



# Soil Health: Recent Advances and Future Directions

Wayne Honeycutt



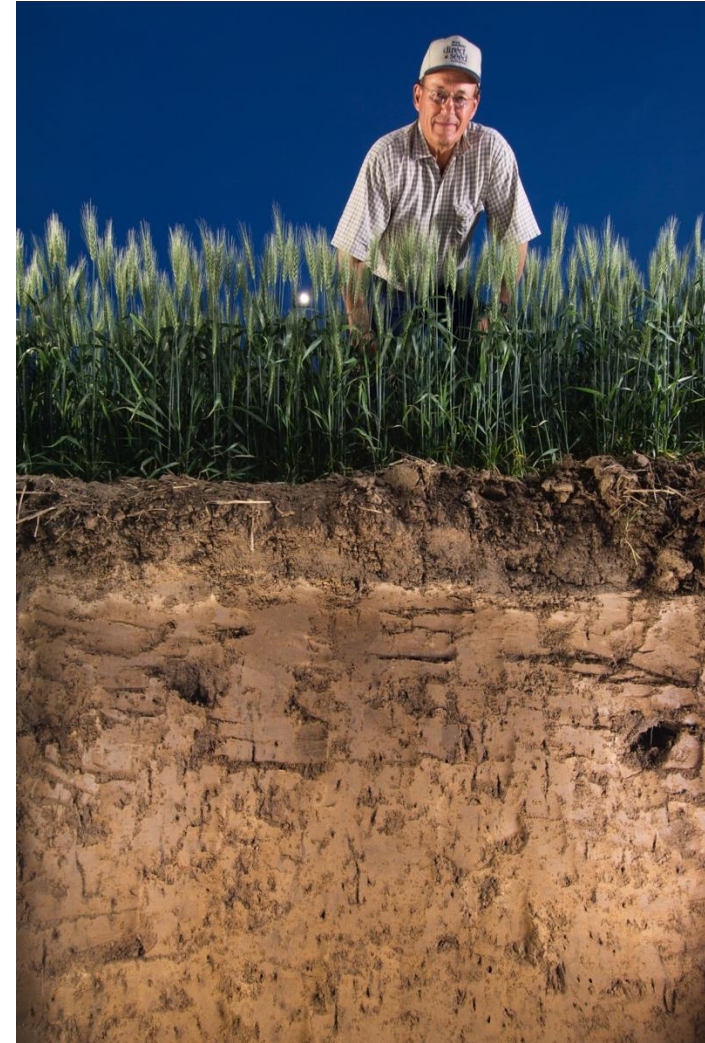
# Soil Health is About Soil Functioning



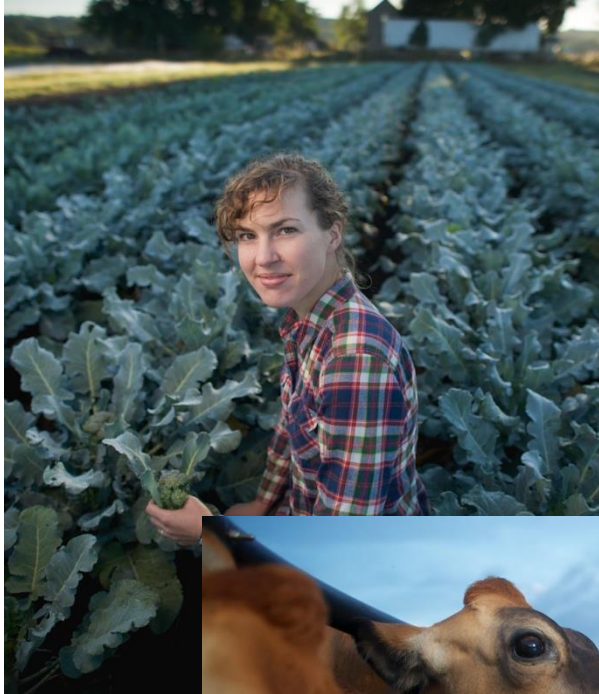
# Soil Health is the Foundation for Regenerative Agriculture

## Benefits of Healthy Soils

- Drought Resilience
- Yield Stability
- Profitability
- Nutrient Availability
- Disease Suppression
- Carbon Sequestration
- Reduced GHG Emissions
- Improved Water Quality



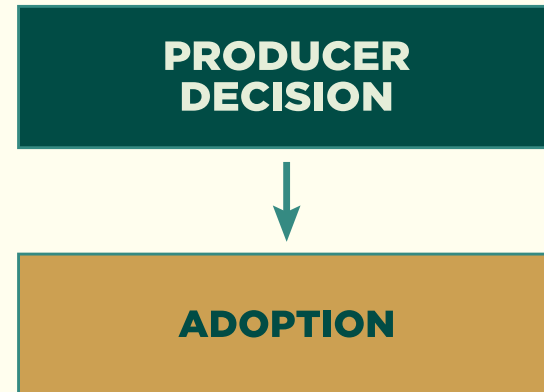
# THE MOST CRITICAL INGREDIENT:



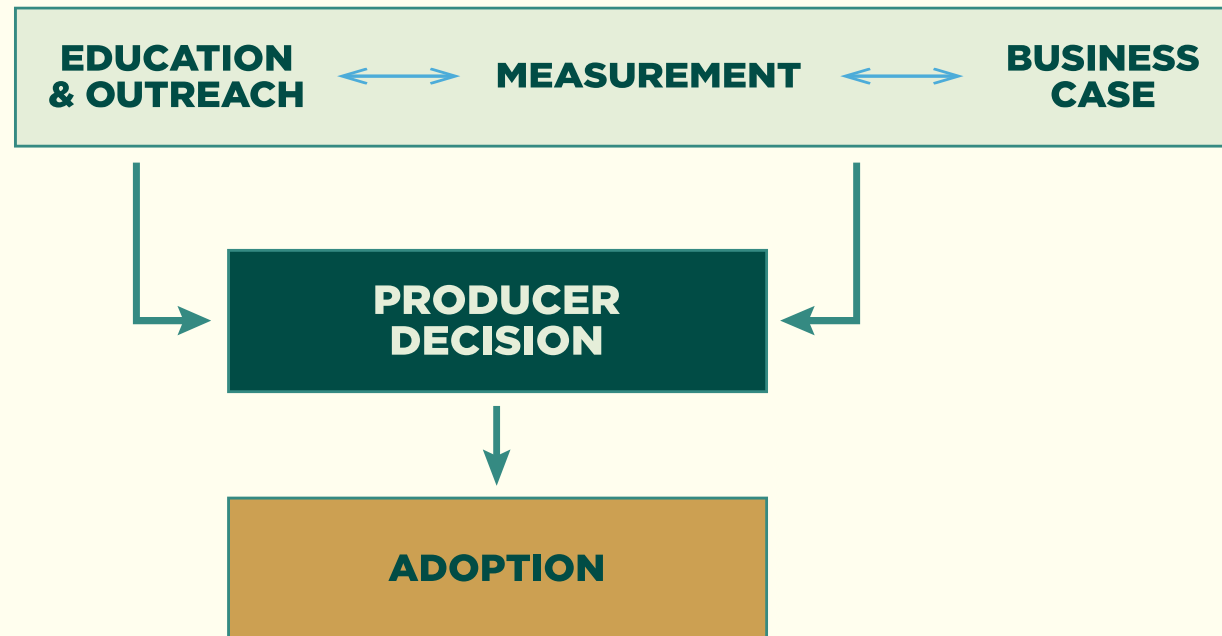
# COMPREHENSIVE STRATEGY TO INCREASE ADOPTION OF SOIL HEALTH MANAGEMENT SYSTEMS

**ADOPTION**

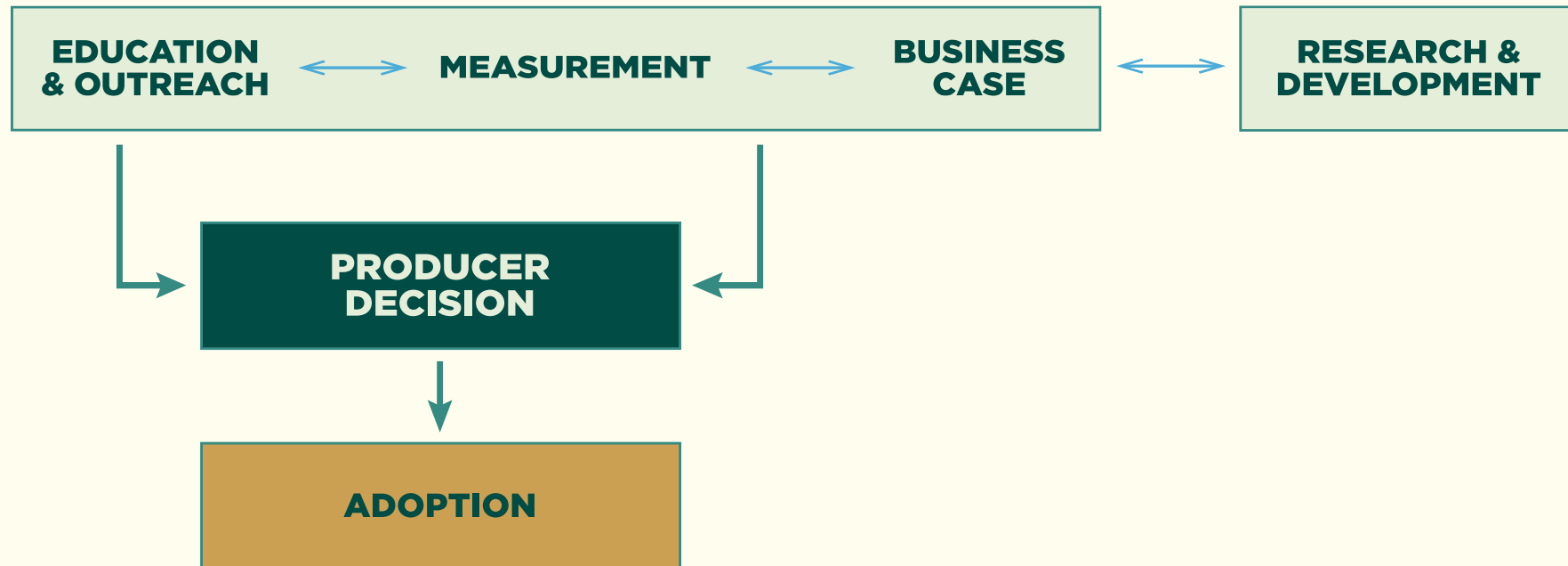
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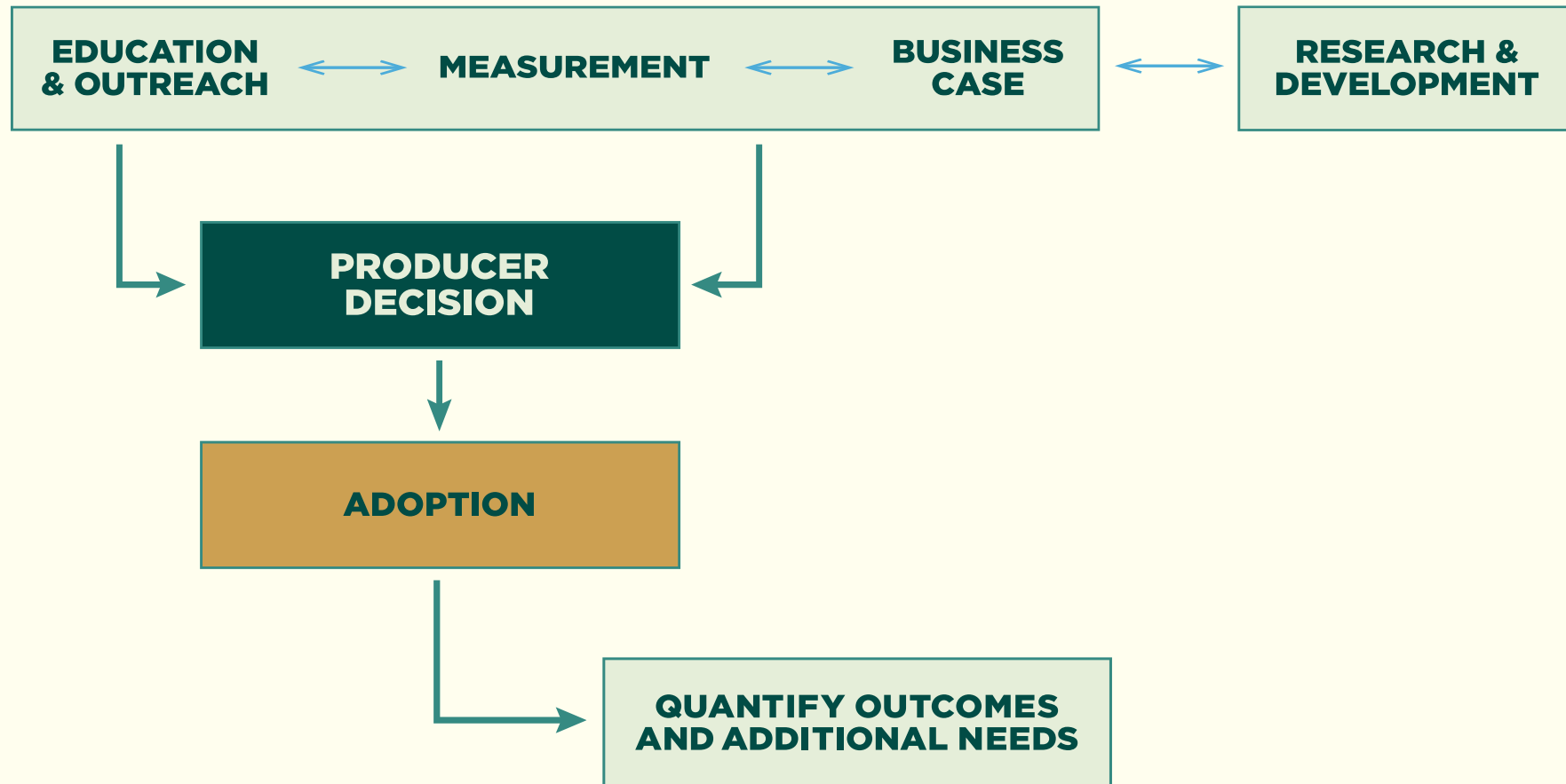
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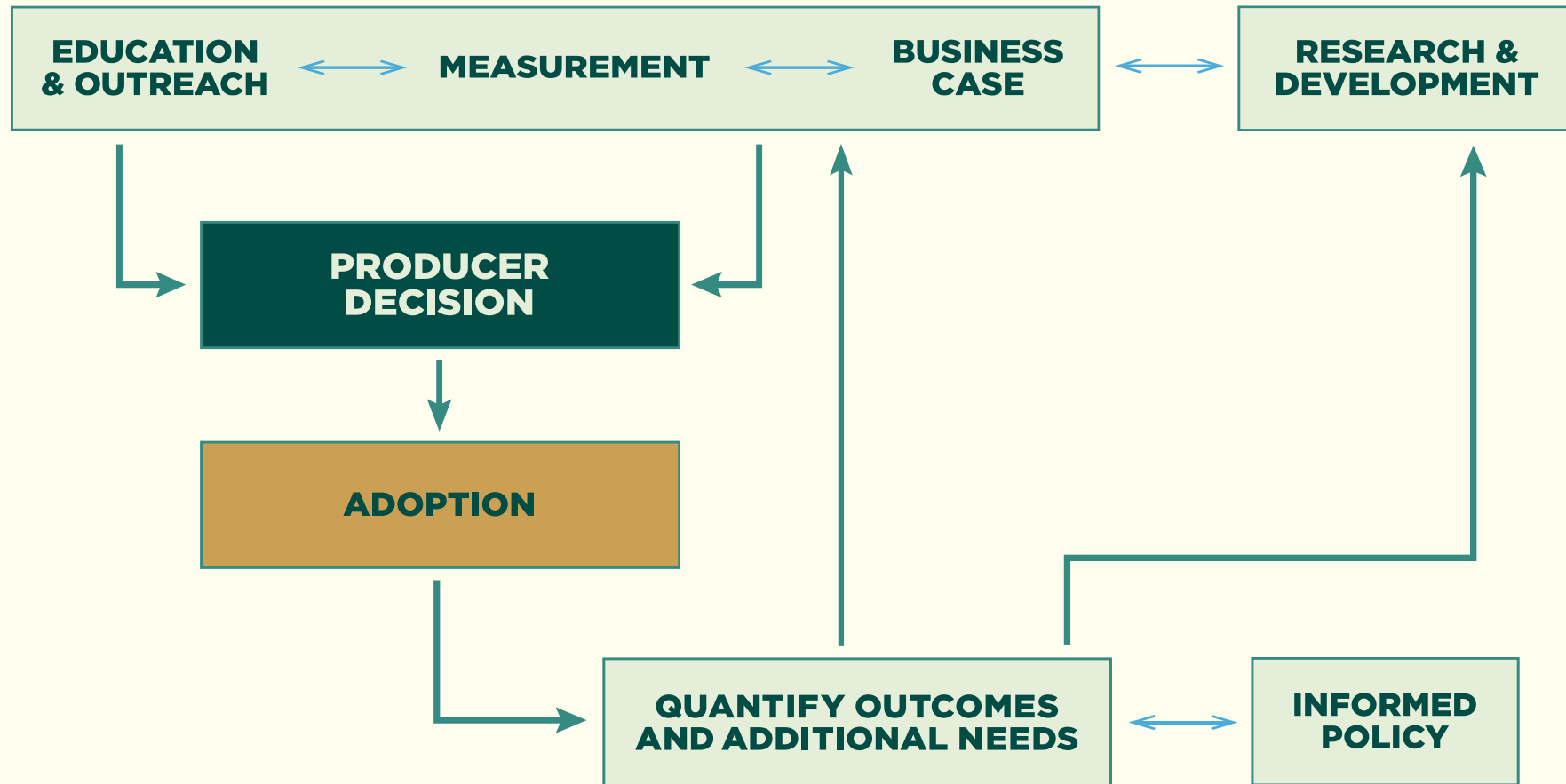
