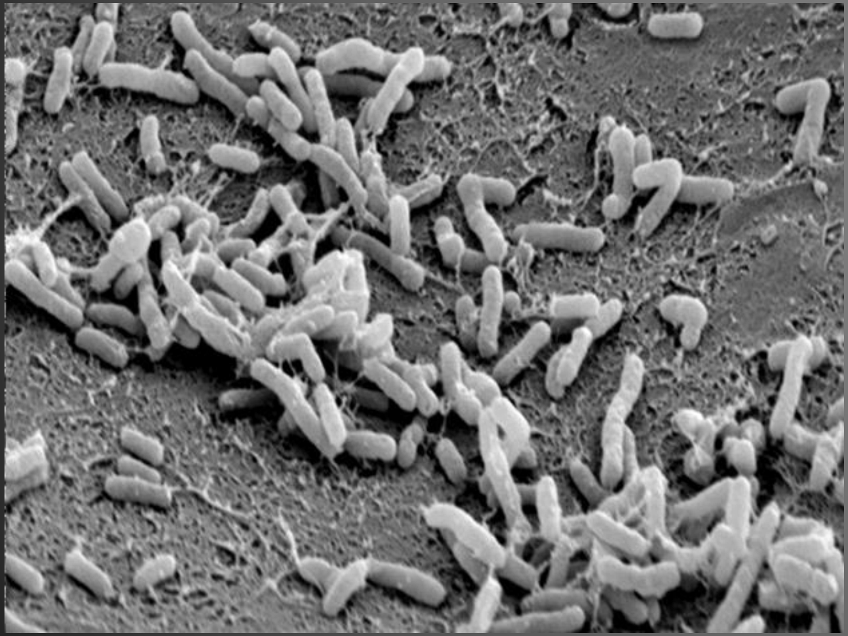
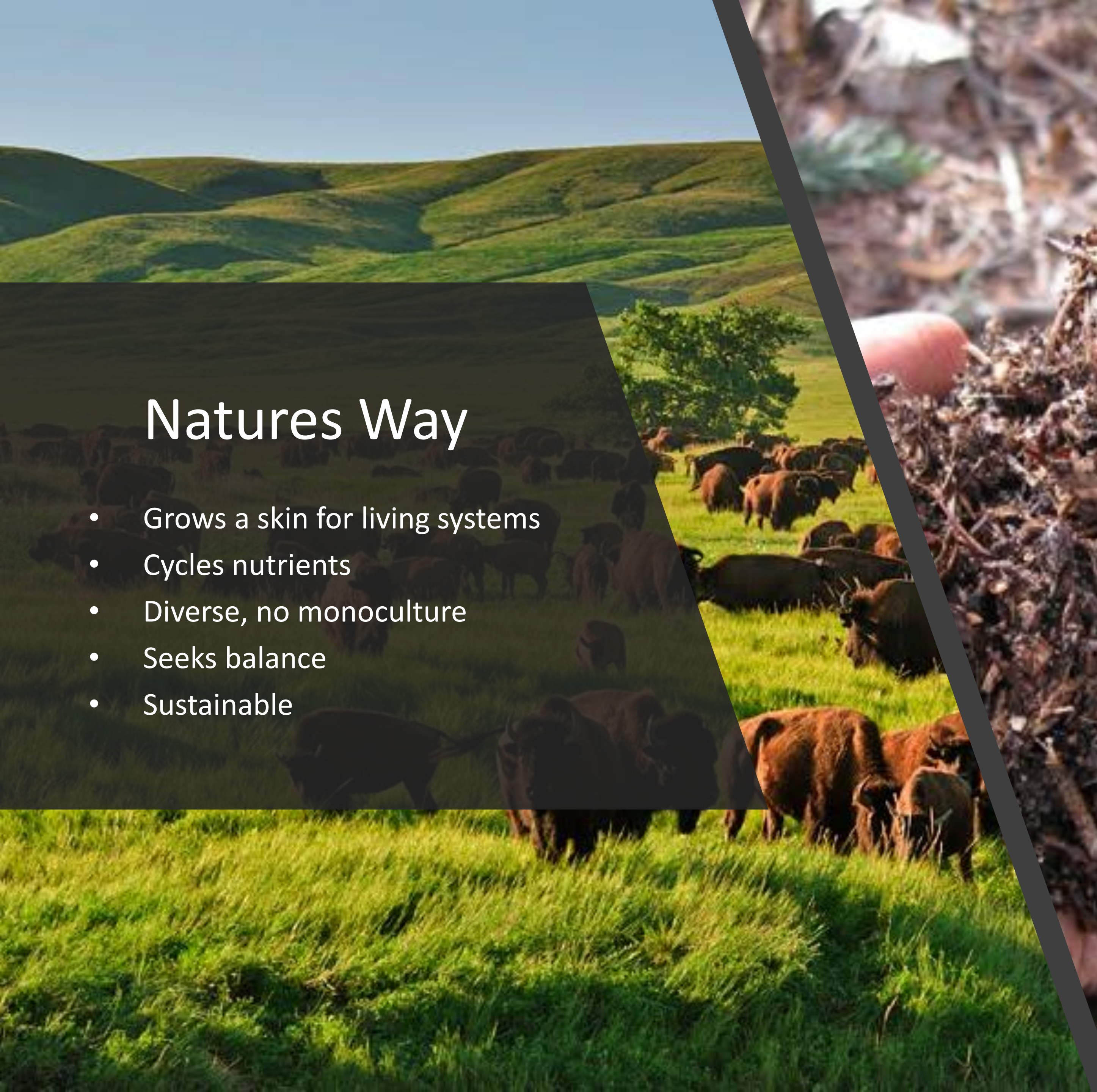
Soil Health Paradigm Shift

Rick Haney PhD, USDA-ARS, Temple, TX



Natures Way

- Grows a skin for living systems
- Cycles nutrients
- Diverse, no monoculture
- Seeks balance
- Sustainable



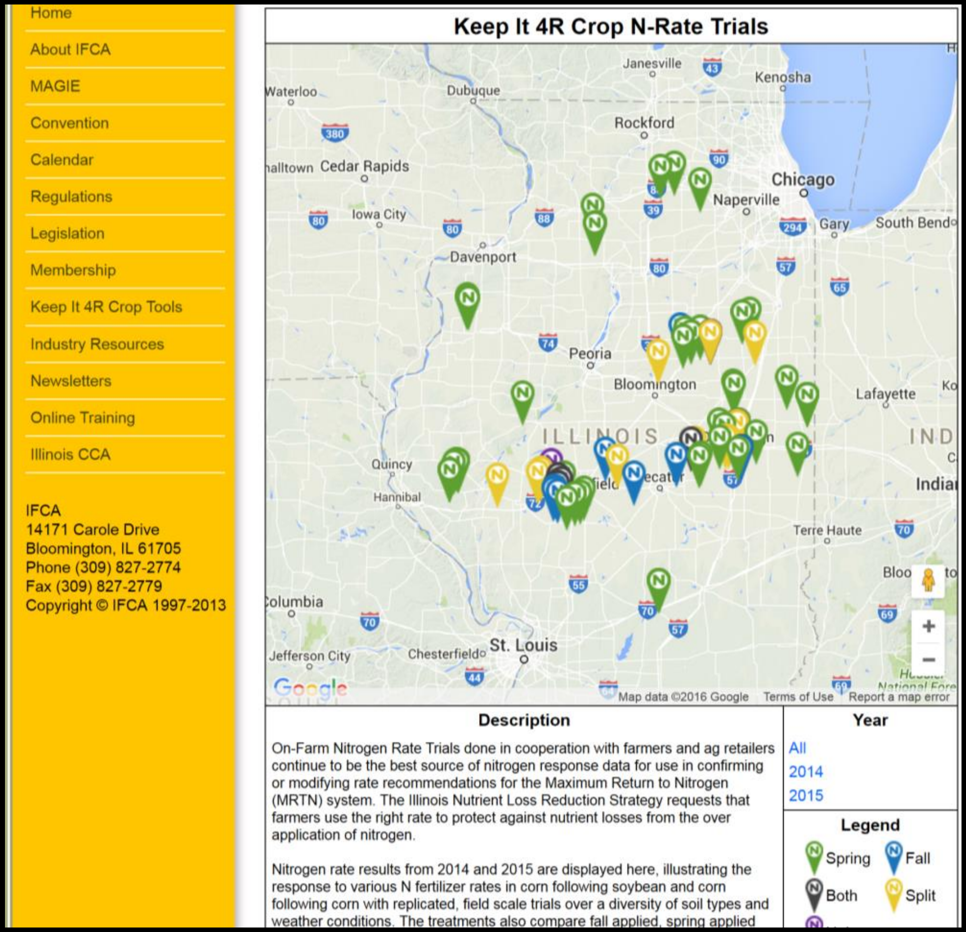
How we do it

- Strip off the soil's skin
- Destroy organic matter
- Increase erosion
- Increase inputs
- Waste water

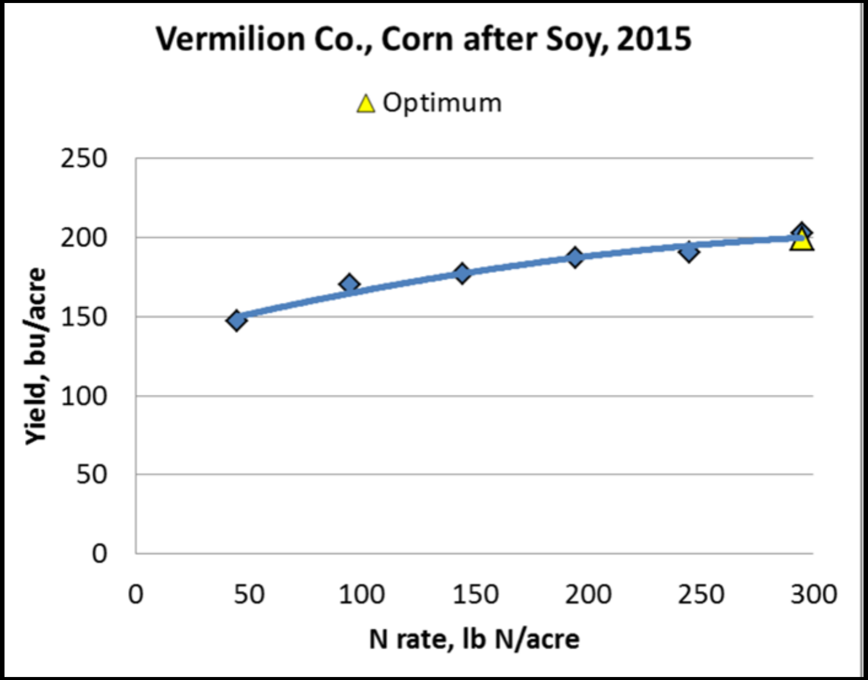
When you go to the bank,
do you throw your money at the window and hope some goes in or do you make it so you can deposit it all.

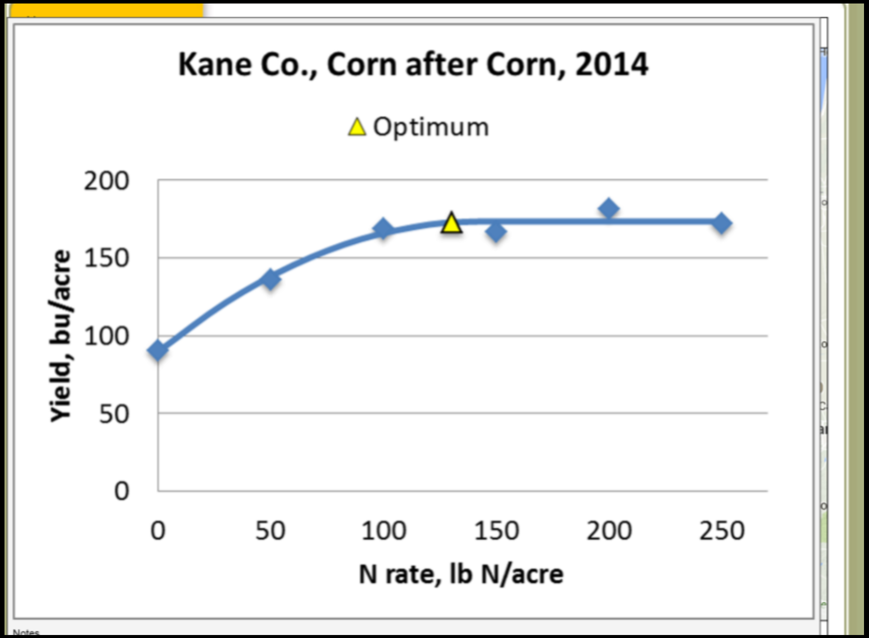
So why do we do this with rainfall and our fields?

Illinois Fertilizer and Chemical Association Data



http://ifca.com/nrate_map/





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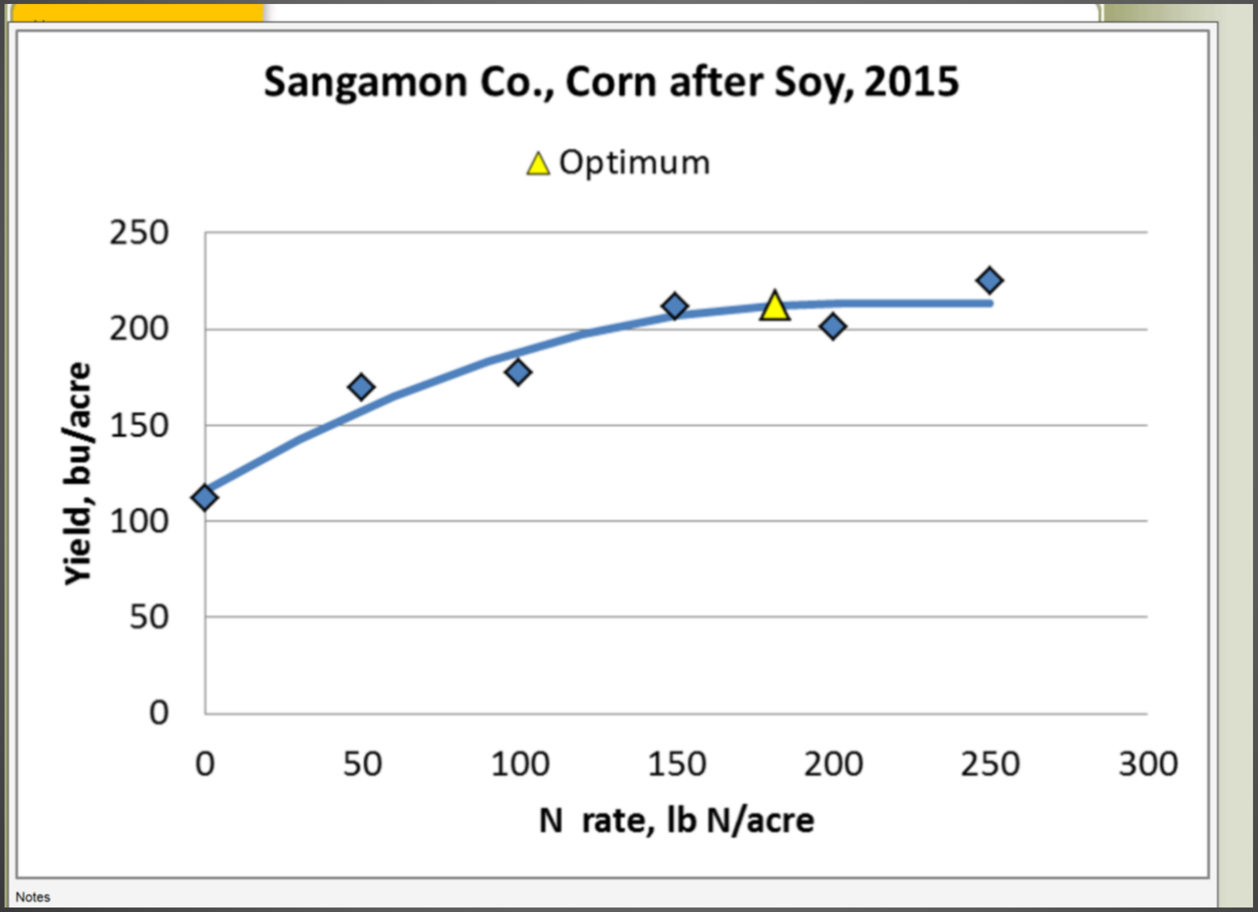
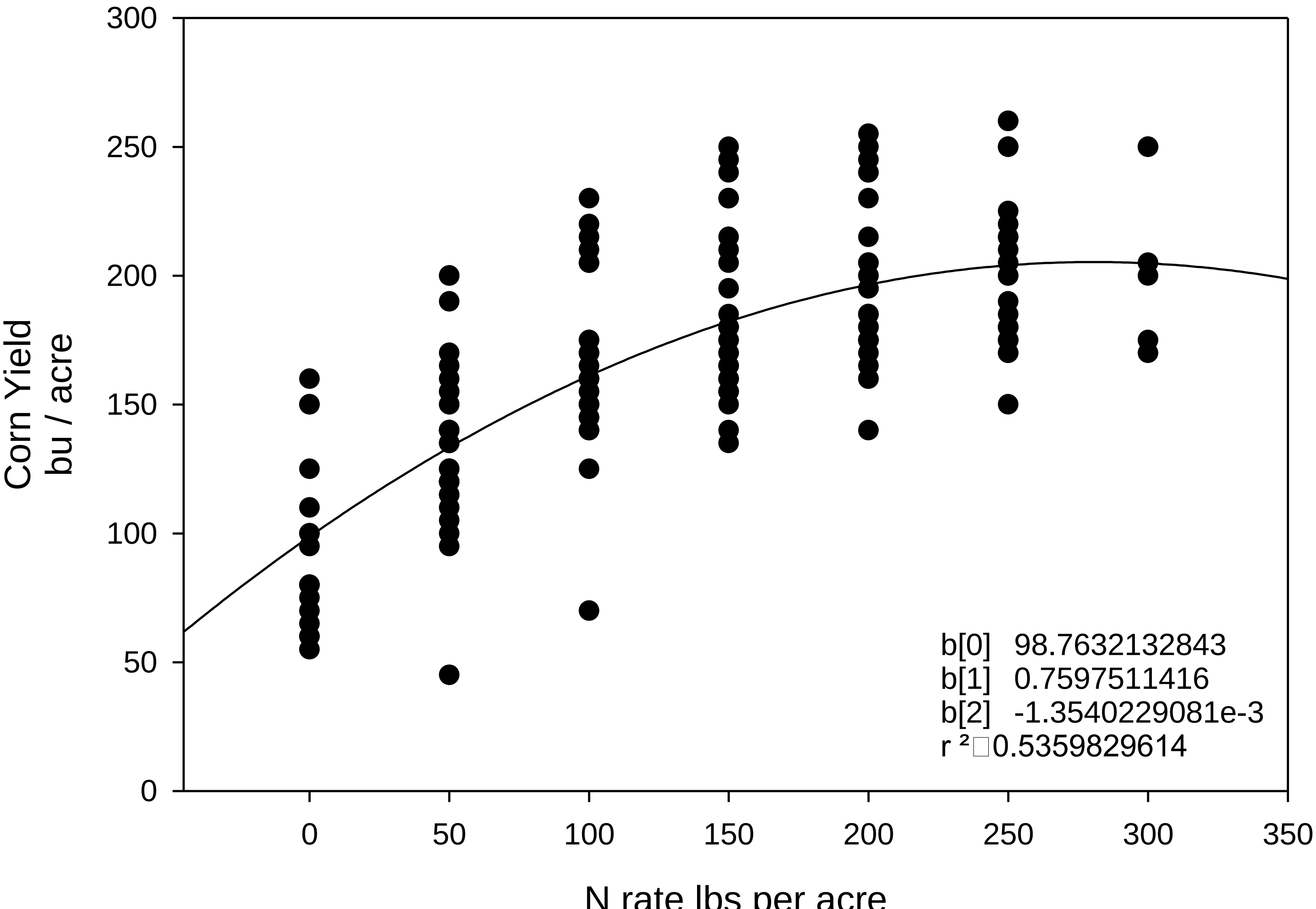
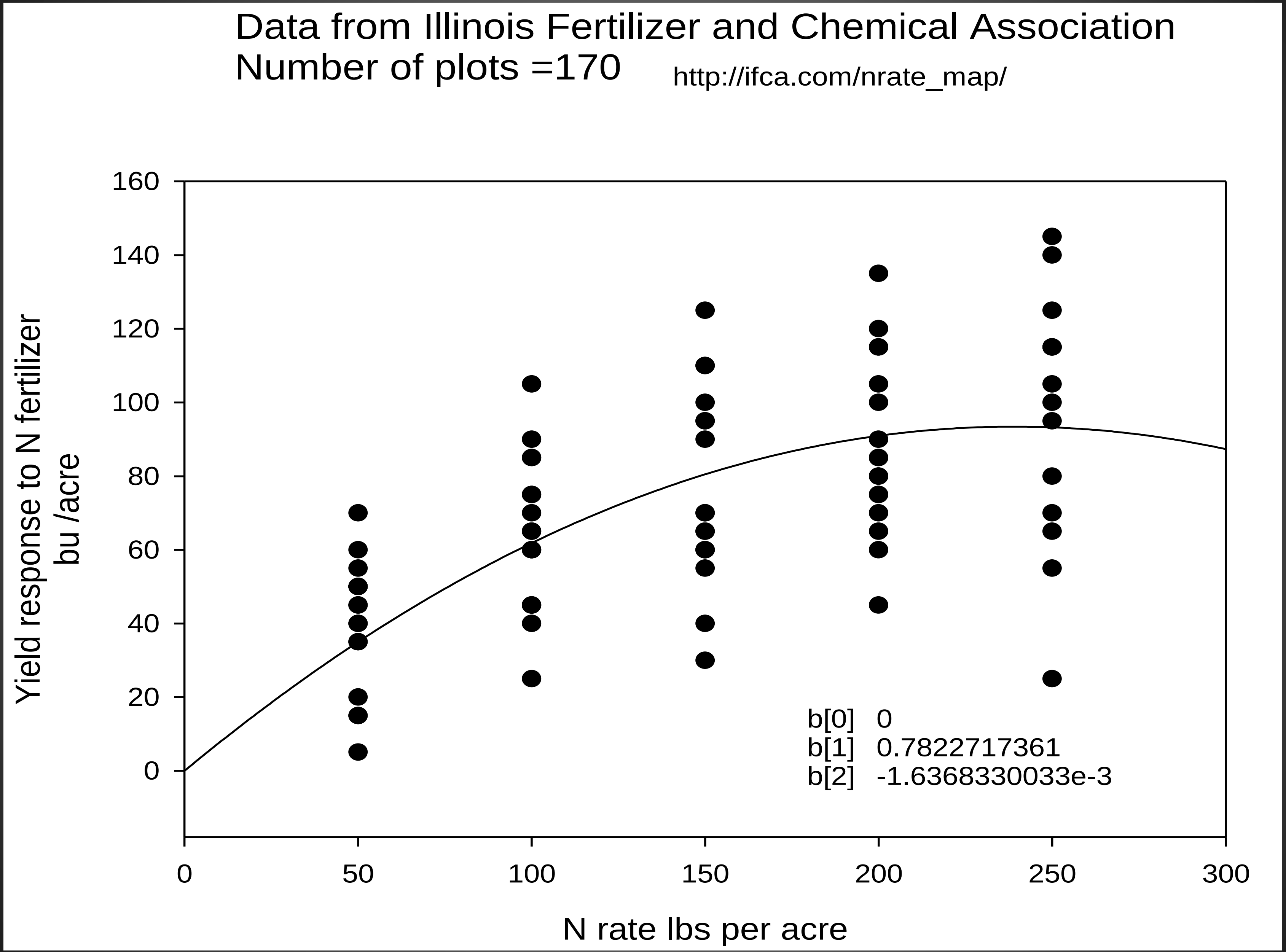


