Soil health, water quality & climate change mitigation in the Lake Champlain Basin: and exploring an agroecological approach

Presentation to the Vermont Citizens Advisory Committee on Lake Champlain's Future

November 8th, 2021

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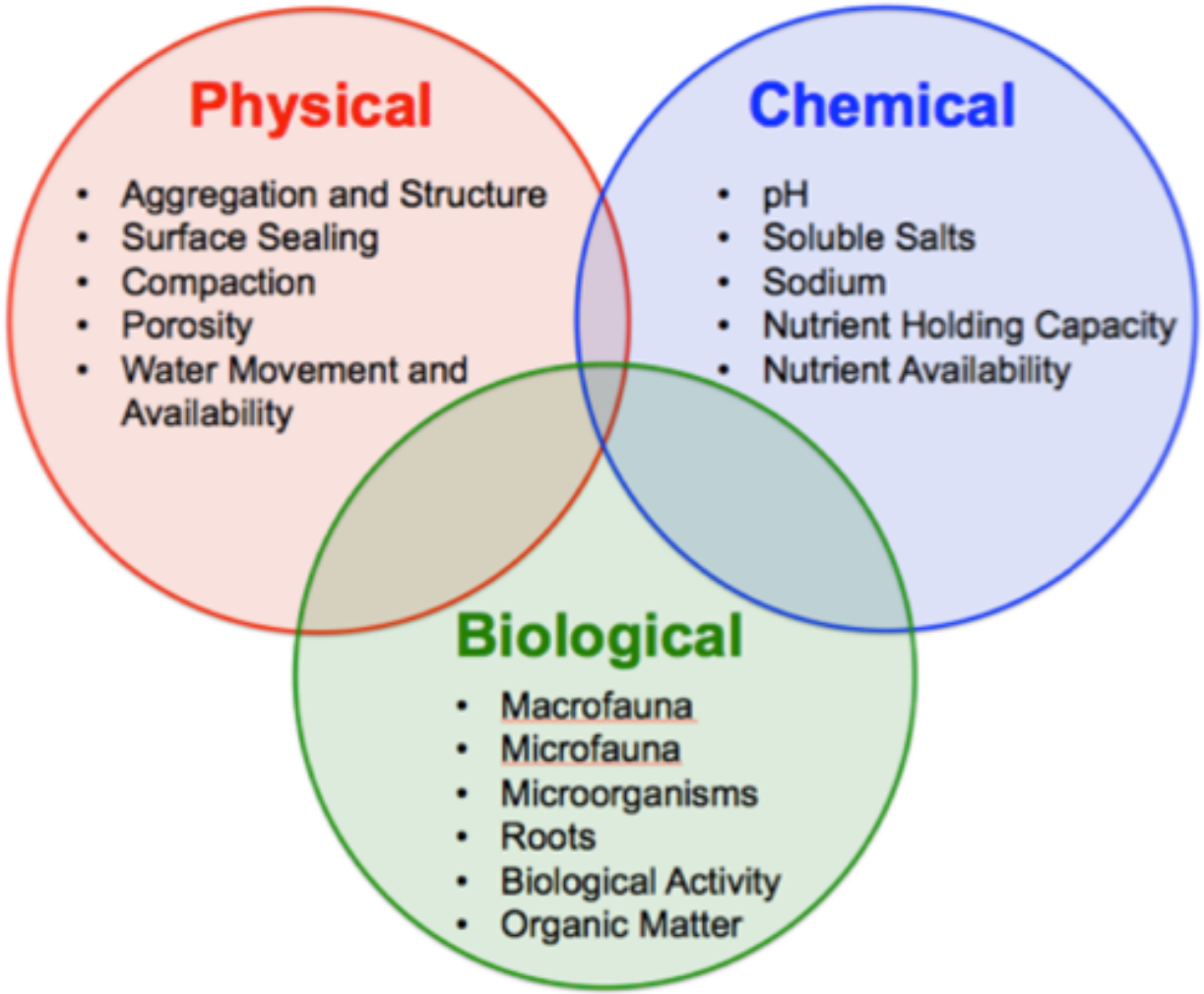
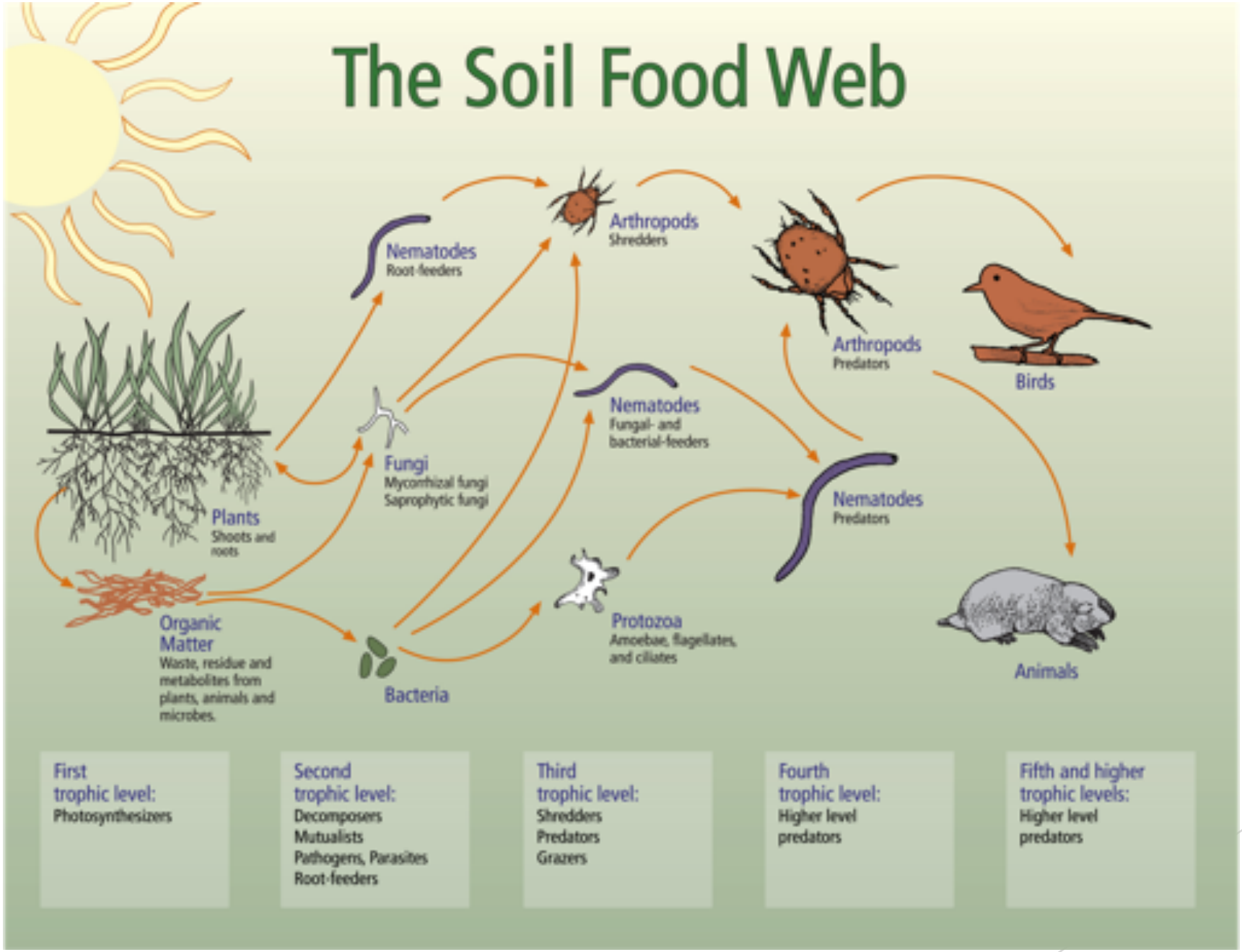
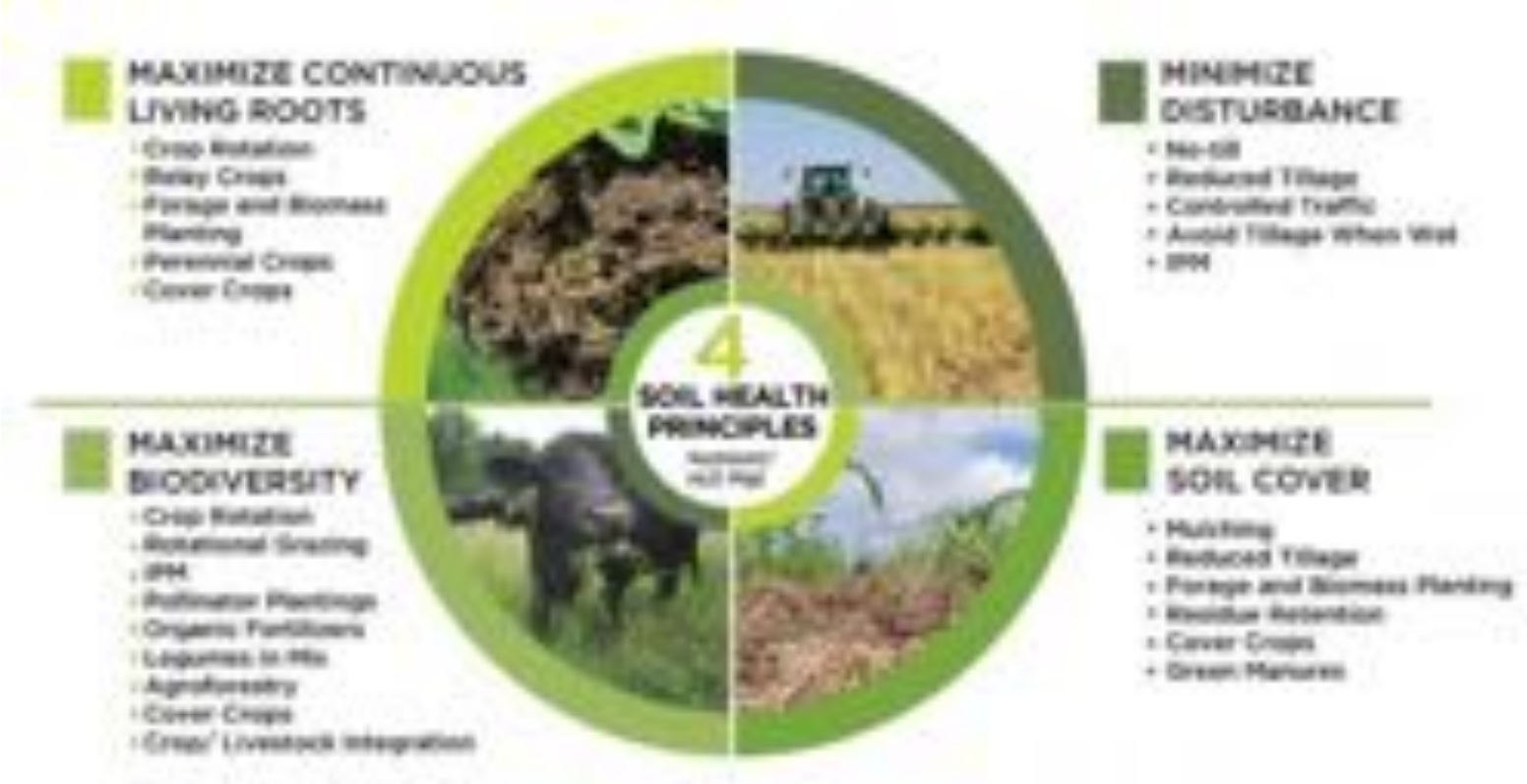
What is soil health?




