The State of Soil Health in Vermont

VAWQP Science Advisory Committee Meeting
March 4th, 2022

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Gund Institute for Environment

The State of Soil Health in Vermont

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Project Goals:

- establish a **baseline of soil health** indicators, carbon stocks and associated ecosystem services in Vermont's agricultural landscapes
- create **standards for soil sampling** across management types and partners so that they will be comparable
- give farmers **contextualized information** about soil health on their farms
- support **collaboration** among the many organizations that work with farmers towards shared goals around soil health
- **build skills & capacity** for soil carbon assessments & measuring soil health

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DARTMOUTH

vermont environmental stewardship PROGRAM

The Nature Conservancy Vermont

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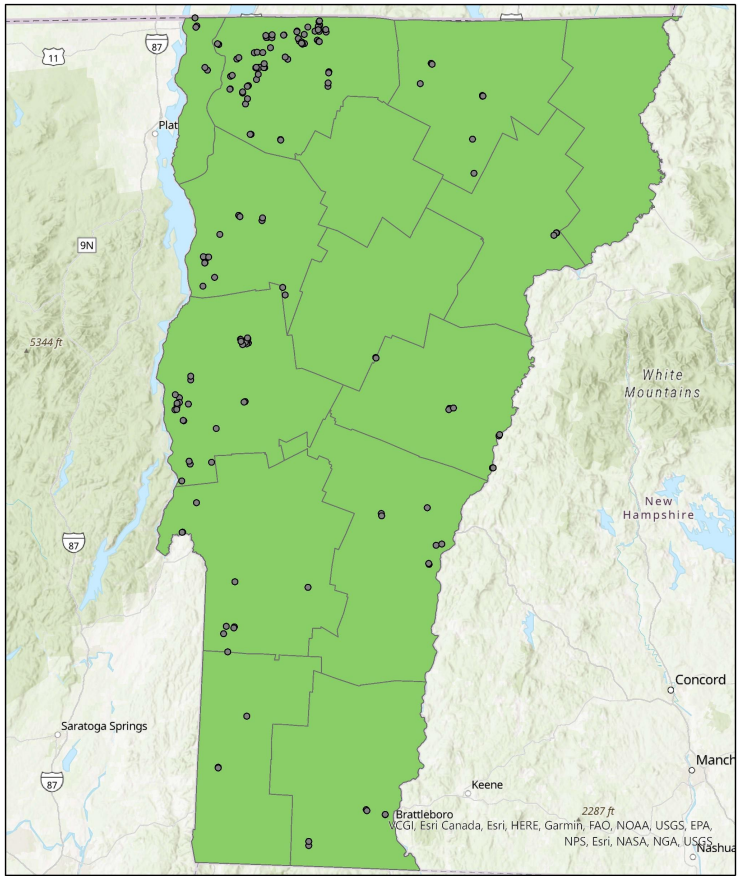
2021 Season Field Sampling



- *Convenience sample* from existing research projects
- Plus *purposeful sampling* to reach
  - greater geographic extent of state
  - diversity of farm types

Crop type	Number of fields
Vegetable	22
Corn	114
Field crops	4
Pasture	37
Hay	44
Total	*221*

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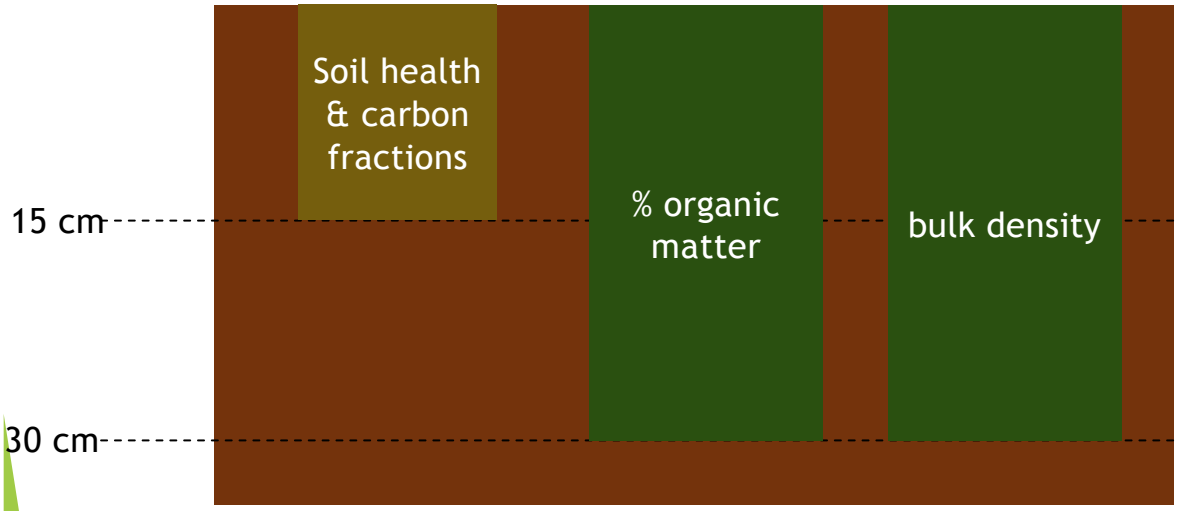
Soil sampling methods



Samples & data from each field:

- one composite soil sample to 15 cm depth foil soil health
- one composite soil sample to 30 cm depth for organic carbon
- three bulk density cores to 30 cm
- field management information

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What did we measure and what does it mean?

