Organic Farming for Soil Health

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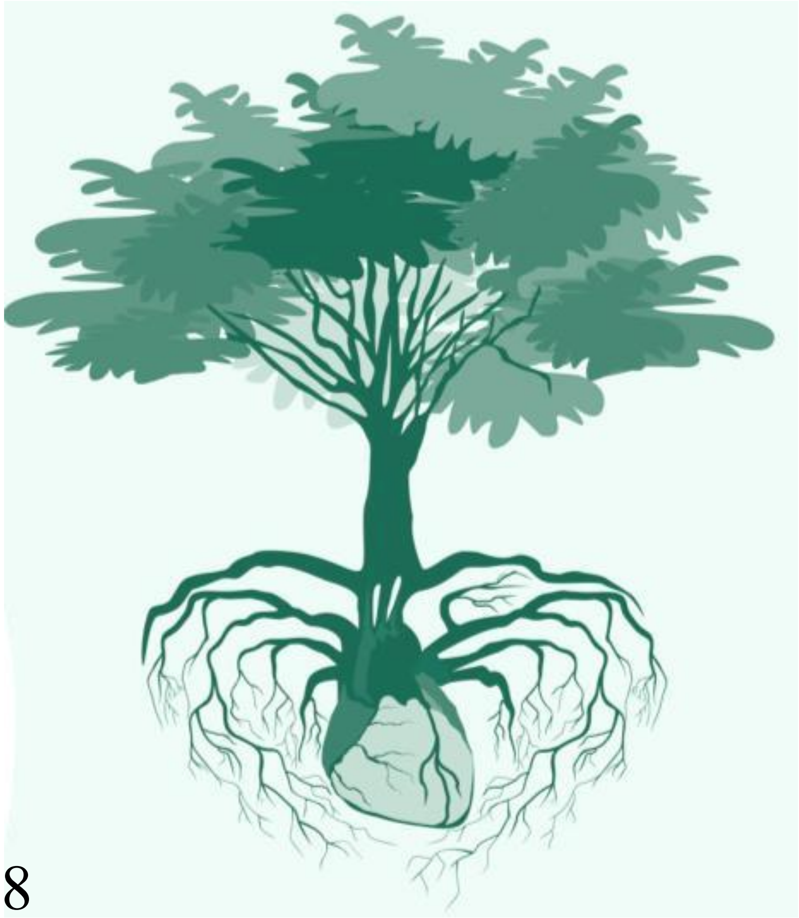
The RODALE INSTITUTE®

Soil is the Heart of the System

- Connects above and below ground
- Recycles C, N, O, P, water, etc.
- Drives physical, chemical, and biological processes
- Uses the most efficient mechanisms
- Value of soil organic matter (~$600-800 per acre depending on decomposition) – Hoorman & Islam, OSU
- Estimated value of soil biota is $1.5 trillion globally per year - Dance, 2008



hello beautiful.

Did you know…

that millions of microscopic organisms are helping your crops every day?

Here are four things you can do to help them help unlock your soil's potential…

- Minimize soil disturbance.
- Energize with diversity.
- Keep the soil covered.
- Maximize living roots.

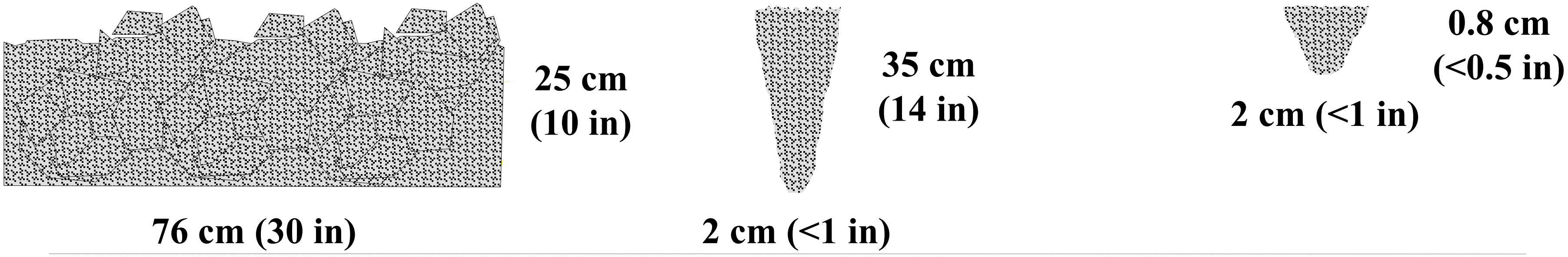
Learn more about soil health at www.nrcs.usda.gov

unlock the SECRETS in the SOIL

USDA

USDA
Natural Resources
Conservation Service

Minimize Soil Disturbance

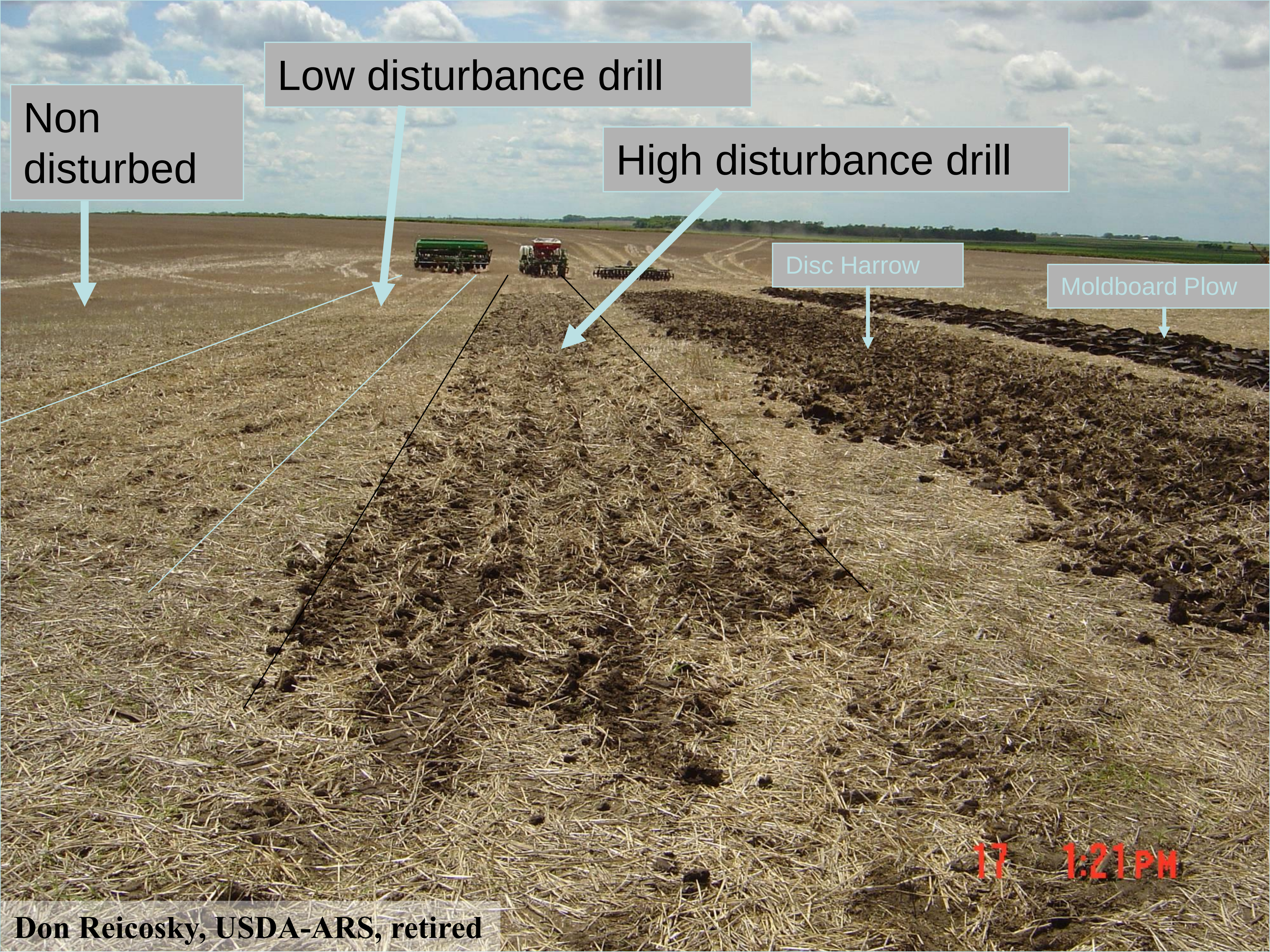


Moldboard Plow

Subsoil Shank

No Knife
No Till Drill

Don Reicosky, USDA-ARS, retired



Non disturbed

Low disturbance drill

High disturbance drill

Disc Harrow

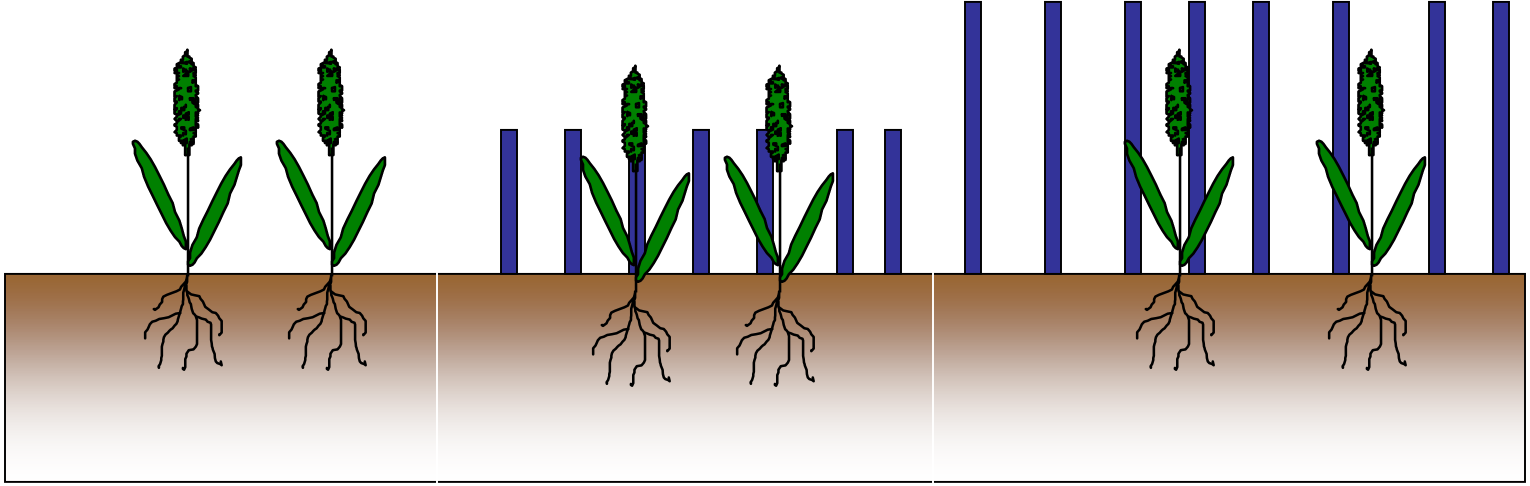
Moldboard Plow

Don Reicosky, USDA-ARS, retired

Organic No Till – Disturbance and Coverage

Keep the Soil Covered

Stubble



Ground Level Effects

	Cultivated	6-8” Stubble	12-14” Stubble
Wind:	**100%**	**85%**	**32%**
Evap. Demand:	**100%**	**95%**	**70%**