Data from Illinois Fertilizer and Chemical Association
Number of plots =170 http://ifca.com/nrate_map/




Data from Illinois Fertilizer and Chemical Association
Number of plots =170
http://ifca.com/nrate_map/
160
140
120
100
80
60
40
20
0
Yield response to N fertilizer
bu /acre
b[0] 0
b[1] 0.7822717361
b[2] -1.6368330033e-3
0
50
100
150
200
250
300
N rate lbs per acre

Soil Test Calibration

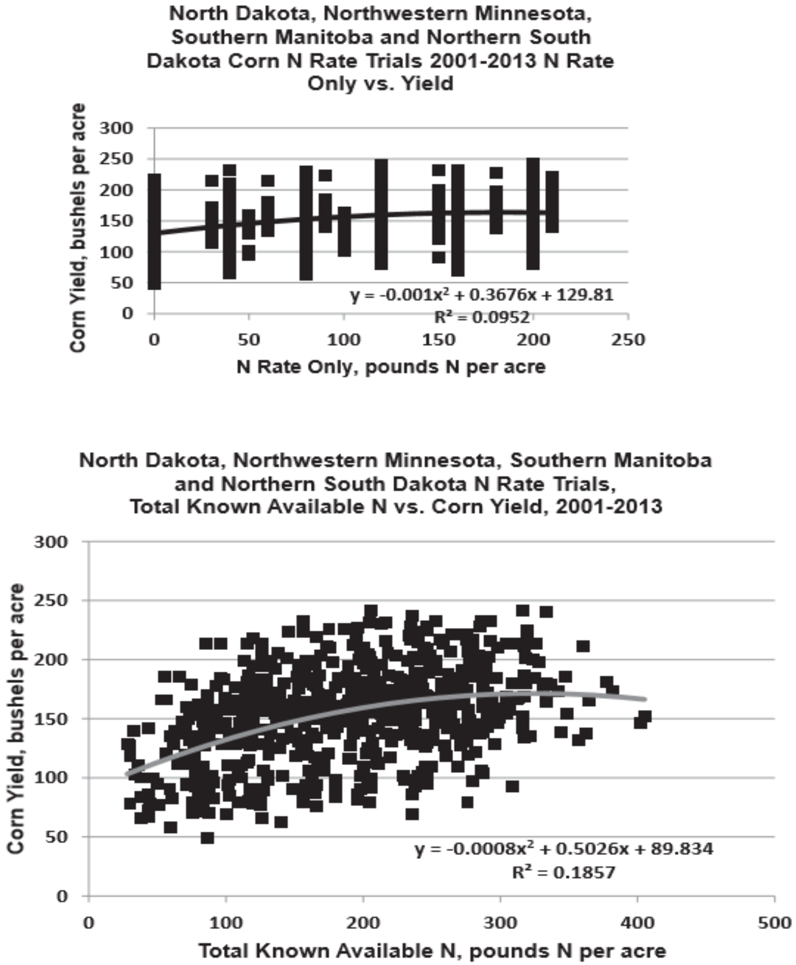
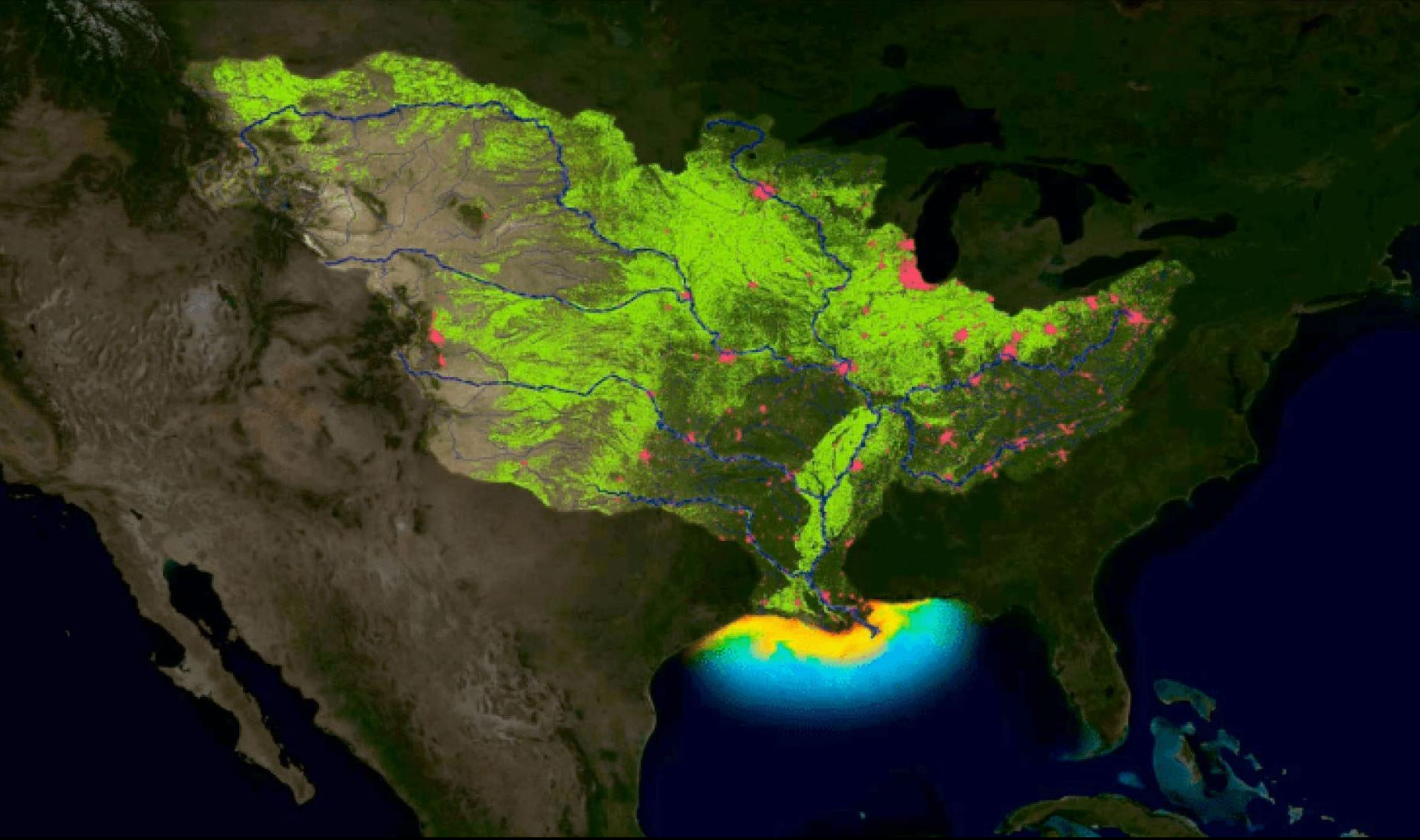


Figure 1. All data from North Dakota, Minnesota, Manitoba and South Dakota relating corn yield to N rate only (top) or N rate with soil nitrate analysis to 2 feet in depth (below).



Dead Zone in Gulf: 8500 square miles in 2019

Paradigm shift

How it's tested: Soil NPK

- As a non-living non-integrated system
- Focus on physical and chemical
- Ignore the biological
- Extract soil with chemistry that soil never sees
- Measure the house and not the food

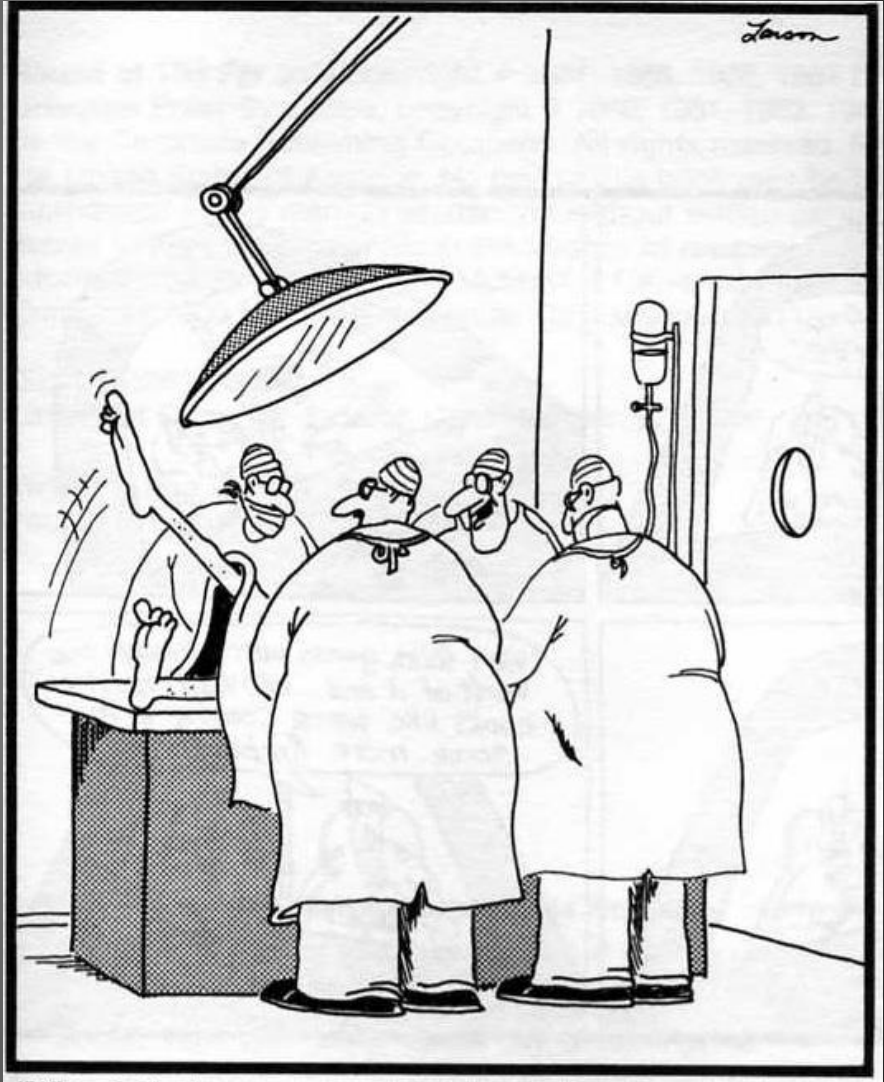
Soil Testing

We are trying to mimic how the soil responds after rainfall in the ***field,*** not how it responds to 30-60 year old lab methods.

Soil Health Tool

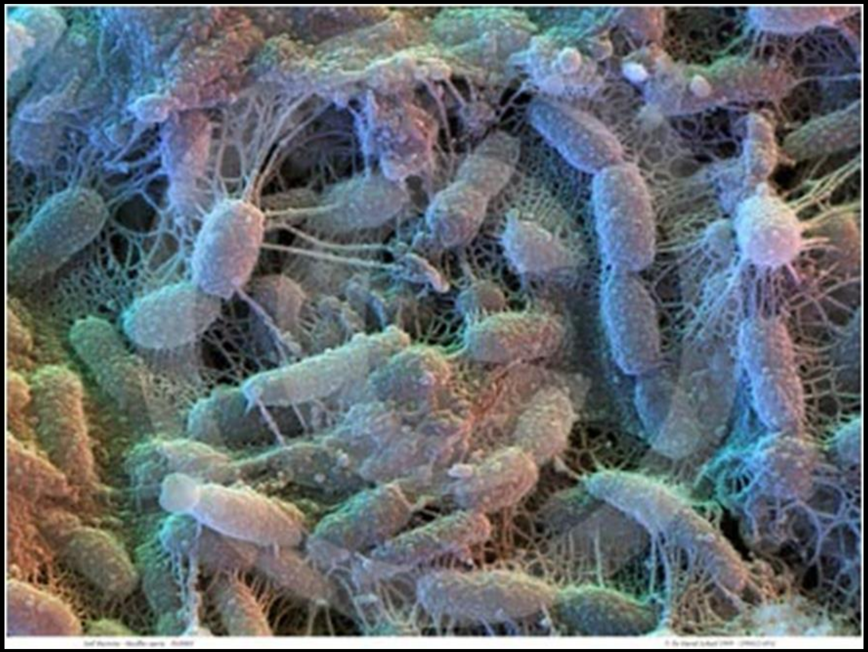
Measure soil health by asking our soil the following questions:

- What is your condition?
- Are you in balance?
- What can we do to help?

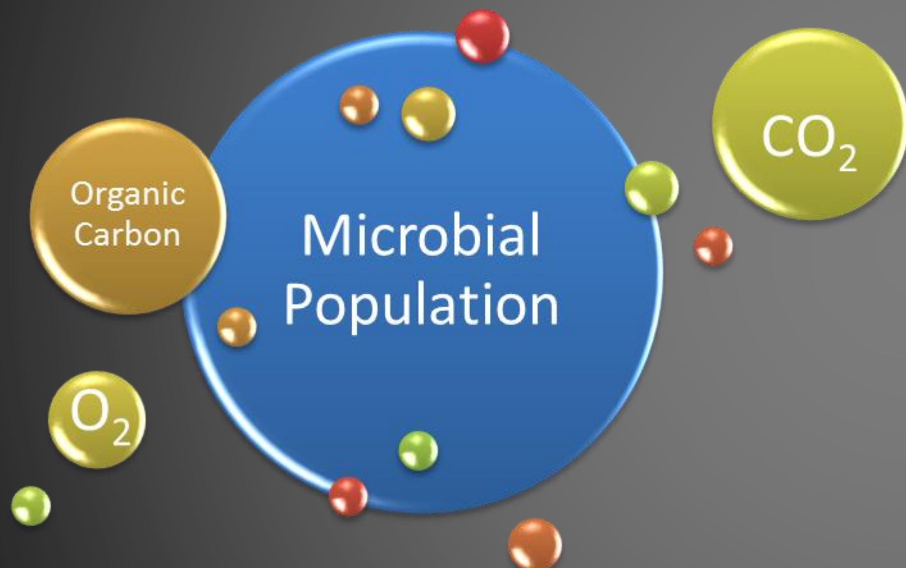


"Whoa! *That* was a good one! Try it, Hobbs — just poke his brain right where my finger is."