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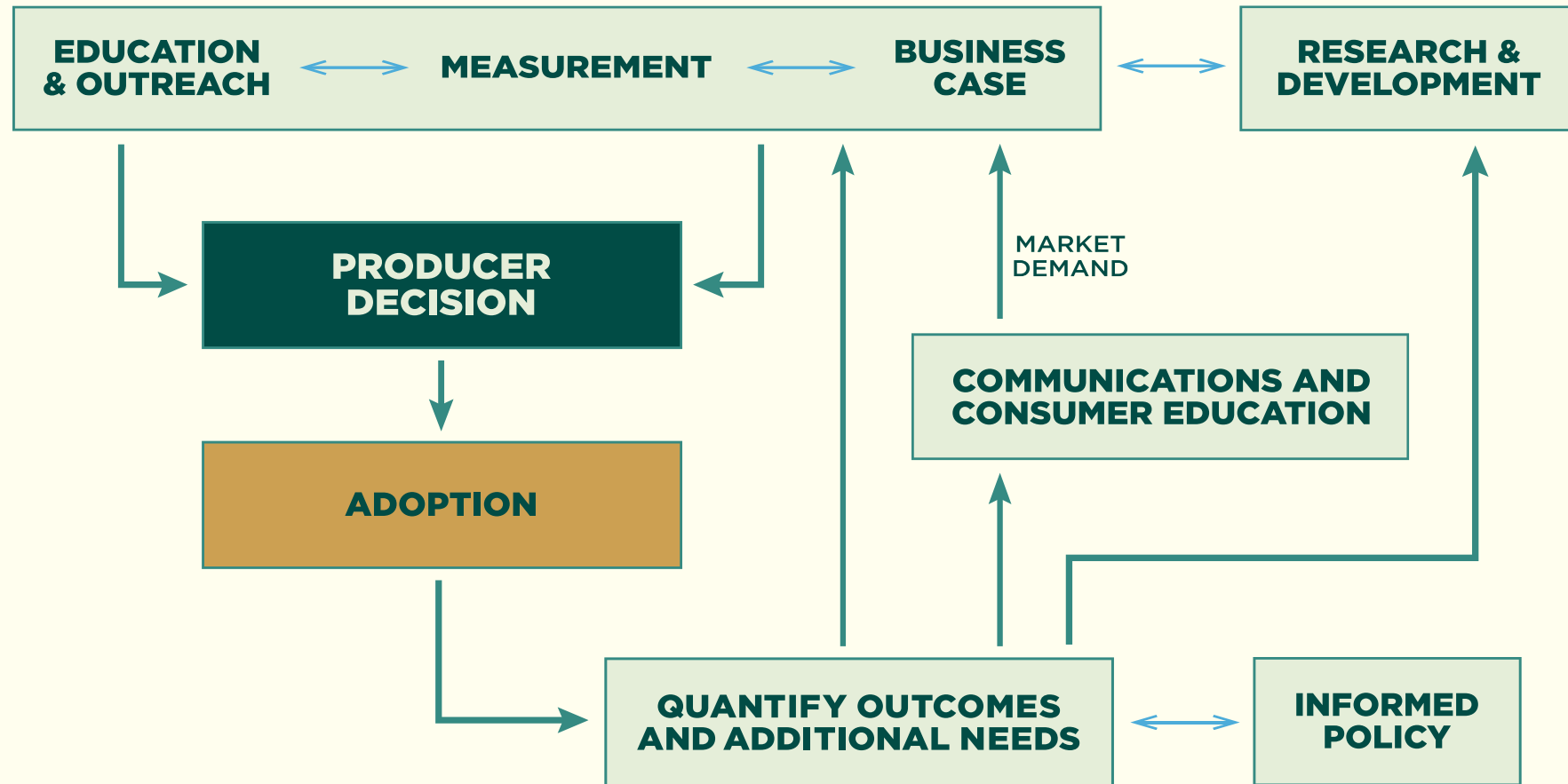
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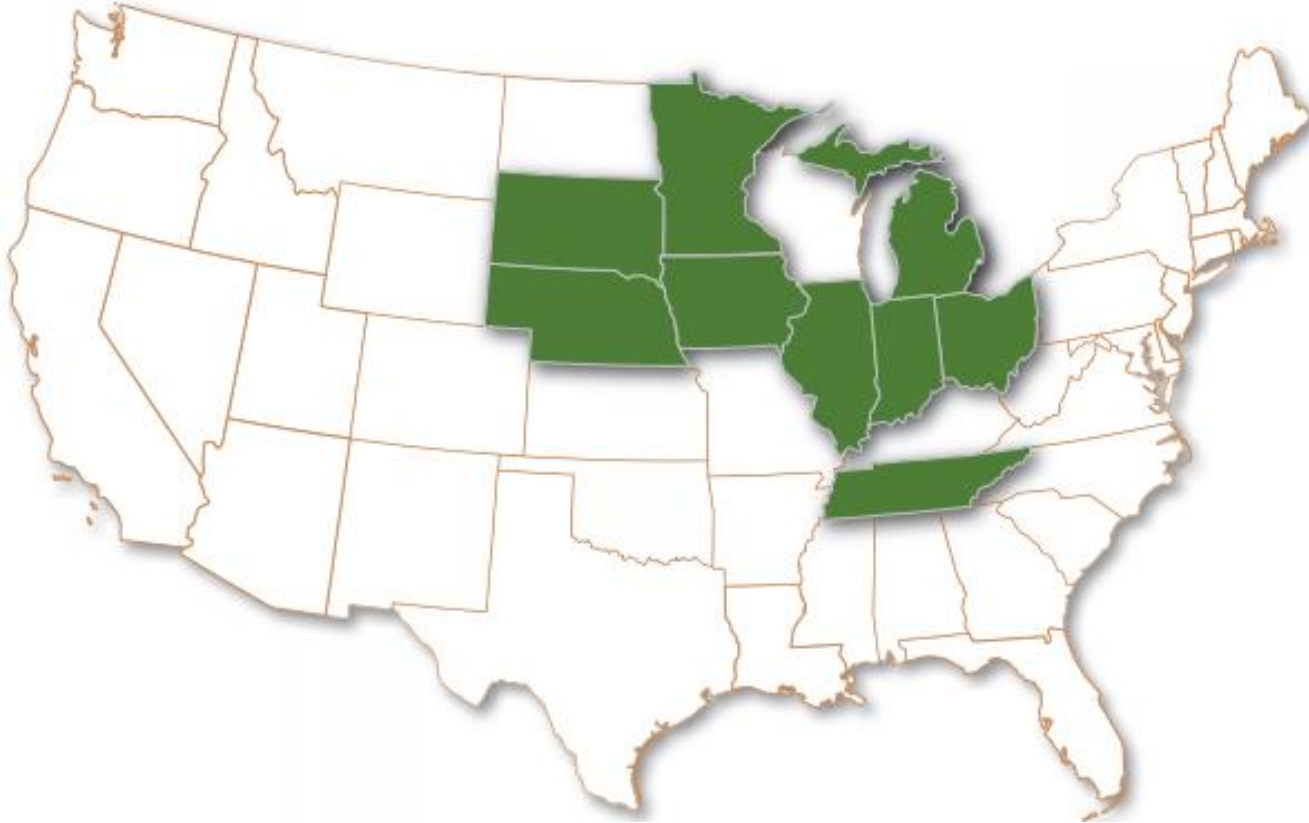
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# LEVER OF CHANGE #1. BUSINESS CASE

