The Real Value of Carbon

Jerry L. Hatfield

Carbon is the Currency of the Soil

Practices that add Carbon to the Soil

Carbon sequestration for carbon markets = $

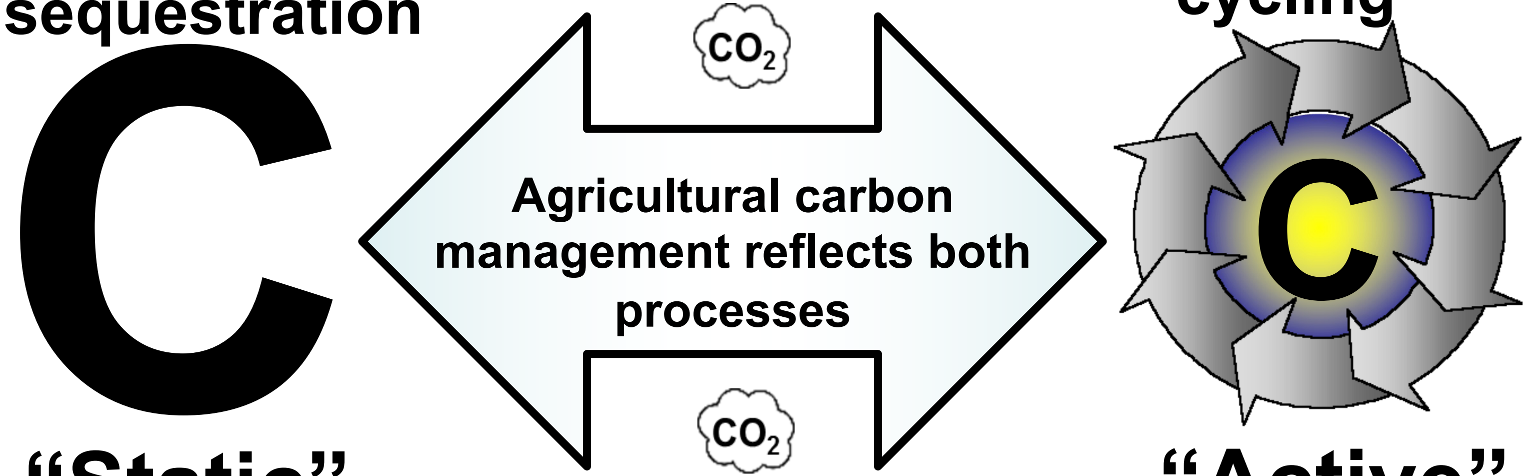
Enhanced water and nutrient availability and profit for farming = $

Our Carbon Conundrum!

Is it C "sequestration" or is it C "cycling"?

C sequestration

C cycling



"Static"

Stored energy

"Active"

Useful energy

Sequestered carbon is energy stored for use at sometime in the future.

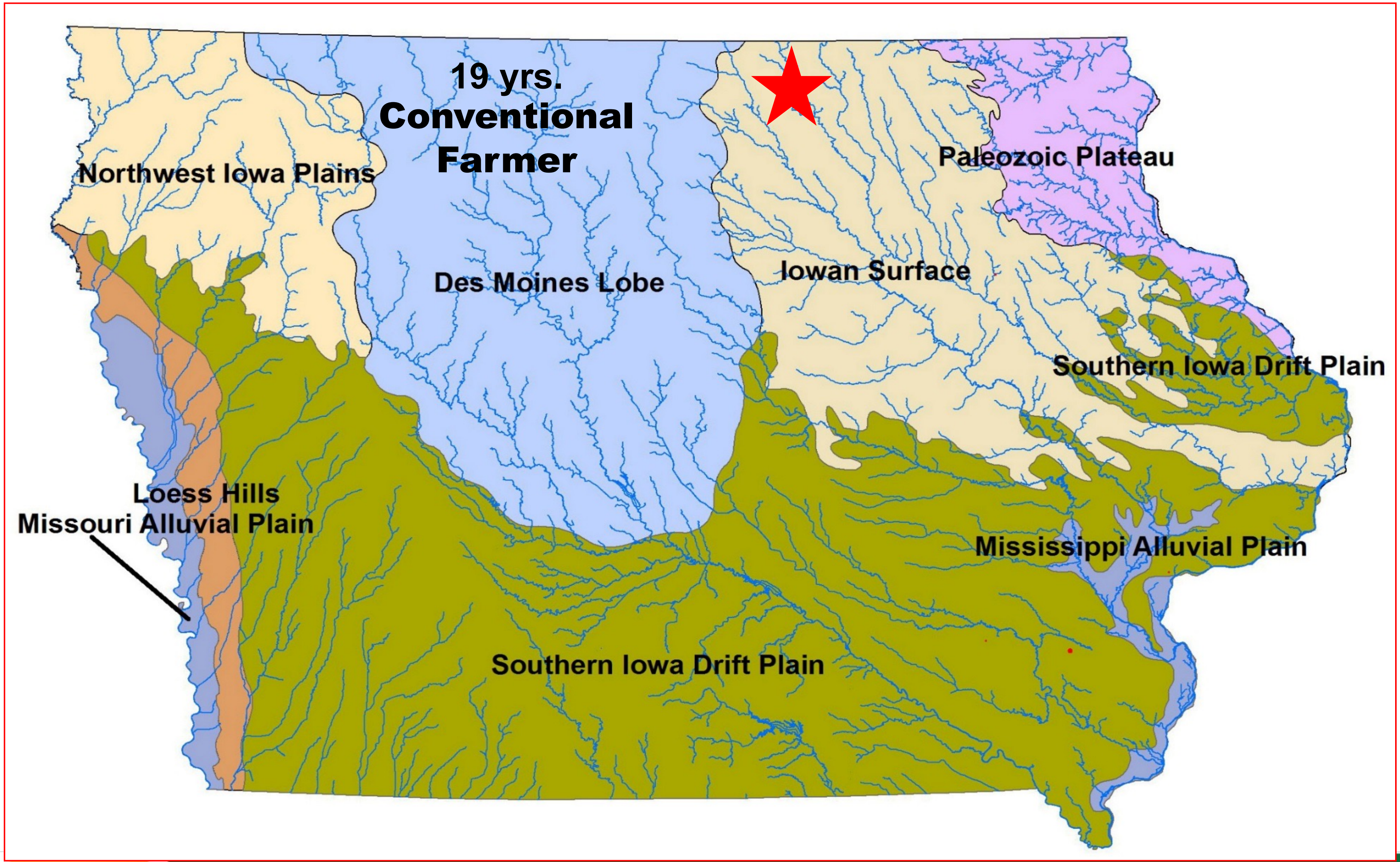
Carbon cycling is carbon in transition fueling ecosystem services.

Janzen, H.H. 2006.The soil carbon dilemma: Shall we hoard it or use it? Soil Biology and Biochemistry, Volume 389 (3):419-424.

How do we put carbon to work to increase production efficiency and profitability?

