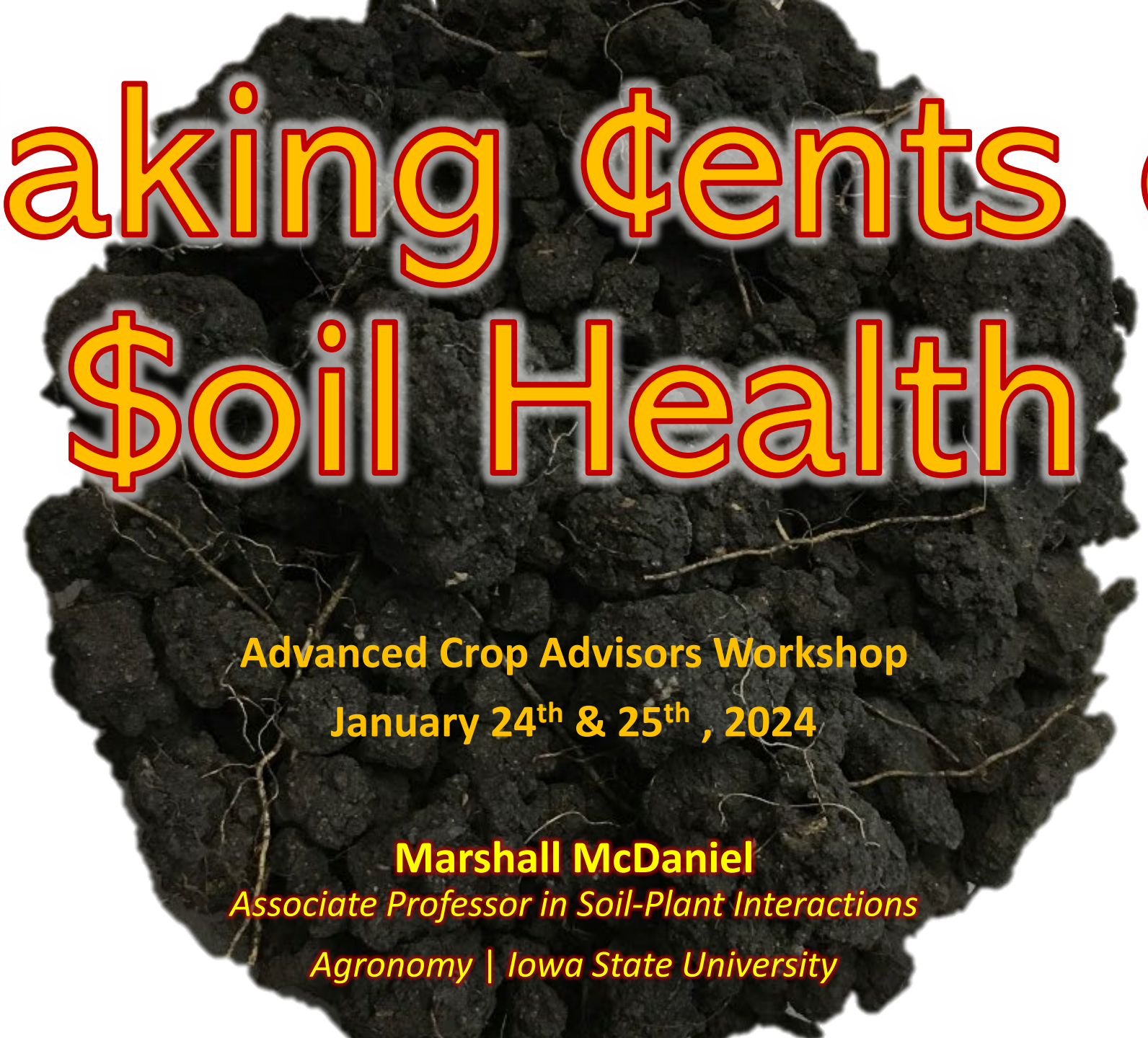
Making ¢ents of $oil Health



Advanced Crop Advisors Workshop

January 24th & 25th , 2024

Marshall McDaniel

Associate Professor in Soil-Plant Interactions

Agronomy | Iowa State University

Outline:

1) Background on Soil Health
2) Introducing the Marsden Agricultural Diversification Experiment (MADE)
3) Money in $oil Ecosystem $ervices (i.e., Soil Health)
4) Conclusions

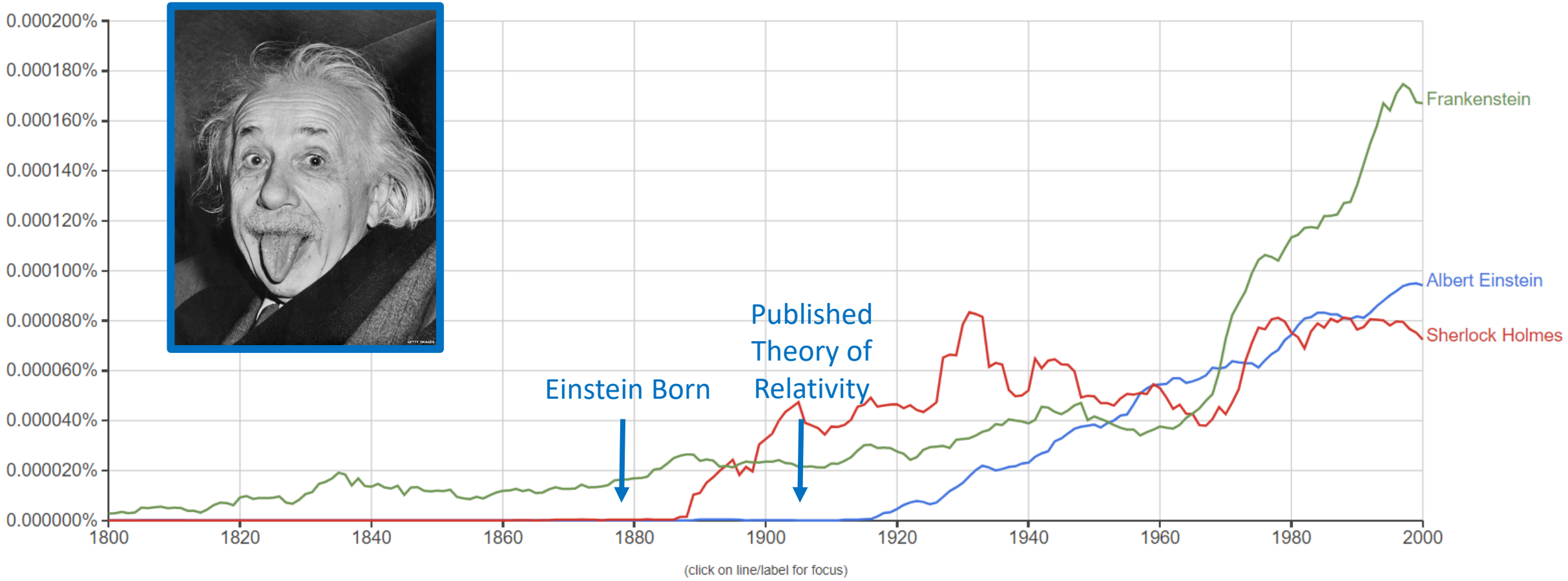
marsh@iastate.edu
@Soil_Plant_IXNS

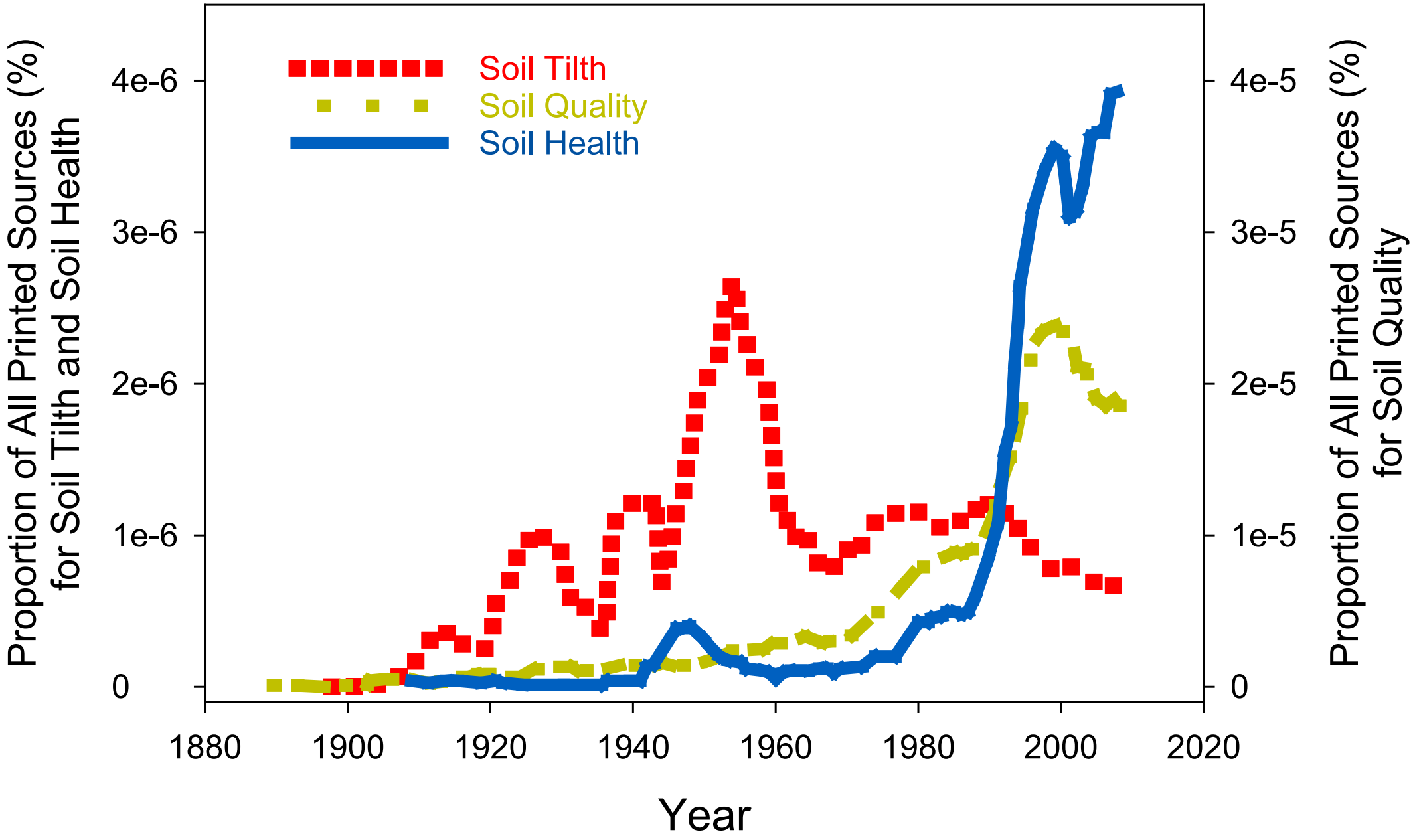

Soil Health

Google Books Ngram Viewer

Graph these comma-separated phrases: Albert Einstein,Sherlock Holmes,Frankenstein case-insensitive

between 1800 and 2000 from the corpus English with smoothing of 3 . Search lots of books

