RODALE INSTITUTE

Organic Agricultural Farming Systems Trial & Organic No-Till

"Healthy Soil = Healthy Food = Healthy People"

By

Jeff Moyer Farm Director

History and key findings

Initiated in 1981, the Farming Systems Trial (FST) is America's longest running, side-by-side comparison of conventional and organic agriculture.

The project documents the feasibility of transitioning to organic production, as well as its economic, environmental, and energy conservation impacts.

FST has shown the potential of organic agriculture to improve our soil and water, while producing crop yields and net returns that are comparable (and sometimes better) than conventional systems.

Main cropping systems in FST

Organic-manure based

Tilled manure system
No-till manure system (added in 2008)

Organic-legume based

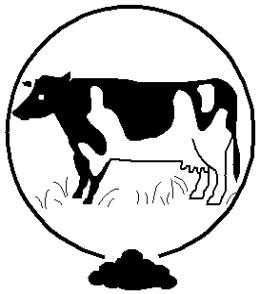
Tilled legume system
No-till legume system (added in 2008)

Conventional-chemically based

Tilled conventional system
No-till conventional system (added in 2008)

Manure System

This system represents an organic dairy or beef operation.
It features a long rotation, including both annual feed grain crops and perennial forage crops. The system's fertility is provided by leguminous crops and periodic applications of manure/compost.



- Organically managed
- Crops grown: Corn, soybeans, wheat, oats, hay, corn silage
- Cover crops: Winter rye and legumes
- Nitrogen source: Cattle manure / compost and legumes

Legume System

This system represents an organic cash grain system. It features a mid-length rotation, consisting of annual grain crops and cover crops. The system's sole source of fertility is leguminous crops.

- Organically managed
- Crops grown: Corn, soybeans, wheat, oats, barley
- Cover crops: Winter rye and legumes
- Nitrogen source: Legumes (hairy vetch, clovers)

Conventional System

This system represents the majority of grain farms in the US. It relies on synthetic nitrogen for fertility, and weeds are controlled by synthetic herbicides.

Tilled system (1981-present)

- Crops grown: Corn, soybeans
- Cover crops: None
- Chemically managed with mineral fertilizers and herbicides

No-till system (2008-present)

- Crops grown: Corn, soybeans, wheat
- Cover crops: Winter rye, hairy vetch
- Chemically managed with mineral fertilizers and herbicides

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	

rep/crop.sys/entry pt.

2010	plot no.		2011
W/HV	323	o	HV/C/rye
rye/O-clv/rye	321	o	rye/SB/W
rye/SB/W	322	o	W/HV
W/HV	331	o	HV/C/rye
rye/SB/W	332	o	W/HV
C/rye	333	o	rye/SB/W
HV/C/rye	312	o	rye/O/rye
W/Hay	311	o	Hay
Hay	313	o	Hay/Csil/W
C	831		SB
SB	833		C
C	832		SB
rye/O-clv/B	821		B/SB/W
B/SB/W	822		W/HV
W/HV	823		HV/C/rye
HV/C/rye	812		rye/O/rye
W/Hay	811		Hay
Hay	813		Hay/Csil/W

2010	plot no.		2011
rye/O-clv/B	221	o	B/SB/W
W/HV	223	o	HV/C/rye
B/SB/W	222	o	W/HV
C	231	o	SB
C	232	o	SB
SB	233	o	C
HV/C/rye	212	o	rye/O/rye
Hay	213	o	Hay/Csil/W
W/Hay	211	o	Hay
rye/O-clv/rye	421		rye/SB/W
rye/SB/W	422		W/HV
W/HV	423		HV/C/rye
HV/C/rye	412		rye/O/rye
Hay	413		Hay/Csil/W
W/Hay	411		Hay
C/rye	433		rye/SB/W
rye/SB/W	432		W/HV
W/HV	431		HV/C/rye
W/Hay	711		Hay
Hay	713		Hay/Csil/W
HV/C/rye	712		rye/O/rye
C	731		SB
SB	733		C
C	732		SB
rye/O-clv/B	721		B/SB/W
B/SB/W	722		W/HV
W/HV	723		HV/C/rye

2010	plot no.		2011
rye/O-clv/rye	121	o	rye/SB/W
W/HV	123	o	HV/C/rye
rye/SB/W	122	o	W/HV
Hay	113	o	Hay/Csil/W
W/Hay	111	o	Hay
HV/C/rye	112	o	rye/O/rye
C/rye	133	o	rye/SB/W
W/HV	131	o	HV/C/rye
rye/SB/W	132	o	W/HV
HV/C/rye	512	o	rye/O/rye
W/Hay	511	o	Hay
Hay	513	o	Hay/Csil/W
B/SB/W	522	o	W/HV
rye/O-clv/B	521	o	B/SB/W
W/HV	523	o	HV/C/rye
C	531	o	SB
SB	533	o	C
C	532	o	SB
rye/SB/W	622		W/HV
rye/O-clv/rye	621		rye/SB/W
W/HV	623		HV/C/rye
W/HV	631		HV/C/rye
C/rye	633		rye/SB/W
rye/SB/W	632		W/HV
Hay	613		Hay/Csil/W
HV/C/rye	612		rye/O/rye
W/Hay	611		Hay

Siegfriedale Road

Tree Line

---60 ft ----

|----------300 ft ----------|

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

Areas of research in FST

- Yields
- Soil quality
- Water quality and quantity
- Energy analysis
- Economics

Rotation (2008-present)

Crop Rotations in the Rodale Institute Farming Systems Trial (2008-present)

Year	1		2		3		4		5		6		7		8	
No-Till Manure System - 8 year rotation																
^{P}hv (cc)	roll hv ^{NT}Corn	^{NT}rye (cc)	*Compost* ^{P}rye Oats	^{P}rye (cc)	roll rye ^{NT}Soybean	^{P}Wheat	Wheat ^{FS}Hay	Hay	Hay	Hay	Hay	Hay	*Compost* ^{P}Corn (silage)	^{P}Wheat	Wheat	^{P}hv (cc)
Tilled Manure System - 8year rotation																
^{P}hv (cc)	^{P}hv Corn	^{NT}rye (cc)	*Compost* ^{P}rye Oats	^{P}rye (cc)	^{P}rye Soybean	^{P}Wheat	Wheat ^{FS}Hay	Hay	Hay	Hay	Hay	Hay	*Compost* ^{P}Corn (silage)	^{P}Wheat	Wheat	^{P}hv (cc)

