Soil Health – What's Old, What's New, and How Does it Relate to Cover Cropping?

Midwest Cover Crop Conference
21 Feb 2019

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COLLEGE OF ACES Department of Crop Sciences
ILLINOIS

https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/

Soils

Soil Health

Related Links

- Get Started with NRCS
- Cover Crop Plant Guides
- Soil Health Division Contacts
- Cover Crop Topic Room (SARE)
- La Salud de los Suelos en Español
- Core Practices Soil Health Checklist
- USDA Service Center Locator
- Korean -language Soil Health Fact Sheets
- Soil Health Literature

Soil Health

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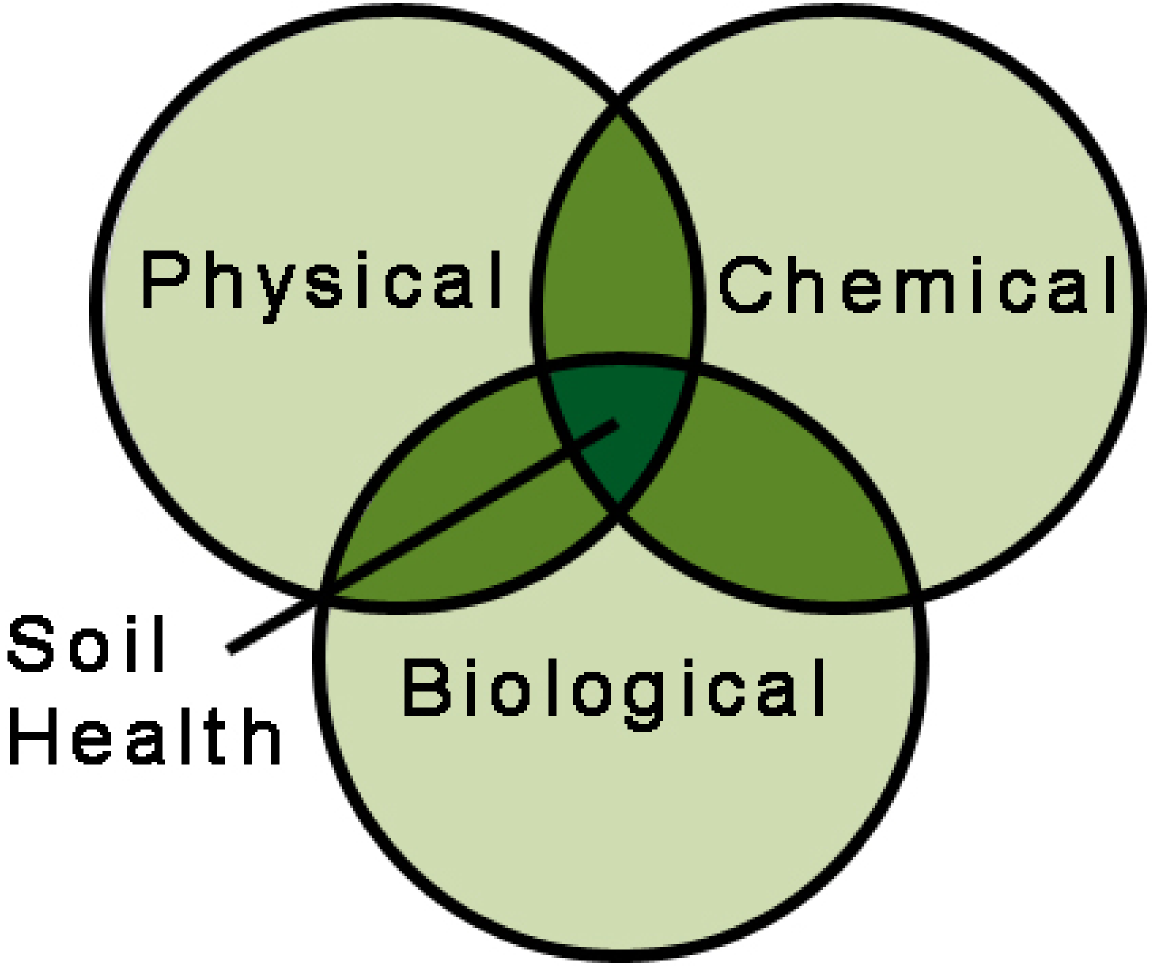
NRCS Definition of Soil Health

“The continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans”

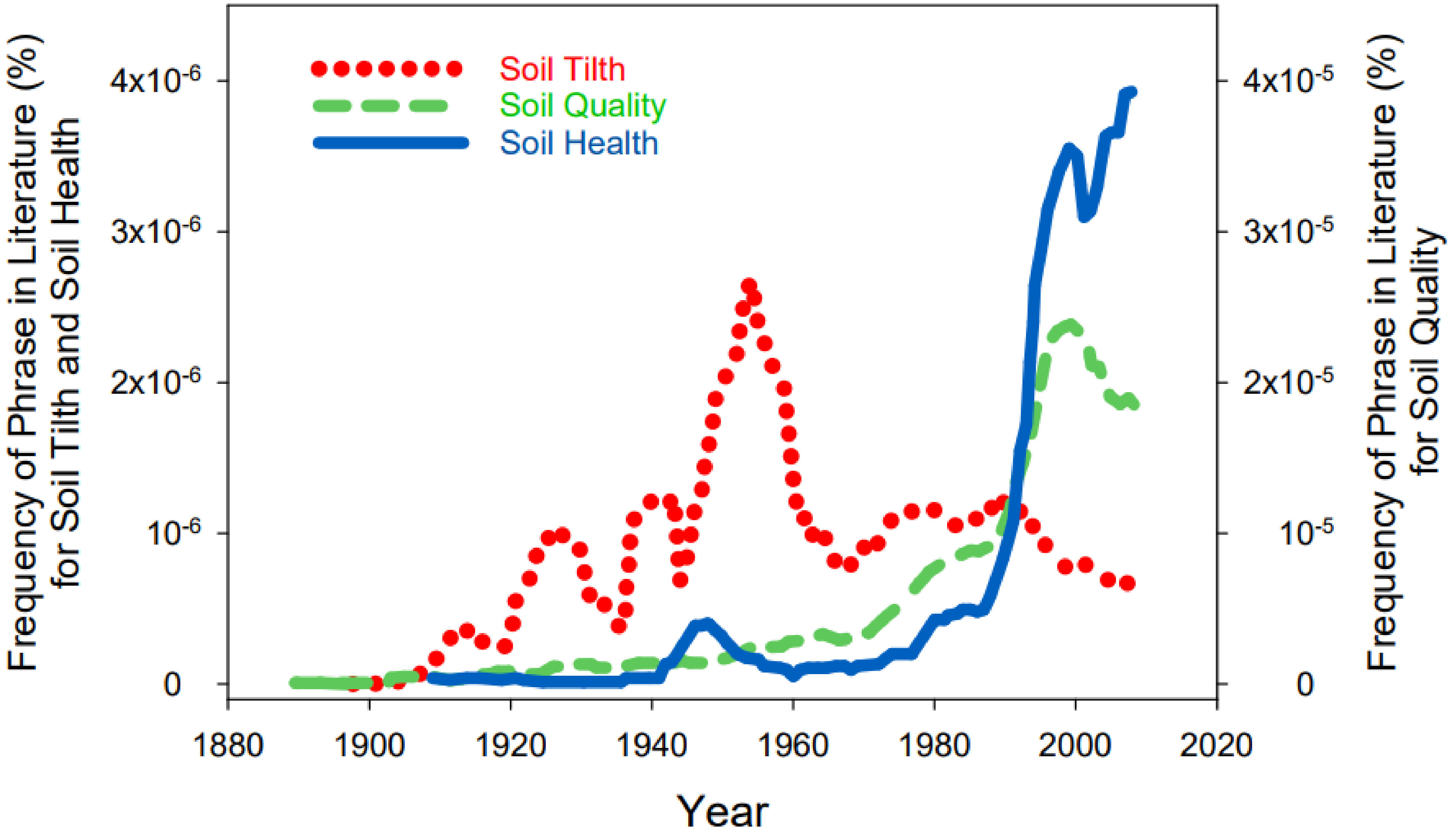
“This definition speaks to the importance of managing soils so they are sustainable for future generations”

“To do this, we need to remember that soil contains living organisms that when provided the basic necessities of life - food, shelter, and water - perform functions required to produce food and fiber”

Conceptualizations of soil health

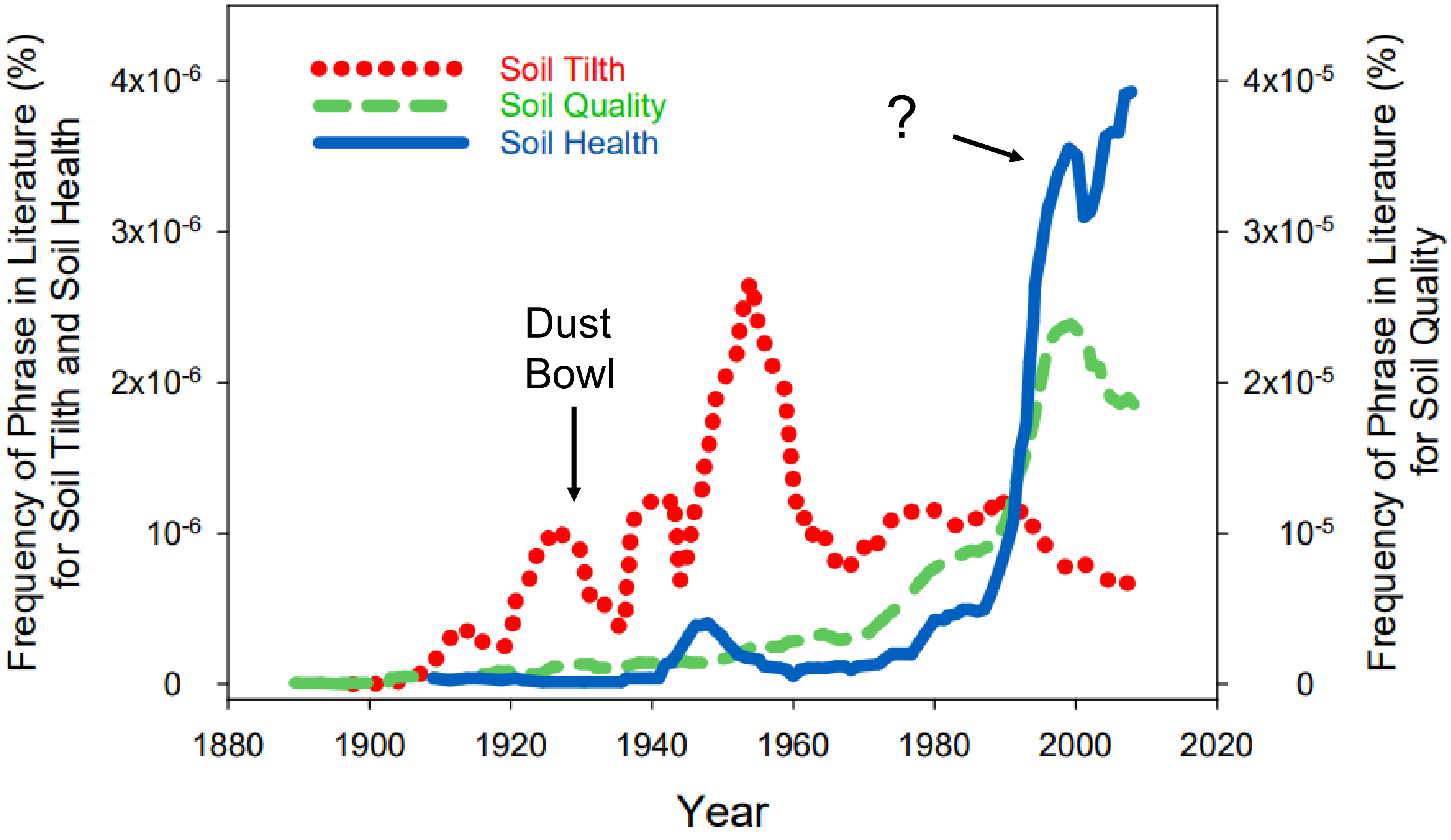


Re-inventing the wheel?



McDaniel, 2017. Integrated Crop Management Conference. Iowa State University

“Biology” distinguishes Soil Quality vs Health



McDaniel, 2017. Integrated Crop Management Conference. Iowa State University

Published January, 1938

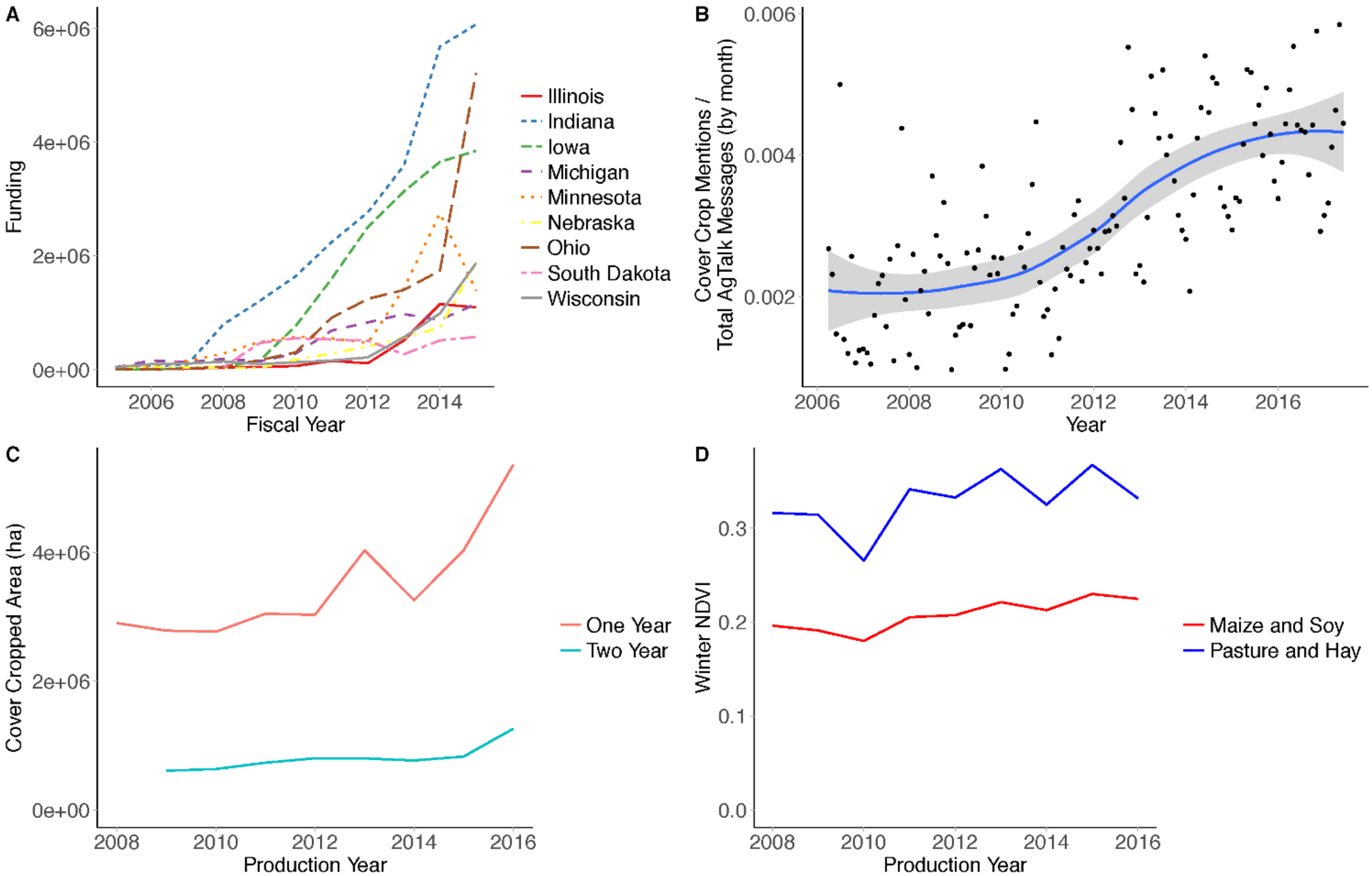
THE VALUE OF COVER CROPS IN CONTINUOUS CORN CULTURE[1]

T. E. ODLAND AND H. C. KNOBLAUCH[2]

THE use of cover crops for the purpose of conserving soil fertility, whenever possible, is becoming a general practice on the better managed farms in Rhode Island as well as in many other localities. Specific evidence on the value of such practice over a considerable period of time is, however, not so plentiful. Results obtained with nonlegume cover crops have sometimes been contradictory. The purpose of this paper is to present some results from a long-continued experiment with rye and clover cover crops in continuous corn culture at the Rhode Island Agricultural Experiment Station.

