Factors of Soil Health

and how they impact interpretation and benchmarking

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Cornell Soil Health

Regenerating Agricultural Lands

Cornell CALS College of Agriculture and Life Sciences

NEW YORK SOIL HEALTH

Assessment

- Indicators, processes, and functions
- Methods of analysis
- Analytical efficiency and pedotransfer functions
- Interpretation and management strategies

Benchmarking

- Database management and analytics
- Production environment targets
- Soil resource inventory
- Global alignment

Regenerative Solutions

- Agronomic integration and decision support tools
- Bionutrient processing, re-use, and re-allocation
- Rural and urban; organic and conventional
- Solar - Agrivoltaics

Research

Education

Business

Policy

Climate

Water

Air

Land

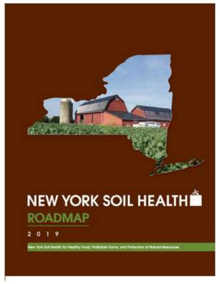
Energy

Health

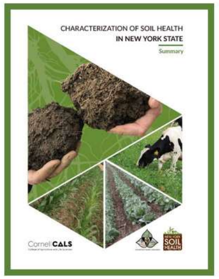
Resources from Website and Social Media

https://www.newyorksoilhealth.org/

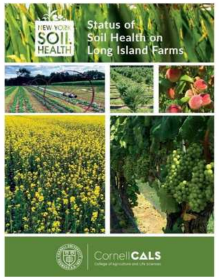
New York Soil Health Guides & Reports



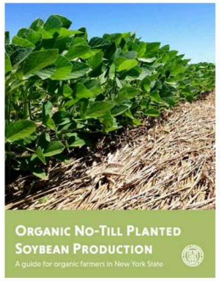
New York Soil Health Roadmap



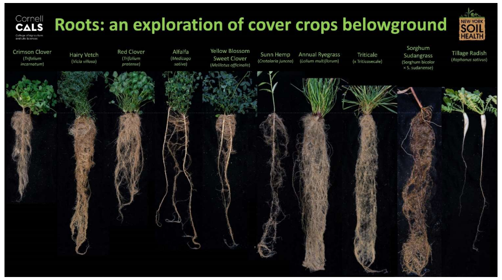
NYS Soil Health Characterization

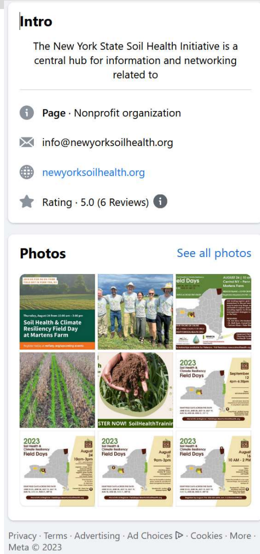


Soil Health on Long Island



Organic No-Till Soybean Guide

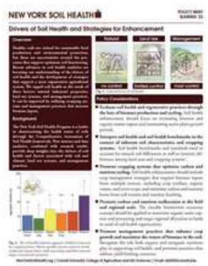




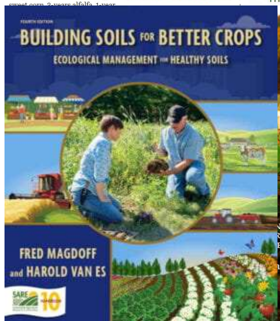
New York Soil Health Policy Briefs

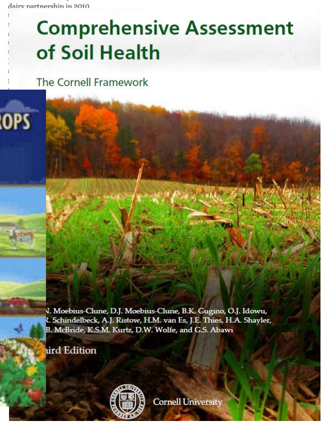
Managing for Better Soil Health on Long Island

Advancing Soil Health in NYS: Updating the Roadmap

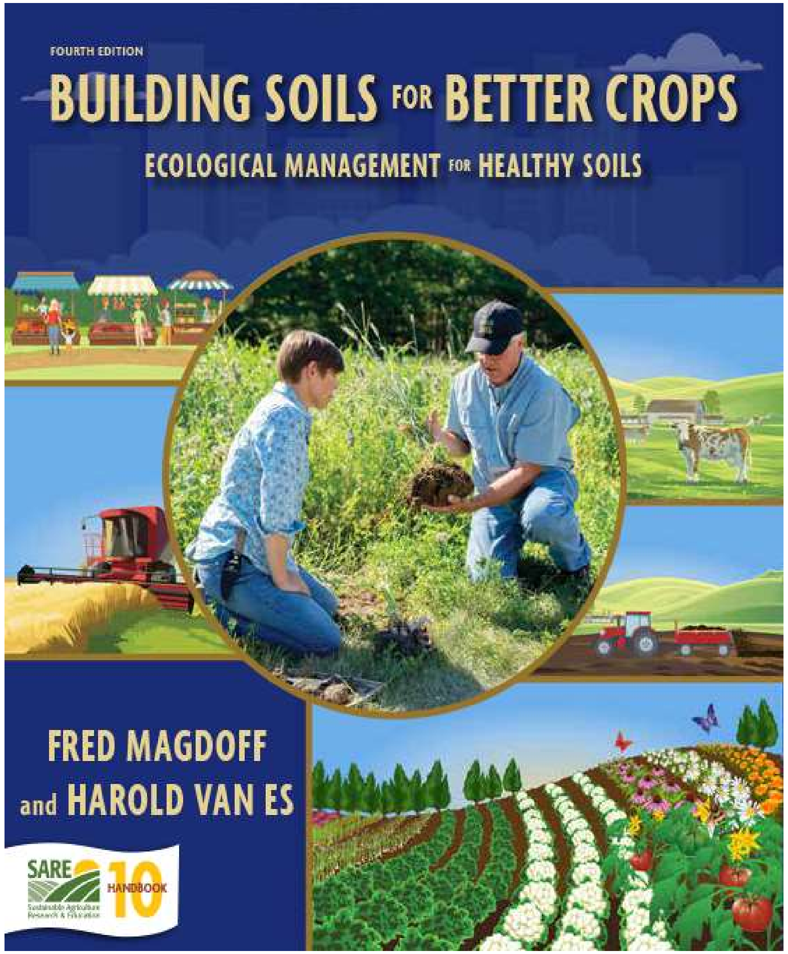


Drivers of Soil Health and Strategies for Enhancement





BSBC Available in Japanese



Comprehensive Assessment of Soil Health

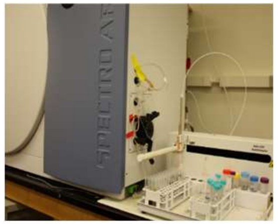
Soil health laboratory launched in 2006

CASH test captures all important soil processes (physical, biological, chemical)

Focus on

- Practical soil health testing services
- Interprets measured values
- Identifies soil constraints
- Guidance for management

Large database (40,000+)



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
https://soilhealthlab.cals.cornell.edu

Agricultural Service Provider:
Joseph Amsili
New York Soil Health / NYSH
jpa28@cornell.edu

Sample ID:
Field ID: | Continuous Corn Field
Date Sampled: 04/26/2022
Tillage: 1-7 inches

Measured Soil Textural Class: **loam**

Sand: **45%** - Silt: **37%** - Clay: **17%**

Group	Indicator	Value	Rating	Constraints
physical	Predicted Available Water Capacity	**0.21**	**78**	
physical	Surface Hardness	**131**	**64**	
physical	Subsurface Hardness	**346**	**33**	
physical	Aggregate Stability	**4.1**	**6**	Aeration, Infiltration, Rooting, Crusting, Sealing, Erosion, Runoff
biological	Organic Matter Soil Organic Carbon: 1.84 / Total Carbon: 1.96 / Total Nitrogen: 0.17	**2.9**	**45**	
biological	Predicted Soil Protein	**5.30**	**36**	
biological	Soil Respiration	**0.5**	**33**	
biological	Active Carbon	**543**	**59**	
chemical	Soil pH	**8.0**	**21**	
chemical	Extractable Phosphorus	**1.6**	**47**	
chemical	Extractable Potassium	**30.2**	**39**	
chemical	Additional Nutrients Ca: 1384.0 / Mg: 121.6 / S: 2.7 Al: 2.1 / Cu: 0.10 / Fe: 0.4 Mn: 2.9 / **Zn: 0.2**		**88**	

Overall Quality Score: **46** / Medium

CASH Test Ties Soil Health Indicators to Soil Processes

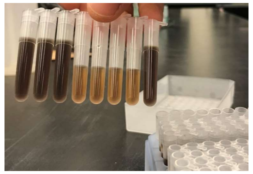
Physical Indicators	Soil Processes
Aggregate Stability	Resistance to dispersal: aeration, infiltration, crusting, germination, rooting, runoff & erosion
Available Water Capacity	Plant available water: water storage, drought resistance
Surface Hardness	0”- 6” compaction: aeration, surface rooting, infiltration, water transmission, germination, runoff & erosion
Subsurface Hardness	6” - 18” compaction: deep rooting, drought resistance, water movement and drainage, extreme precipitation resilience

Biological Indicators	Soil Processes
Soil Organic Matter & Total C	Water and nutrient storage/release, long-term energy storage, C sequestration
POXC - Active Carbon	C easily available as short-term microbial food source; biol. Activity
Soil Protein	Primary N-containing fraction of organic matter; N release
Soil Respiration	Integrates microbial abundance and metabolic activity; nutrient release

