

CROP ROTATION EFFECTS ON MAIZE AND SOYBEAN YIELDS IN THE MID-WESTERN UNITED STATES

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As more complex cropping systems involving livestock, forage, and feed grain crop production were replaced with maize (*Zea mays* L.)-based, cash grain systems in the middle of the twentieth century in the U.S. Corn Belt, soybean (*Glycine max* L.) grew to occupy an area nearly equal to the maize area, and the 2-year, maize-soybean crop rotation became the dominant cropping system. In response to favourable maize prices, maize area has increased while soybean area has decreased in the last decade; in 2012, maize occupied 30.4 million ha in the 12 Corn Belt states compared to 24.5 M ha of soybean. In the two largest maize-producing states (Illinois and Iowa) maize occupied 10.6 M ha and soybean only 7.2 M ha in 2012; in these states, some 20-25% of the maize crop must follow maize each year because the maize area is larger than the area of all other crops combined. We have established several long-term crop rotation studies to see how maize and soybean yields compare when each crop follows itself or another crop or crops in sequence. Over four years (2008-2011) at a productive Illinois site (Monmouth), maize following soybean in a 2-year rotation yielded 1.0 t/ha (8%) more than continuous maize, while soybean following maize in the same rotation yielded 0.4 t/ha (8%) more than continuous soybean. Adding wheat (*Triticum aestivum* L.) as a third crop into the maize-soybean rotation increased the yield of both maize and soybean by 12-15% compared to either crop grown continuously. In a second study at the same location and over the same time period, soybean grown in a 3-year rotation following two maize crops yielded 0.4 t/ha (9%) more than soybean following a single year of maize in a 2-year rotation. Maize following one year of maize yielded 0.4 t/ha (3%) more than continuous maize, and maize following soybean yielded 0.7 t/ha (5%) more than continuous corn. While mixed rotations can increase both maize and soybean yields, the relatively favourable price of maize in recent years has favoured maize at the expense of soybean among U.S. producers. In regions of stress due to lack of water, however, yields of maize following maize have been unusually low in recent years relative to those of maize following soybean; that is, soybean preceding maize can provide unusually large increases in maize yields under some conditions. This has some producers interested in increasing their soybean area in order to increase the percentage of maize that follows soybean. The extent to which this is done will depend on relative prices of soybean and maize, but it is clear that soybean in the rotation can both be profitable itself and can increase the yield and profitability of maize as well.

Crop Rotation Effects on Maize and Soybean Yields in the Midwestern United States

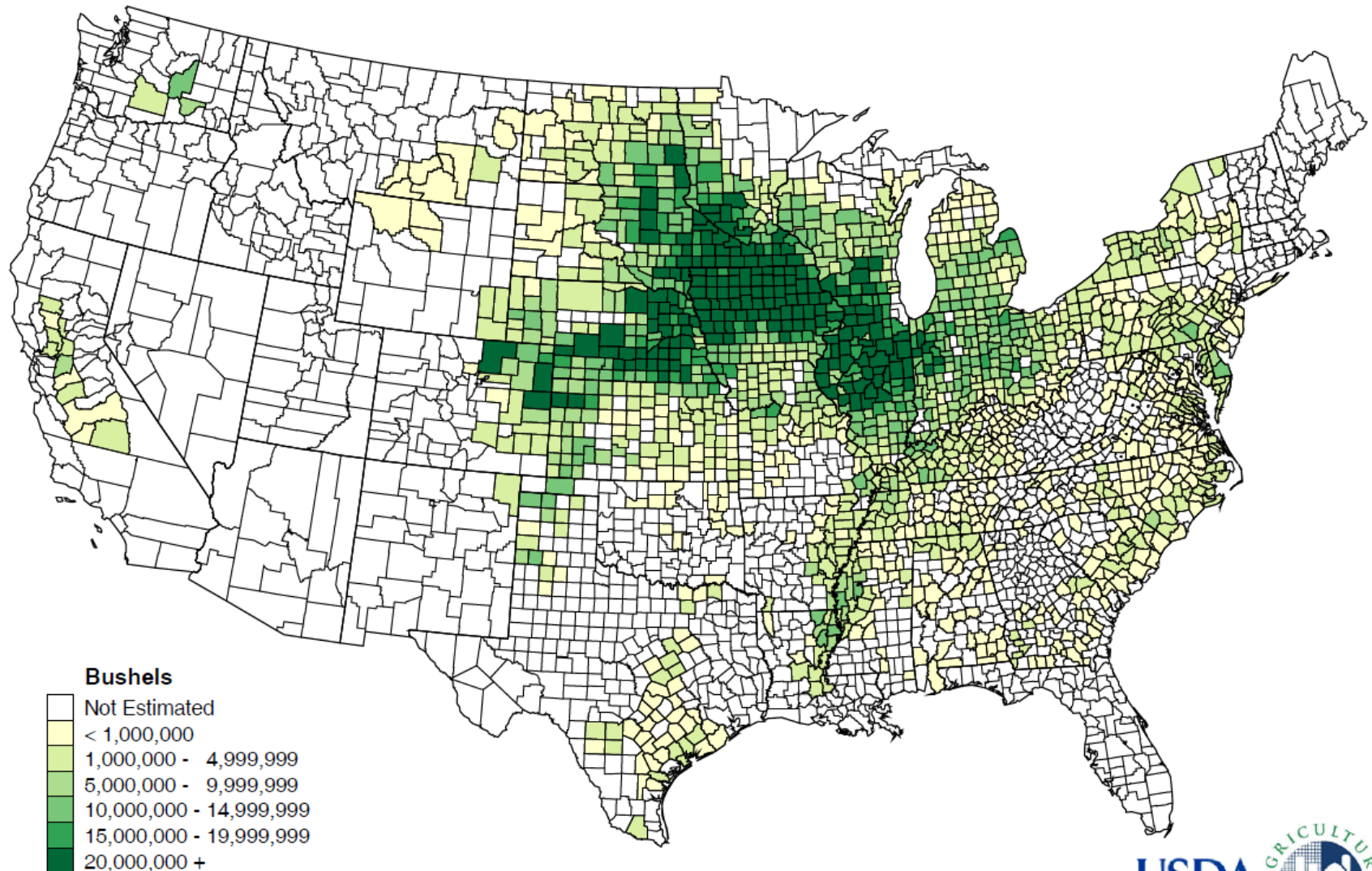
WSRC IX, Durban, 19 February 2013

Emerson D. Nafziger & María B. Villamil

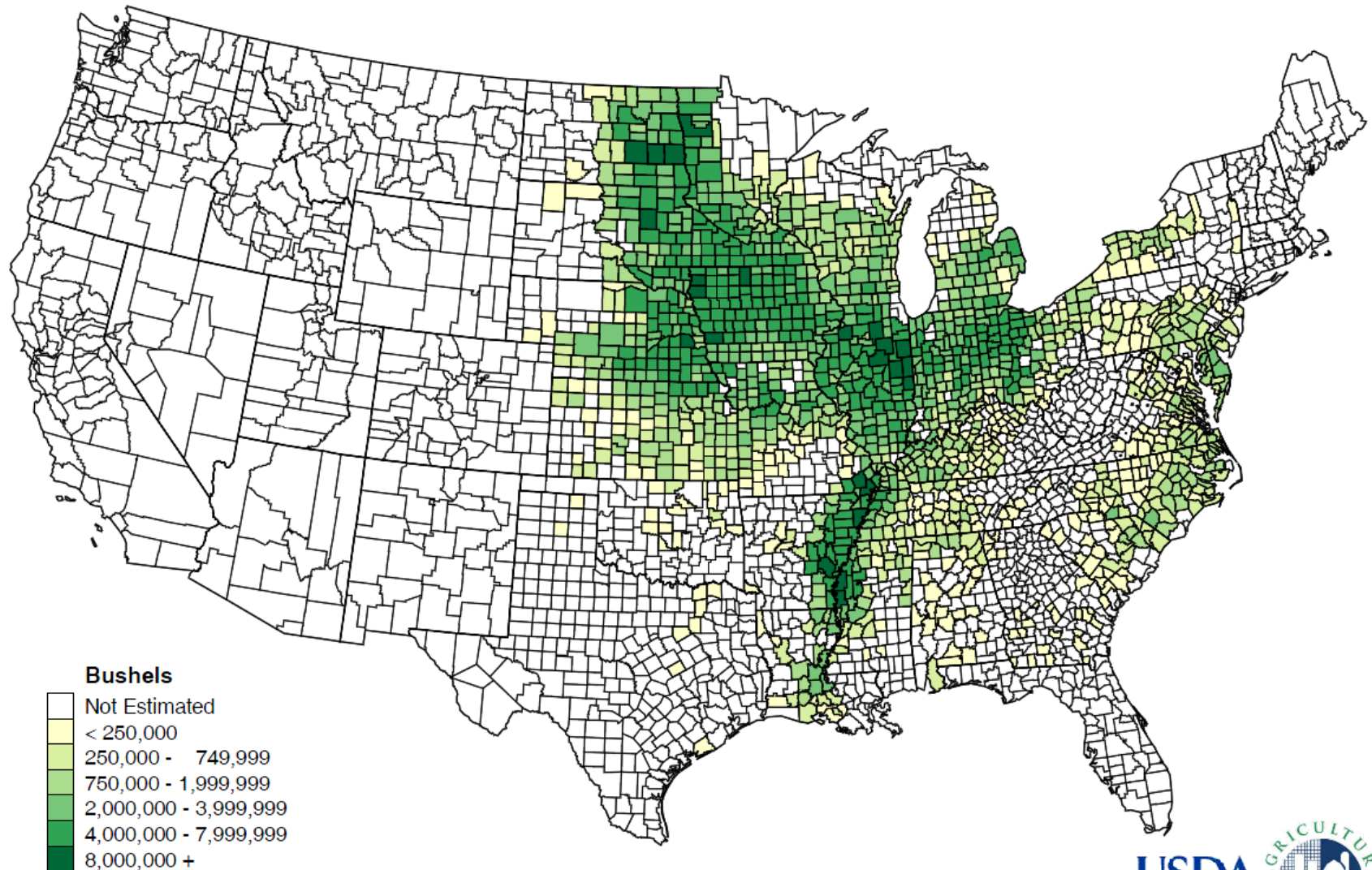
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Corn for Grain 2011 Production by County for Selected States