Soil bacteria and fungi



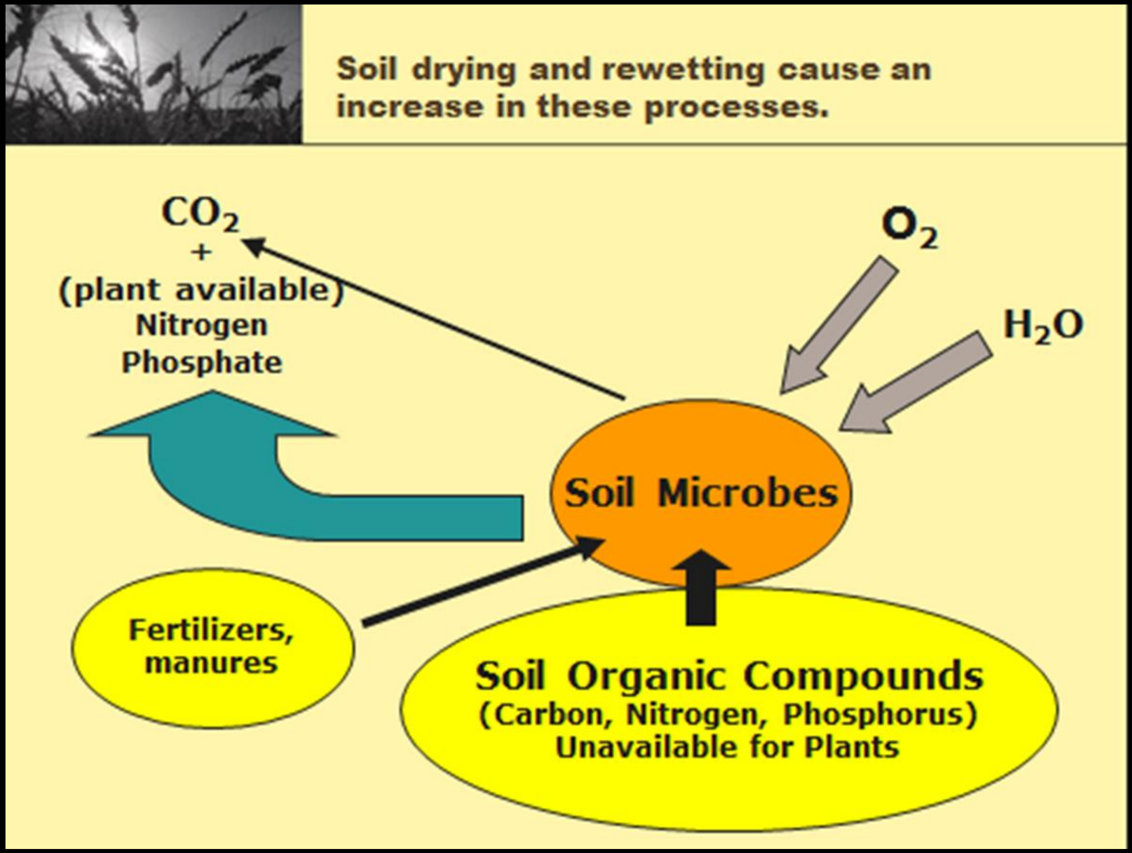
An Incredibly Dynamic Living System



- Soil microbes require **organic carbon** compounds for **growth and energy**
- Soil microbes take in O_2 and release CO_2
- This CO_2 release is coupled with **energy production, nutrient cycling and microbial growth**

Soil microorganisms have been in R&D for millions of years.

Nutrient Cycle



Soil drying and rewetting

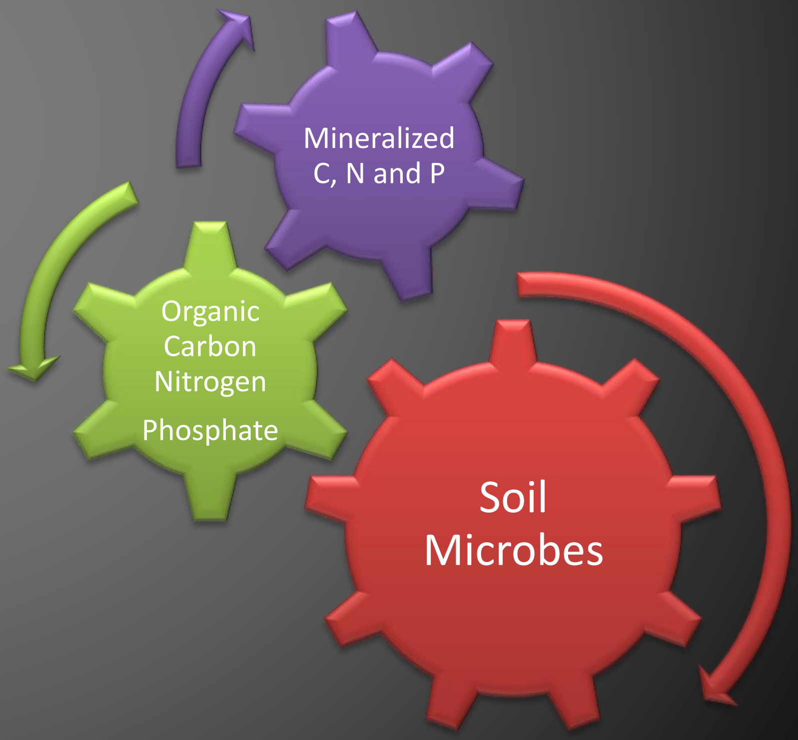
- The majority of nutrient cycling is due to the drying/rewetting effect
- Laboratory analysis does not account for this process
- Plants turn greener after it rains due to the release of N and P, not just the water

Soil Health Methods

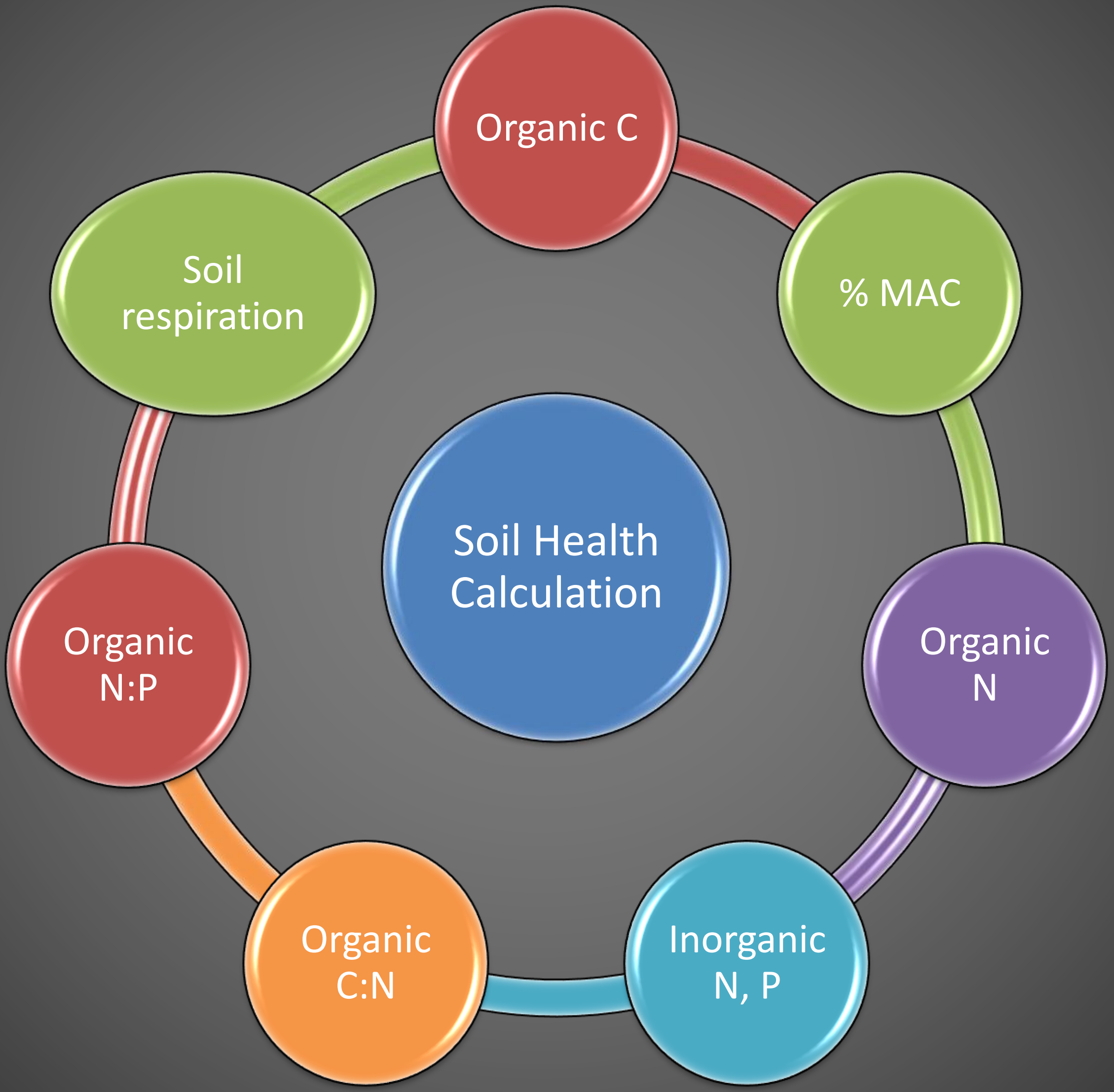
The SHNT is geared towards soil microbial activity and the readily available substrate that they act upon. In other words, we assess the soil as a living system, using many measurements of health viewed collectively to attain an overall picture of soil vigor.

The measurements include:

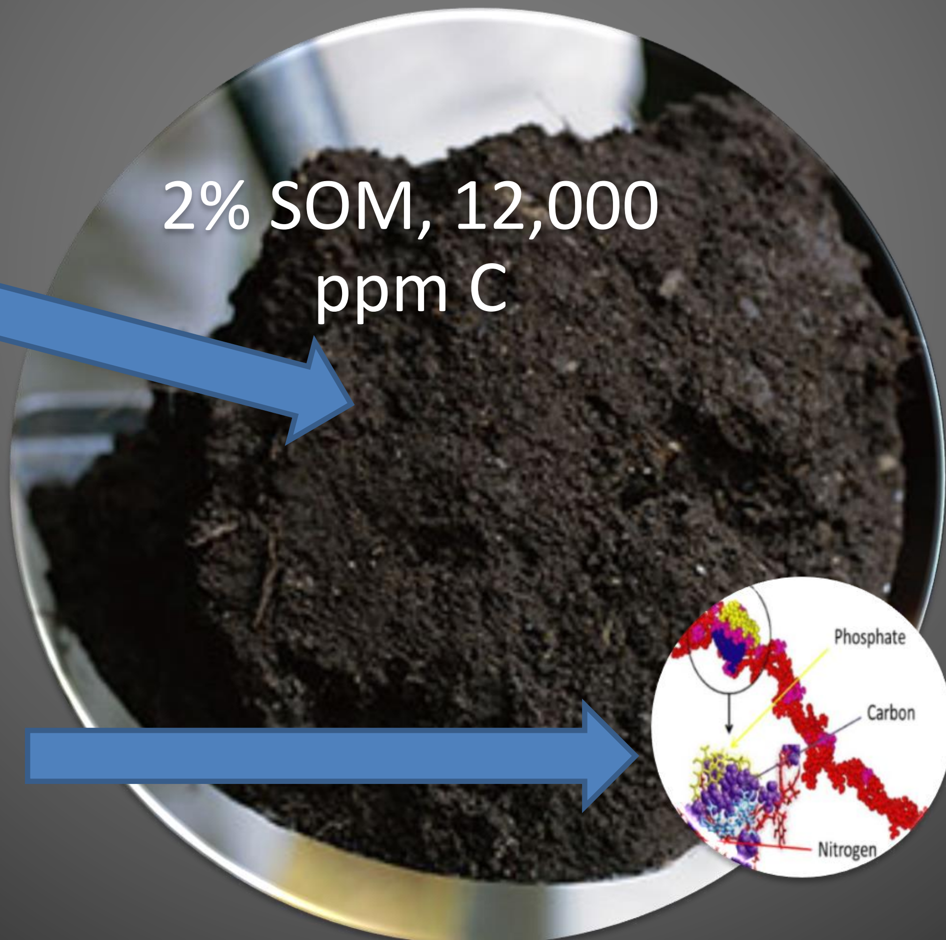
- Water extractable organic C (WEOC)
- Water extractable nitrogen (WEN)
- Water extractable organic N (WEON)
- C: N ratio of the two
- Soil microbial respiration
- Inorganic N and P and K
- H3A extractable Al, Fe, K, Ca, and P.



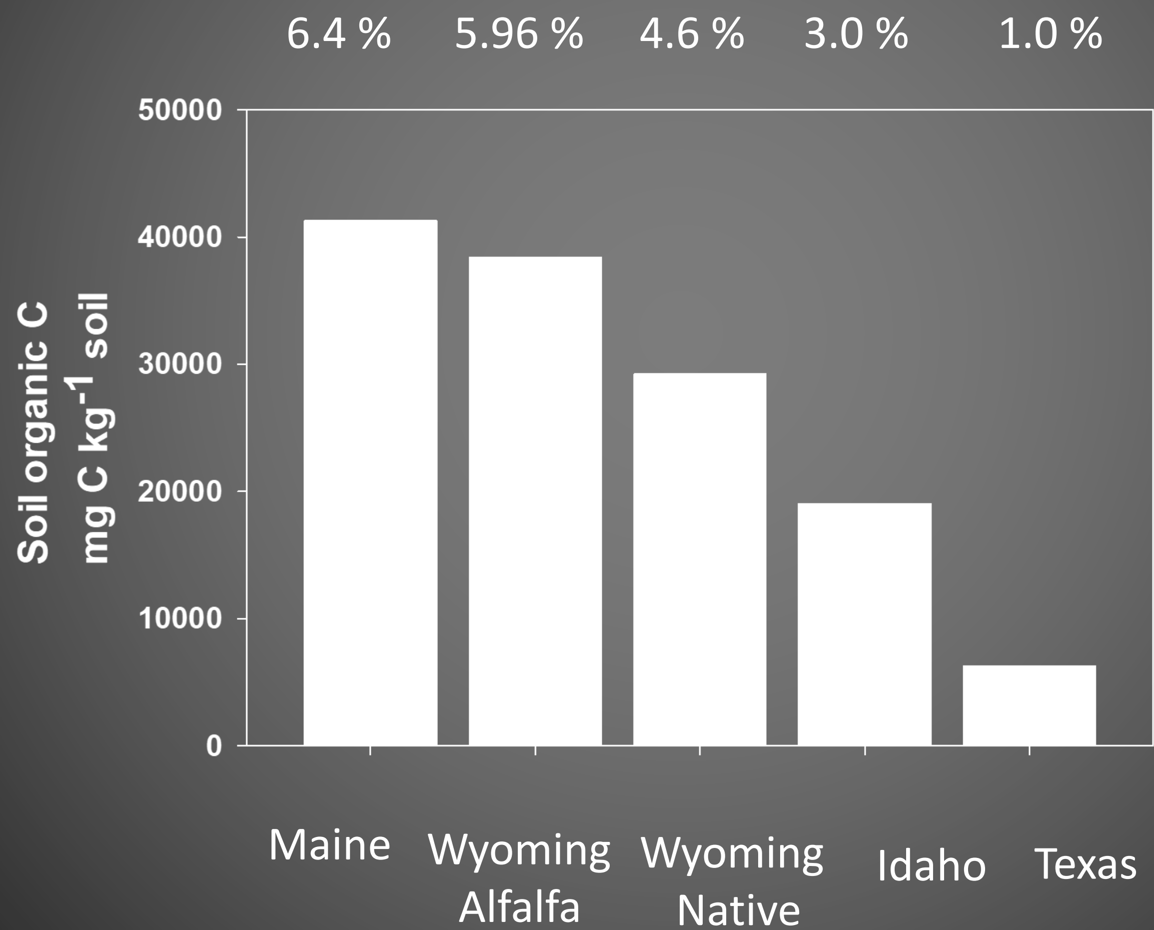
Soil Health Integration



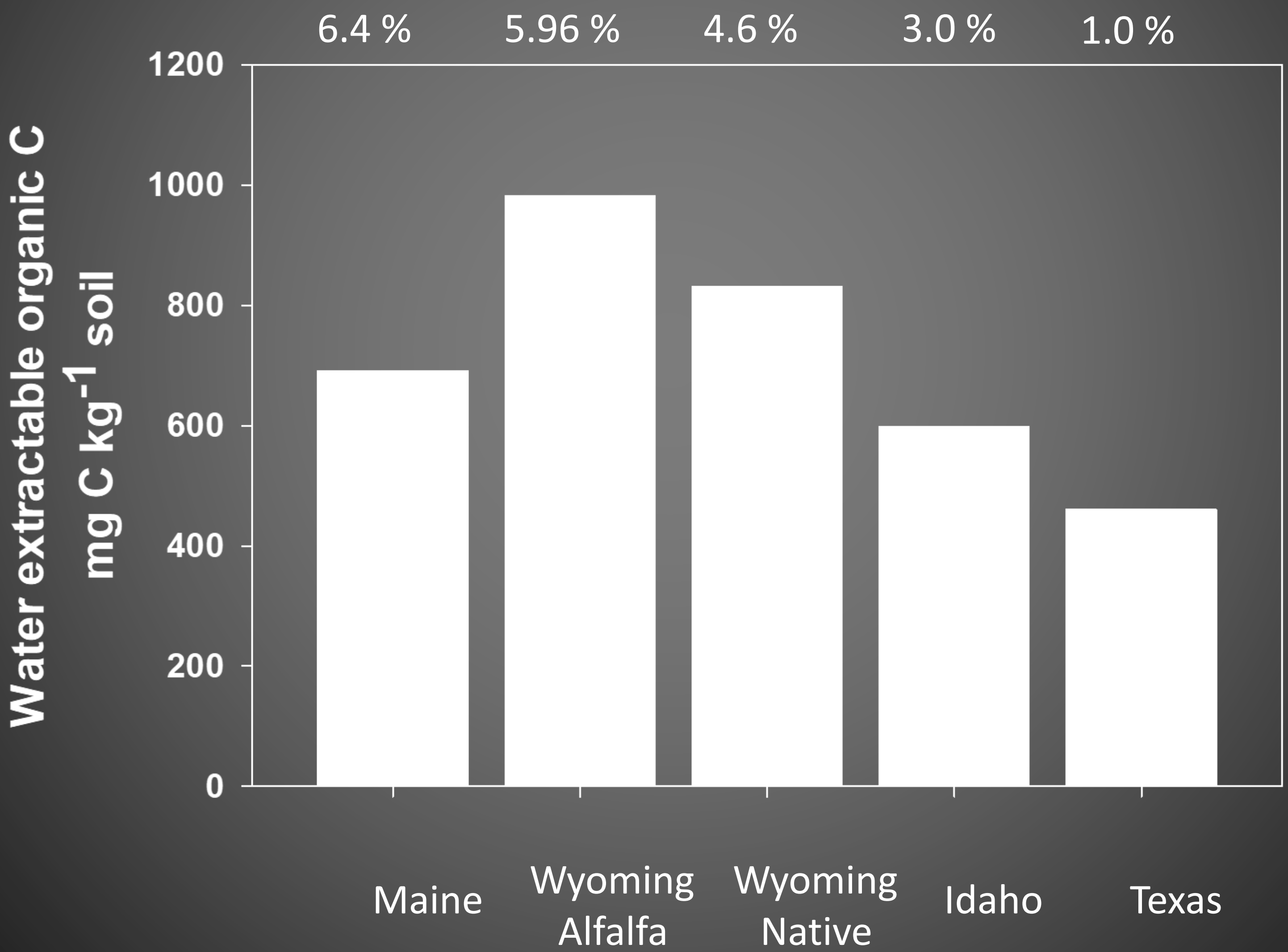
Soil Organic Matter is the "House" microbes live in, Water Extractable Organic Carbon is the "**Food"** they eat.