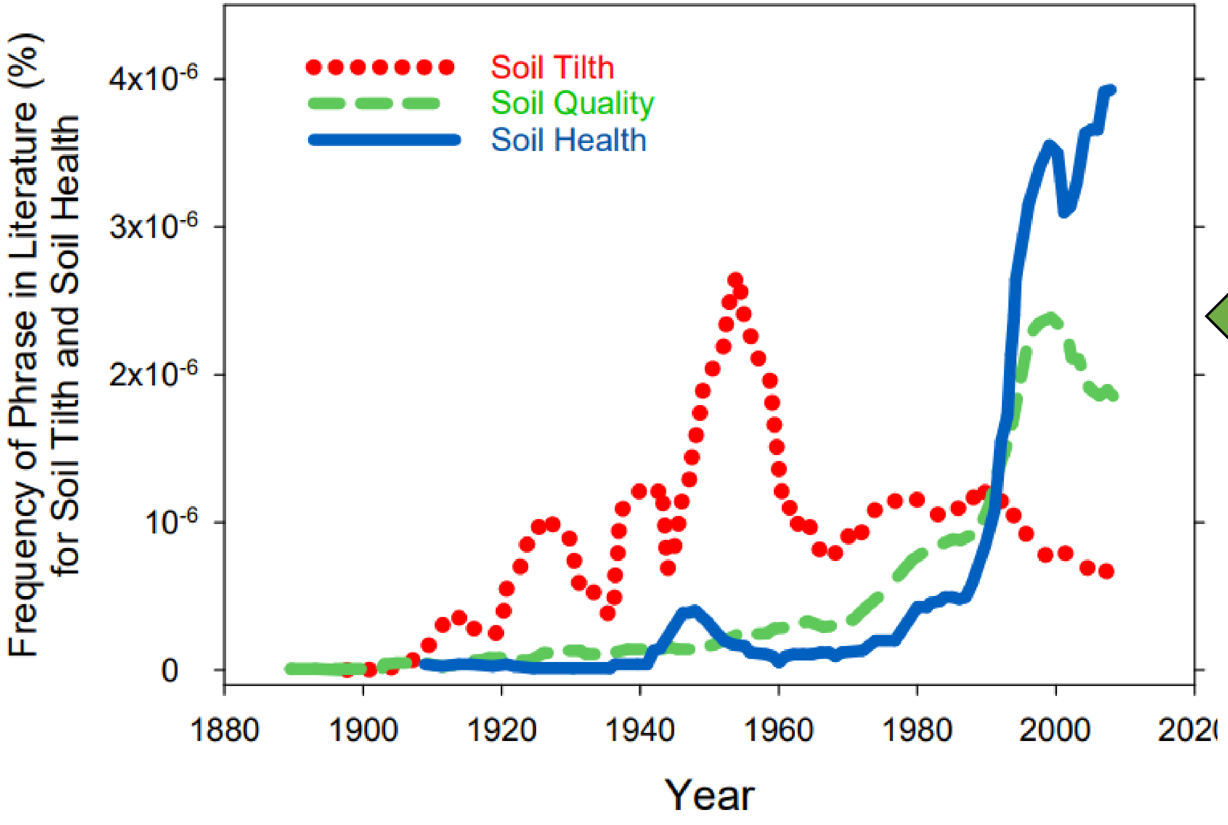
"The practice of using cover crops for conserving soil productivity is a highly desirable practice and should be encouraged"

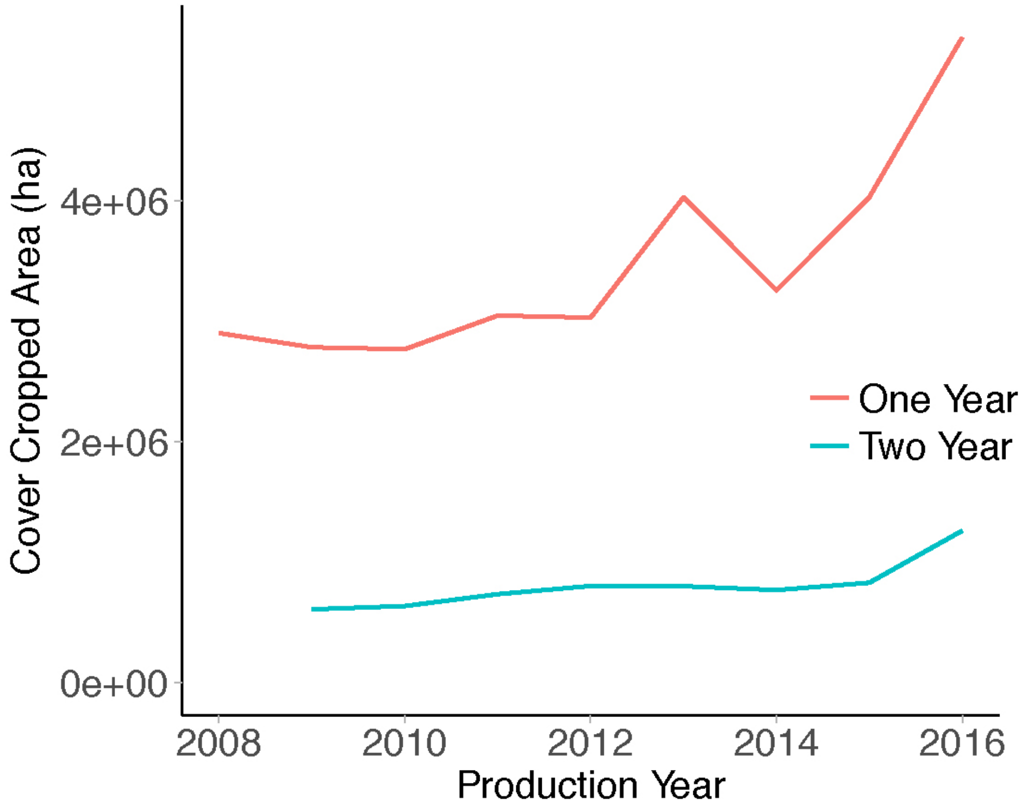
Support for and use of cover crops is increasing



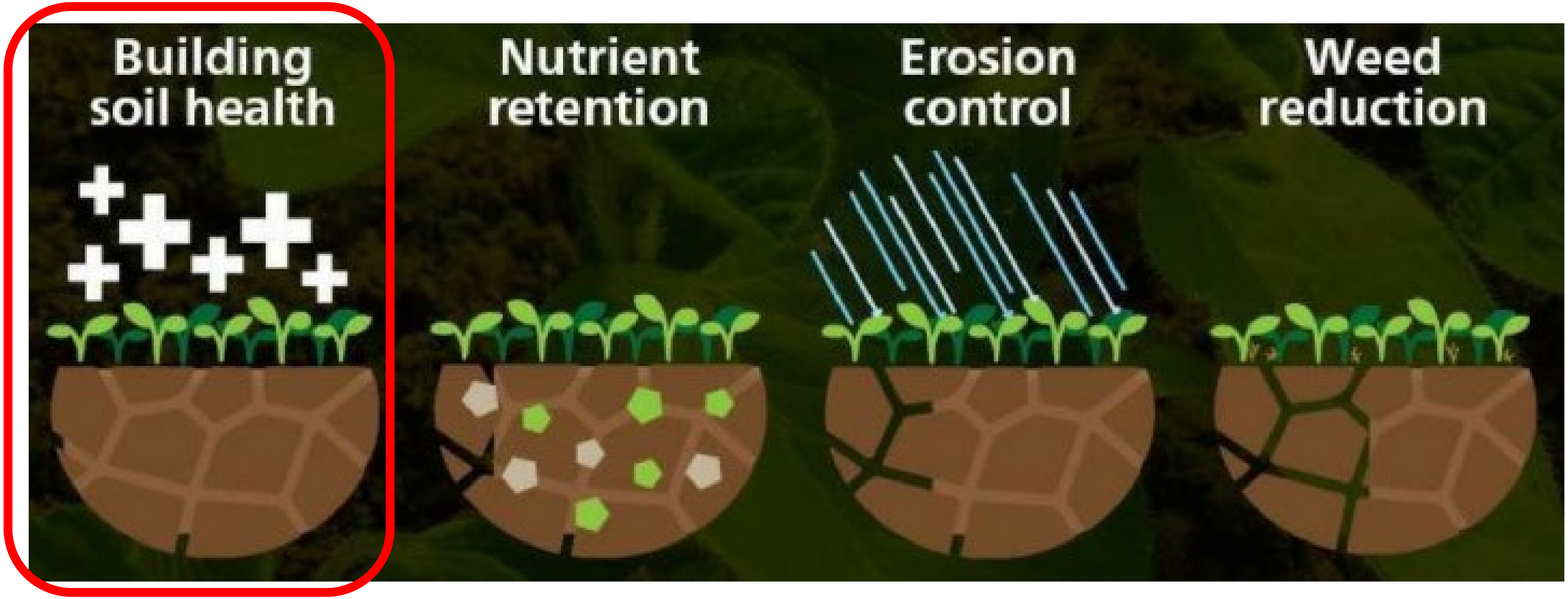
Seifert et al. 2018 *Environ Res Lett* 13:6

Co-rise of "soil health" and cover cropping





Cover crops directly and indirectly influence soil health

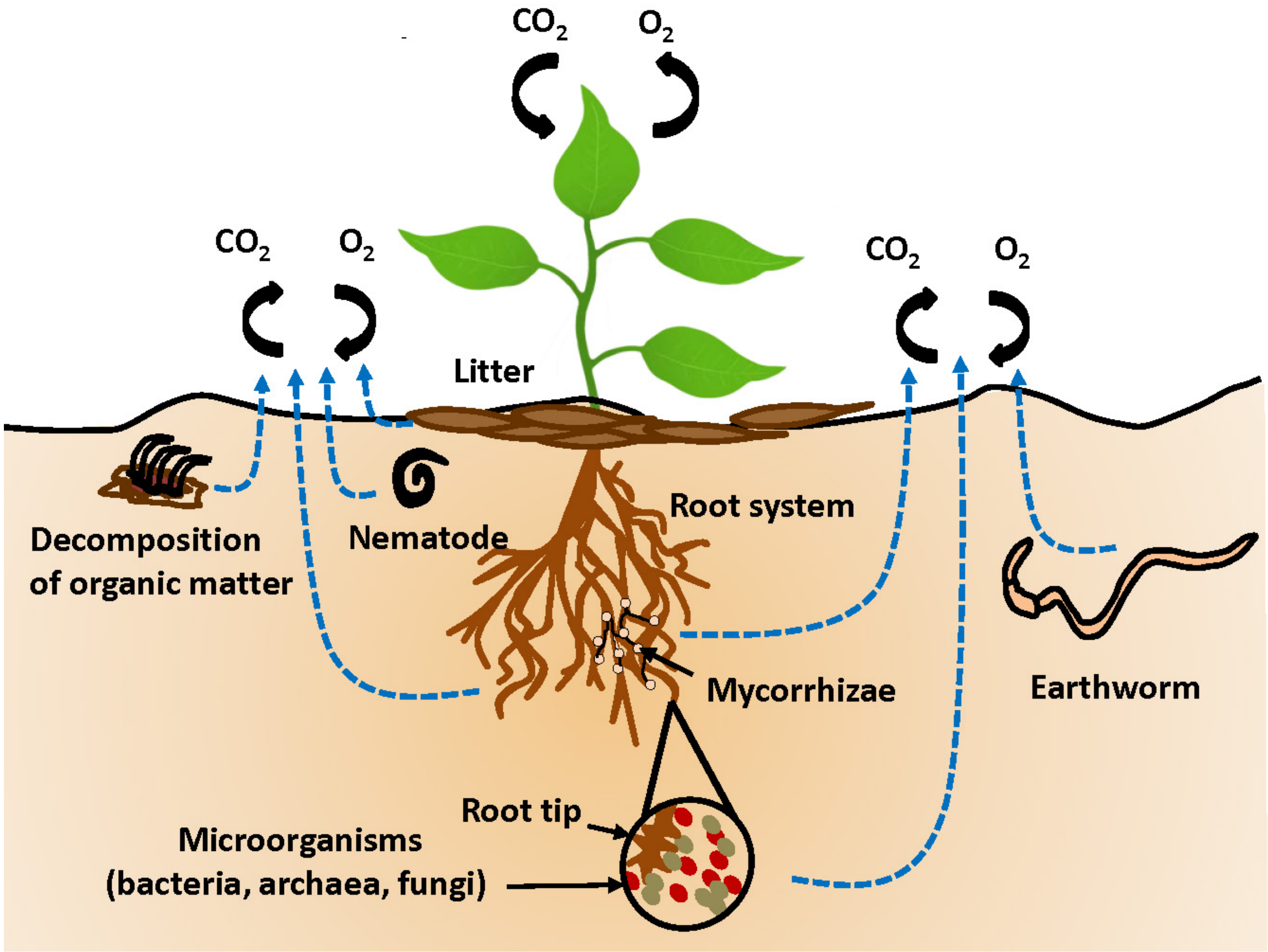


Alltech Crop Science, 2015

How do cover crops factor in soil health?