Soybeans 2011 Production by County for Selected States

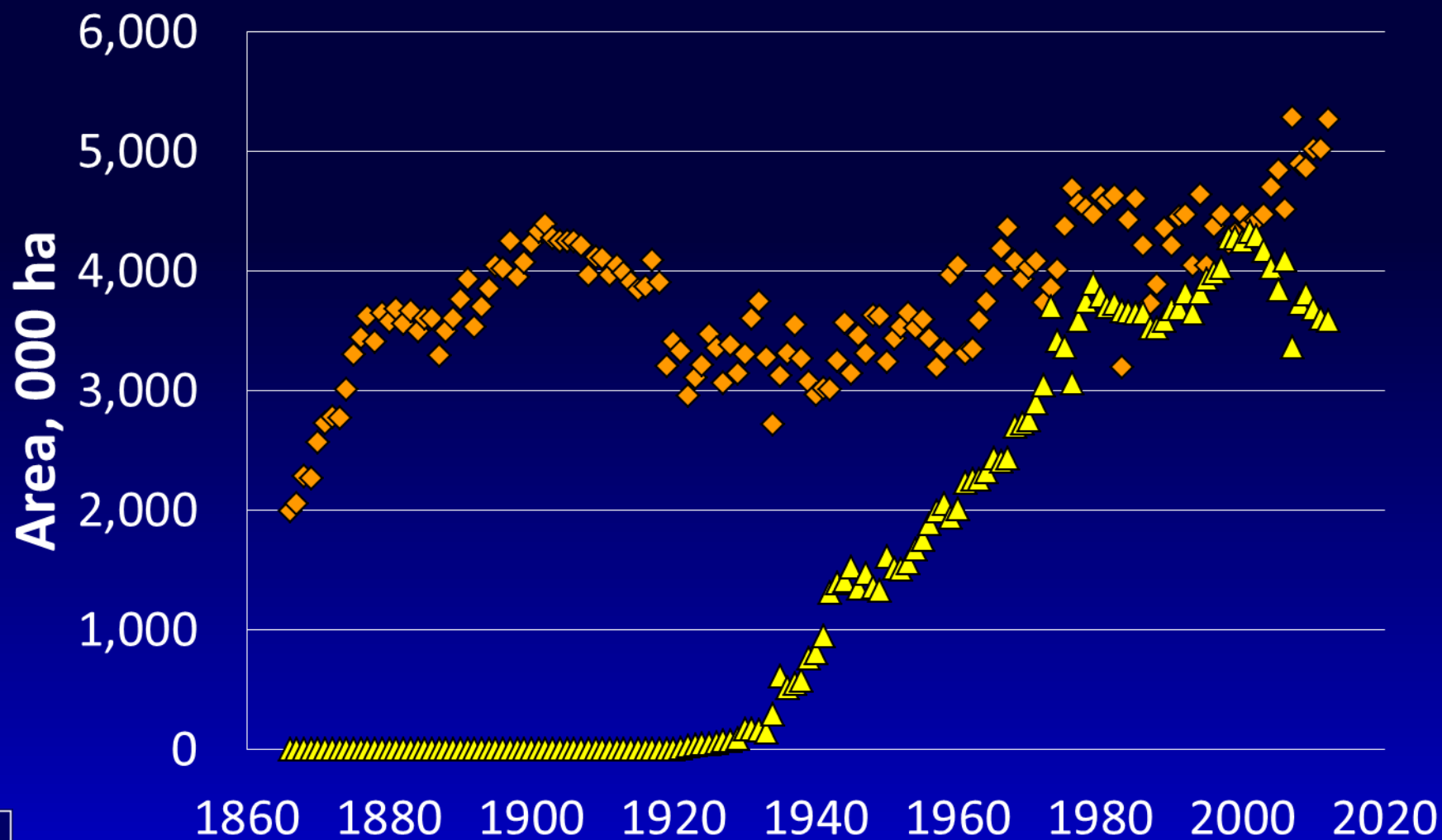


U.S. Department of Agriculture, National Agricultural Statistics Service



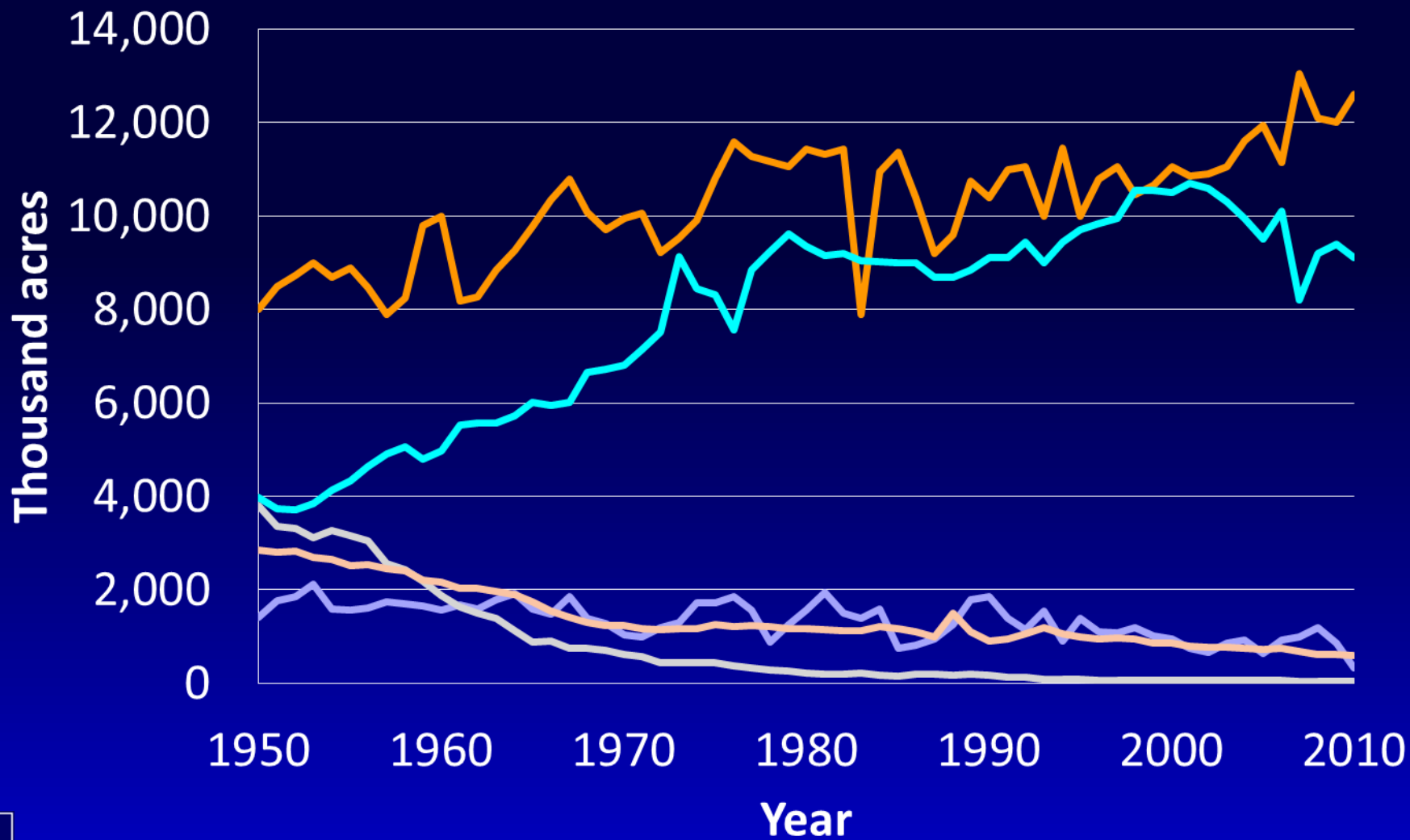
Crop Area, Illinois, 1886-2012

◆ Corn ▲ Soybean



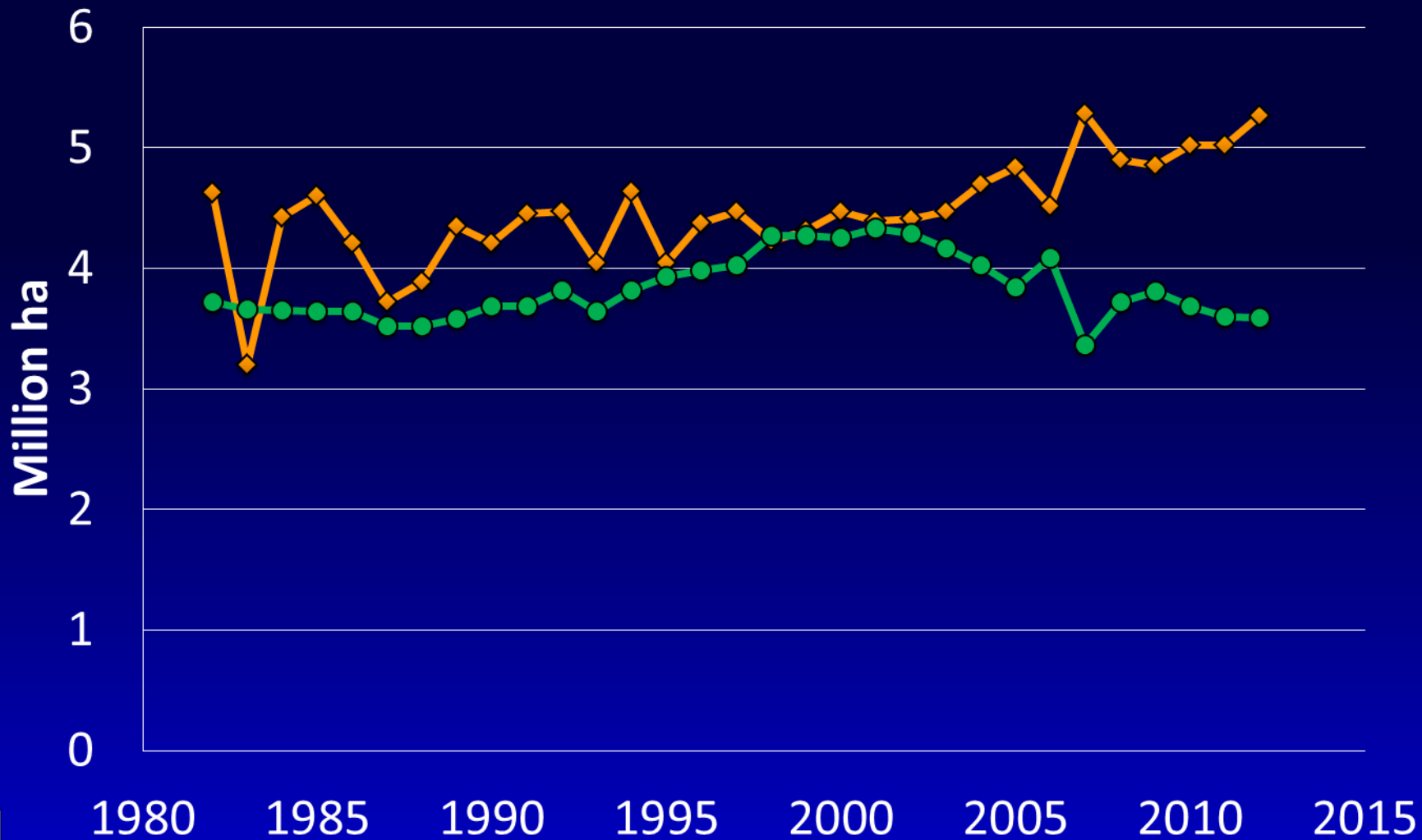
Illinois, 1950-2010

Corn Soybean Wheat Oats Hay



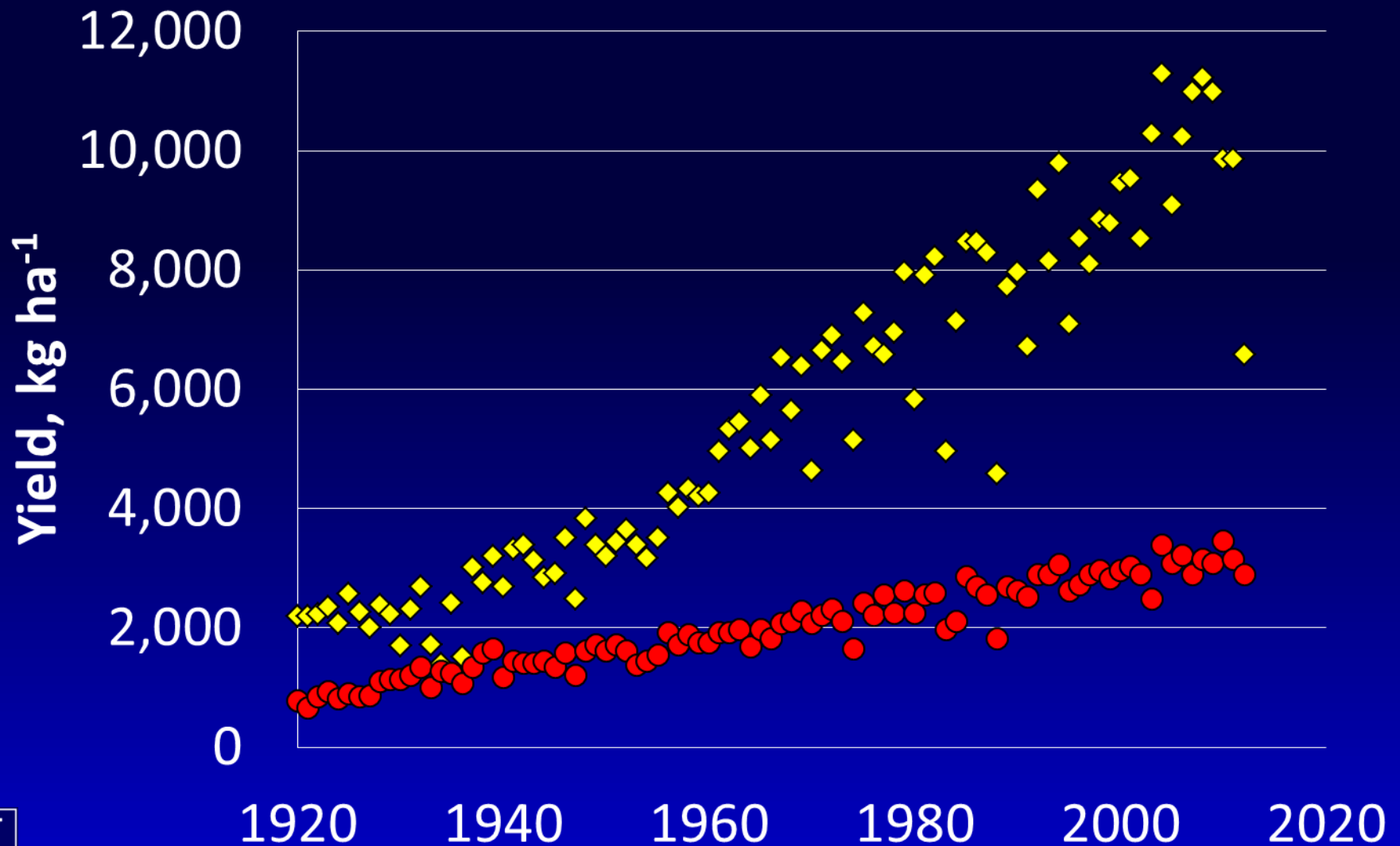
Illinois Corn & Soybean Area, 1980-2012

—♦— Corn —●— Soybean