- Cutforth and McConkey, 1995

Keep the Soil Covered

Residue

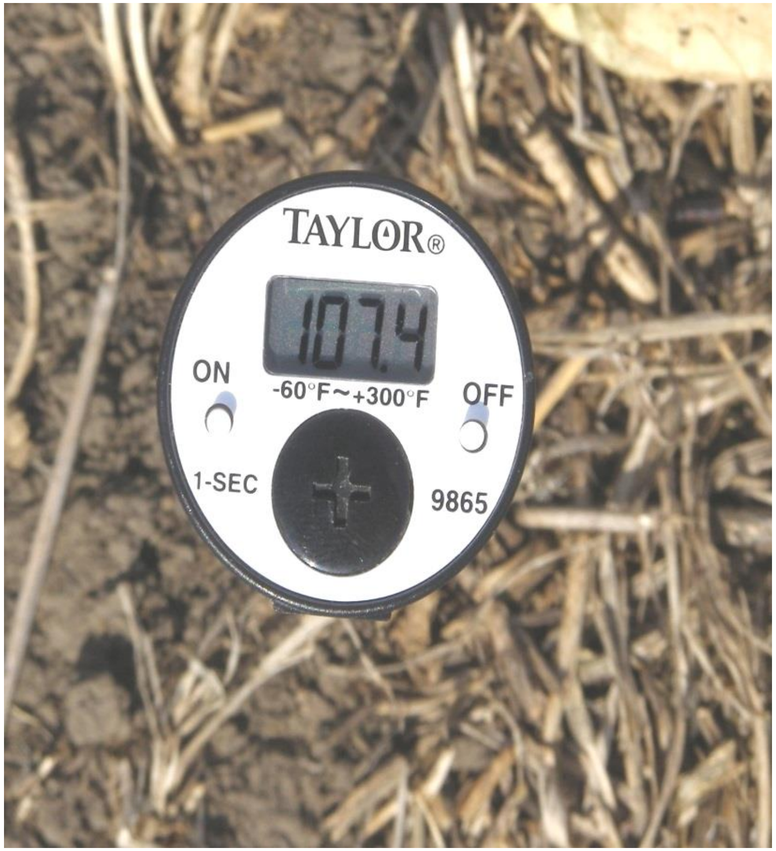
Reduced

Conventional

No-till

Keep the Soil Covered

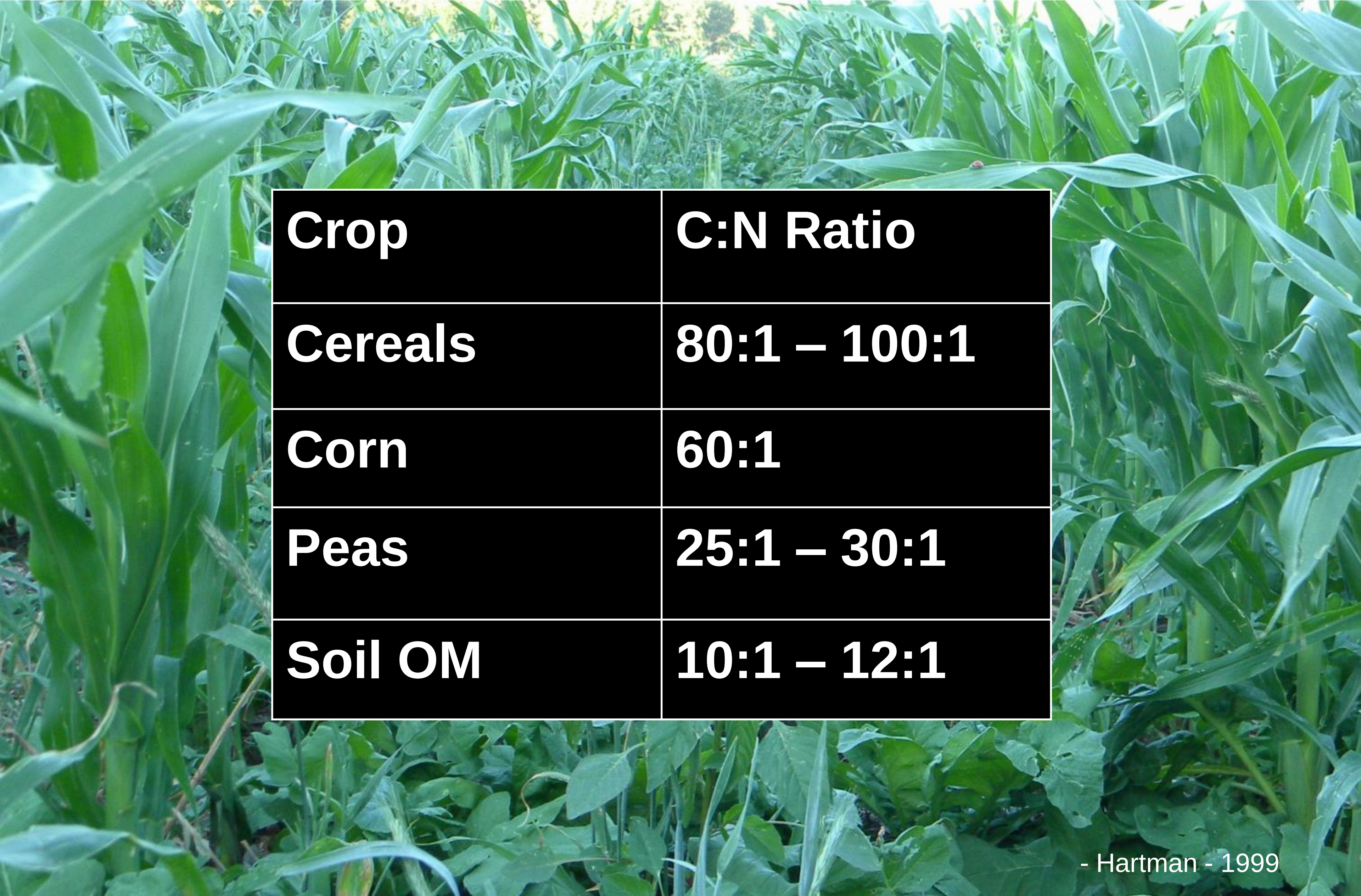
Cover Crops



Energize with Diversity

- Hartman - 1999

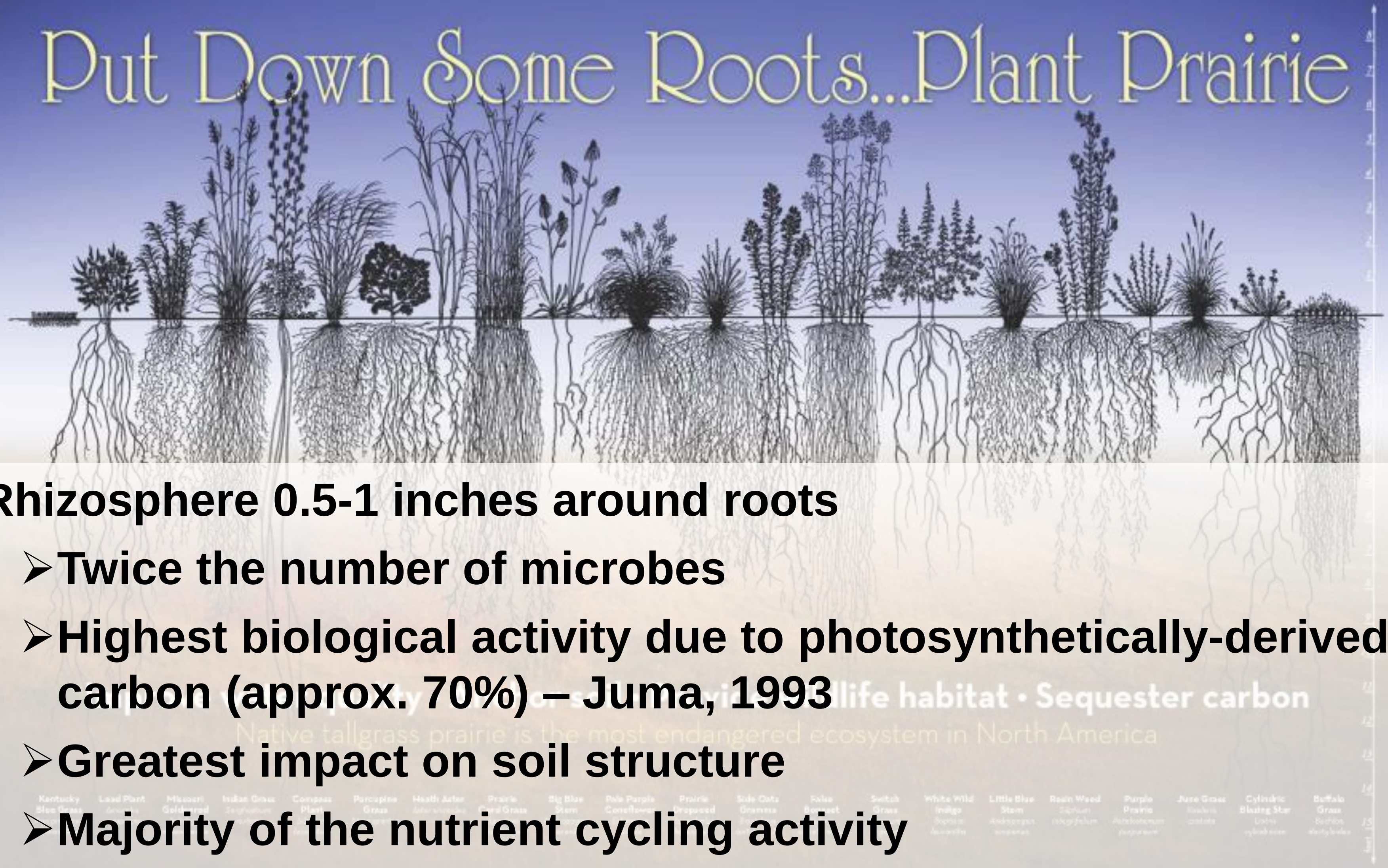
Energize with Diversity



Crop	C:N Ratio
Cereals	80:1 – 100:1
Corn	60:1
Peas	25:1 – 30:1
Soil OM	10:1 – 12:1

- Hartman - 1999

Maximize Living Roots



Rhizosphere 0.5-1 inches around roots

- **Twice the number of microbes**
- **Highest biological activity due to photosynthetically-derived carbon (approx. 70%) – Juma, 1993**
- **Greatest impact on soil structure**
- **Majority of the nutrient cycling activity**
- **Most impacted by aboveground management**

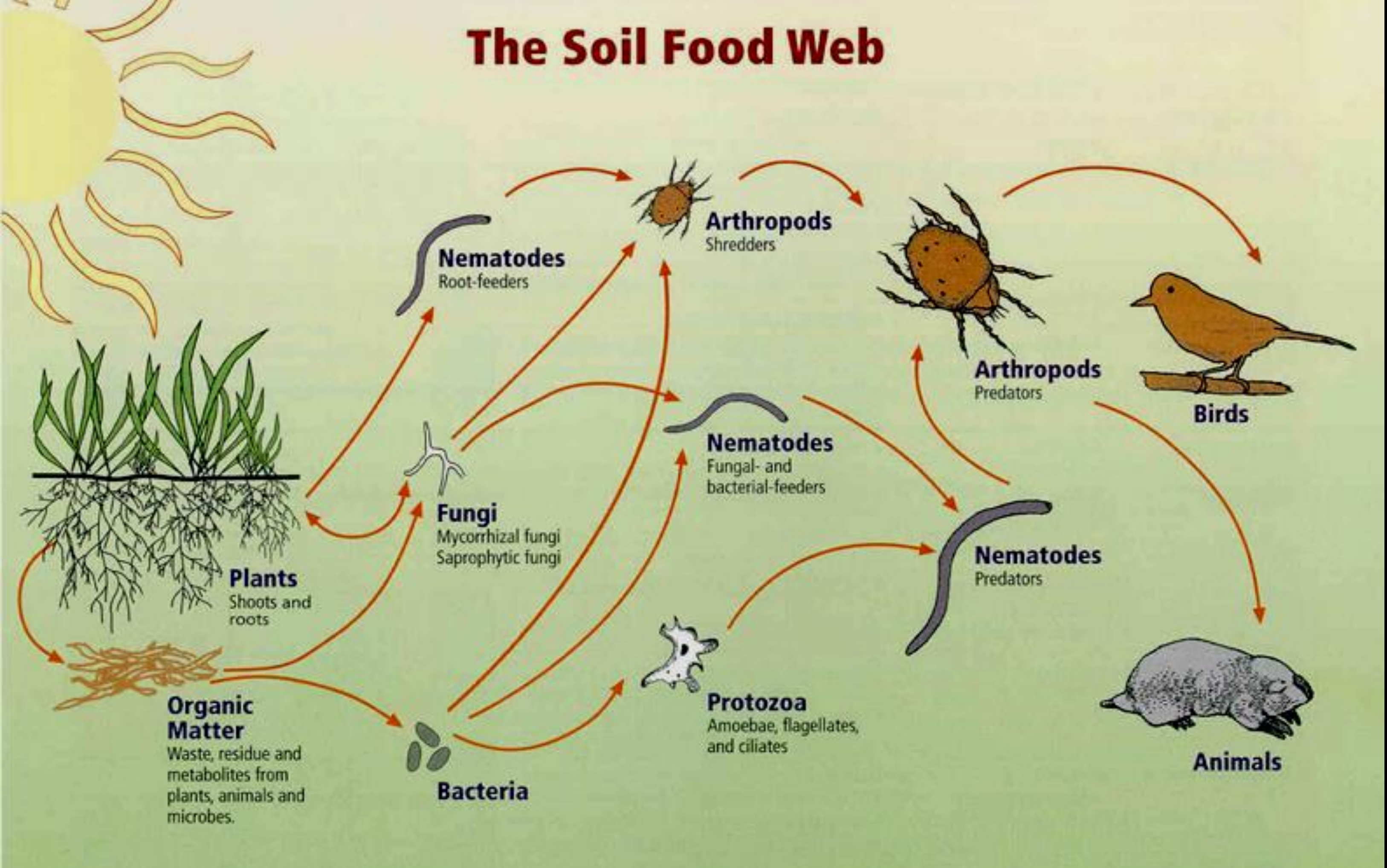
When 2 + 2 no longer equals 4

- Tillage type
- Plant species/variety
- Crop rotation
- Crop residue
- Grazing

- Fertility program
- Cover crops
- Manure/compost addition
- Irrigation
- Timing