# ADVANCEMENT: Evaluated the Business Case for Soil Health

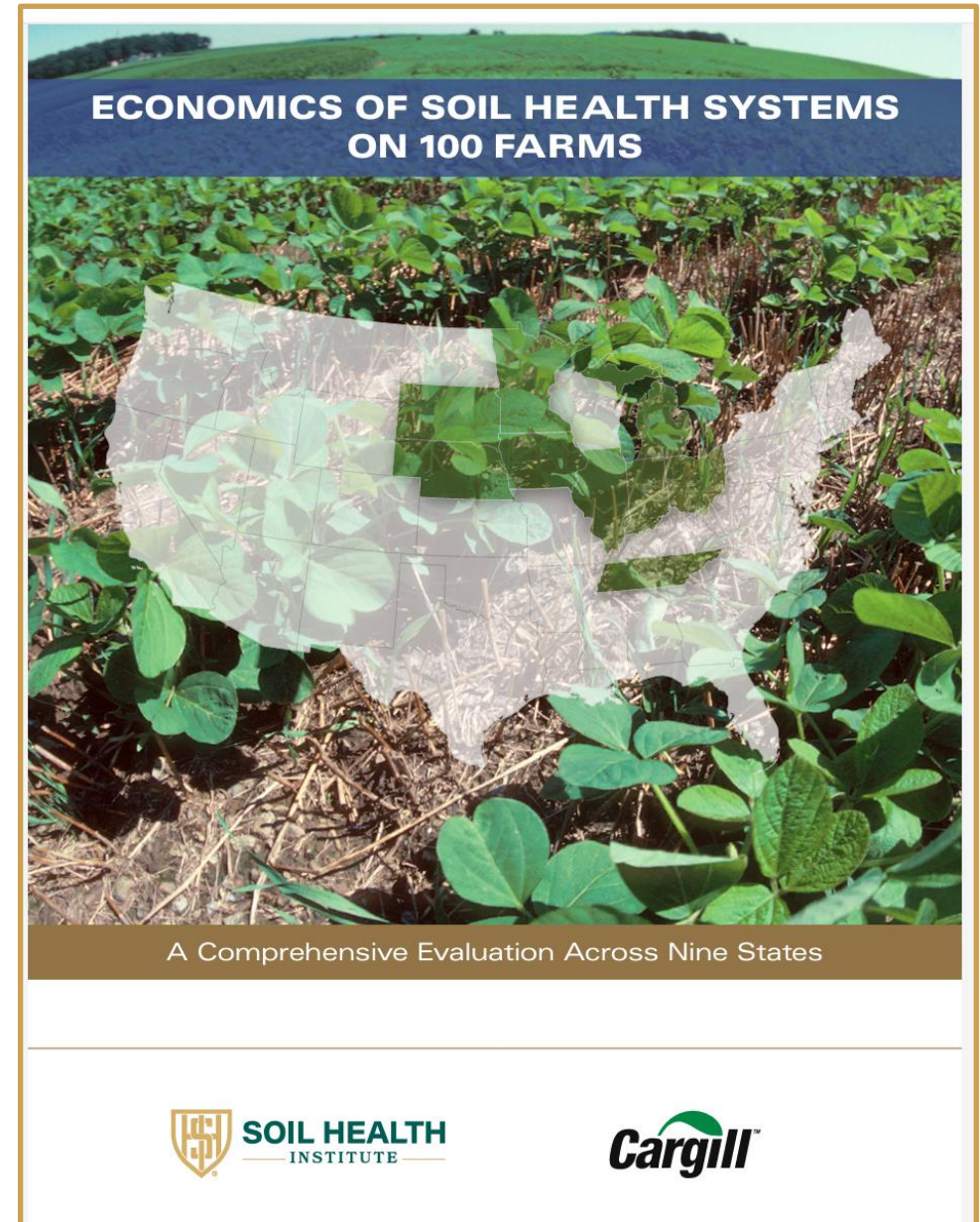


Funder: Cargill

- **100 Farms**
- **9 States**
- **71% Corn in U.S.**
- **67% Soybean in U.S.**
- **MAP: 20 – 55 in. (51 – 140 cm)**
- **MAT: 43 – 61°F (6 – 16°C)**
- **GDD: 2400 – 4000**
- **Average 1940 crop acres/farm**
- **Average No-Till for 19 years**
- **Average Cover Crops for 9 years**

# Summary of Findings from 100 Farms

- **SHMS reduced average production costs by:**
  - \$24/acre for corn
  - \$17/acre for soybean
- **SHMS increased net farm income for:**
  - 85% of farmers growing corn
  - 88% of farmers growing soybean
- **SHMS increased average net farm income by:**
  - \$52/acre for corn
  - \$45/acre for soybean
- **Additional benefits reported by farmers:**
  - 83% reduced fertilizer inputs
  - 93% increased access to their fields
  - 97% increased resilience to extreme weather
- **Based on current adoption rates in these 9 states (41% no-till; 6% cover crops) more farmers could increase net farm income with SHMS**



# ADVANCEMENT: Business Case of Soil Health Mgmt. System Adoption

## Average Net Income Increase from SHMS

### DIVERSE SYSTEMS

↑ **\$65/acre**

across 29 farms in 20 states

### COTTON

↑ **\$150/acre**

across 19 farms in 5 states

### CORN AND SOYBEAN

↑ **\$52/acre**

↑ **\$45/acre**

across 100 farms in 9 states

### SMALL GRAINS

↑ **\$19/acre**

across 10 farms in North Dakota and Kansas

↑ **US\$31/acre**

across 5 farms in Canada



### ECONOMICS of Soil Health Systems

#### Coxey Creek-Tennessee River Watershed of Alabama

**CROPS GROWN**  
50% Cotton  
50% Double-cropped Soybean and Wheat

**SOIL TEXTURE**  
Ranged from Sandy loam to Clay

**SOIL HEALTH MANAGEMENT SYSTEM**  
Minimum tillage  
Cover crops  
Monitoring of soil nutrient levels

**NET INCOME INCREASE**  
Cotton \$796/acre  
Soybean \$180/acre  
Wheat \$29.33/acre

#### INTRODUCTION

The Shun Binford farm in the Coxey Creek-Tennessee River Watershed of Alabama increased profitability for cotton, soybean, and wheat by decreasing production costs with a soil health management system (SHMS) of minimum tillage production and cover crops. The farm began using minimum tillage practices on the heavier clay soils and no-till on the lighter soils in 1997. Cover crops have been planted for four years.

**Benefits of the SHMS reported by the farmer:**

- IMPROVED WATER INFILTRATION
- REDUCED EROSION
- ENHANCED RESILIENCE TO EXTREME WEATHER

ADDITIONAL INFORMATION ON THE FARM IS AVAILABLE IN A REPORT AND VIDEO PRESENTATION AT [WWW.NRCS.EDU/US/STATE/ALABAMA/COXKEY](http://WWW.NRCS.EDU/US/STATE/ALABAMA/COXKEY)

#### METHODS

The Soil Health Institute conducted an interview to obtain production information for evaluating economics of the soil health system based on partial budget analysis. In this approach, the benefits and costs of a soil health system are assessed by calculating changes in revenue and expenses before and after adoption of that system. The change in net farm income associated with adopting a SHMS is calculated as shown below and presented in Table 1.

**Net change in farm income = Benefits - Costs, where:**  
**Benefits = Reduced Expenses + Additional Revenue**  
**Costs = Additional Expenses + Reduced Revenue**

#### FINDINGS

**Initial Management System and Reduced Expenses**

- The initial management system was conventional tillage production.
- Post-plant weed management was exclusively with herbicide in conventional tillage.
- Three tillage operations were eliminated for cotton and soybean, and two were eliminated for wheat.
- Total reduced expenses were \$53.14/acre for cotton, \$31.90/acre for soybean, and \$5.49/acre for wheat.

FARM #11



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#### ECONOMICS of Soil Health Systems: Coxey Creek-Tennessee River Watershed of Alabama

- |   |   |
|---|---|
| <p><b>Soil Health Management System and Additional Expenses</b></p> <ul style="list-style-type: none"> <li>→ The soil health management system adopted was no-till production for soybean and wheat along with minimum tillage production and cover crops before cotton.</li> <li>→ Wheat as a cover crop before cotton was broadcast by custom application for \$8.00/acre in the fall at a seed rate of one bu./acre.</li> <li>→ The cover crop was terminated with herbicide and incorporated into the soil with the vertical tillage implement.</li> <li>→ Total additional expenses were \$45.38/acre for cotton, \$20.10/acre for soybean, and \$24.16/acre for wheat.</li> </ul> | <p><b>Soil Health Management System Impact on Farm Income</b></p> <ul style="list-style-type: none"> <li>→ Reduced expenses were \$796/acre greater than additional expenses for cotton.</li> <li>→ Reduced expenses were \$180/acre greater than additional expenses for soybean.</li> <li>→ Reduced expenses were \$29.33/acre greater than additional expenses for wheat.</li> <li>→ Reduced expenses were realized for all crops without yield reductions.</li> <li>→ <b>Net farm income increased \$796/acre for cotton, \$180/acre for soybean, and \$29.33 for wheat.</b></li> </ul> |
|---|---|

Table 1. Partial Budget<sup>1</sup> Analysis, 24 Years with a Soil Health Management System, \$ per Acre per Year (2019 Dollars)