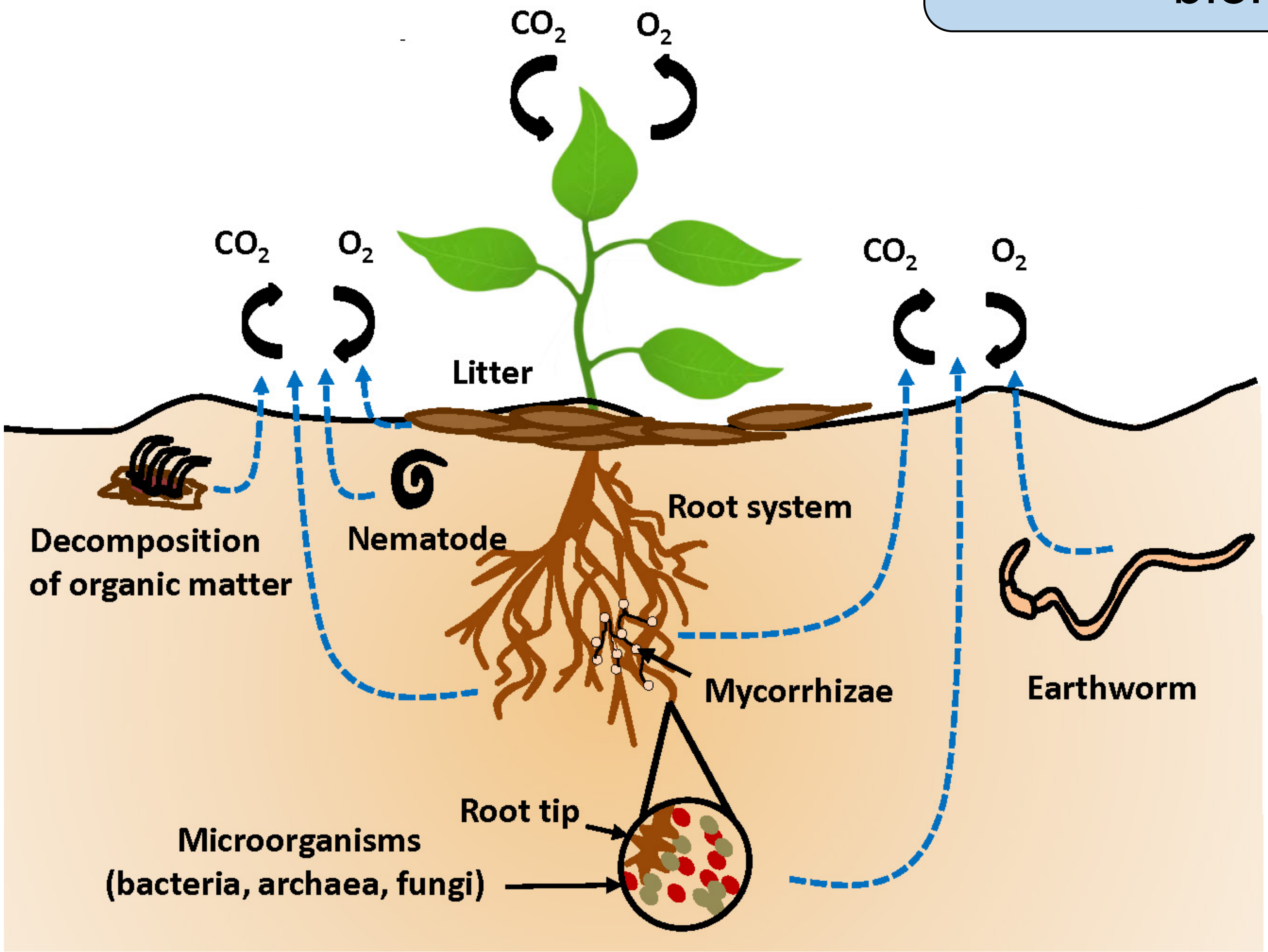
USDA Natural Resources Conservation Service (NRCS) has identified four basic principles for maintaining and improving soil health:

1. Keep the soil covered as much as possible ✓
2. Disturb the soil as little as possible ✓
3. Keep plants growing throughout the year to feed the soil ✓
4. Diversify crop rotations as much as possible ✓


CO_2
O_2
CO_2
O_2
CO_2
O_2
Litter
Root system
Decomposition
of organic matter
Nematode
Mycorrhizae
Earthworm
Root tip
Microorganisms
(bacteria, archaea, fungi)

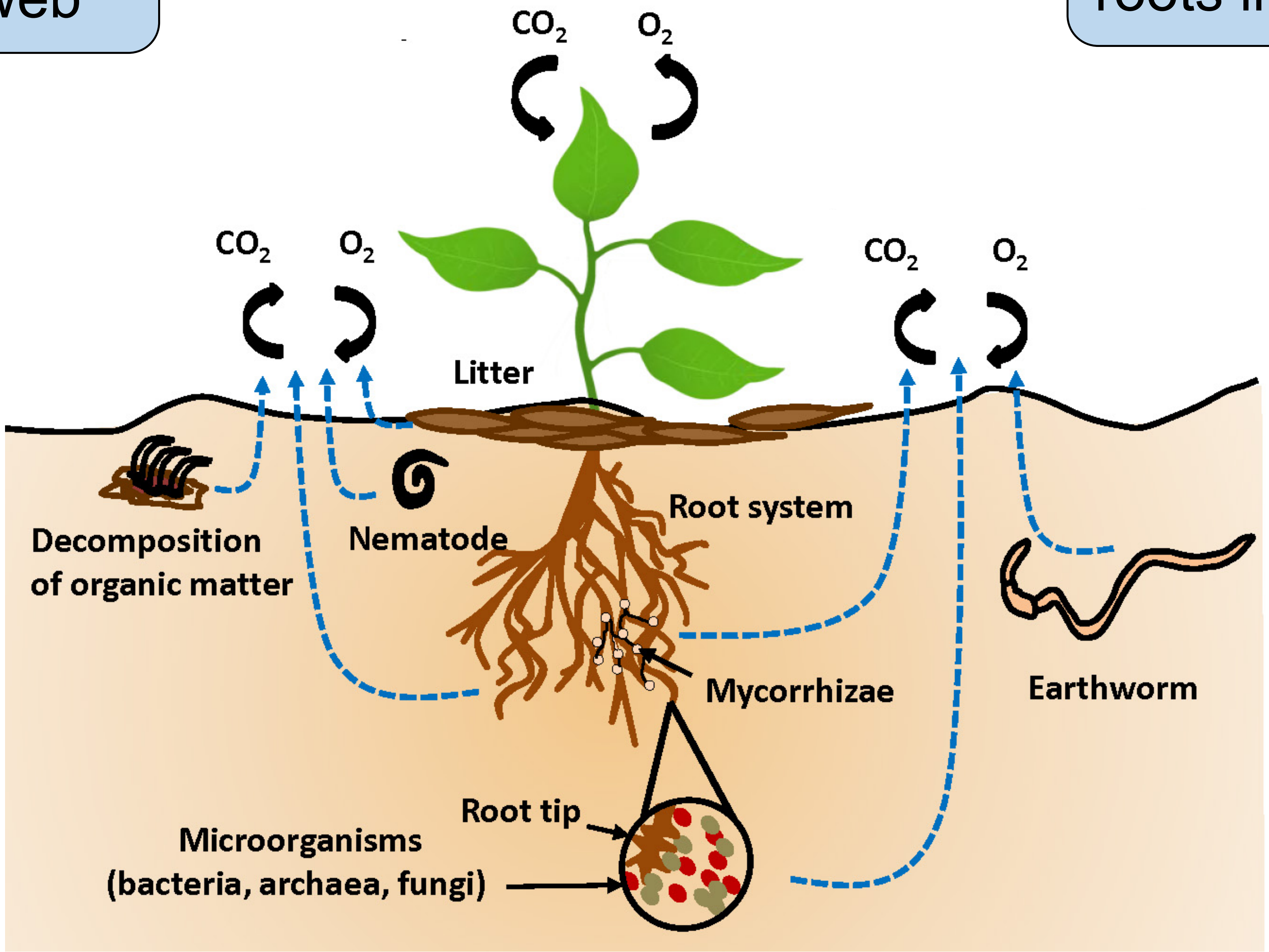
Plants are C pumps

C influx drives soil biology

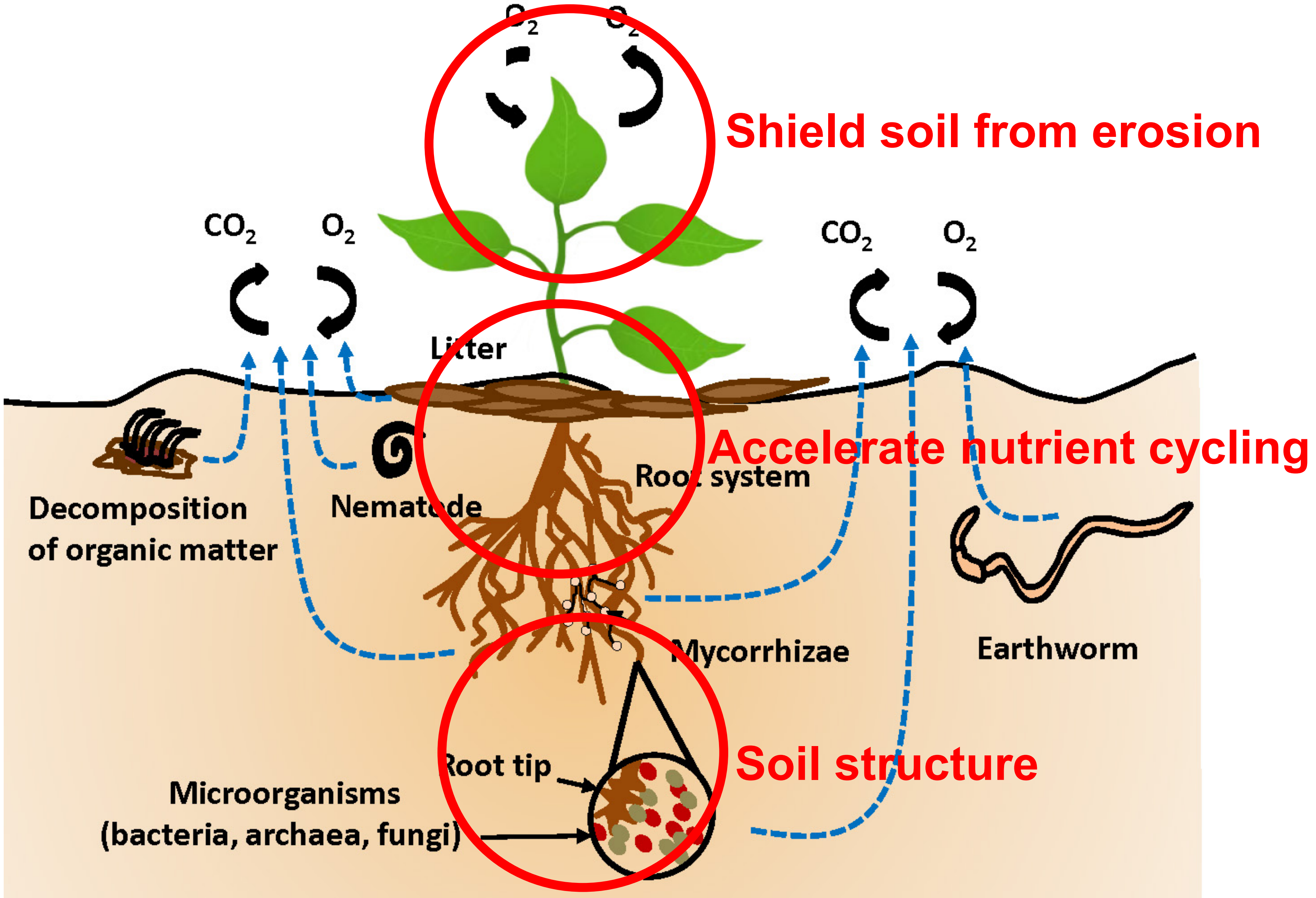


Feeding the soil food web

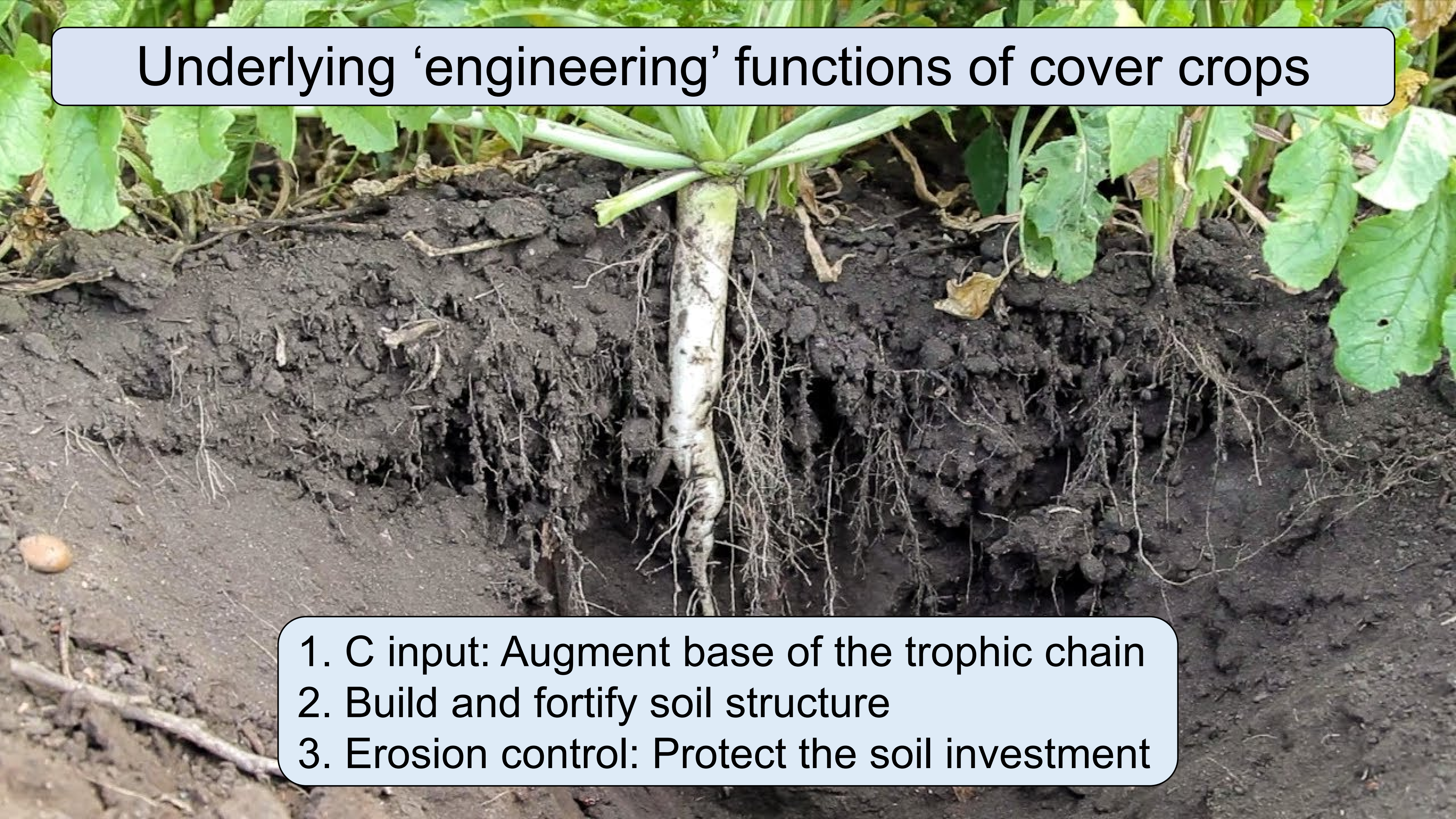
Importance of roots in the ground



The carbon pump of cover crops also comes with a drill and shield



Underlying ‘engineering’ functions of cover crops



1. C input: Augment base of the trophic chain
2. Build and fortify soil structure
3. Erosion control: Protect the soil investment