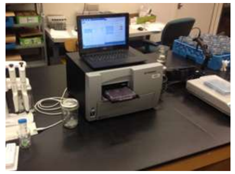
Chemical Indicators:	Processes as per standard soil test: nutrient availability, reaction, toxicity, pollution

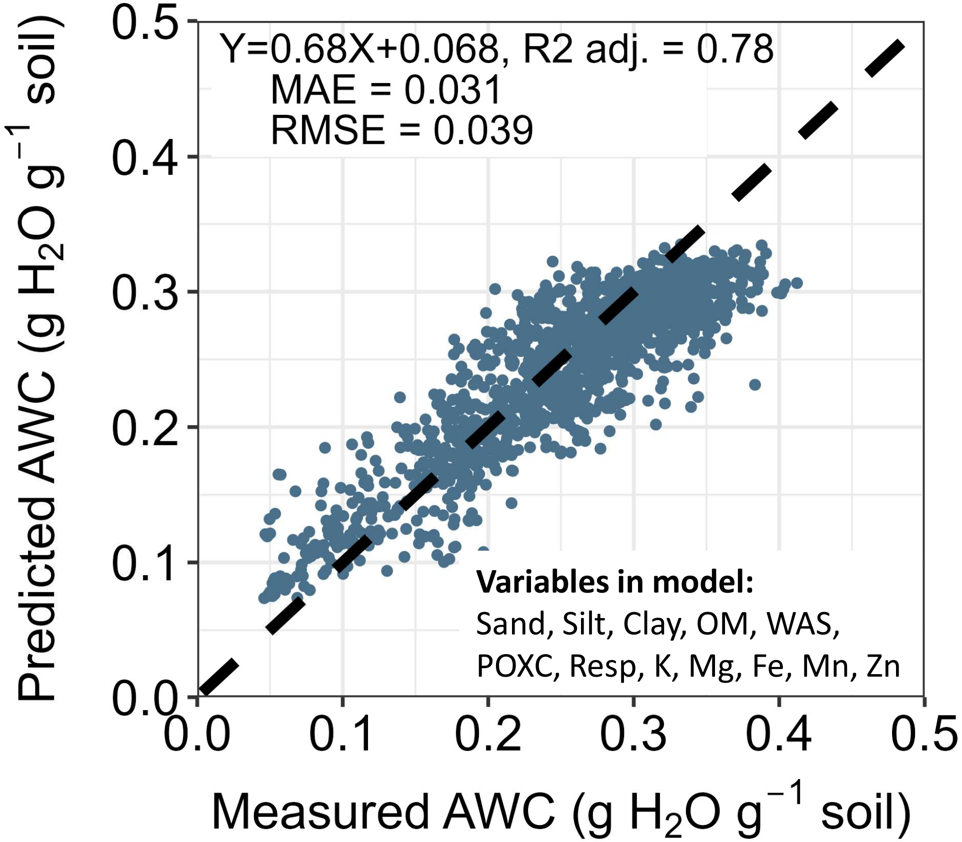
Pedotransfer Functions to Predict AWC and ACE Protein → more efficient assessment of soil health