The Soil Food Web
Nematodes
Root-feeders
Arthropods
Shredders
Arthropods
Predators
Birds
Nematodes
Fungal- and
bacterial-feeders
Fungi
Mycorrhizal fungi
Saprophytic fungi
Plants
Shoots and
roots
Nematodes
Predators
Organic
Matter
Waste, residue and
metabolites from
plants, animals and
microbes.
Protozoa
Amoebae, flagellates,
and ciliates
Bacteria
Animals
First
trophic level:
Photosynthesizers
Second
trophic level:
Decomposers
Mutualists
Pathogens, Parasites
Root-feeders
Third
trophic level:
Shredders
Predators
Grazers
Fourth
trophic level:
Higher level
predators
Fifth and higher
trophic levels:
Higher level
predators

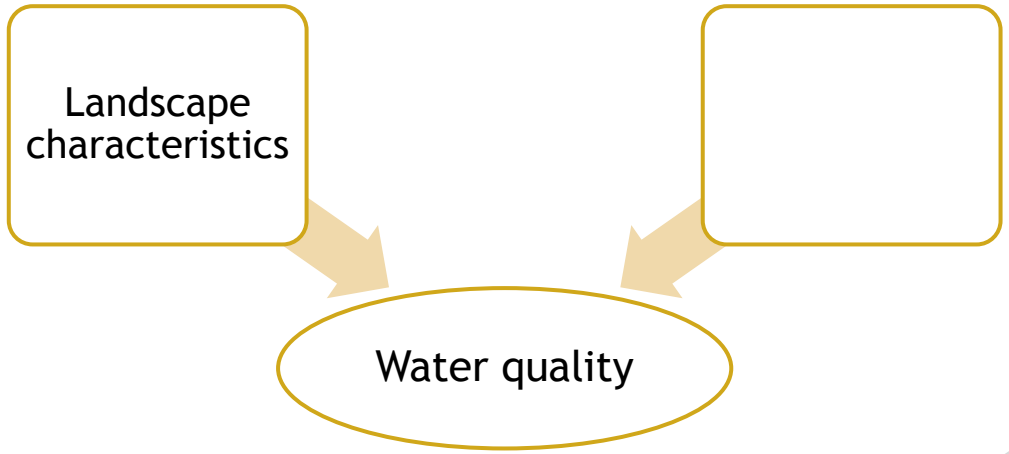


- **Soil health is "Continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans." --** NRCS

https://www.ecolandscaping.org

Water Quality & Soil Health

- Related but not always correlated
- Static & vegetative landscape characteristics are important mediators of nutrient and chemical pathways
  - Landscape characteristics: i.e. Soil texture, hydrologic connectivity
  - Vegetative characteristics: Perennial vs annual vegetation
  - Tools like the VT P-index, RUSLE2 Curve Number capture this



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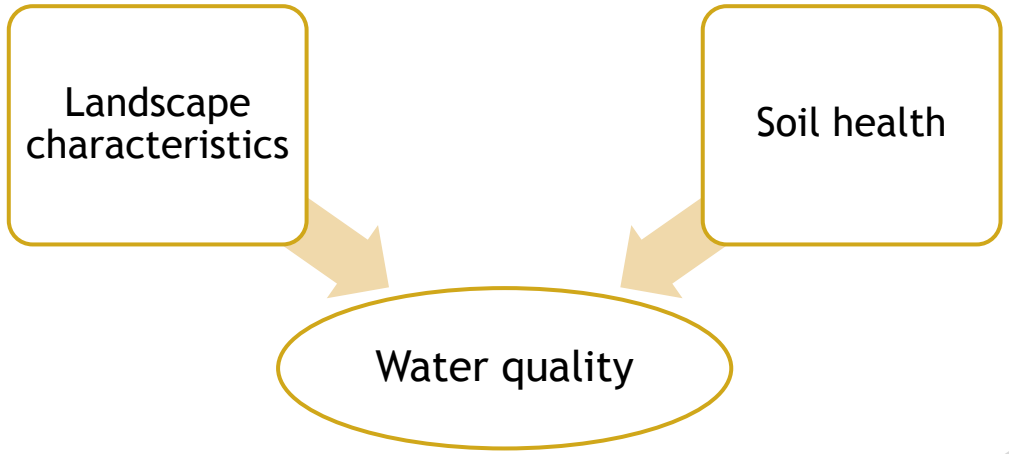
- Soil health is dynamic & driven by biological activity
- Management influences soil characteristics
  - Organic matter content & biology
  - Aggregate stability
  - Infiltration, porosity & bulk density
- … Which influence ecosystem services
  - Carbon storage, Nutrient cycling, Climate resilience, Downstream flood surge reduction



Tools for predicting water quality and soil conservation outcomes

Vermont P-Index Inputs

- Location in VT
  - Five groupings of counties
- Elevation
- STP (ppm)
- Reactive Al (ppm)
- Manure and fertilizer applications:
  - Rate (lb P2O5/ac)
  - Method
  - Timing (season)
  - Time to incorporation
- Erosion rate from RUSLE2 (ton/ac/yr)
- Soil series/type and HSG
- Surface cover at time of planting (%, categories)
- Crop type
- Distance from field to waterway (ft)
- Vegetated buffer width (ft)
- Manure setback within field (ft)
- Presence of pattern tile drainage system

Universal Soil Loss Equation (USLE)

- $A = R \cdot K \cdot LS \cdot C \cdot P$
  - A is **soil loss** in tons per acre per year
  - R is **rainfall erosivity** factor
  - K is **soil erodibility** factor
  - LS is **length-slope** (topographic) factor
  - C is the **land use** or **land cover** factor
  - P is the **treatment** or **conservation practices** factor