Management affects combin

The Soil Food Web



First trophic level:
Photosynthesizers

Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders

Third trophic level:
Shredders
Predators
Grazers

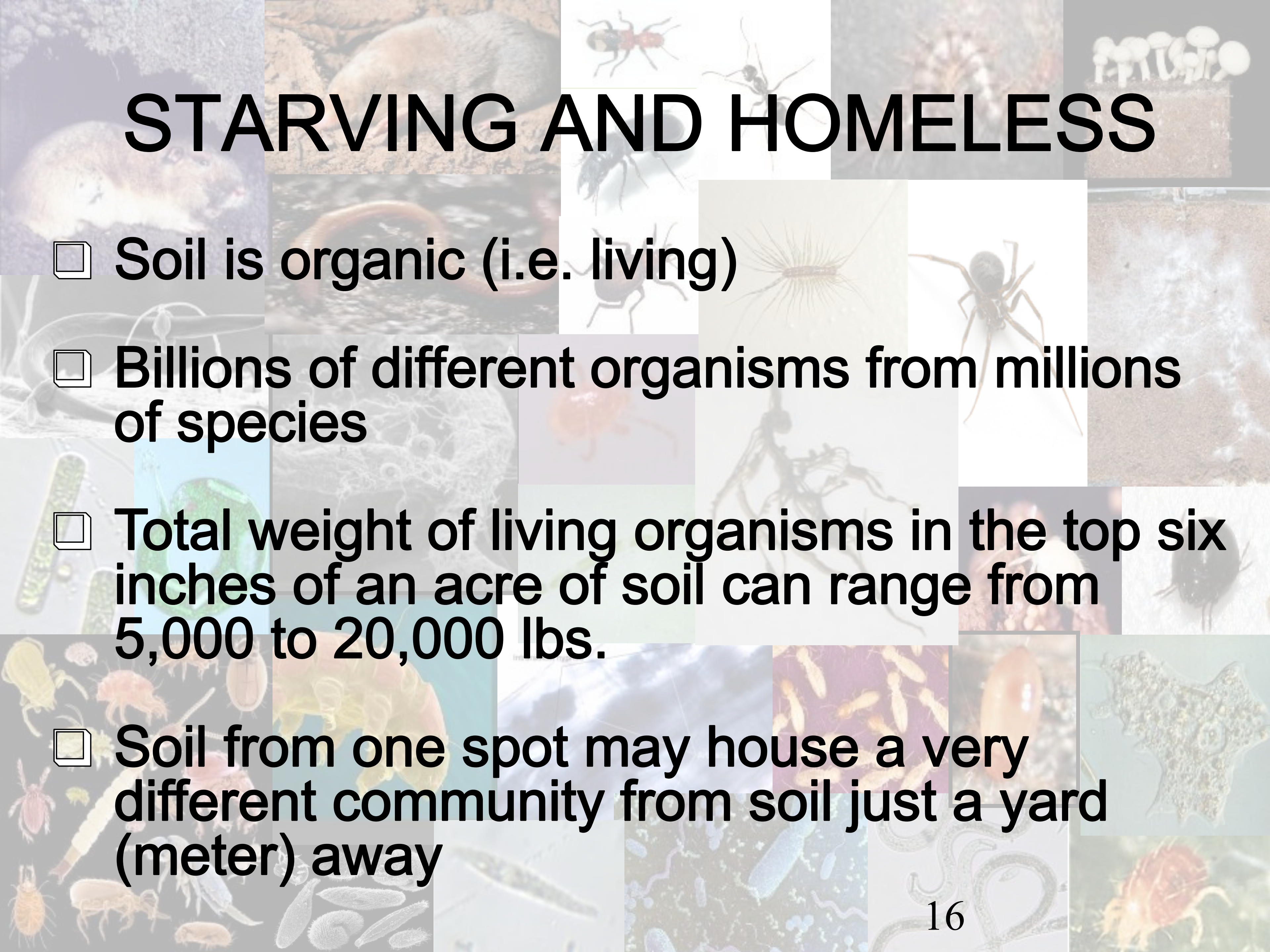
Fourth trophic level:
Higher level predators

Fifth and higher trophic levels:
Higher level predators

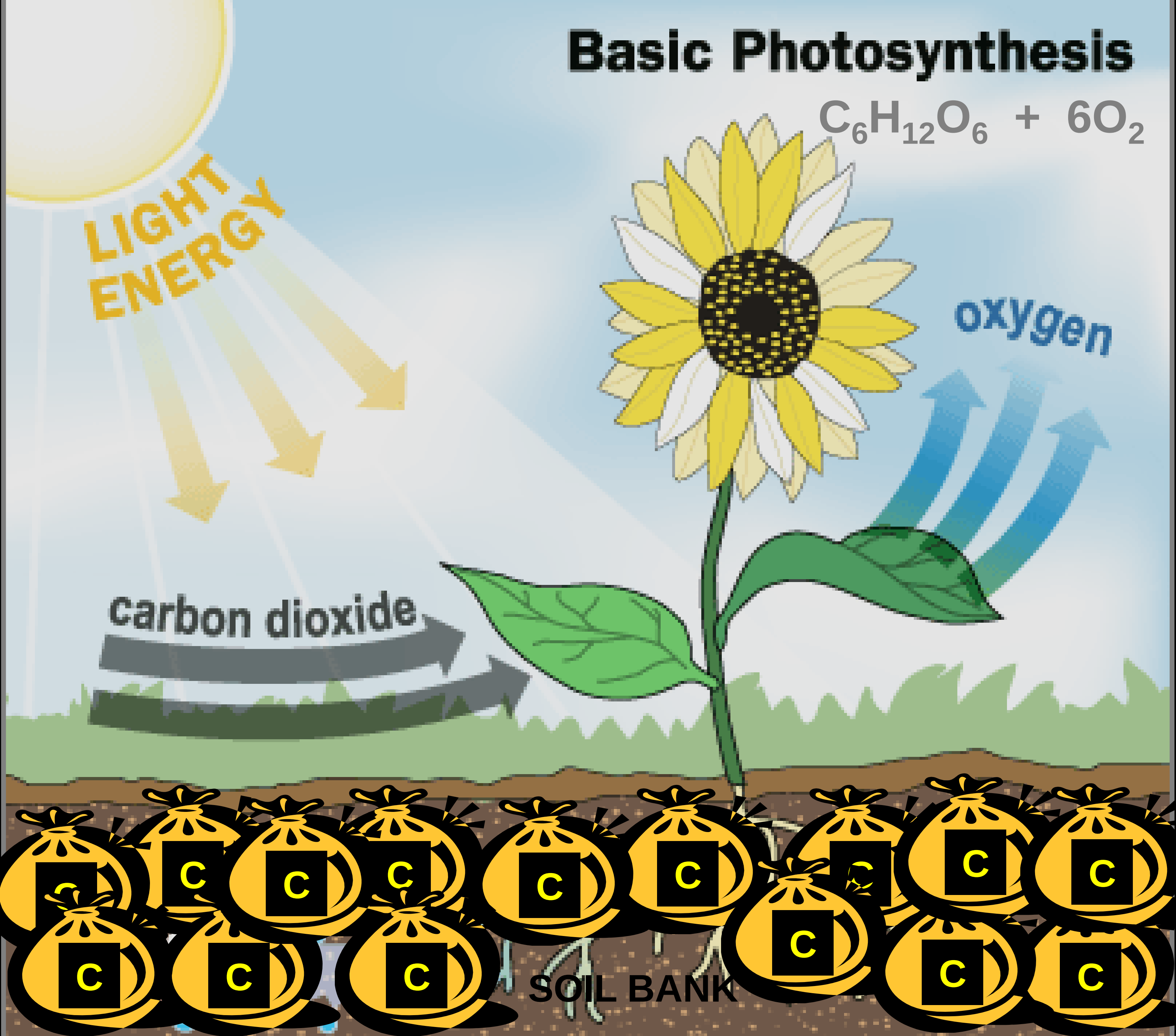
Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.


A
P
C
C
C
Intraradical hyphae
Arbuscules

STARVING AND HOMELESS



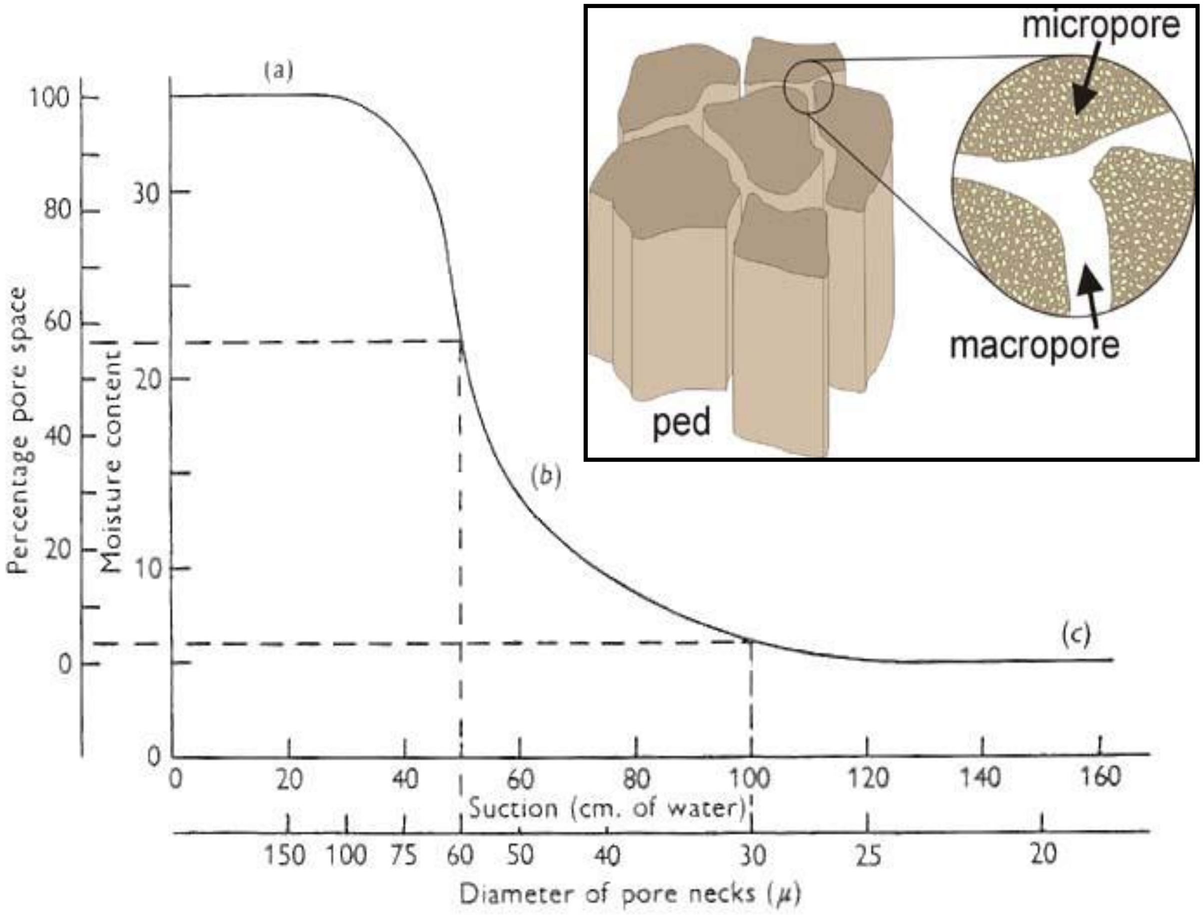
- Soil is organic (i.e. living)
- Billions of different organisms from millions of species
- Total weight of living organisms in the top six inches of an acre of soil can range from 5,000 to 20,000 lbs.
- Soil from one spot may house a very different community from soil just a yard (meter) away