Journey of Change in the Soil

Results from Wayne Fredericks


19 yrs.
Conventional
Farmer
Northwest Iowa Plains
Des Moines Lobe
Iowan Surface
Paleozoic Plateau
Southern Iowa Drift Plain
Loess Hills
Missouri Alluvial Plain
Mississippi Alluvial Plain
Southern Iowa Drift Plain

Changes at Wayne Fredericks

1992

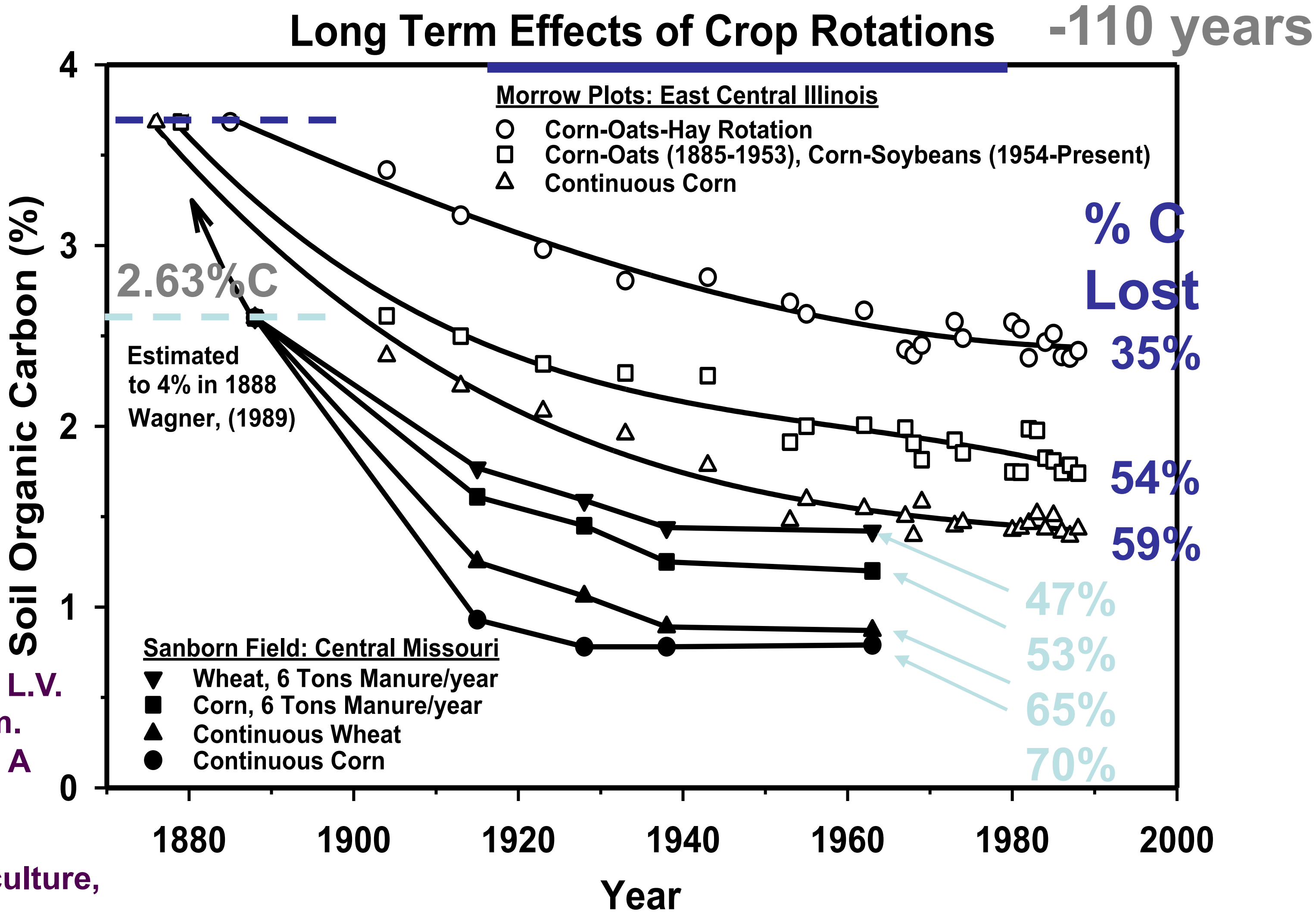
No-till soybeans in 1992

2003

Strip-till corn in 2003

2012

Cover crops beginning in 2010, over all fields in 2012



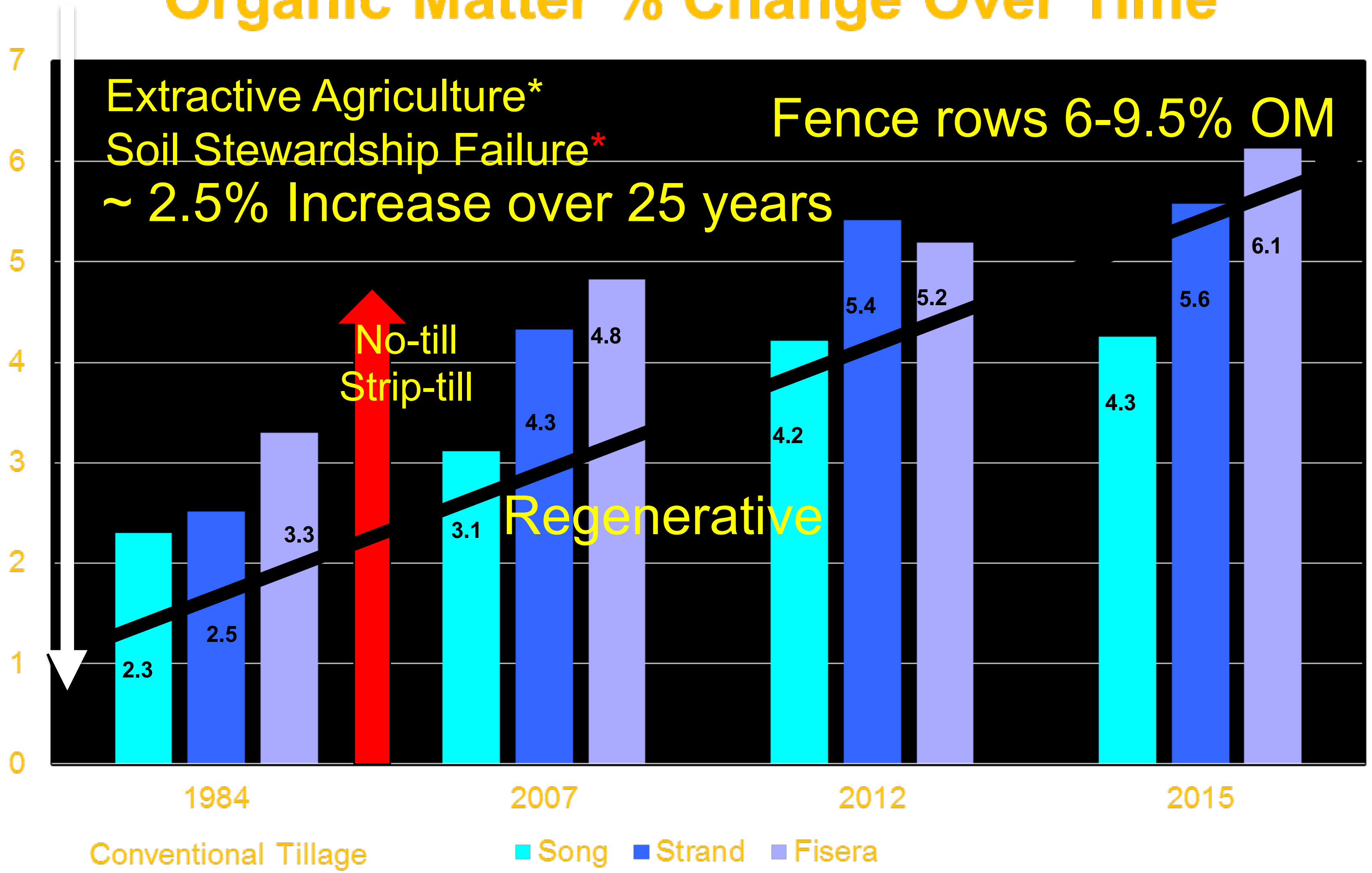
Odell, R.T., W.M. Walker, L.V. Boone, and M.G. Oldham. 1982. The Morrow Plots: A century of learning. Agricultural Experiment Station, College of Agriculture, Univ. of Illinois Bull. 775, Urbana-Champaign, IL.

Brown, J.R. 1993. Sanborn Field: A capsule of scientific agricultural history in central Missouri. Missouri Agric. Experiment Station, Columbia, MO.