Cover crops are a solar panel-powered carbon pump for the soil food web

- Flow of energy through cells facilitated by net C influx from atmosphere to soil
- Measurable **indicators** target specific aspects of soil biology address how this C flows through soil:
  - Who
  - What they're eating
  - How they're eating
- Tier 1 and Tier 2 biological soil health indicators identified by Soil Health Institute
  - Active area of research

Cornell Soil Health Assessment

[redacted]

Agricultural Service Provider:
None
Cedar Basin Crop Consulting
cbcc@earthlink.net

Sample ID:	L_555
Field/Treatment:	Tenge E
Tillage:	1-7 inches
Crops Crown:	COG, COG, SOY
Date Sampled:	12:00:00 AM
Given Soil Type:	Muscatine
Given Soil Texture:	Silty Clay Loam
Coordinates:	[redacted]

Measured Soil Textural Class: Silt Loam   Sand: 28%   Silt: 56%   Clay: 16%

Test Report

	Indicator	Value	Rating	Constraint
Physical	Available Water Capacity	0.31	100	
Physical	Surface Hardness			Not Rated: No Field Penetrometer Readings Submitted
Physical	Subsurface Hardness			Not Rated: No Field Penetrometer Readings Submitted
Physical	Aggregate Stability	49.5	78	
Biological	Organic Matter	4.6	79	
Biological	ACE Soil Protein Index	5.8	29	Organic Matter Quality, Organic N Storage, N Mineralization
Biological	Root Pathogen Pressure	4.7	54	
Biological	Respiration	0.58	4	Soil Microbial Abundance and Activity
Biological	Active Carbon	744	76	
Chemical	pH	6.0	66	
Chemical	Phosphorus	10.9	100	
Chemical	Potassium	164.5	100	
Chemical	Minor Elements Mg: 456 Fe: 0.8 Mn: 9.2 Zn: 0.4		100	
	Overall Quality Score		71	High

Woods End Laboratories Incorporated

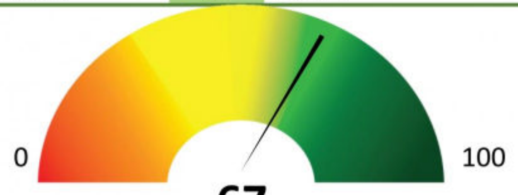
Powered by: SOLVITA®

SOIL FERTILITY & HEALTH REPORT

Client	William Brinton Woods End Farm 290 Belgrade Rd. P.O. Box 297 Mt Vernon, ME 04352 United States	**Sample Identity:**	9529.3
		Acct Number:	100
		Sample:	Soil: Italy: Lower Vineyard Casa Maria 4
		Sample Date:	8/19/2015
		Intended Crop:	Grapes @ 5 t/a

Solvita Soil Health Factors		RANKING:
Solvita - CO2 Burst	90	Medium
Solvita - SLAN, amino-N	48	Low
Aggregate Stability	35	Medium
Organic Matter	3.2	Medium

Nutrients Value per hectare available		
N + P2O5 + K2O hectare =		$221.78
Nutrients Available kg/ha		
N	P2O5	K2O
115	229	210



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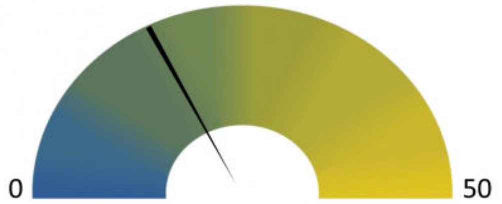
OVERALL FERTILITY SCORE



17

SOIL HEALTH SCORE

NUTRIENT FERTILITY

Analysis	Units	Level Found
Nitrate-N 0-6"	ppm	10
Additonal Nitrate-N	ppm	nt
Ammonium-N 0-6"	ppm	nt
Profile Avail-N	ppm	10
Biological N-Min	kg/ha	97
N-Estimated For Crops		103
Phosphate as P	ppm	45
Potassium as K	ppm	78
Calcium	ppm	480
Magnesium	ppm	153
Sodium	ppm	37
pH	Units	6.3
EC	dS M	nt
Nutrient Index	Rating	1.00
Most Limiting Factor		None
Other factors		
Water Soluble Carbon	ppm	204
Water Soluble-N	ppm	16
Soluble C:N Ratio	Unit	12.8
Aluminum, Extractable	ppm	135
P-Saturation	ratio	14%
Iron, Extractable	ppm	186

Notes and Recommendations

USDA Cover Crop Recommendations

Types of Cover Crop Blends Suggested:

20% Legume 80% Grass/Non-legume

Nutrient Limitations/Recommendations

Nutrient Required (estimated) per hectare kg			
56	17	84	(N - P - K)

Nutrient Deficit (by difference)			
0	0	0	(N - P - K)

Notes on the Report: Soil Health Score integrates: Respiration, Amino-N, Aggregate Stability and Organic Matter
Overall Fertility integrates Health Score and N-min + relative P & K

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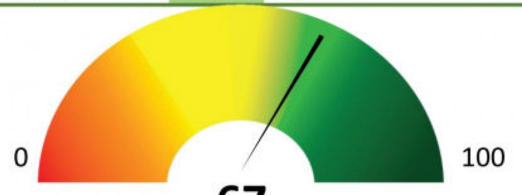

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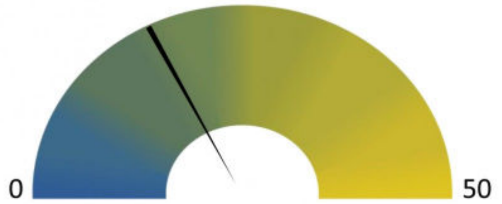

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Overall Fertility integrates Health Score and N-min + relative P & K

Soil health **indicators**: quantifiable measures

19 endorsed indicators
(Tier 1 and 2)

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Physical	**Chemical**	**Biological**
Water-stable aggregation	Organic carbon	Carbon mineralization
Texture	pH	Nitrogen mineralization
Penetration resistance	Cation exchange capacity	Crop yield
Erosion rating	Electrical conductivity	
Bulk density	Base saturation	
Available water holding capacity	Plant available nutrients (e.g. N, P, K)	
Infiltration rate	Micronutrients	

NATIONAL ARCHIVES

FEDERAL REGISTER

The Daily Journal of the United States Government

Notice

Notice of Recommended Standard Methods for Use as Soil Health Indicator Measurements

A Notice by the Natural Resources Conservation Service on 09/14/2018

PUBLISHED DOCUMENT

Start Printed Page 46703

AGENCY:

Natural Resources Conservation Service (NRCS), U.S. Department of Agriculture (USDA).

ACTION:

Notice of availability of proposed technical note “Recommended Soil Health Indicators and Associated Laboratory Procedures” for public review and comment.

SUMMARY:

Notice is hereby given of the intention of NRCS to issue a technical note on a group of recommended standard methods for soil health indicators selected by a

DOCUMENT DETAILS

Printed version:
PDF

Publication Date:
09/14/2018

Agencies:
Natural Resources Conservation Service

Dates:
Applicable Date: This is Applicable September 14, 2018.

Document Type:
Notice

Document Citation:
83 FR 46703

Page:
46703 (1 page)

https://www.federalregister.gov/documents/2018/09/14/2018-19985/notice-of-recommended-standard-methods-for-use-as-soil-health-indicator-measurements

DEPARTMENT OF AGRICULTURE

Natural Resources Conservation Service

[Docket No. NRCS–2018–0006]

Notice of Recommended Standard Methods for Use as Soil Health Indicator Measurements

AGENCY: Natural Resources Conservation Service (NRCS), U.S. Department of Agriculture (USDA).

ACTION: Notice of availability of proposed technical note "Recommended Soil Health Indicators and Associated Laboratory Procedures" for public review and comment.

SUMMARY: Notice is hereby given of the intention of NRCS to issue a technical note on a group of recommended standard methods for soil health indicators selected by a collaborative multi-organizational effort, as described in the document. USDA/NRCS and partner efforts to assess soil health problems and impacts of management nationally, as part of conservation planning and implementation, will be facilitated if soil health indicators are measured using a standard set of methods. Soil health is defined as the capacity of the soil to function as a vital living ecosystem to sustain plants, animals, and humans. Six key soil physical and biological processes were and Sasser 2012). Standard operating procedures to be used in laboratories have been provided in the appendices.

DATES:

Applicable Date: This is Applicable September 14, 2018.

Comment Date: Submit comments on or before December 13, 2018. A final version of this technical note will be published after the close of the 90-day period and after consideration of all comments.

ADDRESSES:

Obtaining Documents: You may download the draft Technical Note at *https://go.usa.gov/xUFJE.*

Comments should be submitted, identified by Docket Number NRCS–2018–0006, using any of the following methods:

- *Federal eRulemaking Portal: http://www.regulations.gov.* Follow the instructions for submitting comments.
- *Mail or hand-delivery:* Public Comments Processing, Attention: Regulatory and Agency Policy Team, Strategic Planning and Accountability, Natural Resources Conservation Service, 5601 Sunnyside Avenue, Building 1–1112D, Beltsville, Maryland 20705.

NRCS will post all comments on *http://www.regulations.gov.* In general, personal information provided with comments will be posted. If your comment includes your address, phone number, email, or other personal

DEPARTMENT OF COMMERCE

Bureau of Industry and Security

Proposed Information Collection; Comment Request; License Transfer and Duplicate License Services

AGENCY: Bureau of Industry and Security (BIS), Commerce.

ACTION: Notice.

SUMMARY: The Department of Commerce, as part of its continuing effort to reduce paperwork and respondent burden, invites the general public and other Federal agencies to take this opportunity to comment on proposed and/or continuing information collections, as required by the Paperwork Reduction Act of 1995.

DATES: To ensure consideration, written comments must be submitted on or before November 13, 2018.

ADDRESSES: Direct all written comments to Jennifer Jessup, Departmental Paperwork Clearance Officer, Department of Commerce, 1401 Constitution Avenue NW, Room 6616, Washington, DC 20230 (or via the internet at *docpra@doc.gov.*)

FOR FURTHER INFORMATION CONTACT: Requests for additional information or copies of the information collection instrument and instructions should be directed to Mark Crace, BIS ICB Liaison, (202) 482–8093 or at *mark.crace@*

Six key soil physical and biological processes were identified that must function well in a healthy soil, and therefore would especially benefit from measurement methods standardization: (1) Organic matter dynamics and carbon sequestration, (2) soil structural stability, (3) general microbial activity, (4) C food source, (5) bioavailable N, and (6) microbial community diversity. The chosen methods met several criteria including indicator effectiveness with respect to management sensitivity and process interpretability, ease of use, cost effectiveness, measurement repeatability, and ability to be used for agricultural management decisions. The soil health indicator methods included are soil organic carbon, water-stable aggregation, short-term mineralizable carbon, four enzymes: β-glucosidase, N-acetyl-β-D-glucosaminidase, acid or alkaline phosphatase, and arylsulfatase, permanganate oxidizable carbon, autoclaved citrate extractable (ACE) protein, and phospholipid fatty acid analysis. Standard operating procedures to be used in laboratories have been provided in the appendices.