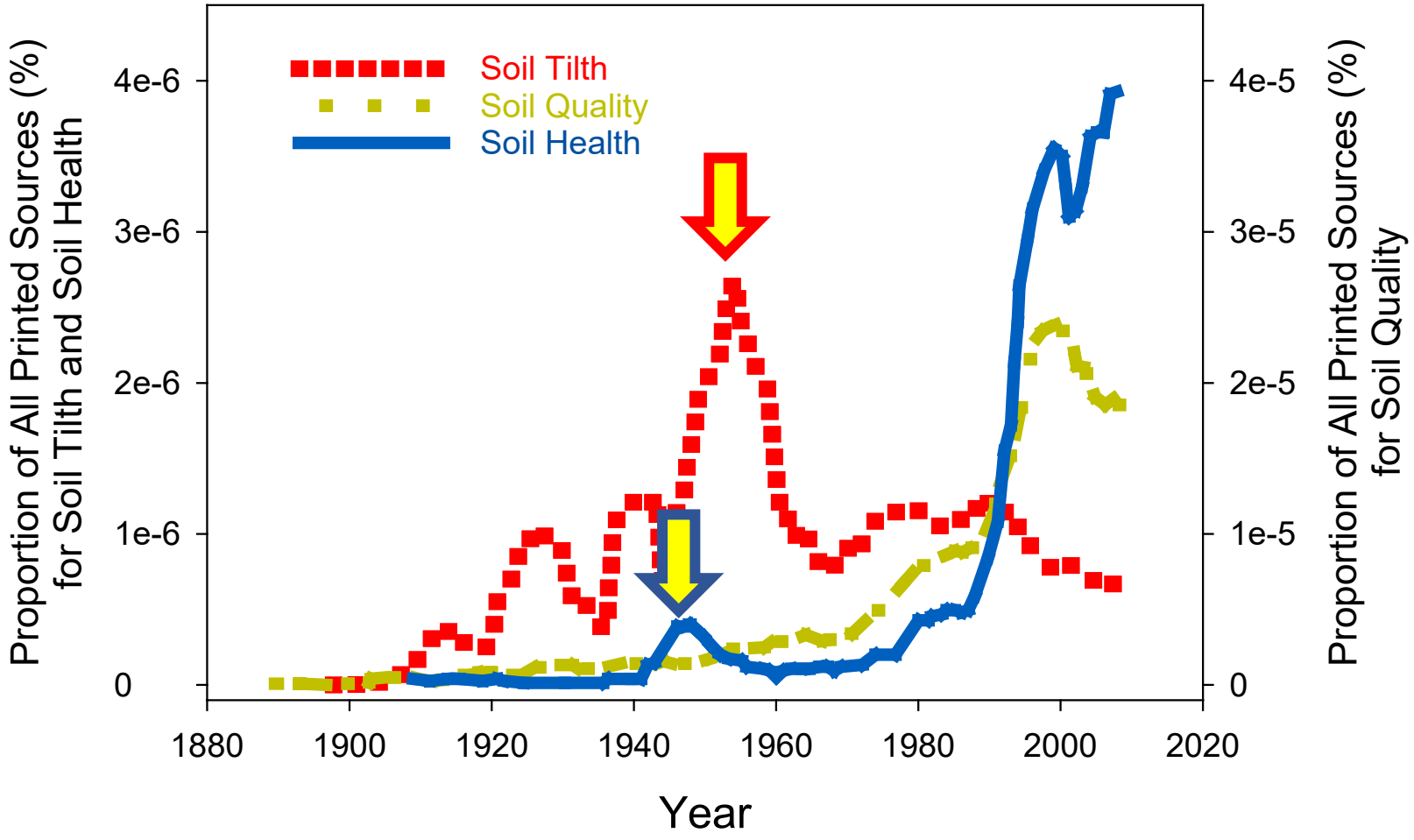



Soil Tilth
Soil Quality
Soil Health
Proportion of All Printed Sources (%) for Soil Tilth and Soil Health
Proportion of All Printed Sources (%) for Soil Quality
0
1e-6
2e-6
3e-6
4e-6
0
1e-5
2e-5
3e-5
4e-5
1880
1900
1920
1940
1960
1980
2000
2020
Year

Google's Ngram of

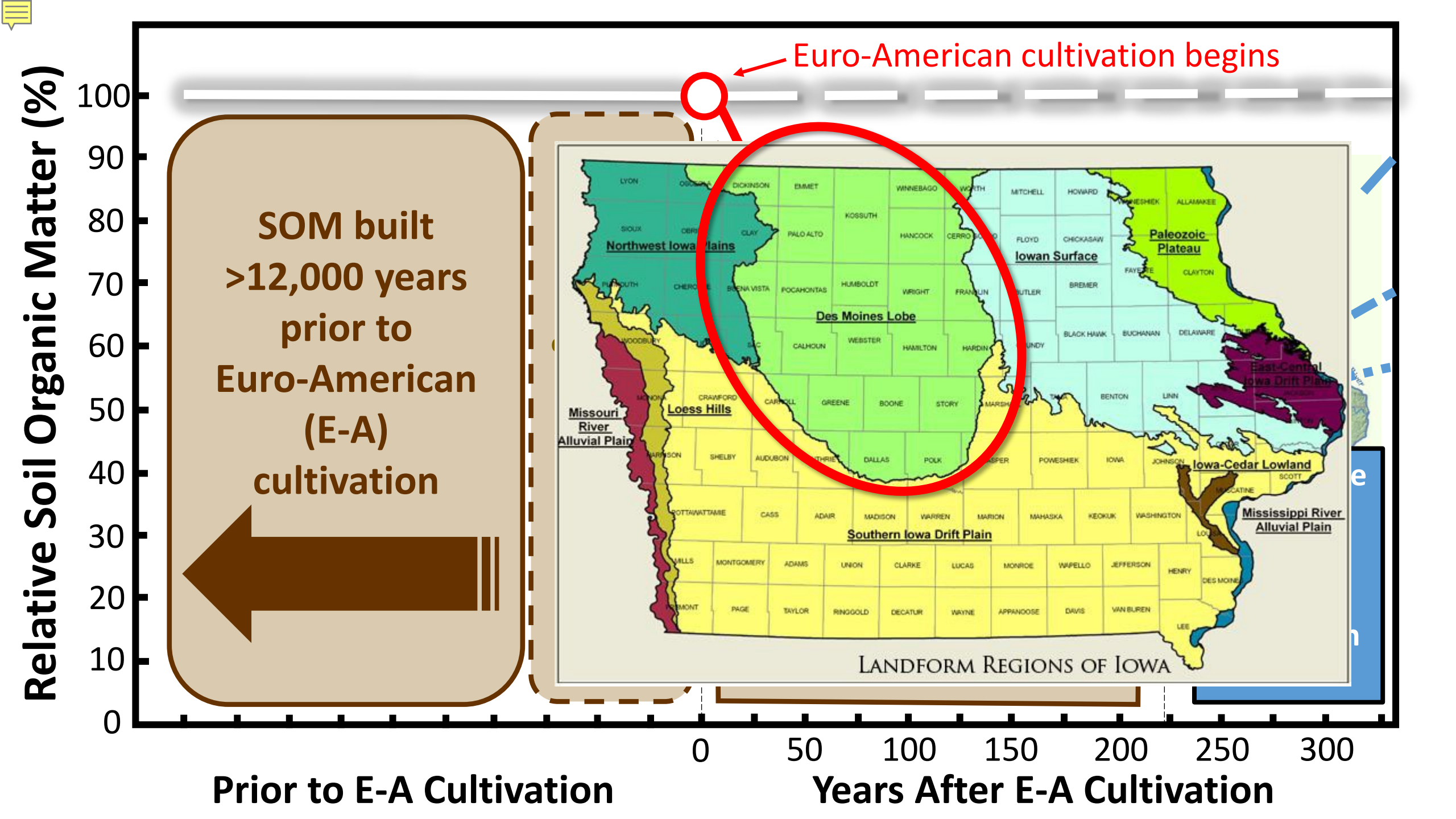
'Soil Tilth', 'Soil Quality' and 'Soil Health'

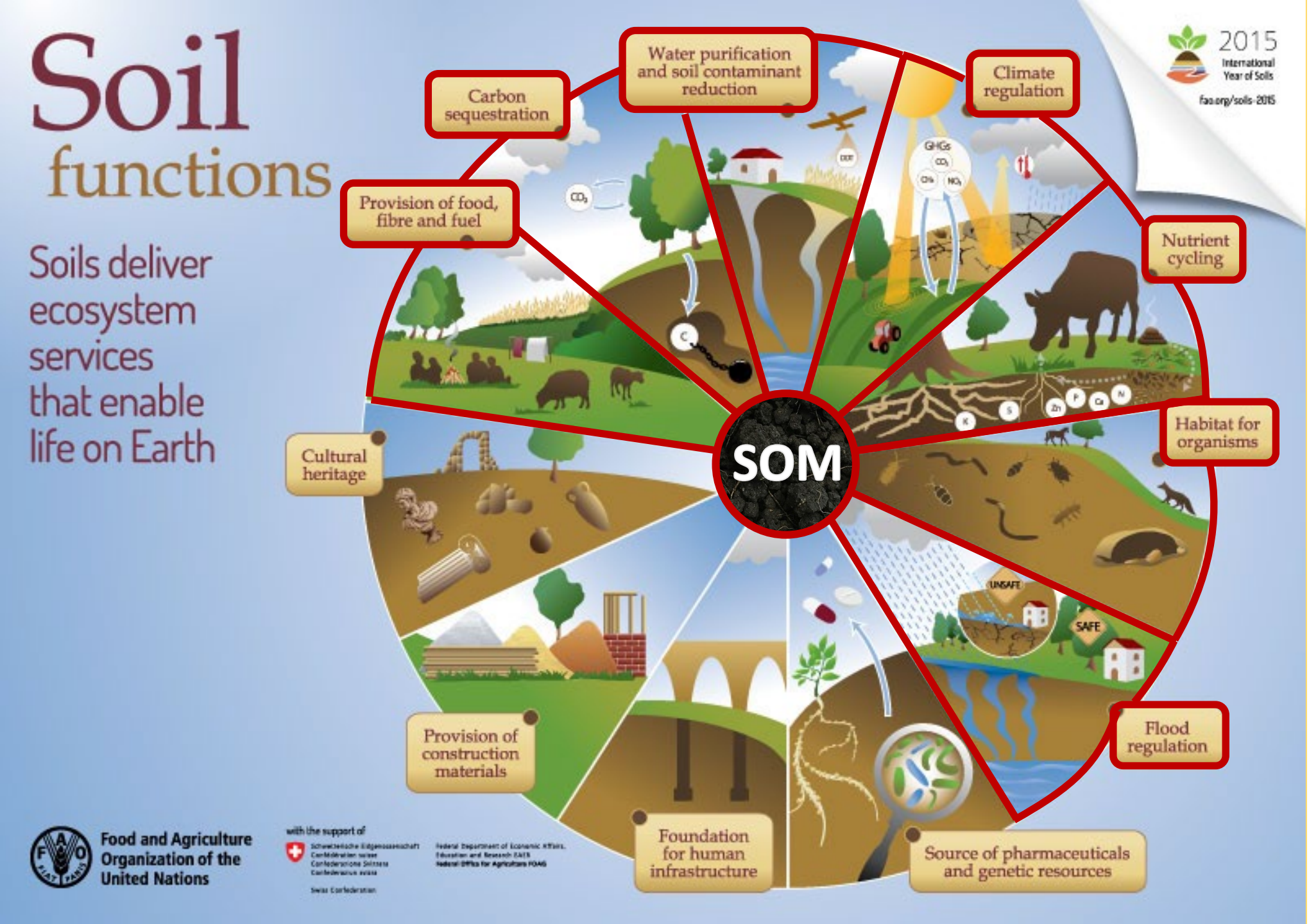
What historical event occurred around this time (or before) that might have caused this change soil's use in printed literature?



