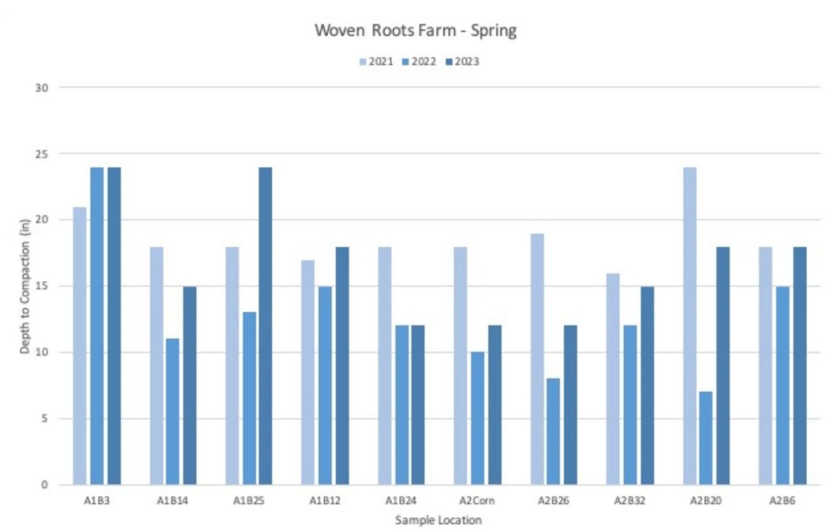
In this discussion we will focus on depth to compaction. For the purposes of this tool compaction has been defined as a soil hardness value of 300 psi, as roots would show restricted root growth at this value. Like with the infiltration we also observed a possible variation within seasons. With the majority of farms showing better penetrometer readings in the Spring with the expectation of two farms that had overall better results in the Fall.

The average depth to compaction value for the entire data set was 11.3 inches; however, the lowest value observed was 3 inches while the highest was greater than 24. The penetrometer is only graduated to 24 inches so in these cases it is determined that the compaction is greater than 24 inches. The actual level of compaction beyond this value is unknown.

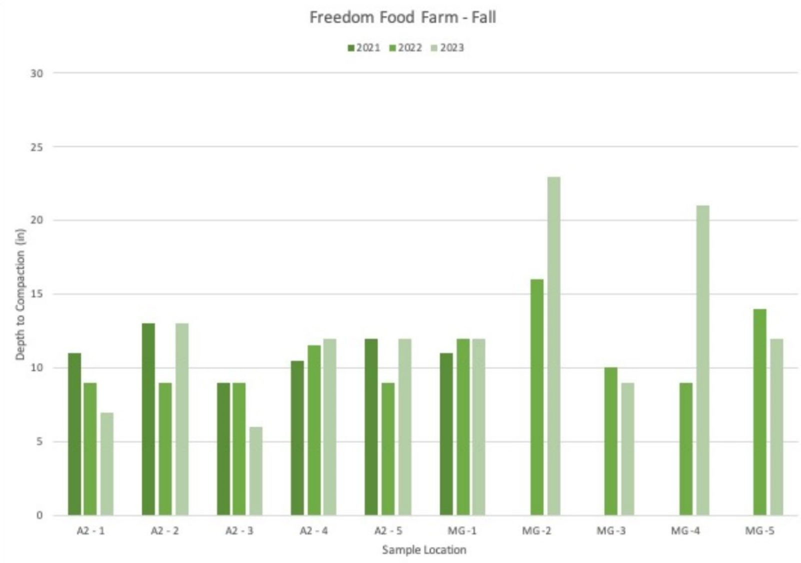
While the average depth to compaction was 11.3 inches these values are skewed as two farms averaged a bit higher than the rest. The average values for these farms were 15.6 and 12.25, with both having a > than 24 inches value for the max and 7 and 6 respectively for the min value. In this next section we will look at these two particular farms and the management they follow.

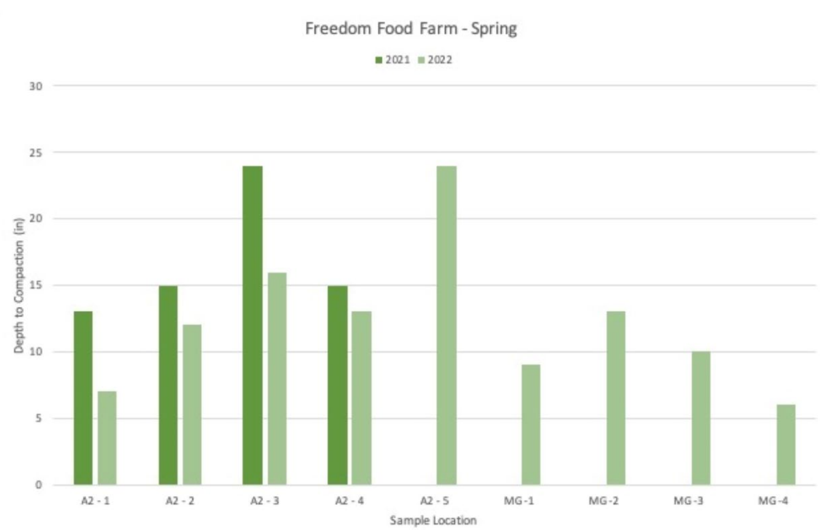
The farm with the 15.6 average value follows a hand scale approach that consists of broadforking, tilthing and sheet mulching. This farm uses a permanent bed system with periodic bed shaping to maintain the same area of cultivation year after year, thus avoiding any type of traffic in the area of cultivation.