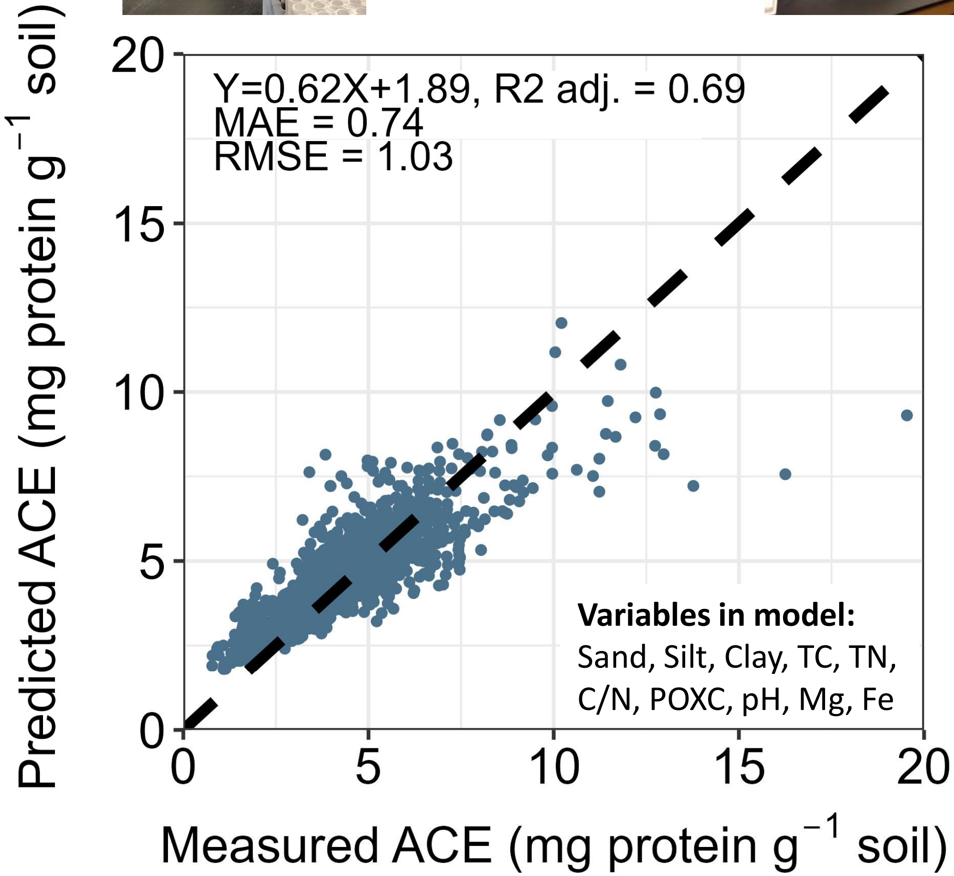
Available Water Capacity



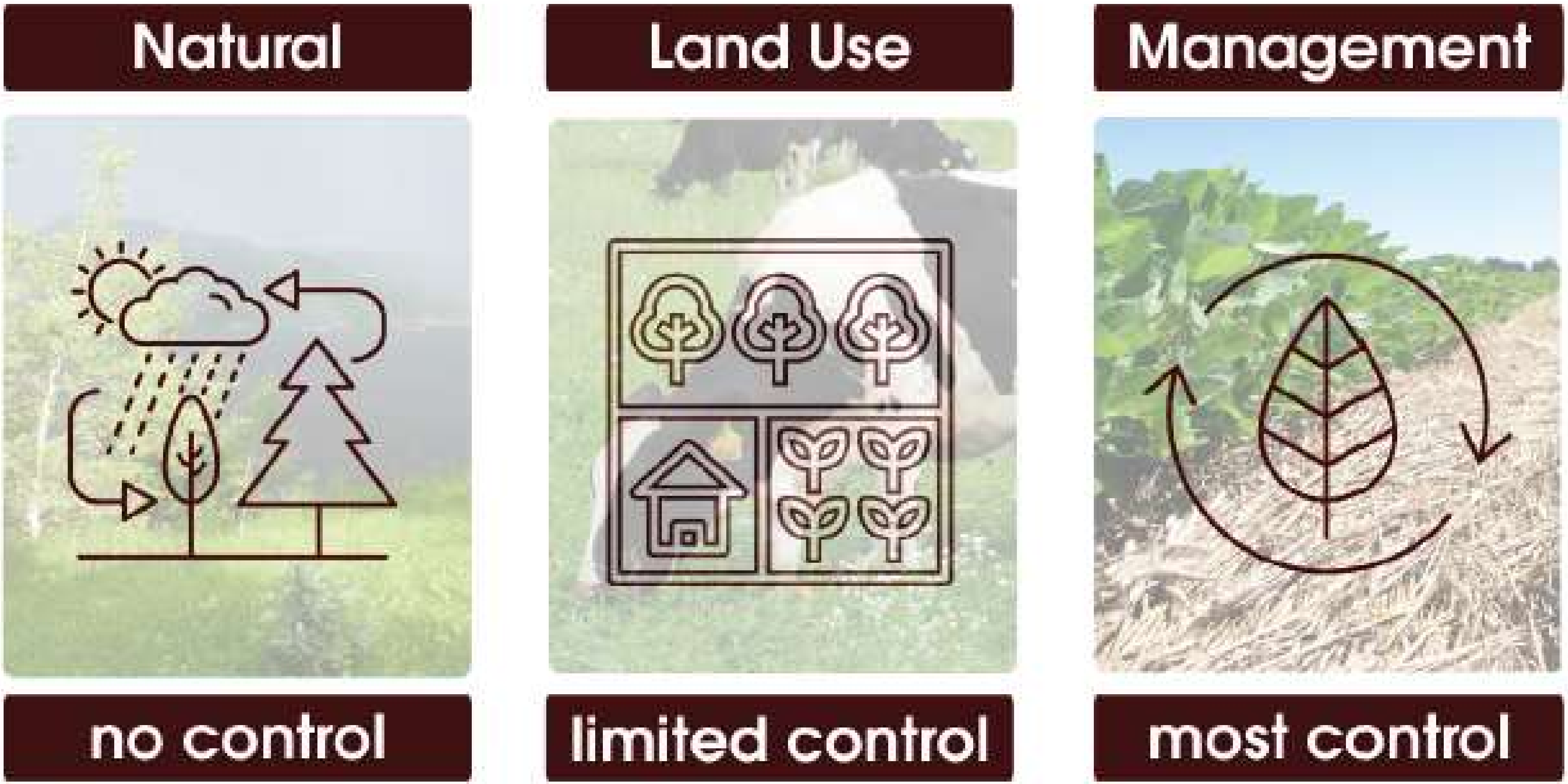
ACE Protein







Major Factors of Soil Health



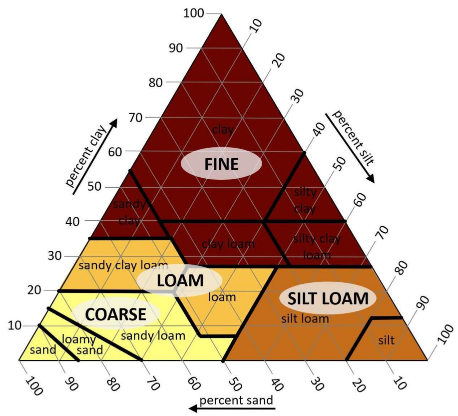
Factors of Soil Health

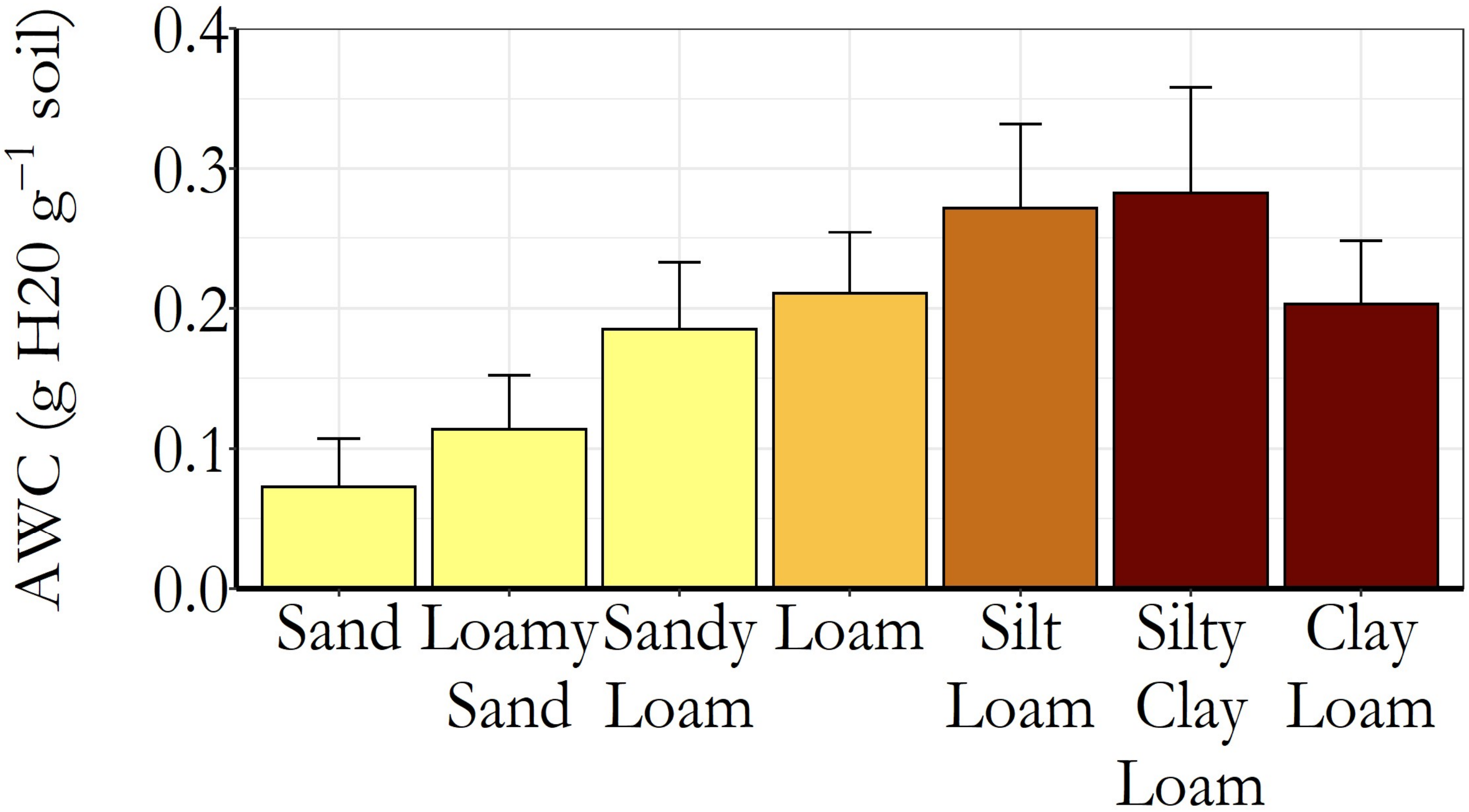
Inherent Properties - Soil Type



Credit: USDA-NRCS and Richard Stehouwer

Available Water Capacity by Soil Texture





Amsili et al., 2021

Soil Biological Indicators by Soil Texture

Finer textured soils store more organic matter, labile organic carbon, and are more biologically active than coarse textured soils

Texture Class	n	Organic Matter %	Active C /POXC mg/kg	Protein mg/g	Respiration mg CO_2/g
Coarse	407	2.5 c	498 d	7.2 a	0.48 c
Loam	714	3.0 b	548 c	6.5 b	0.59 b
Silt Loam	583	3.7 a	578 b	7.7 a	0.69 a
Fine	46	4.1 a	666 a	7.4 b	0.67 ab

Inherent Soil Property SH Data Interpretation: SHAPE

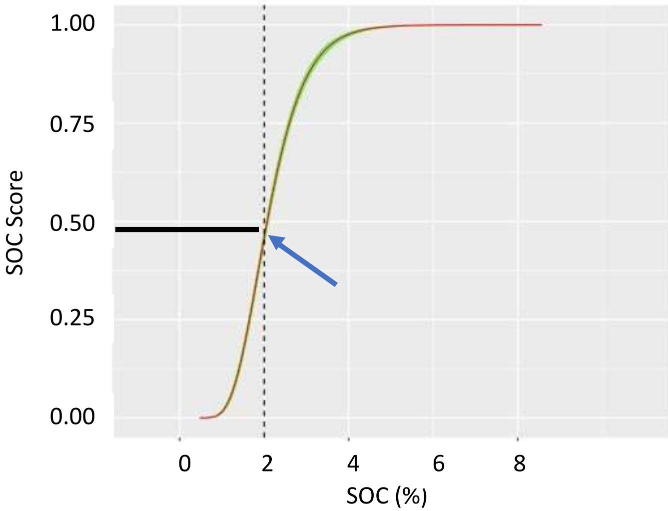
(Bayesian modeling; USDA-ARS, Univ. Missouri, and Cornell University)

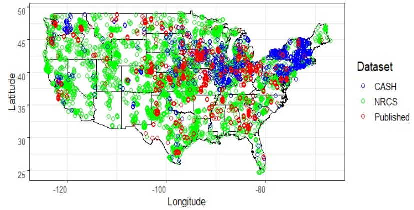
Mollisol - Iowa

Silty clay loam, Endoaquol

Peer group:

Texture:	**T3**
Suborder:	**S3**
Temp:	**10 °C**
Precip:	**900 mm**





SOC = **2%**

Score = **0.46**

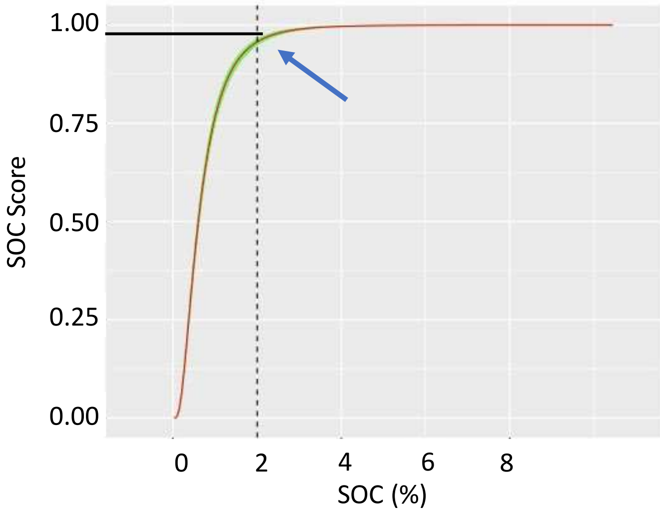
Medium

Aridisol - Texas

Loamy, Calcic Petrocalcids

Peer group:

Texture:	**T2**
Suborder:	**S5**
Temp:	**18 °C**
Precip:	**330 mm**



SOC = **2%**

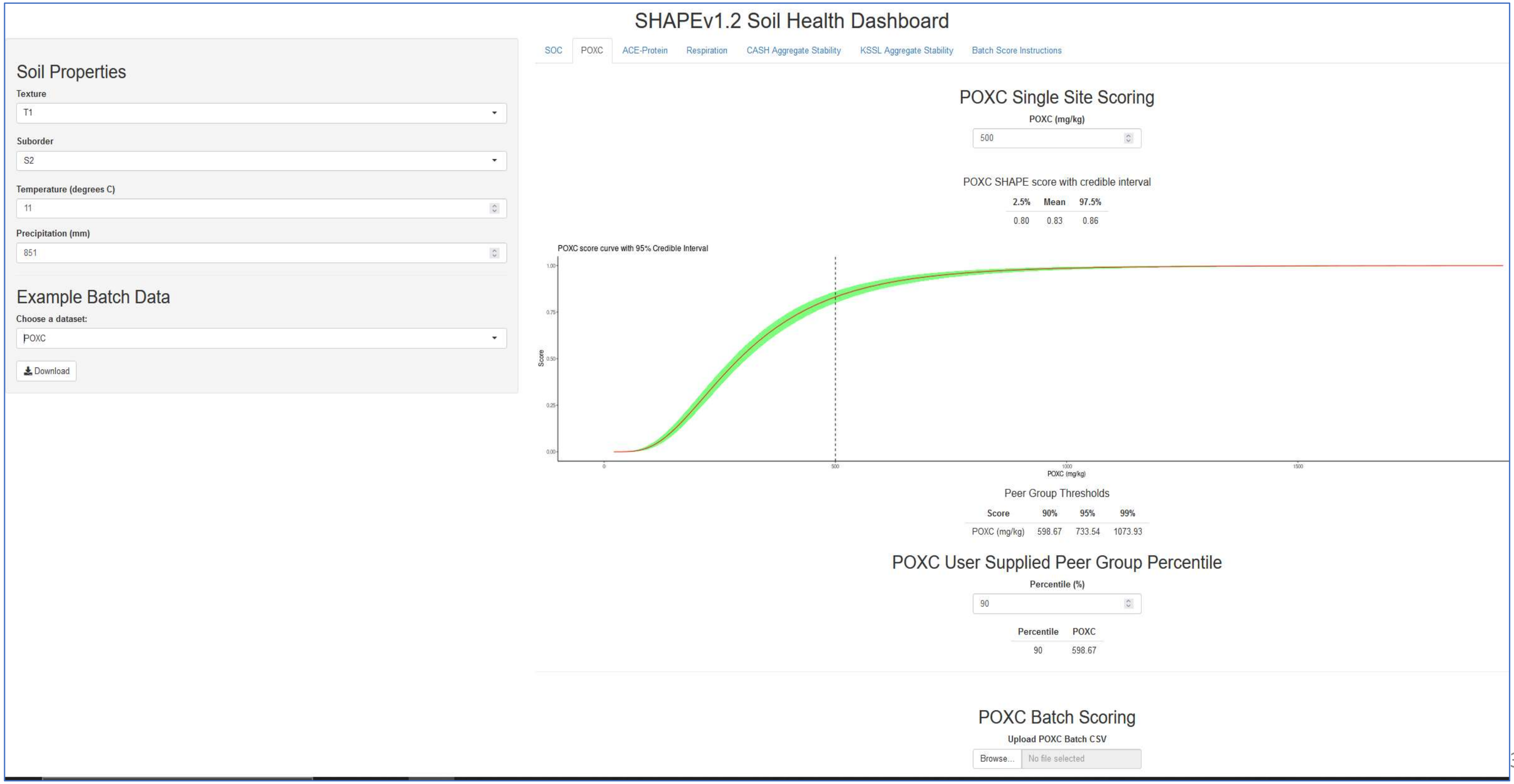
Score = **0.96**

HIGH

Nunes et al., 2021, 2024

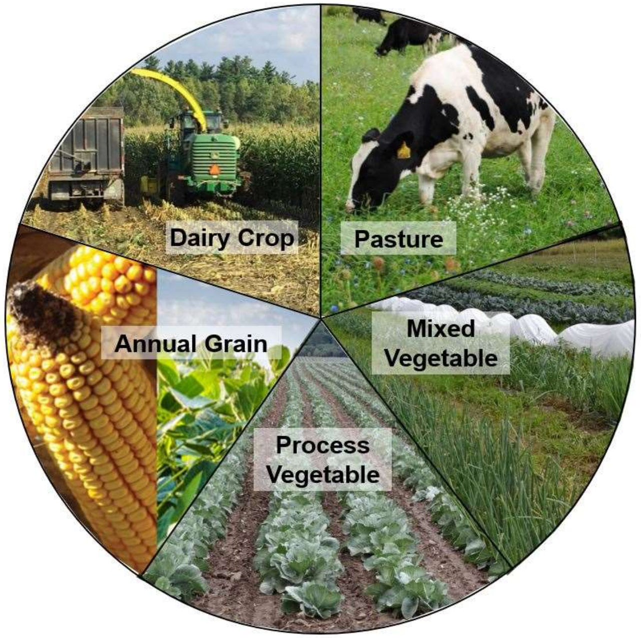
SHAPE calculator

https://paparker.shinyapps.io/shape_app/



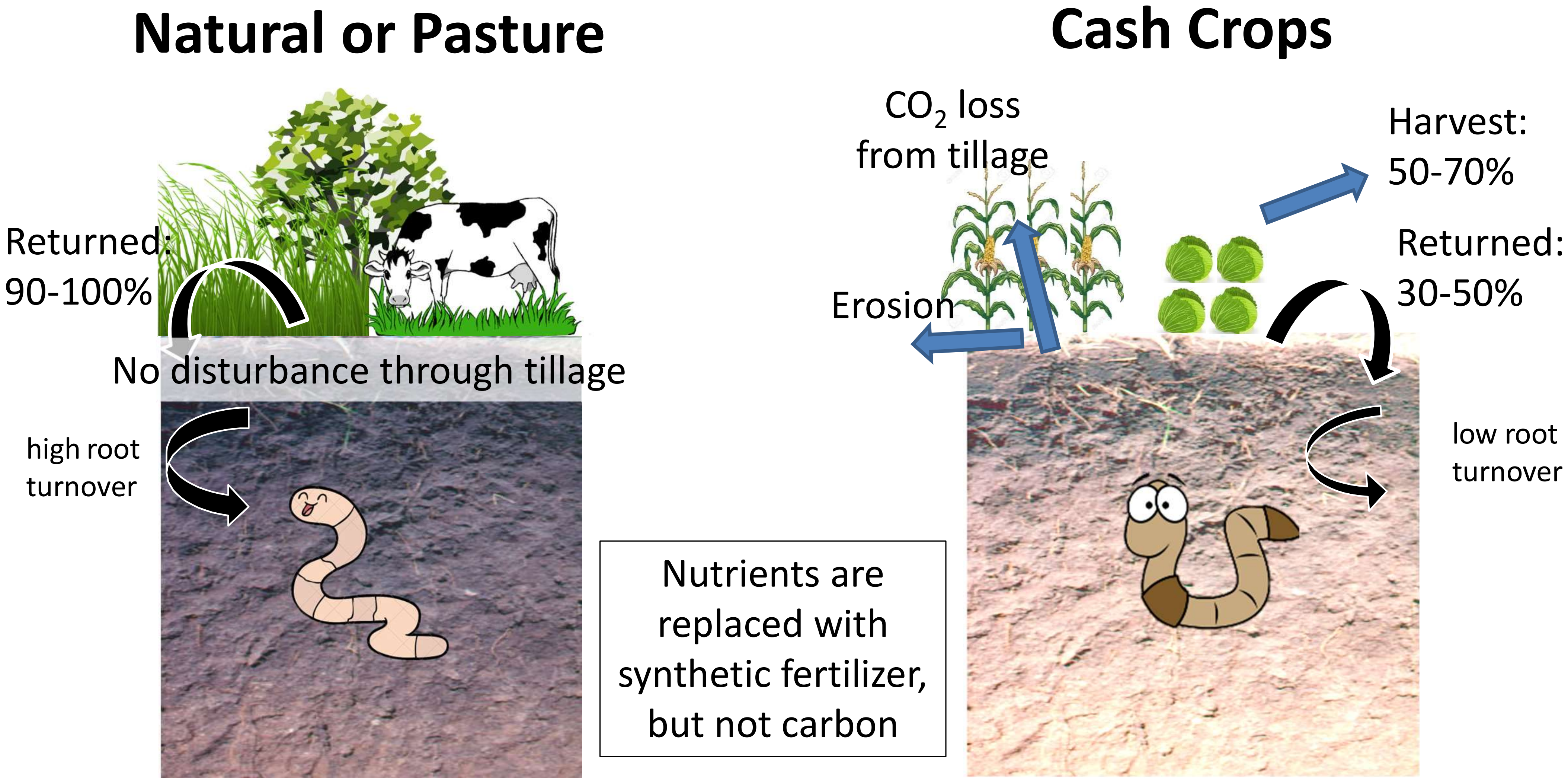
Factors of Soil Health