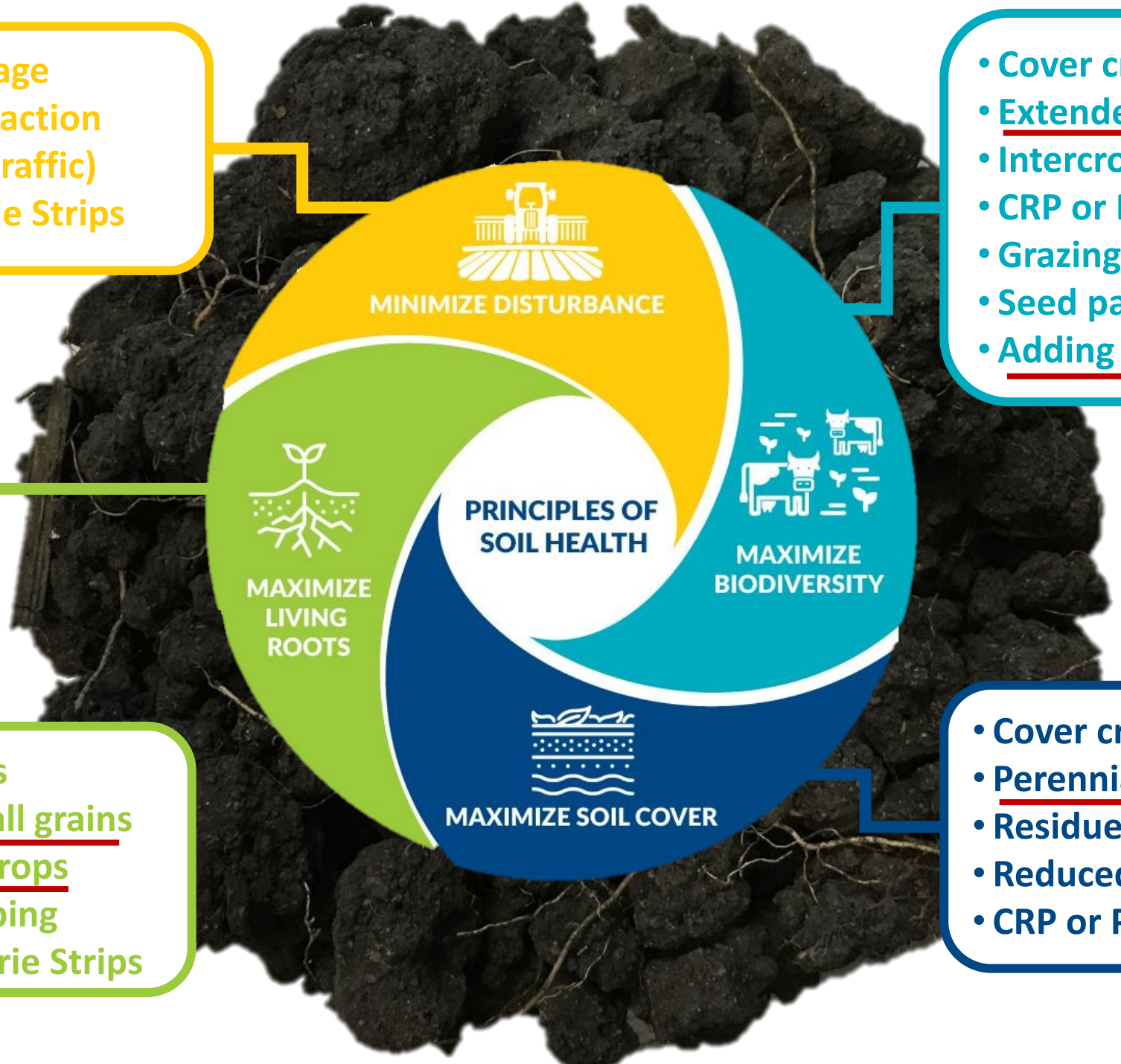
"The nation that destroys its soil destroys itself"

Franklin D. Roosevelt (26 February 1937)


Euro-American cultivation begins
SOM built >12,000 years prior to Euro-American (E-A) cultivation
Relative Soil Organic Matter (%)
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
Prior to E-A Cultivation
Years After E-A Cultivation
Northwest Iowa Plains
Des Moines Lobe
Loess Hills
Missouri River Alluvial Plain
Southern Iowa Drift Plain
Iowan Surface
Paleozoic Plateau
East-Central Iowa Drift Plain
Iowa-Cedar Lowland
Mississippi River Alluvial Plain
LANDFORM REGIONS OF IOWA



soil health is measured by how well soils perform these functions,



- Reduced tillage
- Lower compaction (controlled traffic)
- CRP or Prairie Strips

- Cover crop mixtures
- Extended crop rotations
- Intercropping
- CRP or Prairie Strips
- Grazing cover crops
- Seed pastures in rotation
- Adding manure

- Cover crops
- Winter small grains
- Perennial crops
- Relay cropping
- CRP or Prairie Strips

- Cover crops
- Perennial crops
- Residue retention
- Reduced tillage
- CRP or Prairie Strips

Source: NRCS


MADE
(in IA)

Marsden Agricultural Diversification Experiment (MADE)

3 cropping systems
Plots 60 ft x 276 ft
4 blocks

Initiated in 2001 near Boone, IA
Dr. Matt Liebman (Agronomy)

MADE Mission:

A long-term investigation of how cropping system diversification and crop-livestock integration affect **sustainability**.

MADE Ethos:

Conduct research relevant to IA farmers

- Talk, engage, listen to farmers
- Use farmers' input to inform research
- This makes research more meaningful/impactful

Matt Liebman, Professor Emeritus in Agronomy at ISU, speaking to farmers visiting MADE in 2003. (Source: PFI Website)

MADE is one of the most sampled/studied ~16 acres in IA

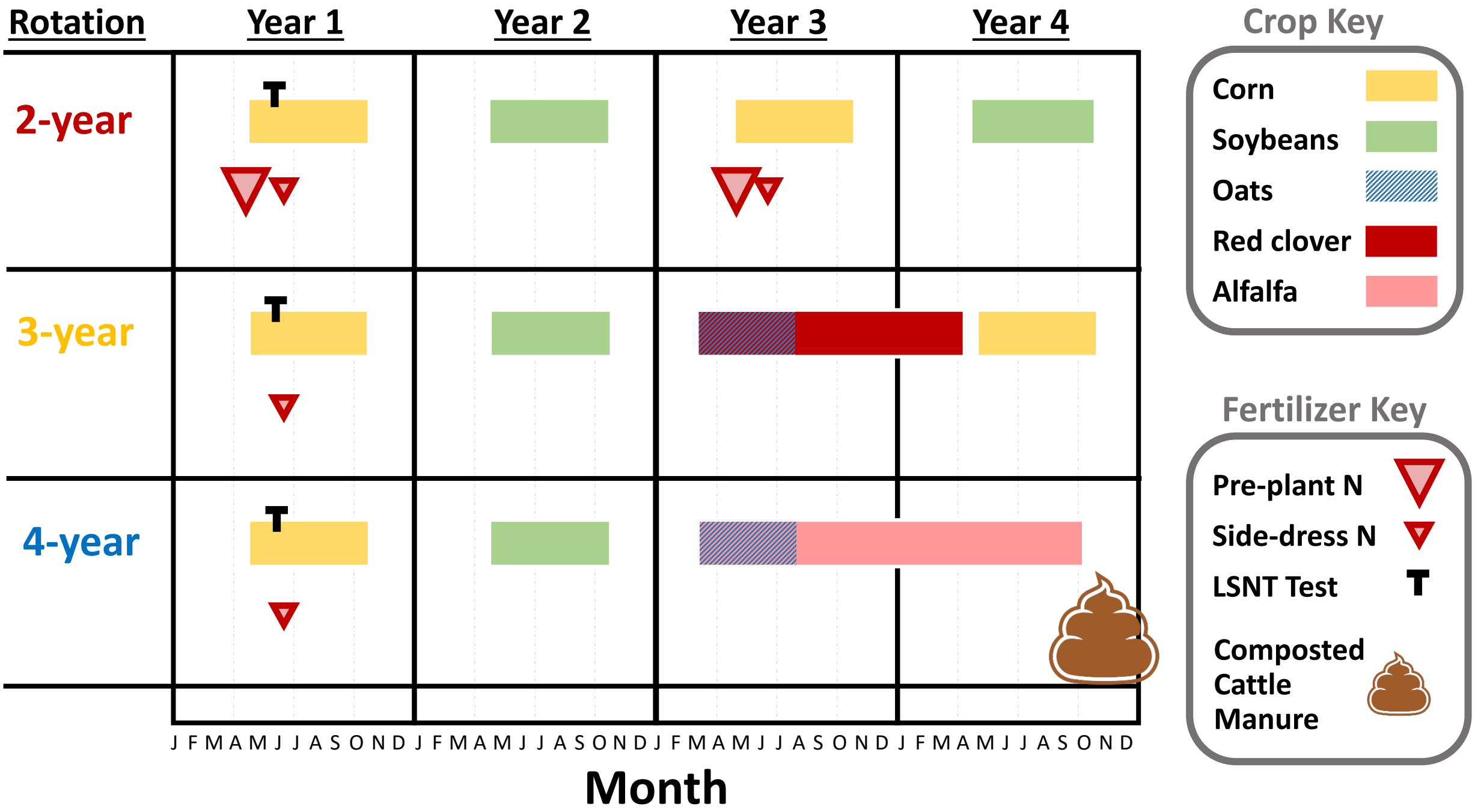
- ✓ 22-year (and going) record of cropping data with each phase of rotation represented
- ✓ > 40 peer-reviewed publications using data collected from MADE
- ✓ Dozens of collaborating scientists, including: weed ecologists, soil scientists, economists, microbiologist, plant pathologists, food nutritionists, crop modelers, etc..
- ✓ Millions $$$ in funding over the years

SCAN ME

MADE Experimental Design

System	Crop Rotation	Fertilization
2-year	 Corn  Soybean	 Synthetic Fertilizer
3-year	 Corn  Soybean  Oats + Red clover	 Composted Cattle Manure
4-year	 Corn  Soybean  Oats + Alfalfa  Alfalfa	 Composted Cattle Manure

Slide Source: Leonor Leandro


Rotation
Year 1
Year 2
Year 3
Year 4
2-year
3-year
4-year
T
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
Month
Crop Key
Corn
Soybeans
Oats
Red clover
Alfalfa
Fertilizer Key
Pre-plant N
Side-dress N
LSNT Test
Composted Cattle Manure

Summing up all the Benefits of Diversified Rotations

Agronomic and Environmental Benefits	Units	Rotation Mean (with standard error)		Effect Size (% Diff. from 2-year)	p-value	Reference
		2-Year	4-Year			
Productivity/Profitability						
Cropping System External Inputs						
Environmental Impact						

* = corn on 15.5% and soybean on 13% moisture

Baldwin-Kordick (2022)