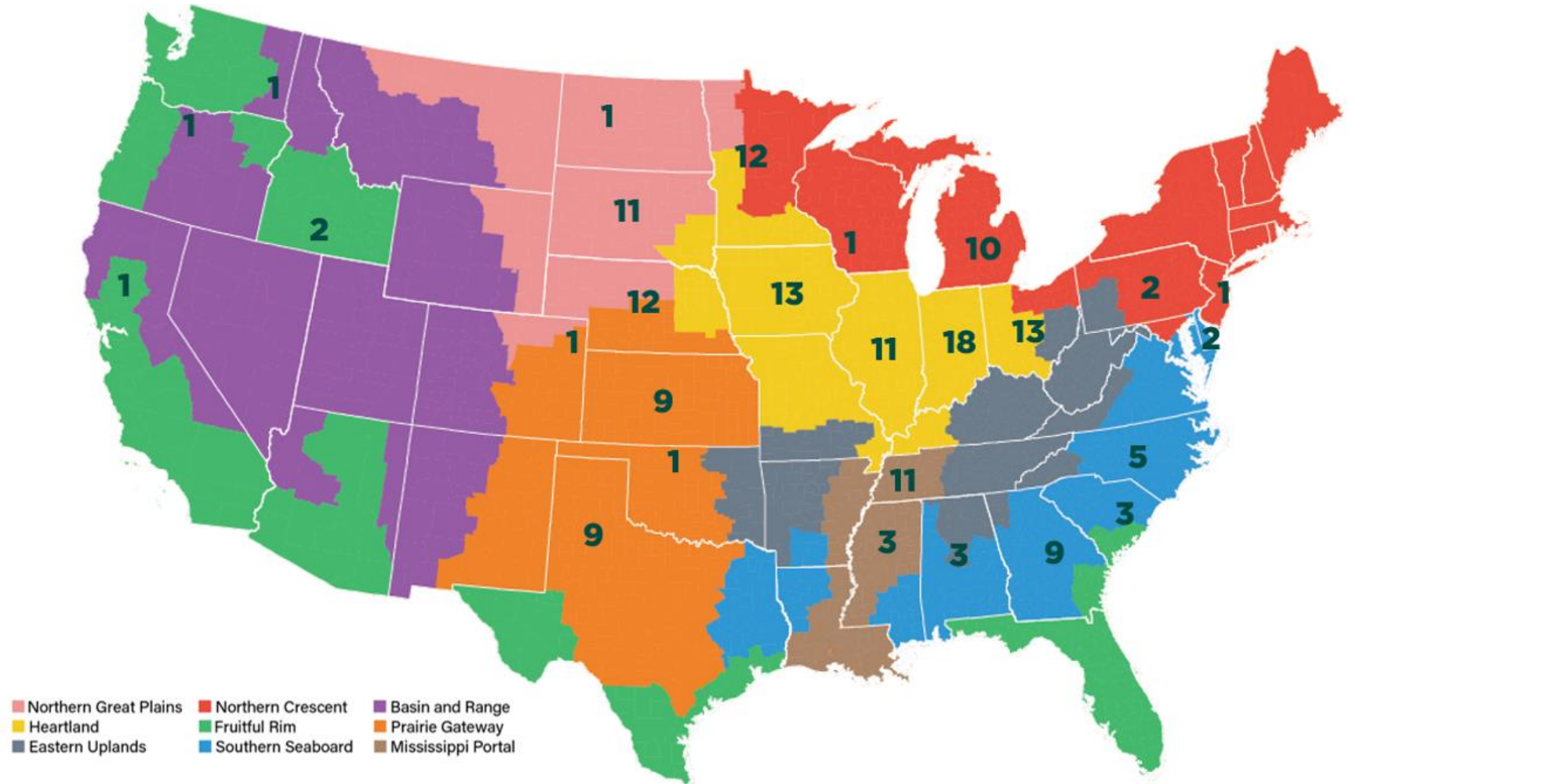
Expense Category	Cotton		Soybean		Wheat	
	REDUCED EXPENSES	ADDITIONAL EXPENSES	REDUCED EXPENSES	ADDITIONAL EXPENSES	REDUCED EXPENSES	ADDITIONAL EXPENSES
Seed	0.00	2.50	0.00	0.00	0.00	0.00
Fertilizer & Amendments	0.00	0.00	0.00	0.00	0.00	0.00
Pesticides	0.00	3.84	0.00	3.84	0.00	3.84
Fuel & Electricity	7.63	2.77	4.19	1.34	7.66	2.05
Labor & Services	14.42	15.84	8.78	4.87	14.34	5.78
Post-harvest Expenses	0.00	0.00	0.00	0.00	0.00	0.00
Equipment Ownership	31.09	17.23	18.93	10.05	31.49	12.49
<b>Total Expense Change</b>	<b>\$53.14</b>	<b>45.38</b>	<b>\$31.90</b>	<b>20.10</b>	<b>\$5.49</b>	<b>24.16</b>
	ADDITIONAL REVENUE	REDUCED REVENUE	ADDITIONAL REVENUE	REDUCED REVENUE	ADDITIONAL REVENUE	REDUCED REVENUE
Yield, bu./acre, Cotton, lb./acre	0.00	0.00	0.00	0.00	0.00	0.00
Price Received, <sup>2</sup> \$/unit	0.67	0.67	10.00	10.00	5.50	10.00
<b>Revenue Change</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
<b>TOTAL</b>	<b>TOTAL COSTS</b>	<b>TOTAL BENEFITS</b>	<b>TOTAL COSTS</b>	<b>TOTAL BENEFITS</b>	<b>TOTAL COSTS</b>	<b>TOTAL BENEFITS</b>
<b>Total Change</b>	<b>\$53.14</b>	<b>45.38</b>	<b>\$31.90</b>	<b>20.10</b>	<b>\$5.49</b>	<b>24.16</b>
<b>Change in Net Farm Income</b>	<b>7.96</b>	<b>11.80</b>	<b>29.33</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>

<sup>1</sup> Expenses and reduced costs were based on current reported production practices. <sup>2</sup> Price received was based on the 2019 market price for cotton, soybean, and wheat. <sup>3</sup> Price received was based on the 2019 market price for cotton, soybean, and wheat. <sup>4</sup> Price received was based on the 2019 market price for cotton, soybean, and wheat.



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# FUTURE DIRECTIONS: 1) Expand Evaluations of Long-Term Business Case 2) Develop Predictive Tool of Short-Term Changes in Economics





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# LEVER OF CHANGE #2. MEASUREMENT

# Workshops to Identify Effective Soil Health Measurements

Organizer/Sponsor	Date	Location
Noble Foundation, Farm Foundation	Nov. 2014	Ardmore, OK
Noble Foundation, Farm Foundation	Apr. 2015	Ardmore, OK
Noble Foundation, Farm Foundation	Oct. 2015	Dallas, TX
Noble Foundation, SHI, NRCS	Feb. 2016	Ardmore, OK
Soil Health Institute – Measurement Straw Papers & Survey (Tier 1, 2, 3 Measurements Followed)	July 2016	Louisville, KY



# LIMITATIONS OF LITERATURE TO IDENTIFY EFFECTIVE MEASUREMENTS

## Data from Multiple Studies Combines Different:

- measurements,
- methods,
- labs,
- sampling intensity & methodology,
- sample handling & shipping,
- sample storage,
- sampling times in relation to management practices,
- unknown inherent soil properties,
- inconsistent and unknown management histories
- ...

# NORTH AMERICAN PROJECT TO EVALUATE SOIL HEALTH MEASUREMENTS

**GOAL: Identify Effective, Widely Applicable Measurements of Soil Health to Scale Soil Health Assessment**

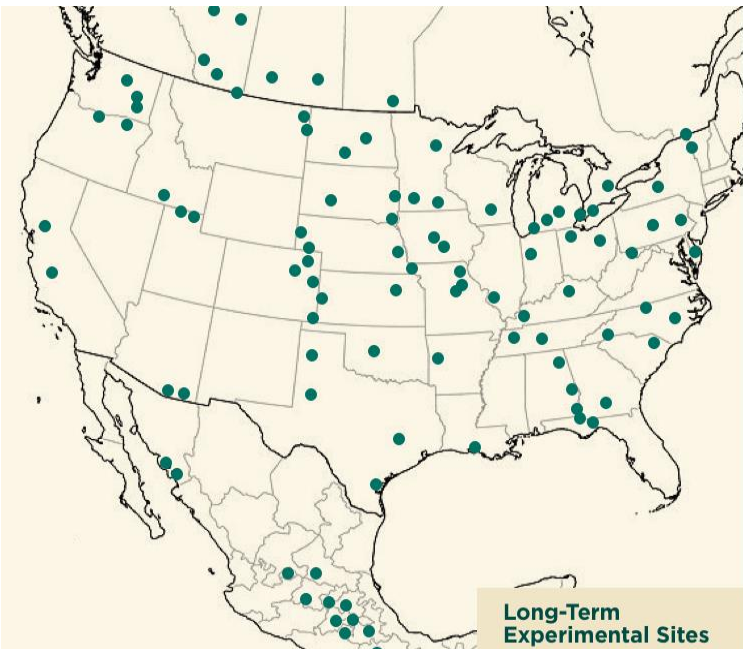


# SOIL HEALTH (AND RELATED) MEASUREMENTS EVALUATED

pH  
Electrical Conductivity  
Cation Exchange Capacity  
Total Nitrogen  
Extractable Phosphorus  
Extractable Potassium  
Percent Base Saturation  
Sec./Micro. (Ca, Mg, S, Fe, Zn, Cu, Mn)  
Organic Carbon  
Short-Term C Mineralization  
Nitrogen Mineralization  
Enzymes: B-Glucosidase, Phosphatase,  
B-Glucosaminidase, Arylsulfatase  
Soil Protein Index - Autoclave Citrate Ext.  
Extractable non-nutrient elements Al,  
As, B, Ba, Cd, Co, Cr, Mo, Ni, Pb, Si, Sr  
Soil Stability Index  
Water Stable Aggregation

Particle Size  
Bulk Density  
Available Water Holding Capacity  
Crop Yield  
Erosion Rating  
Penetration Resistance  
Infiltration Rate  
Saturated Hydraulic Conductivity  
Sodium Adsorption Ratio  
Active Carbon – Permanganate Oxidizable C  
Phospholipid Fatty Acid (PLFA)  
Ester-Linked Fatty Acid Methyl Ester (EL-FAME)  
16S rRNA Amplicon Sequencing  
Shotgun Metagenomic Sequencing  
VisNIR & MIR Reflectance  
Soil Management Assessment Framework (SMAF)  
Cornell (CASH)  
Haney

# ADVANCEMENT: Evaluated > 30 Soil Health Measurements Across North America



**Evaluating Soil Health at Scale**  
ANNOUNCING RECOMMENDED MEASUREMENTS FOR NORTH AMERICA



**30+**  
Soil Health Measurements Evaluated

**124**  
Long-term Research Sites

**688**  
Production System X Management Practice Combinations

**29**  
Peer-reviewed Publications

**7**  
Laboratory Standard Operating Procedures

MAP=6-70 in/yr; MAT=37-77 F; Consistent Sampling, Shipping, Lab Protocols

**\$6.5M, 3-yr.**  
FFAR, Noble Fdn.,  
General Mills,  
Walton Family Fdn.



# ADVANCEMENT: Recommended Essential Suite of Soil Health Measurements for North America and Beyond

1. Soil Organic Carbon Concentration
2. Carbon Mineralization Potential
3. Aggregate Stability
4. *Predicted Available Water Holding Capacity*

(Bagnall et al. 2022. Soil Sci. Soc. Am. J. <https://doi.org/10.1002/saj2.20395>)



# ADVANCEMENT: USDA-NRCS ADOPTION



United States Department of Agriculture

CEMA 216 - Page 1

## Conservation Evaluation and Monitoring Activity

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### Soil Health Testing

#### CEMA 216

#### **DEFINITION**

Quantitative testing for biological, chemical, and physical characteristics of soil and constraints using approved laboratory methods.