$C_6H_{12}O_6 + 6O_2$

SOIL BANK

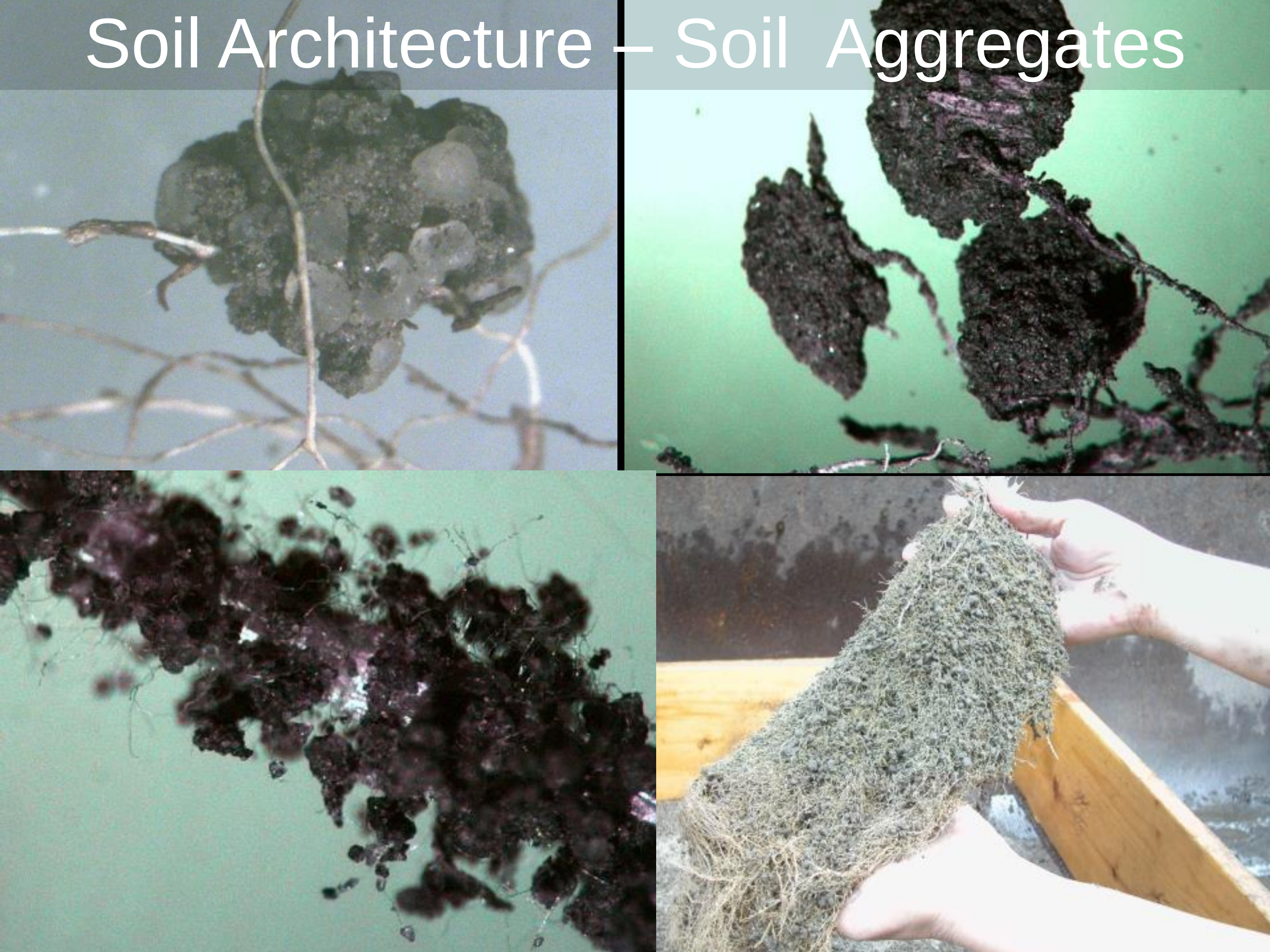
Soil Porosity



- **Macropores**
  - (>10 μm)
  - Between aggregates
  - Nematodes, Protozoa, Microarthropods
- **Micropores**
  - (<10 μm)
  - Inside aggregates
  - Bacteria and Fungi

45% greater porosity increases infiltration by 167% for the first inch and 650% for the second inch - Karlen et al., 1998

Soil Architecture – Soil Aggregates



Aggregate Stability

WSA = 14%

CT, SW-F

WSA = 47%

NT, SW-WW-SF

WSA = 93%

Moderately-grazed pasture

Jamestown, ND
June 16, 2013

Glasgow, MT 2013

Glasgow, MT 2013

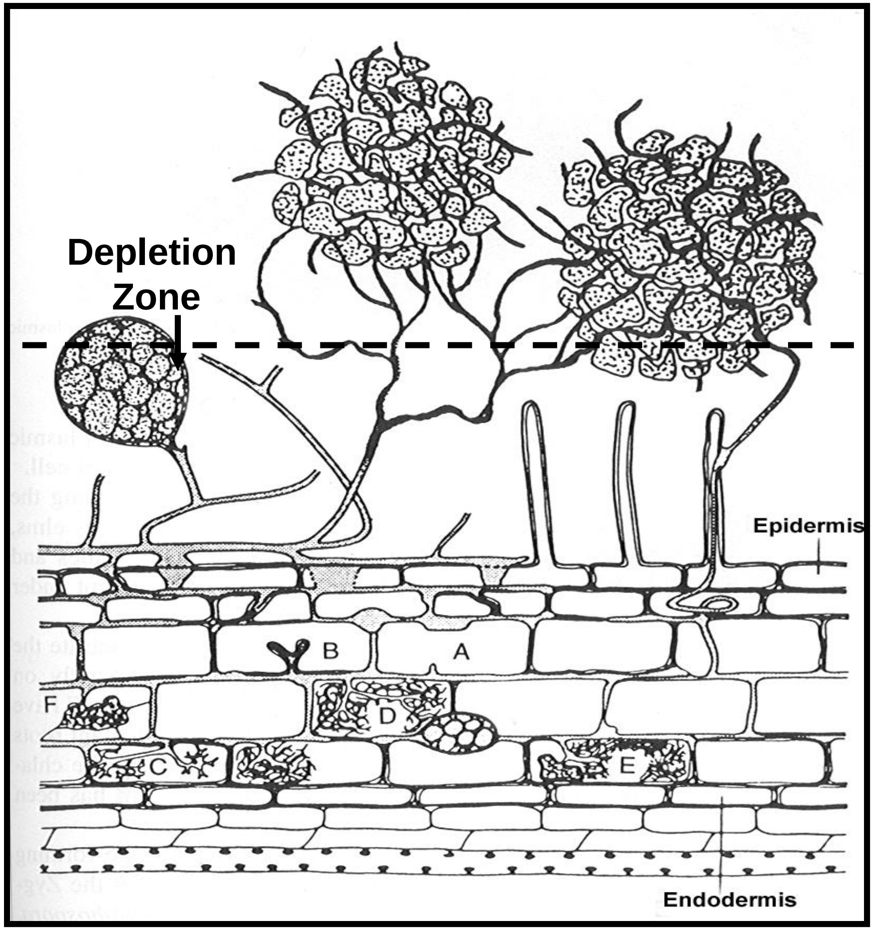
Morris, MN 2012

Fargo, ND 2014

Texas Dust Storms in 1930s and 2012

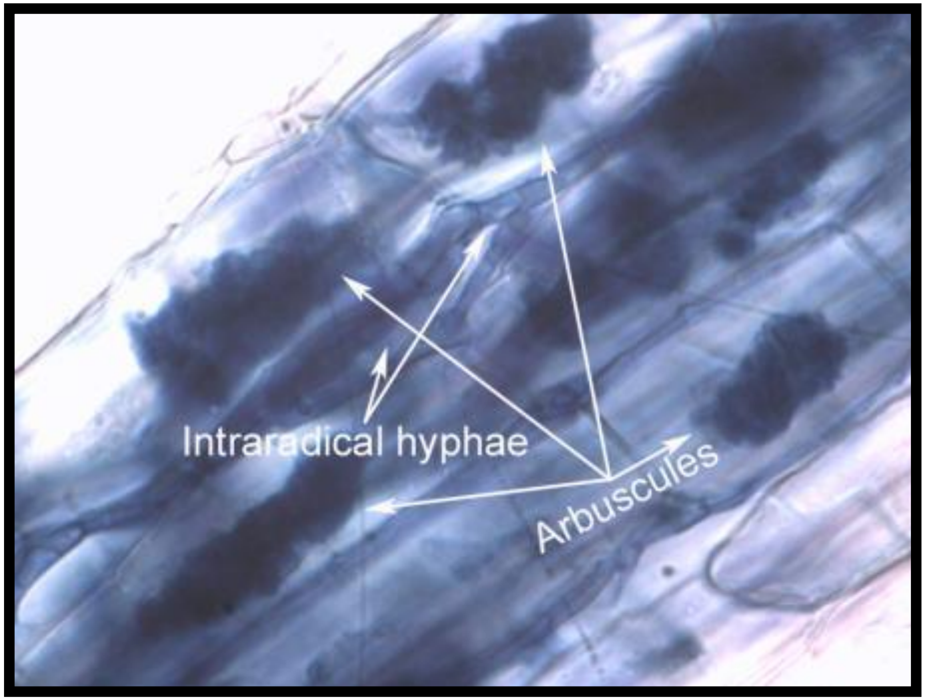
Physiology - Arbuscular Mycorrhizal Fungi

- 4-30% of C is transferred to AM – Jansa et al 2013
- Obtain nutrients (up to 90% of N and P) – Smith and Read, 2008



Physiology - Arbuscular Mycorrhizal Fungi

- 4-30% of C is transferred to AM – Jansa et al 2013
- Obtain nutrients (up to 90% of N and P) – Smith and Read, 2008
- Affected by:
  - rotation (incl. cover crops)
  - fallow
- Create mycorrhizosphere in soil
- Form soil aggregates