$$$ in
Soil Health

$even $oil Ecosystem $ervices

Food,Fiber,Fuel

Cycling Nutrients

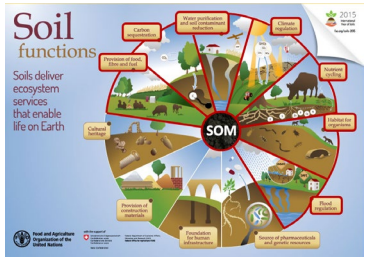
Regulate Flooding

Habitat for Organisms

Water Purification

Climate Regulating

Storing Carbon



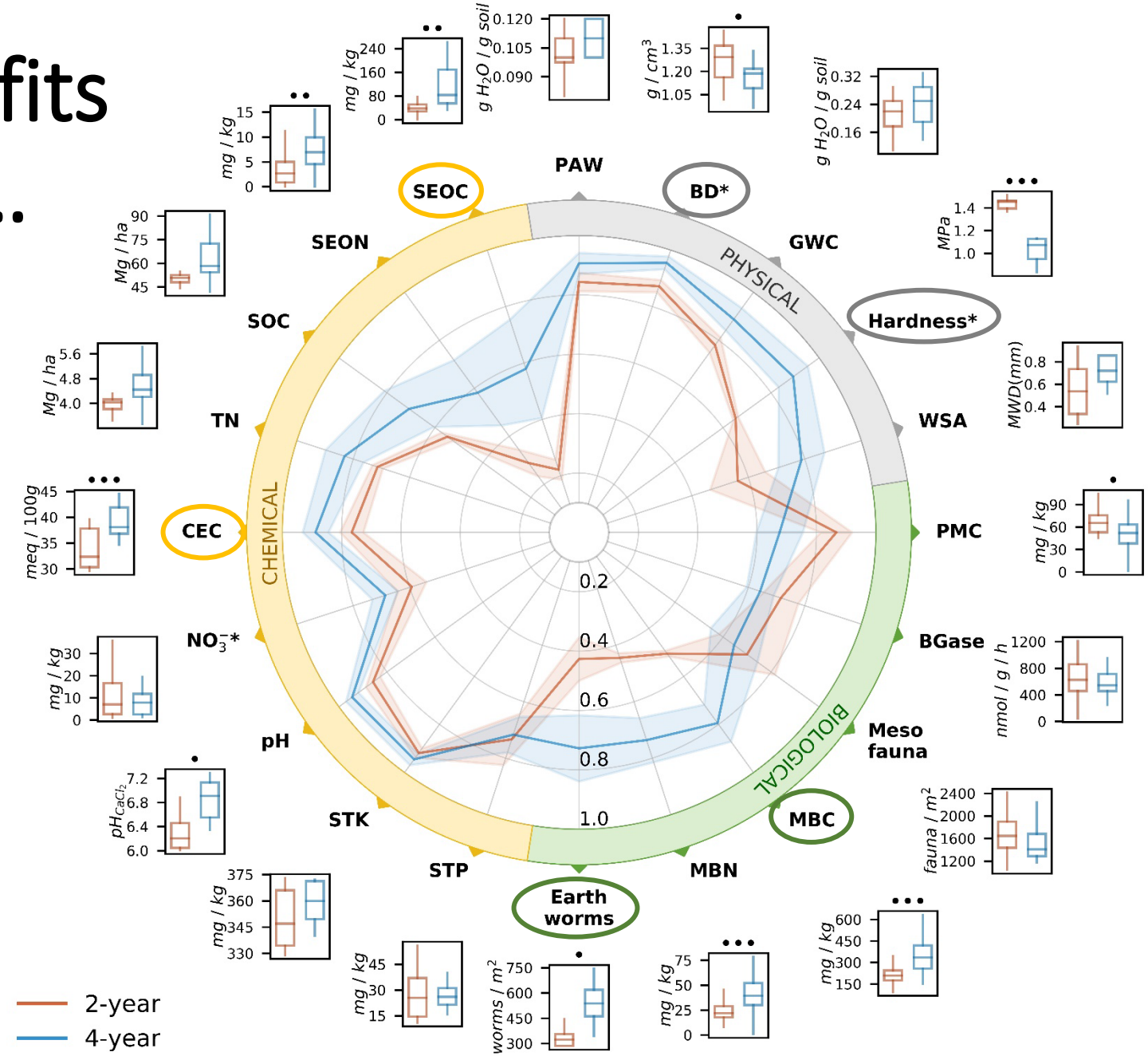
Source: Rebekah Baldwin-Kordick

Many soil health benefits in the 4-year rotation…

A few of the highlights:

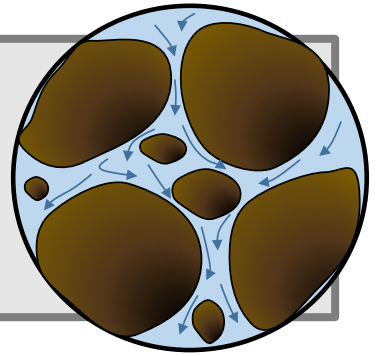
1. Bulk density
2. Soil hardness (penetration resistance)
3. Water infiltration
4. CEC
5. SEOC
6. Earthworms
7. Soil microbial biomass

What are the value of these?
(*to the producer AND society*)

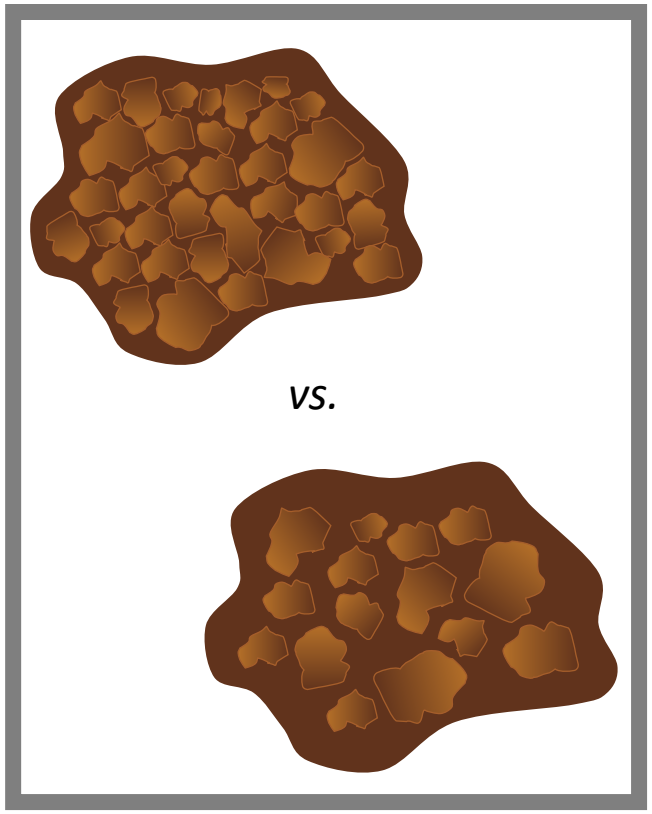


Baldwin-Kordick et al. (2022)

Physical $oil Health Benefits:



Bulk Density

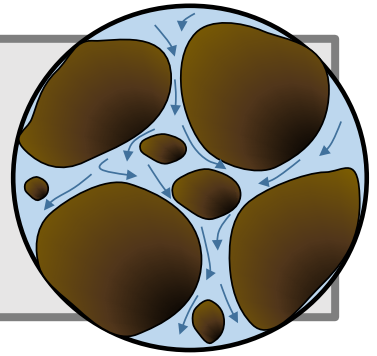


Soil Hardness

Water Infiltration

4-year → -26% | -8% | +15× (>1400%)

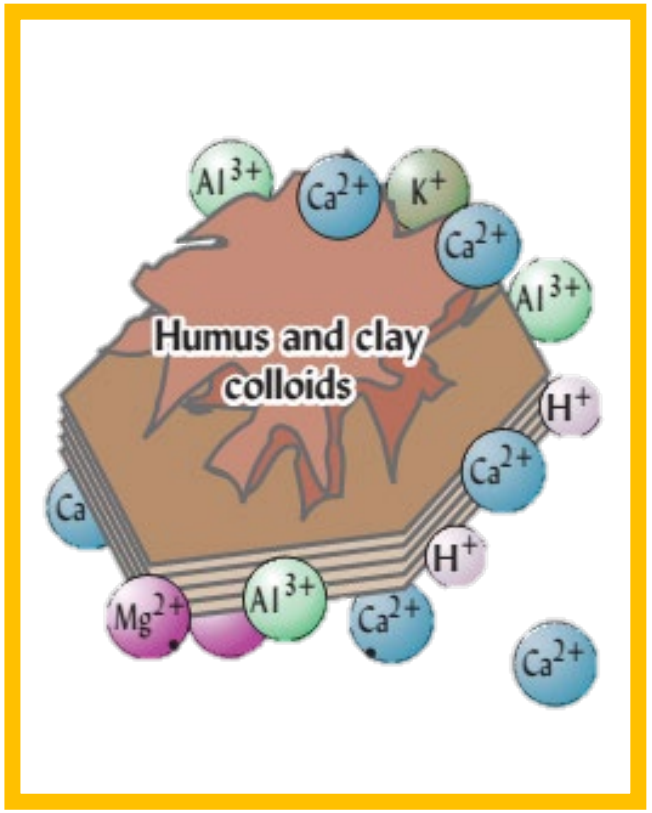
Physical $oil Health Benefits:



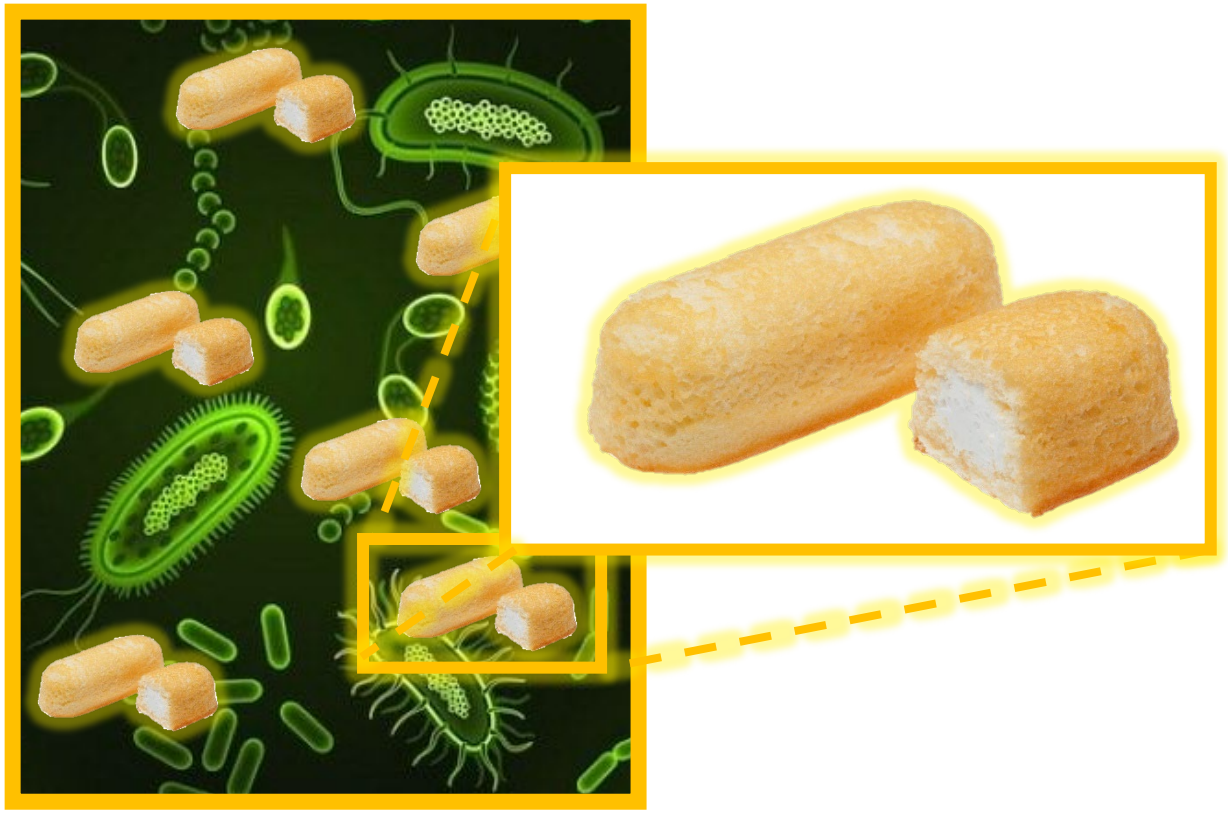
- **Greater ease of root growth → healthier plant, more yield**
- **Increased water intake (i.e., infiltration)**
  - reduced soil erosion and run-off (loss of fugitive nutrients)
  - decreased soil moisture in the spring → increases days-of-operation
- **Increased water storage**
  - increased plant-available water in summer → healthier plant, more yield
  - greater biological activity → healthier plant, more yield

Chemical $oil Health Benefits:

Cation Exchange Capacity



Salt-extractable Organic C

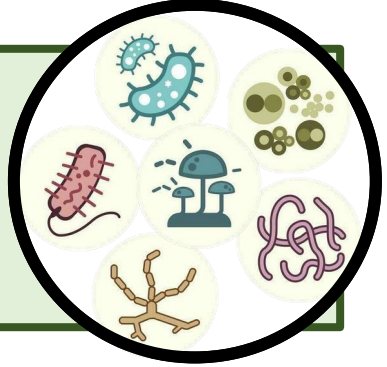


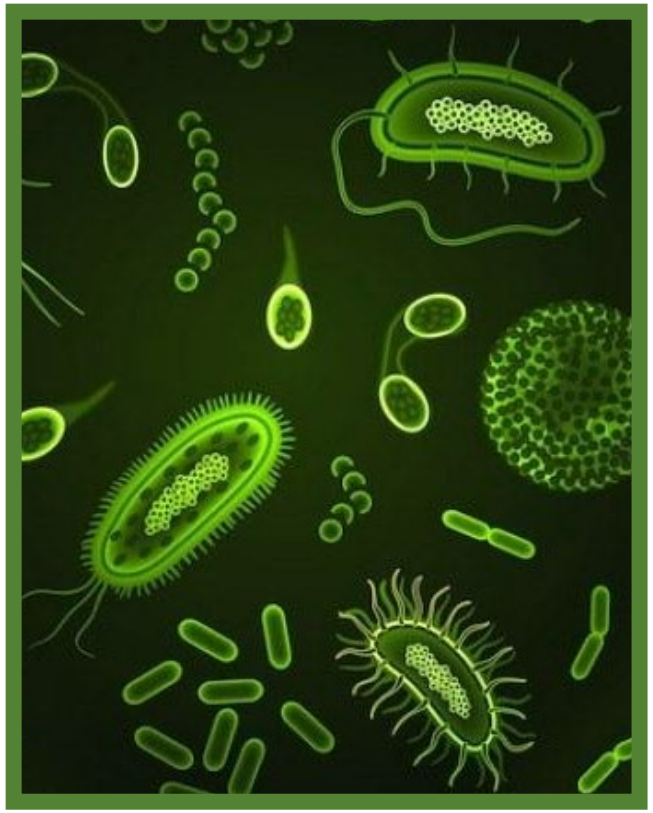
4-year → +16% +157%

Chemical $oil Health Benefits:

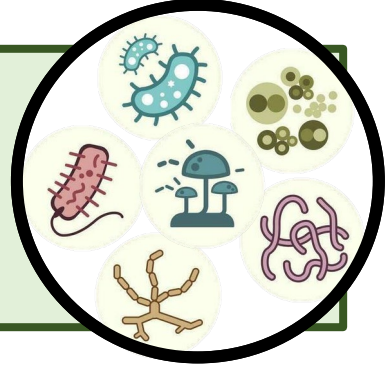
- $ **Greater storage capacity of nutrients → healthier plant, more yield**
  - ¢ reduce $$$ needed for nutrients
  - ¢ more efficient at storing those you do apply
- $ **Greater microbe food**
  - ¢ reduces N loss
  - ¢ greater biological activity → healthier plant, more yield

Biological $oil Health Benefits:



	Earthworms	Microbial Biomass
		
4-year →	+71%	+62%

Biological $oil Health Benefits:

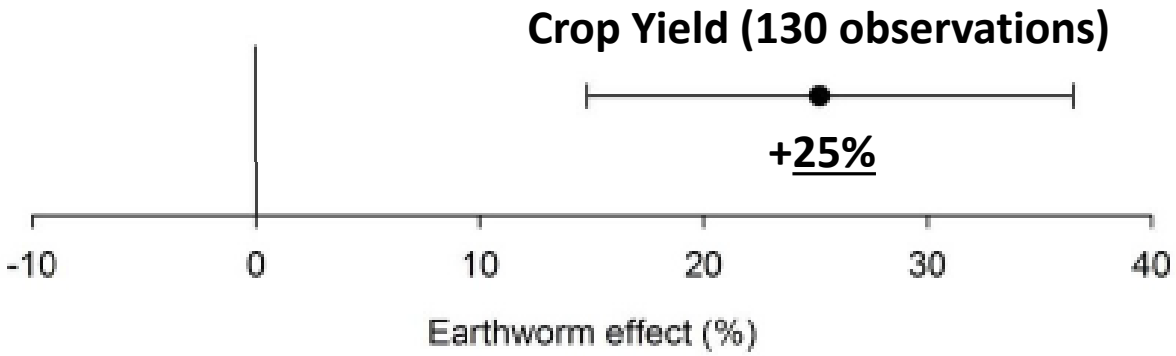


- $ **Earthworms (soil engineers) → healthier soil → more yield**
  - ¢ improved soil physical properties
  - ¢ improved soil chemical properties
- $ **More microbes**
  - ¢ efficient nutrient cycling
  - ¢ reduced need for fertilizer

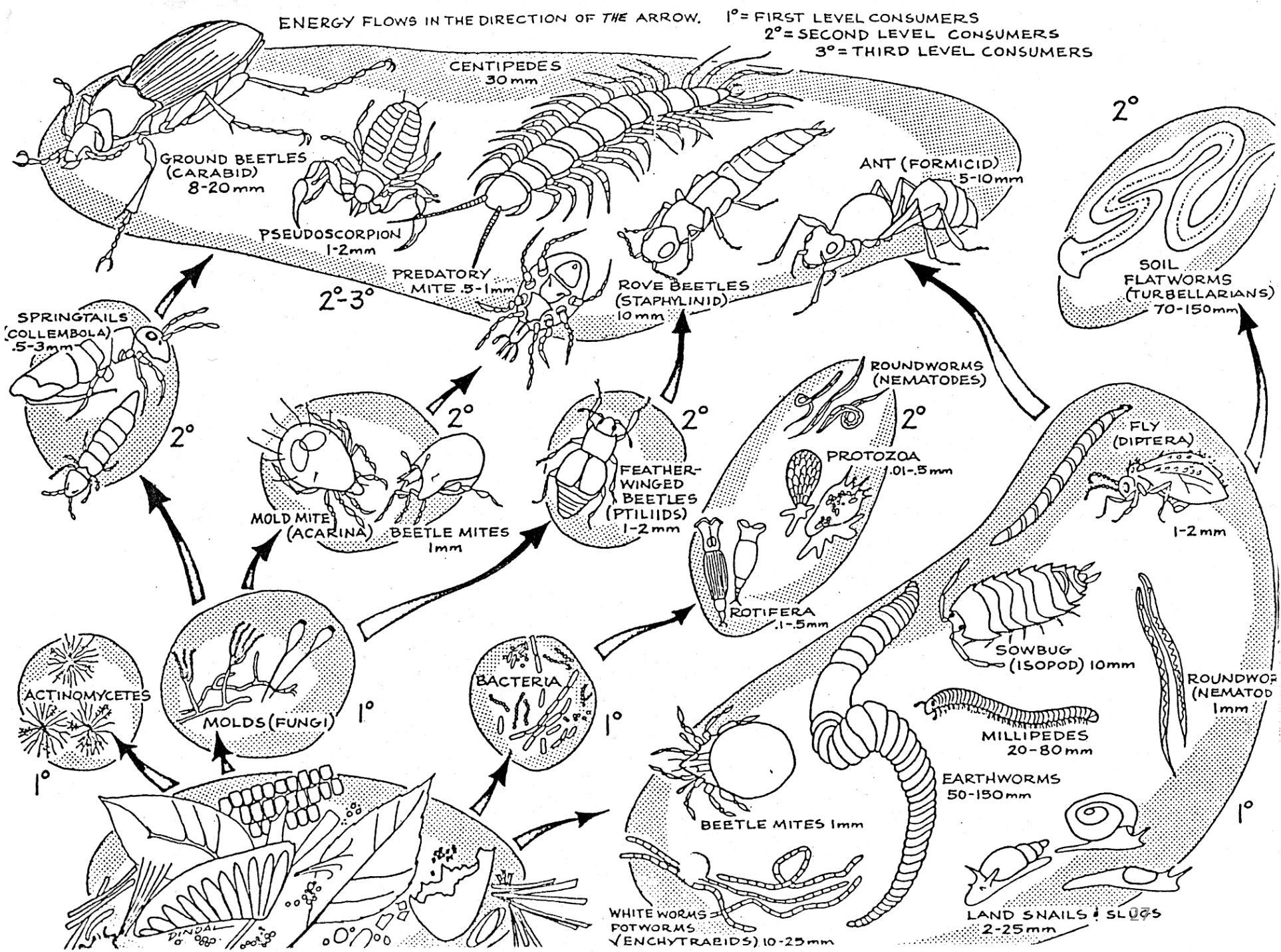
SCIENTIFIC REPORTS

Earthworms increase plant production: a meta-analysis

Jan Willem van Groenigen[1], Ingrid M. Lubbers[1], Hannah M. J. Vos[1], George G. Brown[2], Gerlinde B. De Deyn[1] & Kees Jan van Groenigen[3]



The **"Living"** Soil Organic Matter

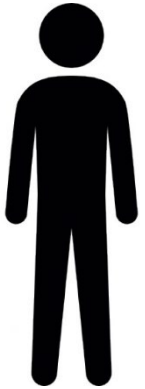


Plays a major role in…

1. Sequestering Soil C
2. Mitigating Atmospheric Greenhouse Gases
3. Supplying Nutrients to Plants

How much ‘animal equivalents’ of soil biomass are in 1 acre of soil?

A. dog (50 lbs)
B. human (150 lbs)
C. bison (1,200 lbs)
D. bull (2,000 lbs)
E. elephant (8,000 lbs)



Who's in our soil?

Soil Flora or Fauna	Size (mm)	Numbers (per g of soil)	Biomass (lbs. / ac)
Viruses	0.0002	$10^{10} – 10^{11}$	???
Bacteria & Archaea	0.001	$10^{9} – 10^{10}$	400 – 4,500
Actinomycetes	0.001	$10^{7} – 10^{8}$	500 – 4,500
Fungi	0.008	$10 – 10^{3}$ m	800 – 13,000
Algae	0.013	$10^{4} – 10^{5}$	10 – 500
Protista	0.050	$10^{2} – 10^{6}$	20 – 300
Nematodes	1	$10^{1} – 10^{2}$	10 – 300
Mites	0.5	1 – 10	1 – 500
Collembola	1	1 – 10	1 – 500
Earthworms	100	NA	50 – 3,500