Human - Cropping Systems and Biomass Cycling



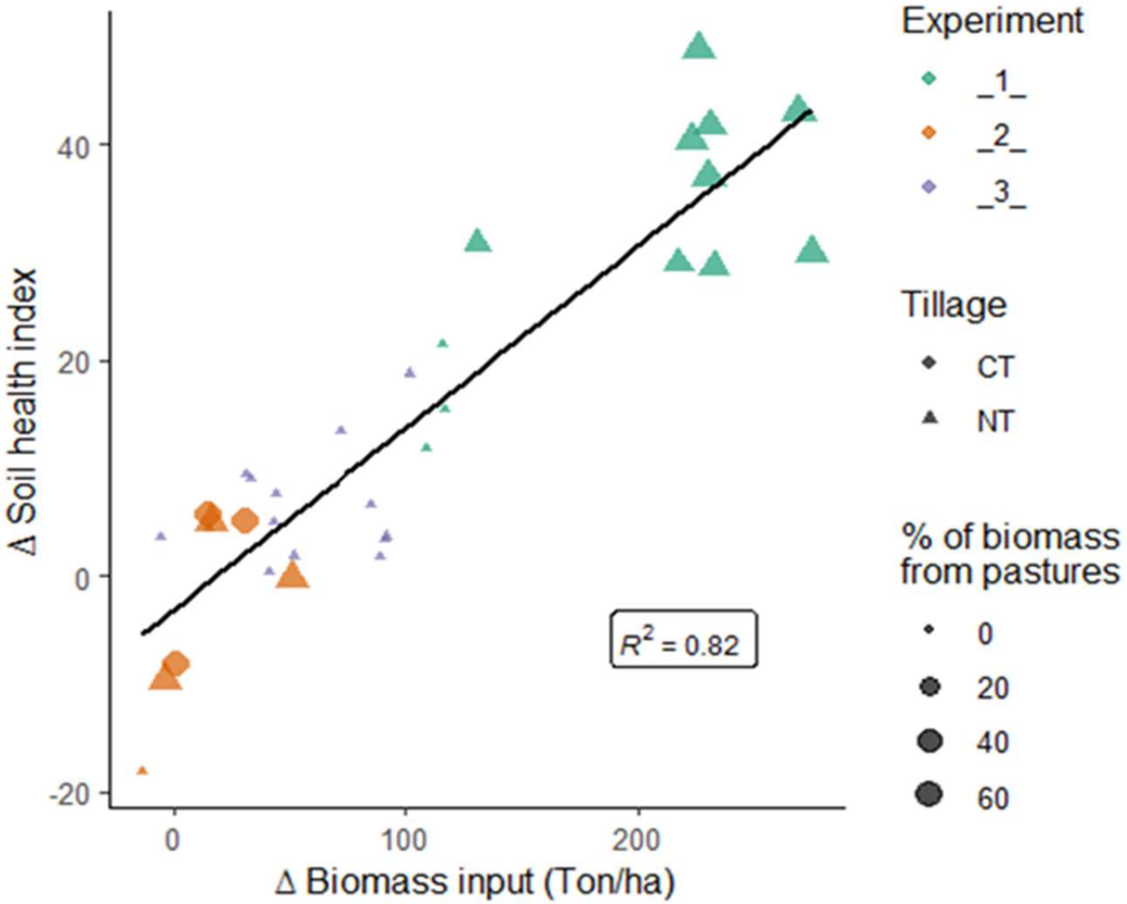
Cropping Systems, Carbon and Nutrient Cycling and Balances

Two Extremes Related to Agricultural Specialization



Nutrients are replaced with synthetic fertilizer, but not carbon

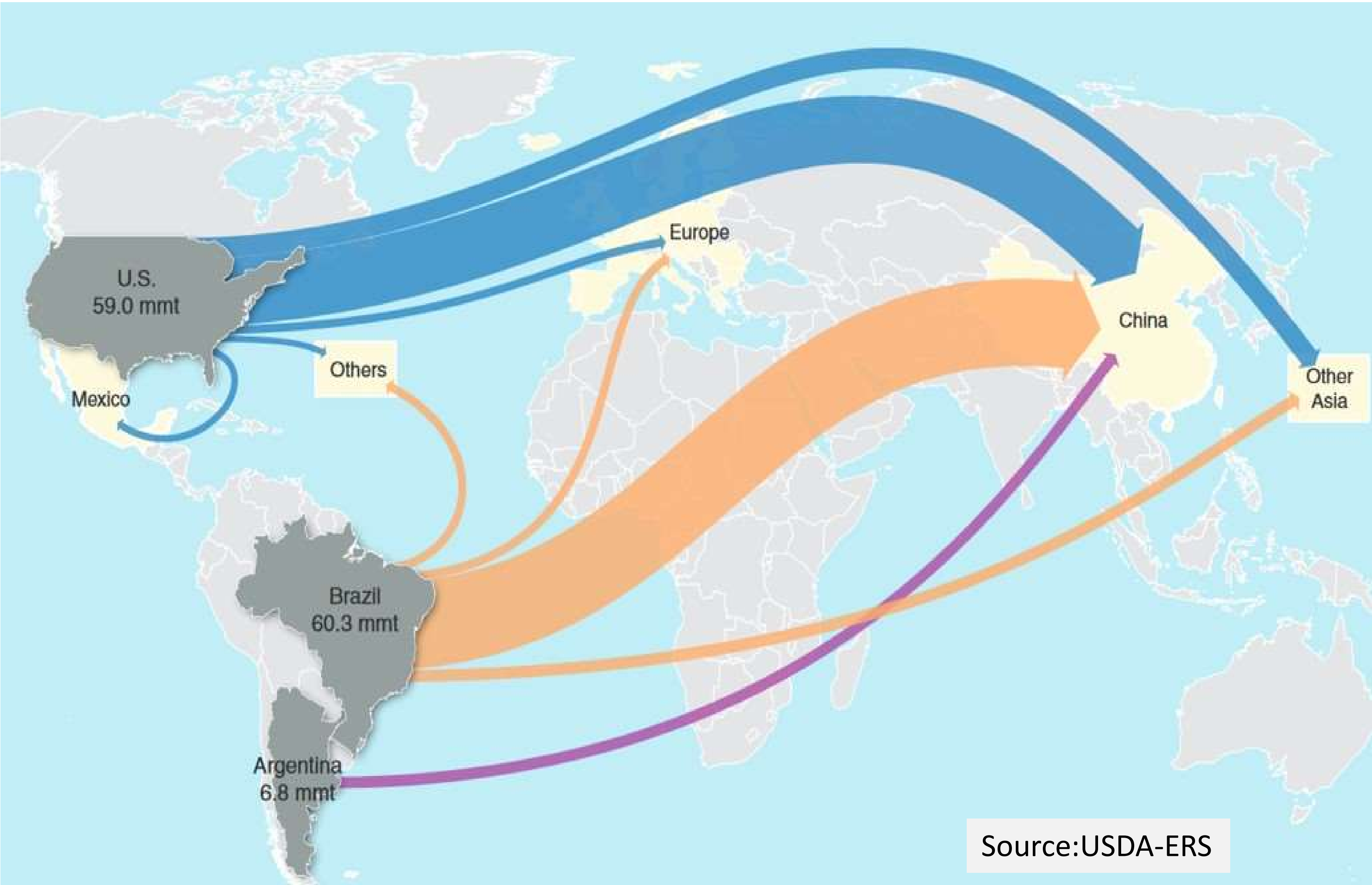
CHANGES IN BIOMASS INPUTS DRIVE CHANGES IN SH – Argentina and Uruguay