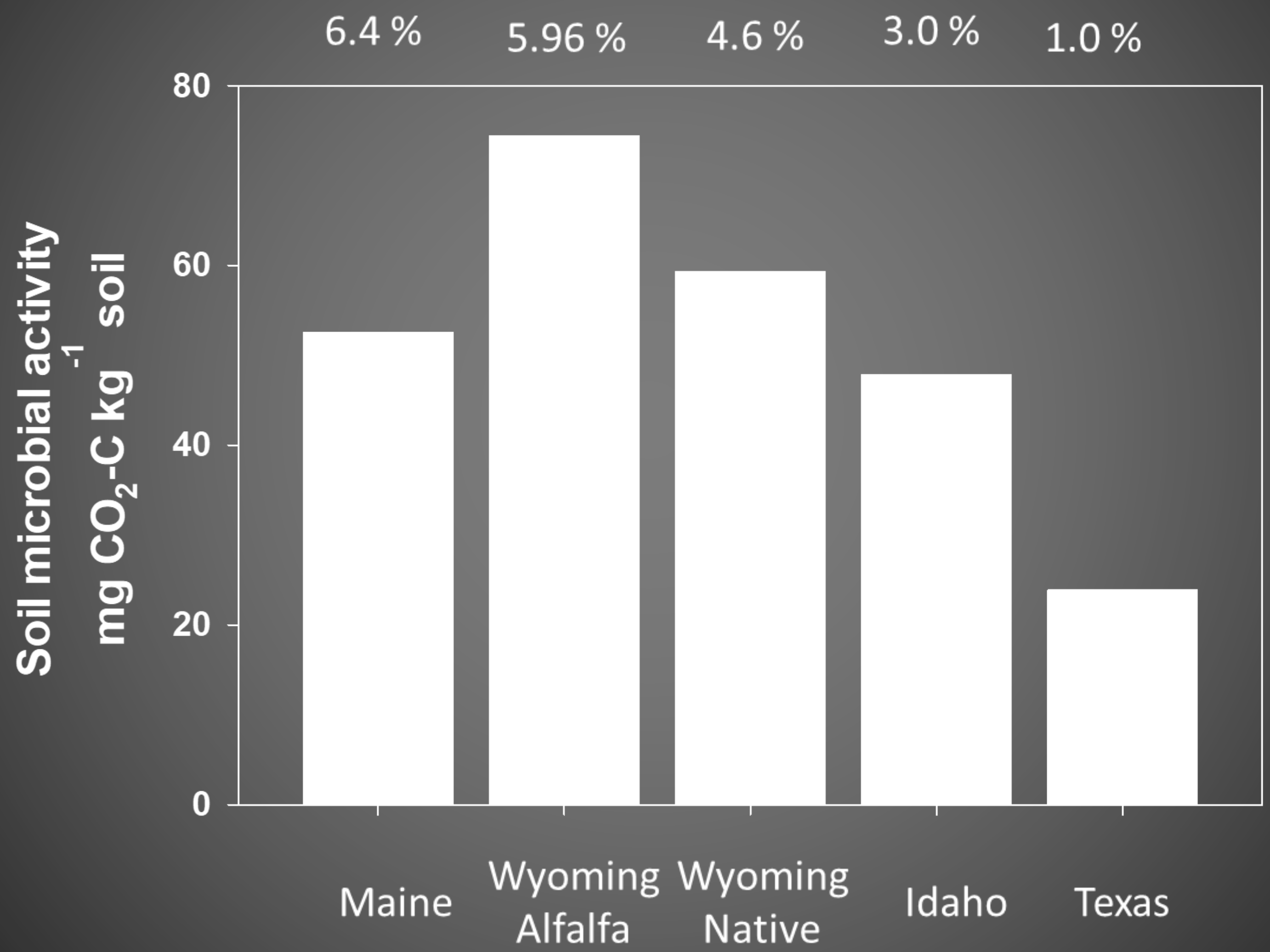
Soil Organic C (%OM)



Soil Organic C (water extract)



Soil Microbial Activity

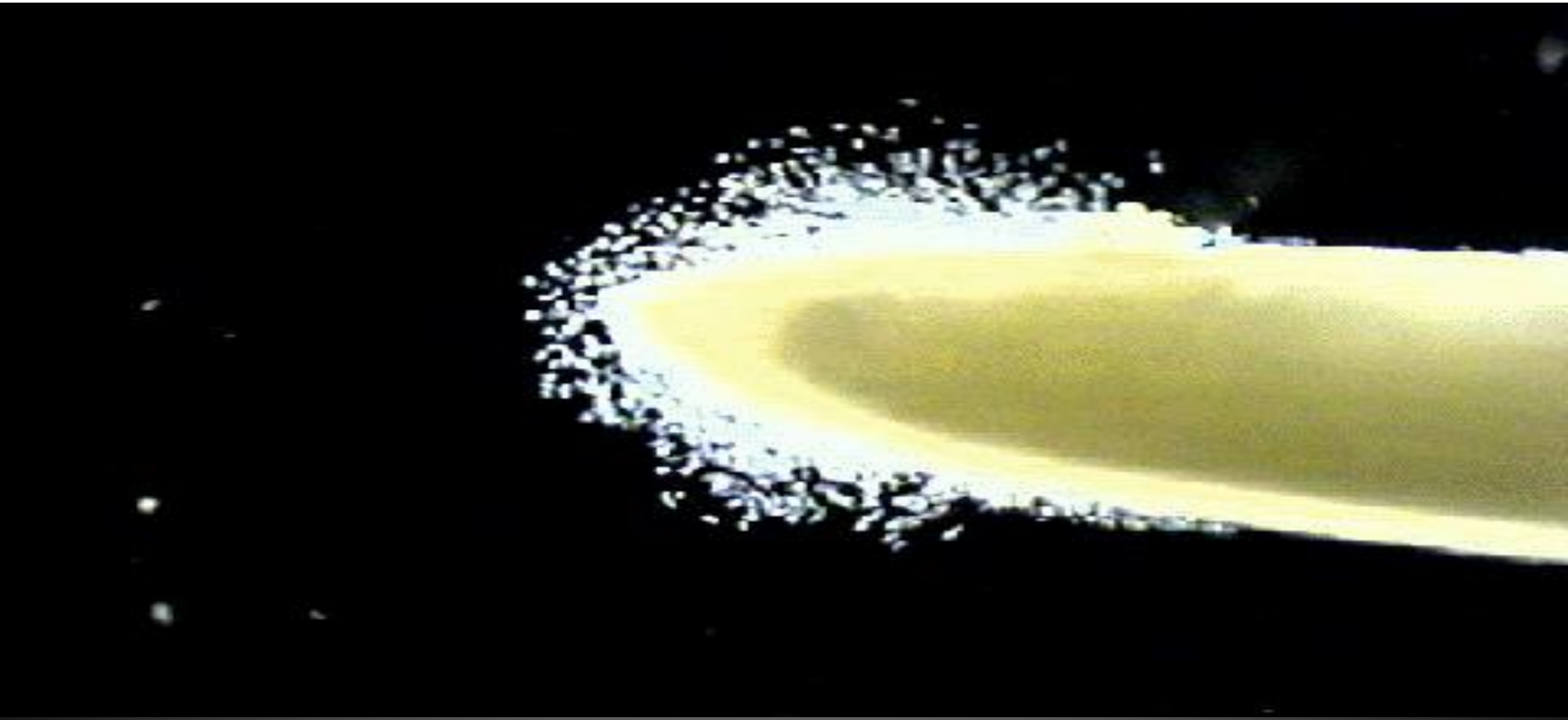


Soil Extraction H3A and Water

What does the plant root really see?

- **WATER and a complex mixture of plant root exudates along with microbial derived enzymes and nutrients**
- **The root system flows with elegance and complexity**
- **We extract soil with highly disruptive acidic or alkali solutions and call it "plant available"**

Liquid Sun



About 20% of the carbon fixed by the plant (photosynthesis) is exuded from the roots into the soil environment.

Phosphate

- **Current labs**

1. ICP P or PO4-P using 7 different extractants

- **Soil Health**

1. ICP P
2. PO4-P
3. H3A (mimics plant root exudates)
4. Soil respiration
5. Org C:N
6. P min
7. % water P/ H3A P
8. % P/ FeAl
9. Ca/FeAl

Nitrogen

- **Current labs**

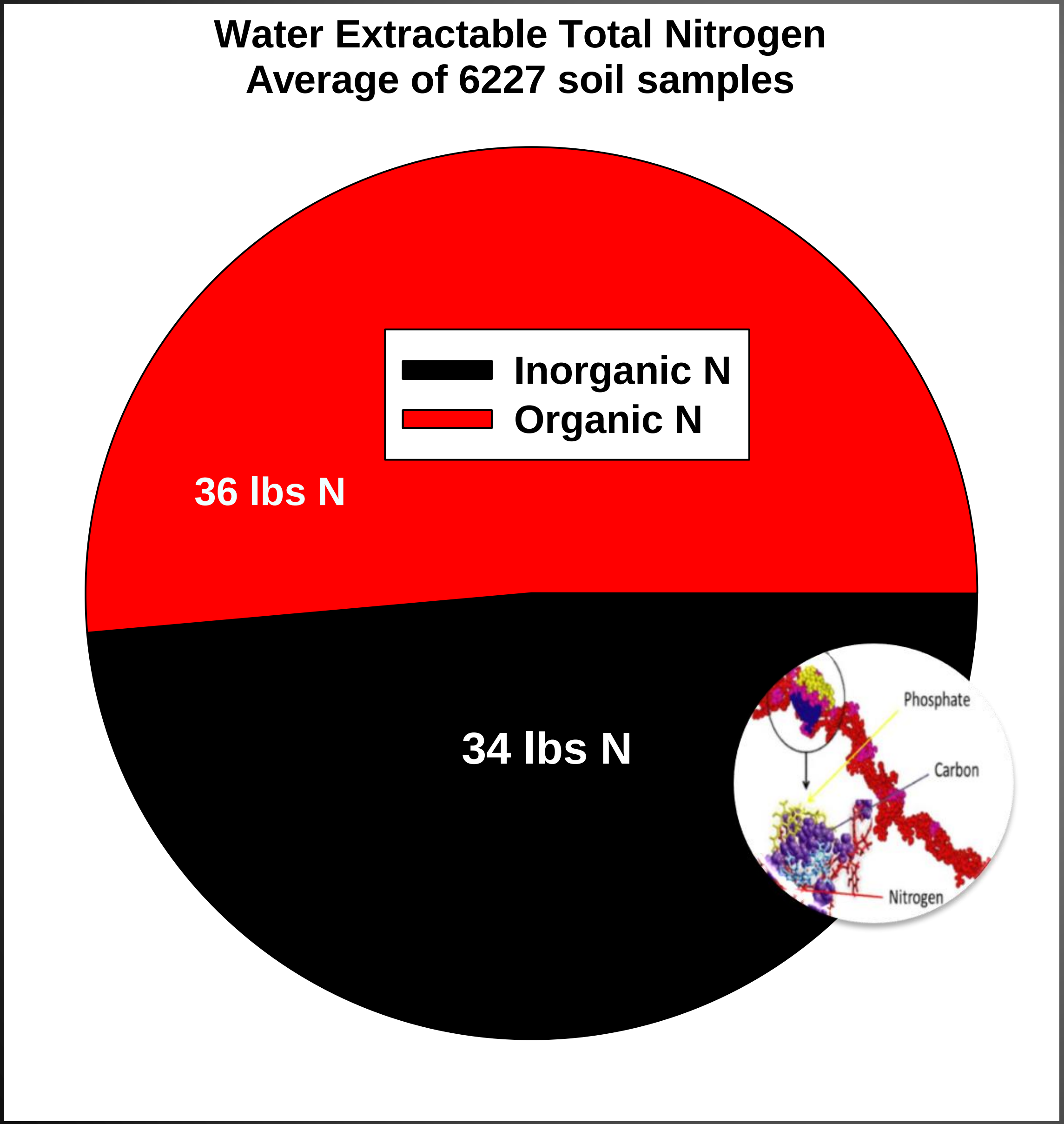
1. NO3-N
2. 2 M KCl (1965)
3. None

- **Soil Health Tool**

1. NH4-N
2. NO3-N
3. WETN
4. Soil respiration
5. Org N
6. Org C:N
7. MAC WEON
8. N min
9. Water

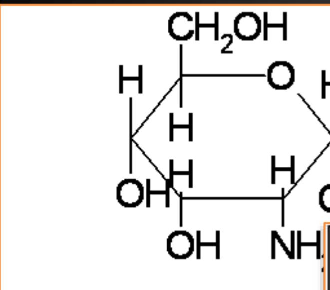
Since 1965* we have been missing half of the N

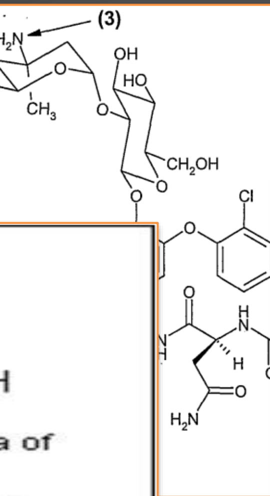
*2M KCl 1965 Bremer

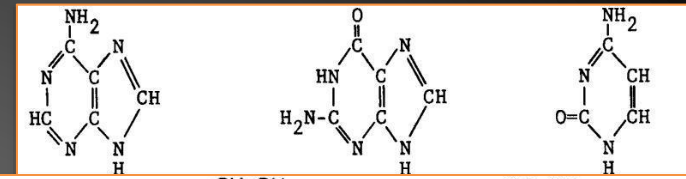


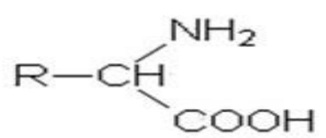
How can we "calibrate" a soil test when we miss half of what we are looking for?

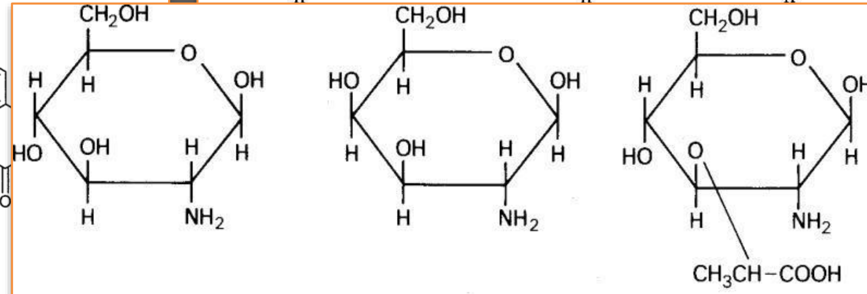
NO_3-N

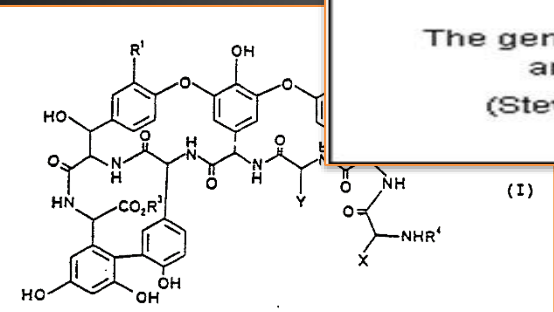

Molecular Structure

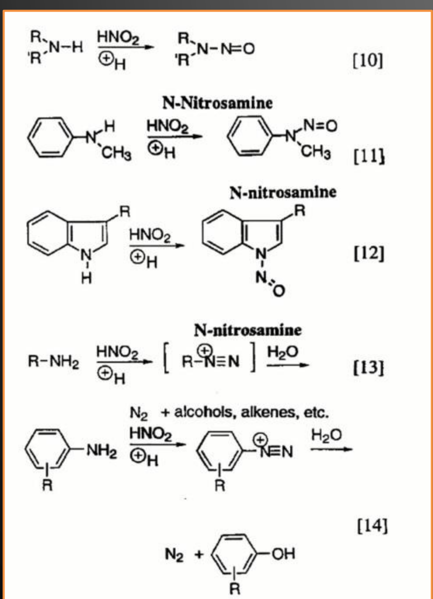


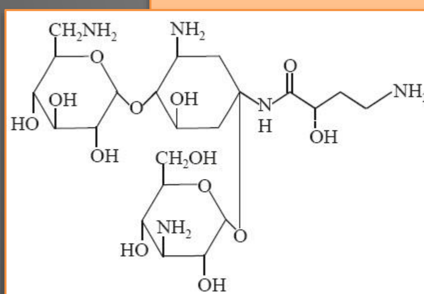


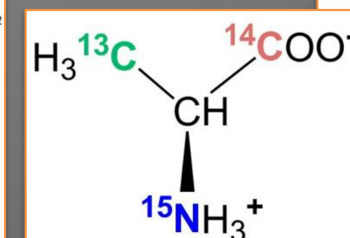

The general formula of amino acids.
(Stevenson 1982)

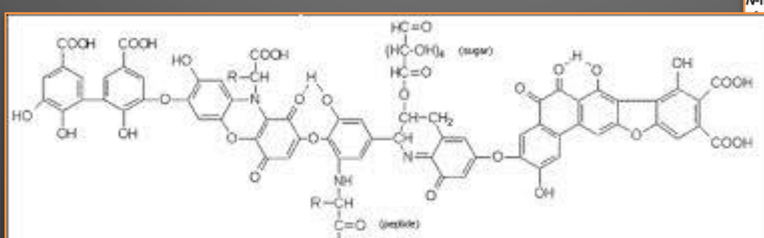

β-D-Glucosamine β-D-Galactosamine β-Muramic acid (3-O-(1-carboxyethyl)-β-D-glucosamine)