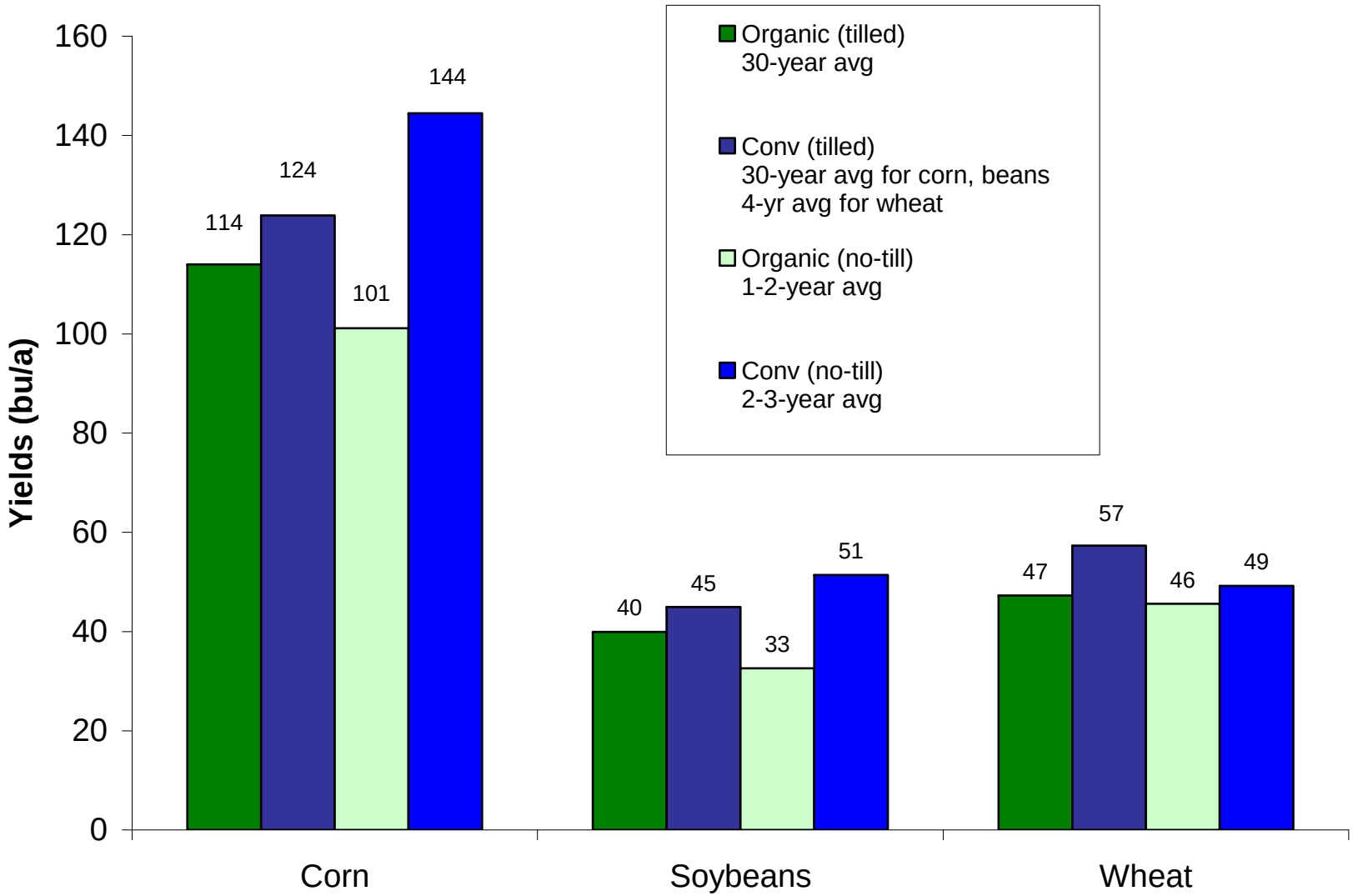
Year	1		2		3		4		5		6		7		8	
No-Till Legume System - 4 year rotation																
^{P}hv (cc)	roll hv ^{NT}Corn	^{NT}rye (cc)	^{P} rye Oats/clover	^{P}rye (cc)	roll rye ^{NT}Soybean	^{P}Wheat	Wheat	^{P}hv (cc)								
Tilled Legume System - 4 year rotation																
^{P}hv (cc)	^{P}hv Corn	^{NT}rye (cc)	^{P}rye Oats/clover	^{P}Barley	Barley ^{P}Soybean	^{P}Wheat	Wheat	^{P}hv (cc)								

Year	1		2		3		4		5		6		7		8	
No-Till Conventional System - 3 year rotation																
^{NT}hv (cc)	burndown ^{NT}Corn	^{NT}rye (cc)	burndown ^{NT}Soybean	burndown ^{NT}Wheat	Wheat burndown	^{NT}hv (cc)										
Tilled Conventional System - 2 year rotation																
	No cover crops ^{CP}Corn		^{CP}Soybean													

Legend
hv = hairy vetch
cc = cover crop
P = Moldboard Plow
CP = Chisel Plow
NT = No-Till
FS = Frost seed

Superscript letters before crop names indicate the tillage/planting method to be used.
All crops in the standard-tilled Organic rotations will be planted into moldboard plowed soil, except for rye used as cover crop.
All crops in the Conventional system will be either planted into chisel plowed soil (for the standard-tilled plots) or no-till planted.

FST long-term grain yields (1981-2010)



FST Soil Results

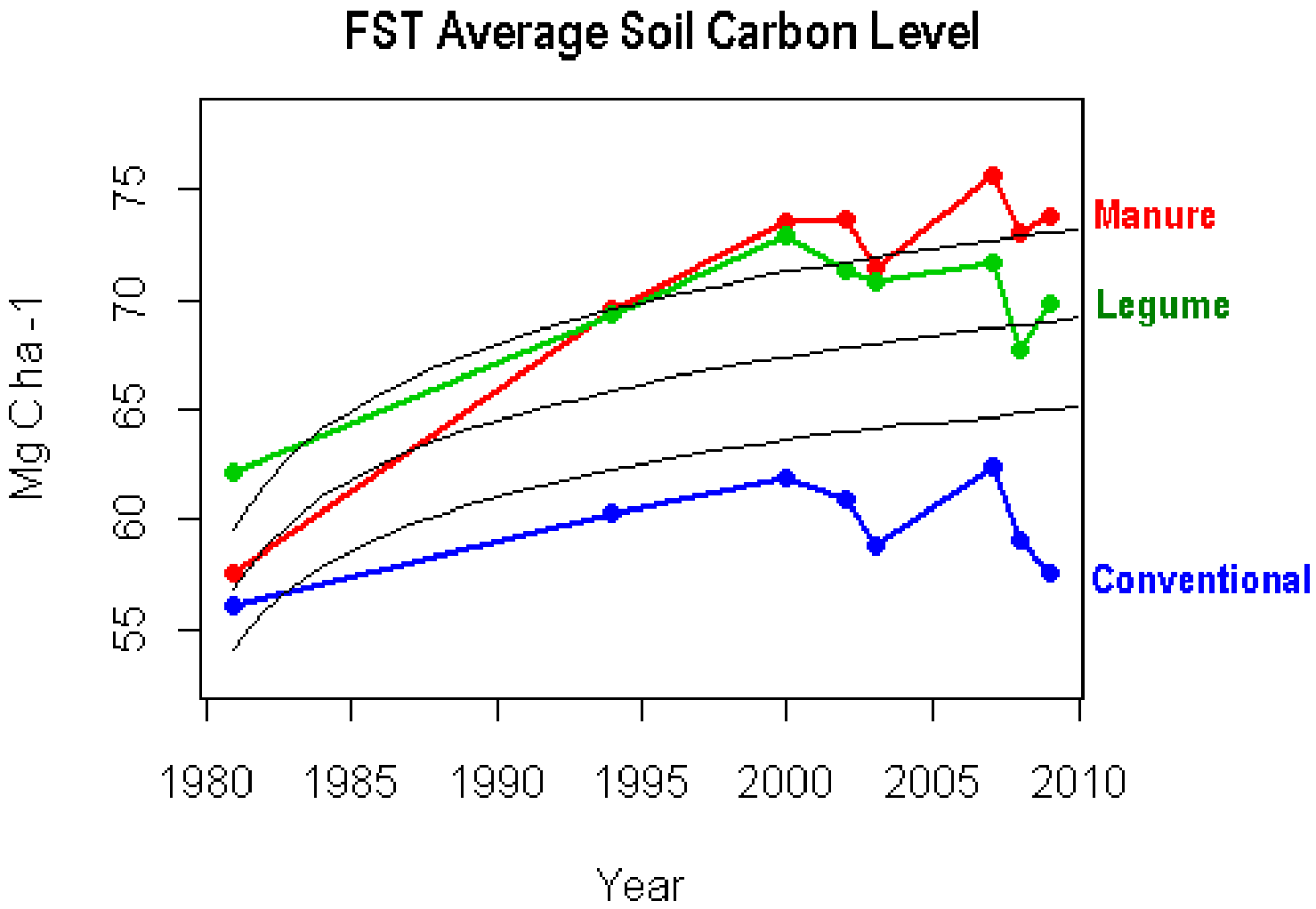
- Soil carbon and nitrogen increased significantly in the organic systems, but not in the conventional system.