Current Conventional Tillage Cropping Systems in the Midwest

- Losing carbon at the rate of 1000 lbs C/acre/year (8000 lbs water/acre/year)
- If you farm 40 years, lost 20 tons of C
- What we consider as proper management is slowly degrading our soils
- We have lost our ability to infiltrate, store, and make water available
- Created yield variation across fields because of limited soil water holding capacity

Organic Matter % Change Over Time



*Dennis Carney, Pres SWCD, IA
*John Phipps, Farm Journal

Tillage and Crop Rotation Effects on Soil Carbon in the top 0-24 inches over 12 years at ISU Farms

Al-Kaisi, 2020

Ave SOC gain=0.22 ton/acre/yr

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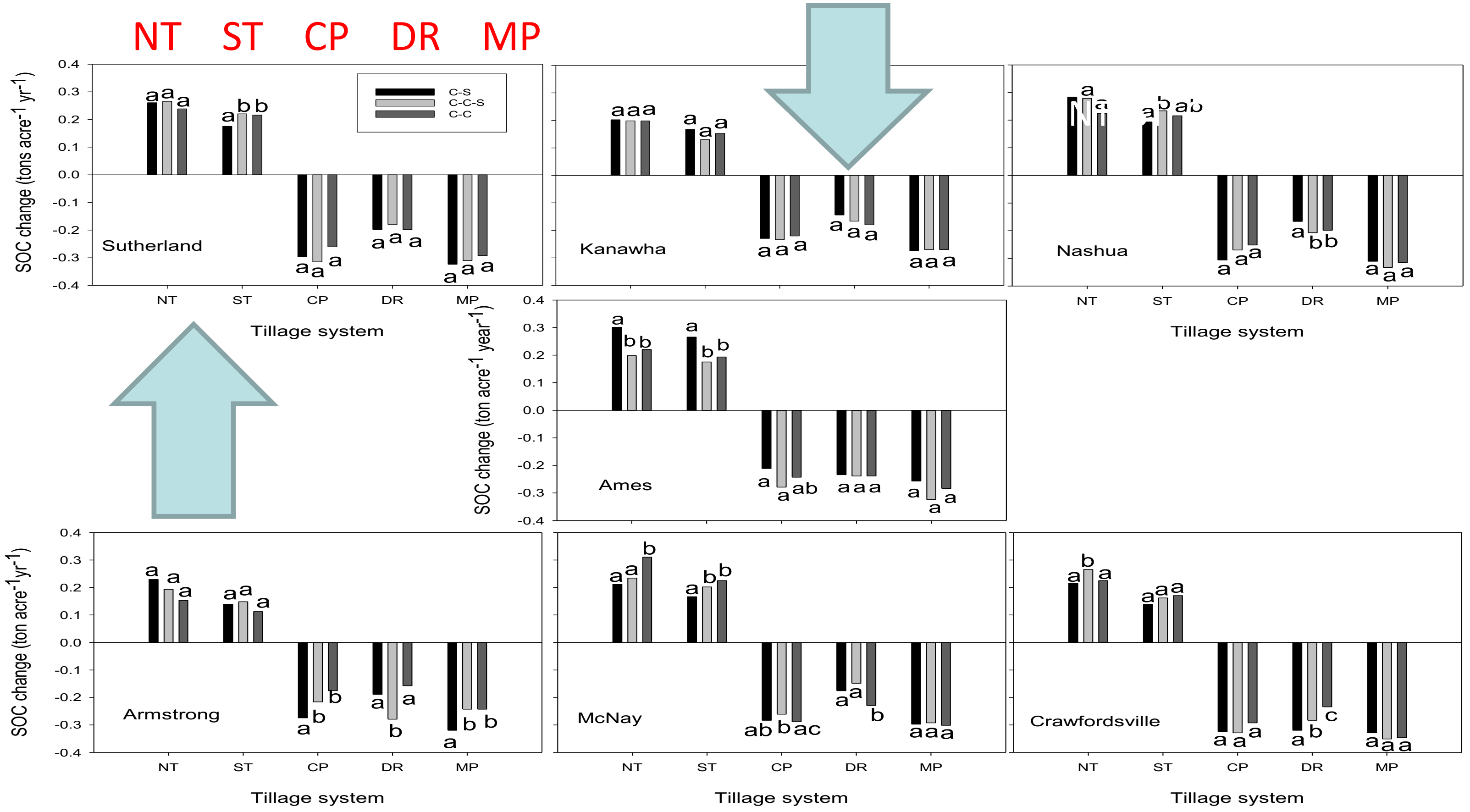
Ave SOC loss=-0.25 ton/acre/yr.

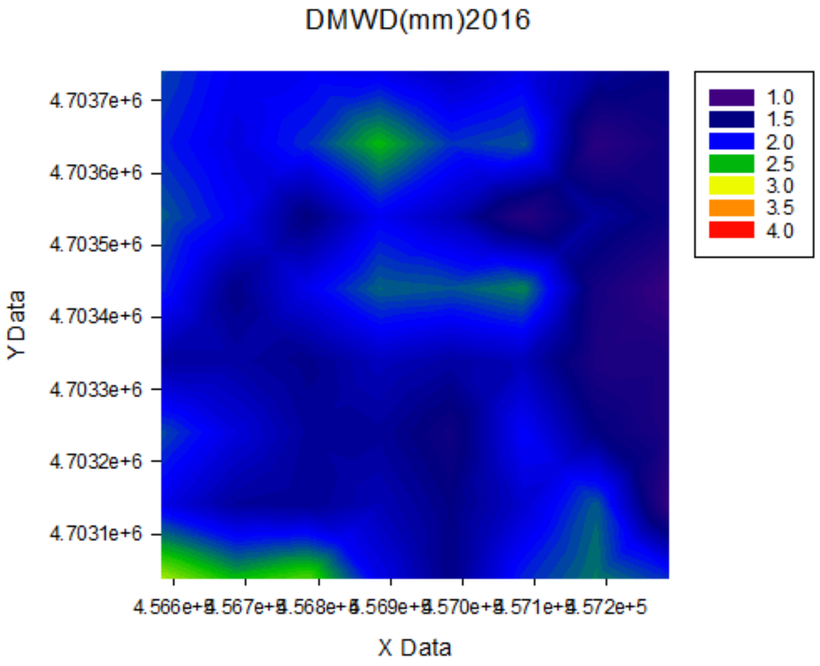


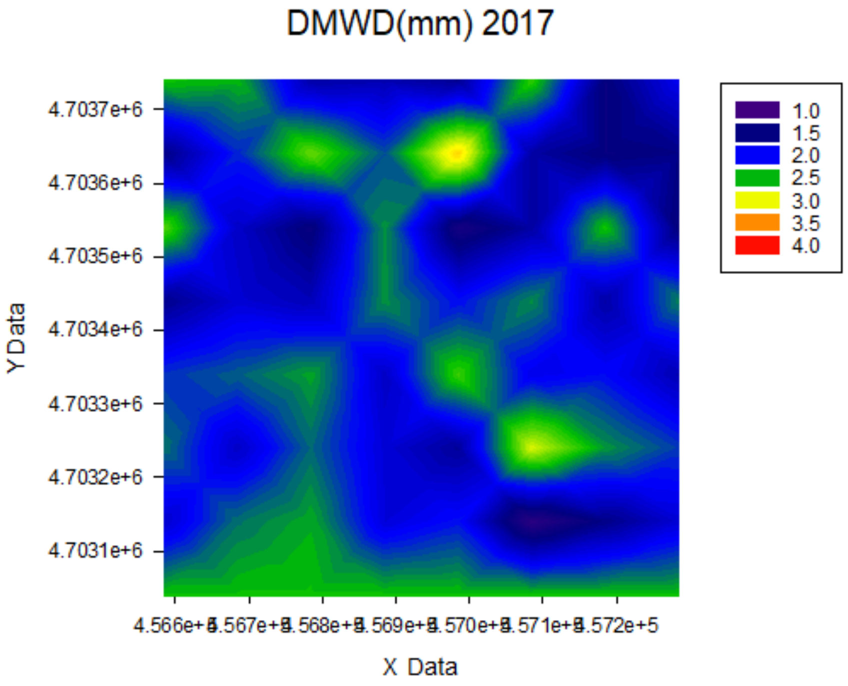
Ave SOC gain=0.19 ton/acre/yr.