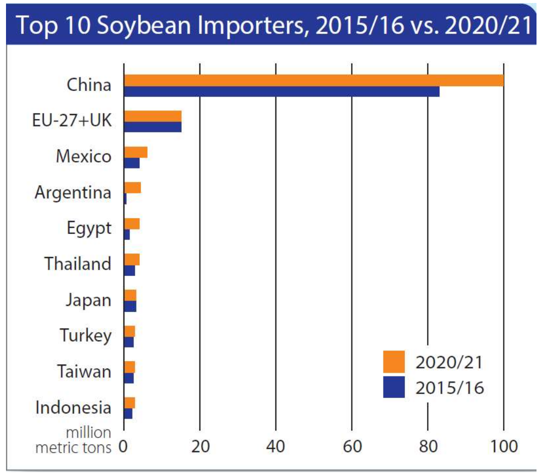
Rubio et al., 2022

Global Grain Flows

Soybean



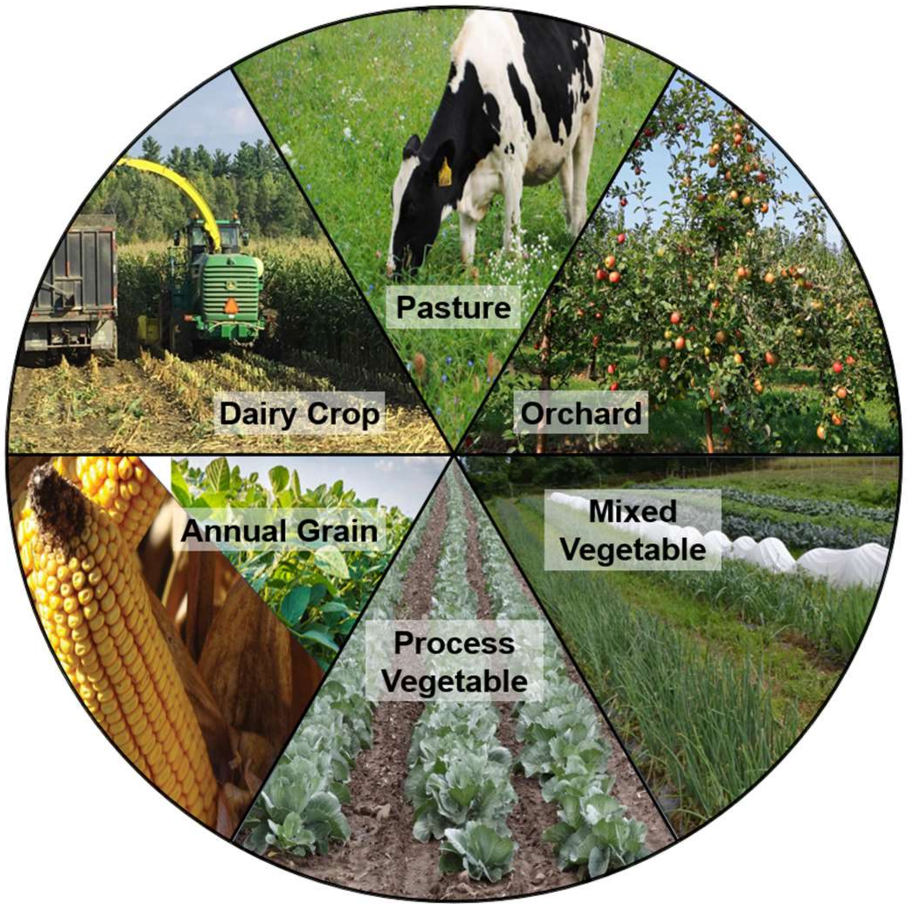
Source:USDA-ERS

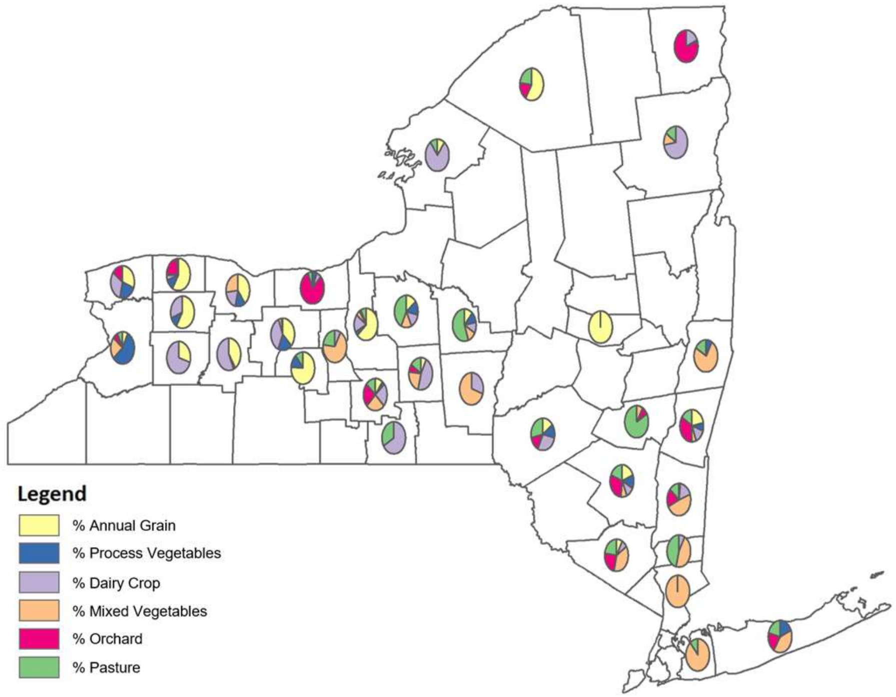


Source:Rabobank

Characterization of Soil Health in New York State

How do Cropping Systems (human land use) impact soil health?

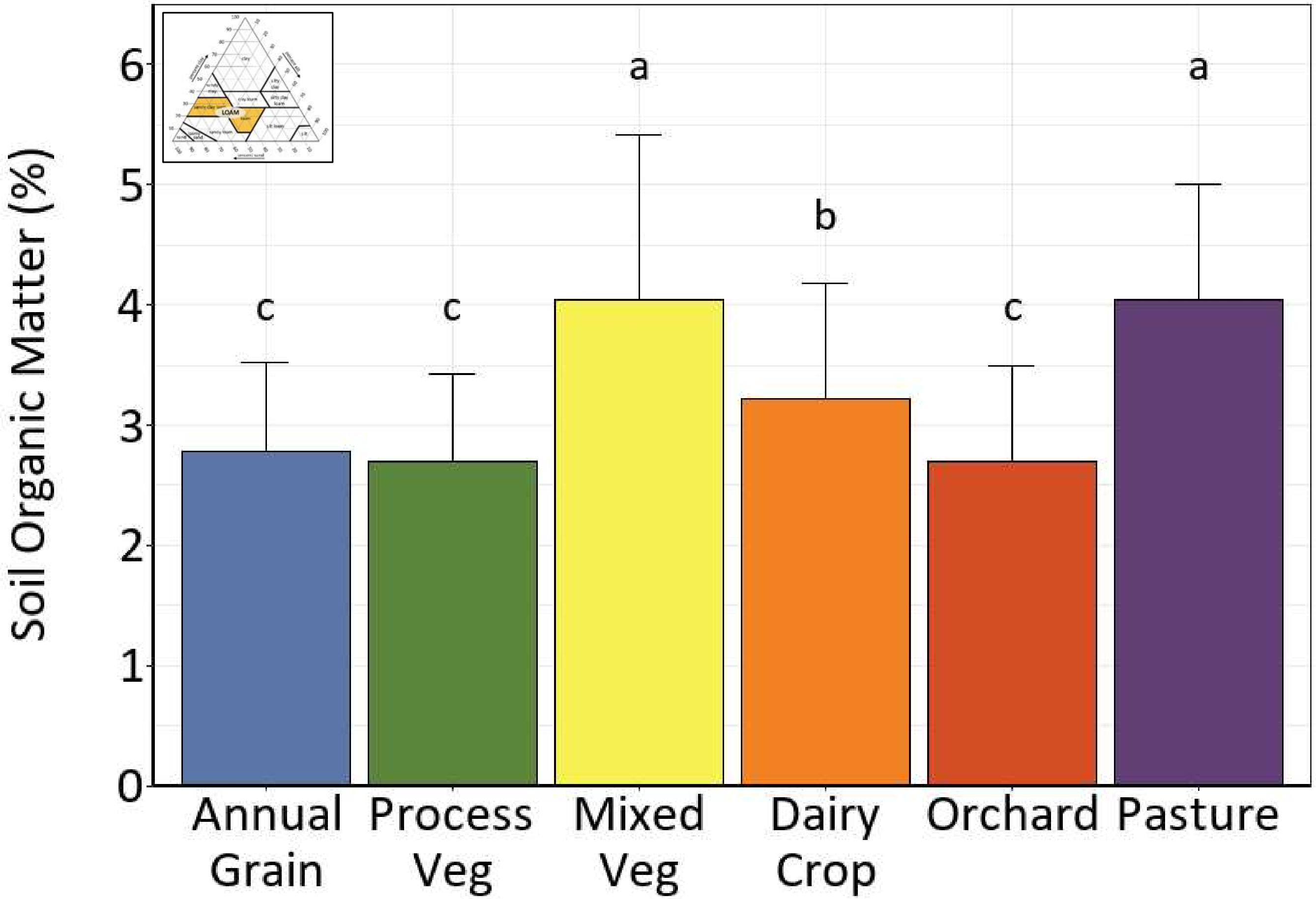




Cornell CALS College of Agriculture and Life Sciences

Amsili et al., 2023. Empirical approach for developing production environment soil health benchmarks

Pastures and Mixed Veg systems maintained the highest levels of soil organic matter



Amsili et al., 2023

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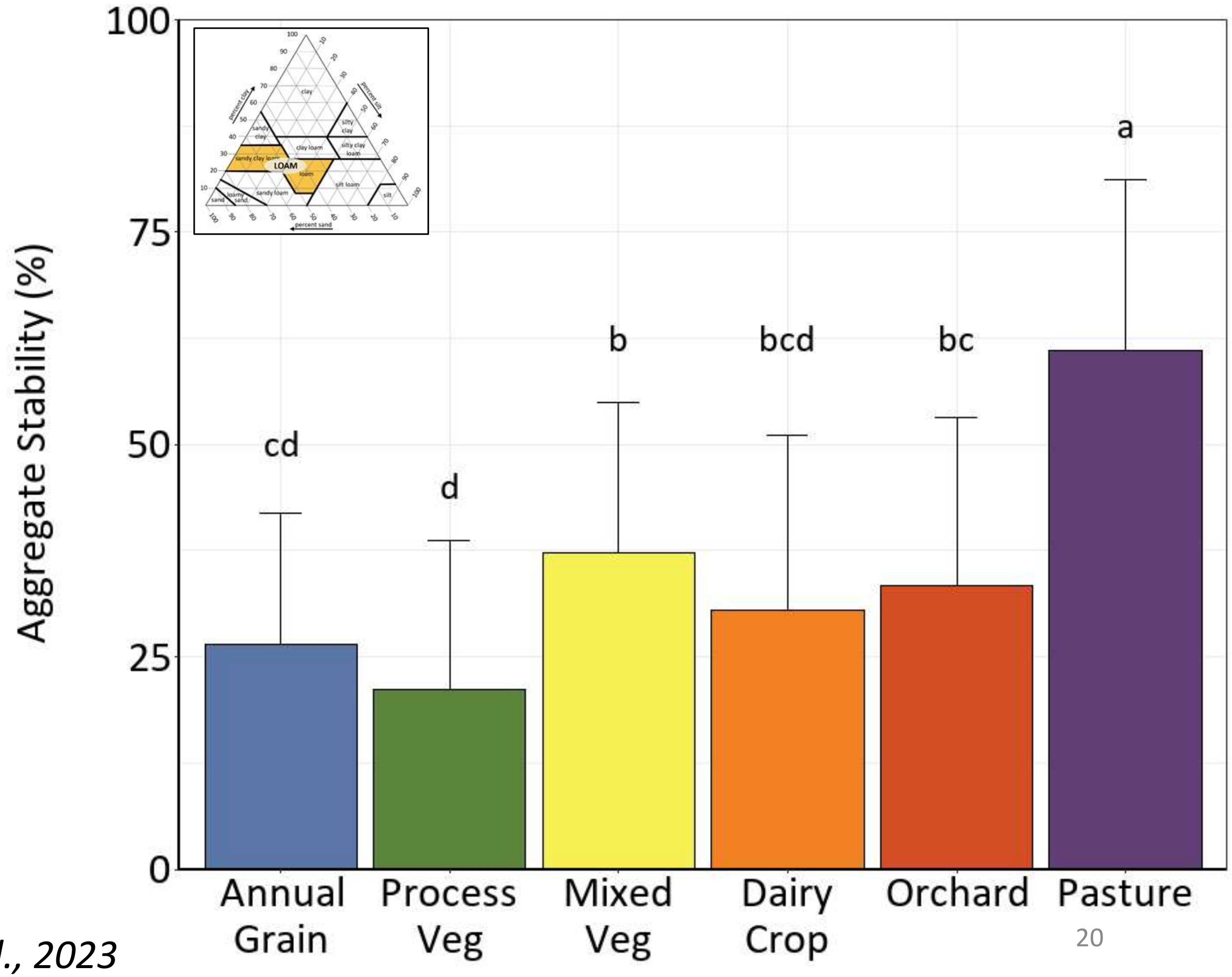
- Undisturbed pastures had the highest aggregate stability
- Mixed Veg had greater aggregate stability than Processing Vegetables