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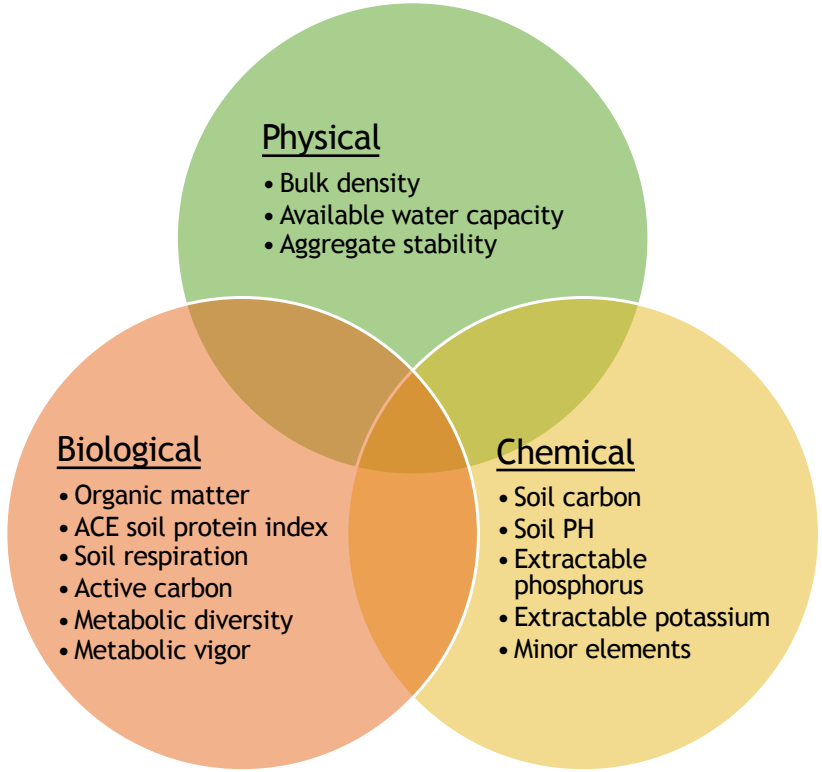

Cornell Comprehensive Assessment of Soil Health

- Available water capacity
- Aggregate stability
- Organic matter
- ACE soil protein index
- Soil respiration
- Active carbon
- Soil PH
- Extractable phosphorus
- Extractable potassium
- Minor elements

Biological Functional Diversity

- Ecoplate carbon substrate test

Carbon fractions

- Particulate VS Mineral organic carbon

Soil Carbon Stocks to 30 cm depth

- Bulk density
- Soil organic carbon

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What did we measure and what does it mean?

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- Nutrient availability
- Ecosystem Services
  - Soil health
  - Resilience to extreme weather
  - Climate regulation (Carbon stocks)
- Biological community in soil
  - Niche diversity & richness
  - Niche partitioning and breadth
- Carbon permanence

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Reporting & Analysis

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- **Individualized farmer reports:**
  - Show farmers how their soils compare to peers
- **Extension reports:**
  - Soil carbon storage and sequestration in Vermont agriculture
  - Descriptive statistics of the 2021 sampling effort
- **Next steps:**
  - How does management influence soil health?
  - Explore relationship between biological diversity and soil carbon
  - Enhance analysis within focused projects (i.e. CEAP & CIG projects)
  - Leverage data for modeling

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Soil carbon storage and sequestration in Vermont agriculture

Alissa White, Heather Darby & Donald Ross. Research Brief, April 2022.
University of Vermont Extension, Gund Institute for Environment, and Department of Plant & Soil Science

Introduction

In 2021, The State of Soil Health (SOSH) project measured indicators of soil health on 221 farm fields across the state of Vermont through a collaborative effort among many organizations. Soil carbon stocks to 30 cm depth were assessed on 191 of those fields. In this brief we share a summary of this new soil carbon stock data alongside data from a national assessment of soil carbon stocks performed by the NRCS from 2010 and highlight its relevance to current policy conversations within the state of Vermont.

Key Ideas

- The protection of existing soil carbon stocks and support for increased carbon sequestration align with both environmental and agricultural goals.
- A collaborative effort to collect and share soil health information in 2021 provides needed state scale data on soil health and soil carbon in Vermont's agricultural landscapes.
- Northeastern soils and climate are naturally conducive to high levels of soil carbon.
- When compared regionally and nationally, Vermont's agricultural soil carbon levels are high. An average of 86 MT carbon per hectare and 4.3% organic matter was observed.
- A wide range in soil health scores and soil carbon levels observed in soil samples showed both that some fields have high levels of carbon storage, and many fields had low carbon levels indicating there are opportunities to further sink more carbon.
- Long term studies in Vermont have documented agricultural soil carbon sequestration rates at between 0.39 and 6.43 MT Carbon per hectare per year. That's equivalent to a range of 1.4 to 23.6 MT CO_2 per hectare per year.
- Increases in soil carbon are possible on Vermont farms, and can complement other strategies to reduce concentrations of atmospheric greenhouse gasses.
- The permanence of soil carbon in our region is linked to agricultural economics, farmer capacity and capability. Permanence can be addressed in part through support of Extension technical assistance, policy and conservation incentive program design.
- Policy tools can help protect the high soil carbon stocks in Vermont. Incentives to maintain high levels of soil carbon for farmers, such as cost-shares or payment-for-ecosystem services programs, should be considered by policy makers.
- Additional research on common and innovative soil management strategies and their influence on soil carbon sequestration in Vermont agriculture is needed.
- Soil carbon changes are only one part of the whole farm carbon balance, and more research is needed to assess how soil carbon changes influence climate change mitigation compared to other interventions on farms in Vermont.

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What's the State of Soil Health in Vermont?

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Aggregate stability

- Indicator of physical structure, resistance to erosion & extreme weather
- Mean is 46.7%
- Significantly greater in fields with perennial roots (ANOVA, $p<0.01$).