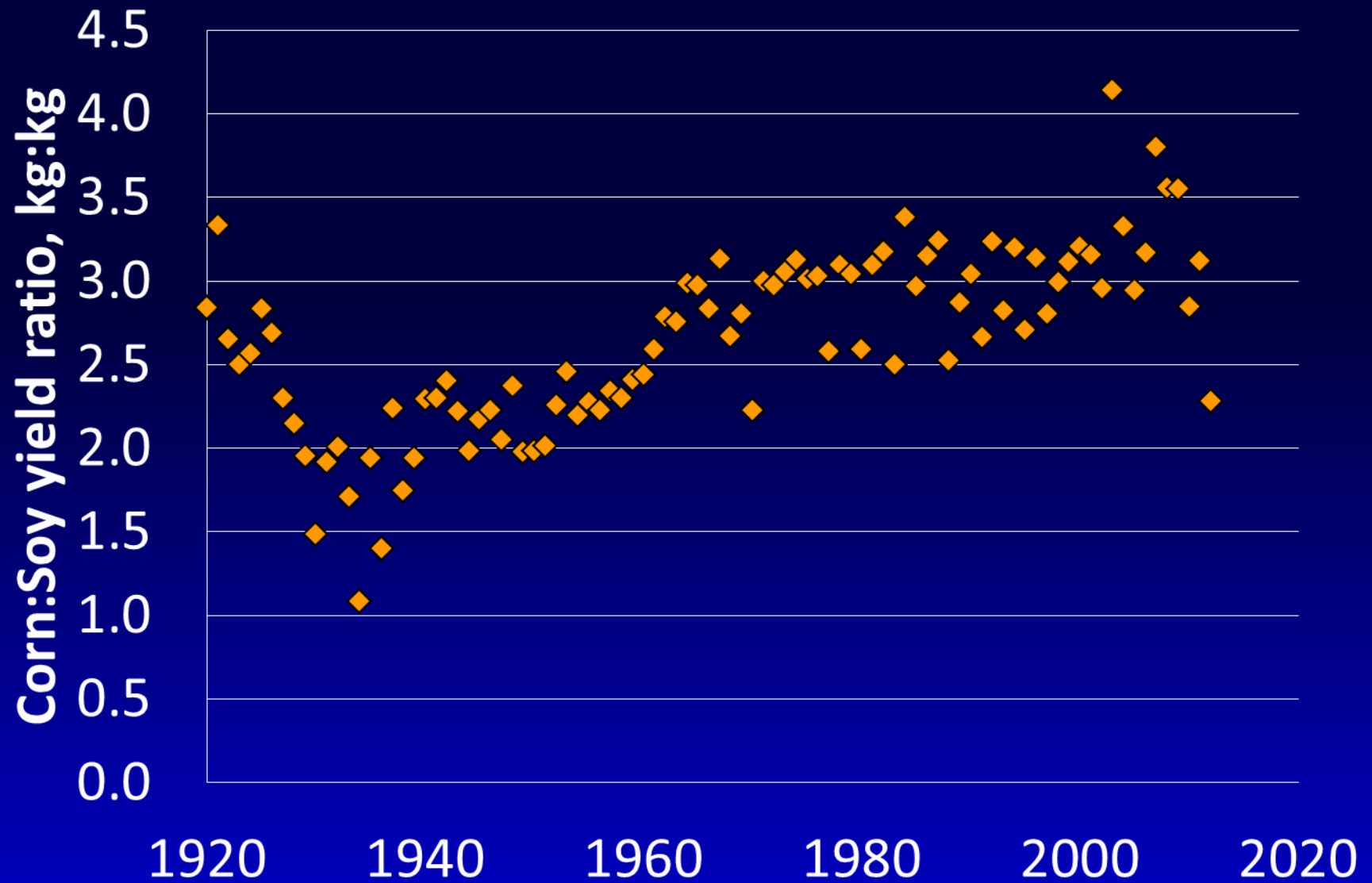


Illinois, 1920-2012

◆ Corn ● Soybean



Illinois 1920-2012



Rotations with Corn and Soybean

- By far the most common rotation in the U.S. Midwest/Corn Belt is corn-soybean, with 1 year of each crop
- In “corn-heavy” states like Illinois (corn:soybean area ratio ~9:13) and Iowa, at least 20 to 25% of the corn must follow corn, since there is nothing else to follow
 - Some continuous corn
 - Some C-C-S or other extended rotations with the two crops