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Federal Register / Vol. 83, No. 179 / Friday, September 14, 2018 / Notices 46703

DEPARTMENT OF AGRICULTURE

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DEPARTMENT OF COMMERCE

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Biological process/property	Biological Indicator
(1) OM dynamics	(1) TOC, mineralizable C
(2) Soil structural stability	(2) water-stable aggregation
(3) General microbial activity	(3) enzyme activities
(4) C food source	(4) labile carbon (POXC)
(5) Bioavailable N	(5) ACE protein
(6) Microbial community diversity	(6) PLFA

SOIL HEALTH

INSTITUTE

TABLE 1. Tier 1 Soil Health Indicators and Methods tc

Indicator
Soil pH
Soil Electrical Conductivity (EC)
Cation Exchange Capacity (CEC)
% Base Saturation (BS)
Extractable P
Extractable K, Ca, Mg, Na
Extractable Fe, Zn, Cu, Mn

Total Nitrogen
Soil Organic Carbon (SOC)
Soil Texture
Aggregate Stability
Available Water Holding Capacity
Bulk Density (BD)
Erosion Rating
Soil Penetration Resistance
Water Infiltration Rate
Crop Yield
Short-Term Carbon Mineralization

- *Is widely considered an effective indicator of soil health;*
- *Is defined regionally and by soil groupings across the nation;*
- *Has thresholds known to indicate (at minimum) "poor", "adequate", and "good" that are outcome-based (crop yield, environmental goals, etc.); and*
- *Is responsive to specific management strategies that can be recommended to improve soil functioning.*

*“A Tier 2 indicator **needs additional research** before users can have the same level of confidence in its measurement, use, and interpretation.”*

TABLE 2. Tier 2 Soil Health Indicators and Methods to be Assessed (updated 10/23/2018)		
Indicator	**Method**	**Reference**
Sodium Adsorption Ratio (SAR)	Saturated paste extract followed by atomic absorption or inductively coupled plasma spectroscopy	Miller, et al., 2013
Soil Stability Index	Combination of wet and dry sieving at multiple sieve sizes	Franzluebbers, et al., 2000
Active Carbon	Permanganate oxidizable carbon (POXC). Digestion followed by colorimetric measurement	Weil, et al., 2003
Soil Protein Index	Autoclaved Citrate Extractable	Schindelbeck, 2016
B-Glucosidase	Assay incubation followed by colorimetric measurement	Tabatabai, et al., 1994
B-Glucosaminidase	Assay incubation followed by colorimetric measurement	Deng and Popova, 2011
Phosphatase	Assay incubation followed by colorimetric measurement	Acosta-Martinez and Tabatabai, 2011
Arylsulfatase	Assay incubation followed by colorimetric measurement	Klose, et al., 2011
Phospholipid Fatty Acid (PLFA)	Bligh-Dyer extractant, solid phase extraction, transesterification; gas chromatography	Buyer and Sasser, 2012
Ester-Linked Fatty Acid Methyl Ester (EL-FAME)	Mild alkaline methanolysis extraction; gas chromatography	Schutter and Dick, 2000
Genomics	18S, 16S or ITS analysis or a combination of 16S and 18S/ITS; and/or Shotgun metagenomics	Thompson, et al., 2017; Quice, et al., 2017
Reflectance	Diffuse reflectance spectroscopy	Veum, et al., 2015

Tier 2 indicators are largely biological

TABLE 2. Tier 2 Soil Health Indicators and Methods to be Assessed (updated 10/23/2018)		
Indicator	**Method**	**Reference**
Sodium Adsorption Ratio (SAR)	Saturated paste extract followed by atomic absorption or inductively coupled plasma spectroscopy	Miller, et al., 2013
Soil Stability Index	Combination of wet and dry sieving at multiple sieve sizes	Franzluebbers, et al., 2000
Active Carbon	Permanganate oxidizable carbon (POXC). Digestion followed by colorimetric measurement	Weil, et al., 2003
Soil Protein Index	Autoclaved Citrate Extractable	Schindelbeck, 2016
B-Glucosidase	Assay incubation followed by colorimetric measurement	Tabatabai, et al., 1994
B-Glucosaminidase	Assay incubation followed by colorimetric measurement	Deng and Popova, 2011
Phosphatase	Assay incubation followed by colorimetric measurement	Acosta-Martinez and Tabatabai, 2011
Arylsulfatase	Assay incubation followed by colorimetric measurement	Klose, et al., 2011
Phospholipid Fatty Acid (PLFA)	Bligh-Dyer extractant, solid phase extraction, transesterification; gas chromatography	Buyer and Sasser, 2012
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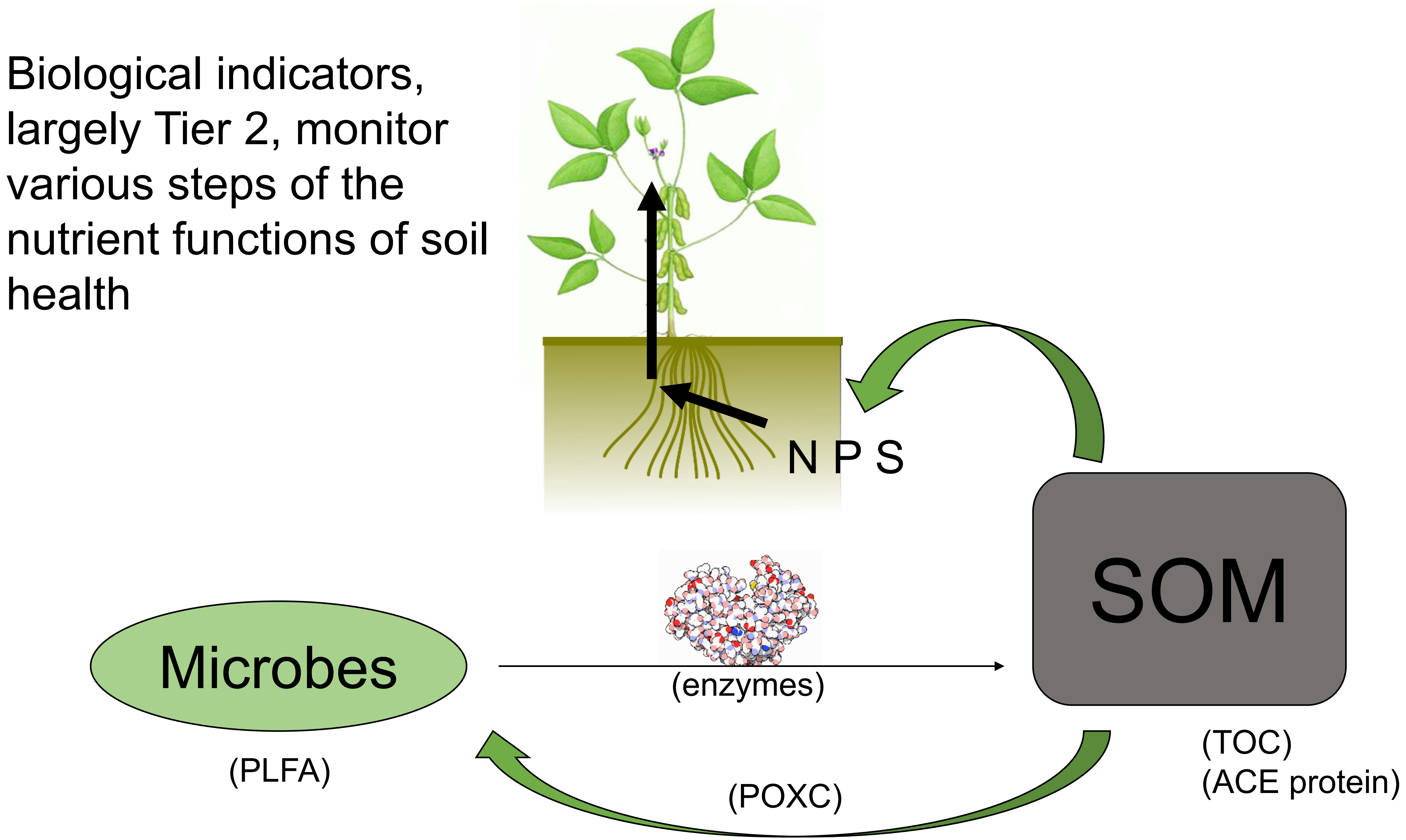
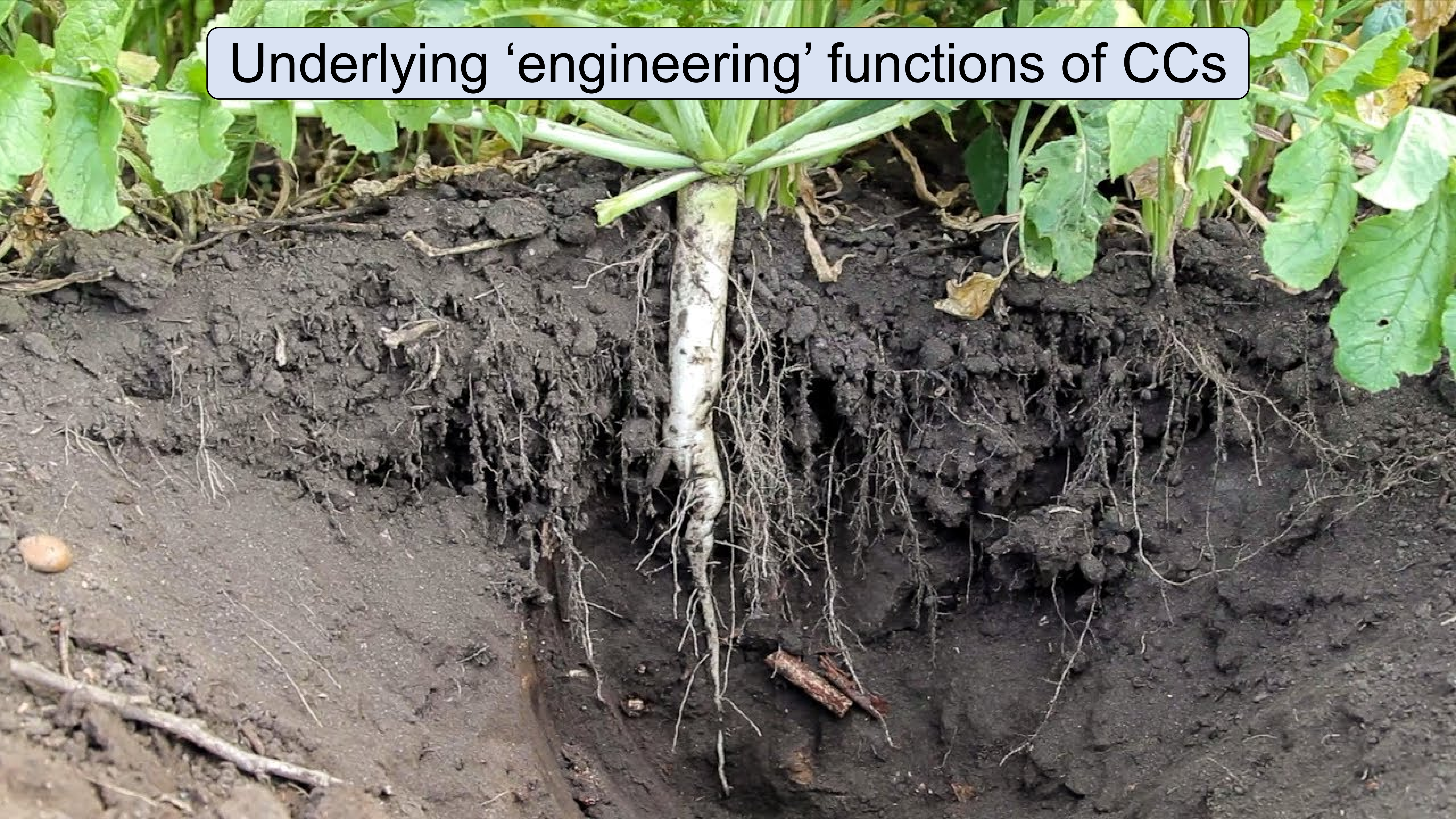
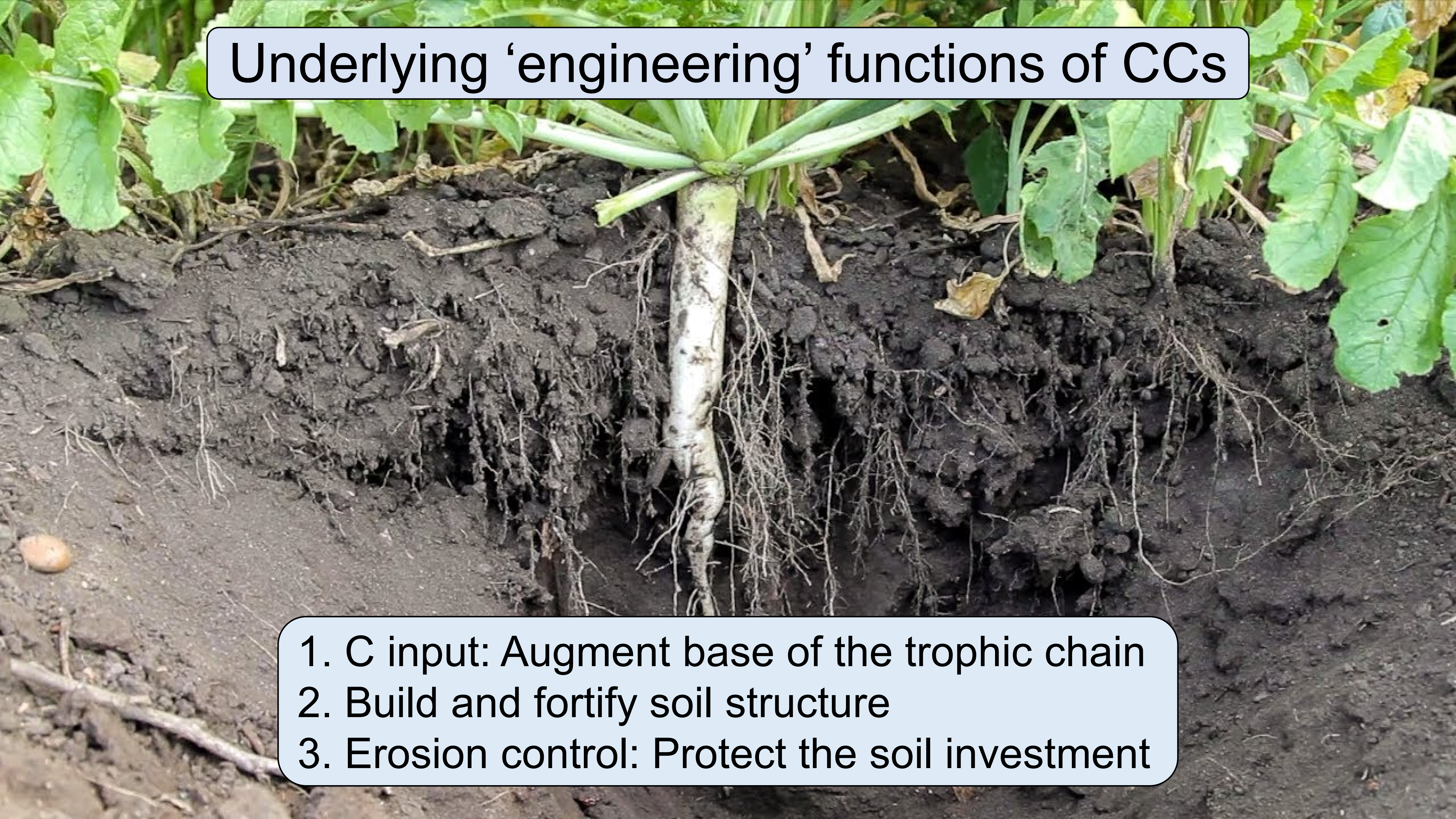

Biological indicators, largely Tier 2, monitor various steps of the nutrient functions of soil health
N P S
SOM
Microbes
(enzymes)
(PLFA)
(POXC)
(TOC)
(ACE protein)