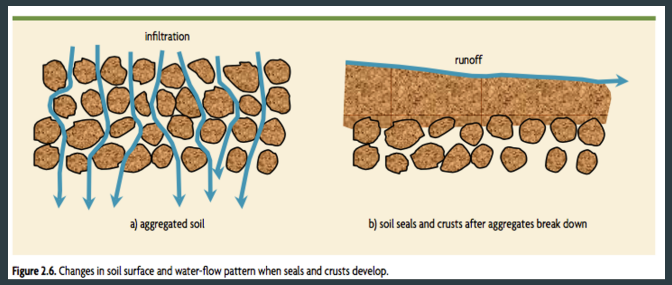
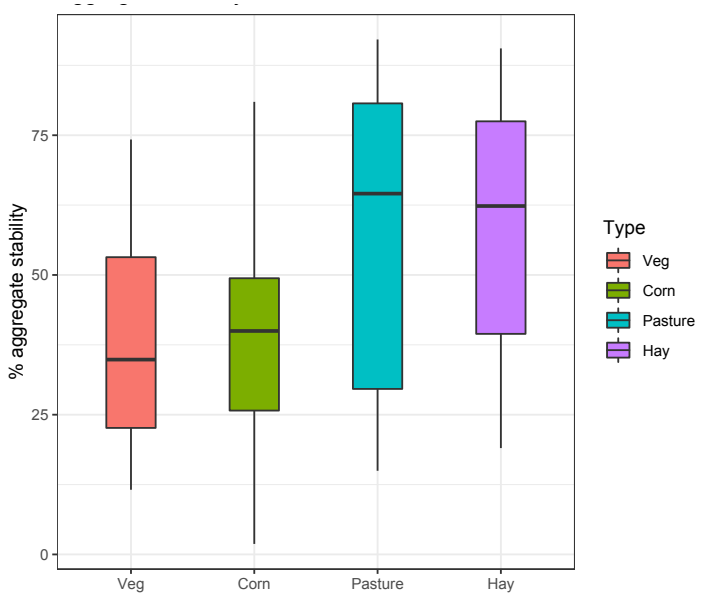


Figure 2.6. Changes in soil surface and water-flow pattern when seals and crusts develop.



Aggregate stability across all fields in 2021

Minimum	Q1	Median	**Mean**	Q3	Maximum
1.9%	29.4 %	43.5 %	46.7 %	64.5 %	92.1 %

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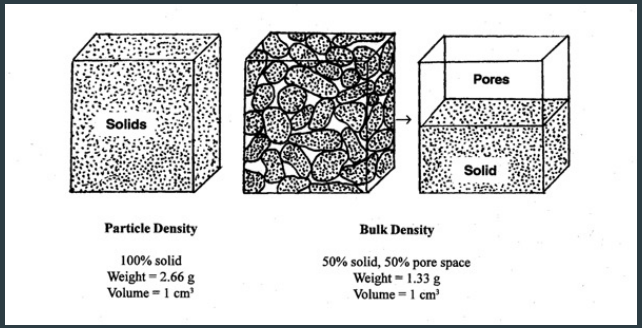
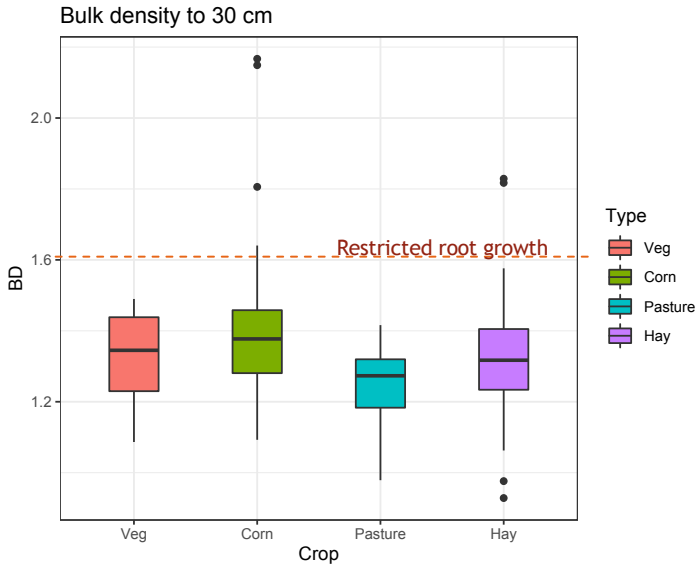
Bulk density

- Indicator of compaction and infiltration
- Mean is 1.35 g/cm^3
- Changes in bulk density can influence the amount of water that will infiltrate into the soil and reduce flooding lower in the watershed.





Bulk density (g/cm^3) across all fields in 2021

Minimum	Q1	Median	**Mean**	Q3	Maximum
0.93	1.25	1.34	**1.35**	1.44	2.17

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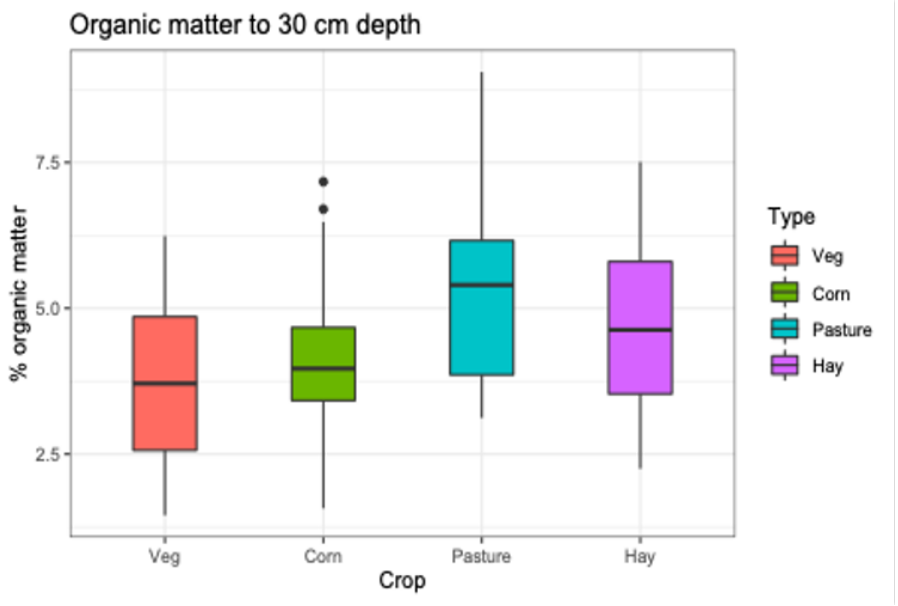
Organic matter

- living or formerly living portion of the soil: a reservoir of organic carbon, biological activity, and nutrients
- Mean is 4.3%
- foundational to many ecosystem services and soil functions
- influenced by soil texture but can be improved by management strategies