Woven Roots Farm - Fall
2021
2022
2023
Depth to Compaction (in)
30
25
20
15
10
5
0
A1B3
A1B14
A1B25
A1B12
A1B24
A2Corn
A2B26
A2B32
A2B20
A2B6
Sample Location


Woven Roots Farm - Spring
2021
2022
2023
Depth to Compaction (in)
30
25
20
15
10
5
0
A1B3
A1B14
A1B25
A1B12
A1B24
A2Corn
A2B26
A2B32
A2B20
A2B6
Sample Location

Conversely the farm with the average 12.25 inches of depth to compaction uses a different approach. This farm is using a more mechanized management with techniques such as roller crimper, cover crops and a grain drill for some of the fields. In addition to cover crops, grain drill, flail mowing and transferred mulch system for the market garden. Despite these differences in management it can be seen that the compaction is being alleviated with a steady progression year after year. One comparison within these farms is the use of permanent bed systems. Although this farm is highly mechanized, dedicated traffic is allowing for the areas of cultivation to be free of severe compaction.





In conclusion, our three-year journey of research and collaboration within the Farmer Learning Cohort has shed light on the complex issue of soil compaction in Massachusetts agriculture. We've presented a comprehensive analysis of key soil health indicators, including Bulk Density, Infiltration Rates, and Penetrometer Readings, collected from various farms. While some farms experienced fluctuations in these indicators, it's clear that there are notable differences in management practices and their impact on soil compaction. Seasonal variations and the dynamic nature of these tests also add layers of complexity to the overall picture. The depth to compaction values ranged from 3 to greater than 24 inches, with management practices playing a significant role in these variations. As we delve into the specific cases of the two farms with higher average depth to compaction values, we find that different approaches, from hand-scale methods to mechanized techniques, can achieve soil health improvements. The journey of discovery continues, and we hope these findings empower fellow farmers to make informed decisions and enhance their soil management strategies for healthier, more productive farms.

Conclusions

Our project demonstrates that addressing soil compaction is not only achievable but also essential for the long-term sustainability of agriculture. The collaboration among farmers, advisors, and the broader agricultural community has highlighted the following key conclusions:

• Soil compaction is a significant challenge that affects farms of all sizes and types.

• Proactive soil management practices, including reduced tillage and strategic cover cropping, can effectively mitigate soil compaction and improve soil health. Although the use of cover crops should be considered upon context.

• Knowledge sharing and peer-to-peer learning are powerful tools for fostering positive change in agricultural practices.

• Sustainability and profitability in farming are closely intertwined with soil health and resilience.

As we conclude this project, we are excited to share our findings and experiences with the agricultural community. We believe that the lessons learned and the practices identified can pave the way for a more sustainable and resilient future for Massachusetts agriculture.

We extend our gratitude to our dedicated Farmer Learning Cohort, project advisors, and all those who have supported and participated in

this endeavor. Together, we have made significant strides in addressing soil compaction and advancing the prosperity of our farms and the agricultural landscape of Massachusetts.

Effective Practices for Soil Compaction Mitigation

Addressing soil compaction is crucial for maintaining healthy and productive soils. Through our three-year study, we've identified several effective practices that can help mitigate soil compaction and improve soil health. It's worth noting that smaller-scale, hand-operated practices have shown more promising results compared to heavy machinery in terms of minimizing compaction. Here are some key practices to consider:

• Deep Broadforking: Hand-operated deep broadforks have proven to be effective in breaking up compacted soil layers without causing additional compaction. These tools are particularly useful in areas with high foot traffic or cultivation. The drawback to this is that it is labor intensive and because of this it does not lend itself to larger acreage at least without a significant cost of more hands on the field.

• No-Till Farming: No-till farming practices reduce soil disturbance and minimize the risk of compaction. By avoiding plowing or excessive tilling, you can maintain soil structure and organic matter, enhancing its natural resilience.