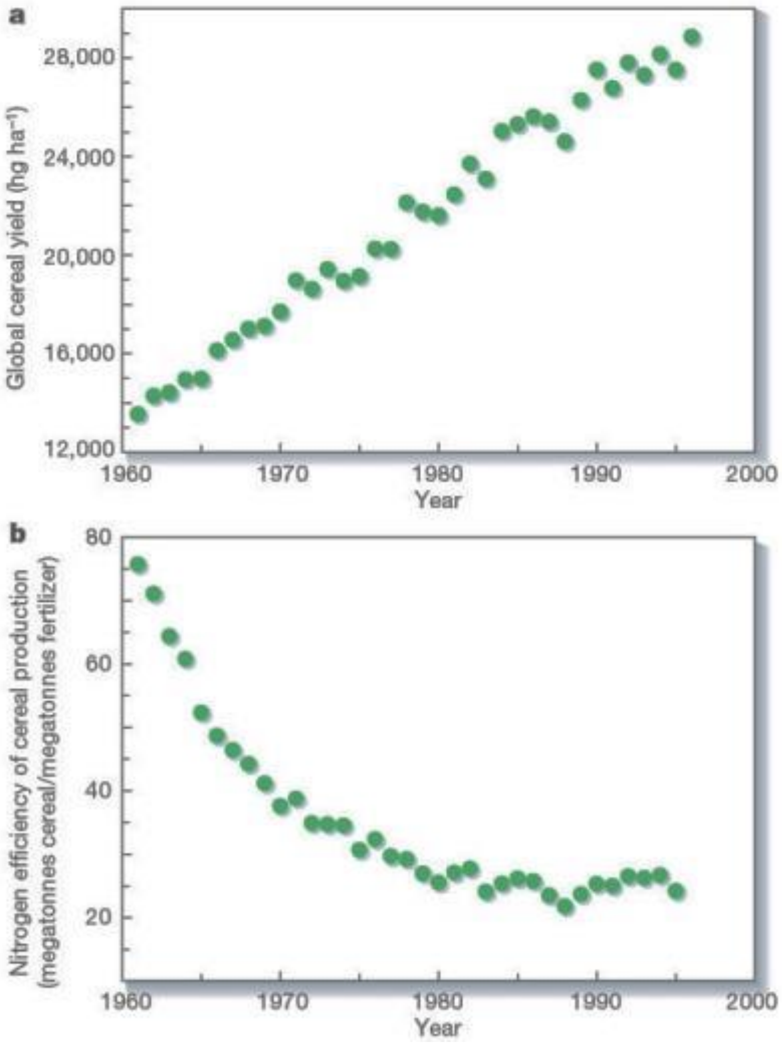
Water Use Efficiency

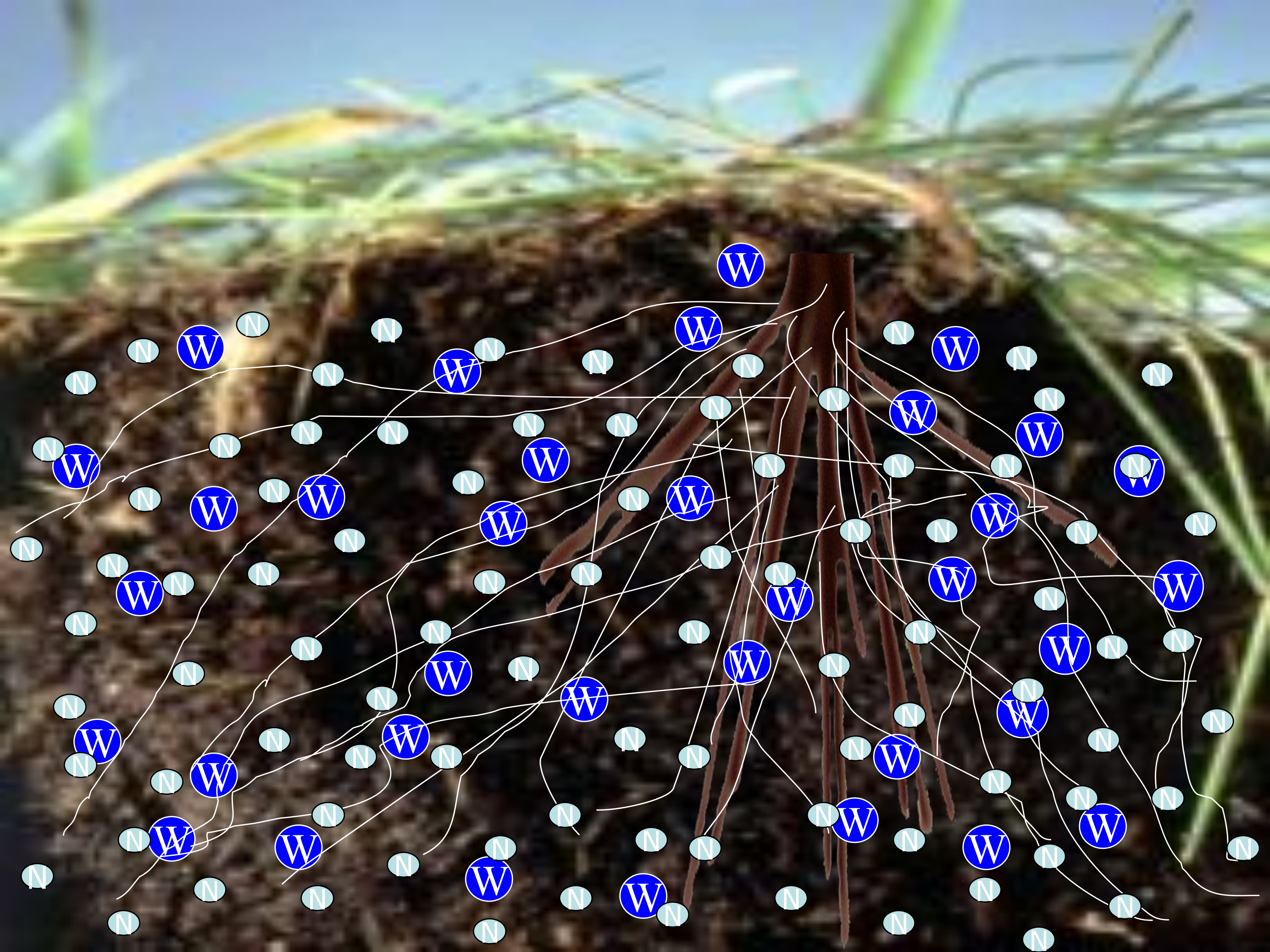


- Porosity - 45% increase in porosity = 167% 1 inch and 650% 2 inch - Karlen et al., 1998
- Water holding capacity – 0.5-3% = 2X – Hudson, 1994
- Water needs per crop
  - Corn – 2500 – 5000 gallons per bushel
  - 1 inch = 27,154 gallons per acre
  - 10 – 25 inches = 93 – 234 bushels
- Water used for nutrition
  - – W.A. Albrecht, University of Missouri, 1950's
  - Unfertilized corn – 468,000 gallons of water per acre (18 bushels)
  - Fertilized corn – 442,400 gallons of water per acre (79 bushels)

Nutrient Use Efficiency

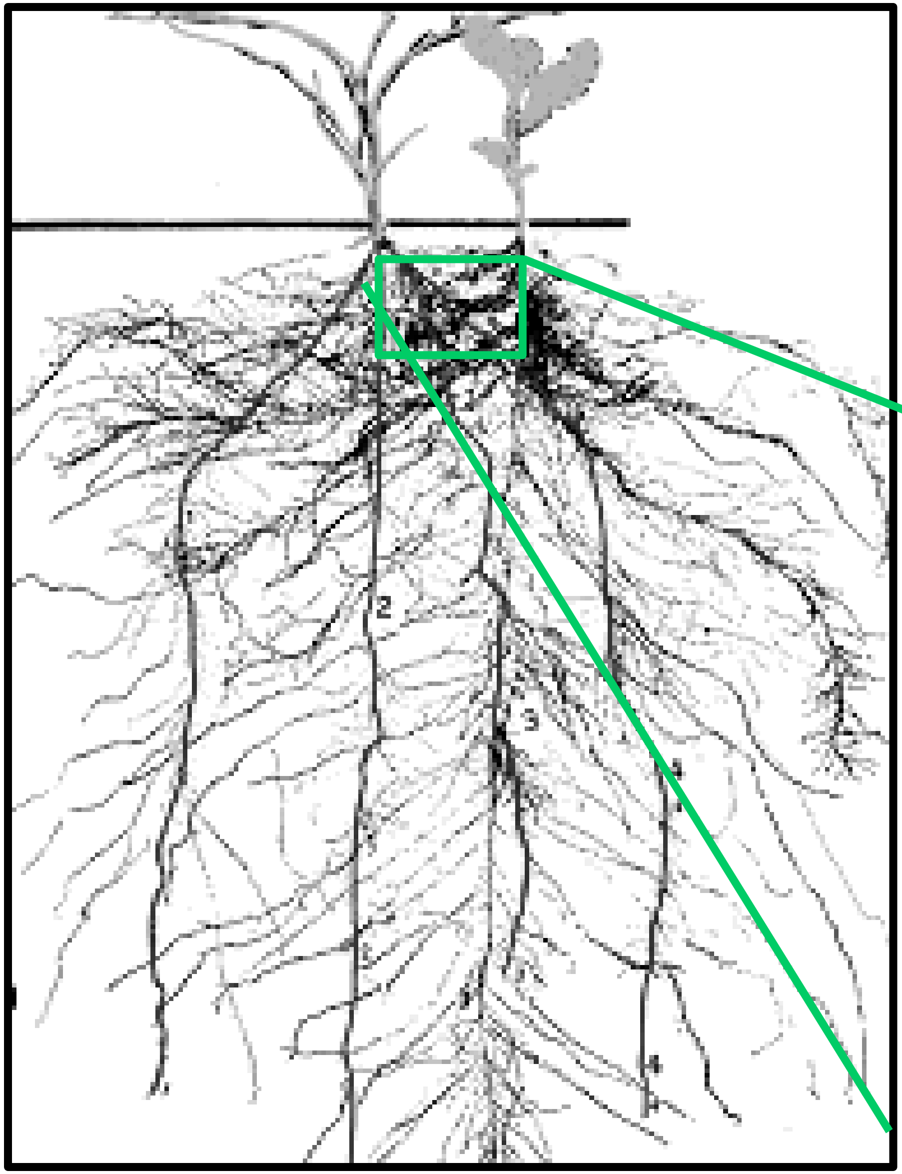
- Plant available – synthetic vs. biologic
- 30-50% of nitrogen fertilizer is used by the plant
- 30% of phosphorus is used by the plant
- Availability, timing, water, and pH

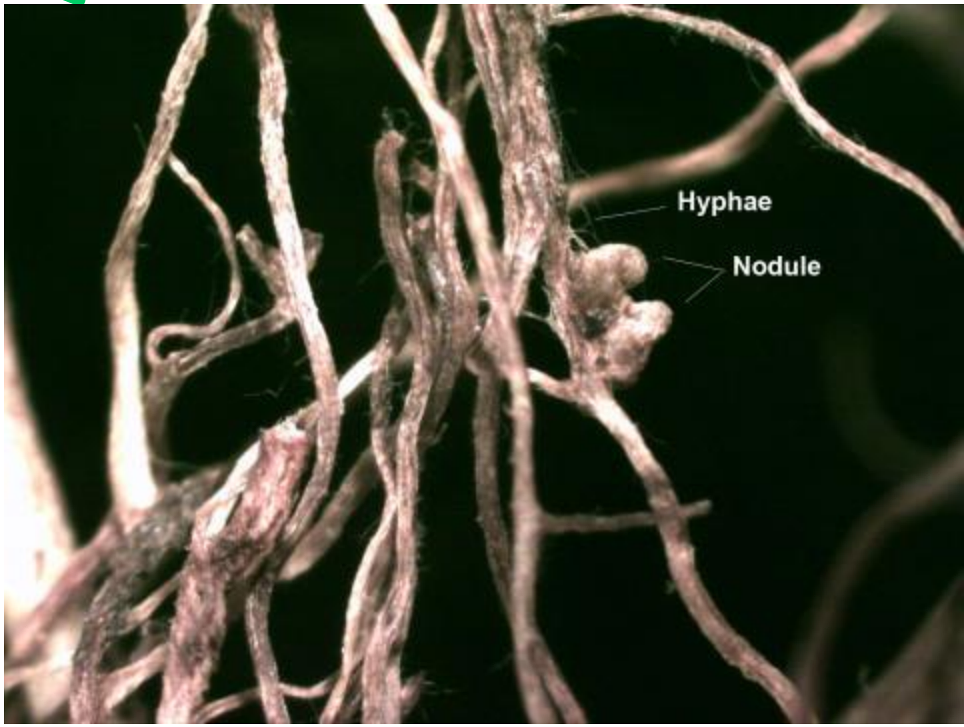




W
N

Interplant transfer, primarily N from biological N fixation and P via mycorrhizal fungal hyphae.