Ave SOC loss=-0.27 ton/acre/yr.

Soils Change Rapidly

- Transition of a field from conventional tillage to no-till with a cover crop showed a rapid change in aggregates and microbial biomass
- The conversion occurred in the fall of 2016 and within one year, there was a doubling of the microbial biomass in the upper soil surface(0-6 in)

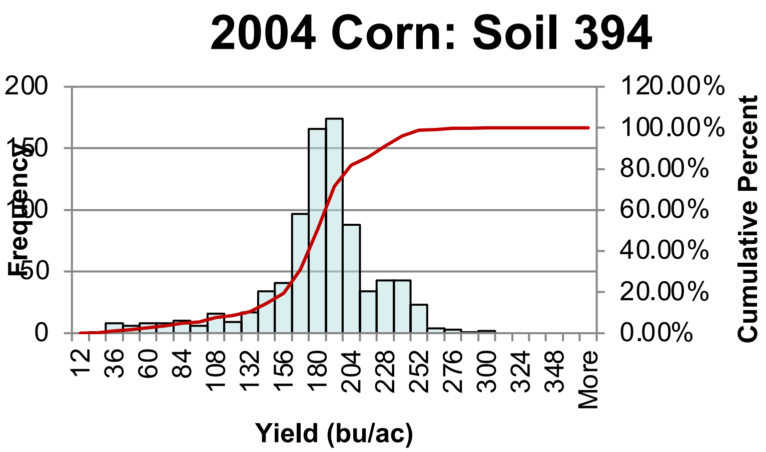


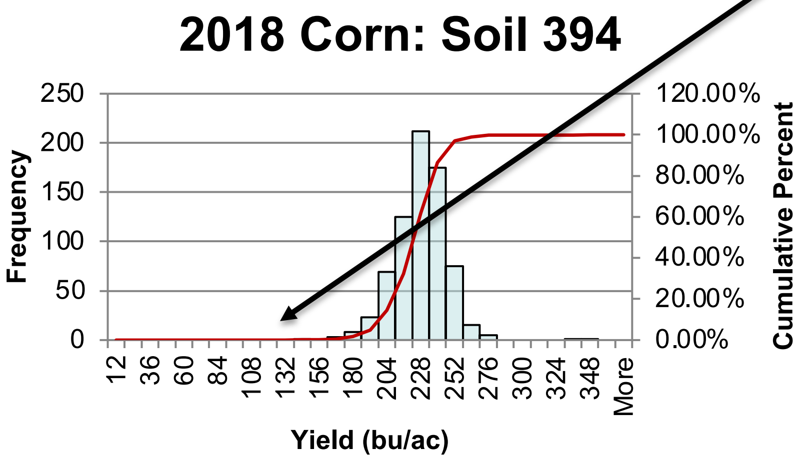


Increasing Uniformity in Fields

Soil 394 Ostrander loam

Increased Profits



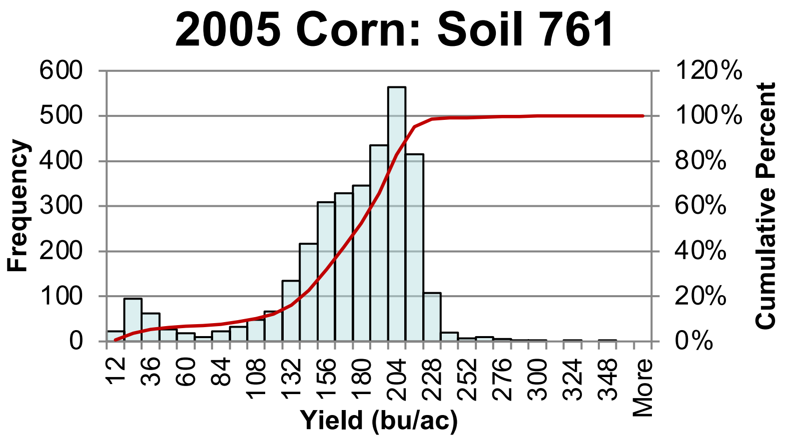


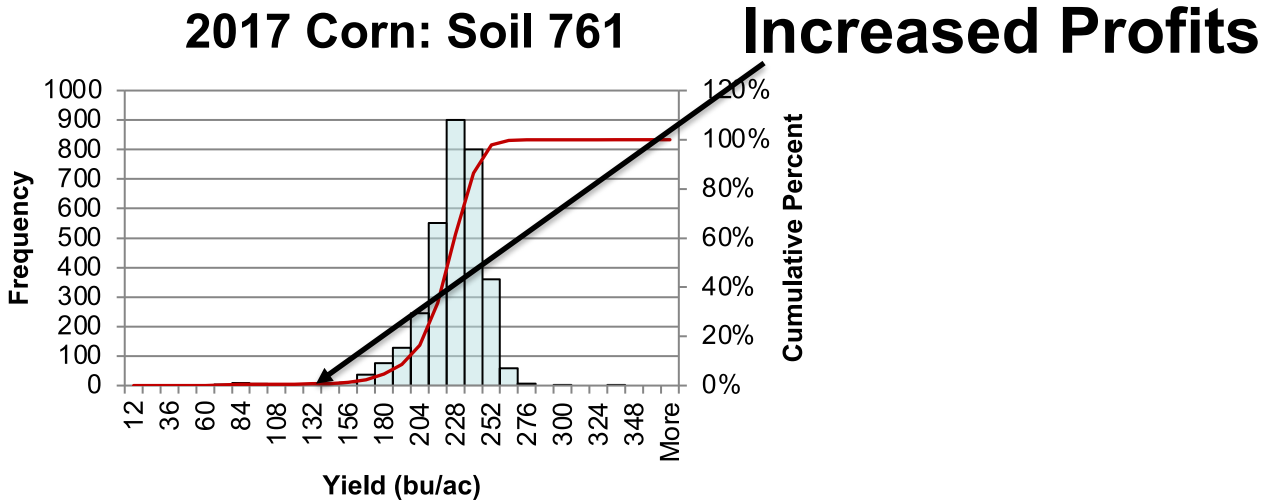
Skewness -1.01
Kurtosis 2.30

Skewness 0.19
Kurtosis 4.48

Increasing Uniformity in Fields

Soil 761 Franklin silt loam

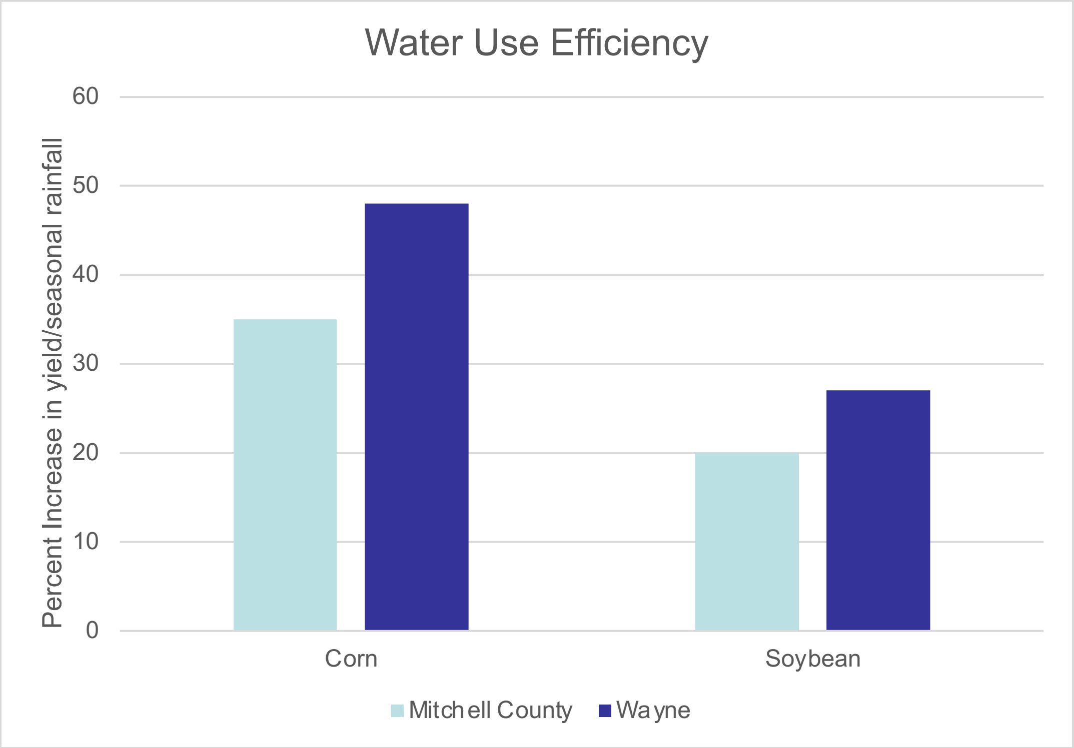




Skewness -1.99
Kurtosis 2.21

Skewness -0.86
Kurtosis 7.91

Water Use Efficiency

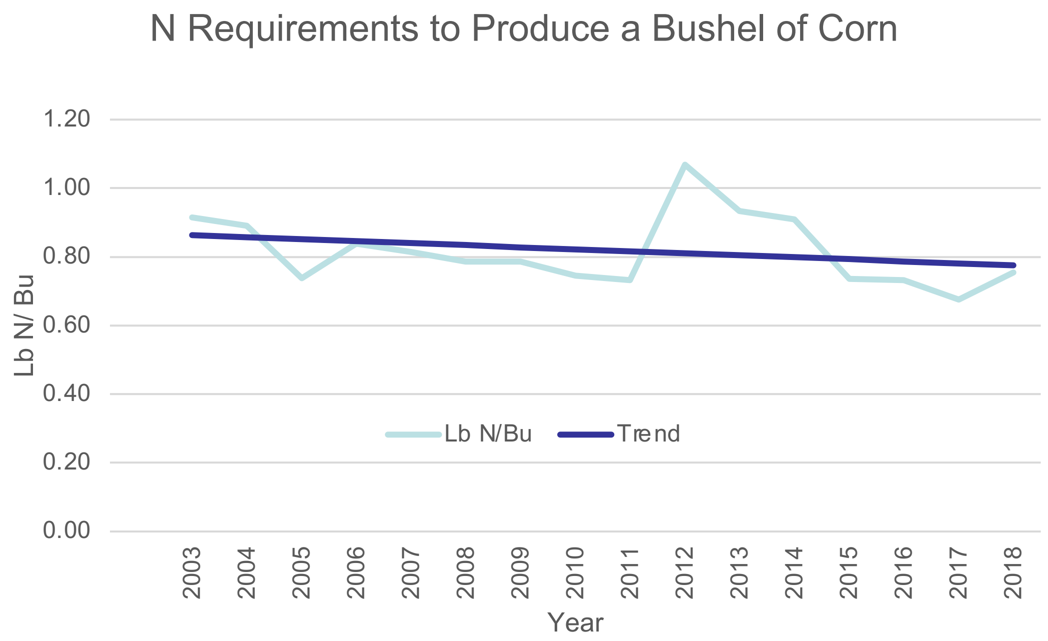


Yield stability among years, less variation among years, standard deviation in yields half of conventional tillage