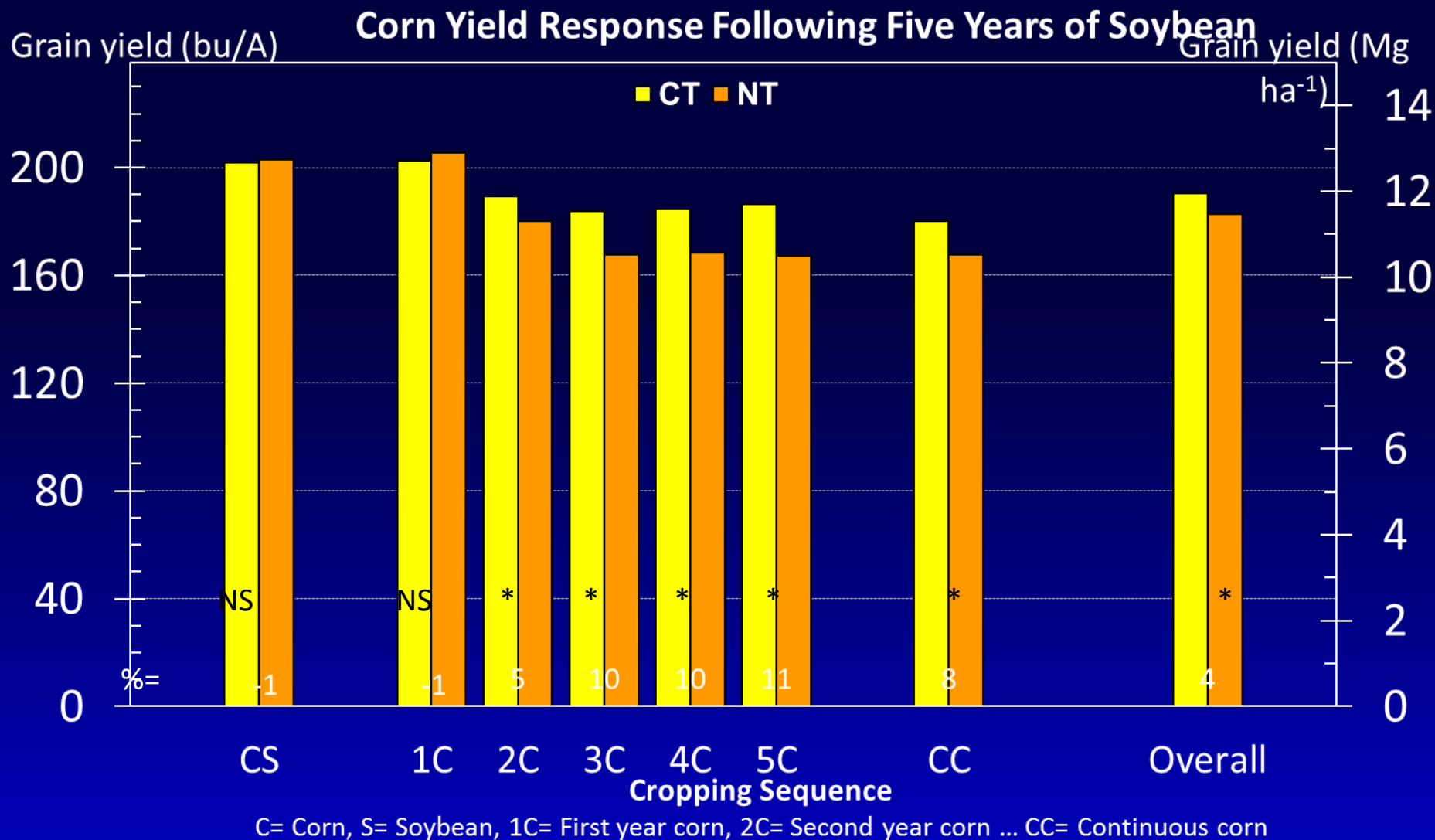


Rotations with Corn and Soybean

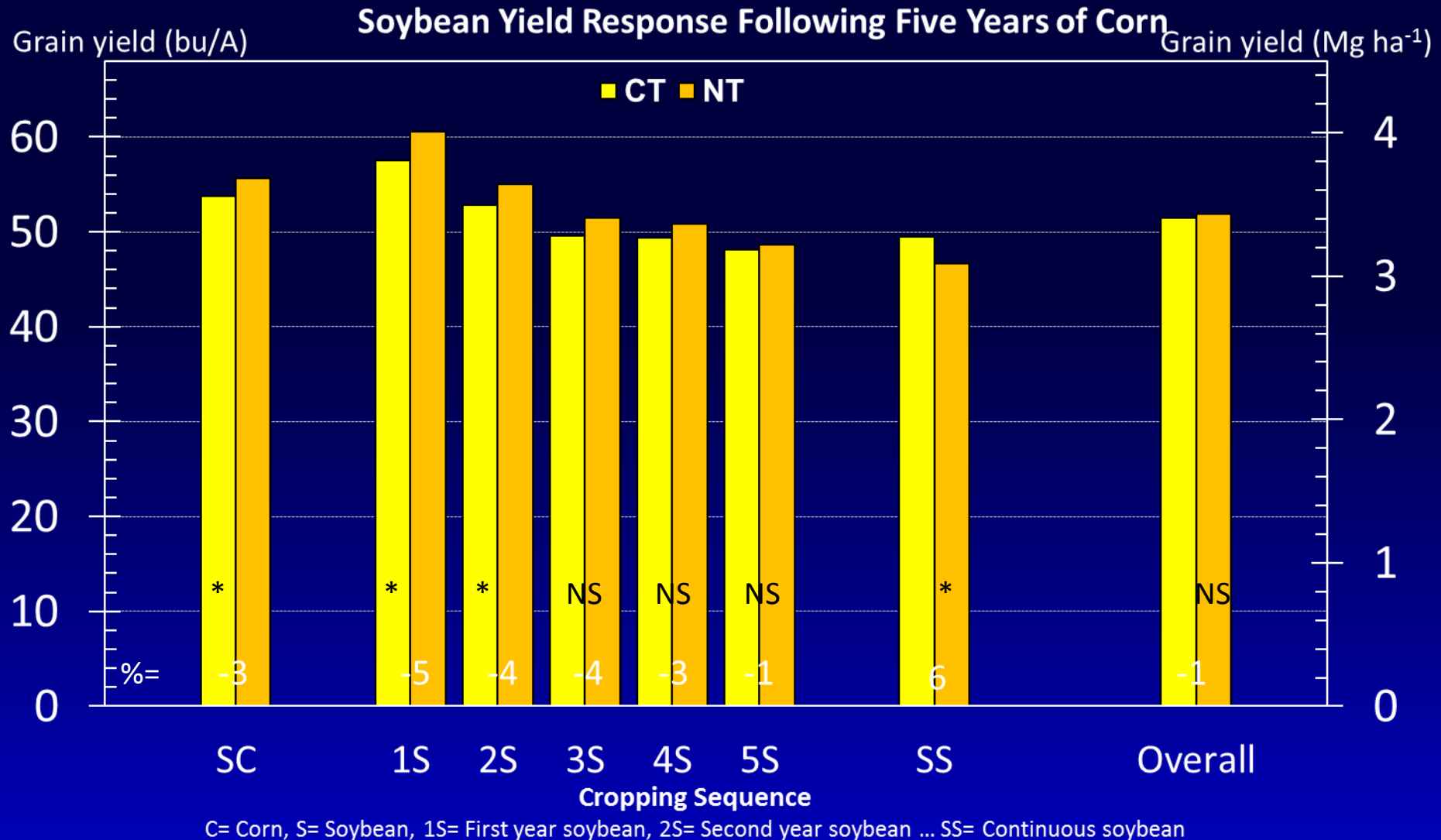
- Rotations including wheat or oats are not uncommon in some areas
 - Wheat doublecropped with soybean in the southern Corn Belt
 - In livestock areas, sometimes planted with forages in longer rotations
- Forages – mostly alfalfa – are part of the rotations in dairy areas
 - Corn in dairy areas often harvested as silage



In Wisconsin, tillage did not affect corn yield in CS/C yr 1, but increased yield 5% in C yr 2, and 10% in C yr 3



No-till increased soybean yield in CS, 1S, and 2S.
Tillage increased yield in continuous soybean.

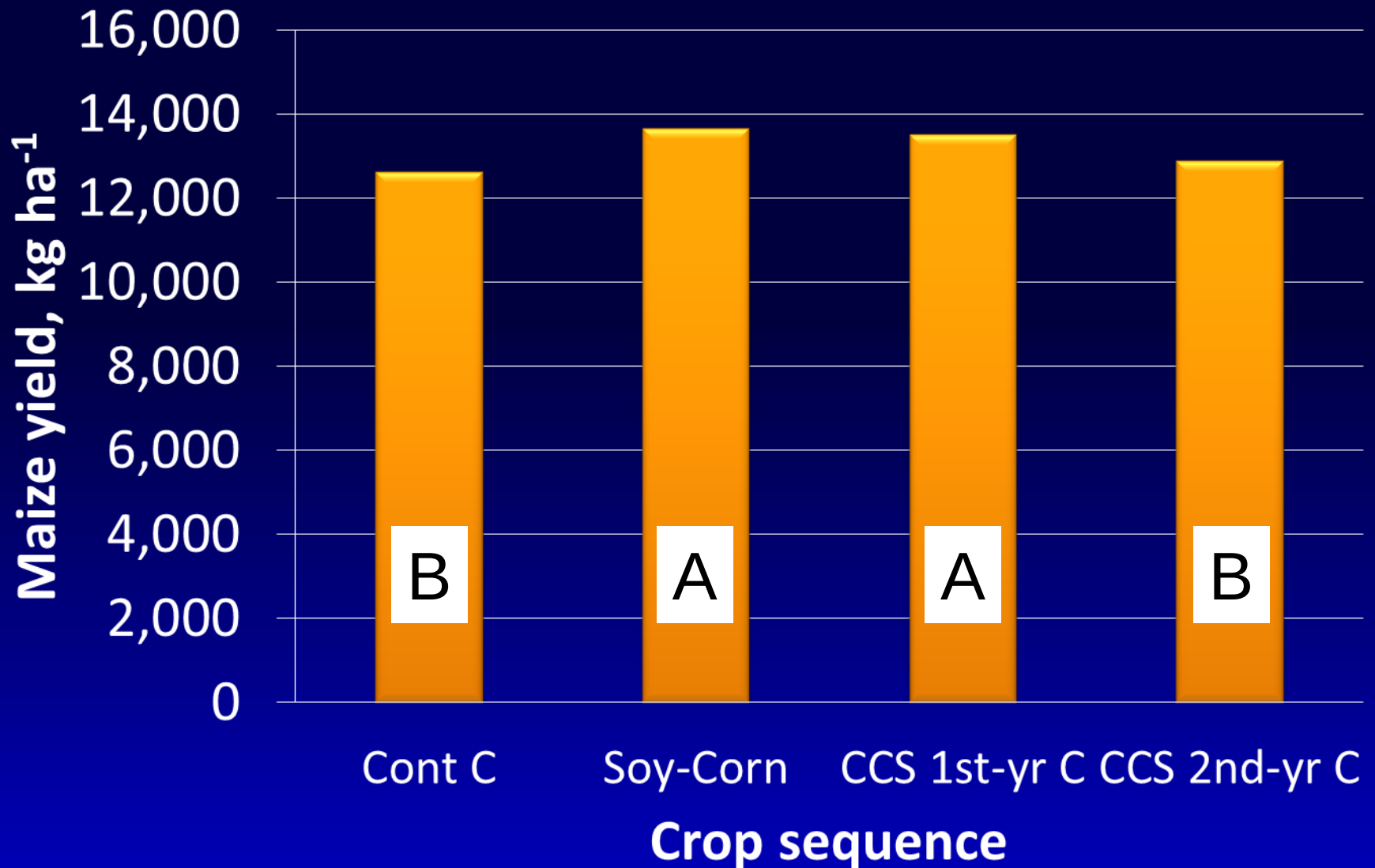


Corn-Corn-Soybean Rotation

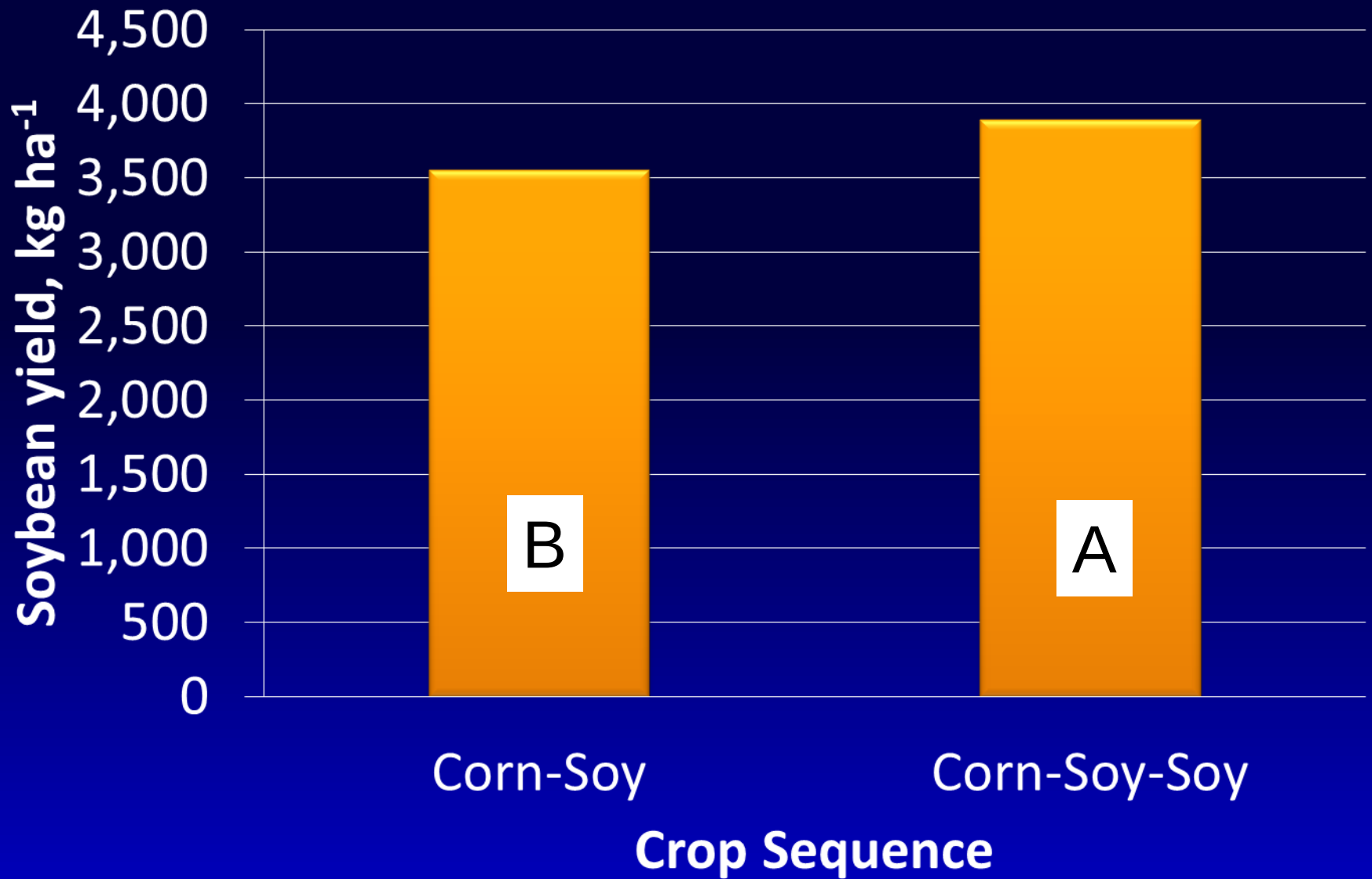
- Has gained some favor for those who have had yield losses in continuous corn
- We expect corn following soybean to yield the same in both CS and CCS (1st-yr corn)
- Need to know if 2nd-year corn in CCS and soybean following 2 yr of corn yield differently from continuous corn and soybean in CS
- We have a study underway at 6 Illinois sites with 6 treatments:
 - Continuous corn (1)
 - Each phase of corn-soybean (2)
 - Each phase of corn-corn-soybean (3)