	Organic		Conventional	
	1981	**2010**	**1981**	**2010**
Soil C	2.0%	2.4-2.5%	2.0%	no change
Soil N	0.31%	0.35-0.37%	0.31%	no change

- Soil carbon increases were greatest in the first 14 years of the trial. Carbon continued to build in both organic systems during the second half (after 1994), but at a slower rate.

- The conventional system has shown a loss in carbon in more recent years.

Long-term soil carbon data



FST Soil Results

Soils of the organic systems have a more active soil biological community

→ higher levels of glomalin (a glycoprotein that acts like 'glue', binding organic matter to mineral particles),

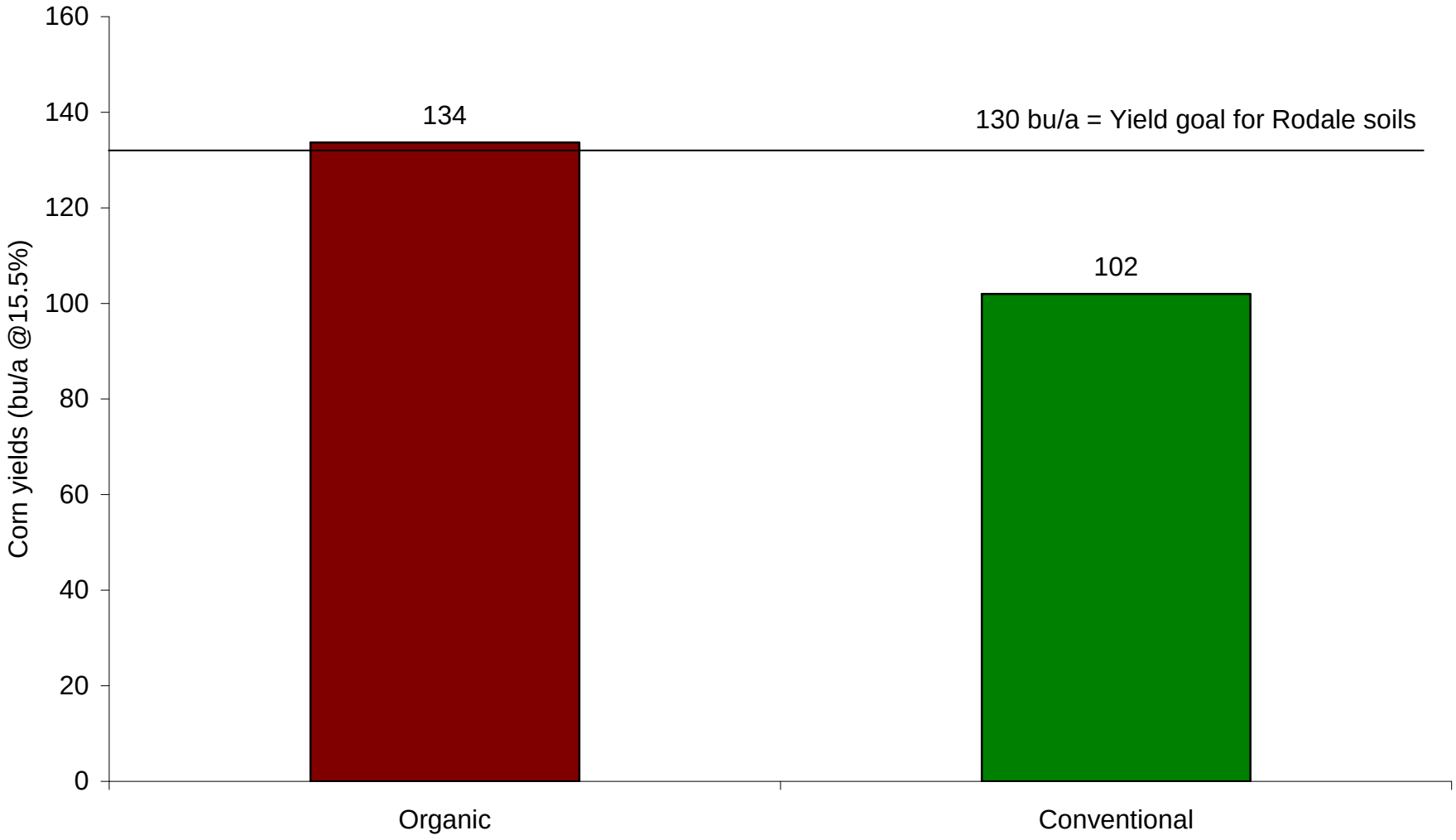
→ greater populations of mycorrhizae (a fungus that forms a symbiotic relationship with its host plant: the fungus receives carbohydrates from the plant, which in return gains access to water and nutrients).

This leads to improved soil structure and enhanced carbon sequestration.

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)



Atrazine

- Atrazine is one of the most widely used agricultural pesticides in the U.S.

- It may be applied before and after planting to control broadleaf and grassy weeds. It is used primarily on corn, sorghum, and sugarcane, and is applied most heavily in the Midwest (EPA Sept 2011).
  http://www.epa.gov/oppsrrd1/reregistration/atrazine/atrazine_update.htm