Organic matter content across all fields

Minimum	Median	Mean	Q3	Maximum
1.45 %	4.03 %	4.33 %	5.28 %	9.05 %

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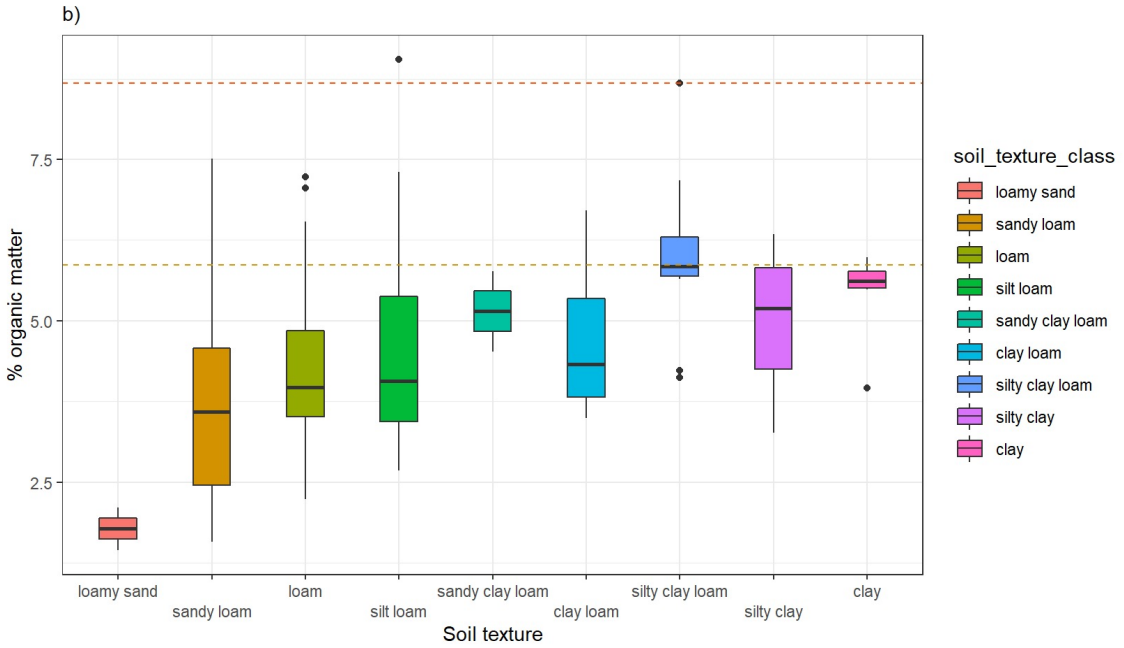

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1.45 %	4.03 %	4.33 %	5.28 %	9.05 %

Soil Carbon Stock Basics

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- % carbon content
- bulk density
- depth of measurement
- area

Carbon stock: amount of carbon in a volume of soil

MTC/ha to 30 cm depth

Soil Carbon Stocks in Vermont agricultural soils

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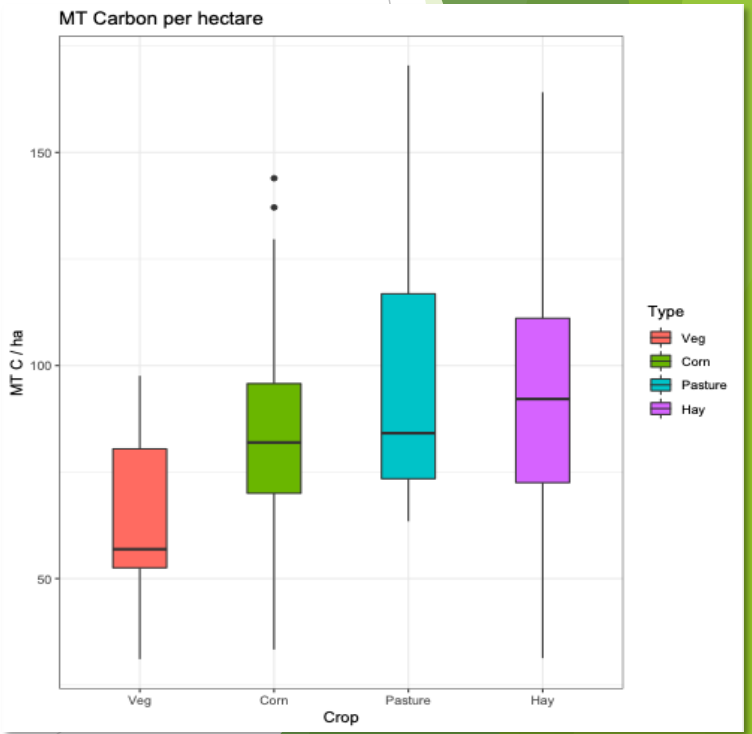
Results from the State of Soil Health 2021

- Pasture & hay fields have the highest agricultural soil carbon stocks
- Vegetable fields have lower soil carbon stocks
- Corn & hay fields have wide range of stocks
- Management and soil texture also have a strong effect

Soil Carbon Stocks in Vermont Agriculture
MT C/ha to 30 cm depth

Type	n	Min	*Median*	Mean	Max
Corn	112	33	***82***	84	144
Hay	37	31	***92***	94	164
Pasture	21	64	***84***	96	170
Veg	17	31	***57***	65	98



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Cornell Comprehensive Assessment of Soil Health

Comprehensive Assessment of Soil Health

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

Measured Soil Textural Class: **sandy loam**

Sand: **55%** - Silt: **32%** - Clay: **11%**

Group	Indicator	Value	Rating	Constraints
physical	Predicted Available Water Capacity	**0.18**	**77**	
physical	Surface Hardness			Not rated: No Field Penetrometer Readings Submitted
physical	Subsurface Hardness			Not rated: No Field Penetrometer Readings Submitted
physical	Aggregate Stability	**25.0**	**36**	
biological	Organic Matter Soil Organic Carbon: 1.62 / Total Carbon: 1.63 / Total Nitrogen: 0.15	**2.2**	**61**	
biological	Predicted Soil Protein	**5.40**	**28**	
biological	Soil Respiration	**0.6**	**46**	
biological	Active Carbon	**463**	**52**	
chemical	Soil pH	**6.7**	**100**	
chemical	Extractable Phosphorus	**31.6**	**100**	High Phosphorus, Environmental Impact Risk
chemical	Extractable Potassium	**83.4**	**100**	
chemical	Minor Elements Mg: 99.9 / Fe: 6.6 / Mn: 2.7 / Zn: 1.2		**100**	