Farming Systems Trial (FST)

Tilled vs. No-Till

➢ Organic-manure based

- 8-year rotation (Oat/rye - Soybean/wheat - Wheat/hay - Hay - Hay - Silage/wheat - Wheat/vetch - Corn/rye)
- 10-year rotation (Oat/rye - Soybean/wheat - Wheat/hay - Hay - Hay -Hay -Hay - Silage/wheat - Wheat/vetch - Corn/rye)

➢ Organic-legume based

- 4-year rotation (Corn/rye - Oats-clv/barley or rye - Soybean/wheat - Wheat/vetch)
- 4-year rotation (Corn/rye - Oats-clv/barley or rye - Soybean/wheat - Wheat/cover crop mix)

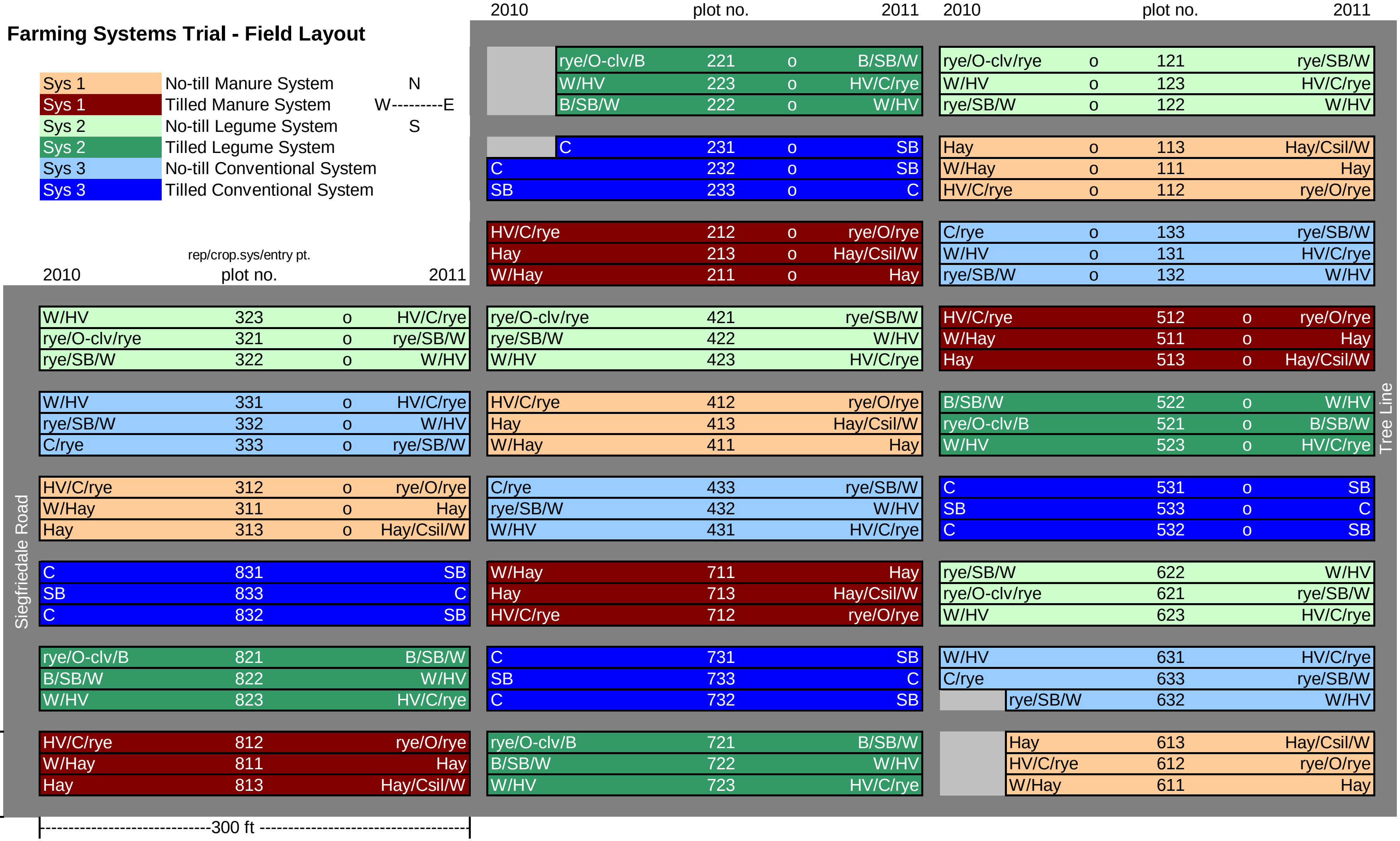
➢ Conventional-chemically based

- 3-year rotation (Corn – Corn - Soybean
- 3-year rotation (Corn/rye – Corn/rye – Soybean/rye)

2011 FST Field Map

Farming Systems Trial - Field Layout

Sys 1	No-till Manure System	N
Sys 1	Tilled Manure System	W---------E
Sys 2	No-till Legume System	S
Sys 2	Tilled Legume System	
Sys 3	No-till Conventional System	
Sys 3	Tilled Conventional System	



2010	plot no.		2011	2010	plot no.		2011	2010	plot no.		2011
				rye/O-clv/B	221	o	B/SB/W	rye/O-clv/rye	o	121	rye/SB/W
				W/HV	223	o	HV/C/rye	W/HV	o	123	HV/C/rye
				B/SB/W	222	o	W/HV	rye/SB/W	o	122	W/HV
				C	231	o	SB	Hay	o	113	Hay/Csil/W
				C	232	o	SB	W/Hay	o	111	Hay
				SB	233	o	C	HV/C/rye	o	112	rye/O/rye
				HV/C/rye	212	o	rye/O/rye	C/rye	o	133	rye/SB/W
				Hay	213	o	Hay/Csil/W	W/HV	o	131	HV/C/rye
				W/Hay	211	o	Hay	rye/SB/W	o	132	W/HV
W/HV	323	o	HV/C/rye	rye/O-clv/rye	421		rye/SB/W	HV/C/rye	512	o	rye/O/rye
rye/O-clv/rye	321	o	rye/SB/W	rye/SB/W	422		W/HV	W/Hay	511	o	Hay
rye/SB/W	322	o	W/HV	W/HV	423		HV/C/rye	Hay	513	o	Hay/Csil/W
W/HV	331	o	HV/C/rye	HV/C/rye	412		rye/O/rye	B/SB/W	522	o	W/HV
rye/SB/W	332	o	W/HV	Hay	413		Hay/Csil/W	rye/O-clv/B	521	o	B/SB/W
C/rye	333	o	rye/SB/W	W/Hay	411		Hay	W/HV	523	o	HV/C/rye
HV/C/rye	312	o	rye/O/rye	C/rye	433		rye/SB/W	C	531	o	SB
W/Hay	311	o	Hay	rye/SB/W	432		W/HV	SB	533	o	C
Hay	313	o	Hay/Csil/W	W/HV	431		HV/C/rye	C	532	o	SB
C	831		SB	W/Hay	711		Hay	rye/SB/W	622		W/HV
SB	833		C	Hay	713		Hay/Csil/W	rye/O-clv/rye	621		rye/SB/W
C	832		SB	HV/C/rye	712		rye/O/rye	W/HV	623		HV/C/rye
rye/O-clv/B	821		B/SB/W	C	731		SB	W/HV	631		HV/C/rye
B/SB/W	822		W/HV	SB	733		C	C/rye	633		rye/SB/W
W/HV	823		HV/C/rye	C	732		SB	rye/SB/W	632		W/HV
HV/C/rye	812		rye/O/rye	rye/O-clv/B	721		B/SB/W	Hay	613		Hay/Csil/W
W/Hay	811		Hay	B/SB/W	722		W/HV	HV/C/rye	612		rye/O/rye
Hay	813		Hay/Csil/W	W/HV	723		HV/C/rye	W/Hay	611		Hay

NOTE: Plots 221, 223, 222, 231 were shortened to 180 feet
Plots 632, 613, 612, 611 were shortened to 200 feet

o =location of zero tension lysimeters

B = Winter barley
C = Corn
Csil = Corn silage
clv = clover mix

Hay = Alfalfa / orchard grass mix
HV = Hairy vetch
O = Oats

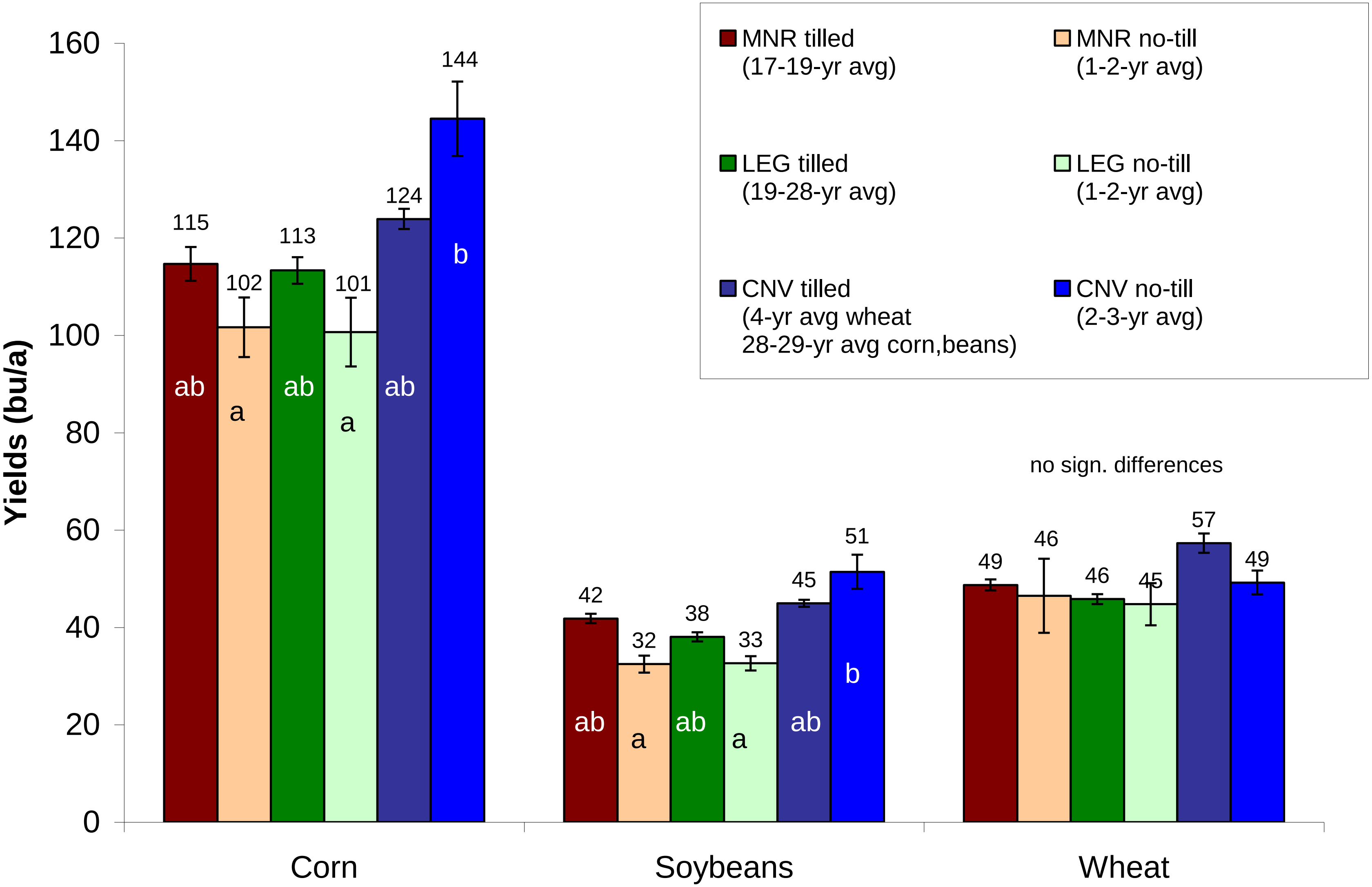
SB = Soybean
W = Winter wheat

compost is applied before oats and corn silage in the Manure systems

FST Soil Results

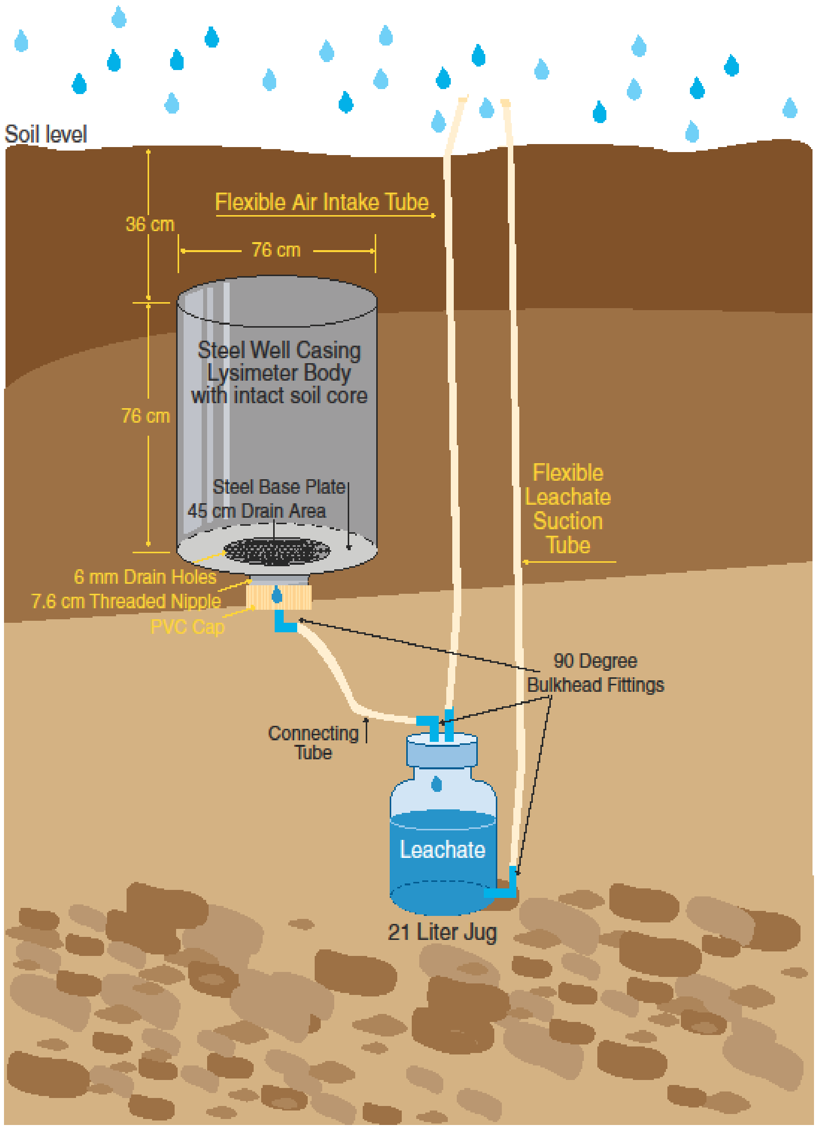
- Higher percentages of water stable aggregates
- Higher carbon levels
- Higher levels of glomalin
- Potentially more arbuscular mycorrhizal (AM) fungi