Monmouth 2004-2012

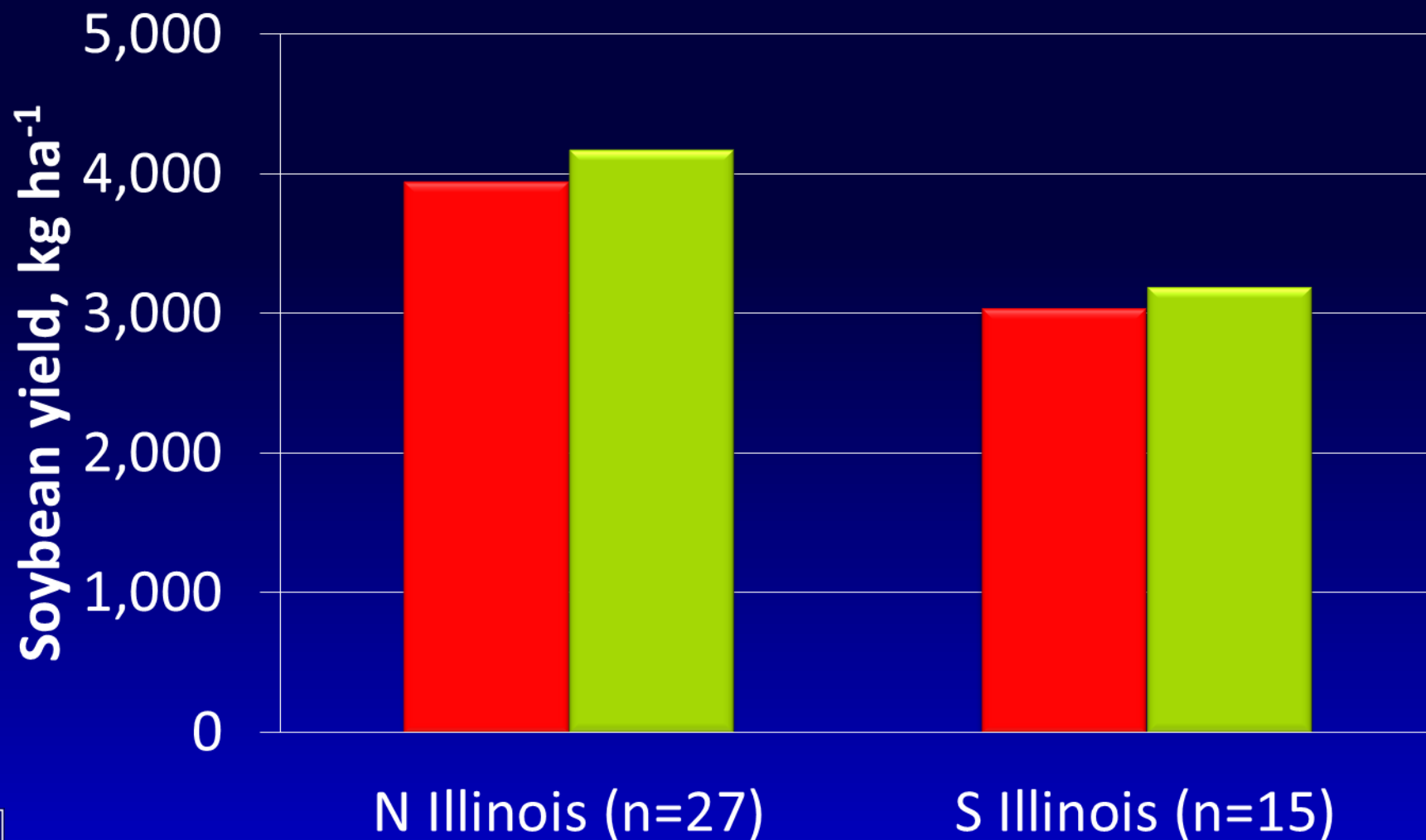


Monmouth 2004-2012



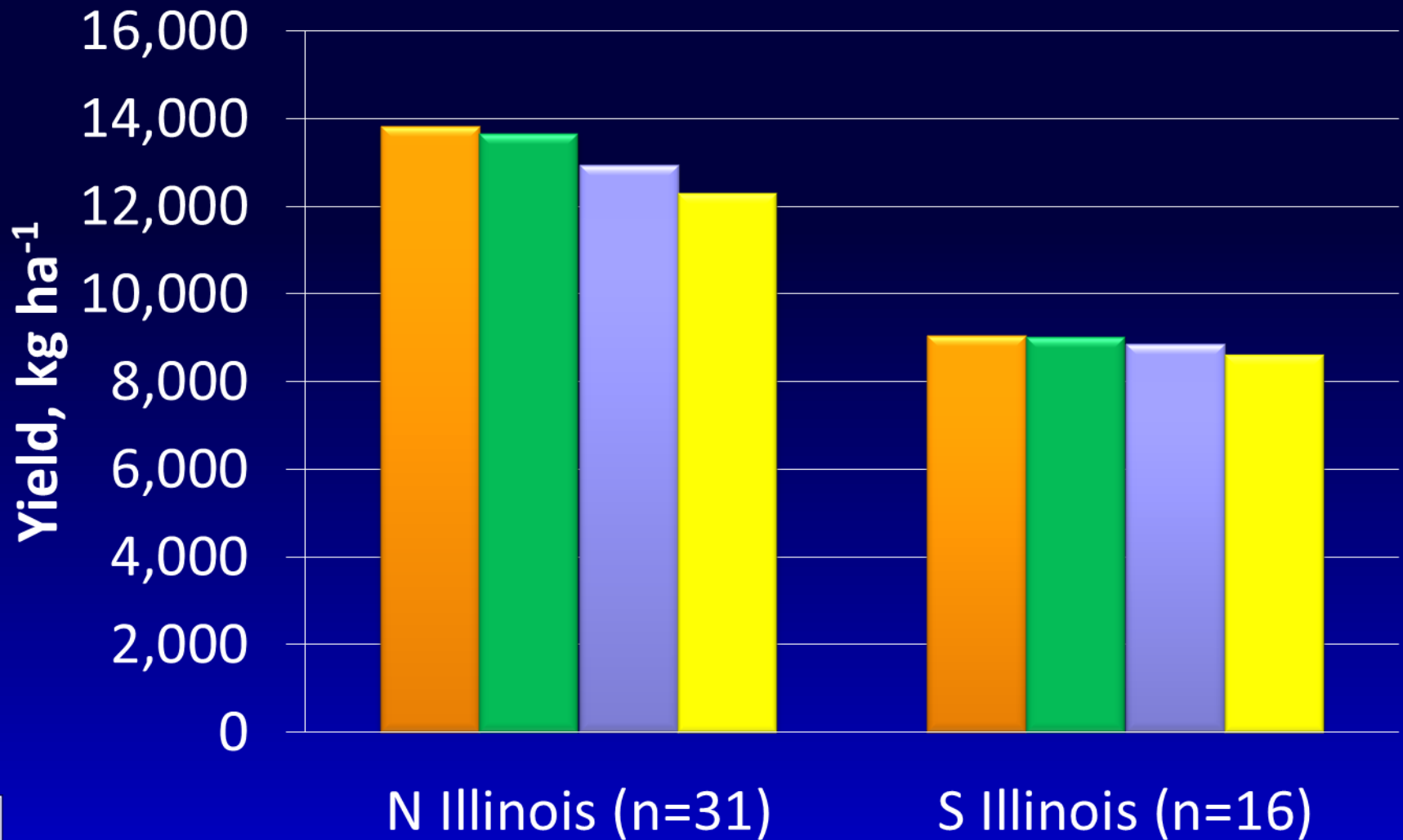
Soybean in Rotation, 2004-2011

■ Corn-Soy ■ Corn-Corn-Soy



Corn in Rotation, 2004-2011

■ Soy-Corn ■ CSC - C1 ■ SCC - C2 ■ Cont C



Corn-Soybean-Wheat



Rotation x Tillage Experiment

- Established beginning in 1996 at two Illinois sites:
 - Monmouth, in WNW Illinois, on Muscatine sil and Sable sil soils (mollisols)
 - Perry, in WSW Illinois, on Clarksdale sil soil (alfisol)
- Both soils are developed in deep loess



Experimental Design

- Rotation assigned to main plots (10):
 - Cont Corn (1)
 - Cont Soybean (1)
 - Corn – Soybean, each phase (2)
 - Corn followed by Soybean followed by Wheat (CSW) – each phase (3)
 - Corn followed by Wheat followed by Soybean (CWS) – each phase (3)



Experimental Design

- Tillage subplots split within each main plot:
 - “Conventional” tillage – primary tillage following fall (summer) harvest then secondary tillage prior to planting the next crop
 - No-Till – “slot” planting into undisturbed soil from previous crop
- Main plots 12 m wide x 24 m long
- Harvested by plot combine and adjusted to 13.5% (W), 13%(S), and 15%(C) grain moisture



Crop Management

- Maize planted at 84,000 - 88,000 seeds ha⁻¹, in April or early May
- Soybean planted at about 375,000 seeds ha⁻¹, in early to mid-May
- Wheat planted at about 3.5 to 4.0 M seeds ha⁻¹, in late September or early October
- Wheat harvested in late June to early July
- Corn and soybean harvested in late September to October



Climate

30-yr averages

Month	Monmouth		Perry	
	Avg Temp	Rainfall	Avg Temp	Rainfall
	°C	mm	°C	mm
May	16.9	121	17.3	107
June	21.9	111	22.5	109
July	23.8	107	24.4	110
August	22.8	103	23.5	98
September	18.7	90	19.0	92