Soil biota in one acre is about the size of two African elephants

- Soil Health Institute

Microbial biomass – eye of the needle that all organic matter passes through

CO_2

Soil Microbial Biomass

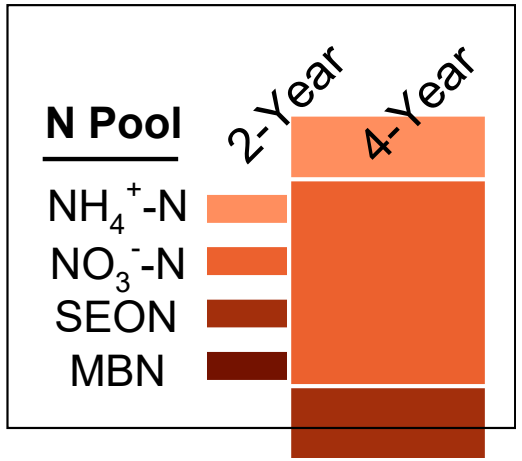
Plant Available Nutrients

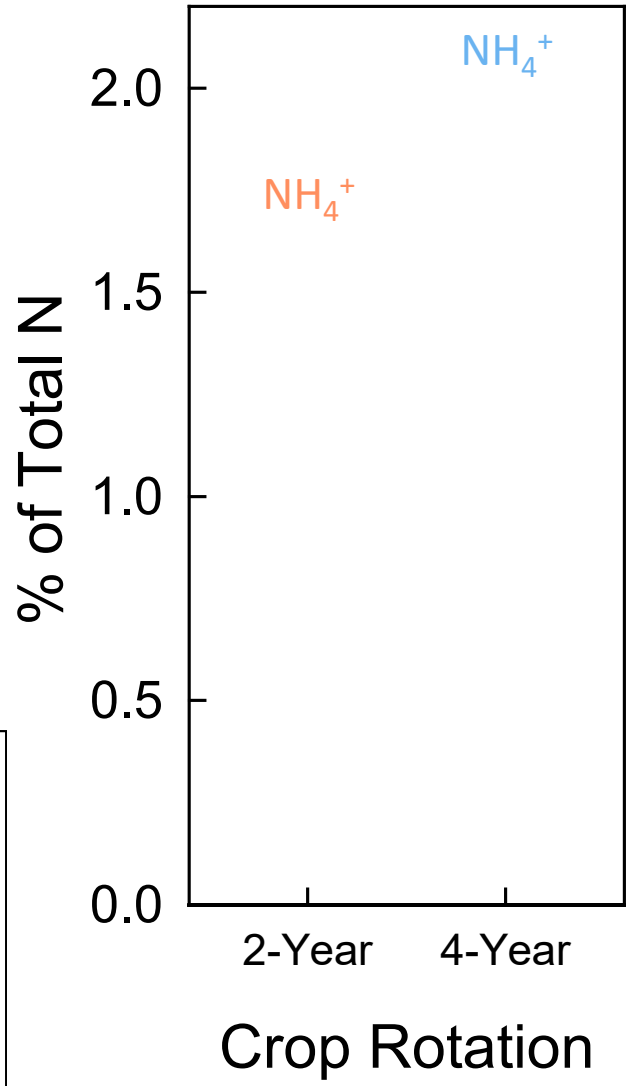
Soil Organic Matter

Adapted from Tate Book Cover

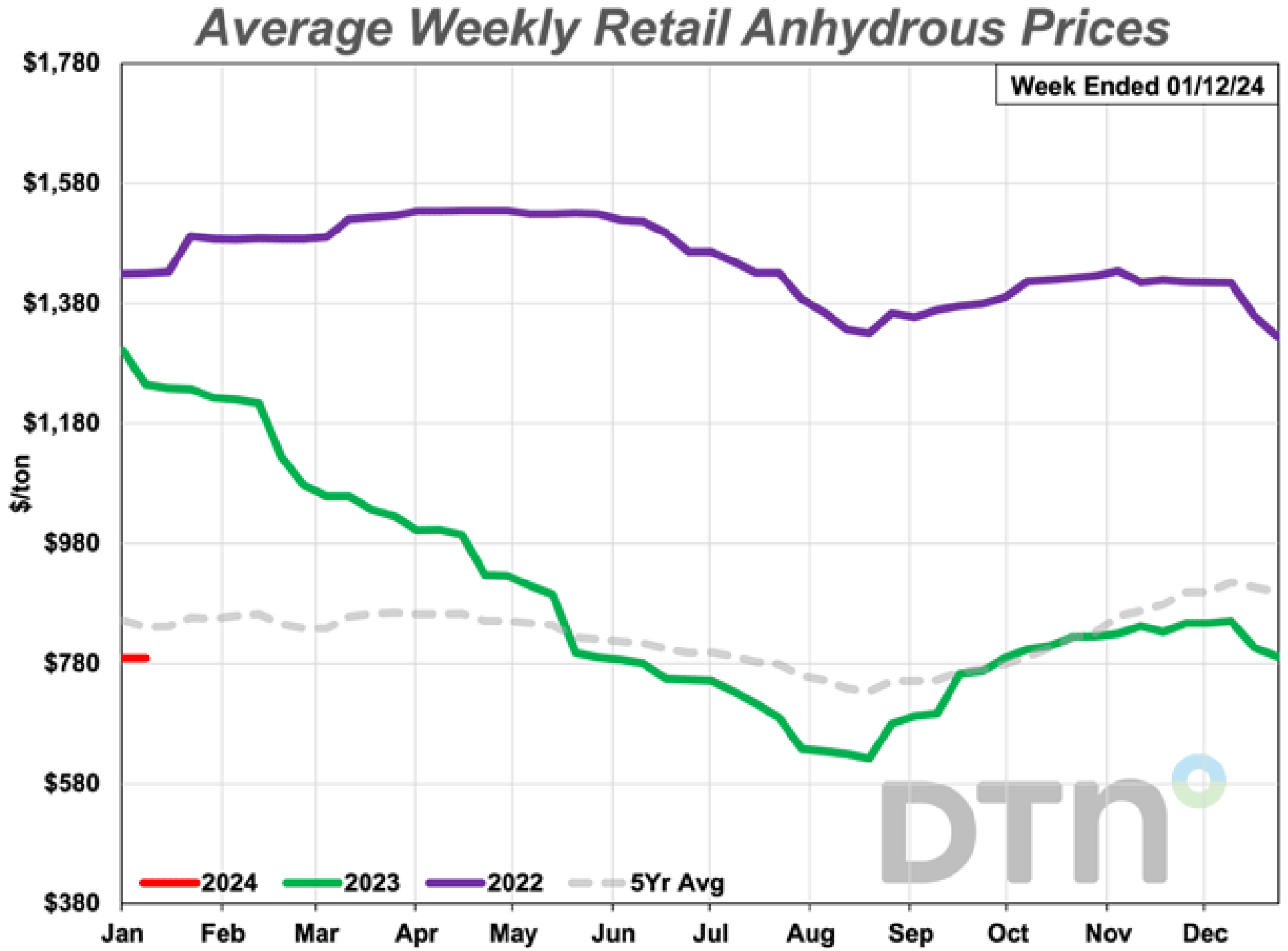
Greater proportion of N in microbes and organic N in 4-year rotation (*in the corn phase*)

- Total soil N concentrations are (not significant):
  - 0.25 ± 0.01 % in 2-year
  - 0.31 ± 0.06 % in 4-year
- Dynamic soil N pools (<4% of TN):
  - **NH_4^+-N** = ammonium-N
  - **NO_3^--N** = nitrate-N
  - **SEON** = salt-extractable organic N
  - **MBN** = microbial biomass N.





De et al. (*unpublished*)

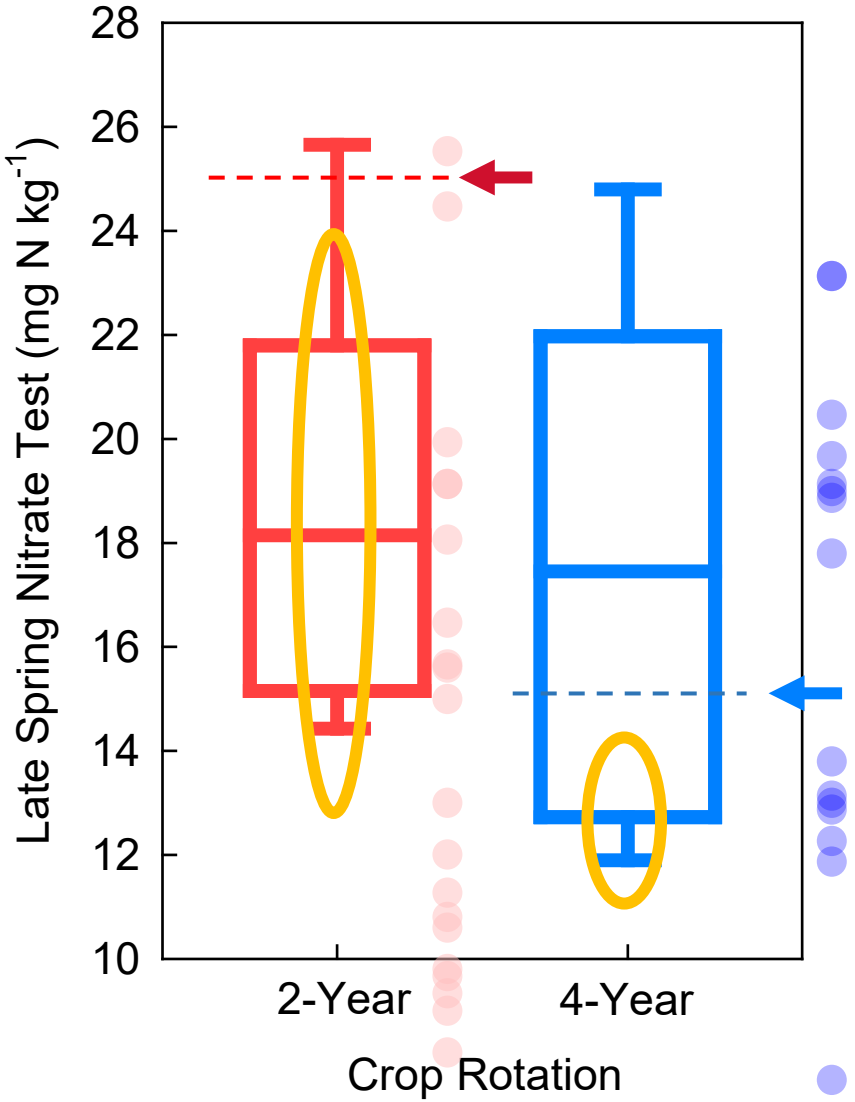

Average Weekly Retail Anhydrous Prices
Week Ended 01/12/24
$1,780
$1,580
$1,380
$1,180
$980
$780
$580
$380
$/ton
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2024
2023
2022
5Yr Avg
DTN

Less need to add N fertilizer to corn in June

Sawyer 2017_CROP3140

Below 25 ppm (Critical Value),
N needed for 2-year

Below 15 ppm,
N Needed for Manure/Alfalfa



- **2-year** gets pre-plant N (100 lbs N/ac) and sidedress N based on LSNT (18/20 years)

- **4-year** *sometimes* gets sidedress N based on LSNT (5/20 years)

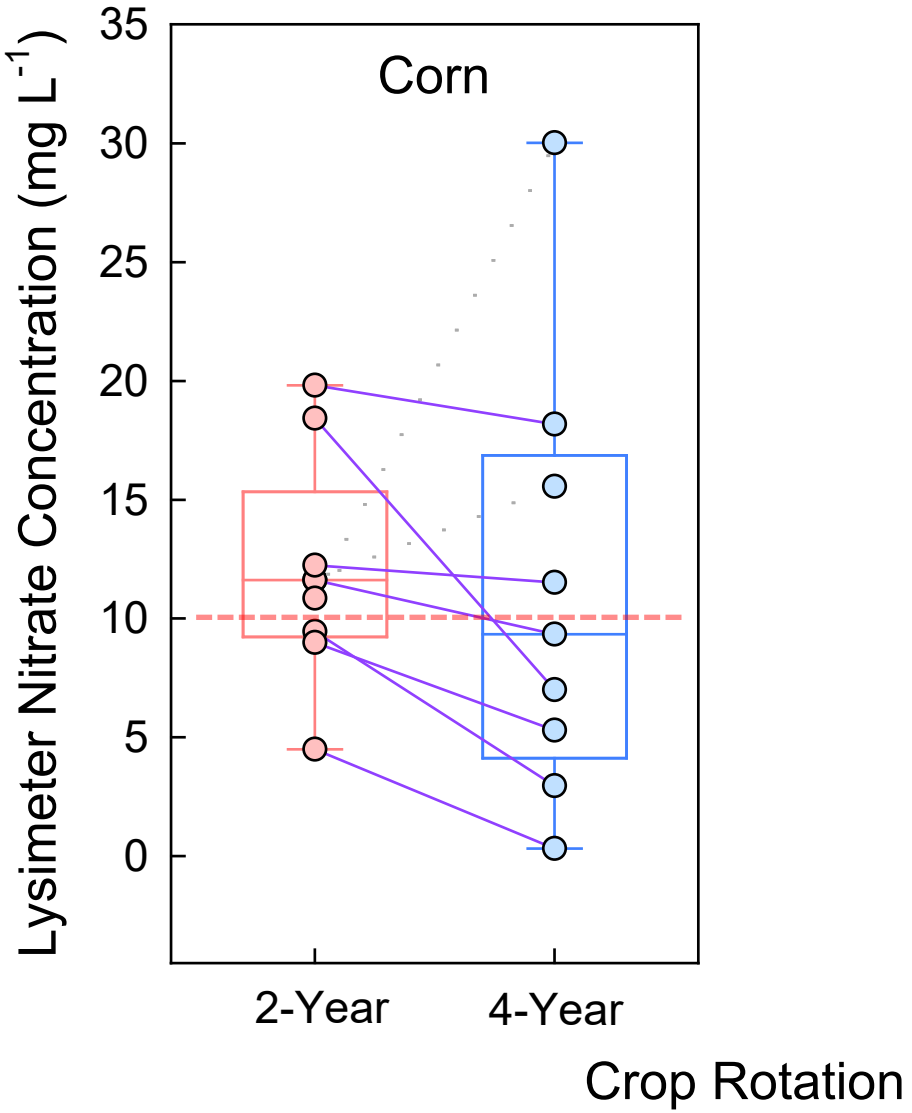
4-year rotation decreases NO_3^- in lysimeters (4’ deep)

Corn years:

- 4-year reduces NO_3^- in 7/9 years
- 9.8% decrease

Soybean years:

- 4-year reduces NO_3^- in 6/9 years
- 30.3% decrease

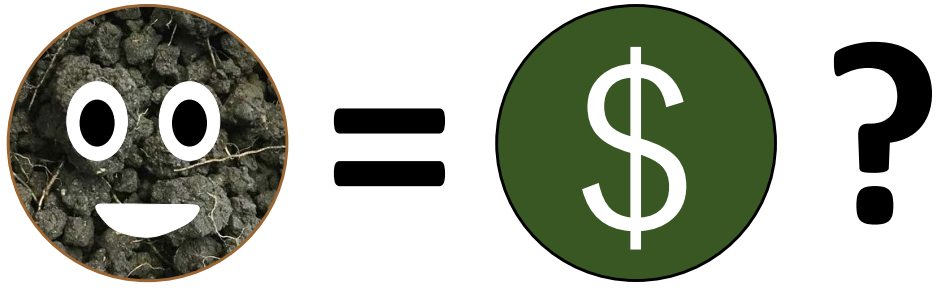


Tomer et al. (2014), De et al. (*unpublished*)


Conclusion
(wrapping up)

$oil Health and the Bottom Line Take-home Messages

- Improving soil health has clear *tangible* and *intangible* economic benefits
  - Demonstrated at MADE and commercial farms
- Soil health at MADE is making $$$ because combination of…
  - Improved Crop Productivity
  - Reduced inputs
- What about other $$$ for other externalities or intangible benefits…?
  - Soil carbon
  - Water quality
  - Reduced greenhouse gases
  - Biodiversity
  - Land value (sort of like CSR2)
  - Resilience?