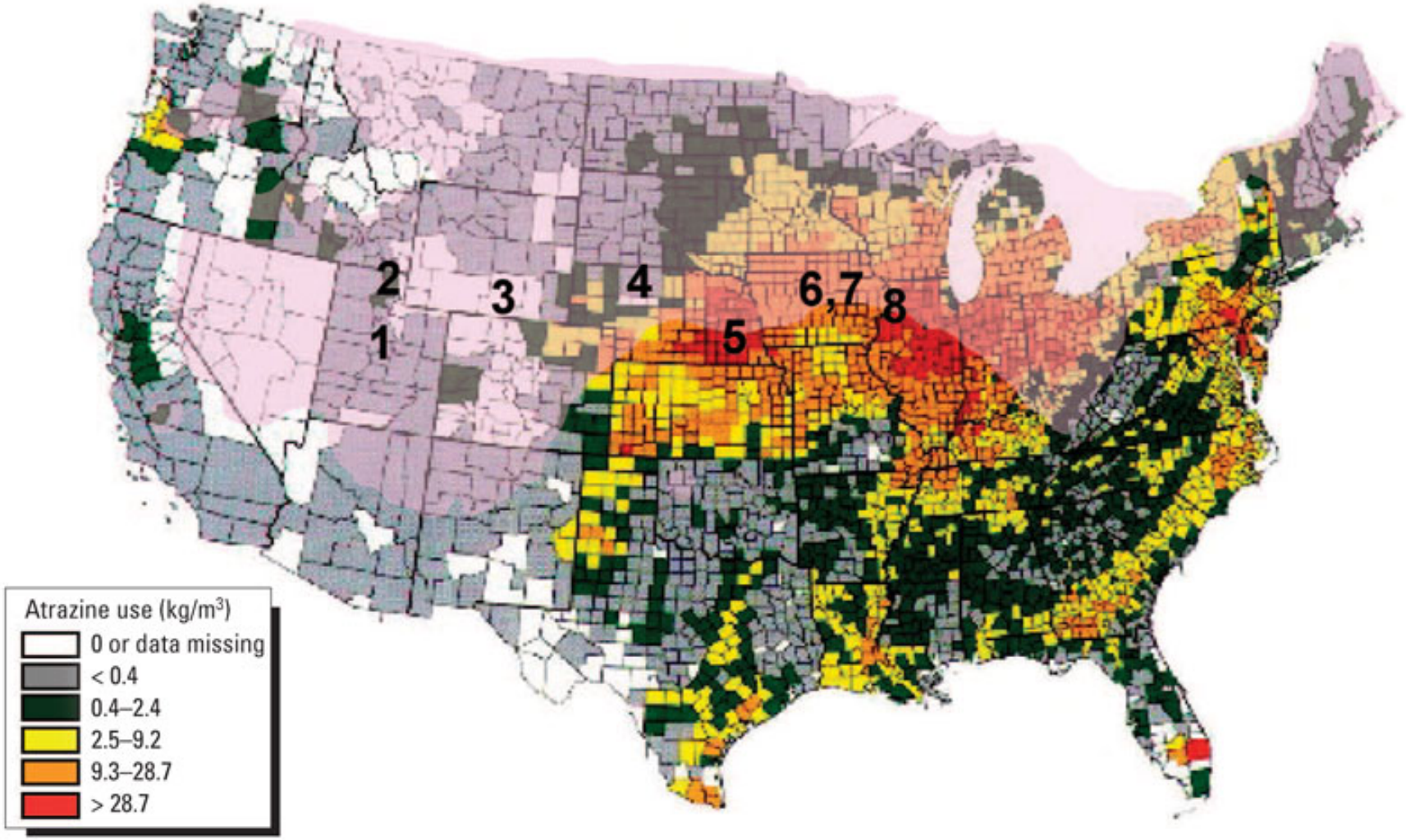
- Atrazine is the top contaminant found in drinking water, ground water, and surface water in the U.S. It is banned in the European Union.

- It is a possible cause of several types of cancer (prostate, breast and ovary) and, according to many researchers, a proven endocrine disruptor—with visible effects, such as hermaphrodism (de-masculinization) in frogs, even at extremely low levels of exposure (Hayes et al. 2002).

  > I'm not saying it's safe for humans. I'm not saying it's unsafe for humans. All I'm saying is that it makes hermaphrodites of frogs.—University of California biologist Tyrone Hayes

- One study suggests a correlation between exposure to atrazine and low sperm quality among men in an agricultural area of the United States

Use of atrazine in the United States



Herbicides in FST conventional systems

Corn

3 qt/a Degree Xtra (= acetochlor + atrazine)
3 oz/a Callisto (= mesotrione)
0.5 lb/a atrazine

Soybeans

0.75 lb ae/acre glyphosate (Roundup products)

Wheat

0.66 oz/acre Harmony Extra (= triazine)

1 pt/acre 2,4-D (Dichlorophenoxyacetic acid)

If cover crops are grown:

0.75 lb ae/acre glyphosate
0.5 lb ae/acre 2,4-D

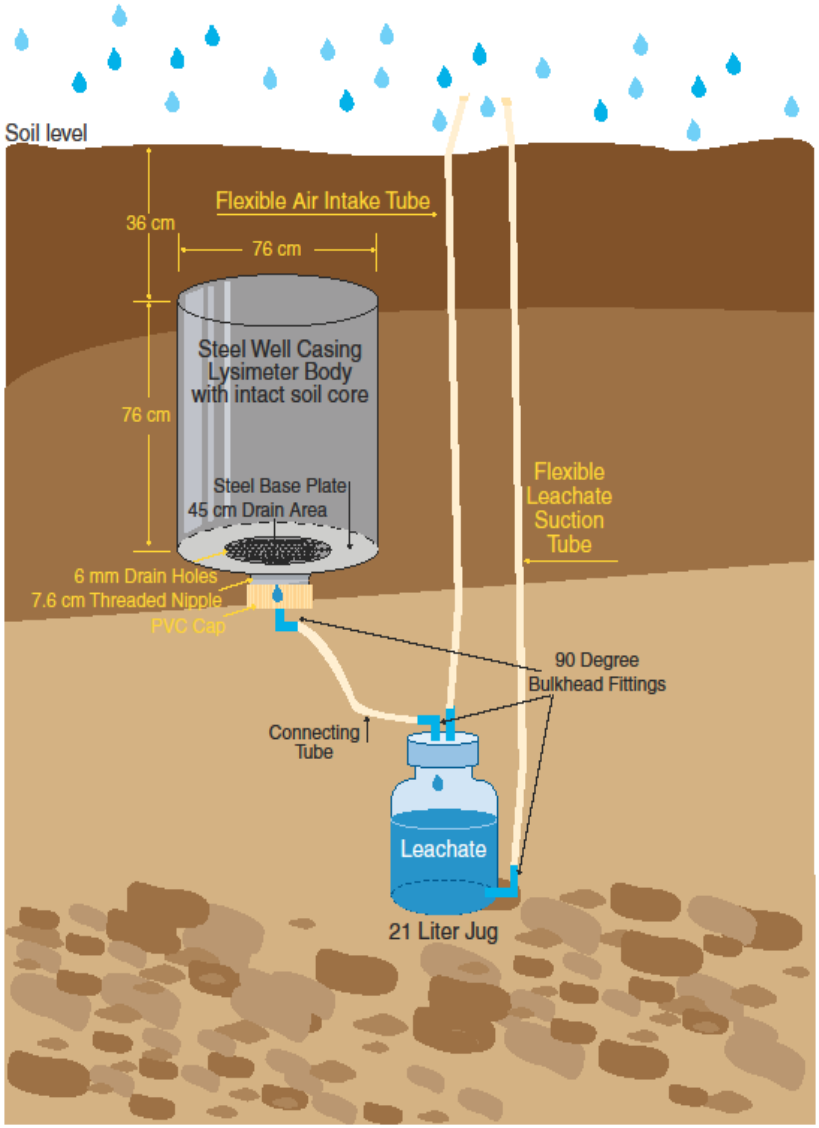
Note: 2,4-D is the most widely used herbicide in the world, and the third most commonly used in North America.