Increased water use efficiency in terms of grain produced per unit of seasonal rainfall, increases in corn of nearly 50%

Broke the correlation between April-May rainfall and low yields, and July-August rainfall and high yields

Changes in N response



With enhanced soil organic carbon and more water available the N requirements have decreased

What it Means

Increased field uniformity

Improved water use efficiency

Improved nutrient use efficiency

Increased climate resilience

Take Away Messages from On-Farm Studies

Strip-till and No-Till works in northern Iowa

↓

Adding cover crops further enhances soil quality

↓

Adoption of these practices changes

Soil organic matter	Water Use Efficiency	Nitrogen Use Efficiency	Climate Resilience	Water Quality

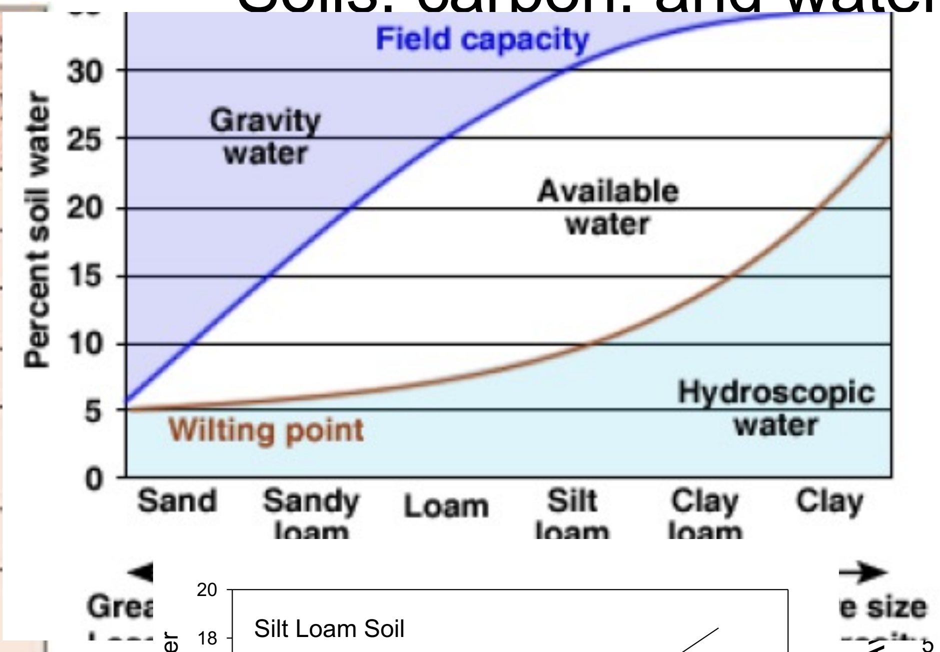
↓

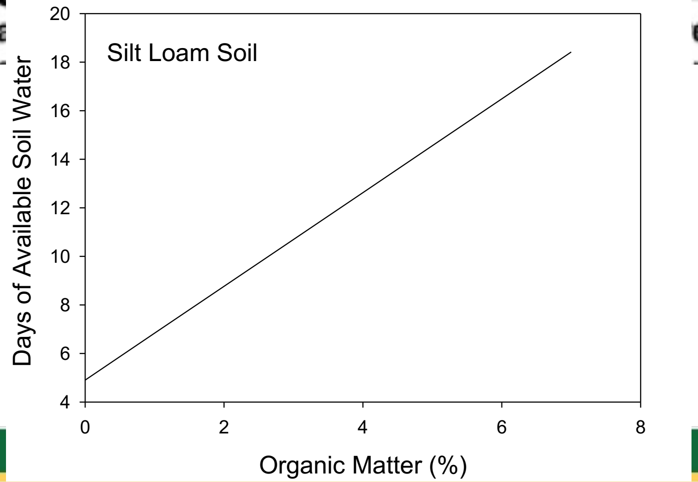
Increases **profitability**

What is the Value of Carbon?