Overall Quality Score: **70** / High

- Package of soil assays available from Cornell University
- Measures a suite of physical, chemical, and biological soil health indicators
- Generates scores for each indicator based on soil texture
- Generates an overall soil health score
- Scoring function is based on northeast regional farm data
- Used across the country to evaluate soil health on many projects

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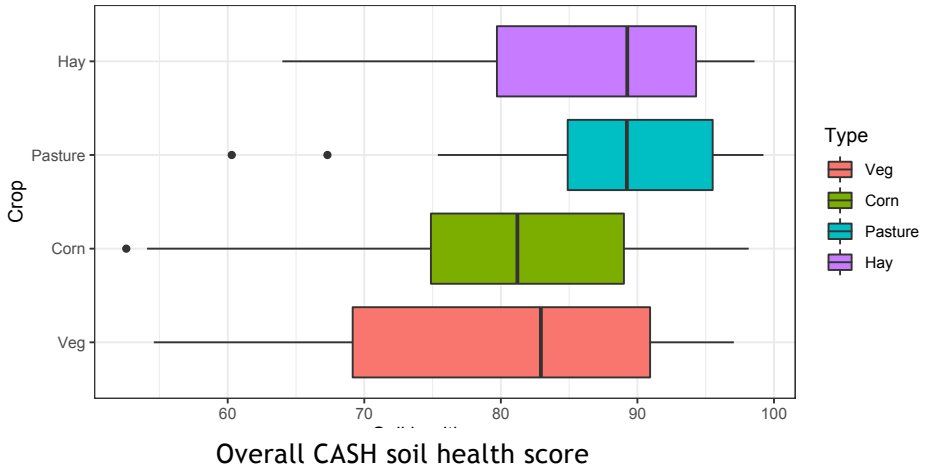
2021 Cornell Comprehensive Assessment of Soil Health Scores on 221 fields



Type	Minimum	Median Score	Mean Score	Maximum
Vegetable	55	85	80	97
Corn	53	81	82	98
Pasture	60	88	87	99
Hay	64	90	87	99

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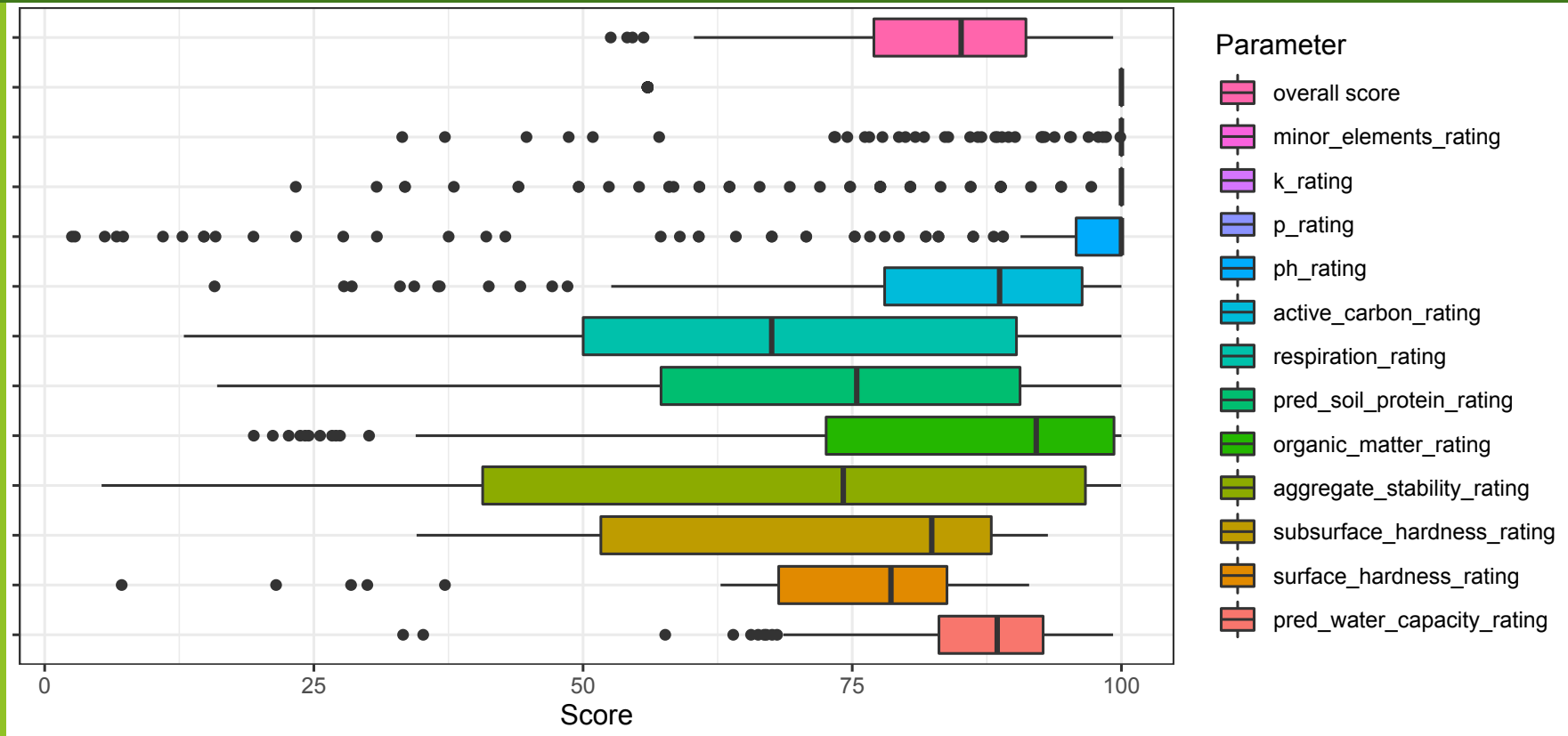