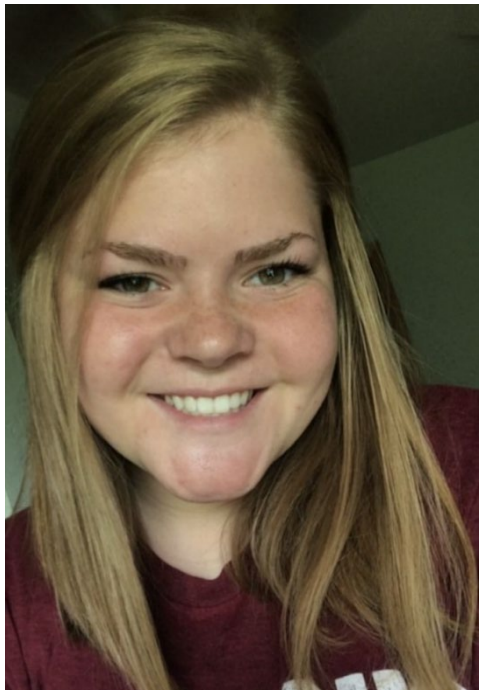


Climate Change Resilience

Dr. Ashani Thilakarathne

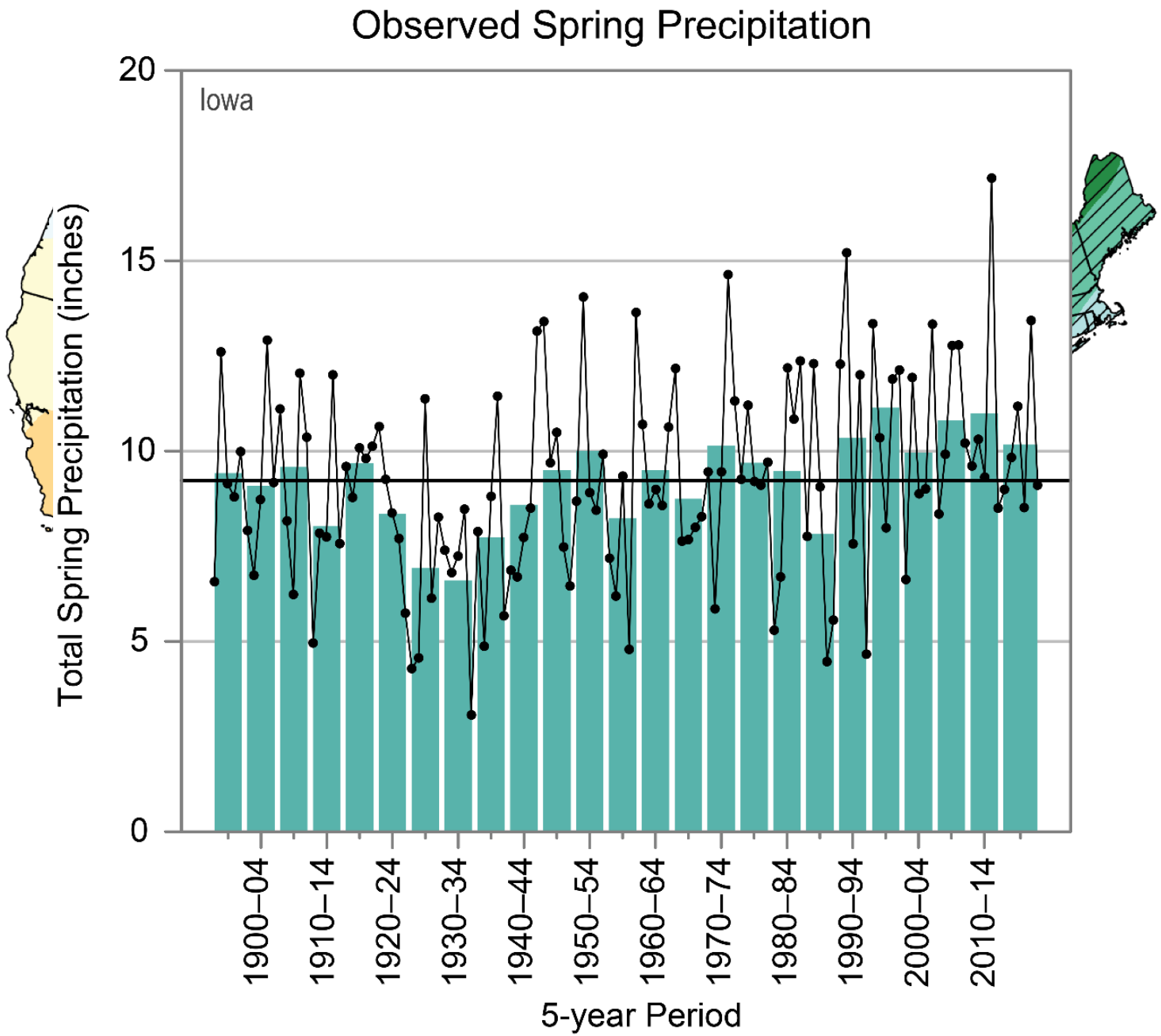
Matt Woods

Ally Larson



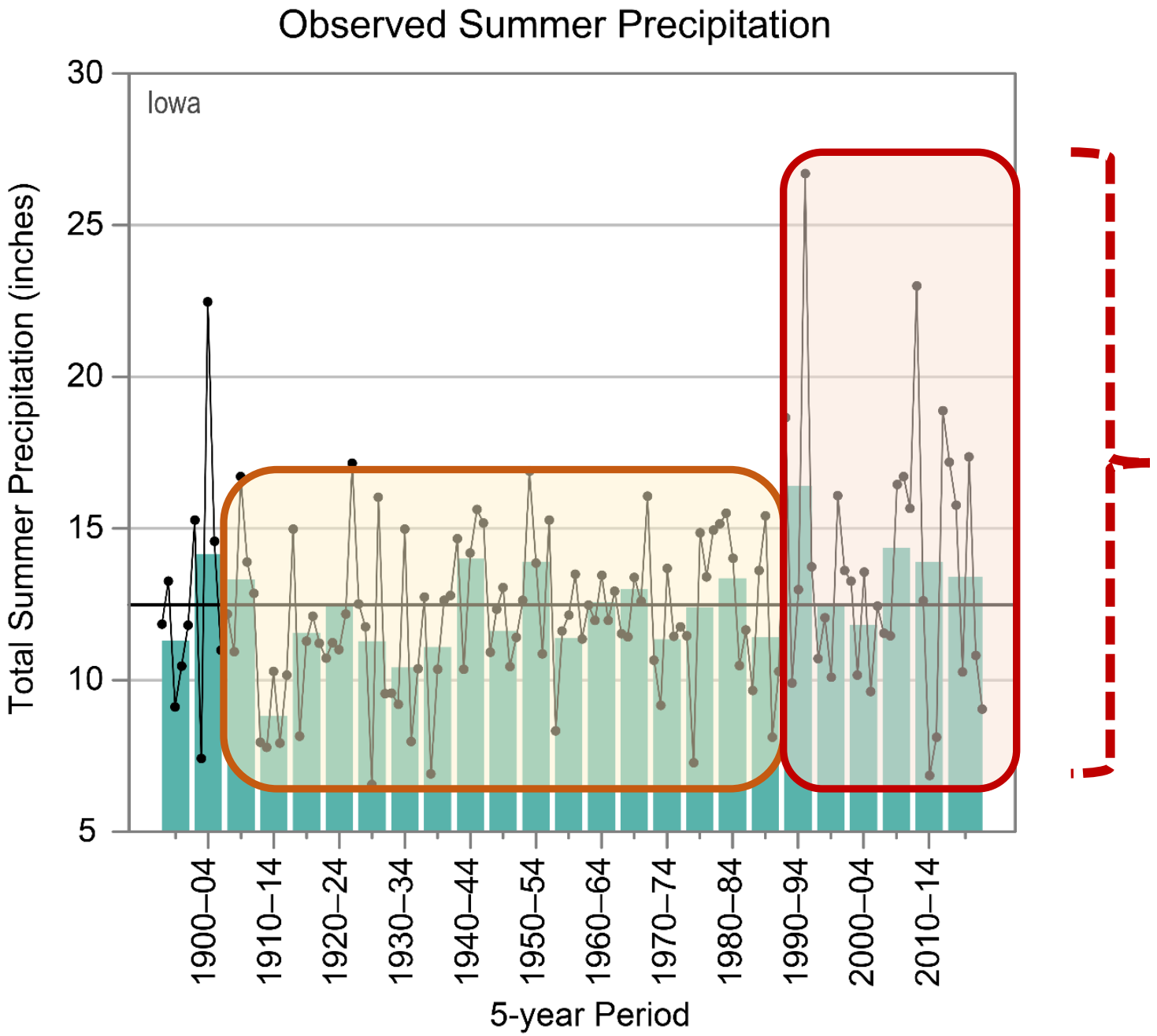
Funding Support:

Springs are getting wetter in Iowa



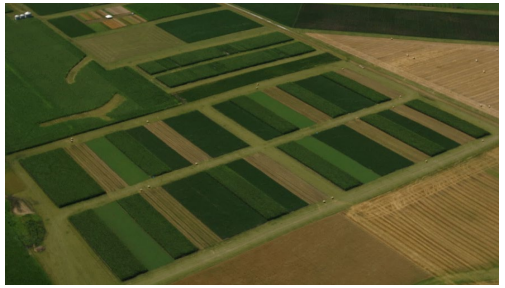
https://statesummaries.ncics.org/chapter/ia/