Underlying ‘engineering’ functions of CCs

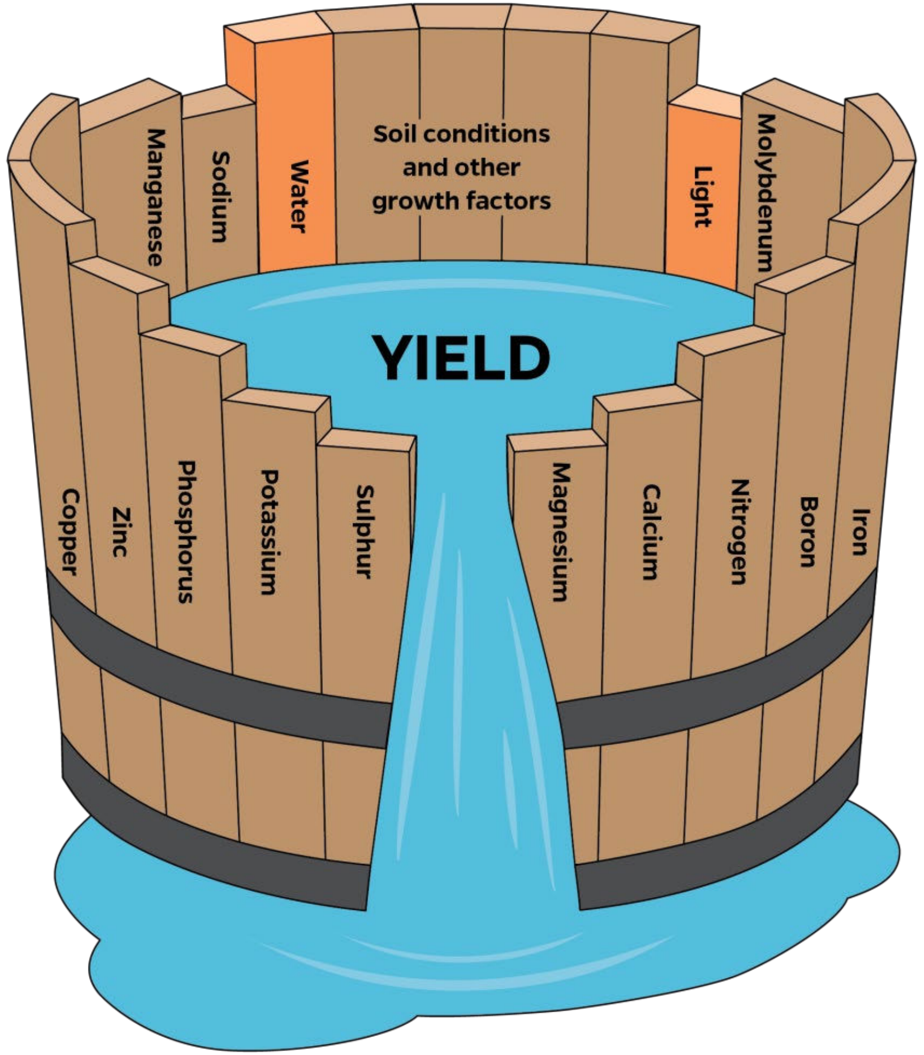


Underlying ‘engineering’ functions of CCs



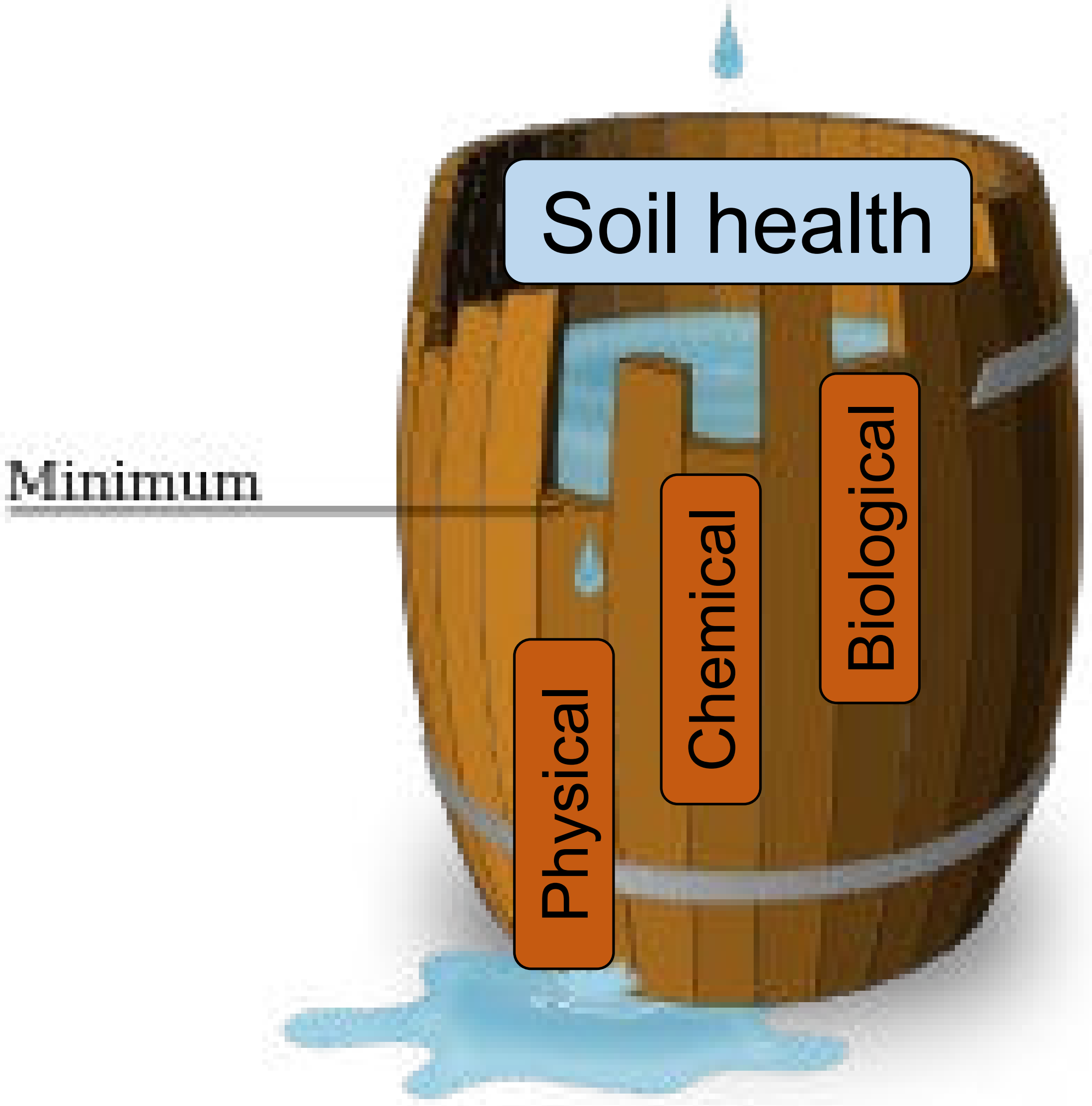
1. C input: Augment base of the trophic chain
2. Build and fortify soil structure
3. Erosion control: Protect the soil investment

“Physical health” component of soil health: overlooked?



Liebig’s Law of the Minimum

“Physical health” as a commonly limiting component of soil health



"Physical health" as an integrator and enabler variable

Integrate
organo-mineral-biota interactions

Soil aggregate

Enable conditions
for soil biological processes

Miller 2017 Nebraska Extension G2284

Context matters: Cover crop choices tailored to the Midwest

Sudex cover crop; CA Central Valley

Rye, canola, pea, radish mixture; western PA

Selector Tools

Row Crop Tool

Vegetable Crop Tool

Browse by category

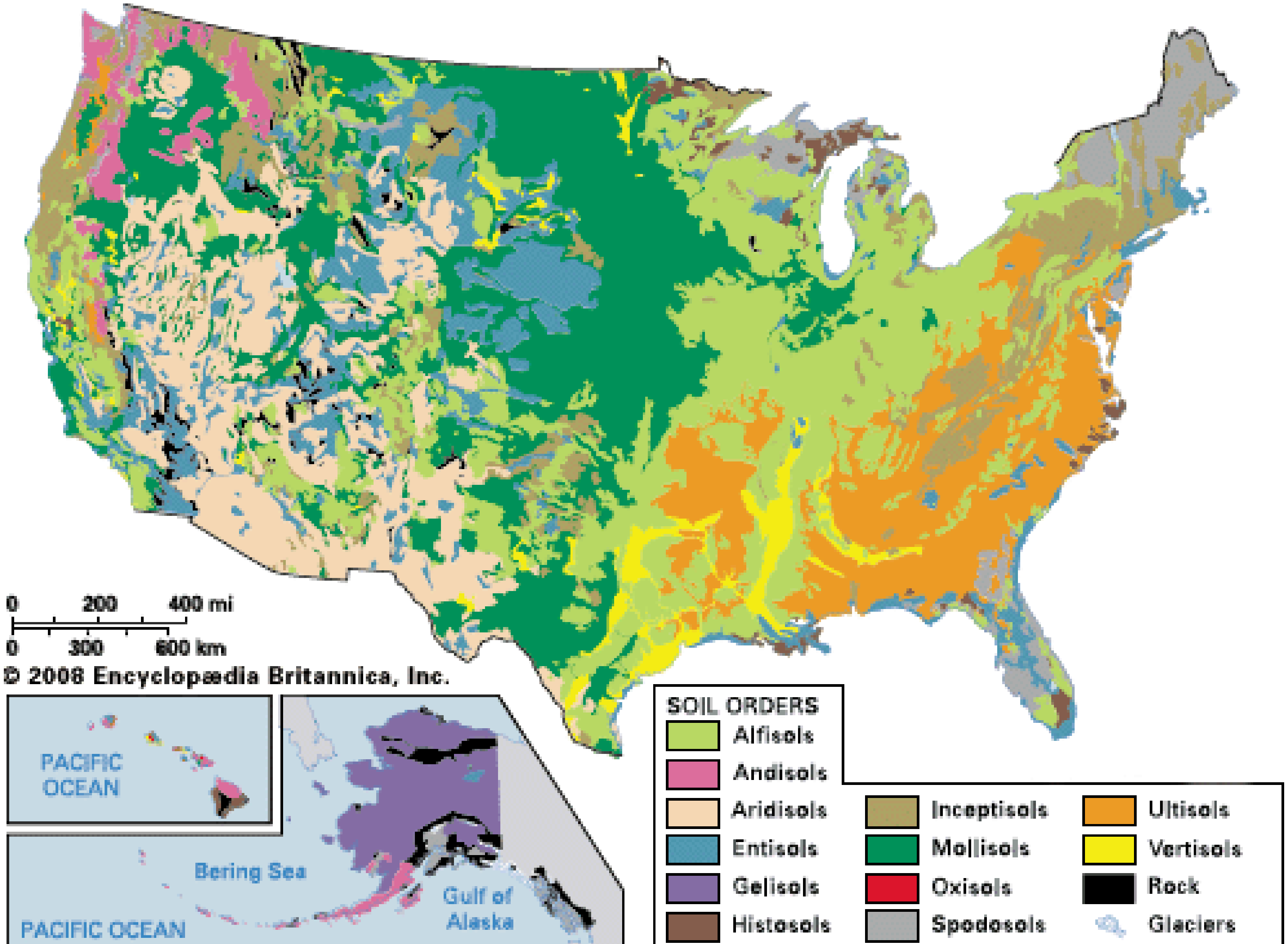
Select Category

MCCC Cover Crop Decision Tools

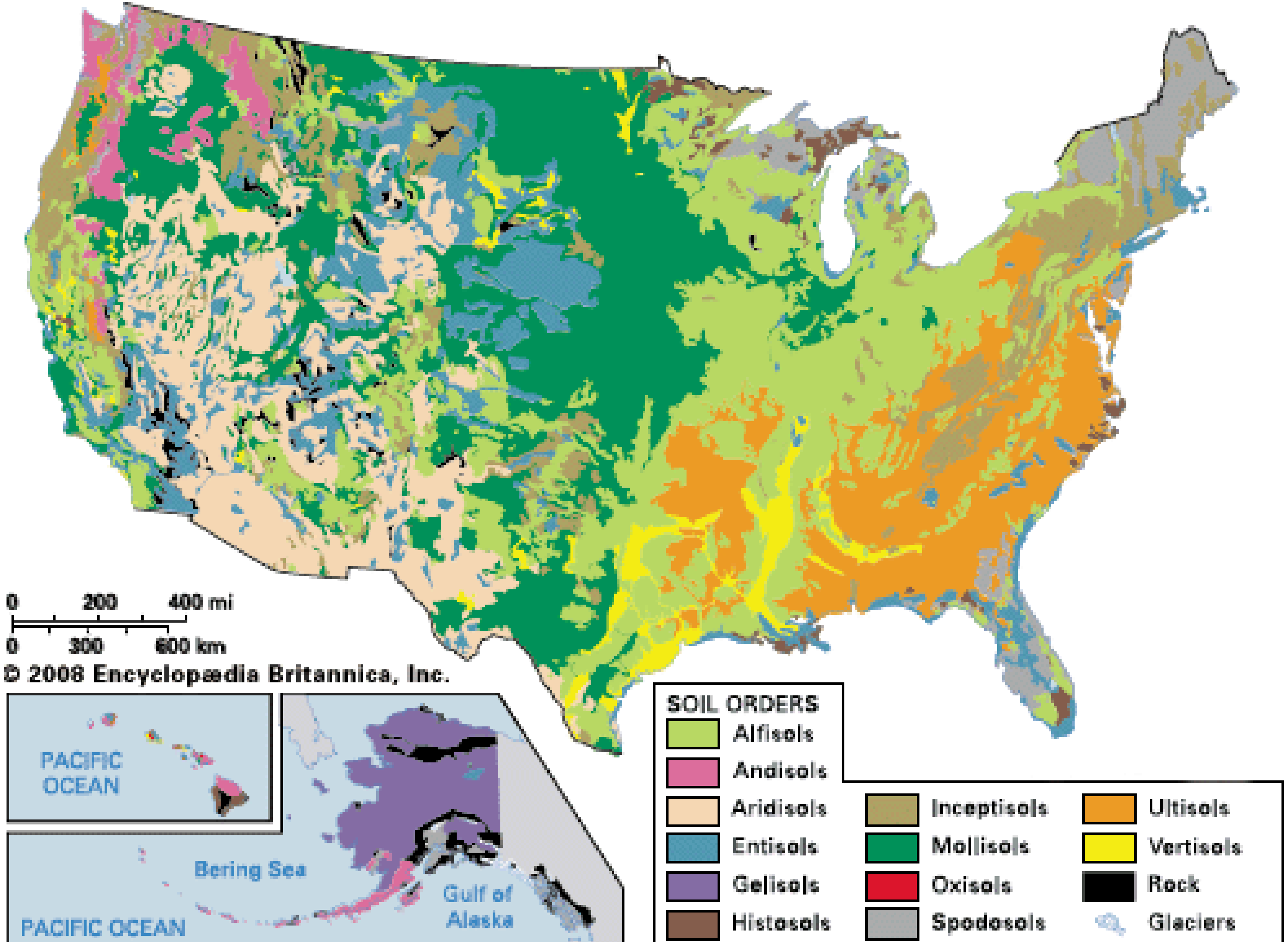
The Midwest Cover Crop Council (MCCC) Cover Crop Decision Tools are web-based systems to assist farmers in selecting cover crops to include in field crop and vegetable rotations.