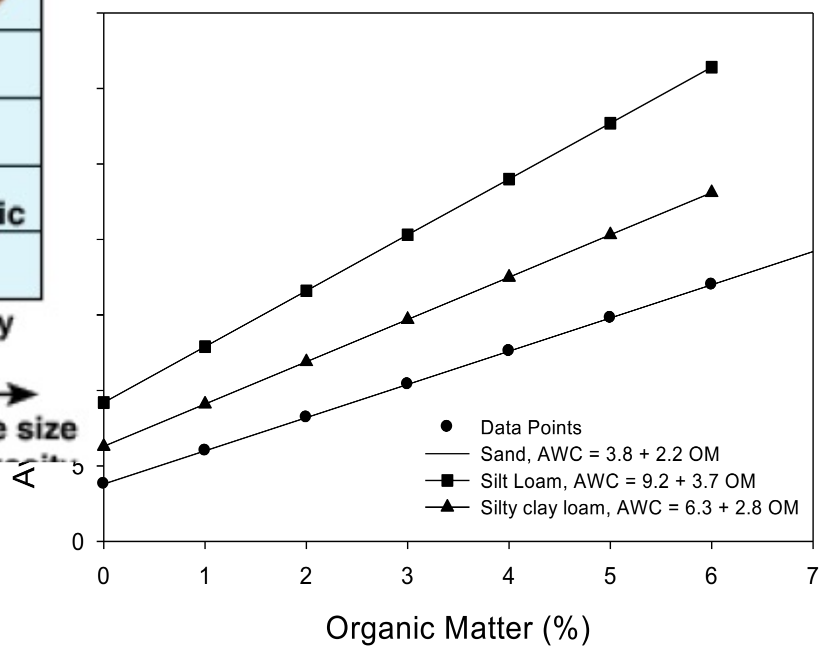
Soils, carbon, and water

Available water capacity by soil texture	
Textural class	Available water capacity (inches/foot of depth)
Coarse sand	0.25–0.75
Fine sand	0.75–1.00
Loamy sand	1.10–1.20
Sandy loam	1.25–1.40
Fine sandy loam	1.50–2.00
Silt loam	2.00–2.50
Silty clay loam	1.80–2.00
Silty clay	1.50–1.70
Clay	1.20–1.50

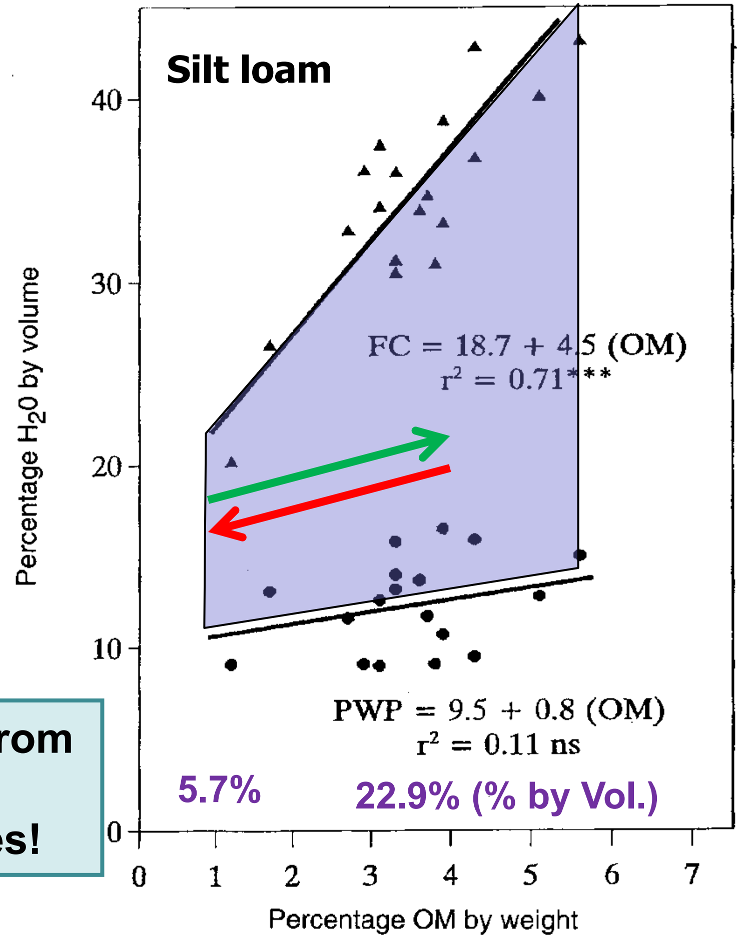




Hudson, 1994



Organic Matter Effects on Available Water Capacity



OM increase from 1% to 4.5% AWC doubles!

Data from Soil Survey Investigation Reports (surface horizons only)

Hudson, B. D. 1994. Soil organic matter and available water capacity. J. Soil Water Conserv. 49(2):189-194.

- Sands: FL (n = 20)
- Silt loams: IA, WI, MN, KS (n = 18)
- Silty clay loams: IA, WI, MN, KS (n = 21)

Sands AWC = 3.8 + 2.2 (OM)
$r^2 = 0.79$

Silt loams AWC = 9.2 + 3.7(OM)
$r^2 = 0.58$

Silty clay loams AWC = 6.3 + 2.8 (OM)
$r^2 = 0.76$

Soil Water Dynamics

- Water is one of the most limiting factors to crop productivity
  - 80% of the yield loss is due to short-term water stress because of insufficient soil water in the profile
  - Yield and profit robber is due to the inability of the soil to infiltrate and store water

Which field is profitable?

Evolution of a continuous no till systems: 4 phases

Time (years)

Initial 0-5

- Rebuild aggregates
- Low 0M
- Low crop residues
- Reestablish microbial biomass
- > N

Transition 5-10

- Increase soil density
- Start increasing crop residue
- Start increasing soil OM
- Start increasing P
- Immobilize N >= Minimum

Consolidation 10-20

- High Crop Residue
- High C
- > CEC
- > H2O
- Immobilize N < Min.
- > Nutrient Cycling

Maintenance >20

- High accum. of crop residue
- Continuous N and C flux
- Very high C
- > H2O
- High nutrient cycling
- Less N & P use

Source:
Sa, 2004

Our Carbon Conundrum!

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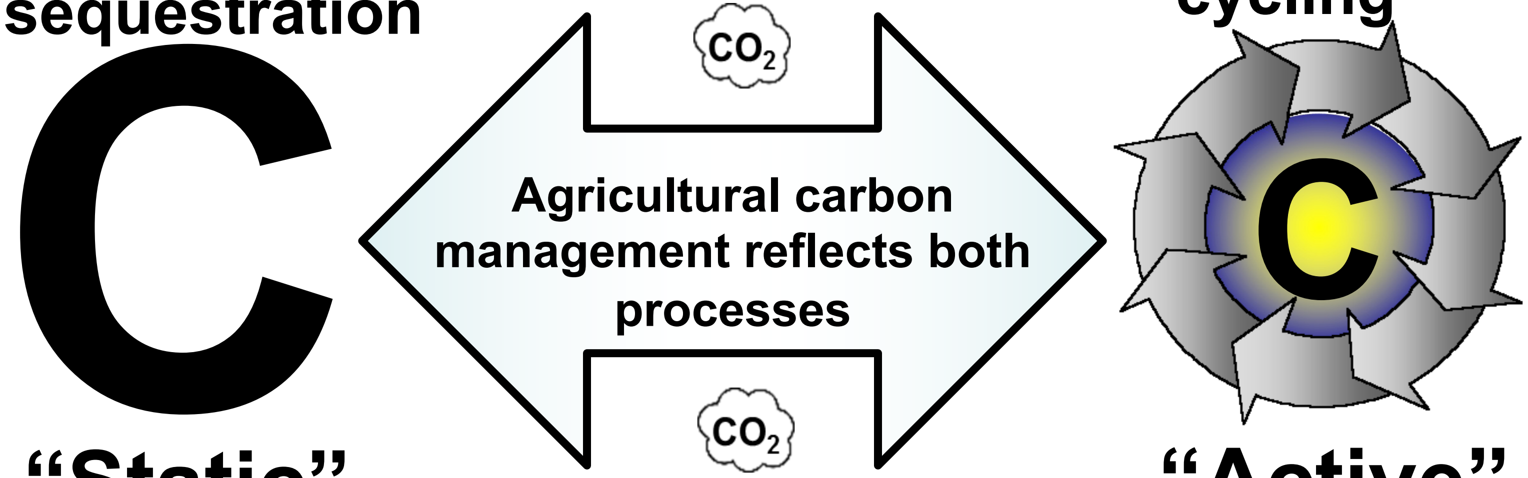
C sequestration