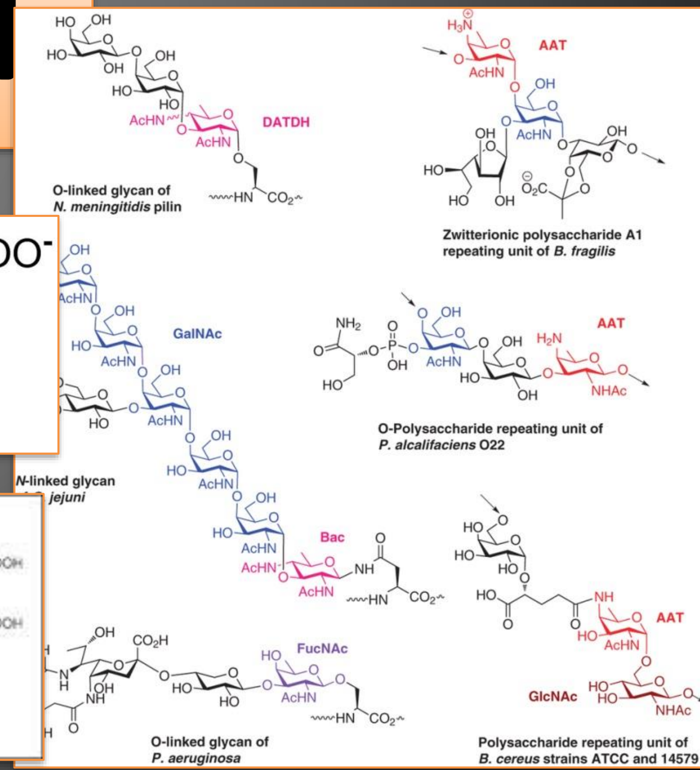


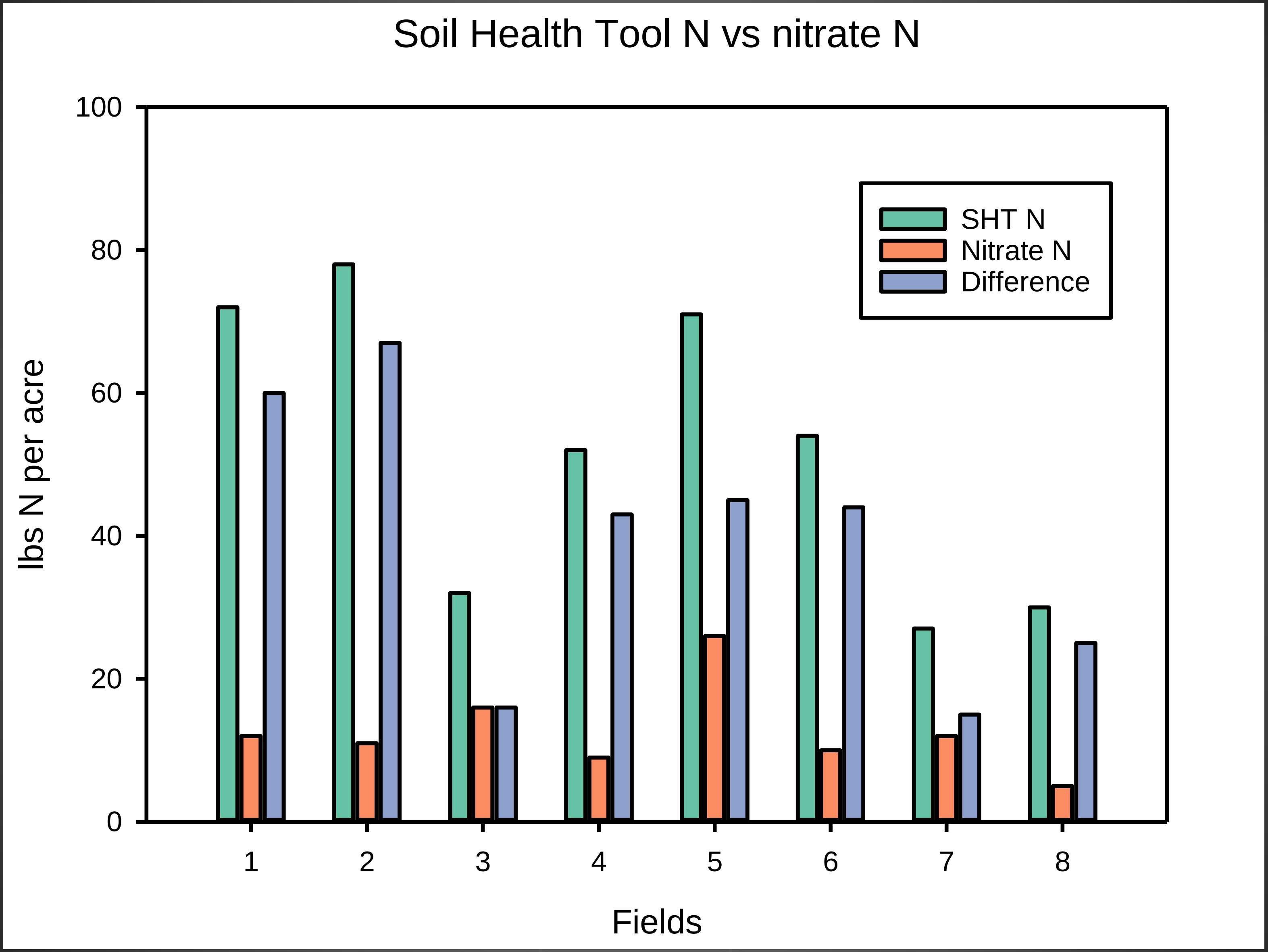



Amikacin



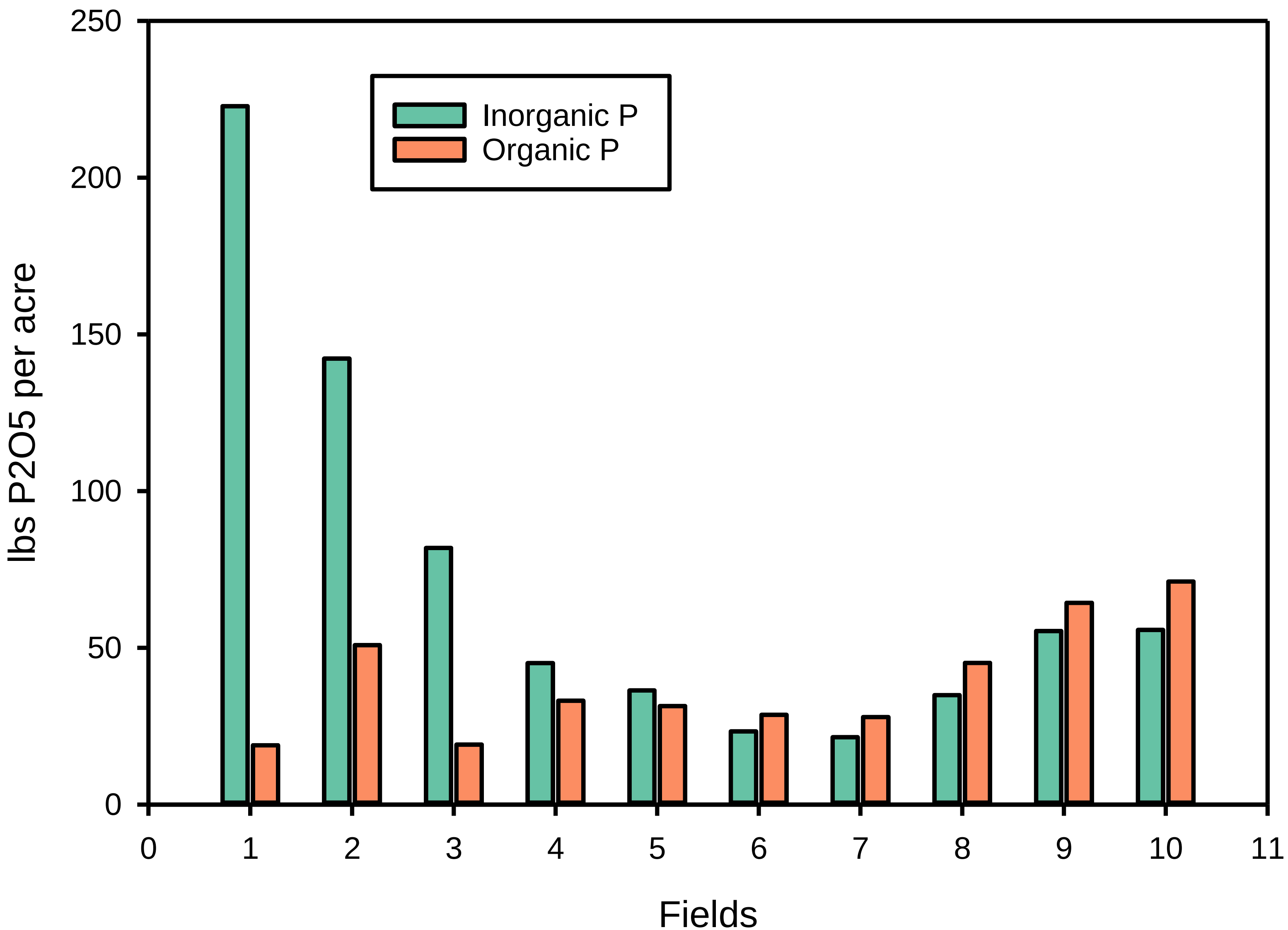

Model structure of humic acid (Stevenson 1982)





Soil Health Tool N vs nitrate N
100
80
60
40
20
0
lbs N per acre
SHT N
Nitrate N
Difference
1
2
3
4
5
6
7
8
Fields

Soil Health Tool Inorganic P vs organic P



2014 Soil Health Tool results2.xlsm - Microsoft Excel

File | Home | New Tab | Insert | Page Layout | Formulas | Data | Review | View | Developer | Add-Ins

C17

	Q	R	S	T	U	V	W	X	Y	
1	1-day CO2-C	Organic C	Organic N	Organic C:N	Soil Health Calculation	Cover crop mix	**Total Nitrogen lbs\acre**	Inorganic N	Organic N	**Total**
2	63.4	273.3	32.3	8.5	12.3	40% Legume 60% Grass	81.4	16.7	64.6	
3	238.6	345.4	33.3	10.4	29.8	20% Legume 80% Grass	82.1	15.5	66.6	
4	16.2	212.4	26.0	8.2	6.3	50% Legume 50% Grass	74.7	22.7	51.9	
5	45.3	193.2	22.6	8.5	8.7	50% Legume 50% Grass	58.2	13.0	45.3	
6	54.3	231.4	24.1	9.6	10.2	40% Legume 60% Grass	85.9	37.6	48.2	
7	49.3	271.2	29.7	9.1	10.6	40% Legume 60% Grass	74.4	14.9	59.5	
8	17.5	130.4	13.8	9.4	4.4	60% Legume 40% Grass	45.0	17.4	27.6	
9	27.5	179.5	19.6	9.2	6.5	50% Legume 50% Grass	47.8	8.6	39.2	

NPK | GraphIt

Ready

2014 Soil Health Tool results2.xlsm - Microsoft Excel

	C	D	E	F	G	H	I	J	K	L	M	N	O
1	N lbs per acre	P2O5 lbs per acre	K2O lbs per acre	Nutrient value per acre		Crop	Yield Goal	lbs N needed	lbs P2O5 needed	lbs K2O needed	NO3-N Only lbs per acre 70%	Additional N lbs per acre	$ nitrogen saved per acre
2	71.7	59.3	40.9	$111.8	Run	corn	200	118	41	29	11.6	60.1	$42.1
3	77.5	60.5	61.6	$125.7		corn	200	113	39	8	10.7	66.8	$46.8
4	31.8	47.8	26.1	$71.5		corn	200	158	52	44	15.8	16.0	$11.2
5	51.5	31.2	29.1	$70.5		corn	200	138	69	41	9.0	42.5	$29.7
6	71.7	74.1	92.3	$147.5		corn	200	118	26	0	26.2	45.6	$31.9
7	53.8	51.5	52.0	$99.4		corn	200	136	49	18	10.3	43.5	$30.5
8	27.3	175.6	176.1	$244.9		corn	200	163	0	0	11.5	15.8	$11.1
9	30.4	97.3	176.6	$180.4		corn	200	160	3	0	5.3	25.1	$17.6

NPK | GraphIt

Example: Yield Goal of 200 bushel corn

Soil 1

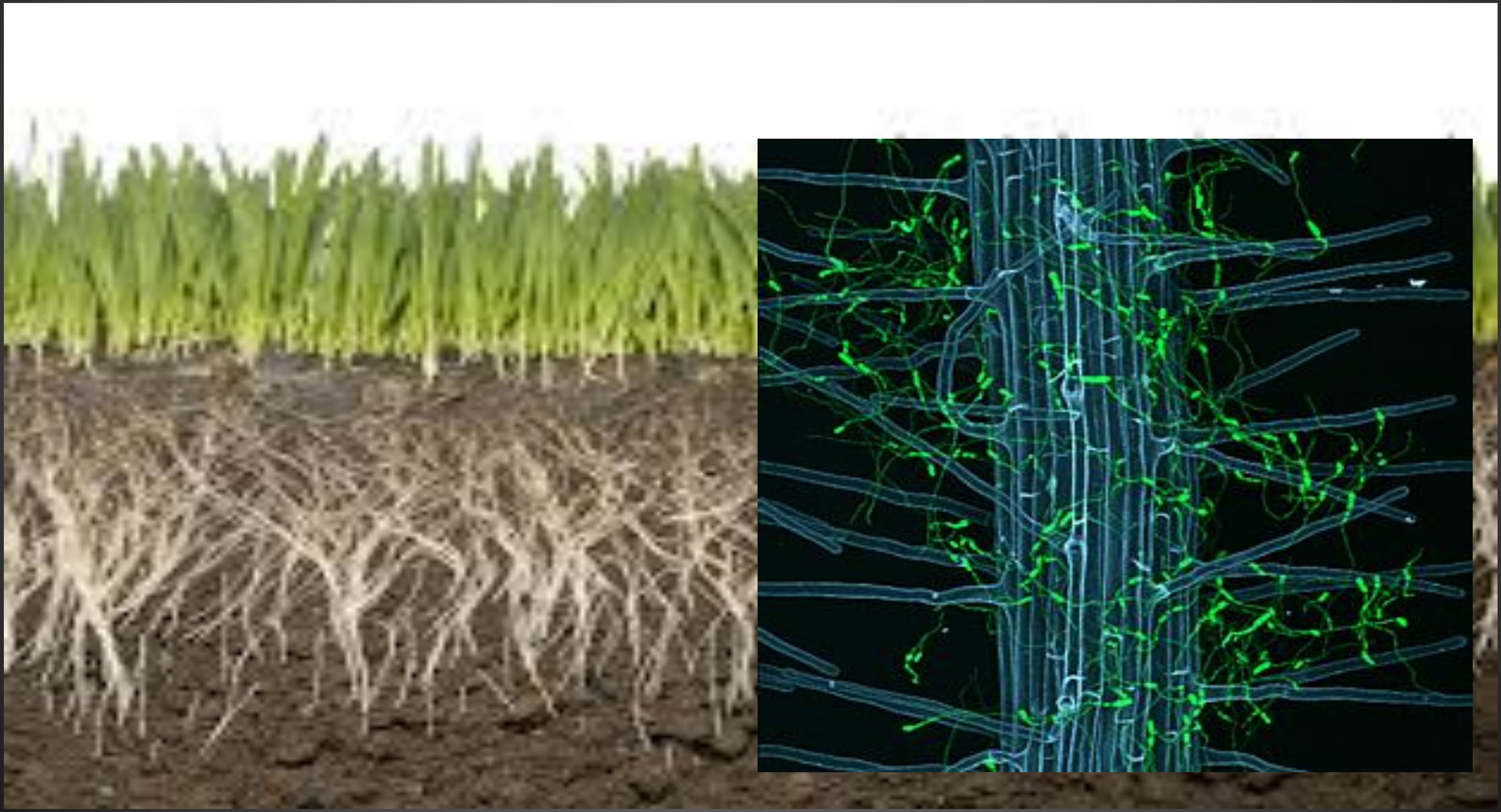
Nitrate nitrogen 20 lbs
Soil respiration 20 ppm
WEOC 200 ppm
WEON 20 ppm
N recommendation 180 lbs
Soil health Score 8.0