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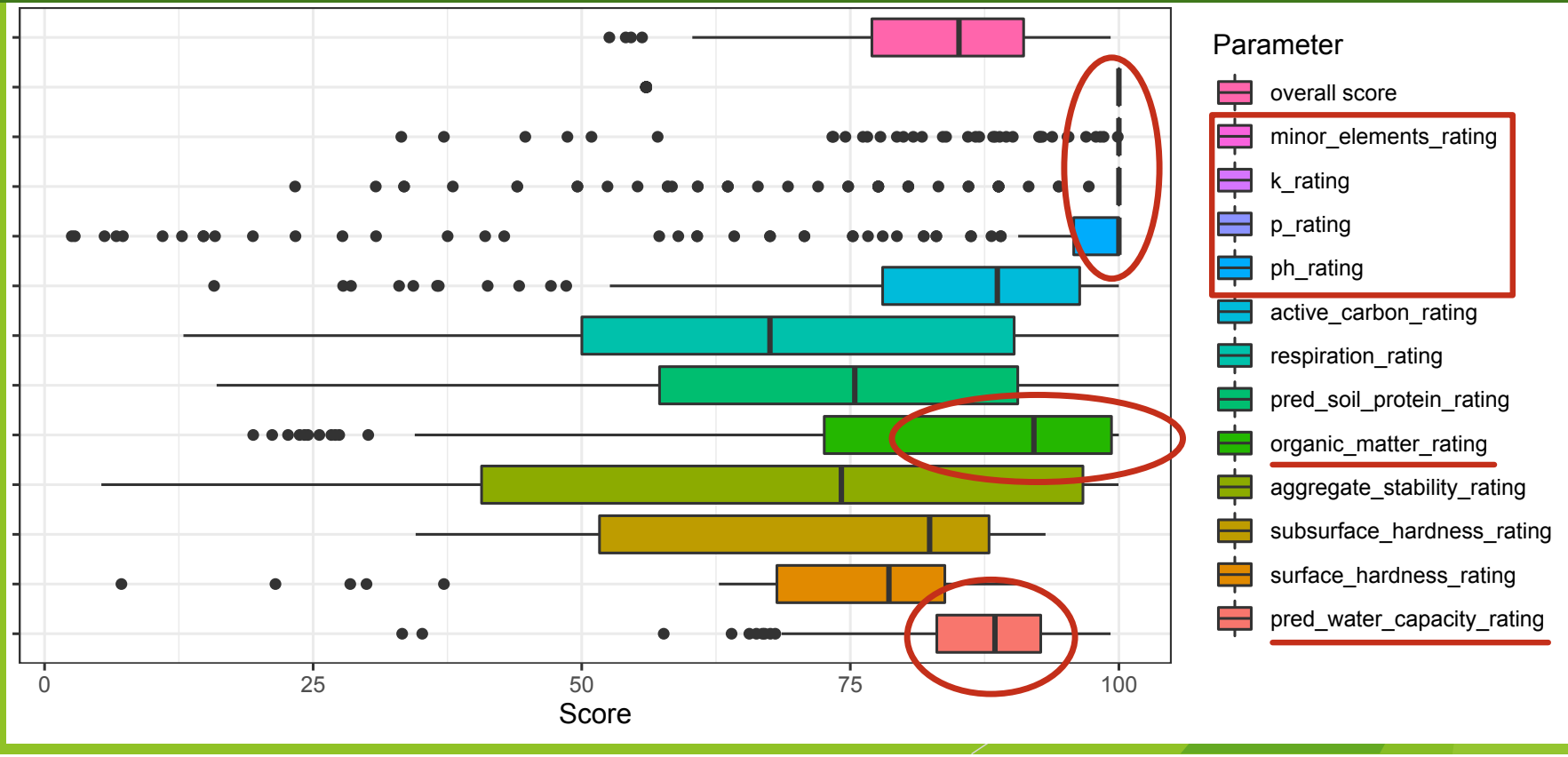

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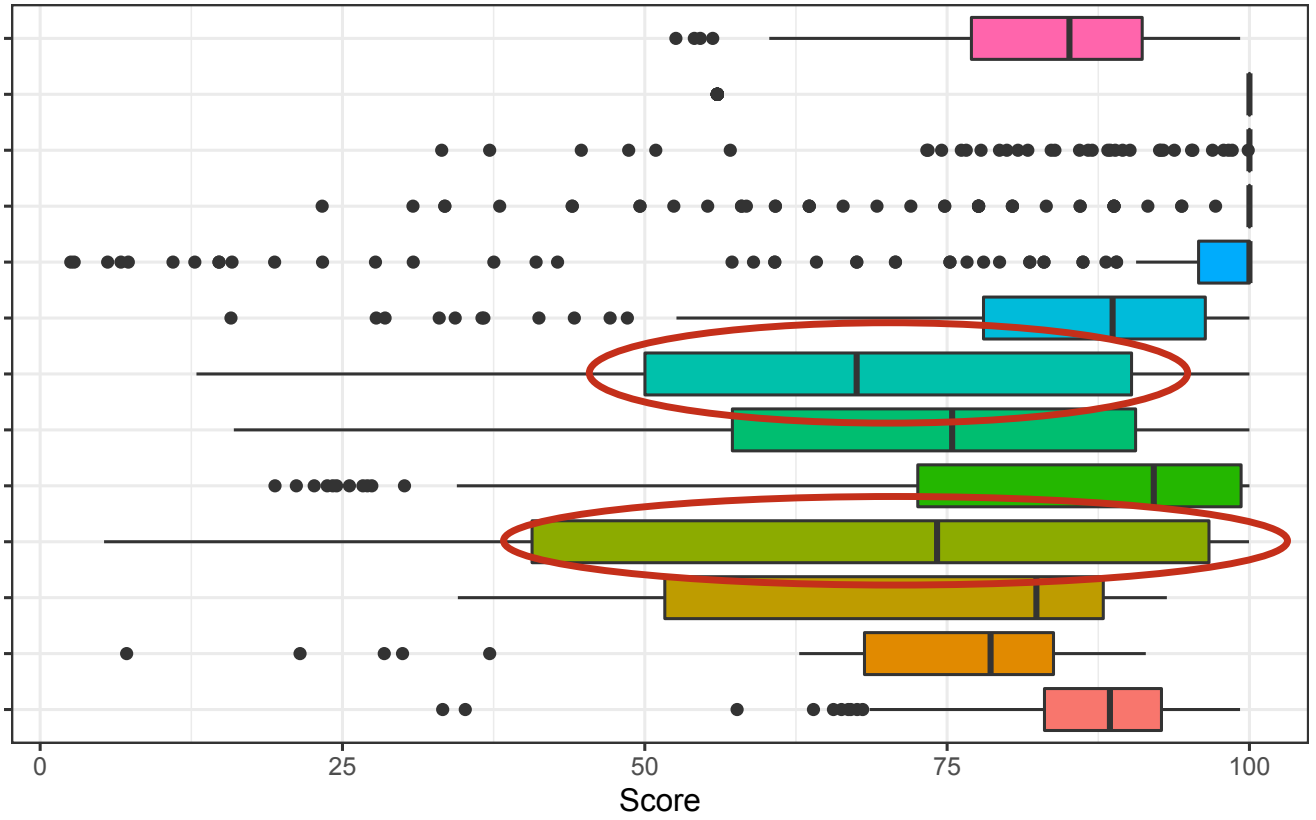