C cycling



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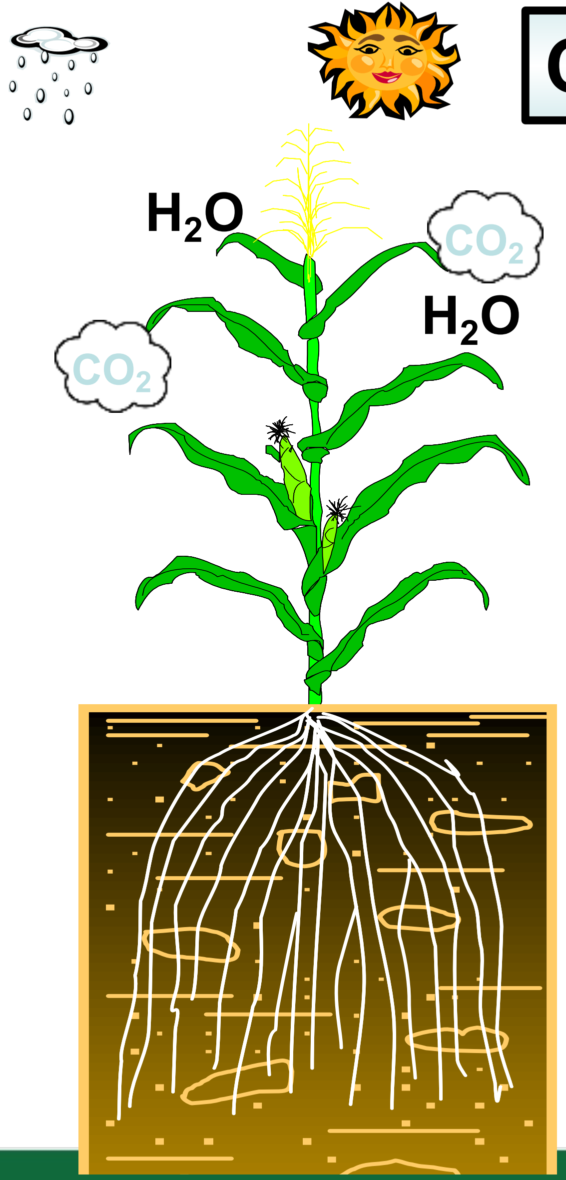
Carbon energy flow path



Sun
↓
$CO_2 + H_2O$
↓
$C_6H_{12}O_6$
↓
Plant stem
↓
Plant roots
↓
Root exudates
↓
microbes
↓
Soil fauna
↓
Nutrient cycling → Plant nutrition → Food nutrition

Carbon cycling → Ecosystem services → $CO_2 + H_2O$

Food

Feed

Fiber

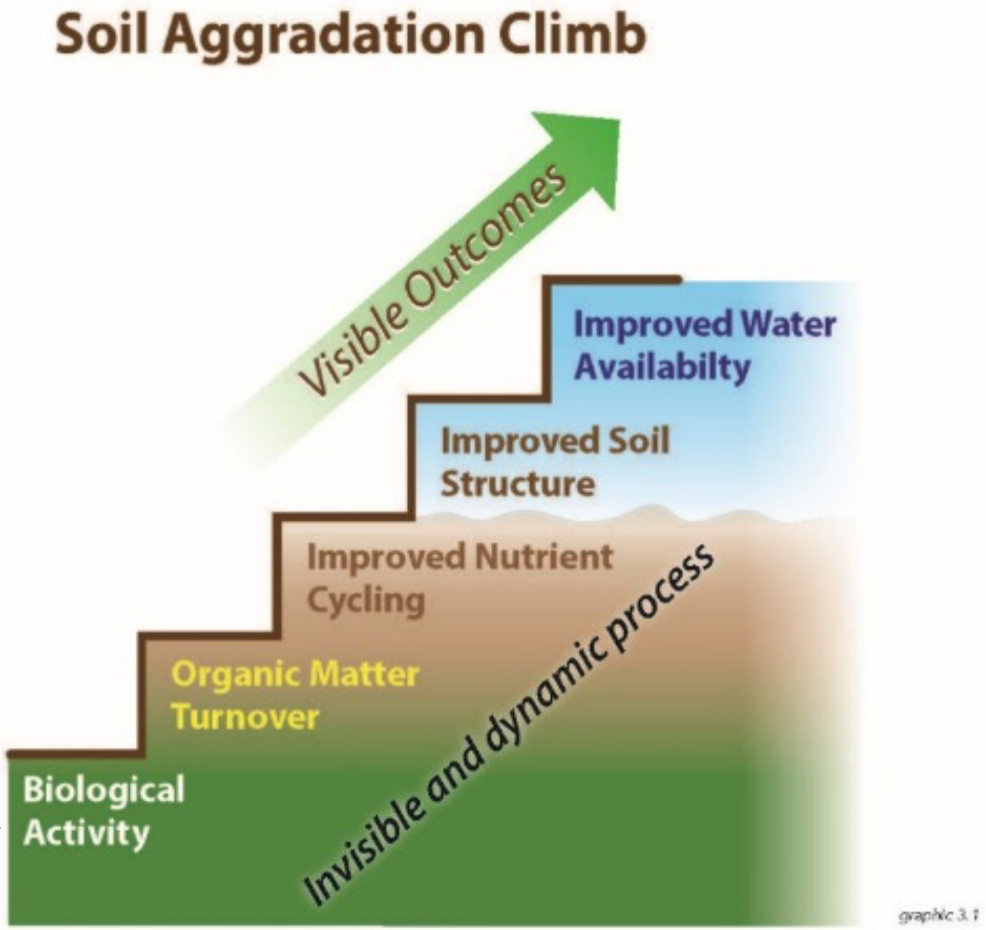
Fuel

CO_2

Indicators of Soil Change

- Microbial activity
- Organic matter changes
- Nutrient availability
- Aggregate stability
- Improved infiltration
- Water availability