FST long-term grain yields 1981-2010



FST Water Results

Lysimeter schematic



Lysimeter pumping year round

te

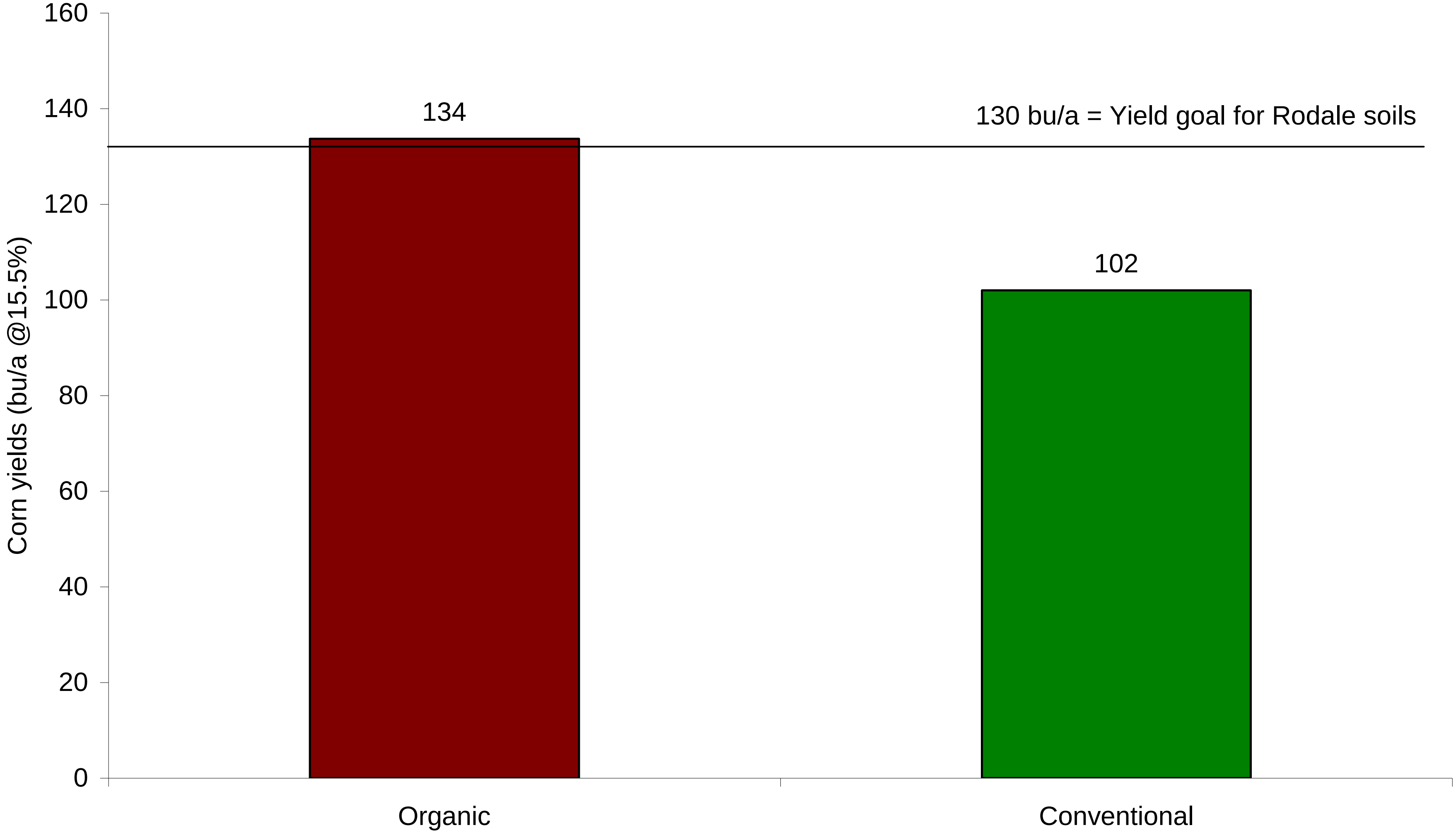
FST Water Results

- Water percolation volumes were 15-20% higher
- Nitrate-nitrogen leaching was the same: 15-18 kg/ha nitrogen per year
  - 20% of water leachate samples in conventional exceeded the legal limit for nitrate-nitrogen concentrations in drinking water (10 ppm) over 15 years of sampling, vs. 15 and 8% of samples in the legume and manure systems respectively.
- Atrazine levels in the leachate sometimes exceeded 3 ppb (EPA's maximum contaminant level for drinking water).
  - Atrazine concentrations in all conventional system samples exceeded 0.1 ppb (a concentration shown to produce deformities in frogs (Hayes et al., 2002).)

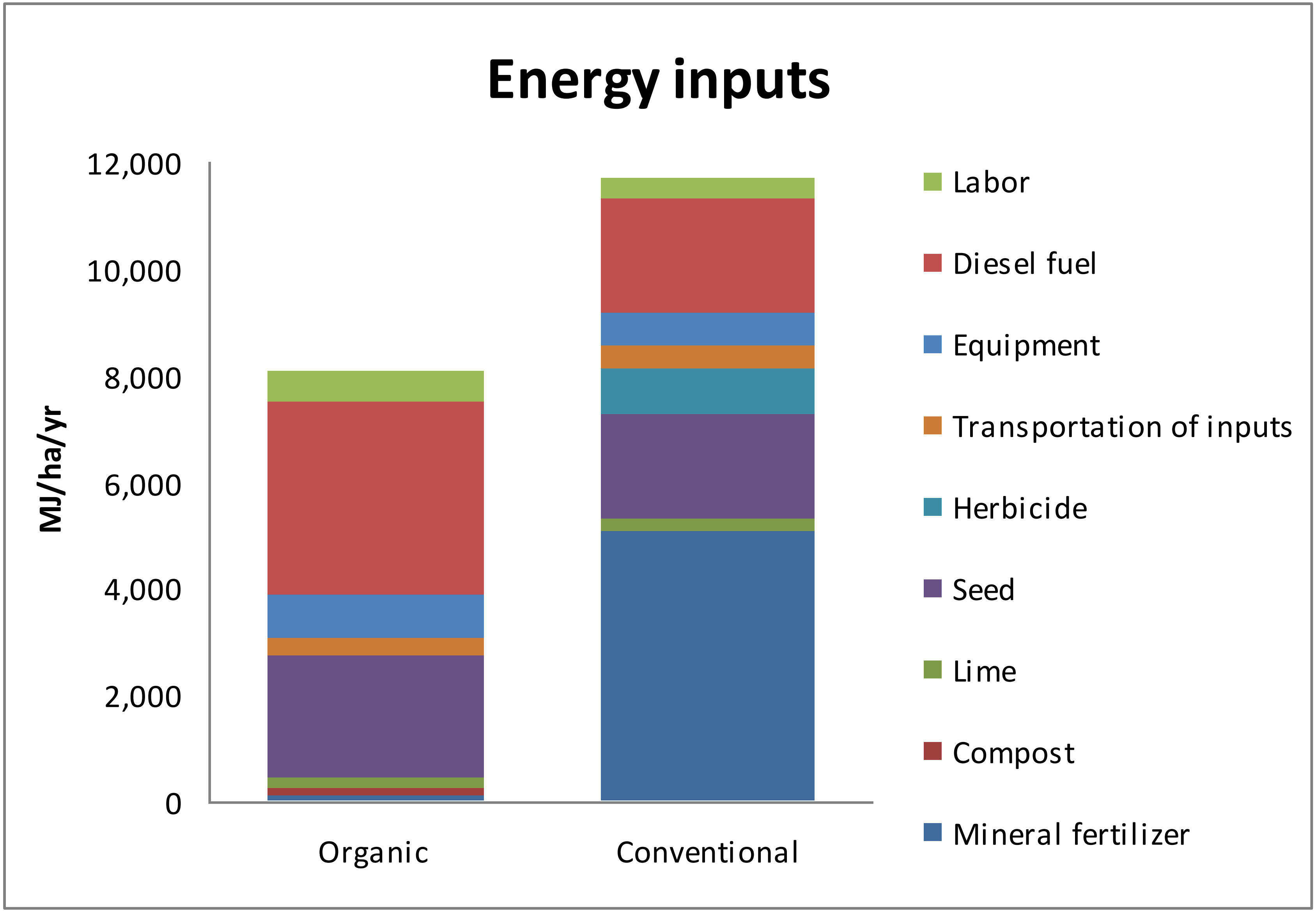
Organic (left) and conventional (right) corn during the 1995 drought – six weeks after planting

FST corn yields in years with moderate drought

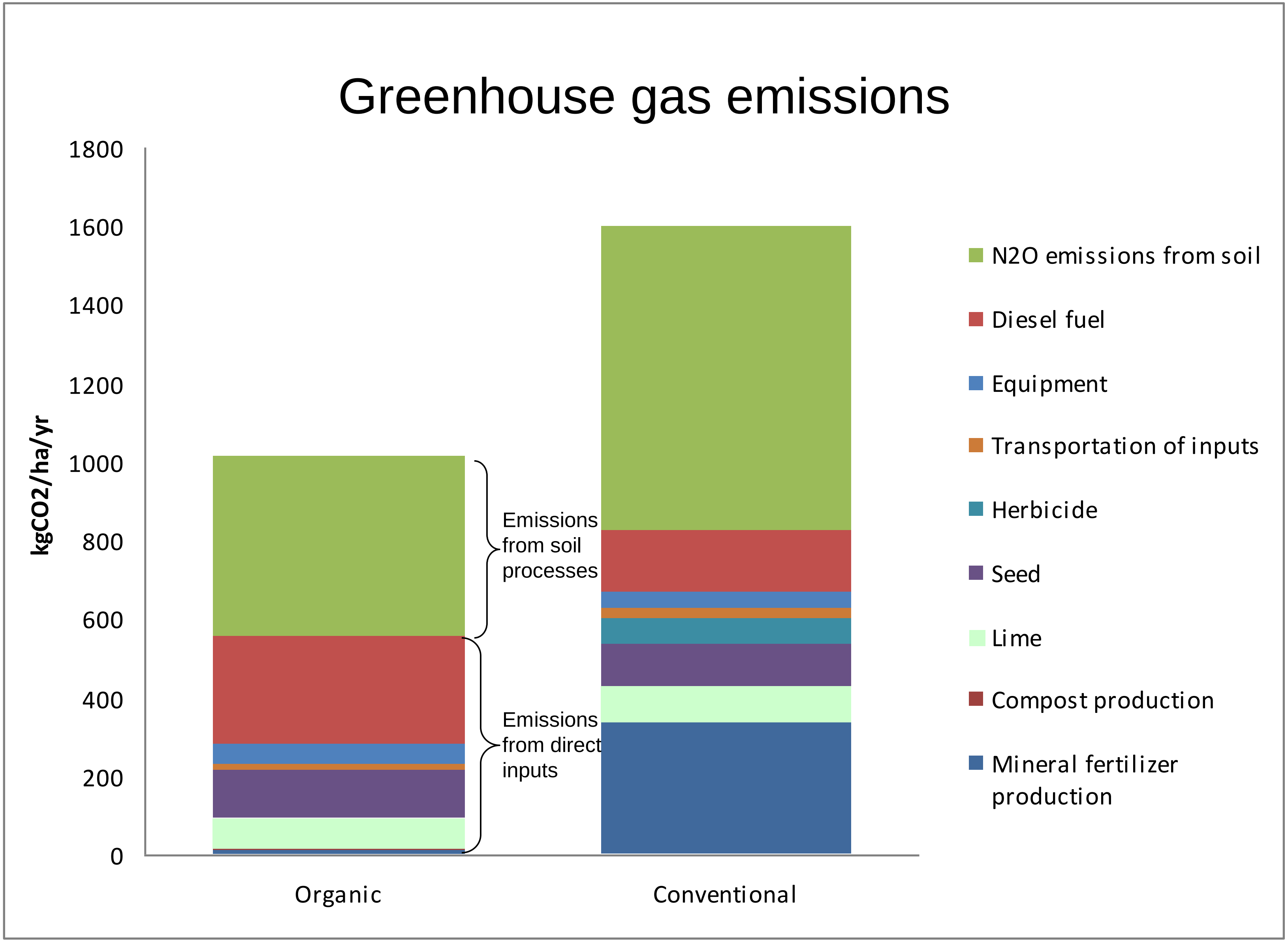
(average of 5 years: 1988, 1994, 1995, 1997, 1998)