#### **APPLICABLE LAND USES**

All Land Uses.

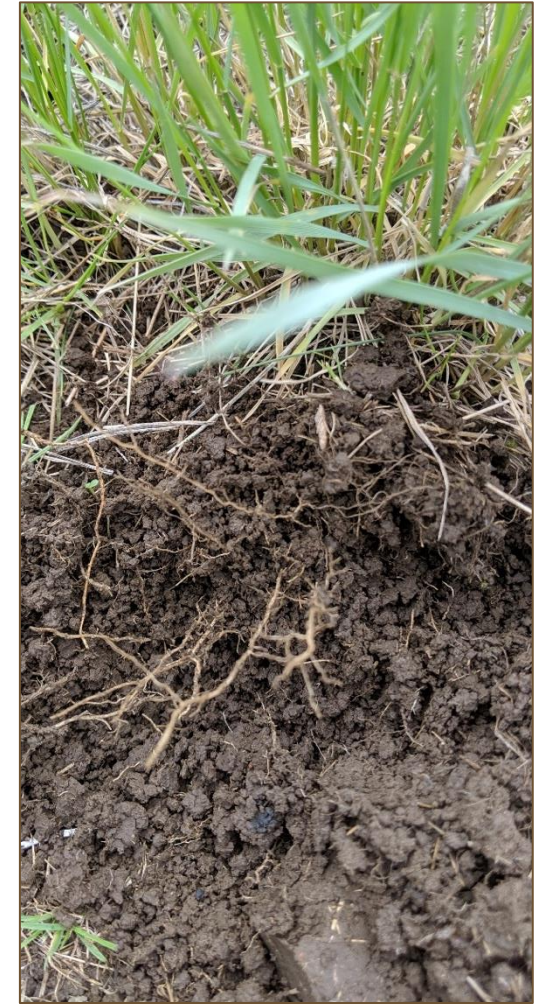
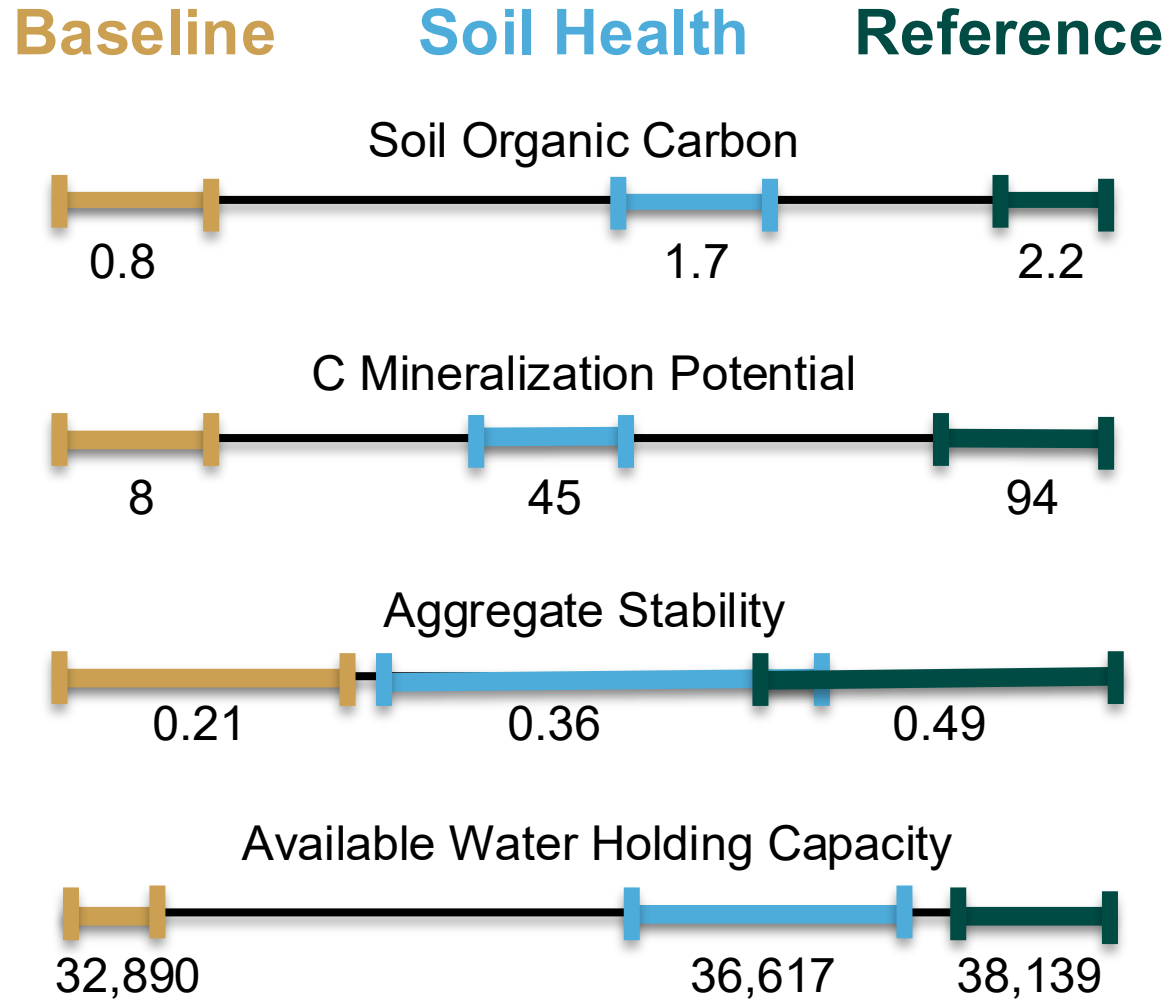
#### **REQUIREMENTS**

##### **Qualified Individual Requirements**

The Natural Resources Conservation Service (NRCS) strongly encourages Conservation Evaluation and Monitoring Activity (CEMA) participants to know the Qualified Individual (QI) requirements to ensure the person they employ to provide the CEMA is fully qualified to meet the objectives of the activity.