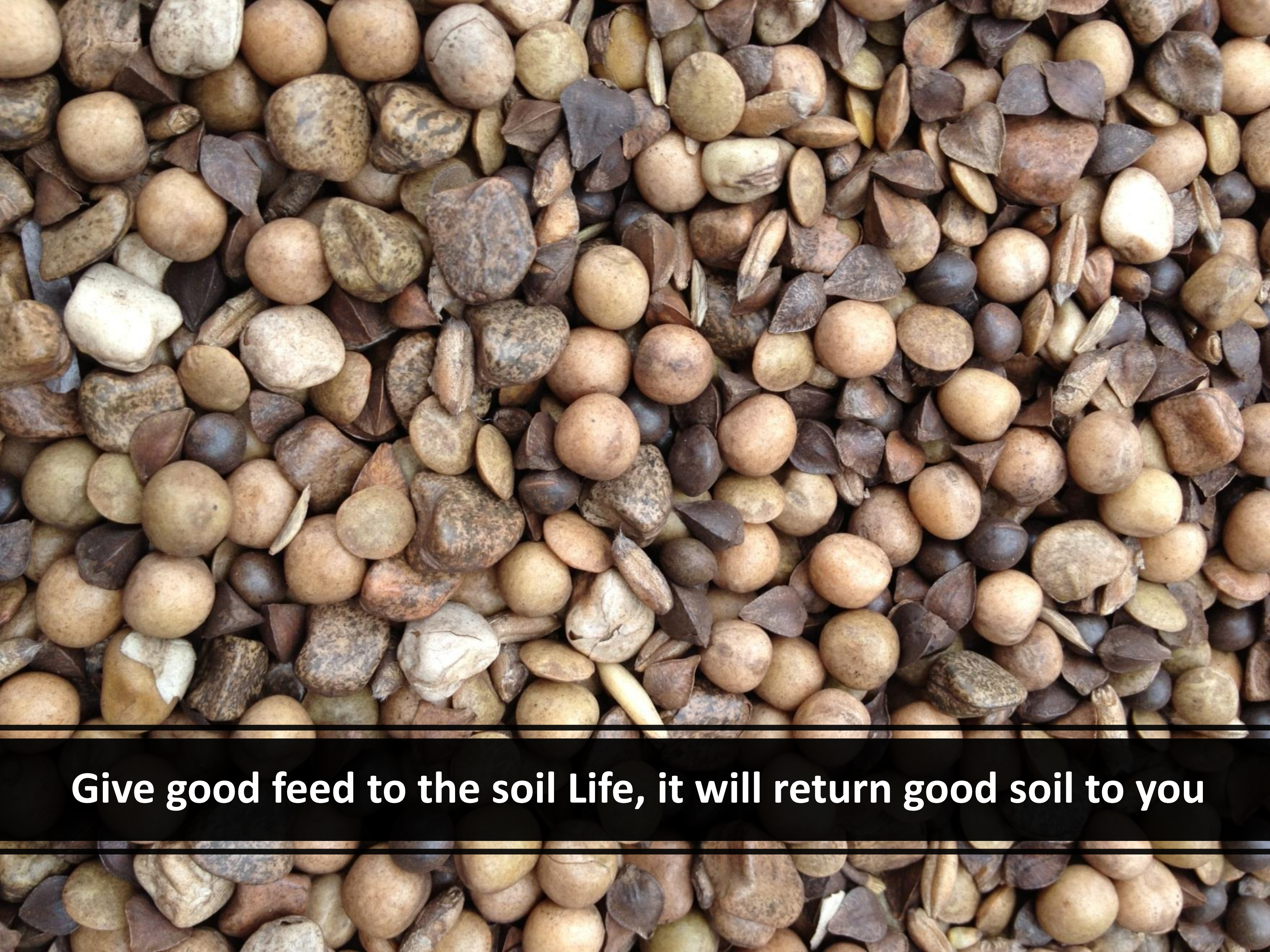
Soil 2

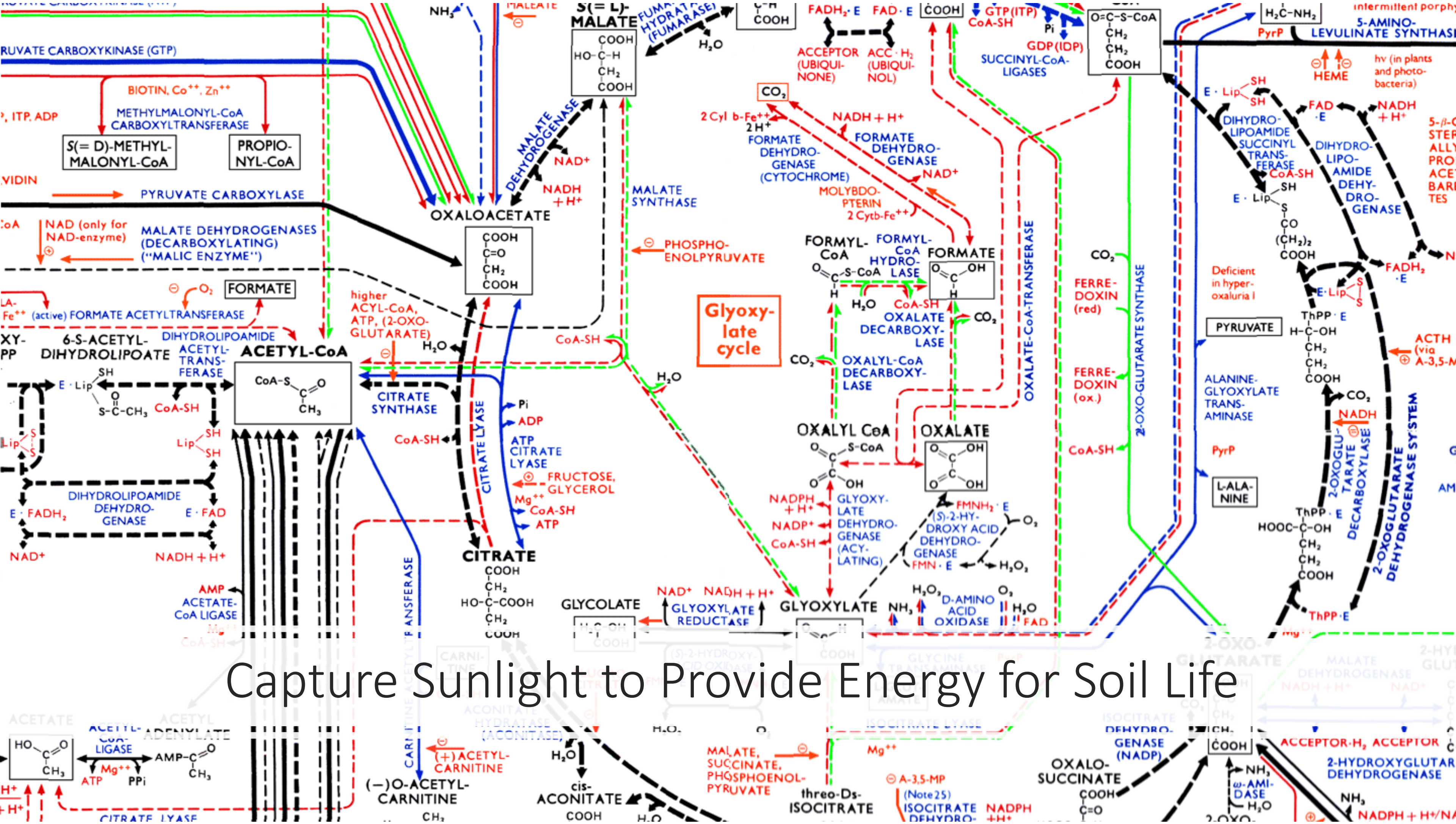
Nitrate nitrogen 20 lbs
Soil respiration 200 ppm
WEOC 400 ppm
WEON 40 ppm
N recommendation 100 lbs
Soil health score 26.0

Cover Crops

Plants fix dirt

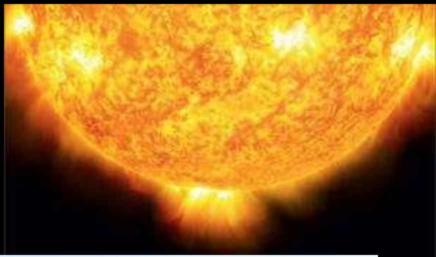



Give good feed to the soil Life, it will return good soil to you



Capture Sunlight to Provide Energy for Soil Life

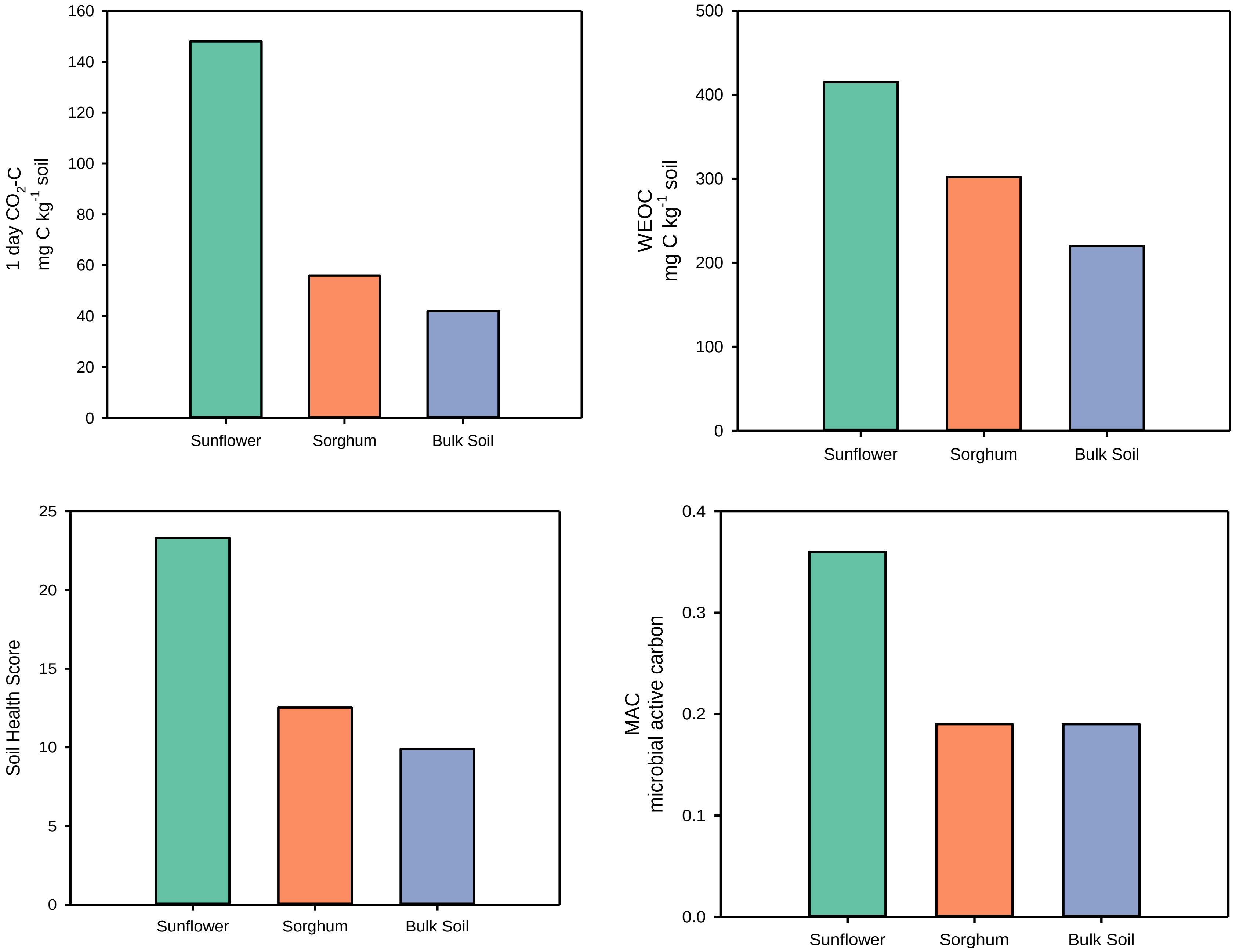
Which Field Captures Solar Energy?



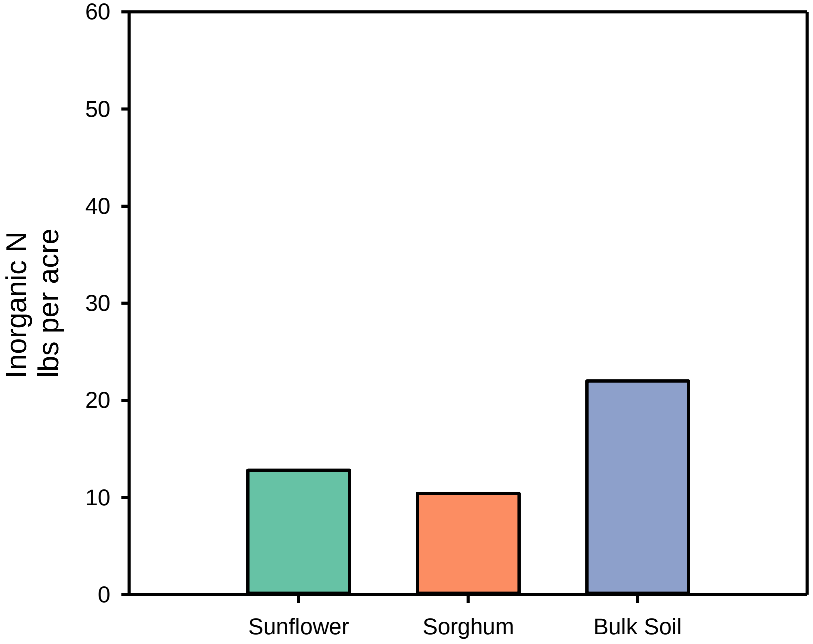

Sunflower Roots

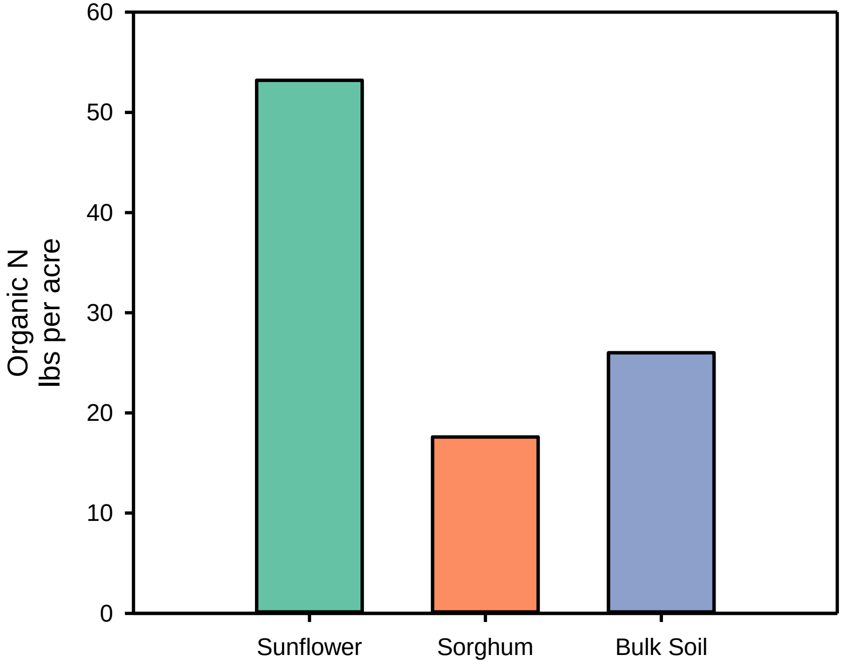

Sorghum Roots

Soil From Root Zone



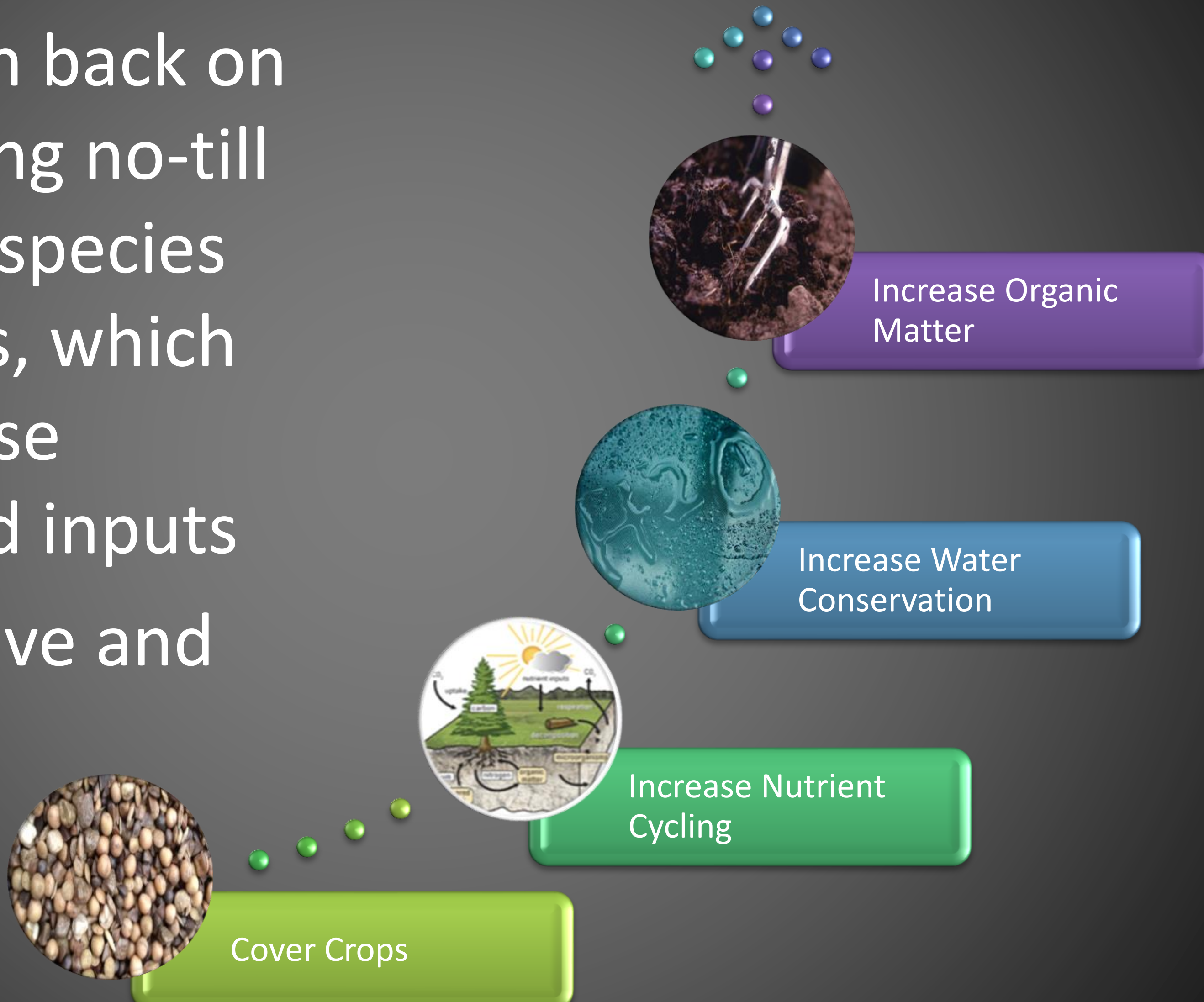
Soil From Root Zone





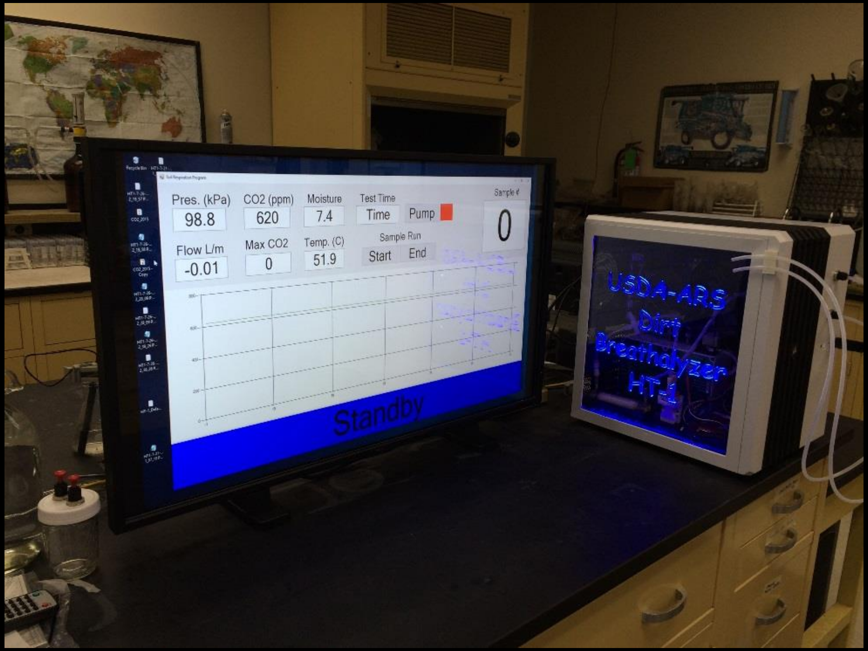
What can we do?