• Cover Cropping: Integrating cover crops into your farming system can improve soil structure and reduce compaction risks. These crops help build organic matter, enhance microbial activity, and protect the soil surface from erosion. The question about cover cropping and farm size has been a topic of discussion as there is a thought that larger acreage (> 3 acres) of cover cropping warrants further investigation as the current tools in the arsenal for that size are still being tweaked. Another aspect of cover cropping not explored in practice through this grant is the inoculation of seeds prior to planting. Because the cover crop seeds are not produced on site these seeds do not necessarily contain the microbiome that relates to that farm. Furthermore, the way that the cover crop seed was grown (monocrop, fertilized, irrigated, and sprayed) also has a major impact on its overall performance. Seed breeding in general is an area of concern and one that we must take into consideration as well as explore ways to reintroduce the seed microbiome. Lastly, although cover cropping is a great strategy on many fronts especially within microbial diversity that drives these systems it is important to note that not all farms in this study perform cover cropping and, in some ways, outperform those that do based on our metrics.

• Crop Rotation: Diversifying your crop rotation can prevent compaction issues caused by continuous cultivation of the same crop. Different crops have varying root structures and nutrient needs, which can benefit soil health. This can also be used to the advantage of the grower. Understanding root architecture can be used to maximize the ability of a plant to grow to its genetic potential which translates into photosynthetic capacity and the higher this capacity is the healthier the plant is and subsequently the microbiome.

• Regular Soil Testing: Implement a routine soil testing program to monitor soil health and compaction levels. This information can guide your compaction mitigation strategies and ensure you're on the right track. It is important to note that the land care giver takes on a comprehensive strategy when conducting soil tests. First consider what your goal is and determine what it would take to achieve this goal. This will inform you on what tools you will use and when to employ them.

• Proper Machinery Use: When heavy machinery is necessary, take precautions to minimize compaction. To avoid topsoil compaction use low-pressure tires, use flotation tires, radial tires, or tracks, and large-diameter tires, reduce the number of passes, drive faster to shorten load dwelling time and avoid working in wet conditions to prevent further soil compression.

• Reduce Soil Traffic: Limit the movement of heavy equipment and vehicles on your fields, especially during wet conditions. Create designated traffic lanes to minimize compaction in high-traffic areas. The use of permanent bed systems appears to be beneficial at farms that have employed this practice independently of scale.

• Ample Organic Matter: Increase the organic matter content in your soil through the addition of compost and organic amendments. Organic matter improves soil structure and provides a buffer against compaction. This should also be used with caution and context, as compost alone will not provide you with all the benefits stated above. For example, to understand what your microbial load is this can be determined via soil microscopy or other methods such as the Microbiometer® this will allow you to understand if your soil is alive so that any additions to the soil are well utilized and not just sit on the surface.

• Farm Cover: Utilize permanent cover such as grassed waterways or buffer strips to protect your fields from erosion and compaction. These features can also enhance biodiversity and water quality.

• Education and Peer Learning: Stay informed about the latest research and best practices for soil health improvement. Engage with farmer learning cohorts, attend workshops, and share your experiences with fellow farmers to collectively work toward healthier soils.

Remember that the effectiveness of these practices may vary depending on your specific soil type and farm conditions. It's essential to adapt and tailor your compaction mitigation strategies to suit your farm's unique needs. By prioritizing sustainable and soil-friendly practices, you can contribute to the long-term health and resilience of your agricultural land.

Lessons Learned

While our project has achieved significant progress in addressing soil compaction, it is important to acknowledge the lessons we've learned along the way. These insights can guide future endeavors in soil health improvement and ensure a more holistic understanding of this complex issue.

• Time Limitations
A fundamental lesson from our project is that soil health improvement is a long-term endeavor. Three years of study, while valuable, provide only a glimpse into the broader trajectory of soil health changes. Soil compaction, influenced by a multitude of factors, including weather conditions and historical management practices, may take several years, if not decades, to fully remediate. Recognizing the necessity of long-term monitoring is crucial for continued success.

• Seasonal Variability
Our project highlighted the substantial influence of seasonal variations on soil conditions. Soil moisture levels, for example, fluctuate significantly throughout the year, impacting soil density and hardness. The use of penetrometers and core sampling tools may introduce bias, as they are susceptible to soil moisture variations. Future studies should consider more extensive data collection over multiple seasons to account for these fluctuations.

• The Role of Soil Types
Soil compaction and its mitigation are inherently influenced by soil types. Different soils respond differently to compaction and remediation practices. Our project primarily focused on farms with specific soil types prevalent in Massachusetts. Recognizing the diversity of soil types across the state and tailoring compaction mitigation strategies accordingly is essential for a more comprehensive approach.