Has become Revised Universal Soil Loss Equation v. 2 = RUSLE2

What is it?		What does it do?	How does it help?
Conservation Crop Rotation Growing a diverse number of crops in a planned sequence in order to increase soil organic matter and biodiversity in the soil.		• Increases nutrient cycling • Manages plant pest (weeds, insects, and diseases) • Reduces sheet, rill, and wind erosion • Holds soil moisture • Adds diversity so soil microbes can thrive	• Maximize nutrients • Decreases use of pesticides • Improves water quality • Conserves water • Improves plant production
Cover Crop An un-harvested crop grown as part of planned rotation to provide conservation benefits to the soil.		• Increases soil organic matter • Prevents soil erosion • Conserves soil moisture • Increases nutrient cycling • Provides nitrogen for plant use • Suppresses weeds • Reduces compaction	• Improves crop production • Improves water quality • Conserves water • Maximize nutrients • Decreases use of pesticides • Improves water efficiency to cro
No Till A way of growing crops without disturbing the soil through tillage.		• Improves water holding capacity of soils • Increases organic matter • Reduces soil erosion • Reduces energy use • Decreases compaction	• Improves water efficiency • Conserves water • Improves crop production • Improves water quality • Saves renewable resources • Improves air quality • Increases productivity

Mulch Tillage

Using tillage methods where the soil surface is disturbed but maintains a high level of crop residue on the surface

- Reduces soil erosion from wind and rain
- Increases soil moisture for plants
- Reduces energy use
- Increases soil organic matter

- Improves water quality
- Conserves water
- Saves renewable resources
- Improves air quality
- Improves crop production

Mulching

Applying plant residues or other suitable materials to the soil surface to compensate for loss of residue due to excessive tillage

- Reduces erosion from wind and rain
- Moderates soil temperatures
- Increases soil organic matter
- Controls weeds
- Conserves soil moisture
- Reduces dust

- Improves water quality
- Improves plant productivity
- Increases crop production
- Reduces pesticide usage
- Conserves water
- Improves air quality

Nutrient Management

Managing soil nutrients to meet crop needs while minimizing the impact on the environment and the soil.

- Increases plant nutrient uptake
- Improves the physical, chemical, and biological properties of the soil
- Budgets, supplies, and conserves nutrients for plant production
- Reduces odors and nitrogen emissions

- Improves water quality
- Improves plant production
- Improves air quality

Pest Management

Managing pests by following an ecological approach that promotes the growth of healthy plants with strong defenses, while increasing stress on pests and enhancing the habitat for beneficial organisms.

- Reduces pesticide risks to water quality
- Reduces threat of chemicals entering the air
- Decreases pesticide risk to pollinators and other beneficial organisms
- Increases soil organic matter

- Improves water quality
- Improves air quality
- Increases plant pollination
- Increases plant productivity

USDA NRCS

United States Department of Agriculture
Natural Resources Conservation Service

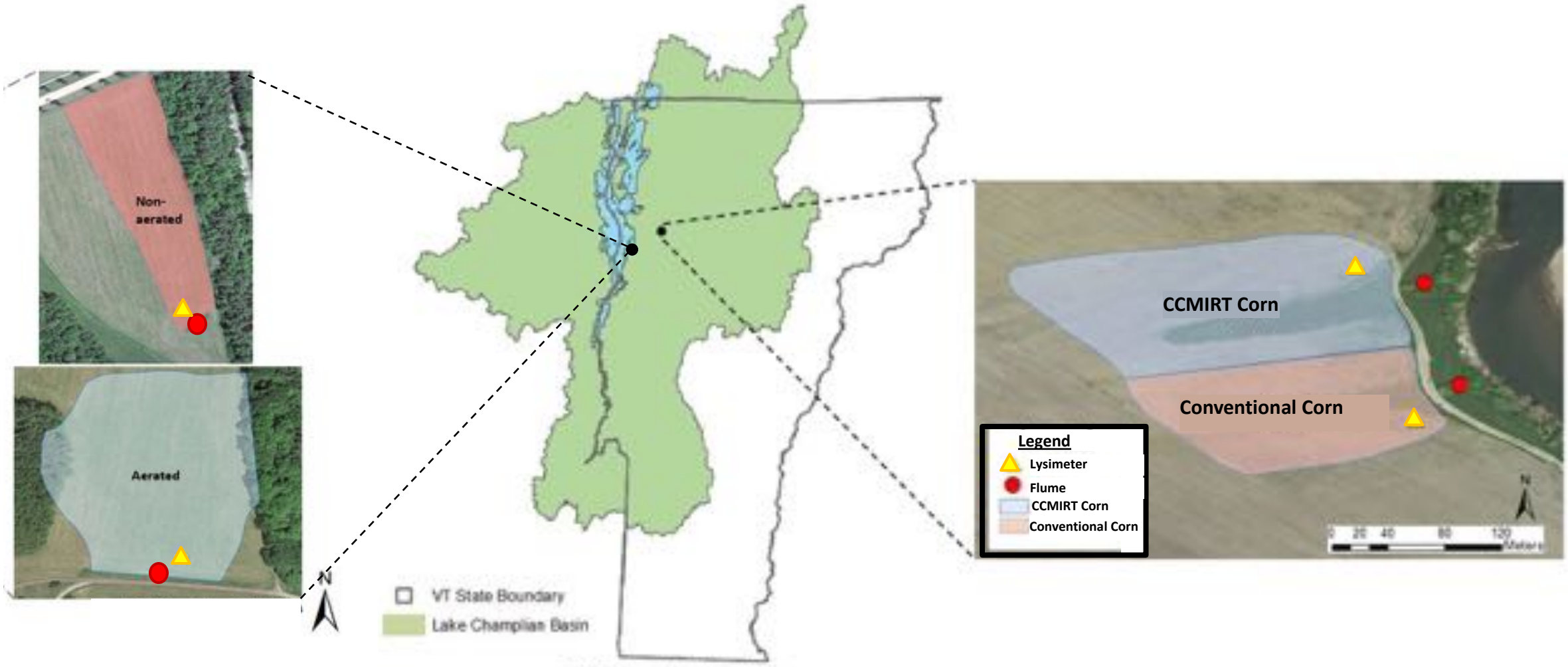
Verifying the impacts of **cover cropping** at a regional scale: looking at data from the Caring Dairy program

- 101 crops fields were evaluated for their impact on soil outcomes using the Cornell Assessment Soil Health
- Crop fields that had cover crops are significantly higher in organic matter content ($p=0.0017$), have significantly higher available water capacity ($p=0.014$), are associated with increased active carbon ($p=0.001$), have significantly higher respiration rates ($p=0.03$), and are significantly associated with increased soil health scores ($p=0.0007$).

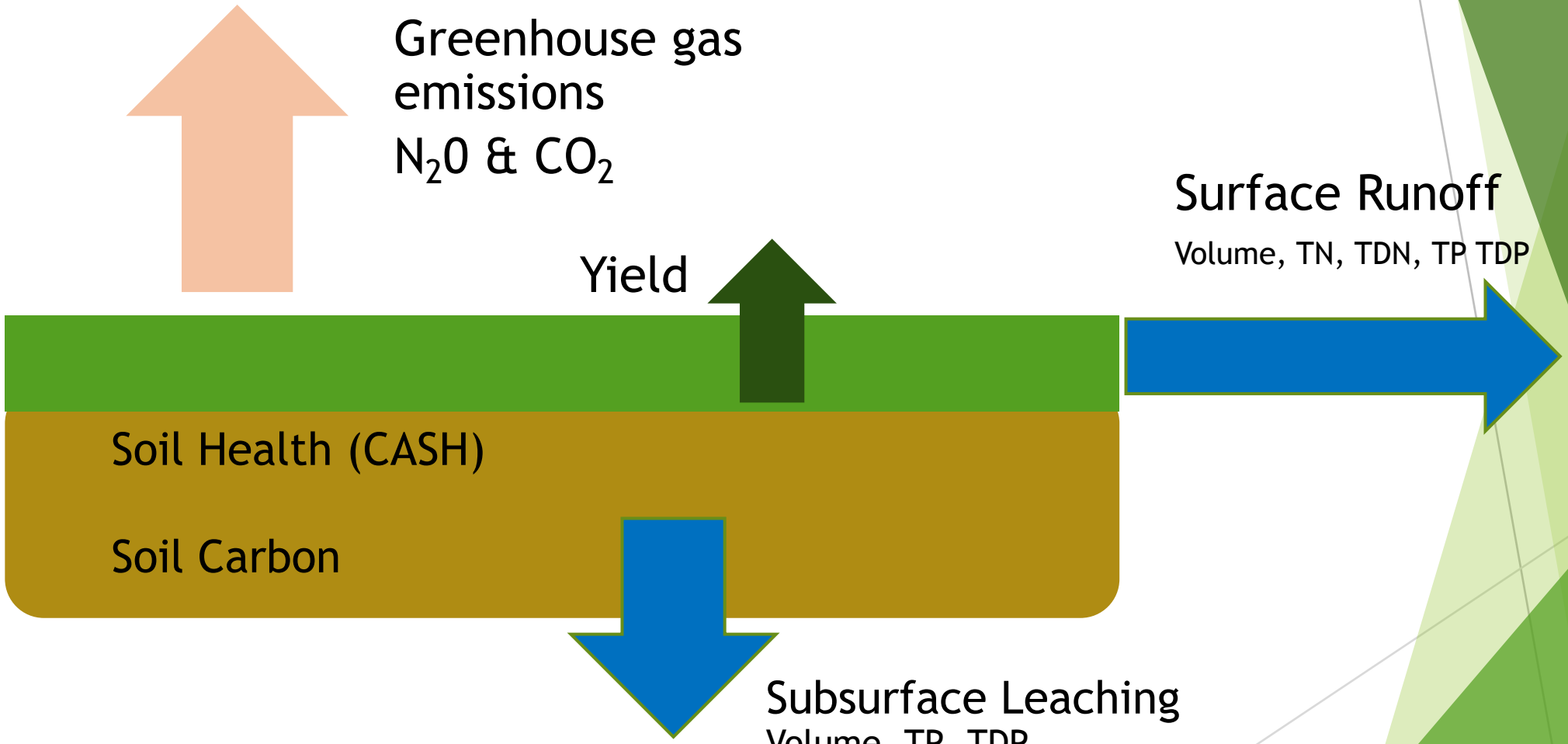
Climate Co-benefits: Water quality best management practices can enhance soil health, climate mitigation & climate resilience