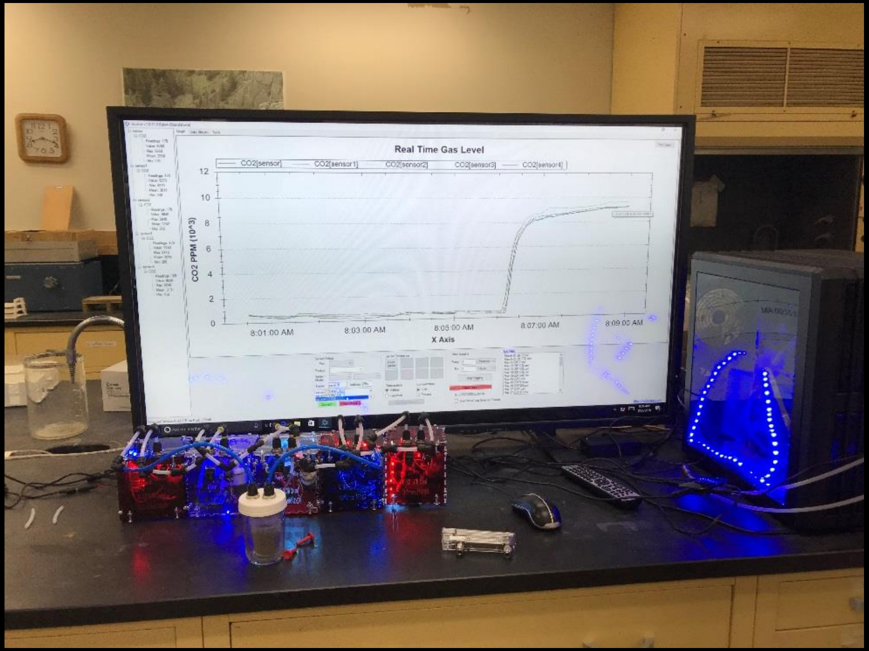
- Put the skin back on the soil using no-till and mixed species cover crops, which will decrease erosion and inputs
- Be innovative and tenacious



Innovation: Cover crop planting in 30 inch rows

Innovation for soil respiration





Working with the Nature

- Why mimic nature?
- It has been doing R&D much, much longer than us
- It fills niches
- It creates balance
- It recycles nutrients
- It conserves water
- It is tenacious

No-till or Conventional-till?

Plant the cover crops

You don't need any test or research to tell you how to help your soil

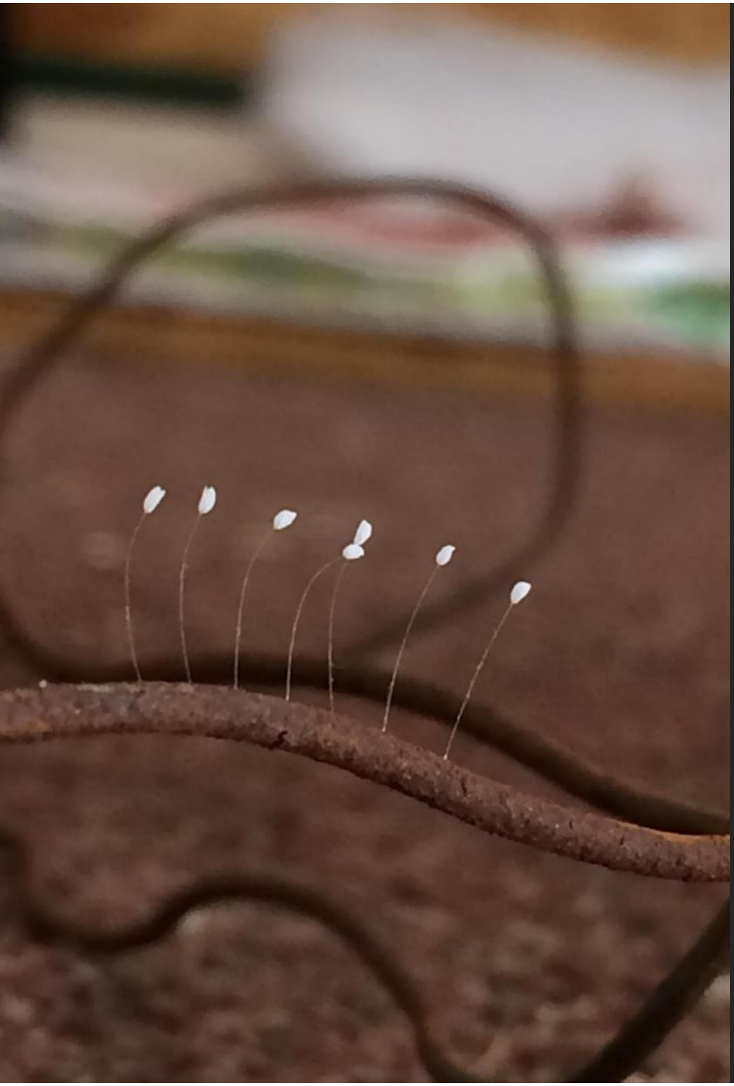
Nature has been showing us the way all along

It is hard to stay excited about research or farming without innovation

Field Research

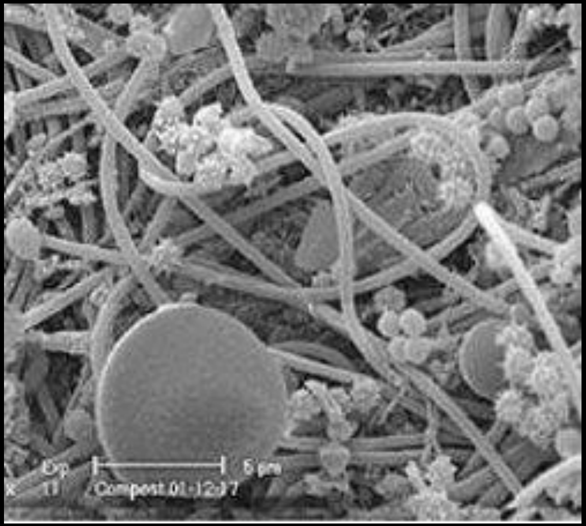
My Conventional-till research field


My No-till research field



Nature finds a way

The End



Contact

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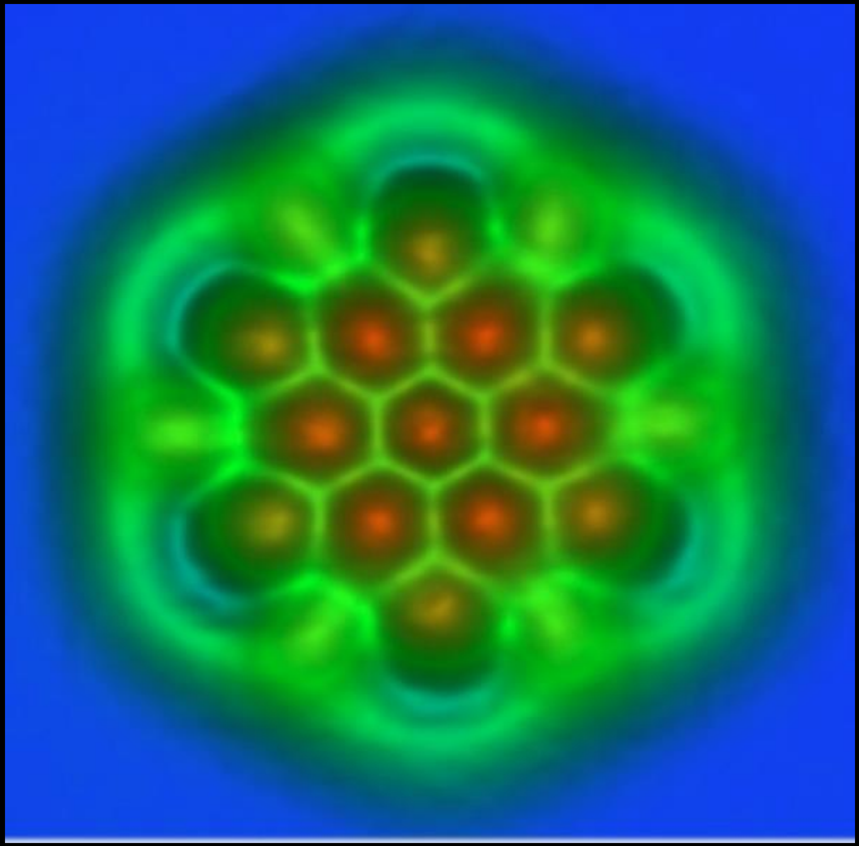
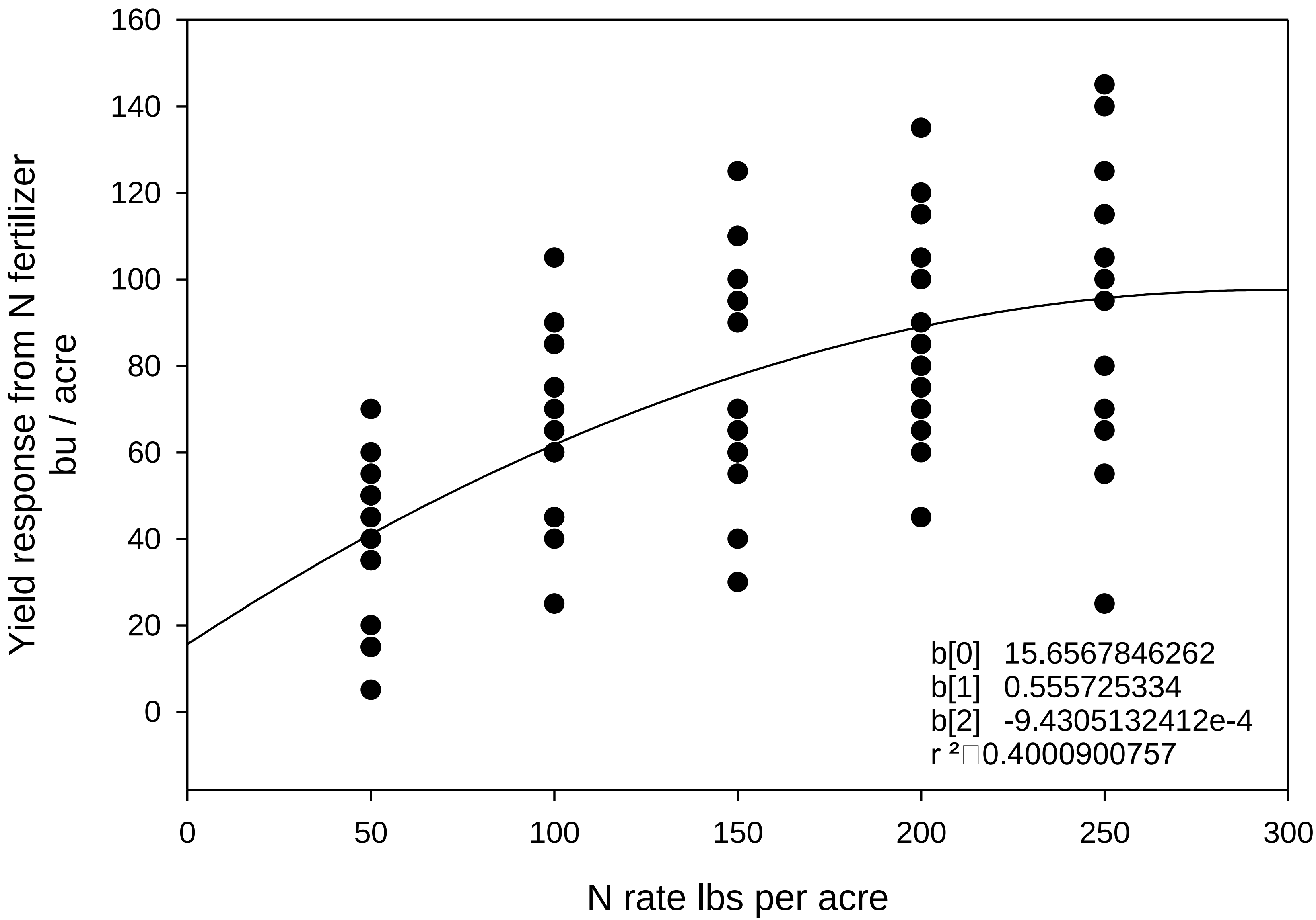
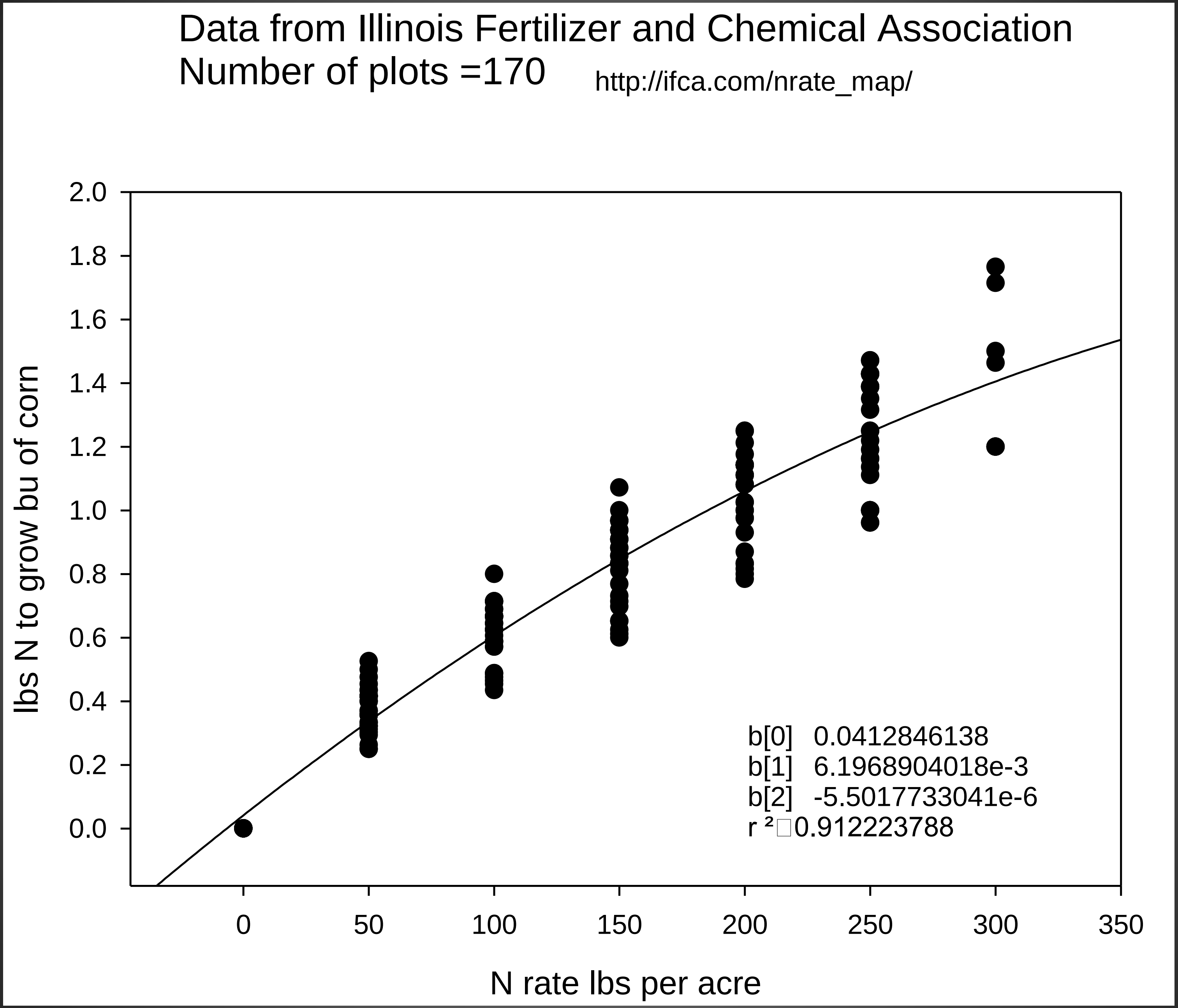


Left: Diatoms circa 1850. Right: Atomic Force Microscopy image of a nanographene molecule, the resolution is so high that for the first time, we can see the individual bonds between atoms, shown here as green lines.

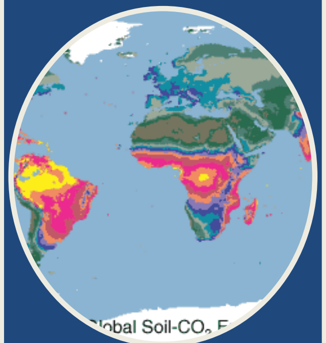
Paradigm shift

Data from Illinois Fertilizer and Chemical Association
Number of plots =170 http://ifca.com/nrate_map/



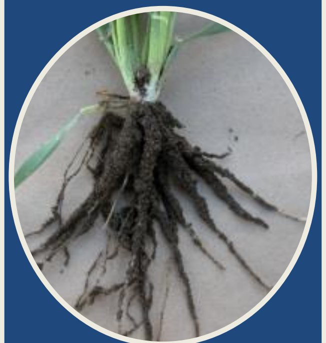


Data from Illinois Fertilizer and Chemical Association
Number of plots =170
http://ifca.com/nrate_map/
lbs N to grow bu of corn
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
350
N rate lbs per acre
b[0] 0.0412846138
b[1] 6.1968904018e-3
b[2] -5.5017733041e-6
r ² 0.912223788



Soil Respiration

- Stoklasa 1905, Lundergardh1924, Jensen 1934, Lees 1949, Makarov 1953, Bunt and Rovina 1955



Nitrogen Root Excretions

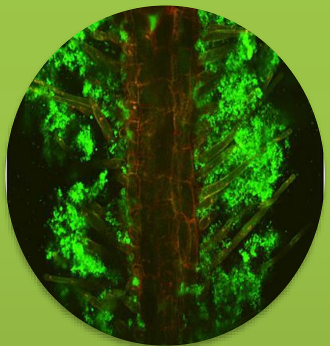
- Lyon and Wilson 1928, N excretions decrease with age of corn plant

Organic Root Excretions

- Dyer 1894, Lemmerman 1907, Künze 1906, Schreiner and Reed 1907, Doyarenko 1909

Legumes as Source of N

- Lipman 1912, cereals, oats and barley



Starkey (1929, 1934) showed that the roots of plants have a considerable influence on the accumulation of microorganisms in the soil