Energy supports



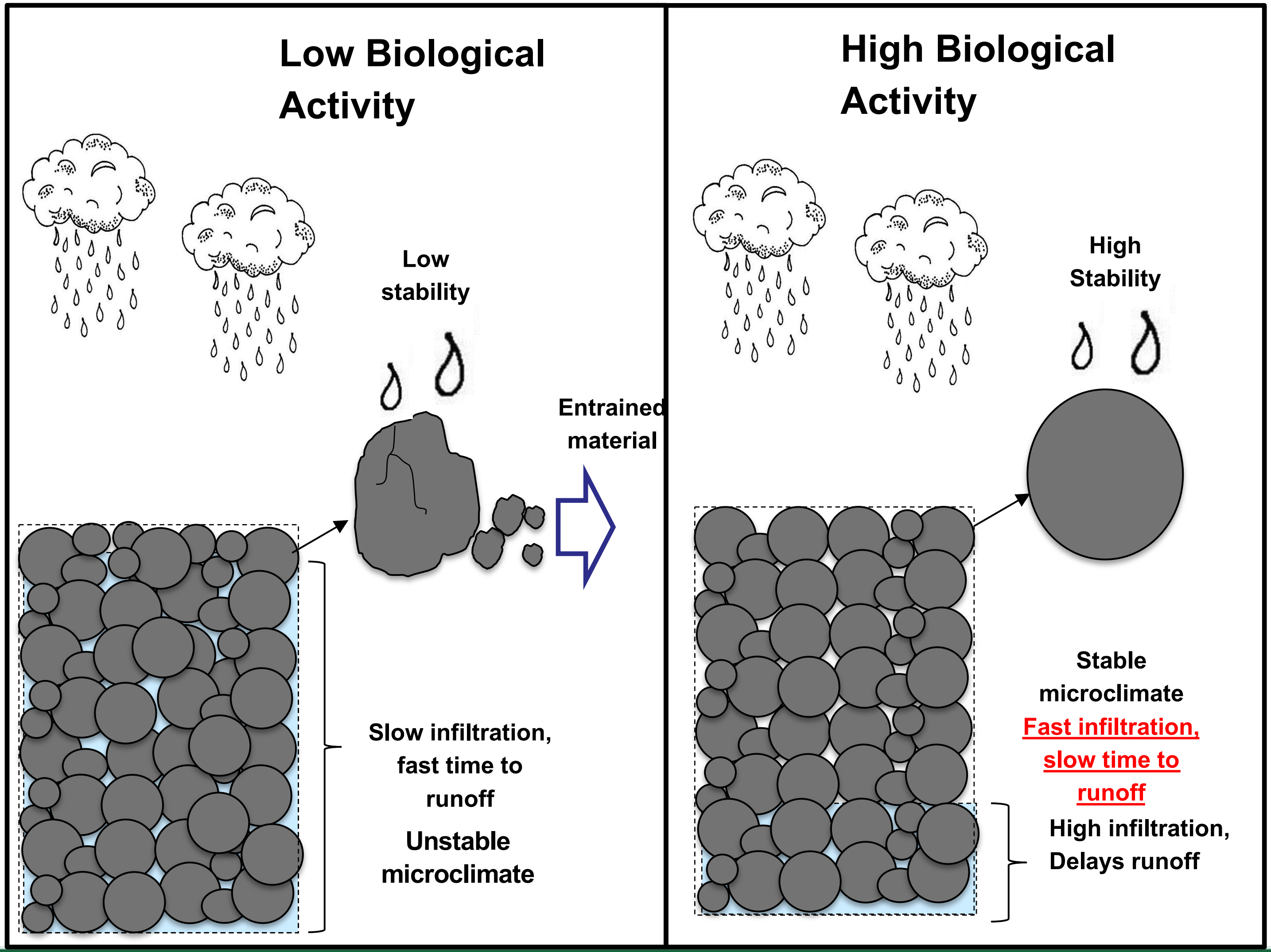
Drivers of SOC storage

Relative ranking of SOC storage drivers

1. Microorganisms/fauna
2. Texture – clay content
3. Land use and management
4. Vegetation
5. Climate
6. Topography
7. Parent material
8. Soil physico-chemistry

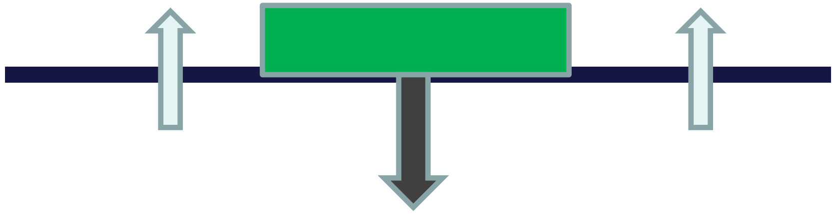
After Fig. 1 Wiesmeier, M., Urbanski, L., Hobley, et al., 2019. Soil organic carbon storage as a key function of soils - A review of drivers and indicators at various scales. Geoderma, 333: 149–162.

Assessing the Dynamics of the Upper Soil Layer Relative to Soil Management Practices

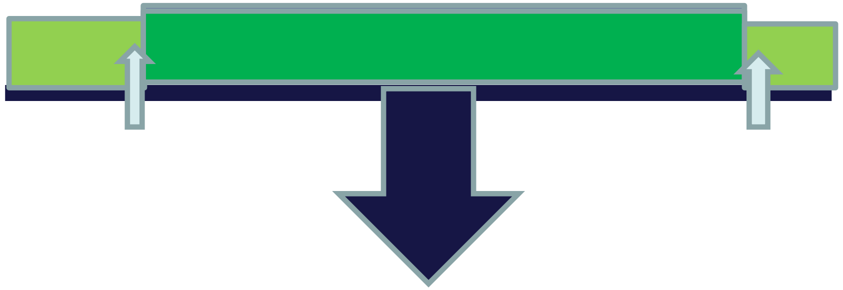


Role of cover crops in cropping systems

Cropping system without cover crops - Limited time for input and losses due to tillage, losses equal the gains or exceed



Cropping system with cover crops - Increased time for inputs into the soil volume with minimal loss due to soil disturbance

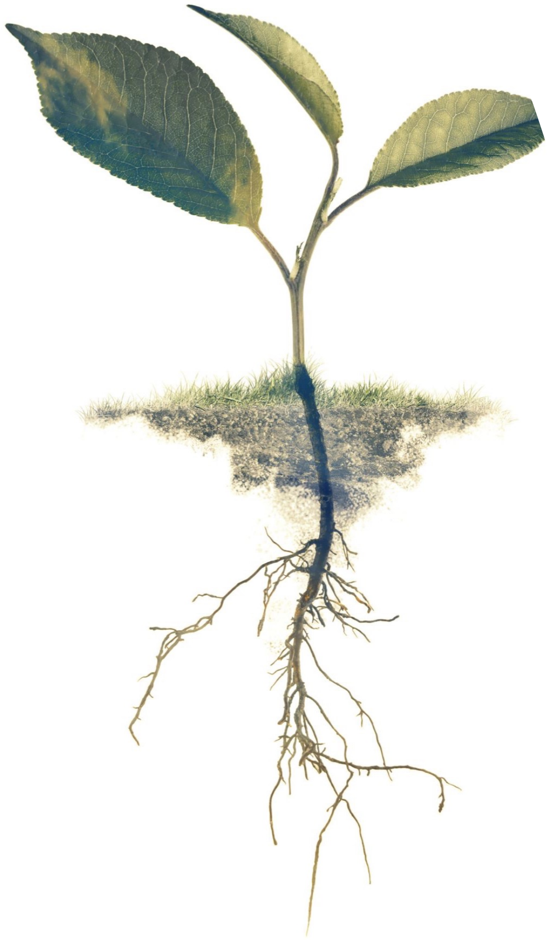


Estimate 25% of the available solar radiation in Ames, Iowa is in these shoulder periods

Challenges being faced by Producers

Midwest is Rainfed Agriculture

- Changing precipitation regime
    - Seasonality
    - Extreme amounts
    - Frequency
- Soil degradation and water holding capacity



Practices that Add Carbon to the Soil

- Maintaining Soil Armor (crop residue).
- Minimizing Soil Disturbance (less tillage).
- Maintaining Continual Living Plant Roots (continual input of energy to the soil microbial system).
- Adding Planting Diversity (diversity pays).
- Integrating Livestock (incorporation of carbon and nutrients).

Practices that add Carbon to the Soil

Carbon sequestration for carbon markets

= $

Enhanced water and nutrient availability and profit for farming

= $

Carbon Impacts on Soil

Which soil profile would you rather farm?

Value Added from Soil Carbon

Short-term

Increase microbial biomass and soil aggregates

Increase nutrient cycling

Increase infiltration

Long-term

Increase nutrient cycling and availability

Decrease field variation

Stabilize yield variation among years

Increase profitability and production efficiency of natural resources

Challenges

Evaluate fields for their variation due to soils and impact of weather variation

Understand and quantify the profit zones across a field

Evaluate how changes in the soil is affecting yield variation and the ROI from seasonal precipitation and nutrient management

Value from soil carbon affects yield stability, yield variation within fields, and the overall profitabilty

Contact

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