- 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
- Farmers use soil health to address extreme precipitation risks
- Research needs:
  - Verify these outcomes for WQ practices in our region
  - Identify and reduce tradeoffs
  - Include unseen pathways
    - Subsurface nutrient flux
    - Soil surface GHG emissions
  - Pesticides

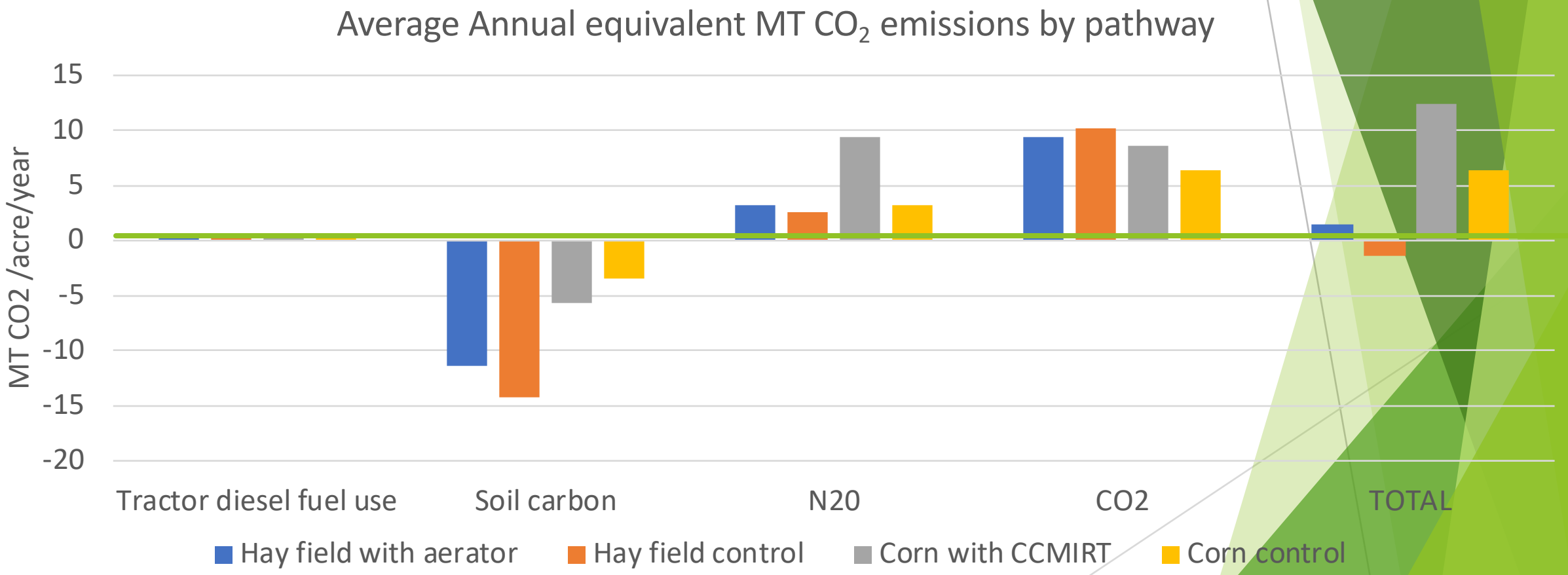
Field Scale Paired Watersheds



Biophysical Dimensions

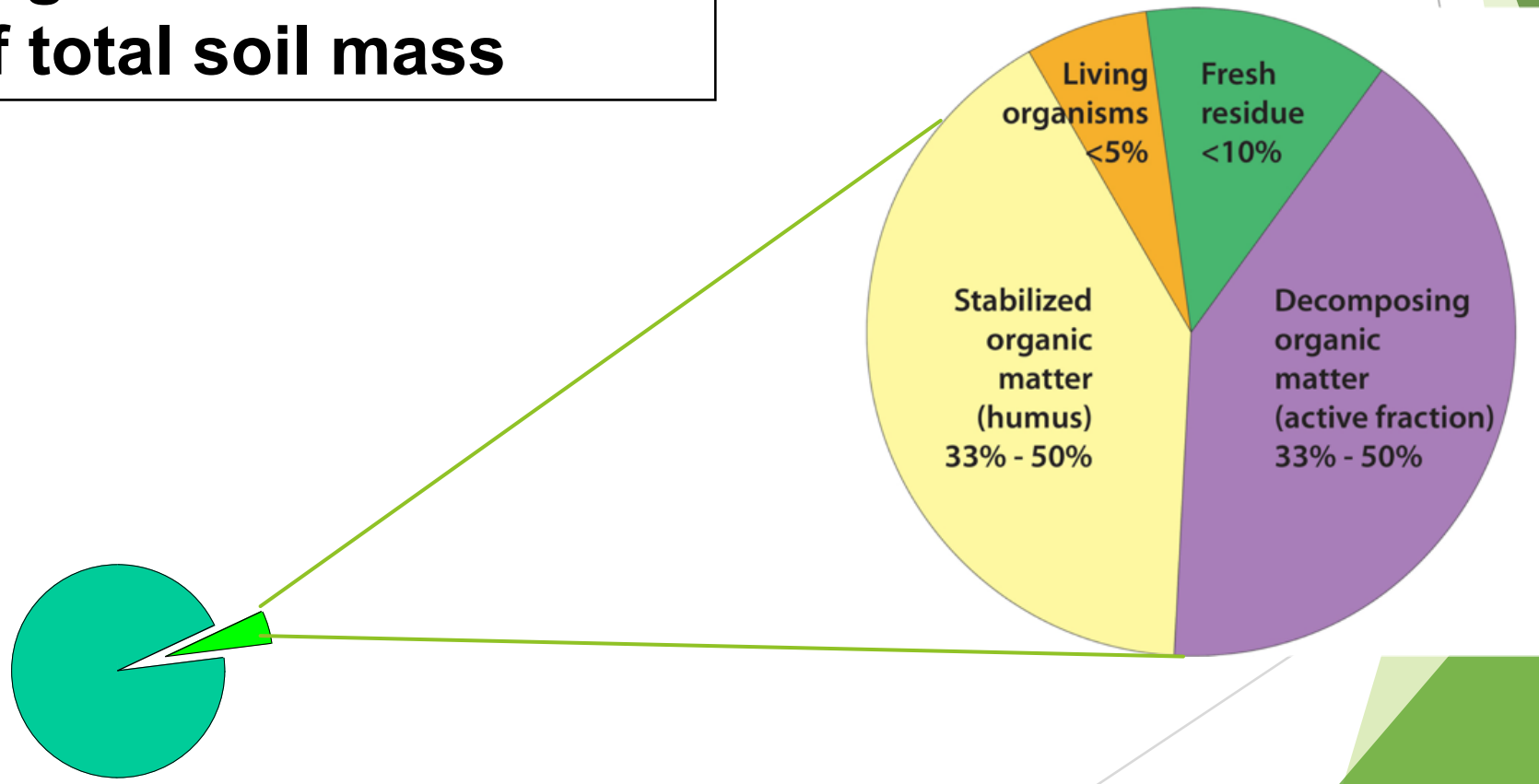


Key findings: unseen pathways