Parameter

- overall score
- minor_elements_rating
- k_rating
- p_rating
- ph_rating
- active_carbon_rating
- respiration_rating
- pred_soil_protein_rating
- organic_matter_rating
- aggregate_stability_rating
- subsurface_hardness_rating
- surface_hardness_rating
- pred_water_capacity_rating

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What did we measure and what does it mean?

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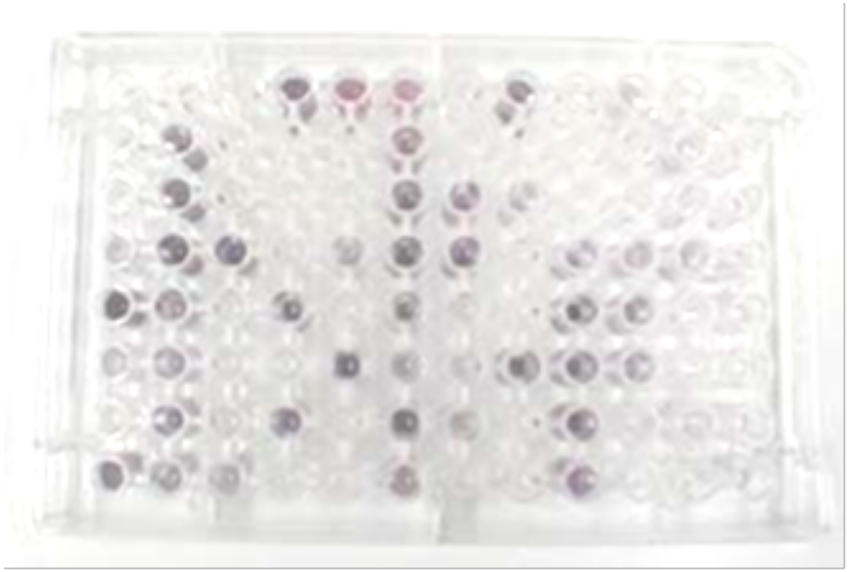
Soil biodiversity

Functional metabolic diversity (FMD)

- a measure of the functional richness of the soil microbial community.
- the percent of the 31 different carbon substrates being utilized by the microbes in your soil.

Average metabolic response (AMR)

- a measure of how much of each carbon substrate is being consumed by the microbes in your soil within the time period
- a measure of microbial community vigor & activity



Biolog Ecoplate Test

- 31 carbon substrates in triplicate
- Look for color change at 48 and 72 hours

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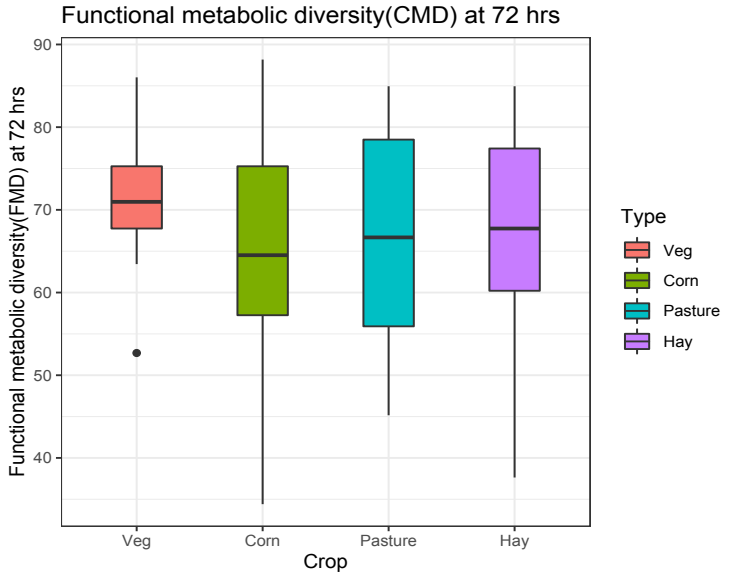
- a measure of microbial community vigor & activity

Type	n	Q1	Median	Mean	Q3
Veg	22	67.74 %	70.97 %	71.46 %	75.27 %
Corn	114	57.26 %	64.52 %	65.13 %	75.27 %
Pasture	37	55.91 %	66.67 %	66.29 %	78.49 %
Hay	44	60.22 %	67.74 %	65.84 %	77.42 %
All fields	221	58.06 %	66.67 %	66.08 %	75.81 %