• Farmer Engagement and Education
We've learned that farmer engagement and education are key drivers of success. Farmers' willingness to adopt new practices and their understanding of soil health concepts significantly impact project outcomes. Continuing efforts to educate and support farmers in adopting compaction mitigation strategies is an ongoing necessity.

• The Need for Continuous Monitoring
To overcome the limitations of our study's time frame, we emphasize the importance of continuous monitoring. Soil health is dynamic, and regular assessments are crucial to track changes over the long term. Implementing data collection beyond the project's duration ensures that farmers can make informed decisions based on evolving soil conditions.

• Multi-Disciplinary Collaboration
Soil health improvement involves a diverse range of expertise, from agronomy to soil science and engineering. Collaborative efforts, as demonstrated by our project advisors and the Farmer Learning Cohort, are essential. Future initiatives should continue to bring together experts from various fields to address soil compaction comprehensively.

In conclusion, our project has shed light on the complexities of soil compaction and the strategies to mitigate it. We have learned that successful soil health improvement requires patience, adaptability, and a commitment to ongoing education and collaboration. As we move forward, we remain dedicated to furthering our understanding of soil health and promoting sustainable farming practices in Massachusetts.

Future Projects
Our journey in addressing soil compaction has provided valuable insights that can guide future proposals and projects aimed at improving soil health. We offer the following advice to inform and enhance upcoming initiatives:

• Embrace Long-Term Commitment
Recognize that soil health improvement is a long-term endeavor. Plan for extended project durations that allow for comprehensive data collection and the tracking of soil health changes over time. Soil compaction, influenced by numerous factors, requires ongoing attention and monitoring.

• Account for Seasonal Variations
Acknowledge the significant impact of seasonal variations on soil conditions. Incorporate multiple seasons of data collection to account for fluctuations in soil moisture levels, temperature, and other environmental

factors. This ensures a more accurate understanding of soil health dynamics.

• Tailor Strategies to Soil Types
Understand the diversity of soil types within your project area. Soil compaction and its mitigation strategies vary depending on soil characteristics. Tailor your approaches to the specific soil types present, taking into account their unique responses to compaction.

• Prioritize Farmer Engagement and Education
Recognize the central role of farmers in soil health improvement. Prioritize farmer engagement and education to foster understanding and encourage the adoption of sustainable practices. Build strong relationships with the farming community to ensure project success.

• Implement Continuous Monitoring
Emphasize the importance of continuous monitoring beyond the project's duration. Soil health is dynamic and subject to change. Establish systems for ongoing data collection and analysis to inform farmers' decisions and track long-term improvements.

• Foster Multi-Disciplinary Collaboration
Encourage collaboration among experts from various fields. Soil health improvement requires expertise in agronomy, soil science, engineering, and more. Form partnerships and advisory committees that bring together a diverse range of knowledge to address soil compaction comprehensively.

• Seek Funding for Longitudinal Studies
Consider seeking funding specifically for longitudinal studies on soil health. Long-term projects allow for in-depth investigations, the establishment of comprehensive datasets, and a better understanding of the impacts of compaction mitigation practices.

• Promote Knowledge Sharing
Actively promote knowledge sharing among project participants, advisors, and the broader agricultural community. Create opportunities for farmers to share their experiences and insights, fostering a collaborative learning environment.

• Encourage Sustainable Practices
Advocate for the adoption of sustainable farming practices that prioritize soil health. Highlight the long-term benefits of compaction mitigation and soil improvement for crop yields, farm resilience, and environmental sustainability.

• Stay Committed to Resilience
Maintain a commitment to building resilient agricultural systems. Soil health improvement contributes to climate resilience and sustainable food production. Your project plays a crucial role in ensuring the long-term viability of agriculture.

Incorporating these lessons and recommendations into future proposals will not only enhance the effectiveness of soil health projects but also contribute to the broader goal of sustainable agriculture and environmental stewardship.

Appendices

Additional Resources

Newsletter- Be a Better Grower: Caring for your Soil Understanding Soil Aggregation and Compaction https://www.nofamass.org/articles/2022/03/caring-for-your-soil-understanding-soil-aggregation-and-compaction/

Experiments in Reduced Tillage at Alprilla Farm

Tools for Transitioning to No-Till Vegetable Production

No Till Transition Year 2 – Lessons Learned

Farmer to Farmer Intensive Session 1- Tillage Reduction

No-Till Tools for Small Scale Farmers

Reducing Tillage at Freedom Food Farm with Chuck Currie

Compaction Mitigation at Freedom Food Farm

Soil Health Field Day at Freedom Food Farm

Transitioning to No-Till Farm with Bryan O'Hara

Cover Crop Strategies for No-Till Systems

No-Till Keynote Panel from Purpose to Practicality

Newsletter – Fist Full of Soil