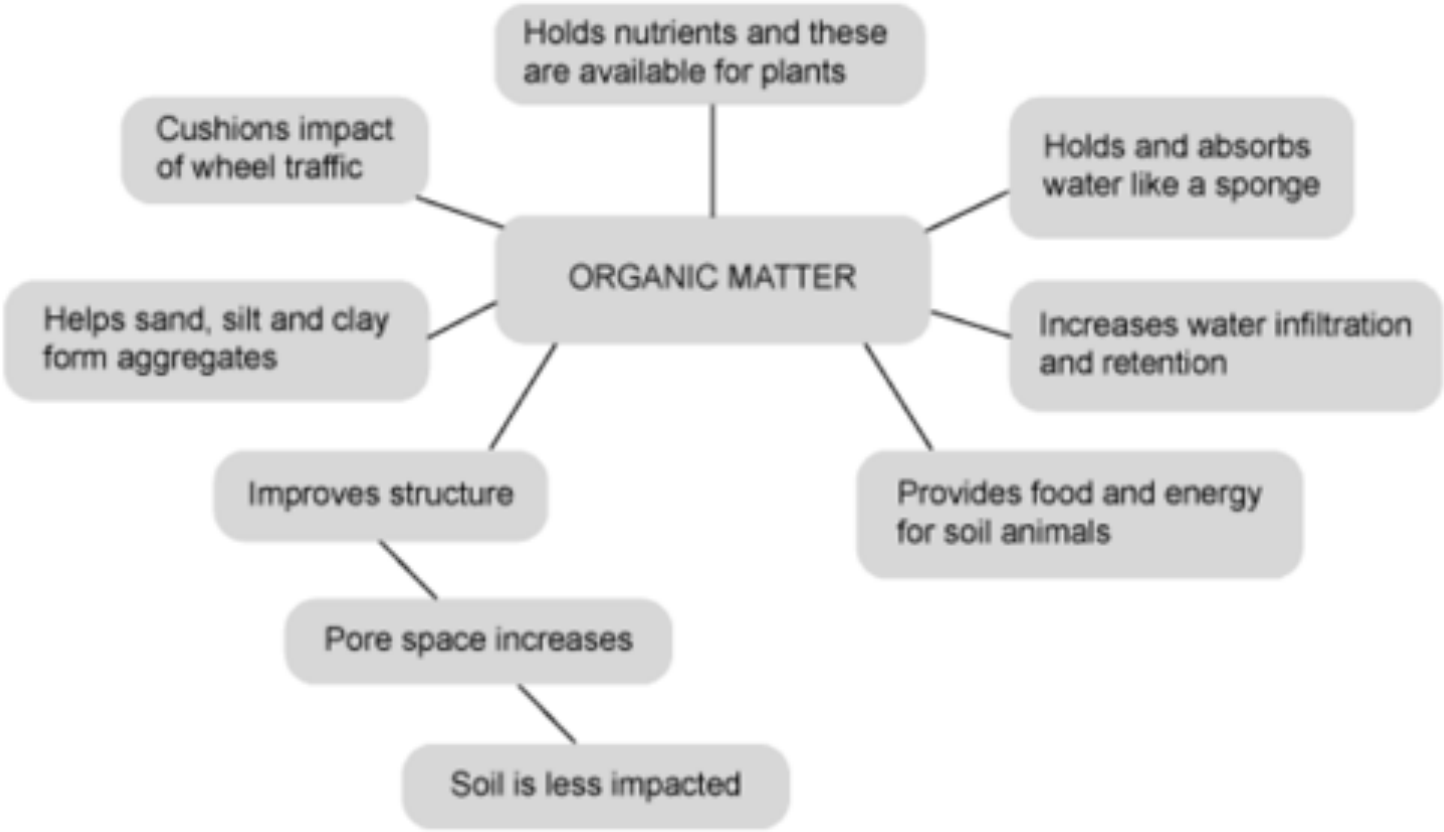


Soil Organic Matter

Organic matter is 1-6% of total soil mass



Soil organic matter



Erosion Prevention

Data used in the universal soil loss equation indicate that increasing soil organic matter from 1 to 3 percent can reduce erosion 20 to 33 percent because of increased water infiltration and stable soil aggregate formation caused by organic matter

Soil Structure & Aggregation

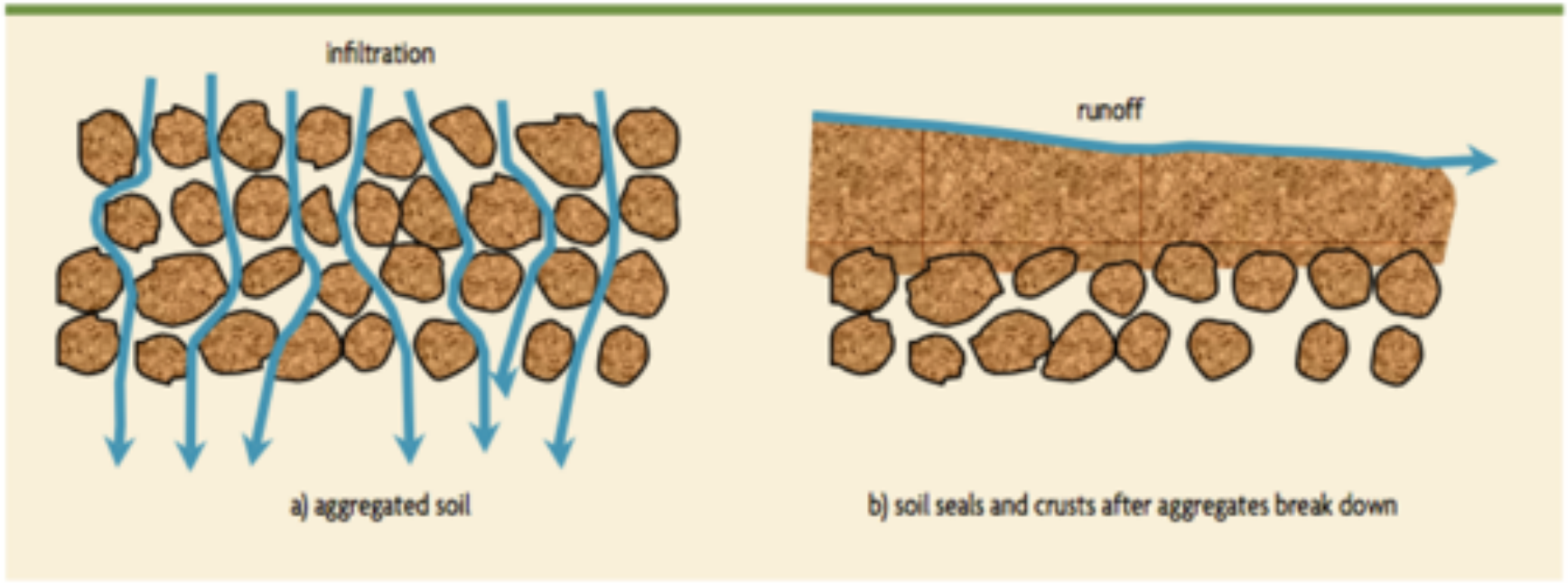
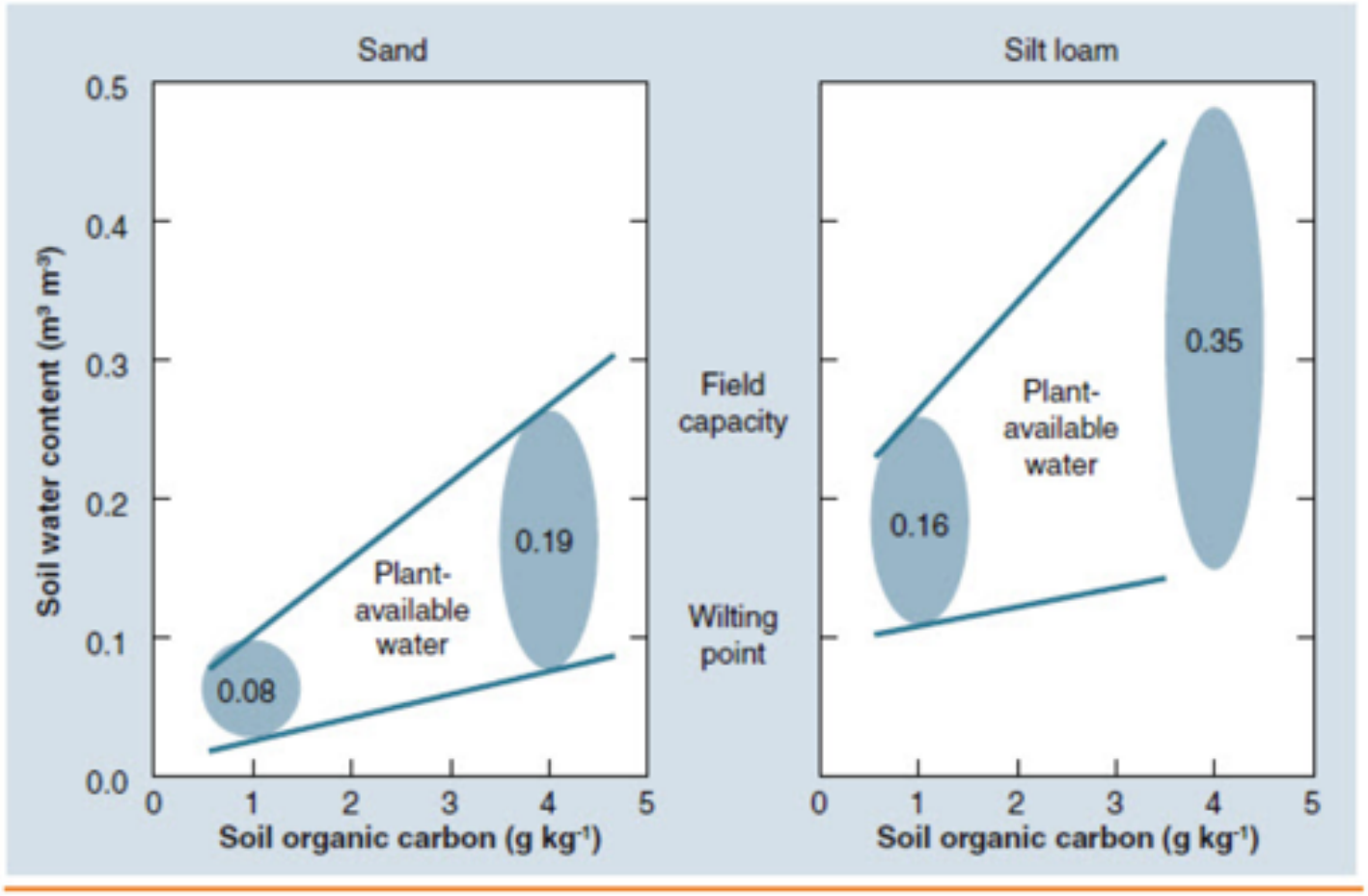