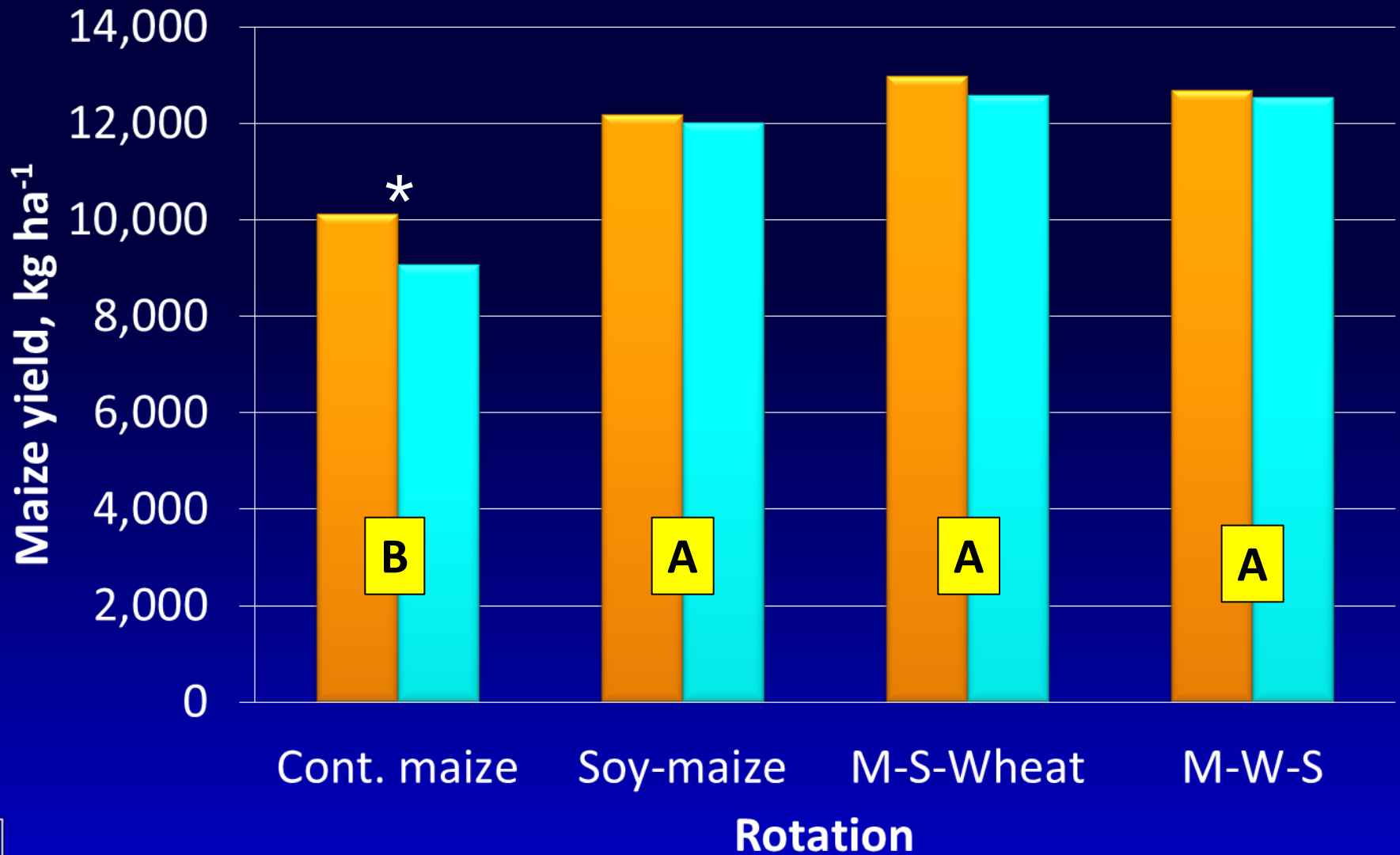
Monmouth, 1998-2012

Rotation <0.001

Tillage <0.001

Rot x Till <0.001

Tilled No-till





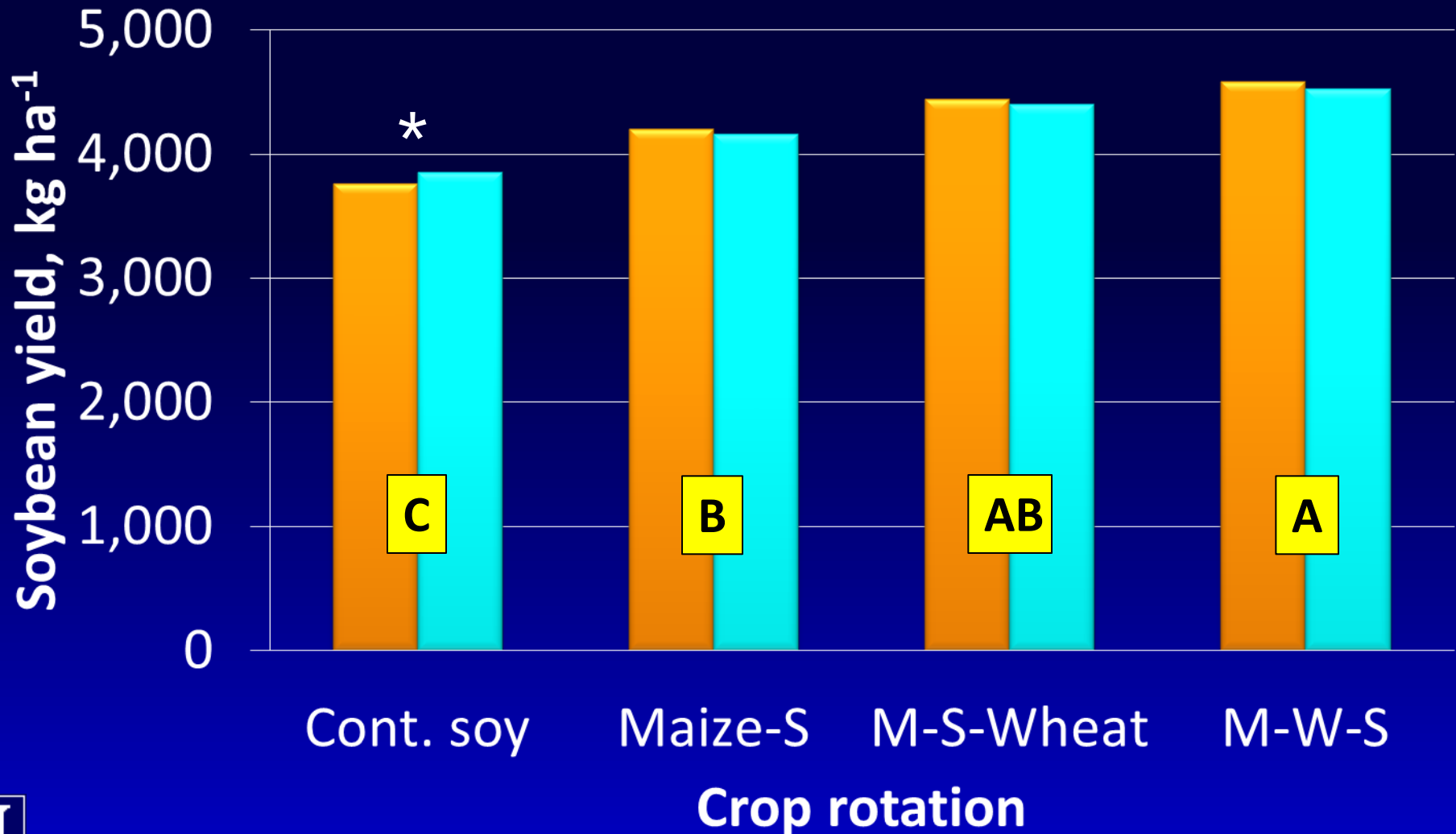
Monmouth 1998-2012

Rotation <0.001

Tillage 0.53

Rot x Till 0.03

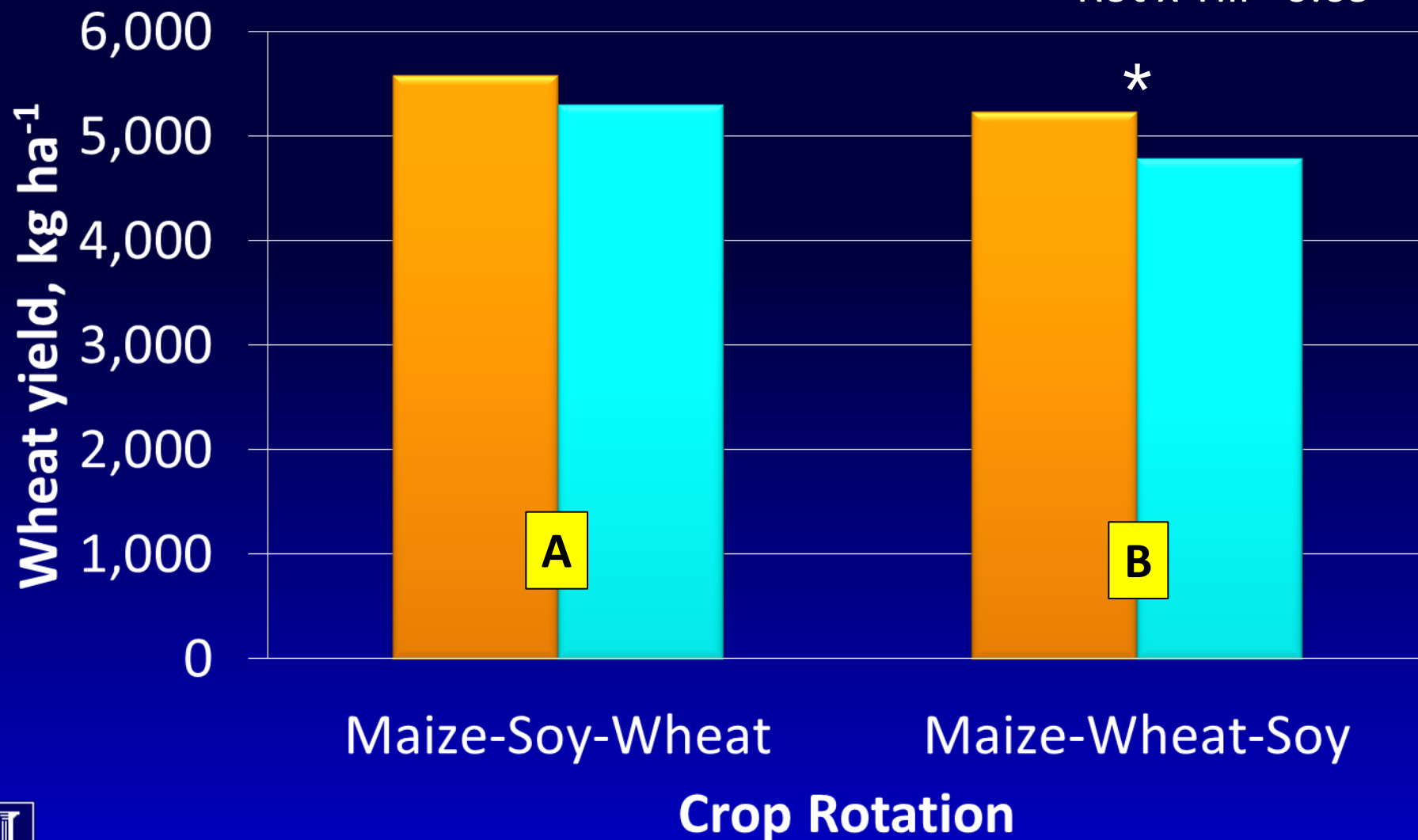
■ Tilled ■ No-till



Monmouth 1998-2012

■ Tilled ■ No-till

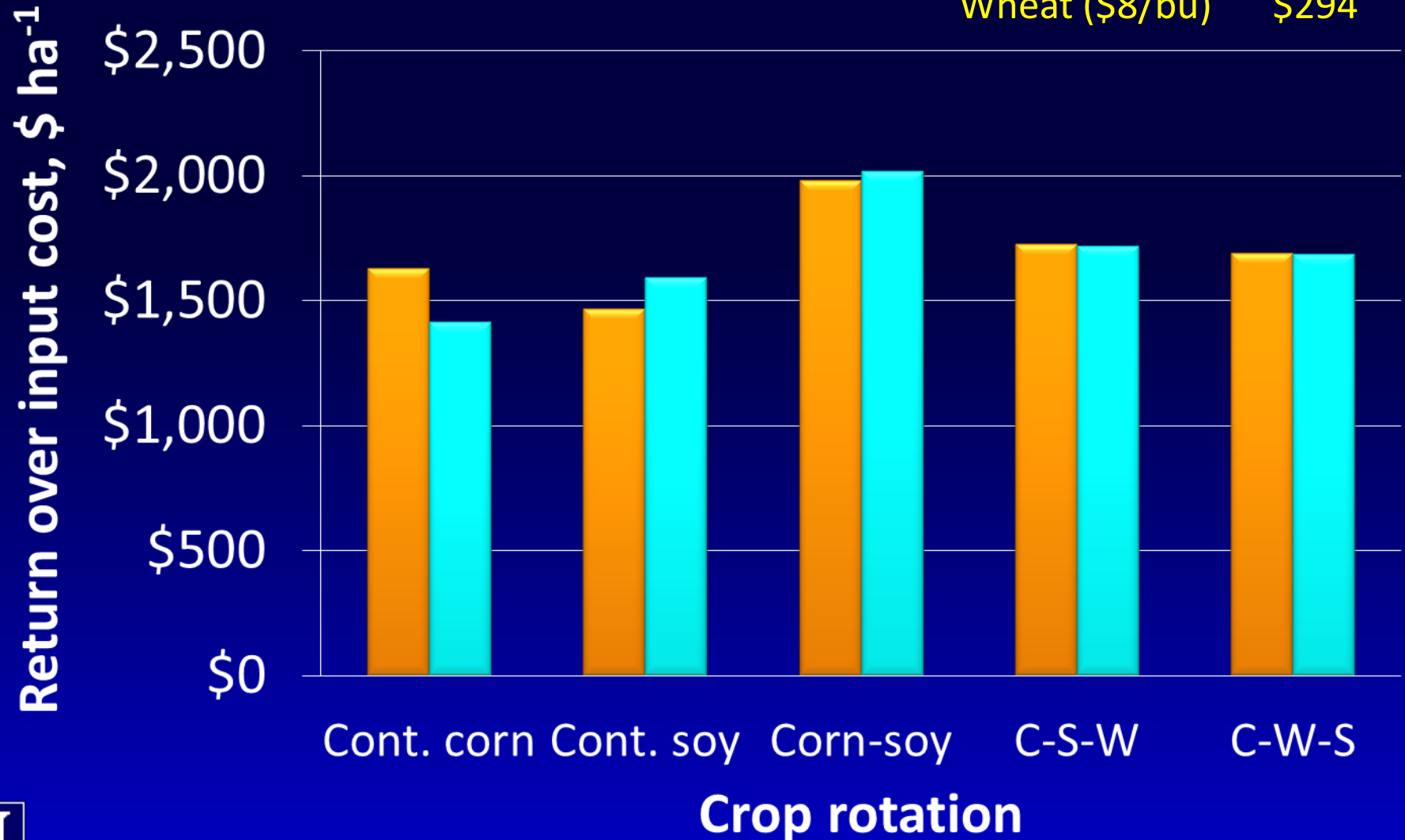
Rotation 0.01
Tillage <0.001
Rot x Till 0.09



Monmouth 1998-2012

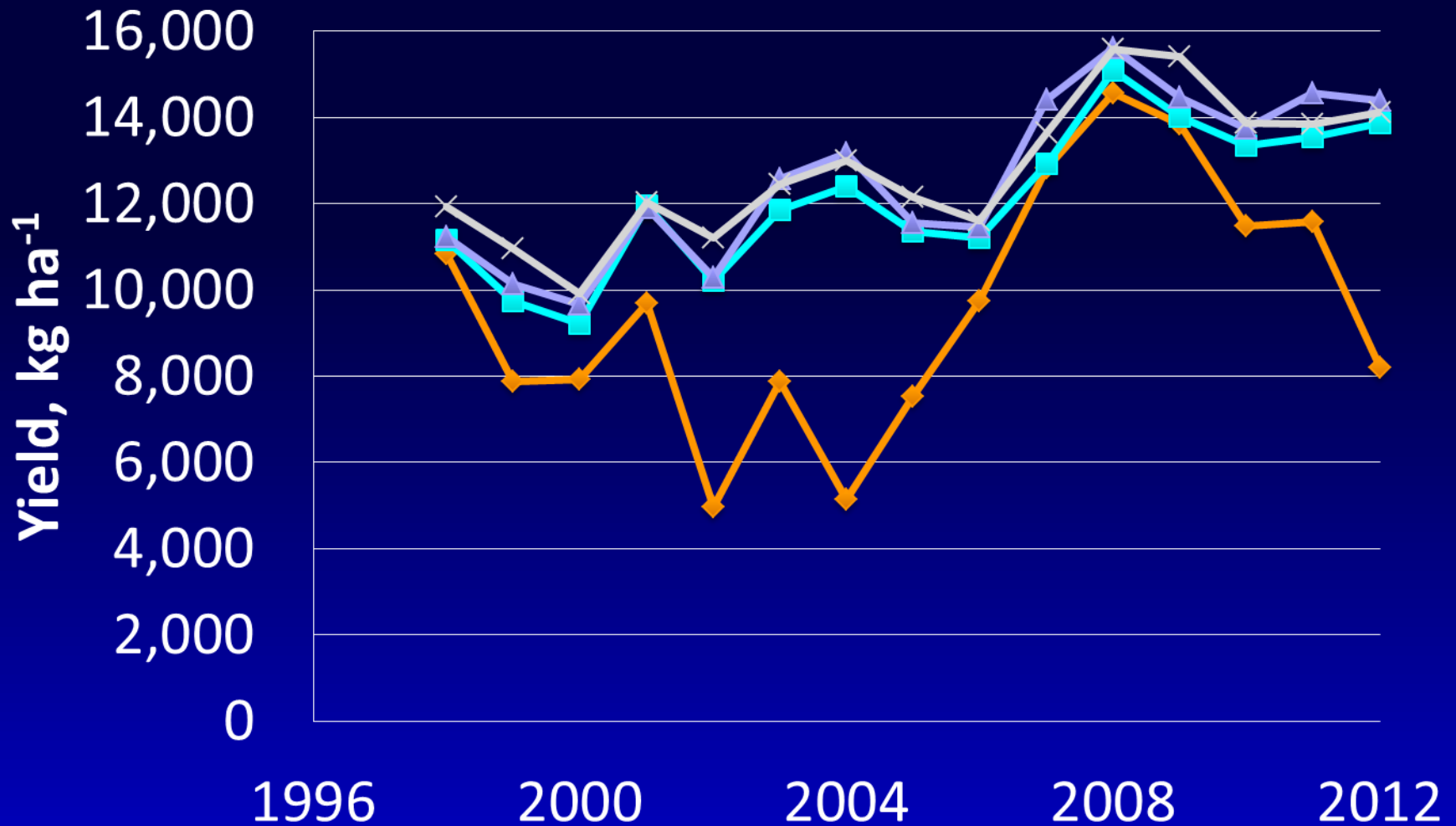
<u>Price</u>	<u>\$/Mg</u>
Corn (\$7/bu)	\$276
Soy (\$15/bu)	\$551
Wheat (\$8/bu)	\$294

■ Tilled ■ No-till



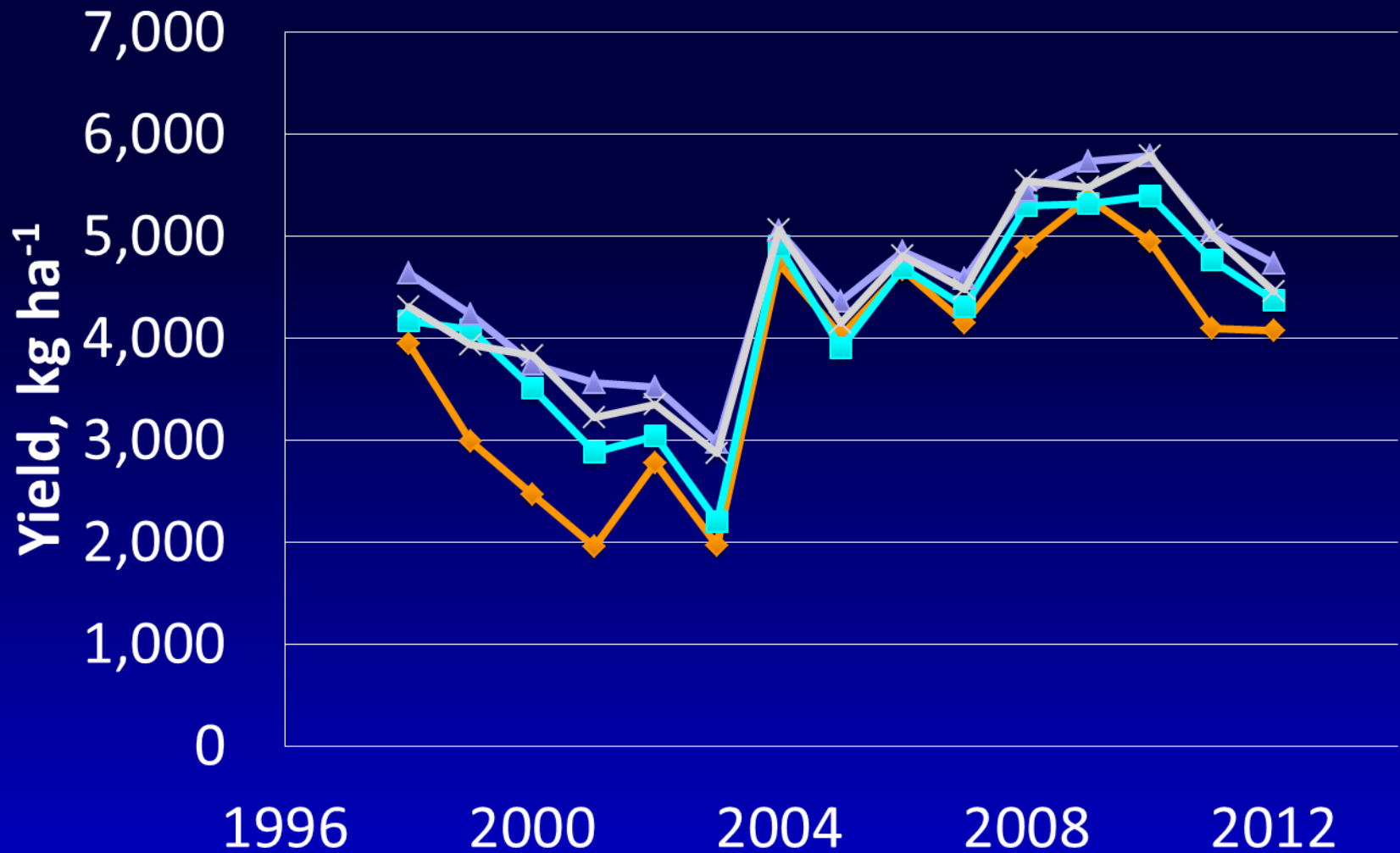
Corn Yield Trends, Monmouth

◆ Cont C ■ Corn-soy ▲ WSC ✕ SWC



Soy Yield Trends, Monmouth

Cont soy Corn-soy WSC SWC



Monmouth Summary - Rotation

- **Corn** following soy yielded 26% more than continuous corn and corn in CSW/CWS yielded 32% more than continuous corn; the rotations CS, CSW, CWS did not yield differently
- **Soybean** in CS yielded 10% more than cont. soy and soy in CWS yielded 9% more than CS; soy in CSW was between CS and CWS, but not different from either
- **Wheat** yields in CWS and CSW were not significantly differently



Monmouth Summary - Tillage

- In corn, CT yielded 445 kg ha^{-1} (4%) more than NT:
 - Rotation x tillage interaction was due to CT>NT by some $1,000 \text{ kg ha}^{-1}$ in Cont C; $\sim 400 \text{ kg ha}^{-1}$ in CSW; not in other rotations
- In soybean, tillage effect was NS; interaction due to NT>CT in cont. S by 97 kg ha^{-1} (3%); no effect in rotated soybeans
- In wheat, CT>NT by 360 kg ha^{-1} (7%); larger effect in CSW than in CWS



Monmouth Summary - Returns

- Return to inputs: $CS > CWS = CSW > \text{cont C} = \text{cont S}$
- $CT > NT$ in continuous corn; $NT > CT$ in continuous soybean; little effect of tillage in multi-crop rotations
- Rotation stabilized yields; continuous corn and soybean yield penalties were greater when yield levels were lowered by stress, but correlations between yield level and yield penalty (to continuous cropping) was low