Amsili et al., 2023

NYS Soil Health and Climate Resiliency Act

- Signed by Gov. Hochul on Dec. 23, 2021 (approved unanimously in Assembly and Senate)

"…

establish appropriate voluntary standards and objectives for soil health

…."

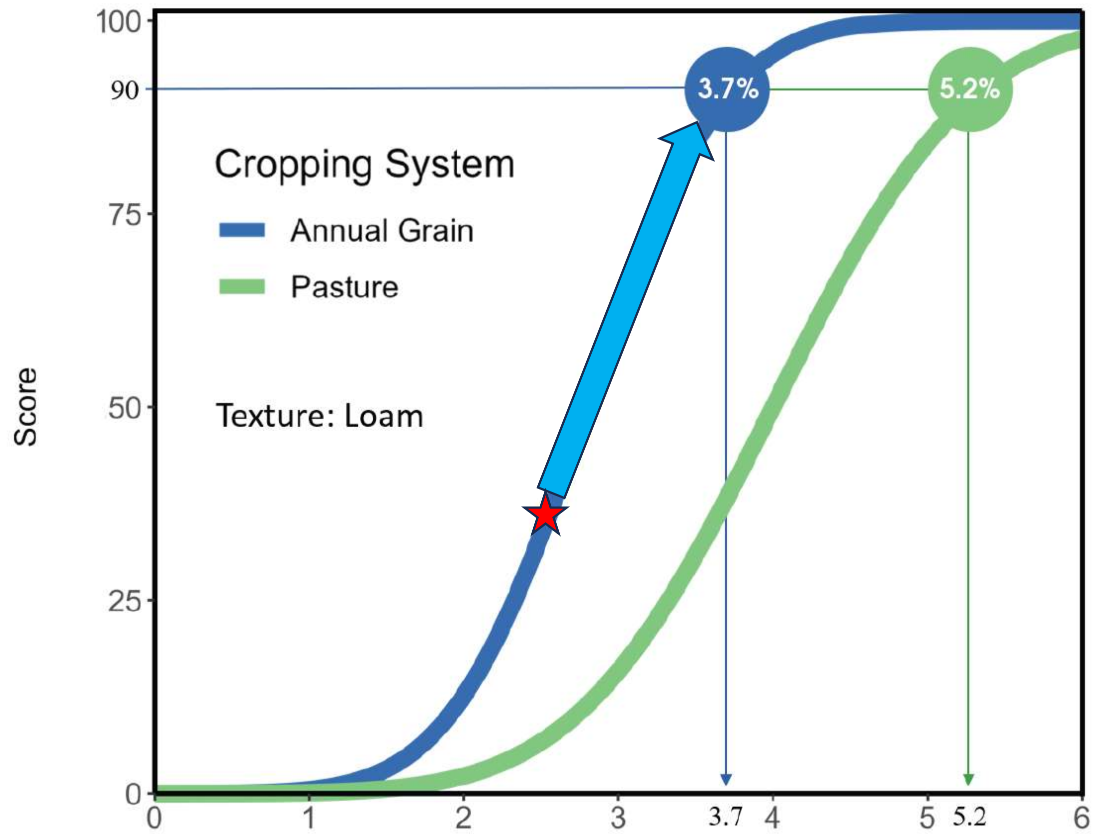
Production Environment Soil Health (PESH) Benchmarks

Example - Annual Grain systems on loam soils in upstate NY

- Development of soil health benchmarks by soil type, cropping system, and region (**production environment**)

- → define benchmarks
  - ○ 75th percentile: resource concern
  - ○ 90th percentile: aspirational goal

- Establish resource concerns, goals and pathway.



Amsili et al., 2023

PESH Benchmarks (Q90) by Cropping System – New York

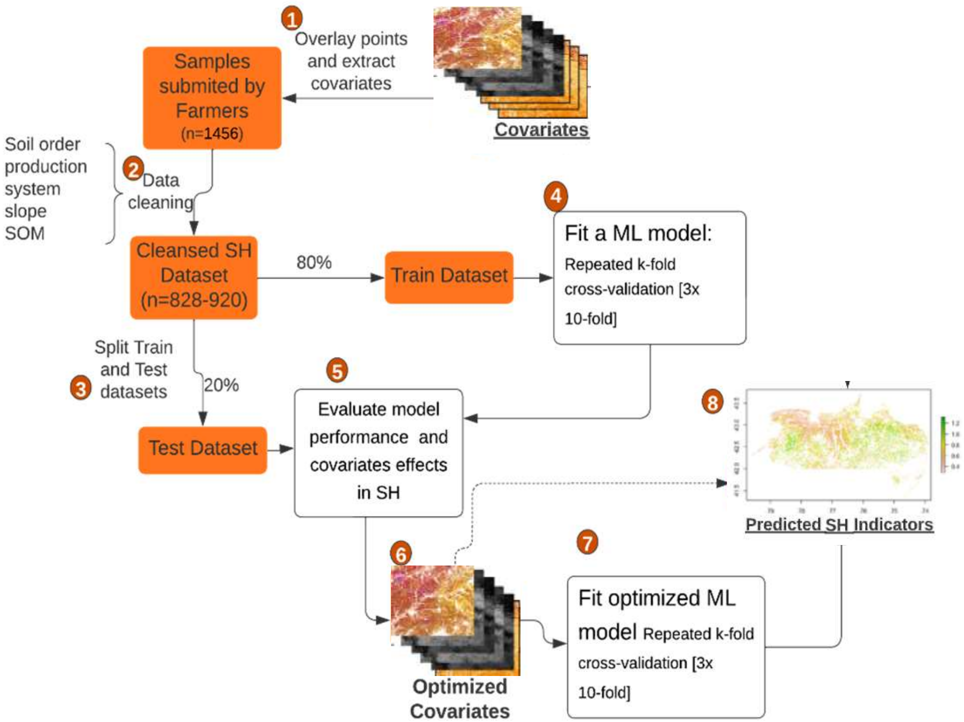
Q90 Basis, Coarse Texture

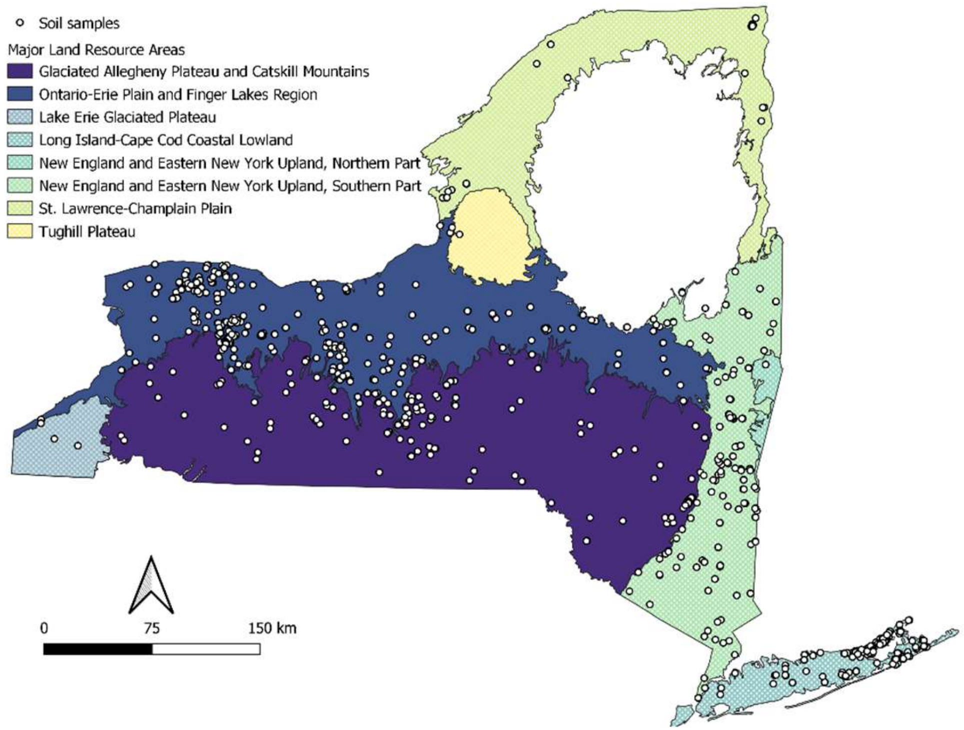
	90th Percentile						
Cropping System	**SOM** %	**SOC** %	**POXC** mg C/ kg	**Protein** mg/g	**Resp** mg CO_2/g	**WAS** %	**AWC** g H_2O/g
Annual Grain	2.8	1.9	620	7.5	0.58	58.3	0.20
Processing Veg	2.8	1.9	603	7.7	0.60	43.9	0.23
Dairy Crop	4.3	3.1	954	9.4	0.85	71.6	0.24
Mixed Veg	5.0	3.4	900	15.0	1.00	69.1	0.24
Orchard	3.0	2.1	843	9.6	0.54	65.9	0.20
Pasture	4.2	2.9	735	9.6	0.87	86.1	0.28
All	4.2	2.9	836	11	0.78	72.2	0.23