Figure 2.6. Changes in soil surface and water-flow pattern when seals and crusts develop.

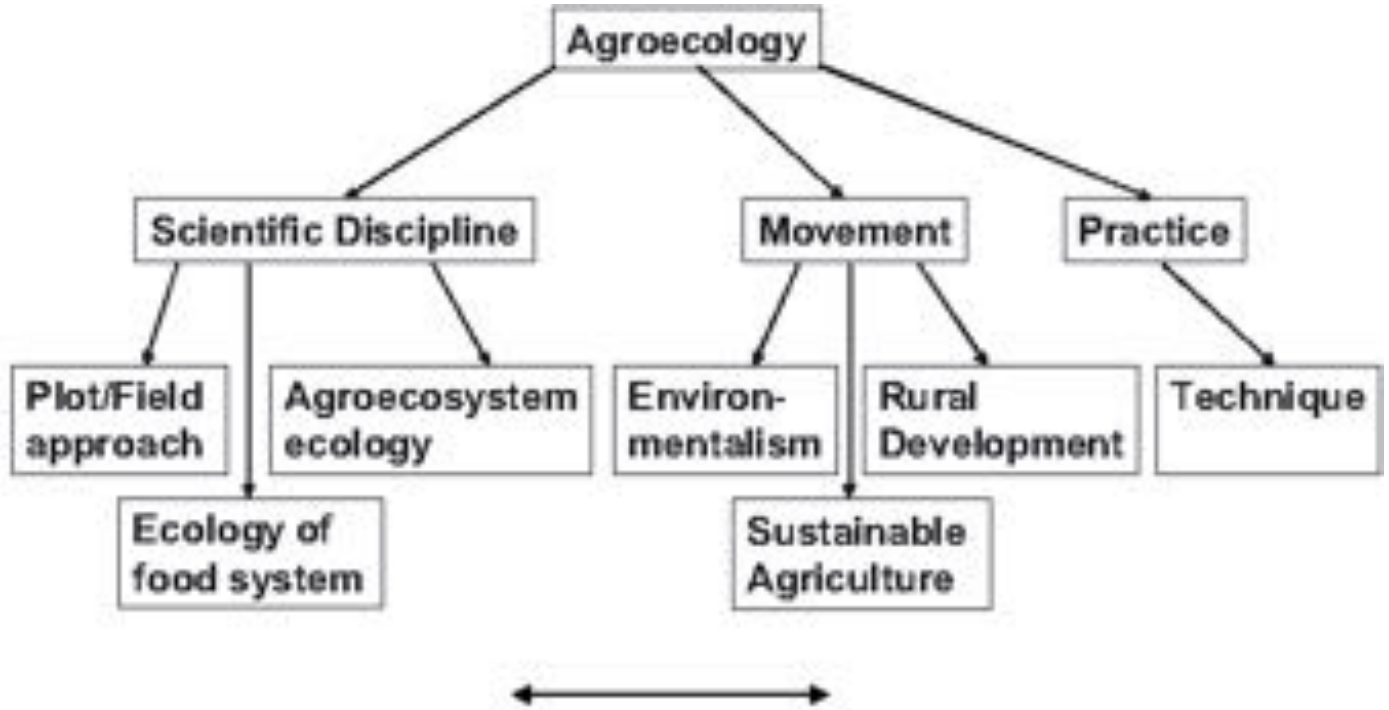
Organic matter causes soil to form soil aggregates and pores, which improves soil structure. With better soil structure, permeability (infiltration of water through the soil) improves, in turn improving the soil's ability to take up and hold water.

Water-Holding Capacity



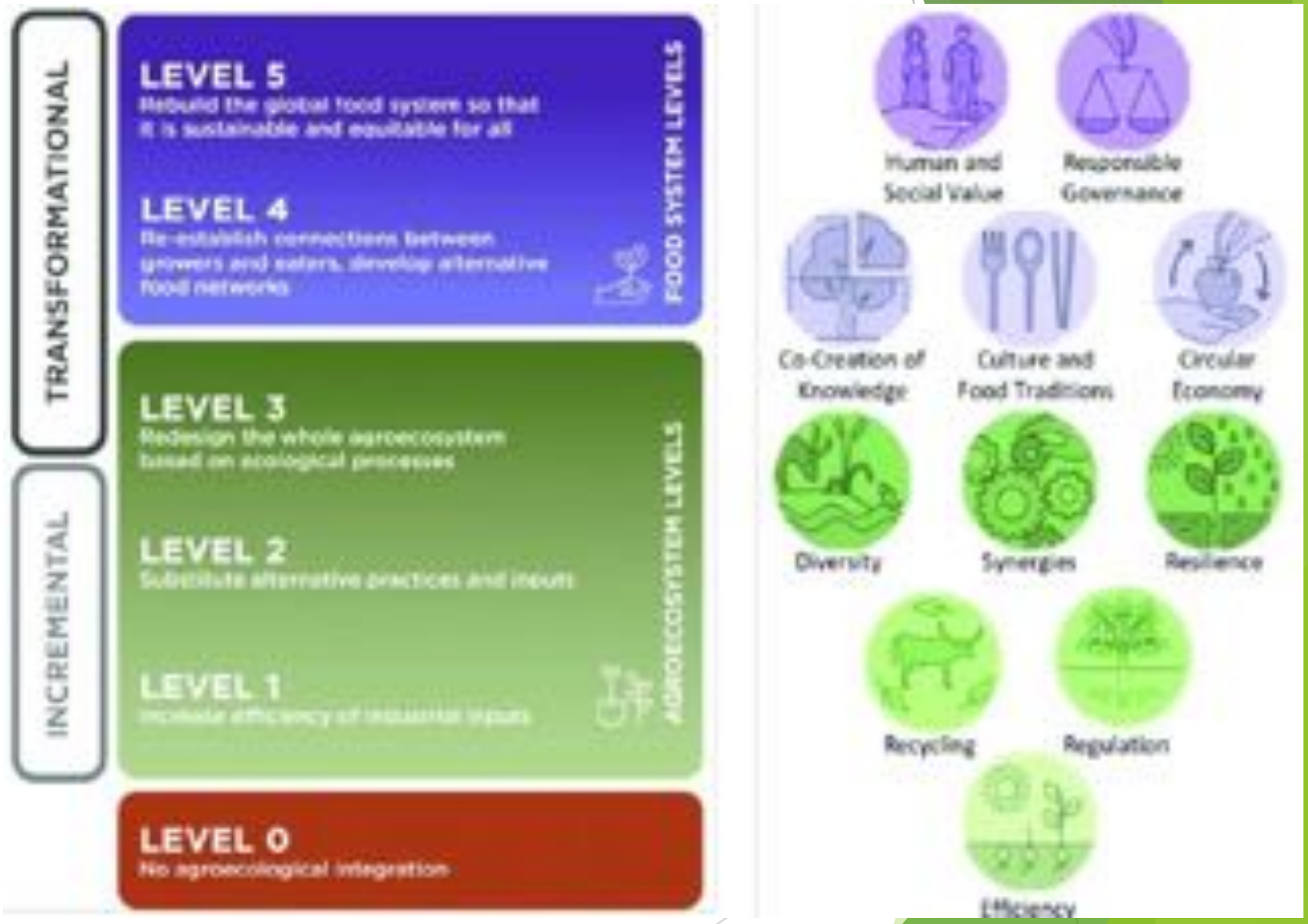
Organic matter behaves somewhat like a sponge, with the ability to absorb and hold up to 90 percent of its weight in water. A great advantage of the water-holding capacity of organic matter is that the matter will release most of the water that it absorbs to plants.