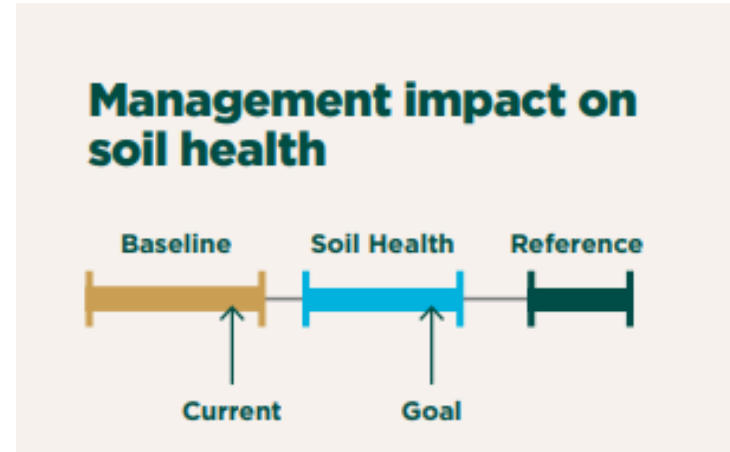
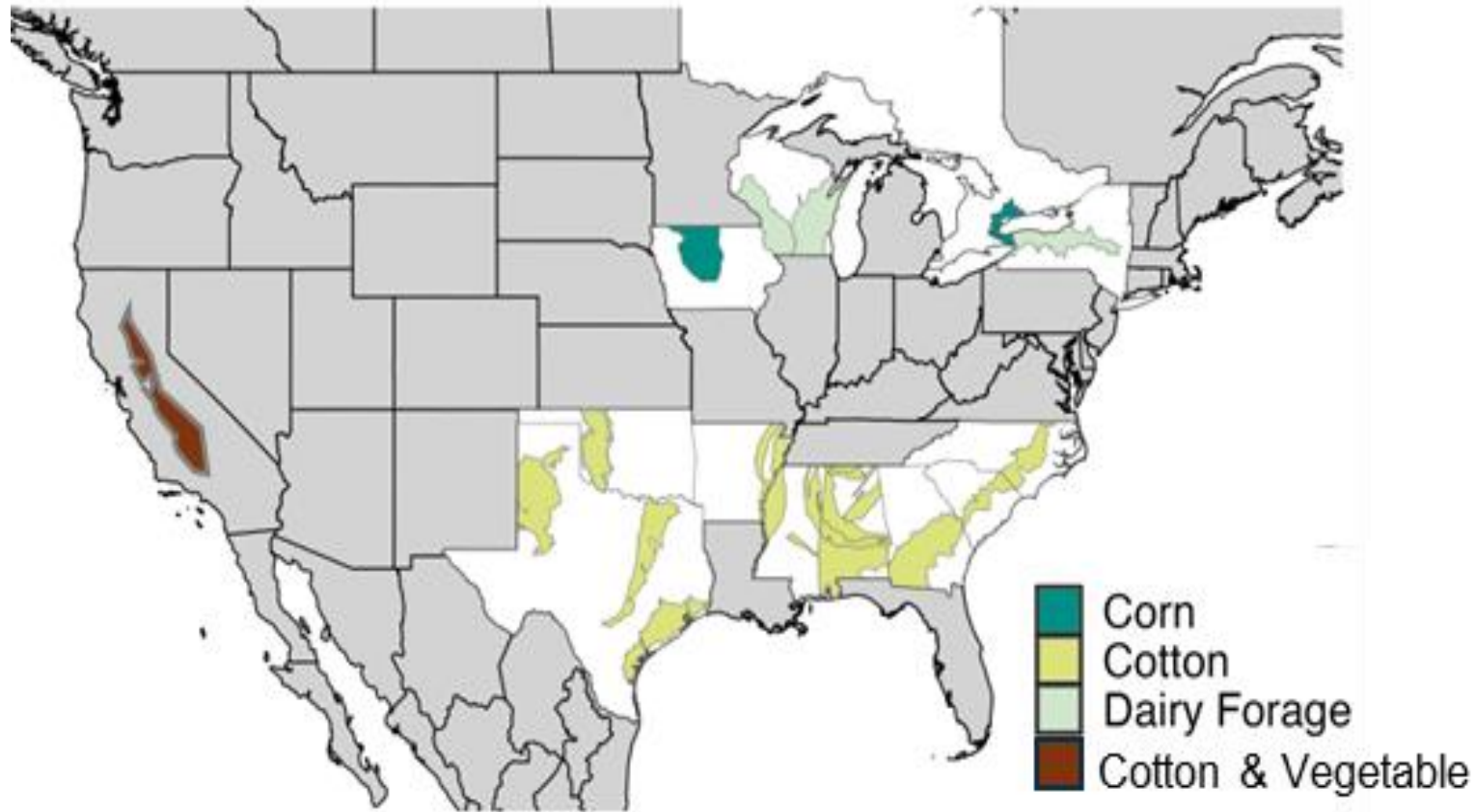
# ADVANCEMENT: Local Soil Health Interpretations with Benchmarks

## Management Systems





# ADVANCEMENT & FUTURE DIRECTION: Establishing Soil Health Benchmarks



**19M**  
Acres with established benchmarks

**508**  
Farmer reports

## Funders:

Ralph Lauren Foundation, Walmart Foundation, Dairy Mgmt. Inc., FFAR, VF Foundation, Levi's, Wells Fargo, Cotton Inc.

# ADVANCEMENT & FUTURE DIRECTION: Soil Health Reports for Farmers, Conservationists, & Consultants

## 2025 Soil Health Report

Farm/Farmer Name



### YOUR REGION

Your results were compared to soil health indicator values for similar soils under different management systems throughout the Georgia Southern Coastal Plain (shaded region below).



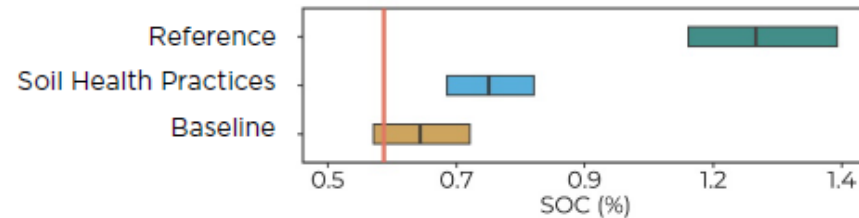
- 59 farmers participated
- 129 fields sampled
- 149 soils sampled

### YOUR SOIL

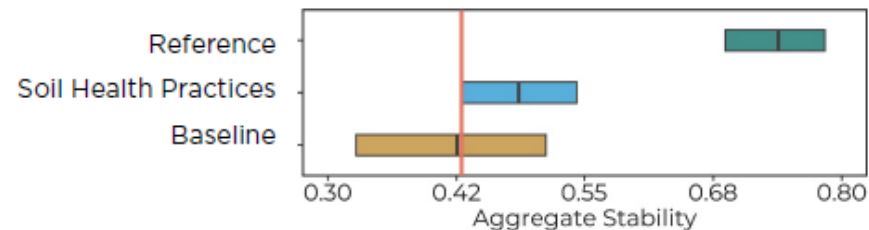
Soil texture: Loamy sand  
Crop at sampling: Cotton  
Soil Survey map unit: Tifton loamy sand, 2 to 5 percent slopes



**Soil Organic Carbon (SOC)** measures the carbon contained in soil. Increasing SOC promotes soil structure, microbial activity, available water, and available nutrients. Soil organic matter can be estimated by multiplying SOC by 1.72.



**Aggregate Stability** measures soil structure and resistance to disturbance. Soils with greater aggregate stability are more resistant to erosion and have improved aeration and water filtration and storage.





**SOIL HEALTH**

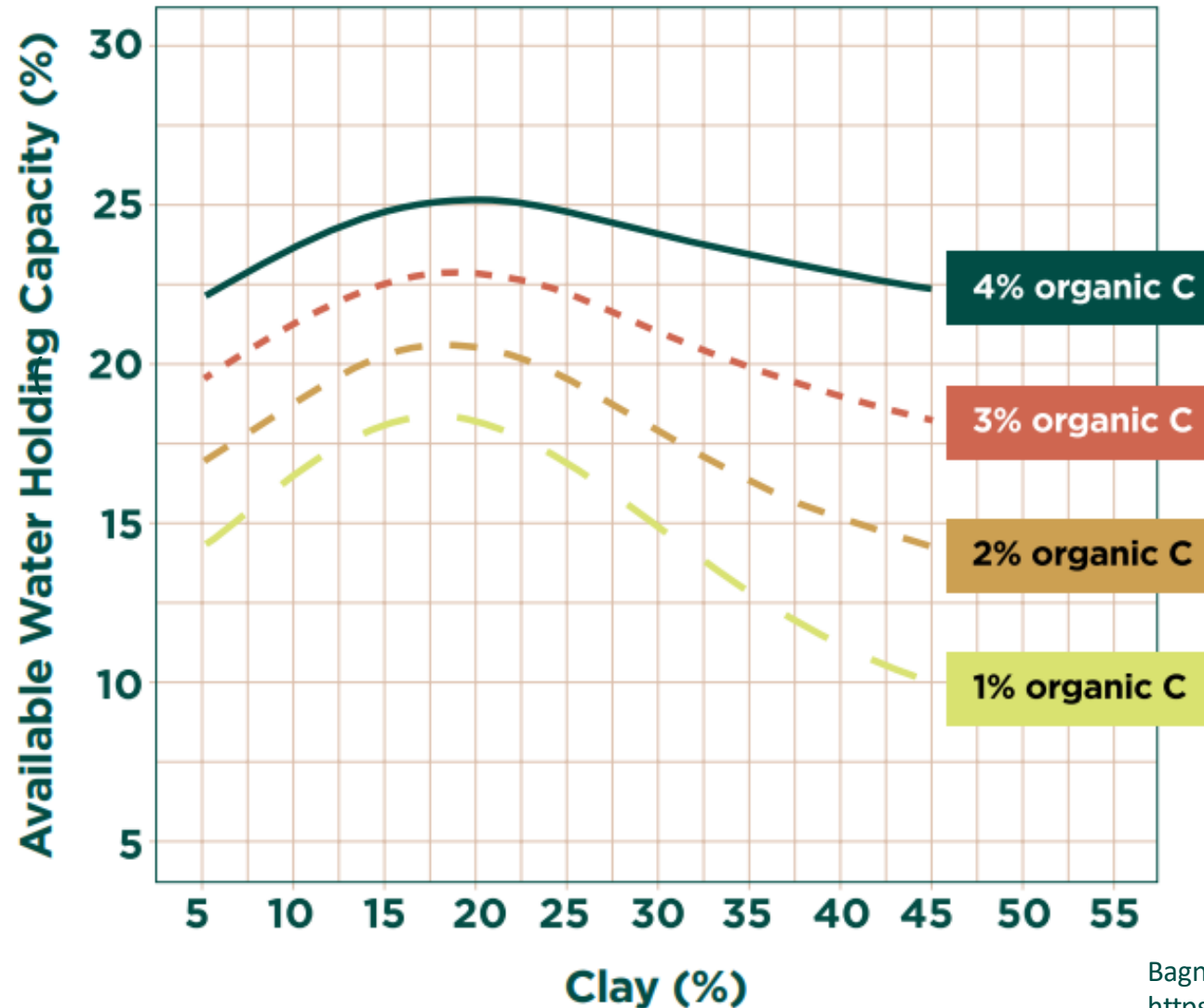
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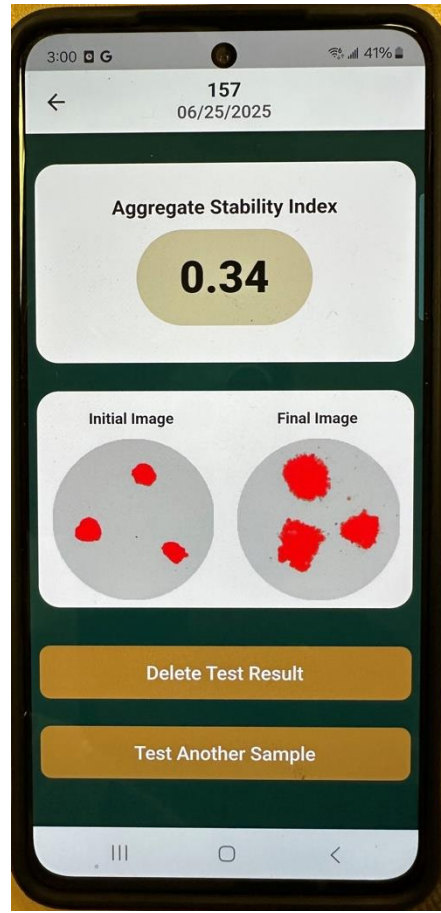
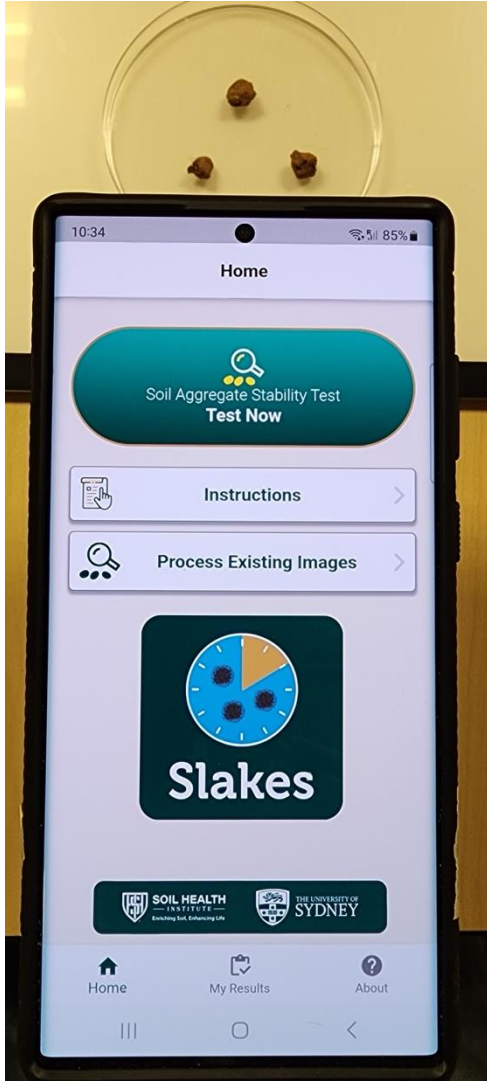
# LEVER OF CHANGE