FST conventional systems

	Tilled Conventional (2 year rotation)	No-till Conventional (3 year rotation)
Corn	NPK starter fertilizer N side dress 2 herbicide applications - pre- and post emergence	NPK starter fertilizer N side dress 4 herbicide applications - pre- and post emergence in corn - weeds and cover crop burn down
Soybeans	no fertilizer 1 herbicide application - post-emergence	no fertilizer 2 herbicide application - pre- and post emergence
Wheat	*no wheat in rotation*	N top dress 2 herbicide applications - pre- and post emergence
Total per year	**1.5 herbicide applications**	**2.7 herbicide applications**

FST Water Results

Lysimeter schematic



Lysimeter pumping year round

FST Water Results

Water percolation volumes were 15-20% higher in the organic systems
→ increased groundwater recharge and reduced runoff under organic management

Nitrate-nitrogen leaching was the same for all systems, and fairly low:
15-18 kg nitrogen/ha/year

Nitrate-nitrogen concentration:

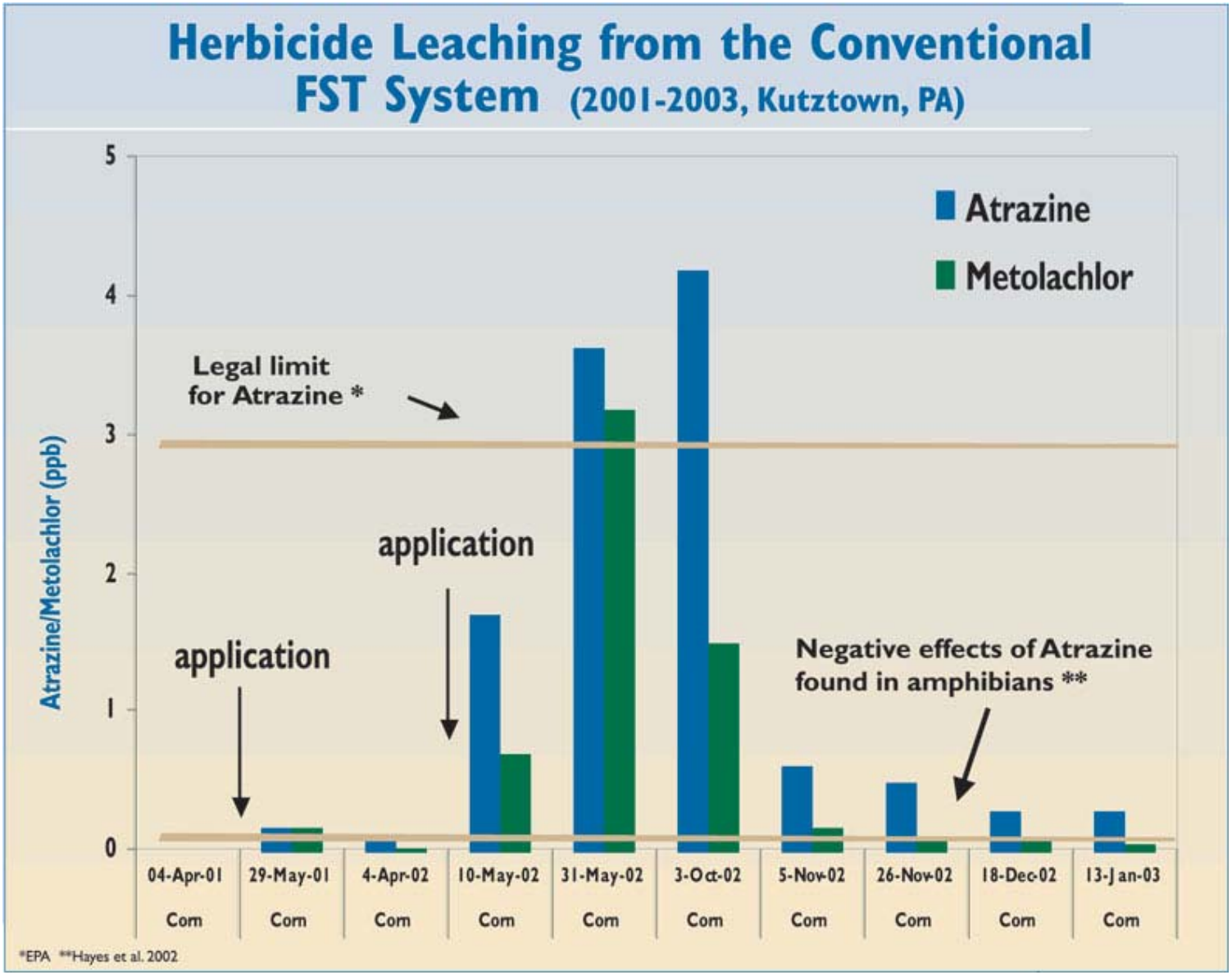
- Conventional plots: 20% of water samples >10 ppm
- Organic plots: 15 and 8% of samples > 10 ppm

(10 ppm = legal limit for nitrate-nitrogen concentration in drinking water)

Herbicides:

- Only detected in water from conventional plots
- When atrazine was applied two years in a row, atrazine levels sometimes exceeded 3 ppb (EPA's maximum contaminant level for drinking water)

FST Water Results



Recent agricultural trends

Switch from the old "conventional" crop varieties to genetically modified varieties:

94% of all soybeans and 72% of all corn grown in the U.S. are genetically modified (USDA 2007).

- RoundupReady corn and soybeans
- Bt (*Bacillus thuringiensis*) corn, potato and cotton

2002 study in nine Midwestern states:

- Glyphosate was detected in 36% of the 154 samples, while its degradation product, aminomethylphosphonic acid (AMPA) was detected in 69% of the samples.
- Atrazine was detected at or above the 3 microgram per liter MCL in 30% of the samples.
- Atrazine concentrations were generally lower than those found in previous USGS studies conducted in the 1990s.

Source: http://toxics.usgs.gov/highlights/glyphosate02.html

Resistance to Roundup products and Bt:
Horseweed, lambsquarter, diamondback (cabbage) moth

=> **"super weeds" and "super insects"**

FST Energy Analysis

Energy input in the conventional systems was 45% higher

- Conventional systems: Nitrogen fertilizer (41%)
- Organic systems: Fuel for field operations (45%)