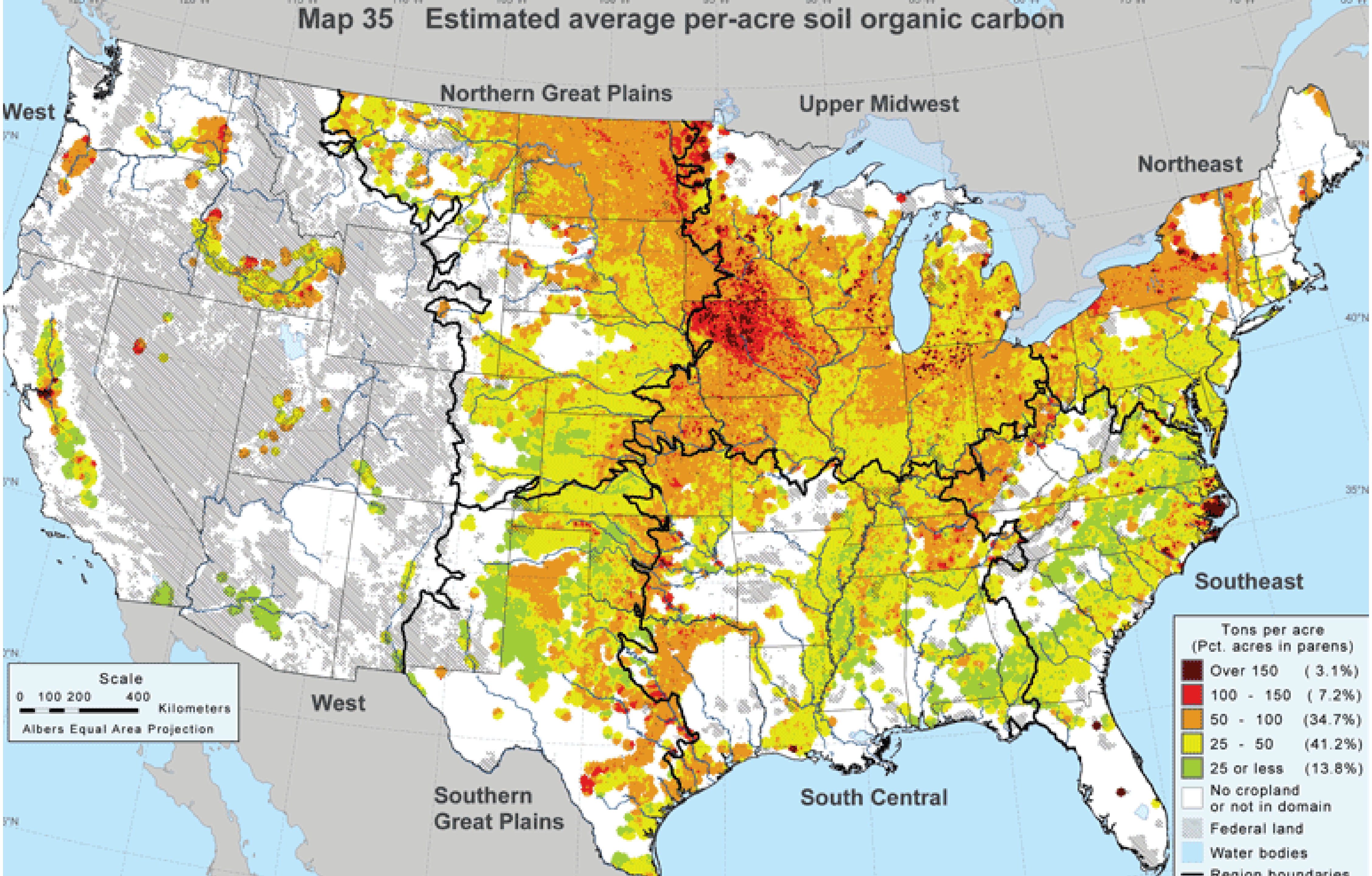
Instructions for using the Row Crop and Vegetable Crop Selector Tools

What about tailoring soil health for the Midwest?

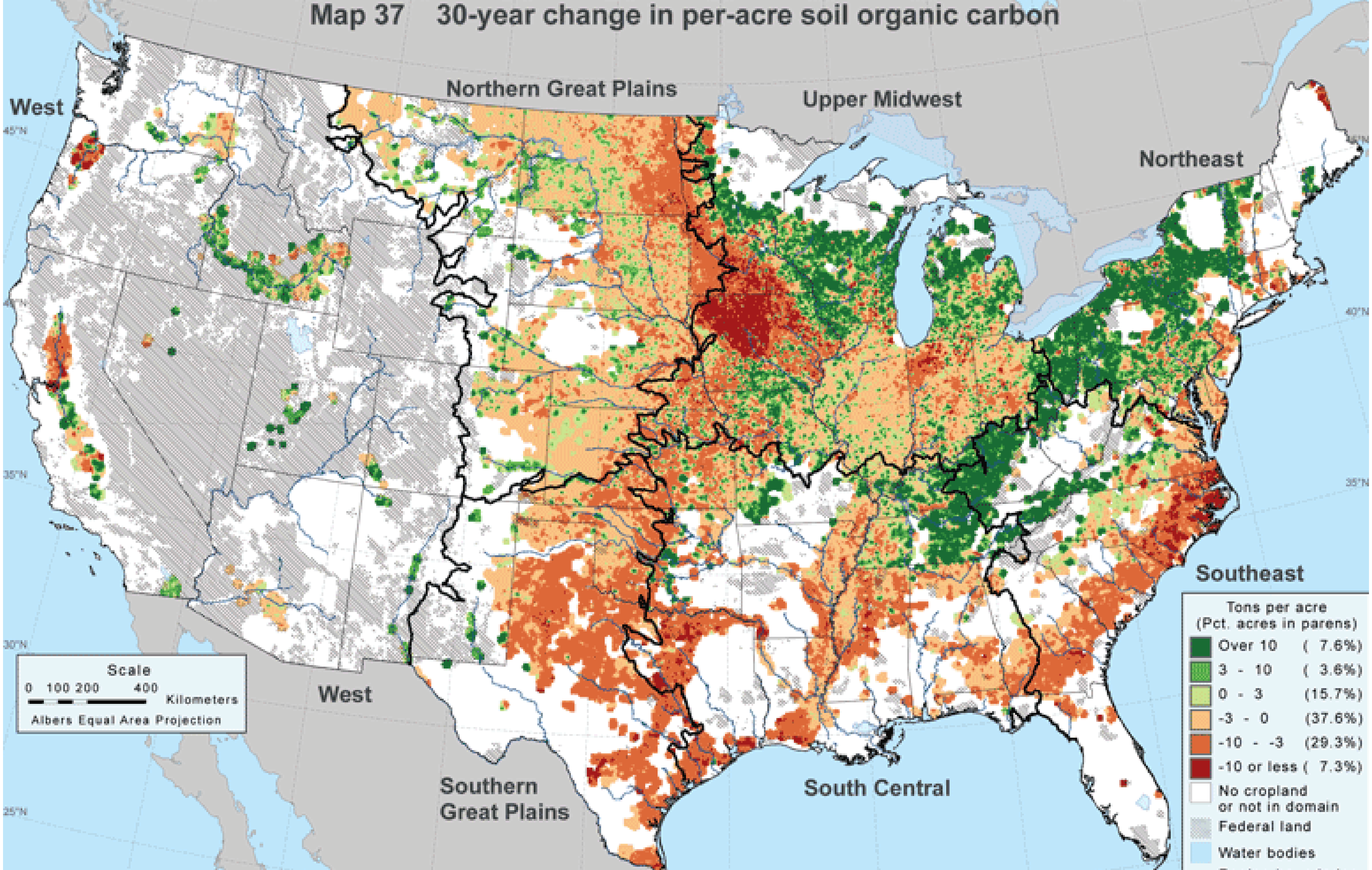


What about tailoring soil health for the Midwest?



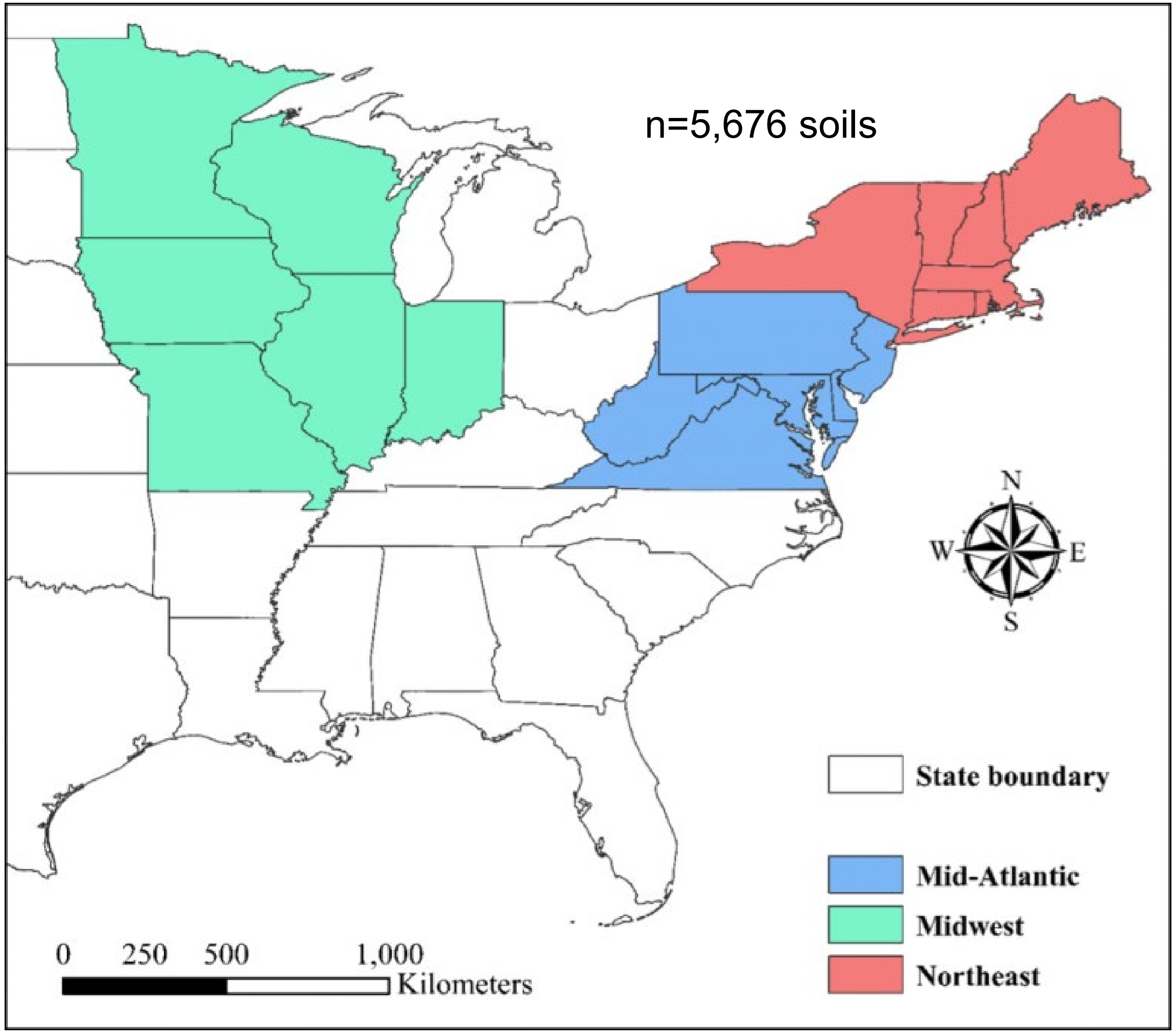

Map 35 Estimated average per-acre soil organic carbon
West
Northern Great Plains
Upper Midwest
Northeast
Southeast
West
Southern Great Plains
South Central
Scale
0 100 200 400
Kilometers
Albers Equal Area Projection
Tons per acre
(Pct. acres in parens)
Over 150 (3.1%)
100 - 150 (7.2%)
50 - 100 (34.7%)
25 - 50 (41.2%)
25 or less (13.8%)
No cropland or not in domain
Federal land
Water bodies

USDA NRCS


Map 37 30-year change in per-acre soil organic carbon
West
Northern Great Plains
Upper Midwest
Northeast
Southeast
South Central
Southern Great Plains
West
Scale
0 100 200 400 Kilometers
Albers Equal Area Projection
Tons per acre
(Pct. acres in parens)
Over 10 (7.6%)
3 - 10 (3.6%)
0 - 3 (15.7%)
-3 - 0 (37.6%)
-10 - -3 (29.3%)
-10 or less (7.3%)
No cropland or not in domain
Federal land
Water bodies

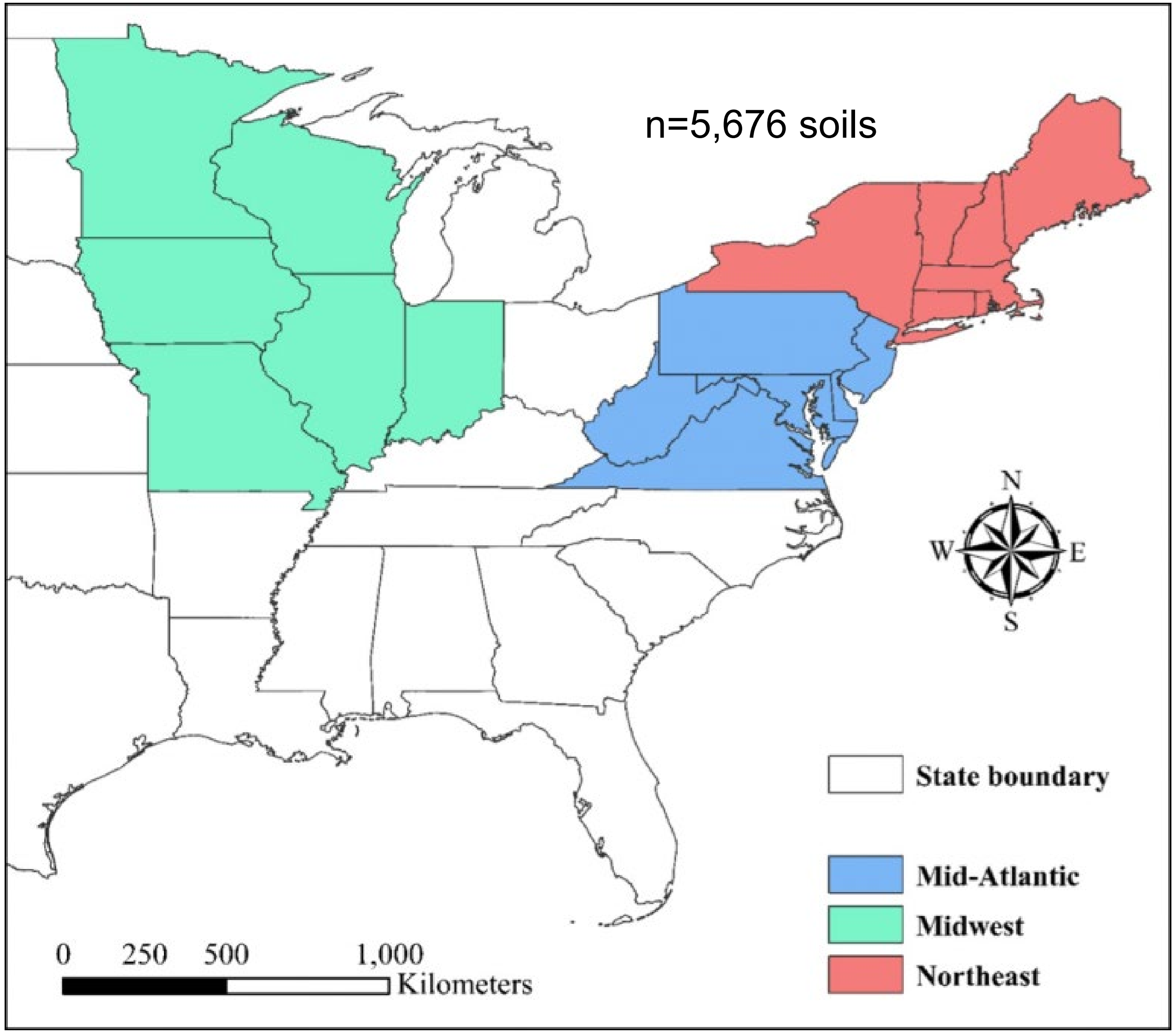
USDA NRCS

What about tailoring soil health for the Midwest?