## #3. RESEARCH & DEVELOPMENT

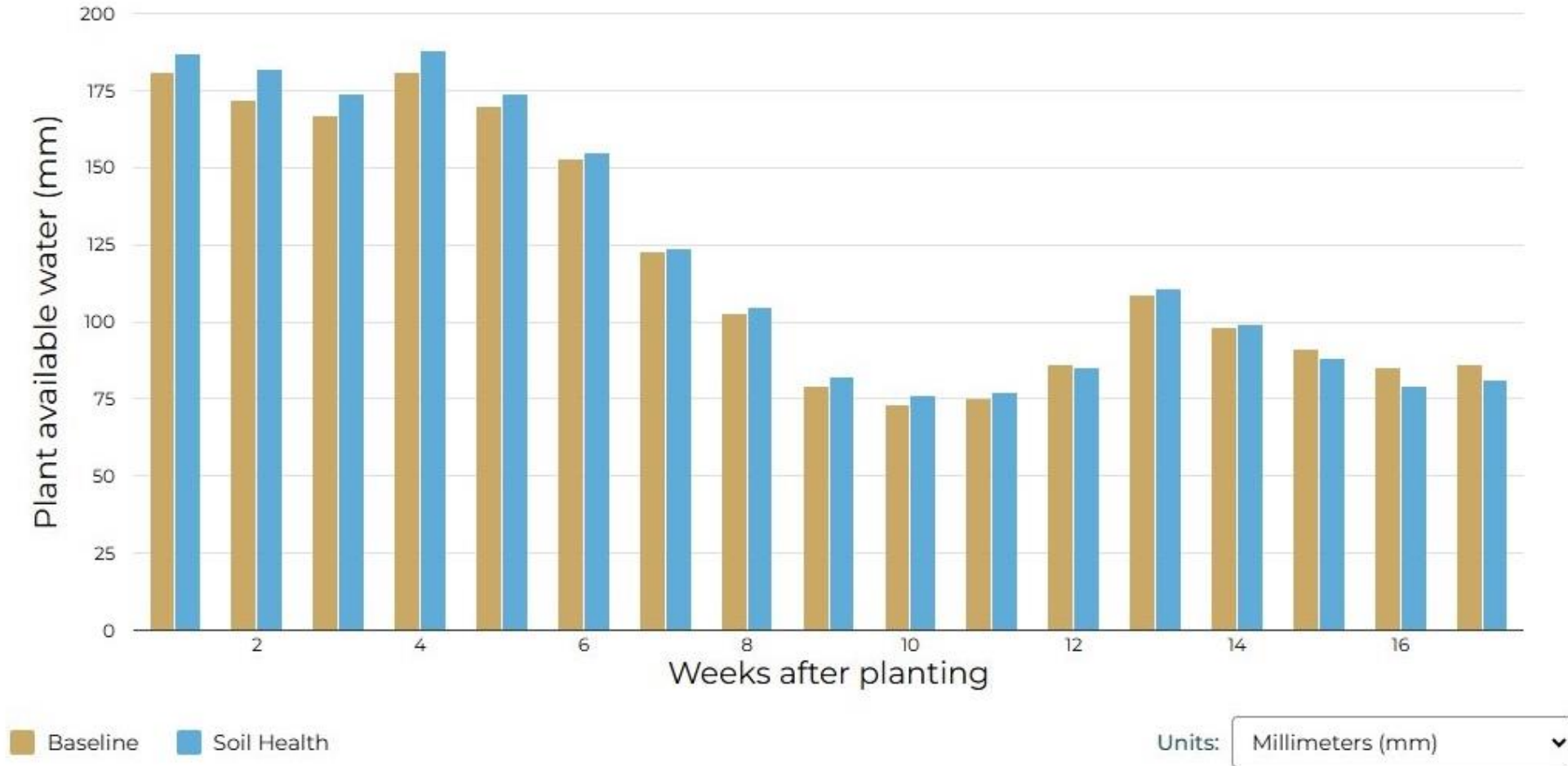
# ADVANCEMENT: Equations to Predict Increases in Available Water Holding Capacity from Increasing Soil Organic Carbon



# ADVANCEMENT: Slakes App for Measuring Aggregate Stability



# ADVANCEMENT & FUTURE DIRECTION: Drought Resilience Calculator





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# LEVER OF CHANGE #4. EDUCATION

# ADVANCEMENT: Established Education Programs for Farmers

## Approach:

- Continuous Engagement
- Local Hub & Spoke Farmer-to-Farmer Networks
- Local Farmer Mentors & Technical Specialists
- In-person Field Days & Workshops
- Webinars, Videos, Fact Sheets
- Integrate Economics, Measurements, Benchmarks, Decision Support Tools



# ADVANCEMENT: Implemented Education Programs for Farmers

8

Soil Health Educators

10

Local Technical Specialists

14

Local Farmer Mentors

38

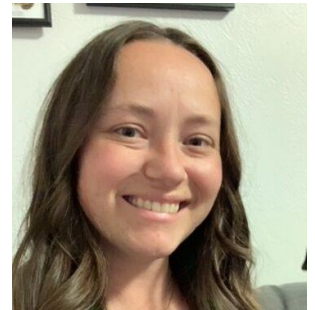
States and Provinces

100+

Education Sessions

25K+

Stakeholders Reached



# FUTURE DIRECTION: Expand Farmer Education Programs & Partnerships

- In-Person, Local Farmer-to-Farmer Networks
- Educational Webinars
- Farmer-to-Farmer Videos
- Virtual Field Days
- Train the Trainer Program & Certification
- Closed Captioning for the above  
(multiple languages)





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**FUTURE DIRECTION:**

**INTEGRATE ALL LEVERS OF CHANGE  
INTO A PRODUCER PORTAL**

# FUTURE DIRECTION: Integrate All Levers of Change into A Producer Portal: A Place-Based, Science Translation & Delivery Tool



## Google Earth Type Interface with Locally Relevant Resources:

- Business Case
- Soil Health Benchmarks
- Educational Materials for Measuring Soil Health
- Educational Materials for Improving Soil Health
- Local Farmer Mentors & Technical Specialists
- Field Days / Workshops
- Option for Farmers to Share their Soil Health Data with SHI

# THANK YOU!