Agroecology
as science, practice & movement



Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., & David, C. (2009). Agroecology as a science, a movement and a practice. A review. *Agronomy for sustainable development*, *29*(4), 503-515.

Agroecology: guided by principles & pathways



Andrieu, N., & Kebede, Y. (2020). Agroecology and Climate Change: A case study of the CCAFS Research Program.

Co-creation of knowledge: Farmer voices in Transdisciplinary Agroecology

IDENTIFIES KEY LEVERAGE POINTS TO SUPPORT CHANGE AND RESILIENCE

2020 Soil Health Survey Preliminary Results

What enhances your ability to support soil health on Vermont farms?

Money	• Financial incentives
Knowledge and education	• Networks • Research and data
Practices	• Materials • Technical assistance
Community support and collaboration	• Relationships • Social capital • Consumer support

2020 Soil Health Survey Preliminary Results

What limits your ability to support soil health on Vermont farms?

Money	• Cost, funding • Material needs
Time	• Farmer capacity
Data	• Connecting science to practices
Policy	• Path dependence
Disconnection	• Multi stakeholder roles

The State of Soil Health in Vermont

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

GUND INSTITUTE FOR ENVIRONMENT

THE UNIVERSITY OF VERMONT EXTENSION

DARTMOUTH

vermont environmental stewardship PROGRAM

The Nature Conservancy Vermont

BEN & JERRY'S

The State of Soil Health in Vermont

Phase 1 : Analyze existing data

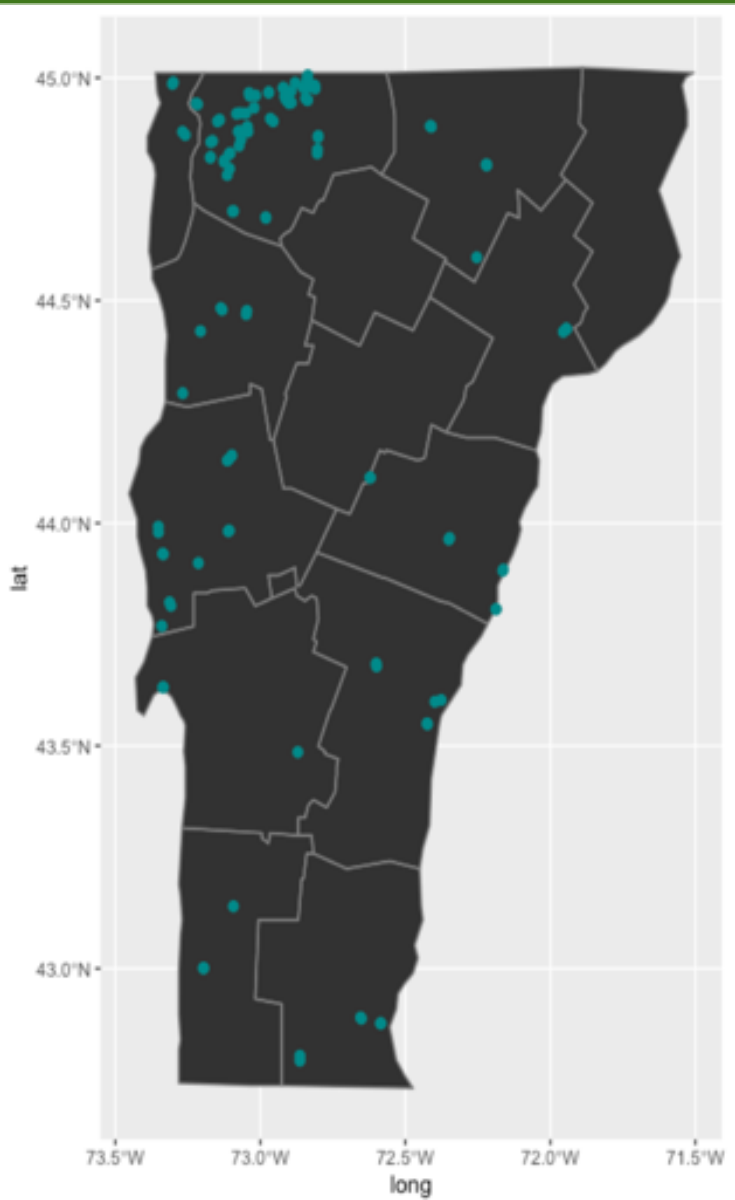
Phase 2 : 2021 Baseline Assessment

- Coordinate data sharing between existing projects
- Establish shared sampling methods, data sharing standards, trust, shared goals
- Assess current range of soil carbon stocks and soil health indicators in agricultural landscapes
- Demonstrate value to stakeholders
- Use as basis for education about ecosystem services and soil health

Phase 3 : 2022 and beyond

- More robust sampling, greater participation
- Responsive to farmers, network liaisons
- Additional measurements & analyses

The State of Soil Health in Vermont



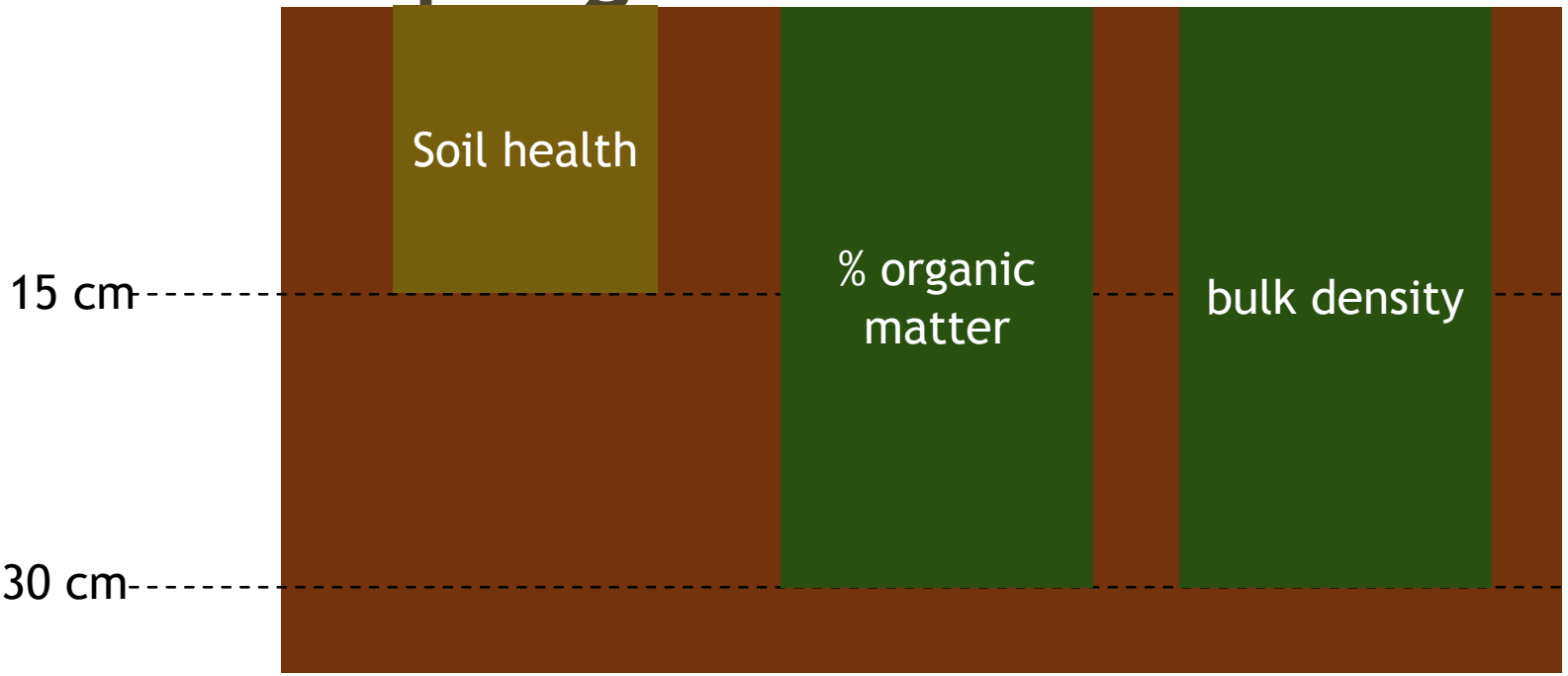
2021 Baseline Assessment

- *Convenience sample* from existing research projects, plus purposeful sampling to reach greater geographic extent of state
- 200 fields sampled

Analysis:

- What is the current state of soil health on farms?
- What kinds of farm management are associated with the highest levels of soil health?
- Where are the most important places to focus on improvement?
- How do soil texture and management influence soil health indicators, soil carbon stocks and associated ecosystem services?