Fine et al 2017 *SSSAJ* 81:589

What about tailoring soil health for the Midwest?



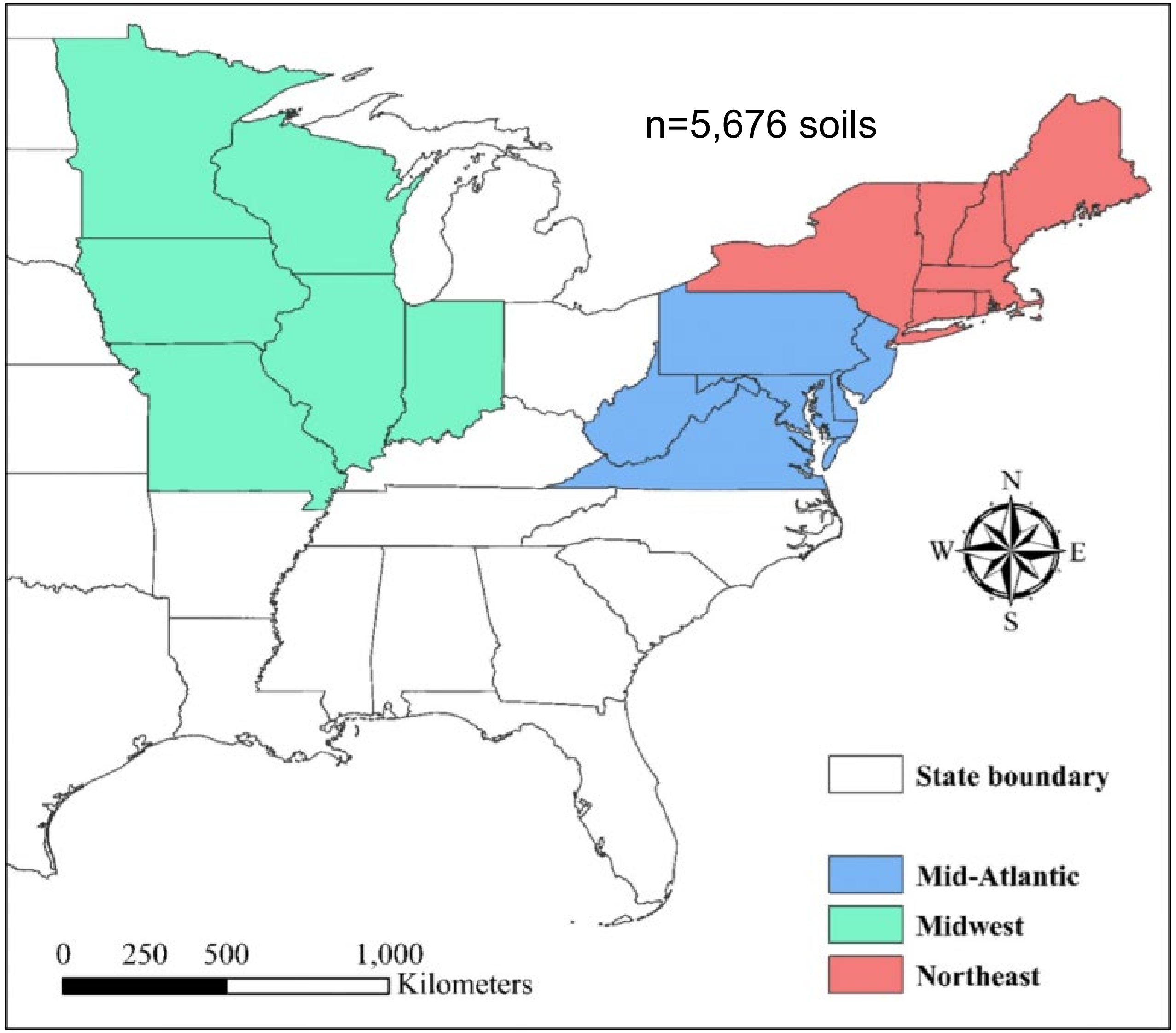
Findings

"In general, **soil health** values **for the Midwest** region were **less favorable** compared to the Mid-Atlantic and Northeast, notably for Wet Aggregate Stability, Organic Matter, Active Carbon, Protein, Respiration, and Root Health."

"Midwestern soils generally showed **lower variability** in measured values."

Fine et al 2017 *SSSAJ* 81:589

What about tailoring soil health for the Midwest?



Findings

"In general, **soil health** values **for the Midwest** region were **less favorable** compared to the Mid-Atlantic and Northeast, notably for Wet Aggregate Stability, Organic Matter, Active Carbon, Protein, Respiration, and Root Health."

"Midwestern soils generally showed **lower variability** in measured values."

Explanations?

"Northeast and Mid-Atlantic soils generally receive more **organic inputs** (especially manure) and are often managed to include **diverse rotations** with perennial crops, as opposed to typical corn-soybean rotations in the Midwest.

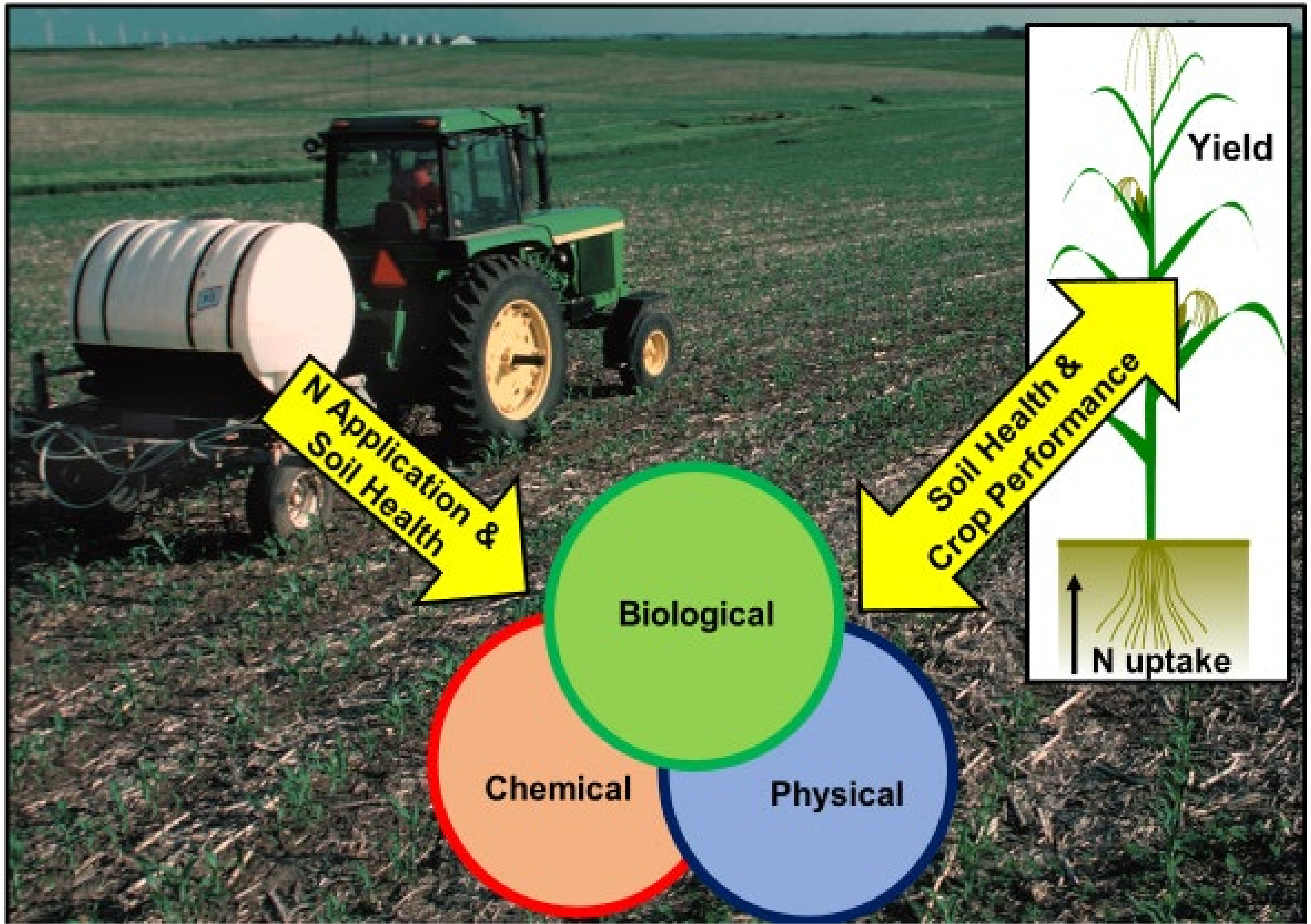
Fine et al 2017 *SSSAJ* 81:589

Integrating cover crop + soil health research and initiatives stands to maximize ROI

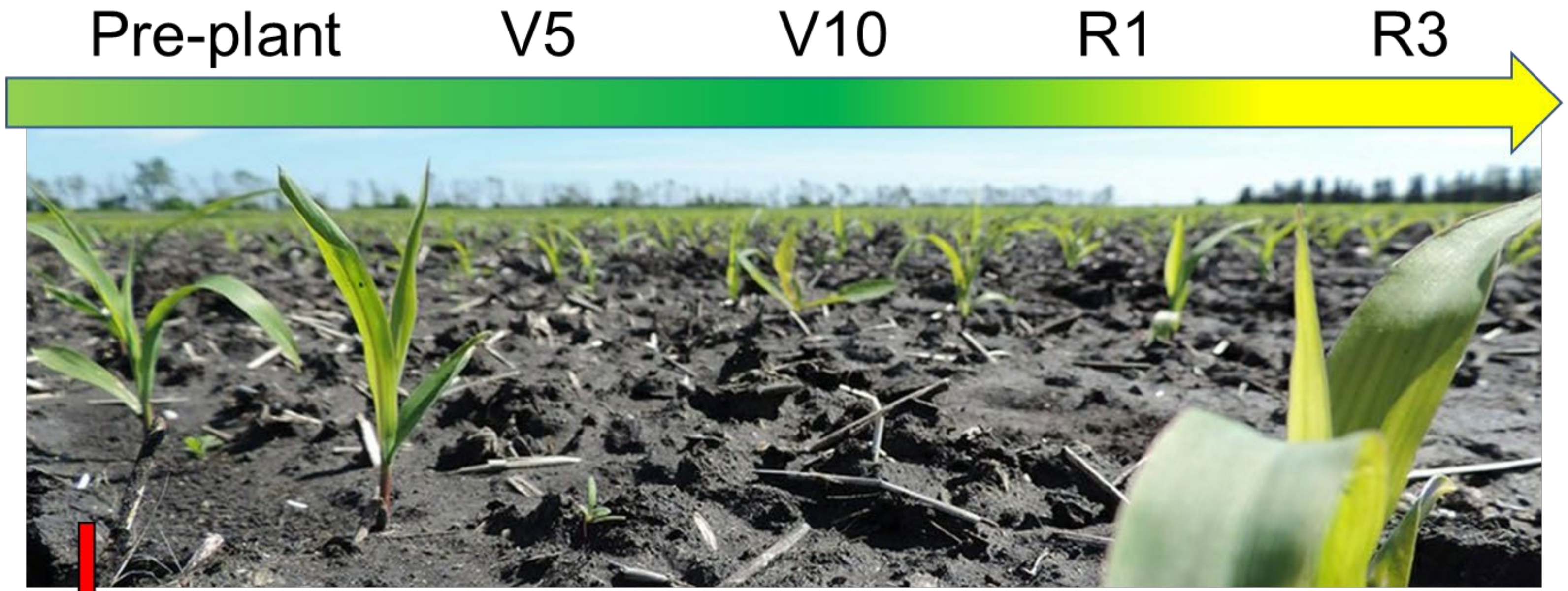
- Cover crops can drive and enable soil health improvements
  - Fulfill 4 principles of soil health management:
    1. Keep the soil covered as much as possible
    2. Disturb the soil as little as possible
    3. Keep plants growing throughout the year to feed the soil
    4. Diversify crop rotations as much as possible, including cover crops
- Physical health as an ‘integrator’
  - Easy(er) to evaluate
  - Functional
  - Enables conditions for soil biology
- Next steps: making soil health specific to Midwest cover crop systems

MI landscape (fishhawk via Flickr)

Current soil health research in Illinois: UIUC-ICGA partnership at Pistorius Farm



Experimental design: ICGA Macon Co. Field Lab



Soil sample
(3x within replicate plot)

Conventional Soil Health Indicators
- Chemical
- Physical
- Biological

Biological Indicators
- AM Fungi
- Nematodes
- Arthropods

1. How do conventional & novel **soil health** indicators reflect **N rate in Illinois corn**?
2. Can **soil health** indicators explain **soil-crop N transfer** and **crop performance**?

Dr. Nick Seiter (left) and UIUC students performing the first soil sampling at ICGA Field Lab in Macon Co.