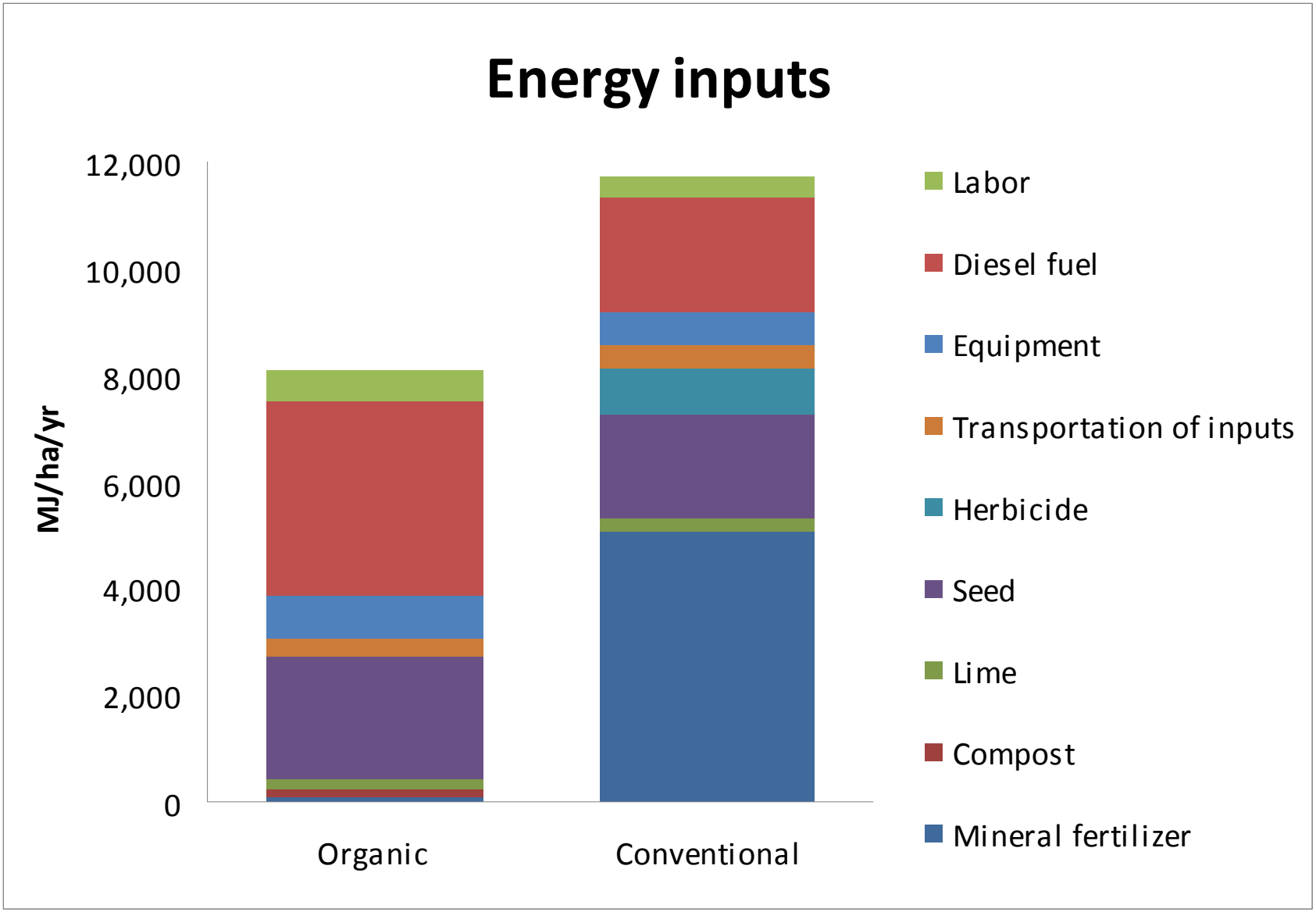
Production efficiency:

28% higher in the organic systems (energy inputs per crop produced)

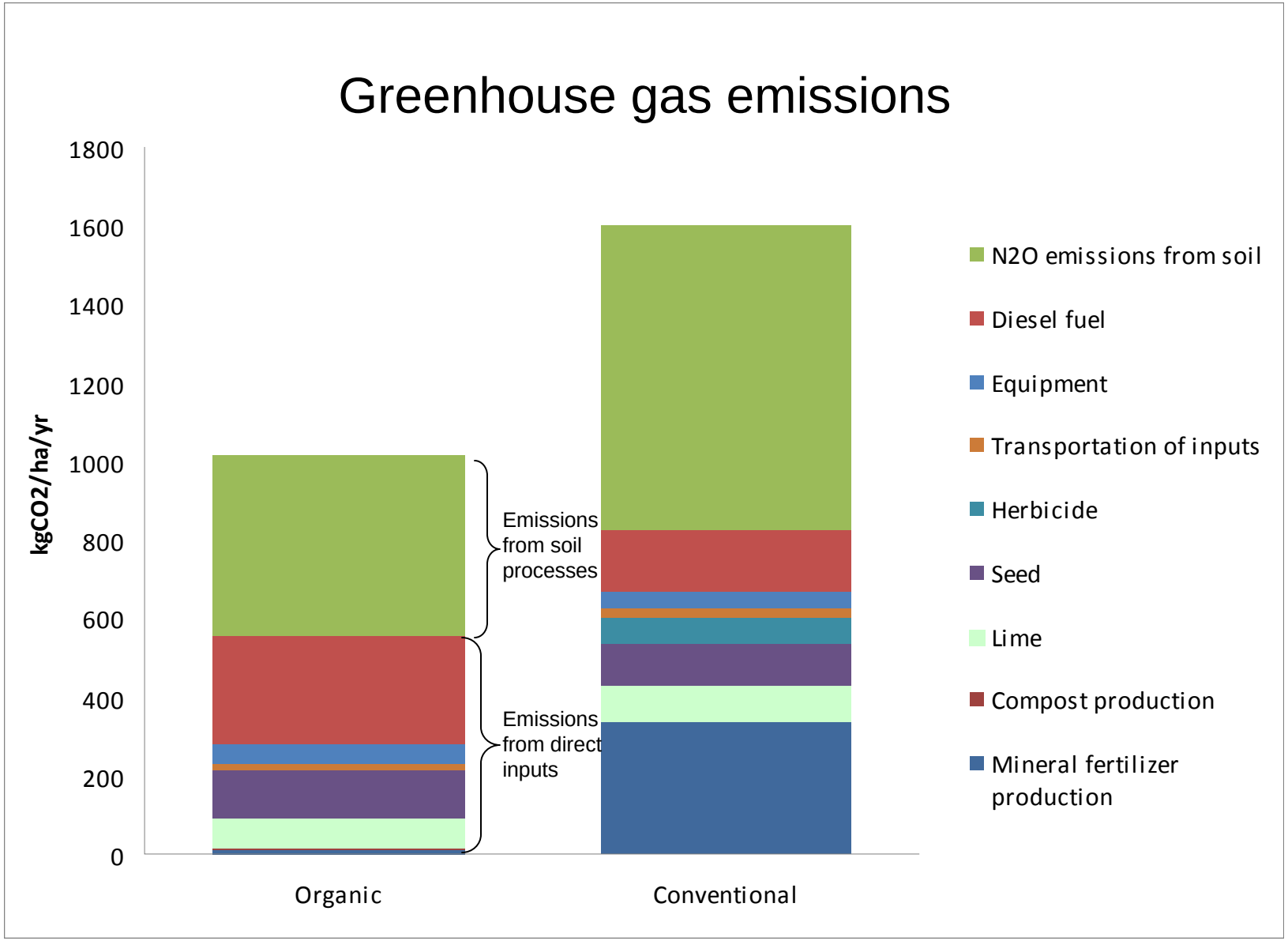
Greenhouse gas emissions:

40% less in organic systems (GHG emitted per crop produced)

FST Energy Analysis



FST Energy Analysis



FST Economic Analysis

Conventional systems had the lowest profits of all 6 systems:

- No-till: $170 /acre/year
- Tilled: $210 /acre/year

Organic systems had profits that were ~3-4 times higher:

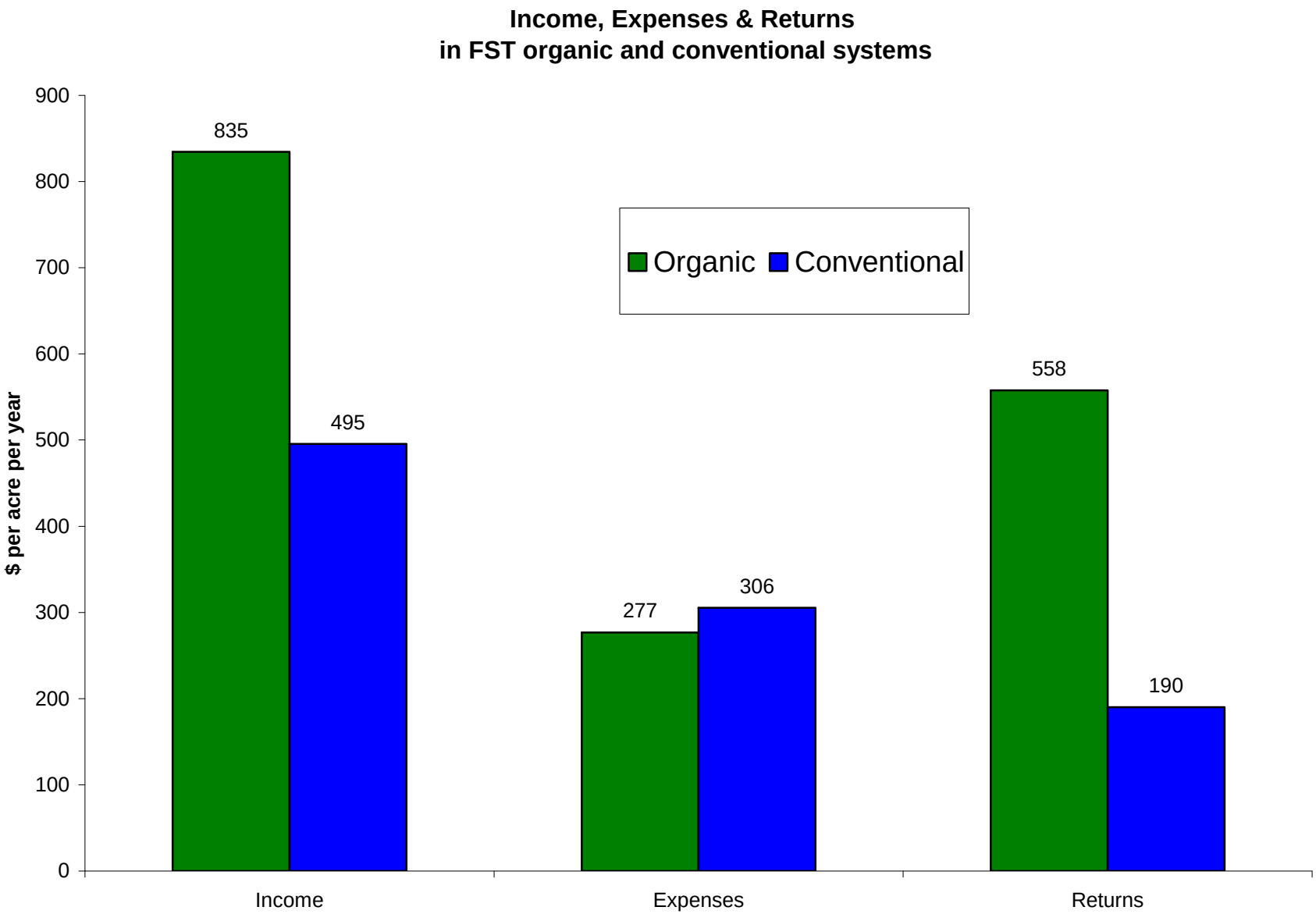
$491 to $653 /acre/year

Most and least profitable grain crops:

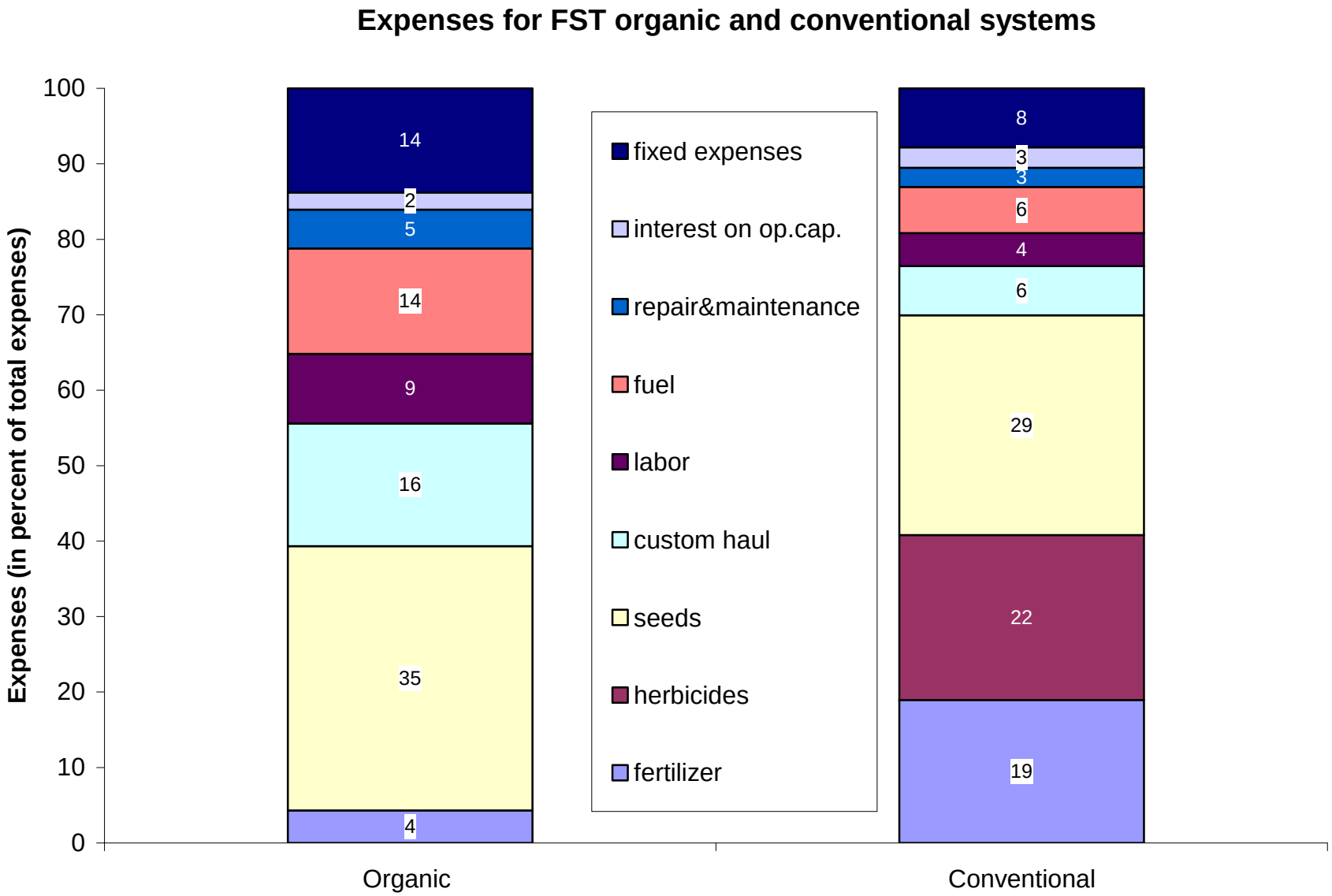
- Organic systems: Wheat (~$800/acre/year)
- Conventional systems: Soybeans (~$300/acre/year)