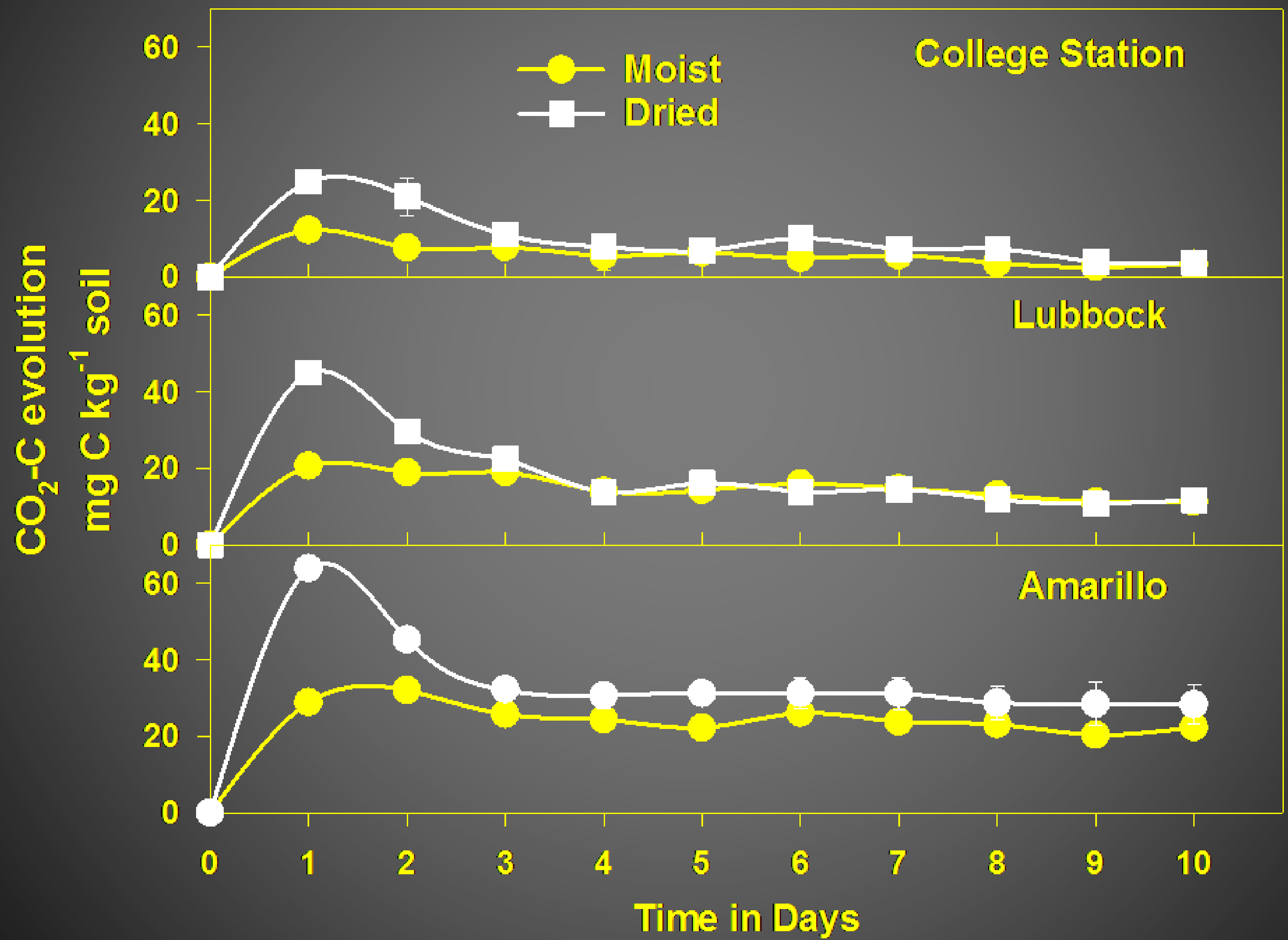
Rhizosphere of beets, (427 million bacteria per gram)

Control soil (only 8.2 million per gram)

In clover, he found 932 million per g and in the control soil only 6.6 million per g

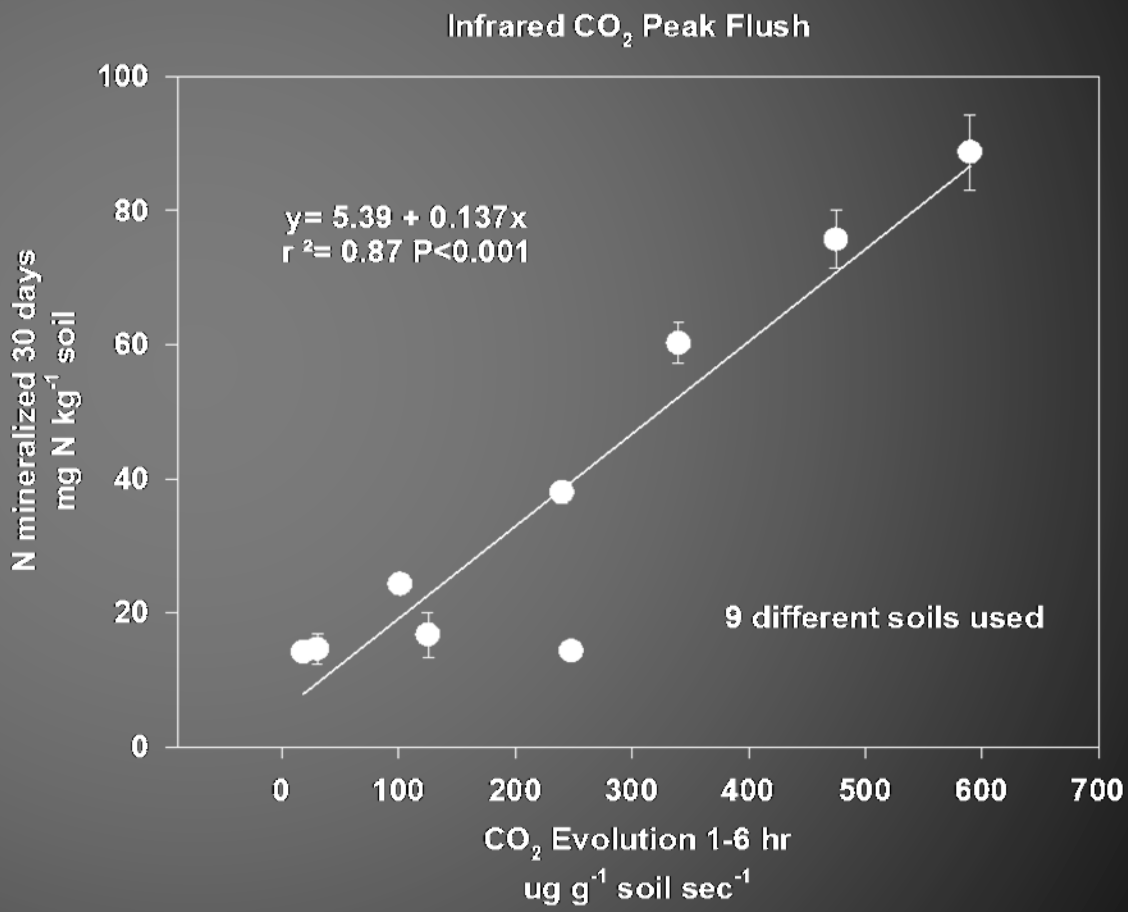
In the rhizosphere of wheat, 653.4 million per g were found; and in the control soil, only 22.8 million bacteria per g

Research History - 1994

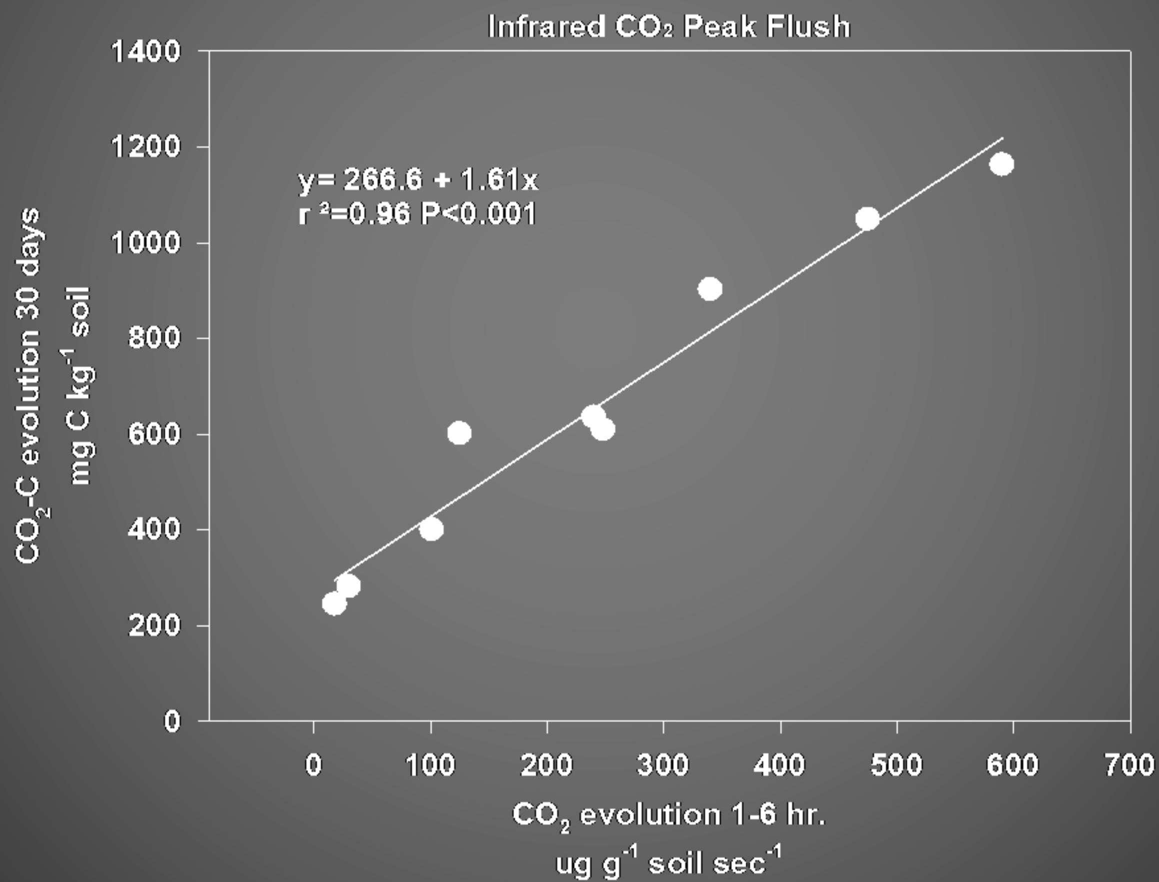


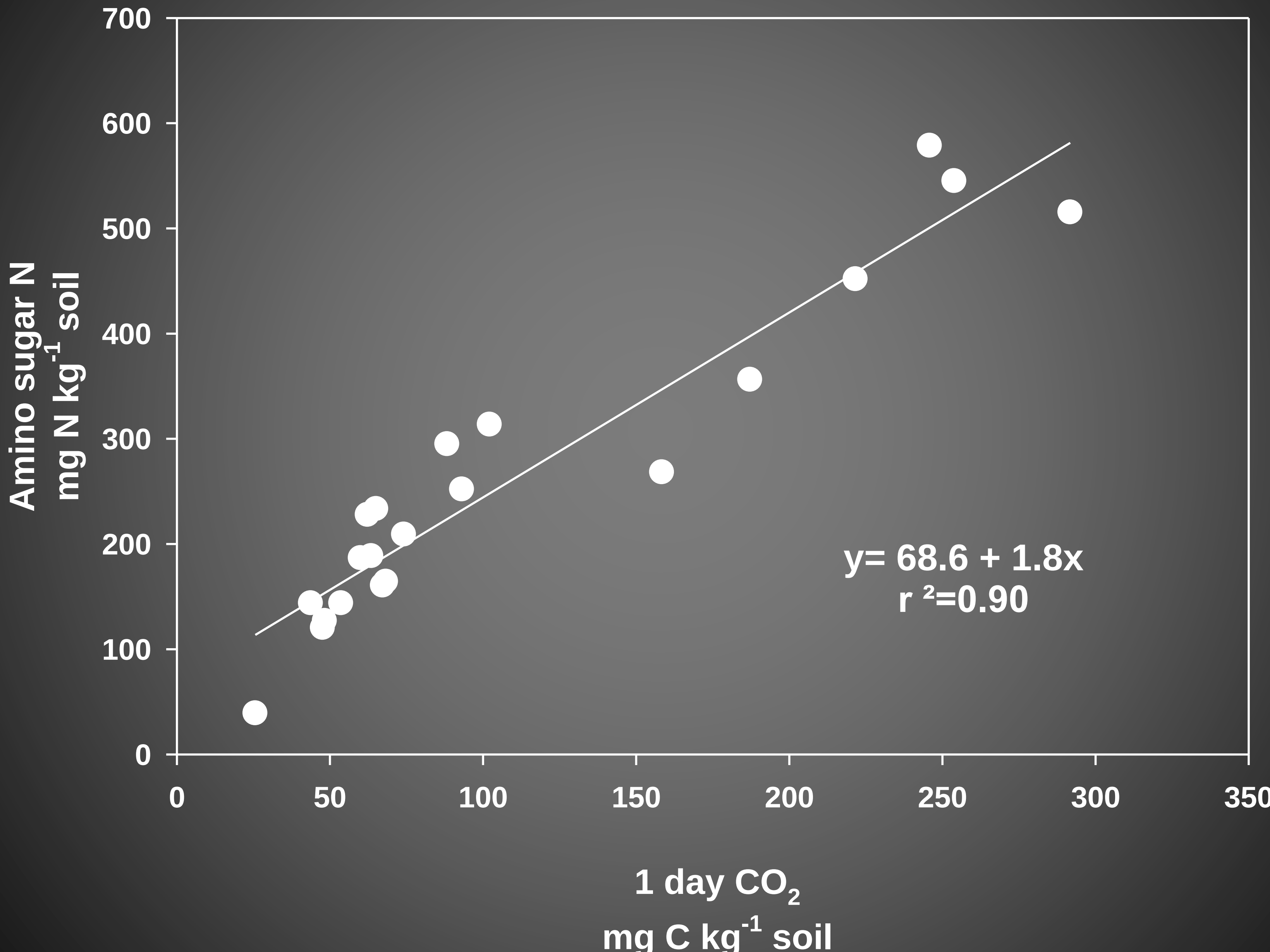
Research History 1995

- 1995: Haney's first attempt at publishing using a technique involving drying and rewetting soil and recording the flush of CO_2 in 1 day to estimate N mineralization is rejected (finally published in 2000).
- It's deemed "too simplistic" by reviewers in spite of the data presented.
- Haney becomes emotionally disturbed.



1996: CO_2 vs. 30 day CO_2

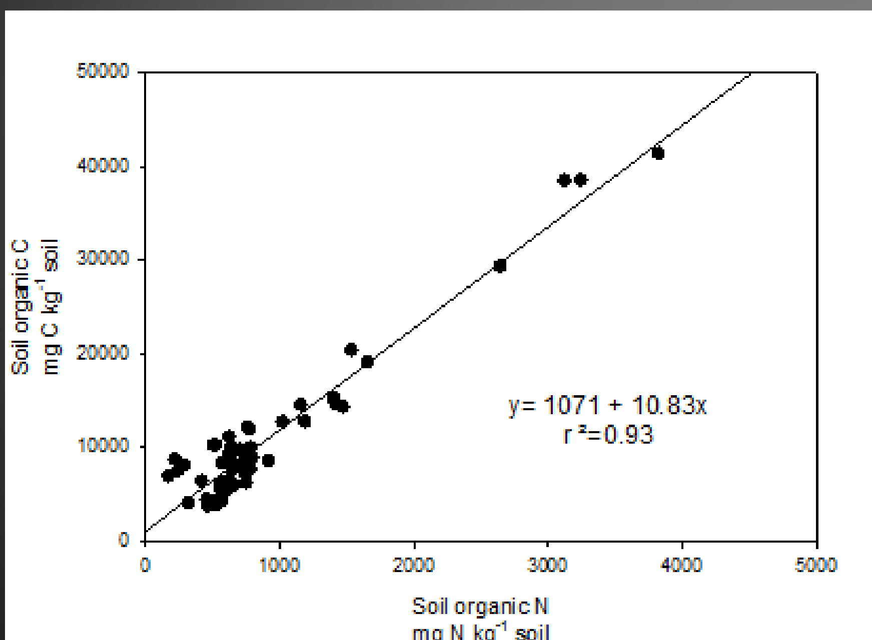


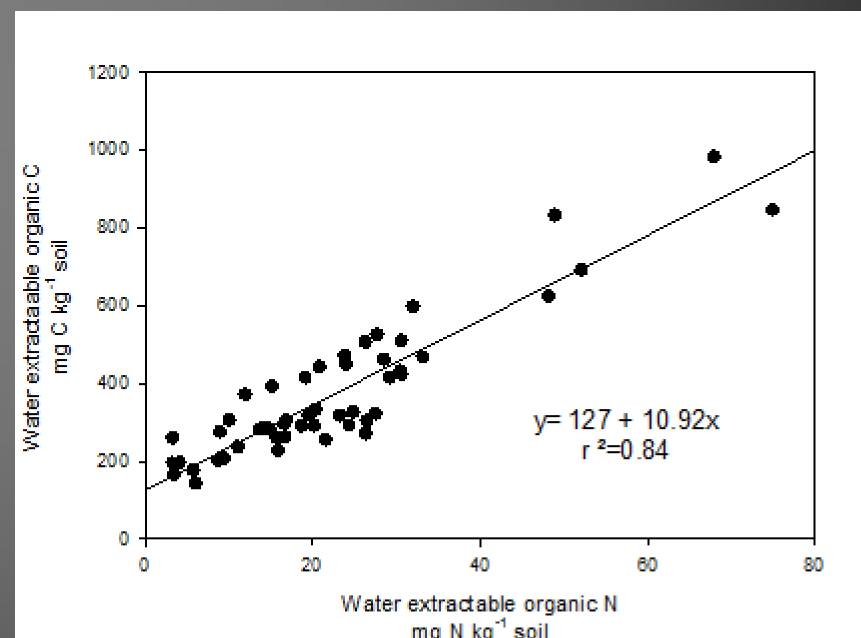


Amino sugar N
mg N kg-1 soil
700
600
500
400
300
200
100
0
0
50
100
150
200
250
300
350
y= 68.6 + 1.8x
r ²=0.90
1 day CO2
mg C kg-1 soil

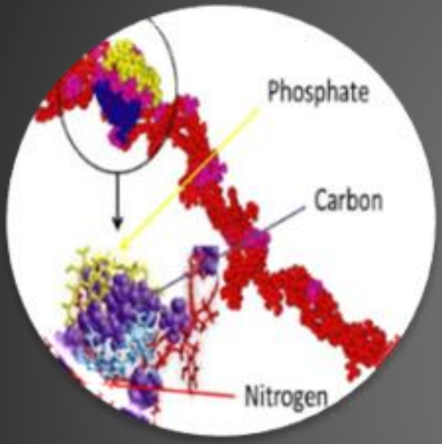
Soil Organic C vs. Water Extractable Organic C

A soil with 2 % soil organic matter (SOM) would have 12,000 ppm C. When we analyze the water extract from the same soil, that number could be from 100-300 ppm C. The organic C in the soil water extract reflects the carbon in your soil that is highly related to the microbial activity. % SOM is about the quantity of organic C, water extractable organic C is about quality.





Soil Respiration and Nitrogen



1 day CO2-C of 50 ppm WEON of 40 ppm WEOC 400 ppm
Calculation 50/400=0.125
0.125*40=5 5*4 (rainfall events)=20 ppm
20*2 (0-6 inch sample)=**40** lbs N

1 day CO2-C of 80 ppm
Calculation 60/400=0.2
0.2*40=8 ppm
8*4(rainfall event)=32 ppm   32*2=**64l** bs N

1 day CO2-C of 300 ppm
Calculation 300/400=0.75
0.75*40=30 ppm
30*4 (rainfall event)= 120 ppm 120*2=**240** lbs N

BUT, we only measured 40 ppm WEON or 80 lbs of N

Therefore we will never credit more N from the WEON pool than we measure

AND whether the credit is 80 lbs, or 40 lbs, this is nitrogen we would have missed if we just measured nitrate

Soil Nitrogen

Soil-water Total N

(Pool 1)

Soil-water inorganic N

(Pool 2)

Soil-water organic N

(Pool 3)

% of total N in each pool

(organic and inorganic)