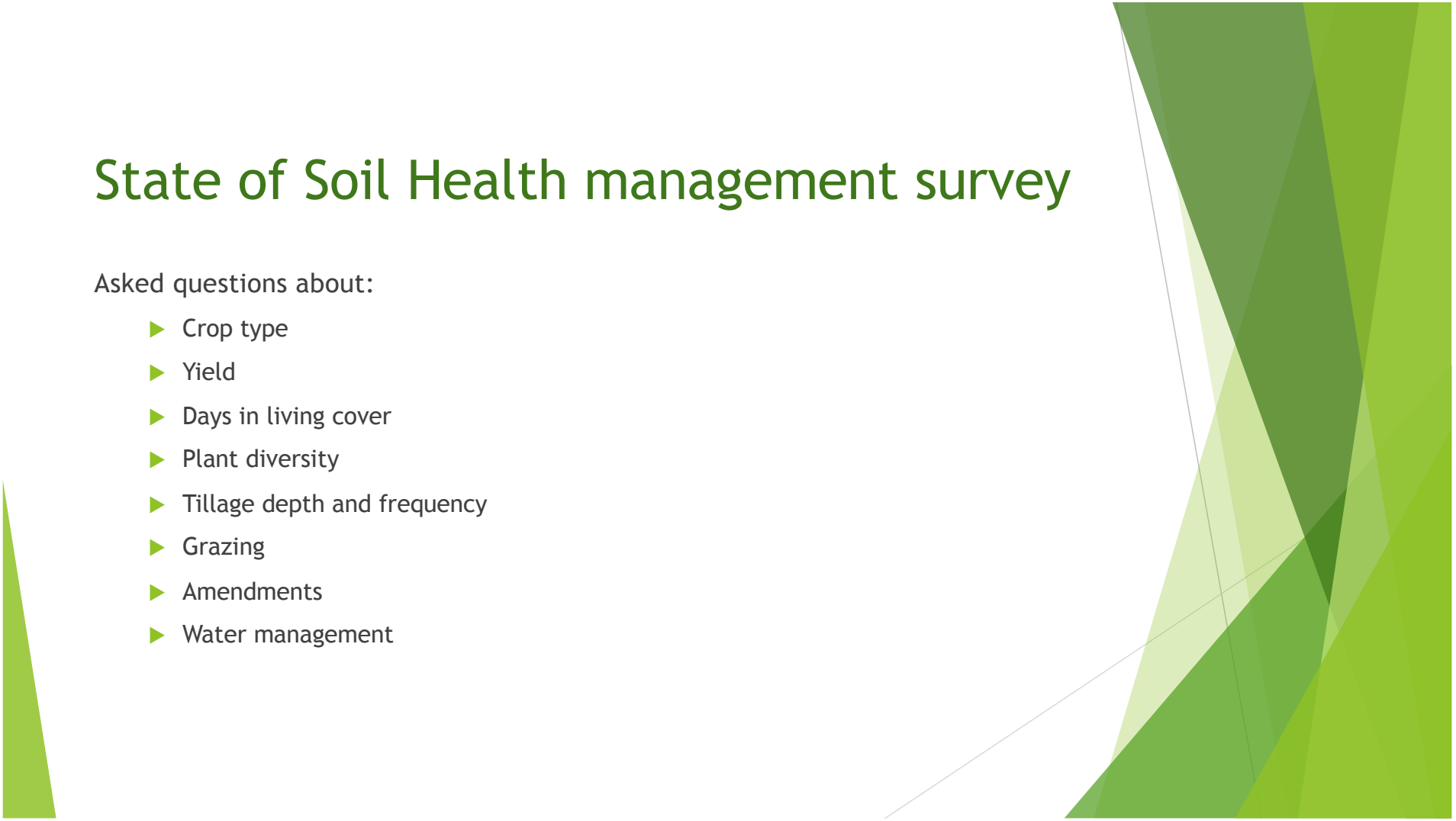


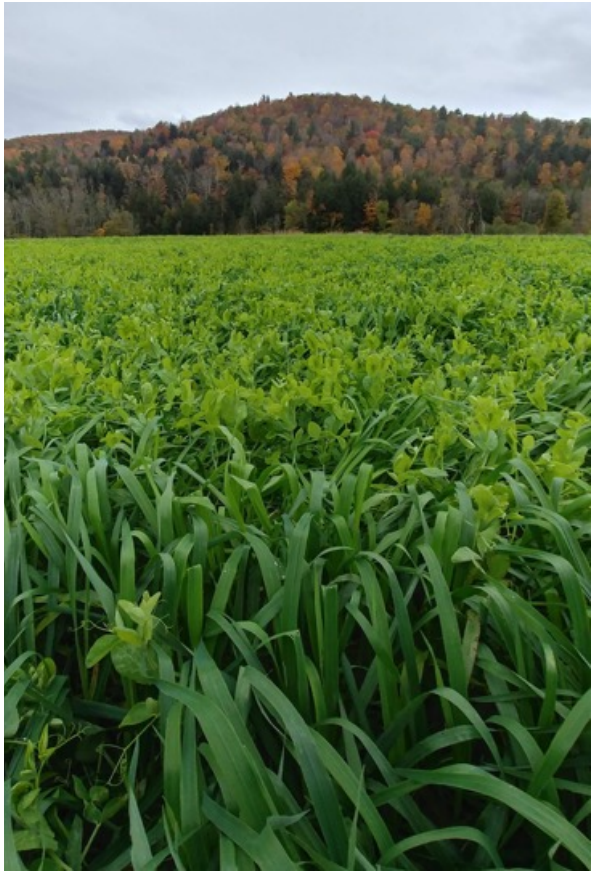
How does management influence soil health?

State of Soil Health management survey

Asked questions about:

- Crop type
- Yield
- Days in living cover
- Plant diversity
- Tillage depth and frequency
- Grazing
- Amendments
- Water management





Looking at data from Ben & Jerry's Caring Dairy program

- 101 crop fields were evaluated using the Cornell Comprehensive Assessment Soil Health in 2020
- Analysis was conducted using ANOVA and regression modeling
- Fields that had cover crops were significantly higher in
  - organic matter content ($p=0.0017$)
  - available water capacity ($p=0.014$)
  - active carbon ($p=0.001$)
  - respiration rates ($p=0.03$)
  - overall increased soil health scores ($p=0.0007$).
- Evidence that **covers crops increase biological activity, provide greater resilience to drought and increase carbon storage.**

Looking ahead: Intersections of water quality practices & soil health

- Water quality best management practices can also enhance soil health, climate mitigation & climate resilience
- Biological activity and soil organic matter: the life of the soil
  - Soil aggregation → reduced erosion
  - Water holding capacity → drought resilience
  - Organic carbon → carbon storage and sequestration
  - Infiltration & porosity → reduced storm surges
- Research needs:
  - Evaluate these outcomes for WQ practices in our region
  - Identify and reduce tradeoffs
  - Include unseen pathways
    - Subsurface nutrient flux
    - Soil surface GHG emissions

Thank you!

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