FST Energy Analysis

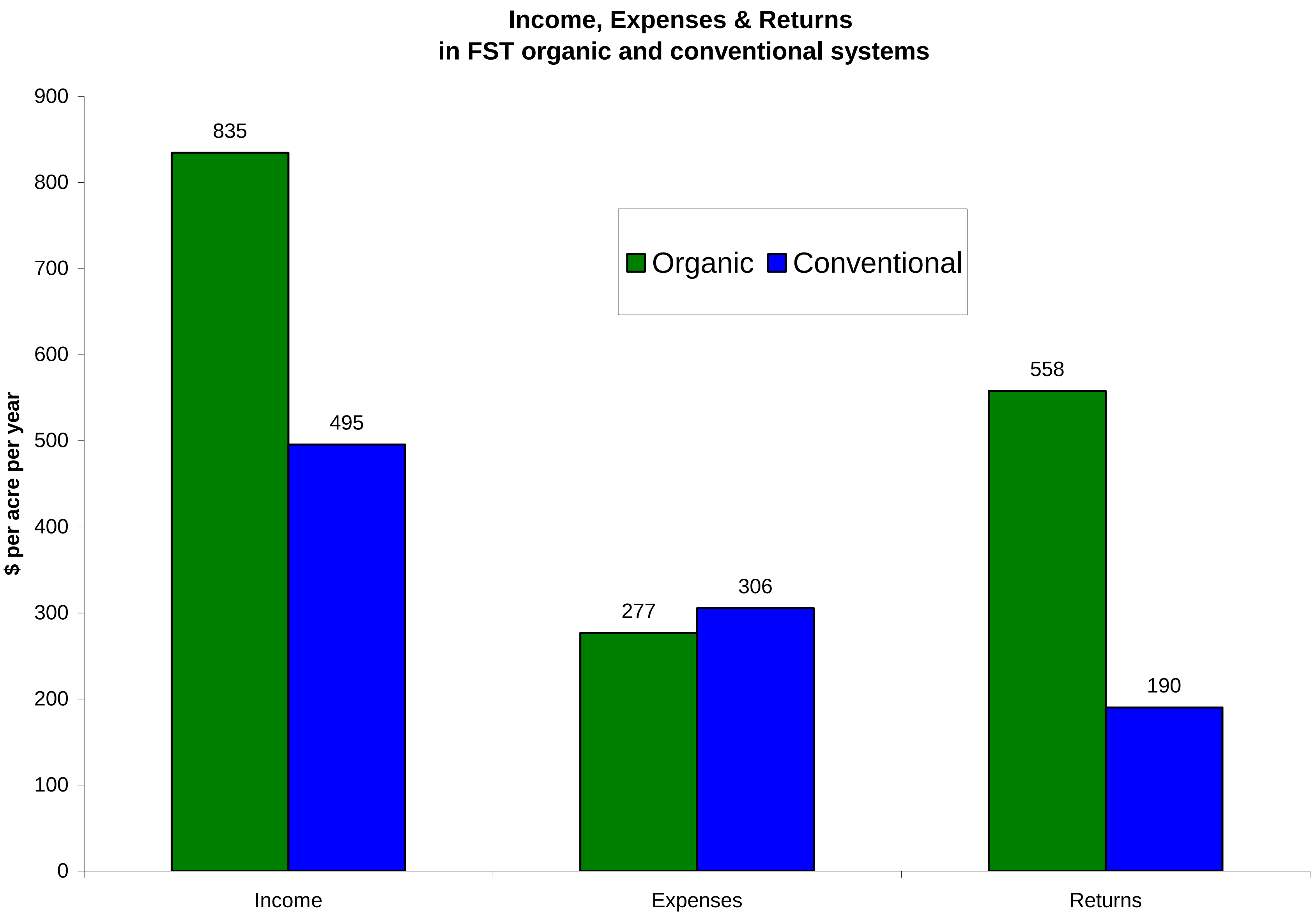


FST Greenhouse Gas Emissions

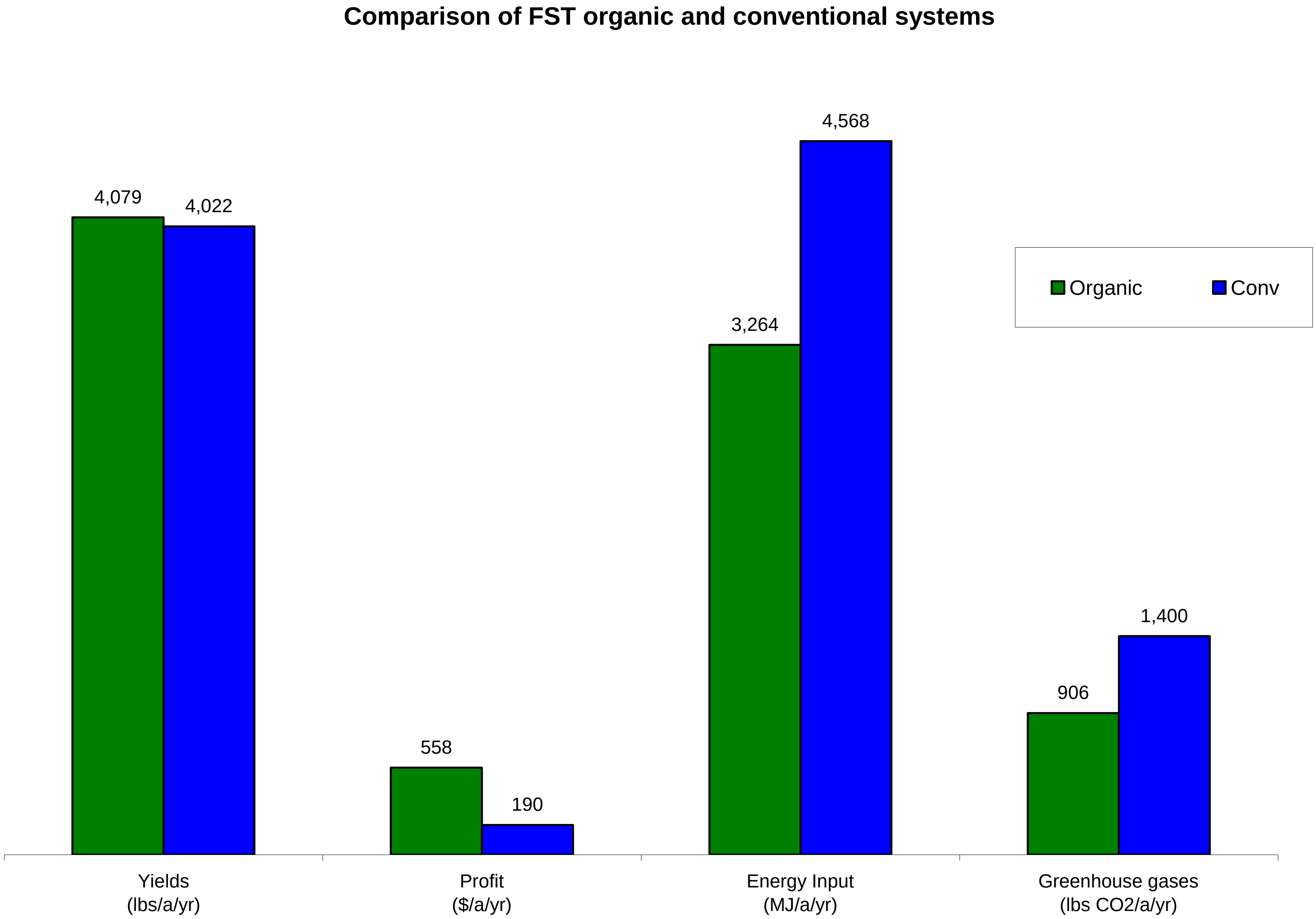


FST Economic Analysis

(2008-2010)



Overall comparison



Yields = grain and forage yields combined

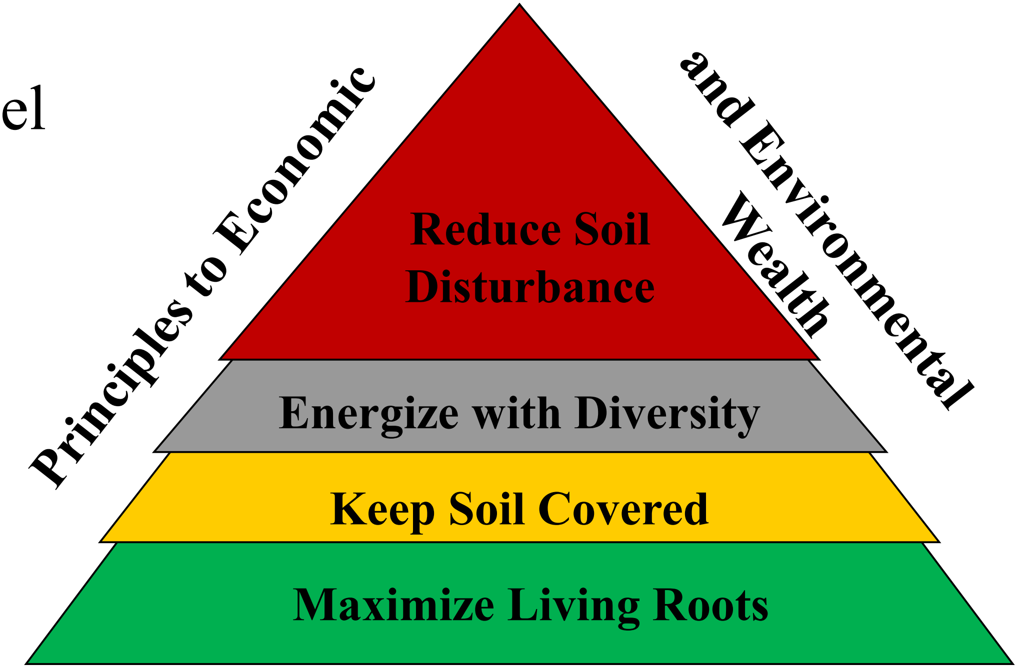
New GREEN REVOLUTION is a BROWN (SOIL) REVOLUTION

- **To cultivate soil organisms, they need:**
  - **Food – exudates, residue, humus**
    - Diverse crop rotation
    - Consistent source from continuous cover provided by perennials, cover crops, double cropping, companion cropping, or long-season crops
  - **Habitat**
    - Stable aggregates that are not destroyed by tillage

The BROWN REVOLUTION

Recognize proper soil management as the most ecologically and economically sustainable form of agriculture.

Provide food, fiber, and fuel
Provide nutrients
Protect the soil
Consistency
Resiliency
Moisture to roots
Maximize efficiency
Make money



Soil Food Web Pyramid

Thank You!

To be a successful farmer one must first know the nature of the soil.

-*Xenophon, Oeconomicus, 400 B.C.*

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Regenerative Organic Agriculture and Climate Change

http://rodaleinstitute.org/assets/RegenOrgAgricultureAndClimateChange_20141001.pdf