- No-till conventional corn: $27/acre/year

FST Economic Analysis



FST Economic Analysis

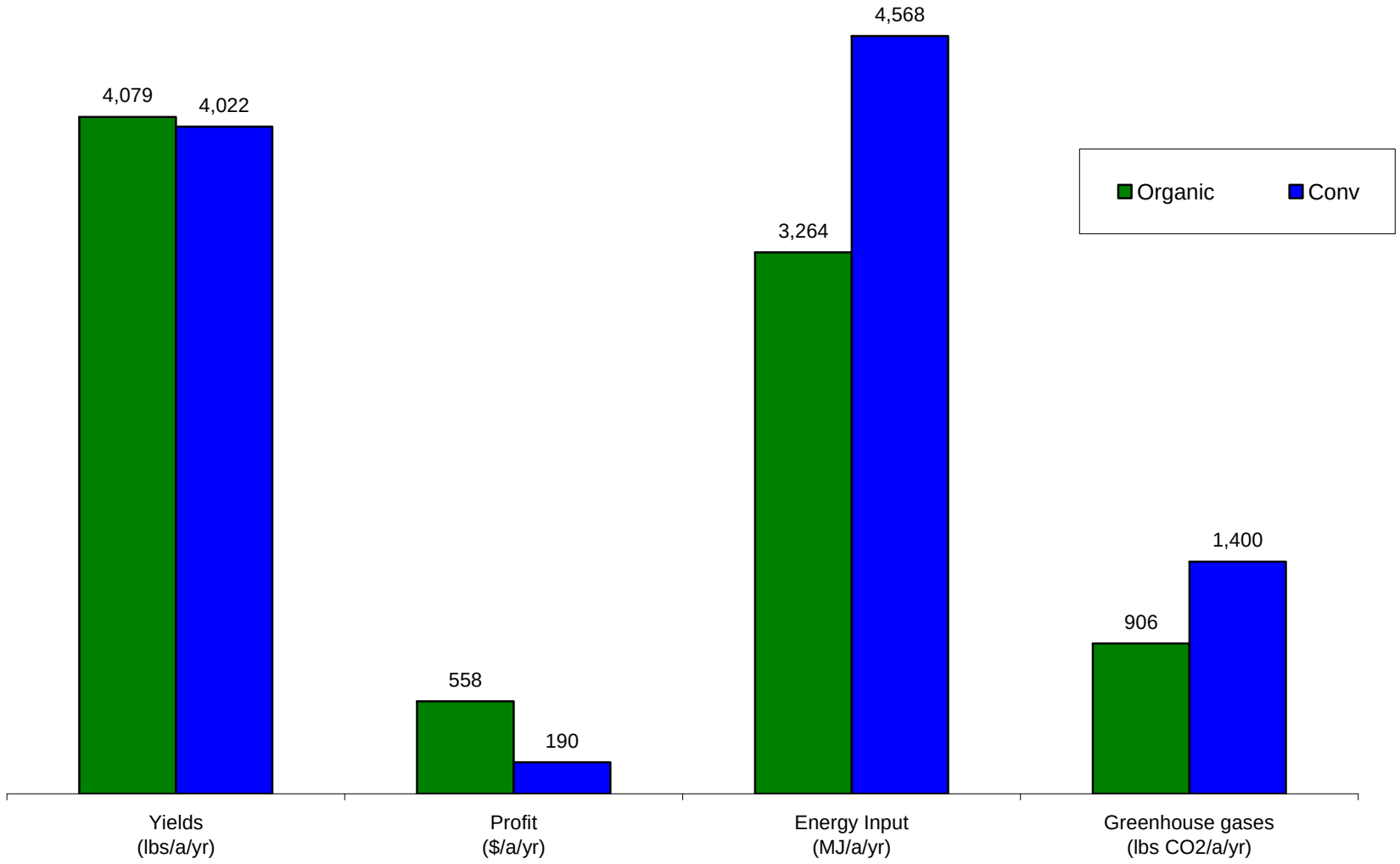


FST Summary

- Over the 30 years of the trial, yields were the same between organic and conventional systems.
- Corn and soybean crops in the organic systems tolerated much higher levels of weed competition than their conventional counterparts, while producing equivalent yields.
- Soil organic matter and soil structure improved in the organic systems while they stayed the same in the conventional system.
- Energy inputs were 45% higher in the conventional systems and production efficiency was 28% higher in the organic systems.
- The organic systems emitted 40% less GHG than the conventional systems.
- The organic systems were 3-4 times more profitable than the conventional systems.

FST Summary

Comparison of FST organic and conventional systems



Yields = grain and forage yields combined

Tillage has it’s Drawbacks

Organic No-Till

Corn Mid-Season

2010 Soybean Research Plots

Windy Acres Farm 2011

2009 Tomato

Pumpkins 2010 Planted on 30” Rows – 5’ Centers
Hairy Vetch Cover

Roller/Crimper in Action

Integrating two BMP's

Horse Drawn & Pull Type

30’Roller – West Africa

Roller/Crimper for Raised Beds

The Concept is Scale Neutral

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& Professional
Garden Tools

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Thank You!

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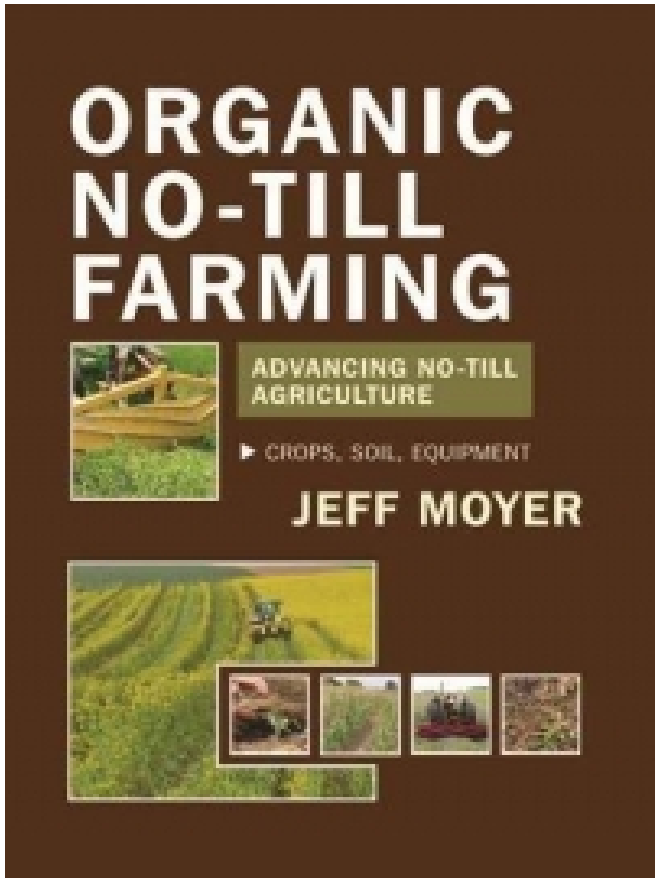

Organic No-Till Farming

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