Amsili et al., 2023

MAPPING SOIL HEALTH AT REGIONAL SCALE ACROSS NY STATE: DISENTANGLING DRIVERS AND PREDICTING SPATIAL LAND USE EFFECTS

Expanding Digital Soil Mapping methods with dynamic properties driven by anthropogenic processes





- Alfisols, Entisols, Inceptisols
- No forest areas
- No urban areas

(Rubio, 2023)

Predicted SH indicators

Biological

- Organic Matter
- POXC
- Respiration
- ACE Protein

Physical

- Available Water Capacity (AWC)
- Wet Aggregate stability (WAS)

Composite SH Index of scored values

Model covariates: Inherent properties

Climate

- Annual Precipitation
- Mean Temperature

MODIS

Soil & Topography

- Slope

NASADEM_HGT/001

- Soil Order
- Drain class

SSURGO

- pH, Clay, Silt, BD, OM (5-15 cm) →

Polaris

Model covariates: Land Use

Cropping system

- Crops
- Crops_Past_Hay (Dairy)
- Mix_Veg
- Past_Hay

Crop frequencies

- Vegetables
- Annual Grain Crops (Soybean/Corn/Wheat & Barley/Rye & Oat)
- Pastures & Hay (Alfalfa & hay)

Cropland Data Layer USDA

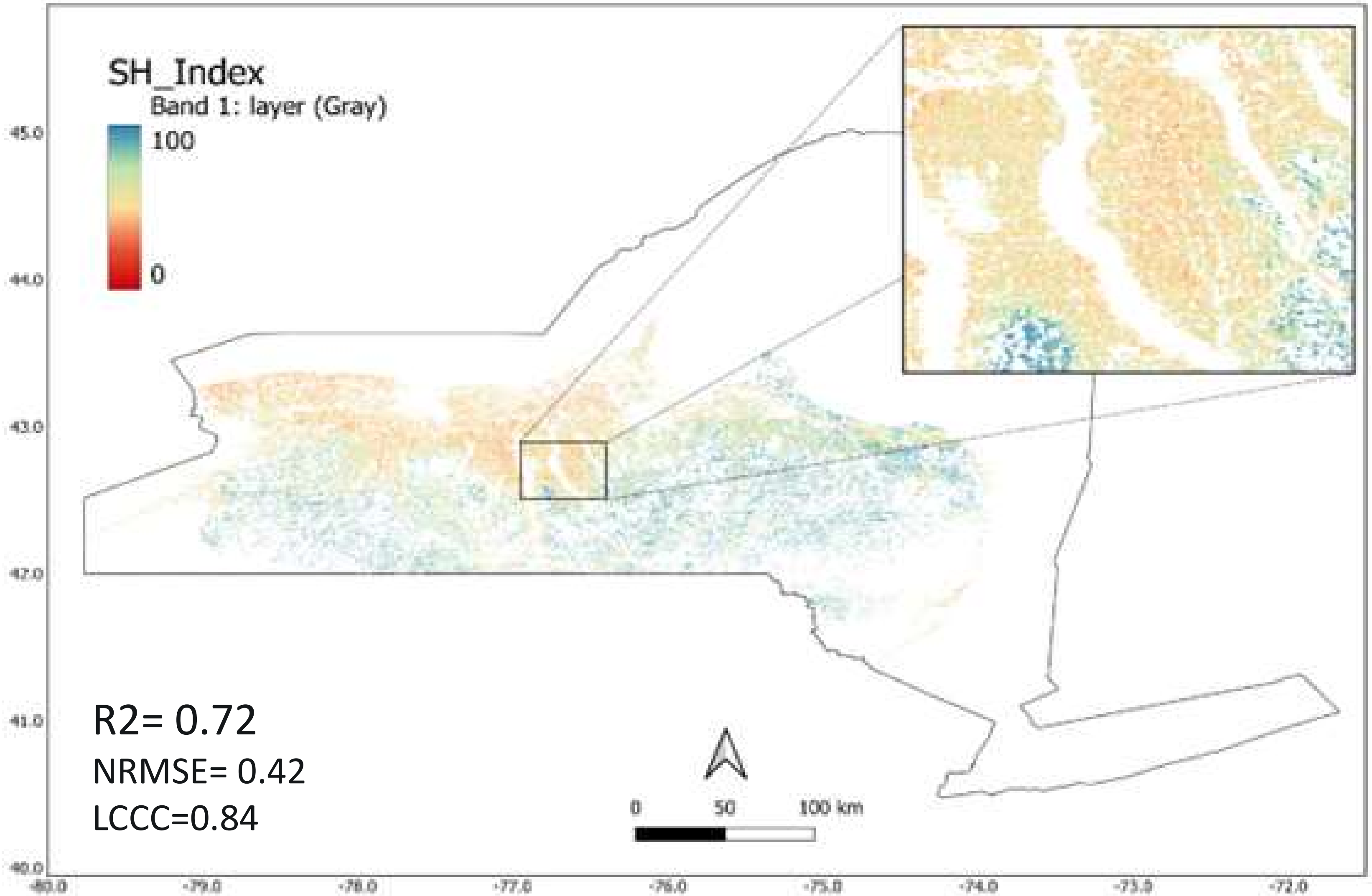
6 YEARS PRE-SAMPLING

Crop Productivity /biomass

- Mean NDVI (6 years)
- Annual NDVI (1 year)

Landsat 6

Model performance and predictions

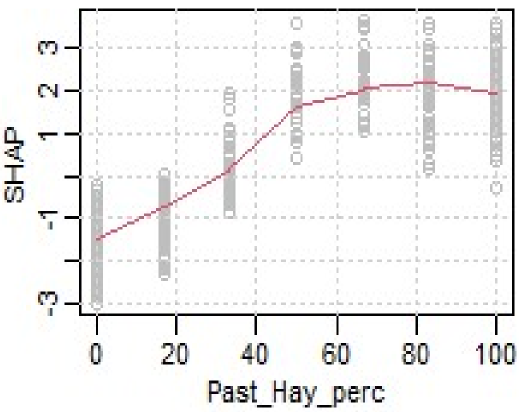


(Rubio, 2023)

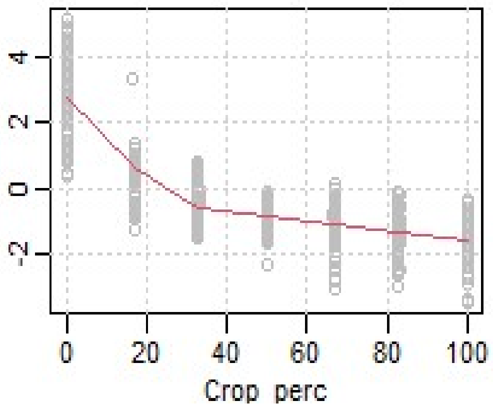
Understanding covariates effects on SH

Composite SH Index

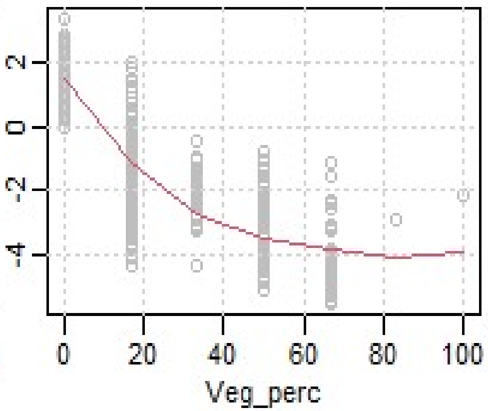
% of Pastures



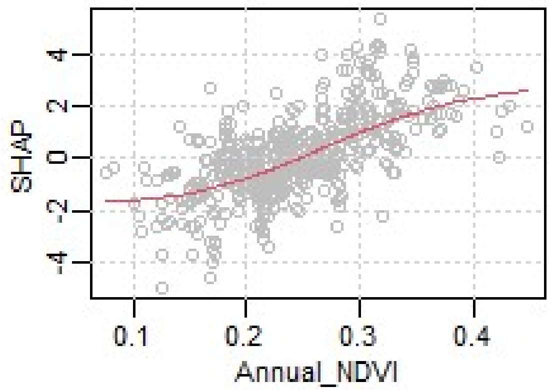
% of Annual crops



% of Vegetables



Annual NDVI



Confounding factors:
Climate & management

(Rubio, 2023)

Conclusions

Soil health is influenced by three major factors

- Inherent
- Land use type / cropping system
- Management practices

Biomass is an important driver of soil health.
SH is enhanced with higher biomass production and greater cycling

Soil health interpretation and benchmarking needs to be based on “peer production environments”

Mapping of soil health (dynamic soil properties) can be successfully done using ML methods and relevant inputs