Soil Sampling



Samples & data for each field:

- one composite soil sample to 15 cm depth for Cornell CASH test, Ecoplate carbon substrate assays (UVM) & carbon fractions (Dartmouth)
- one composite soil sample to 30 cm depth for UVM
- three bulk density cores to 30 cm for UVM
- field management information

The State of Soil Health in Vermont

What are we measuring and what does it mean?

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

Soil Carbon Stocks to 30 cm depth
- Bulk density
- Soil Organic Carbon

Biological Functional Diversity
- Ecoplate carbon substrate test

Carbon fractions
- Particulate VS Mineral organic carbon

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

Soil Carbon Stocks in Vermont agricultural soils

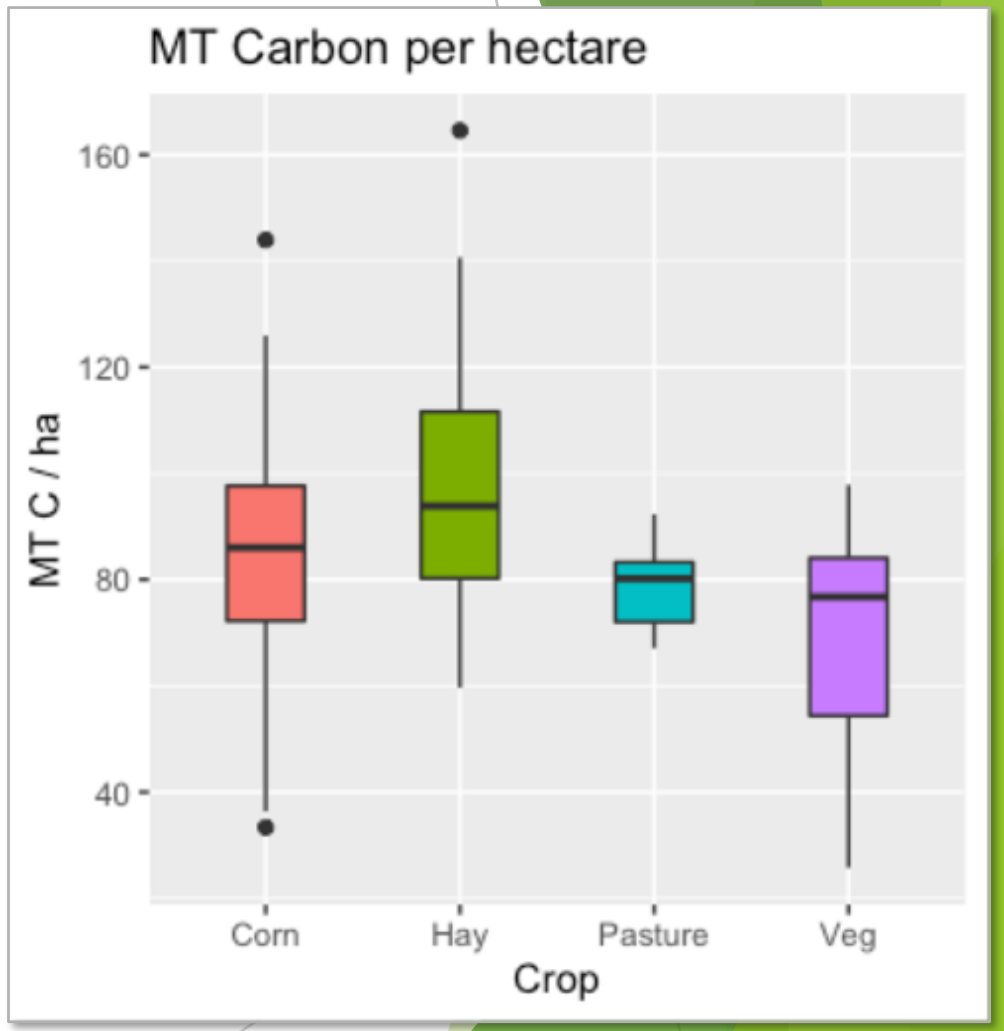
The University of Vermont

Preliminary results from the State of Soil Health 2021 data

- Hay fields have the greatest agricultural soil carbon stocks
- Corn & hay fields had some of the highest soil carbon stocks.
- Vegetable fields have lowest soil carbon 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	Standard deviation
Corn	96	33.35	***86.01***	85.52	143.95	21.68
Hay	24	59.64	***93.84***	99.65	164.56	28.34
Pasture	16	67.06	***80.18***	79.00	92.32	9.09
Veg	18	25.73	***76.75***	69.30	97.84	21.60



Soil Organic Carbon in Vermont

The University of Vermont

Comparing existing data on agricultural soils

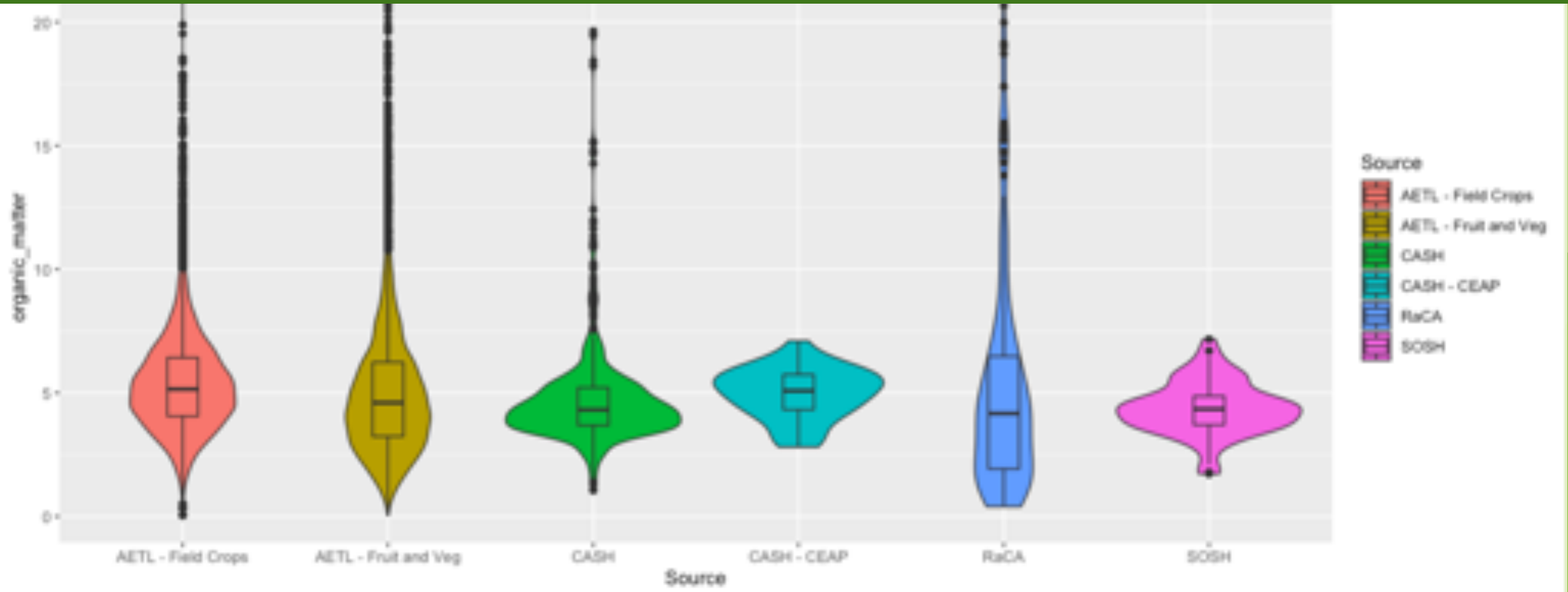
- Organic matter content in Vermont agricultural soils are outstanding
- Climate, soil texture and **management** contribute to high organic matter levels

Soil organic matter levels in hay, pasture and crop fields from available data

Dataset	n	Average OM%
Vermont - UVM AETL data	9,415	5.3%
Vermont - USDA RaCA data	26	5.6%
Vermont - Cornell CASH data	622	4.8%
Vermont - State of Soil Health 2021 data	145	4.4%
USA - USDA RaCA data	6,236	3.2%

Soil Organic Carbon in Vermont

The University of Vermont



- Organic matter content in Vermont agricultural soils from over 26,000 samples in multiple datasets corroborate that the **median and mean organic matter content are over 4%**
- Greater gains are possible. The high end of the interquartile range (Q3) for soil testing data from Vermont is **6.4% organic matter.**

Thank you!

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