Summer precipitation becoming more variable

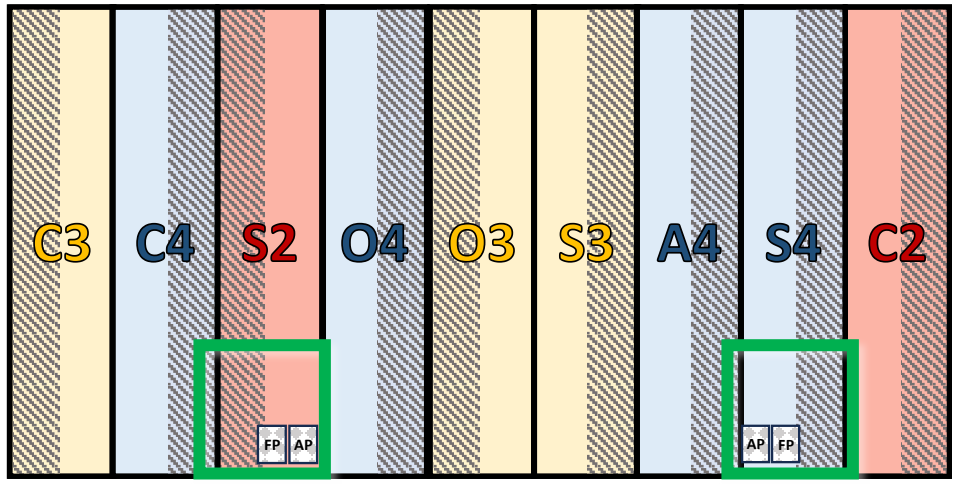


https://statesummaries.ncics.org/chapter/ia/

MADE 2.0

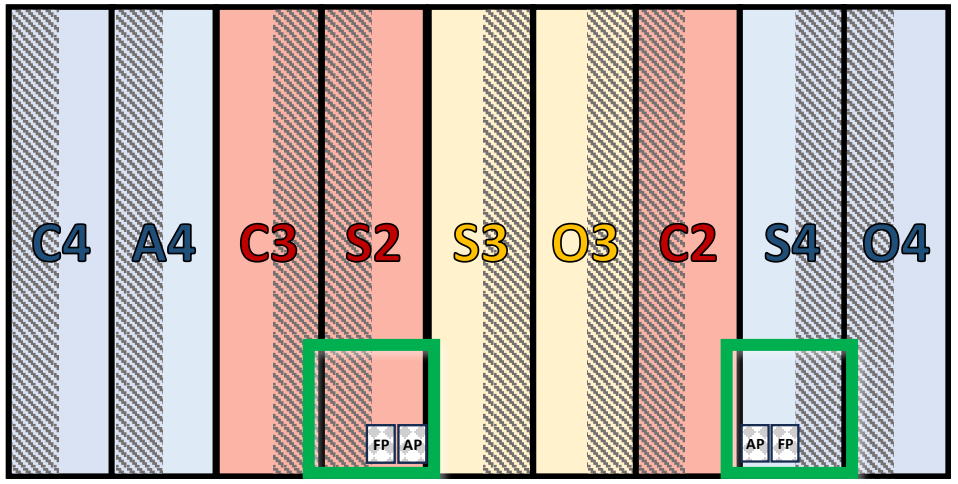


BLOCK 1



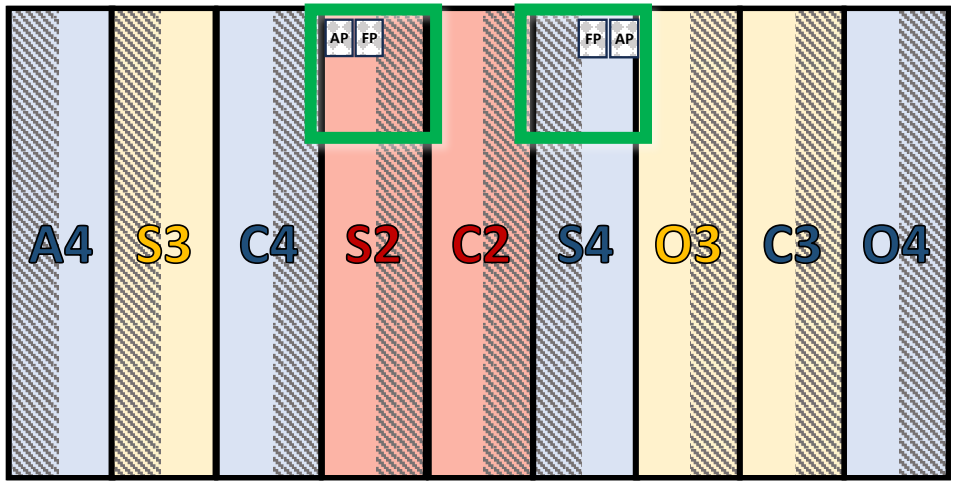
11 12 13 14 15 16 17 18 19

BLOCK 2



21 22 23 24 25 26 27 28 29

BLOCK 4



41 42 43 44 45 46 47 48 49

corn-soybean

corn-soybean-oat/red clover

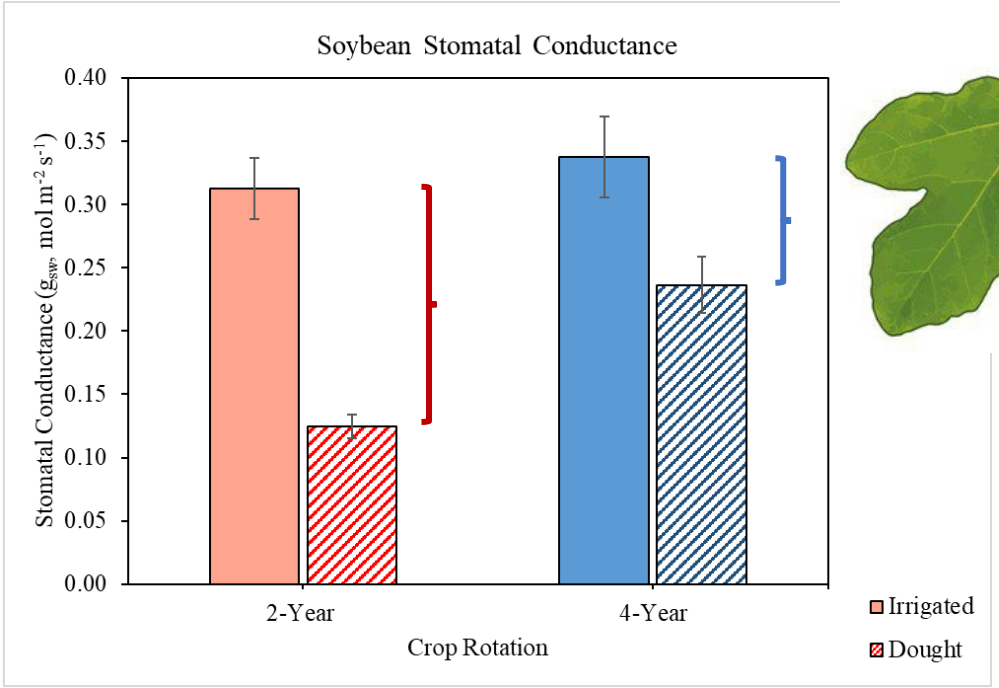
corn-soybean-oat/alfalfa-alfalfa

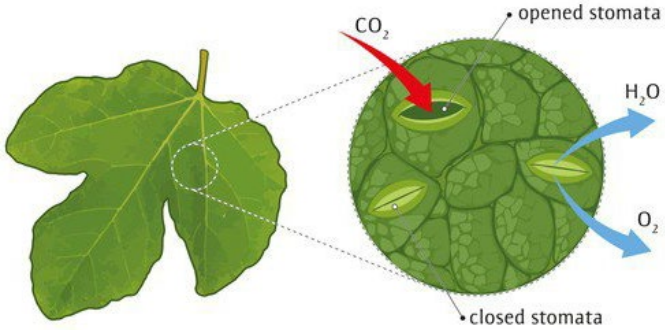
cereal rye cover crop

no cover crop


9/21/23
Drought
+H_2O

The **4-year** rotation enables soybeans to better resist drought is more





$even $oil Ecosystem $ervices

Food,Fiber,Fuel

Cycling Nutrients

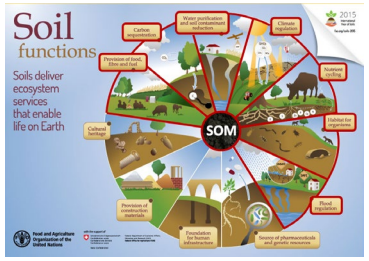
Regulate Flooding

Habitat for Organisms

Water Purification

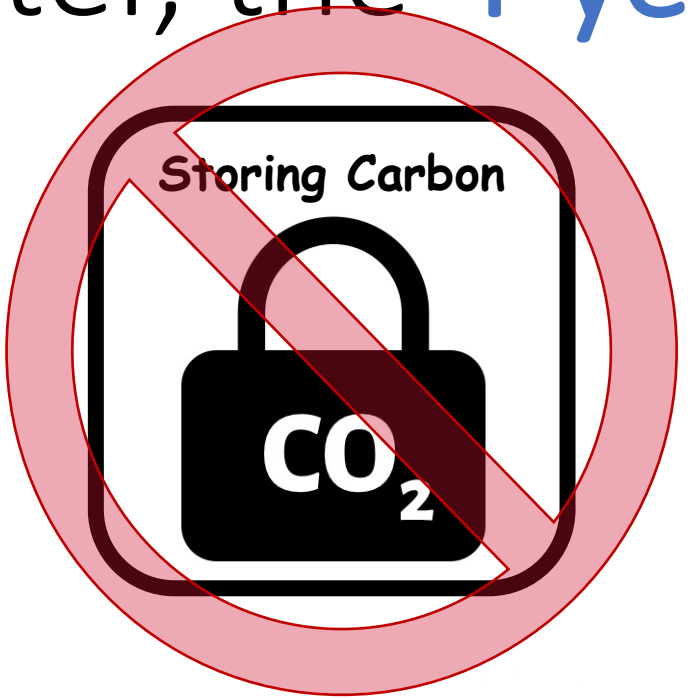
Climate Regulating

Storing Carbon

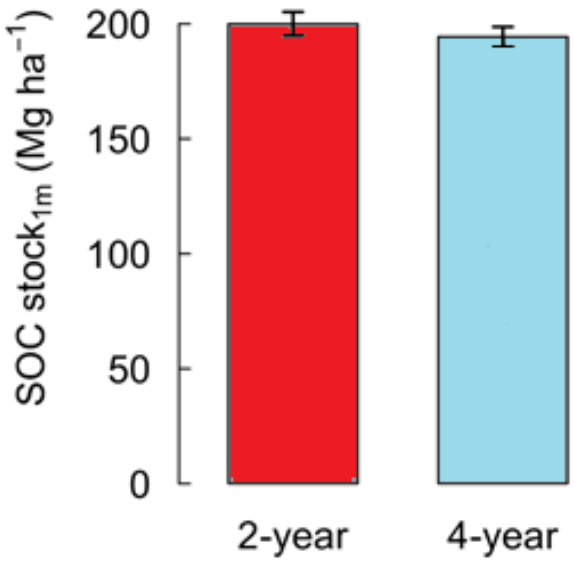


Source: Rebekah Baldwin-Kordick

19 years later, the 4-year rotation…

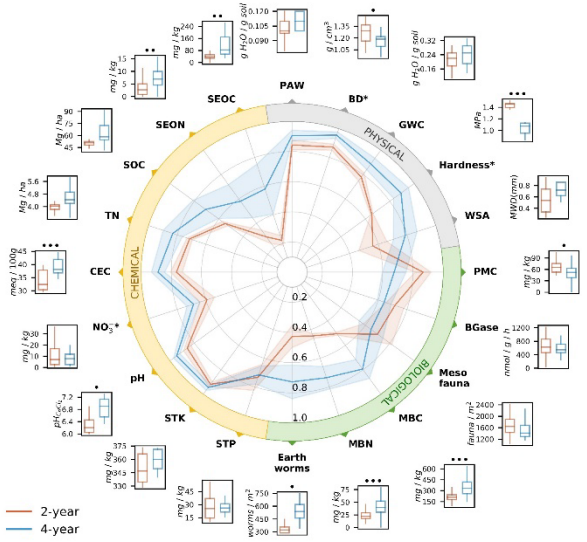


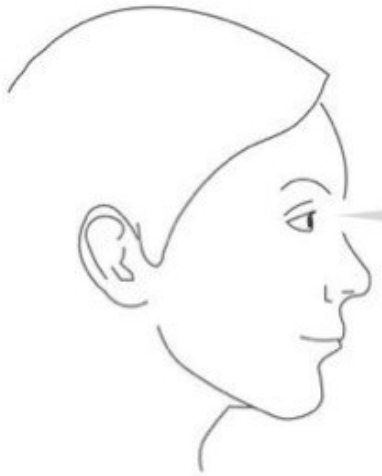
More recently (19 years later)…



Data from Huang & Hall_unpublished

Soil Carbon Tunnel Vision





Reduced Inputs

More Earthworms

Nutrient Retention

Water Storage

Lower Bulk Density

Water Infiltration

$ $ $ $ $ $

Soil C Sequestration

Increased Microbial Activity

Increased CEC

Reduced Greenhouse Gas Emissions

Enhanced Yields

Ease of Root Growth

Original Graphic: Jan Konietzko

SCAN ME

Questions?

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