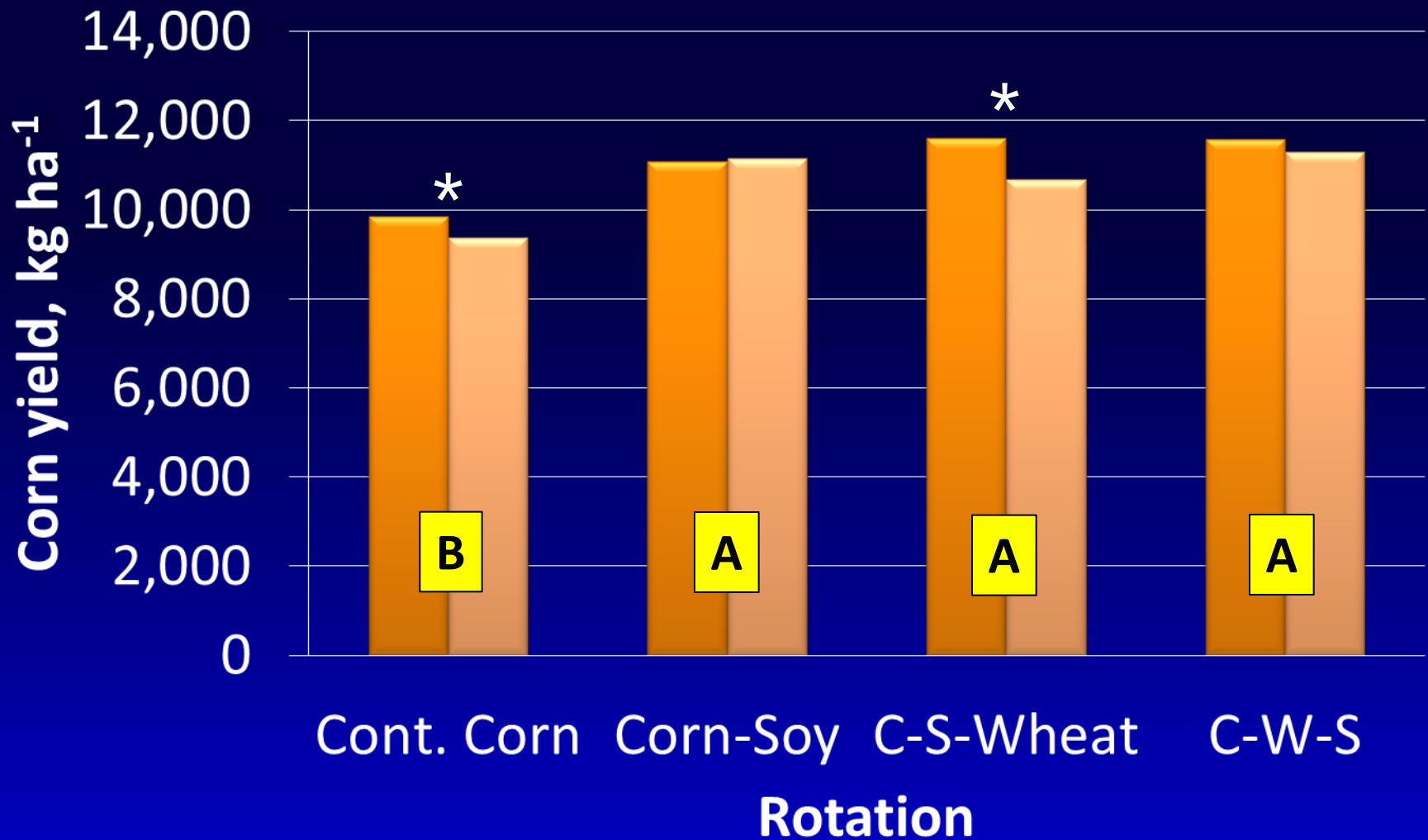
Perry 1998-2012

Rotation <0.001

Tillage 0.53

Rot x Till 0.03

■ Tilled ■ No-till



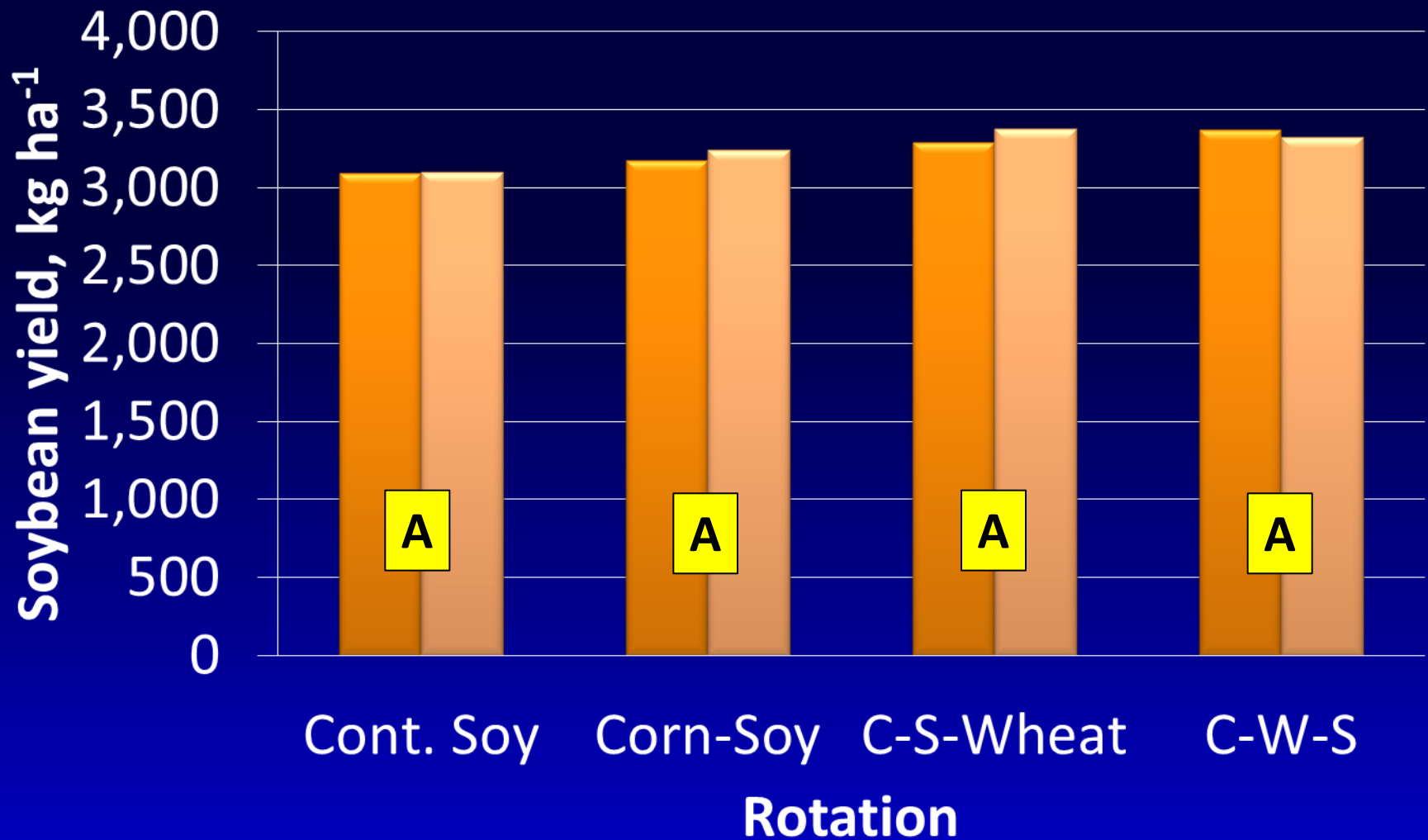
Perry 1998-2012

Rotation 0.13

Tillage 0.33

Rot x Till 0.33

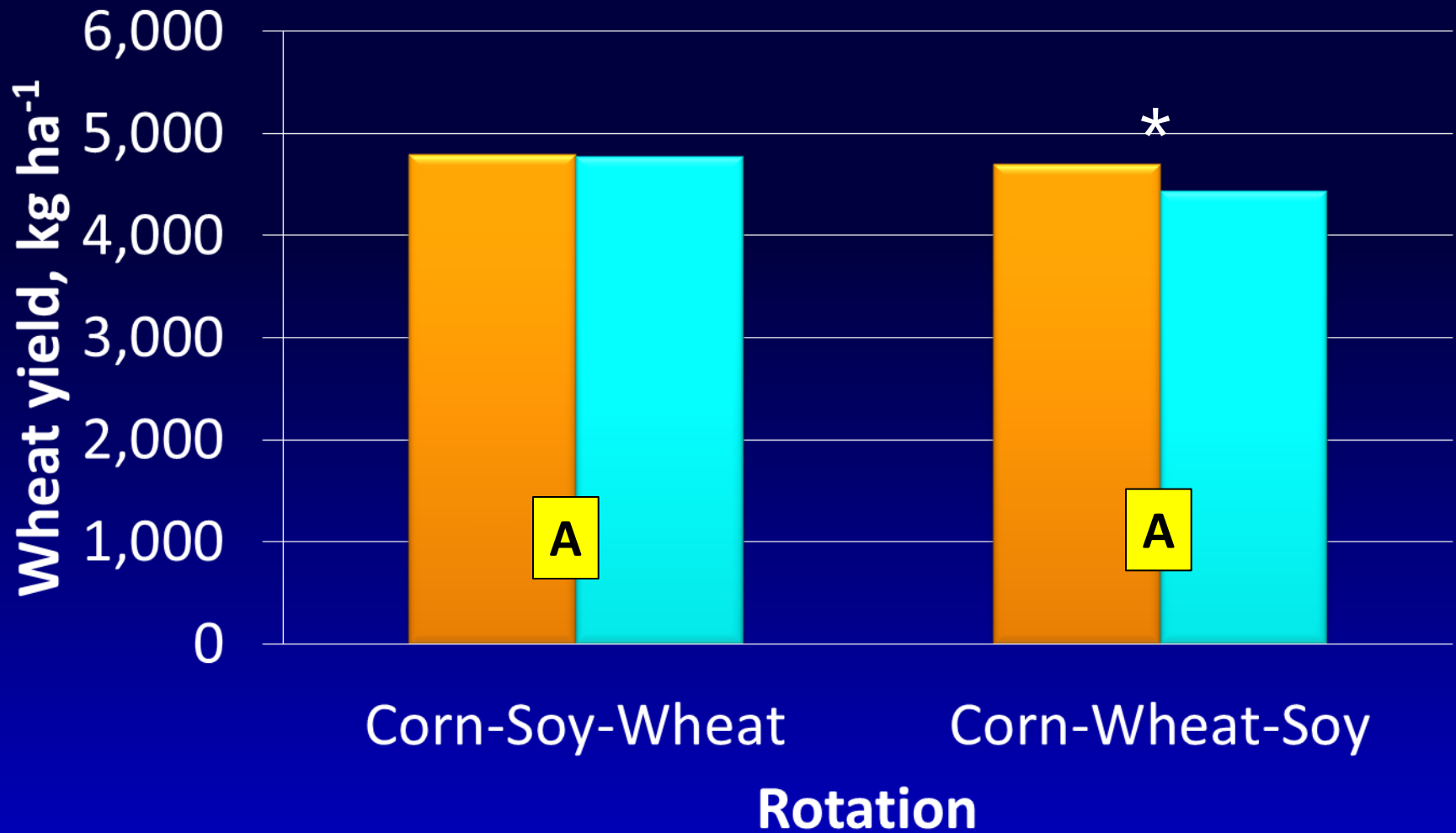
■ Tilled ■ No-till



Perry 1998-2012

Rotation 0.15
Tillage 0.02
Rot x Till 0.04

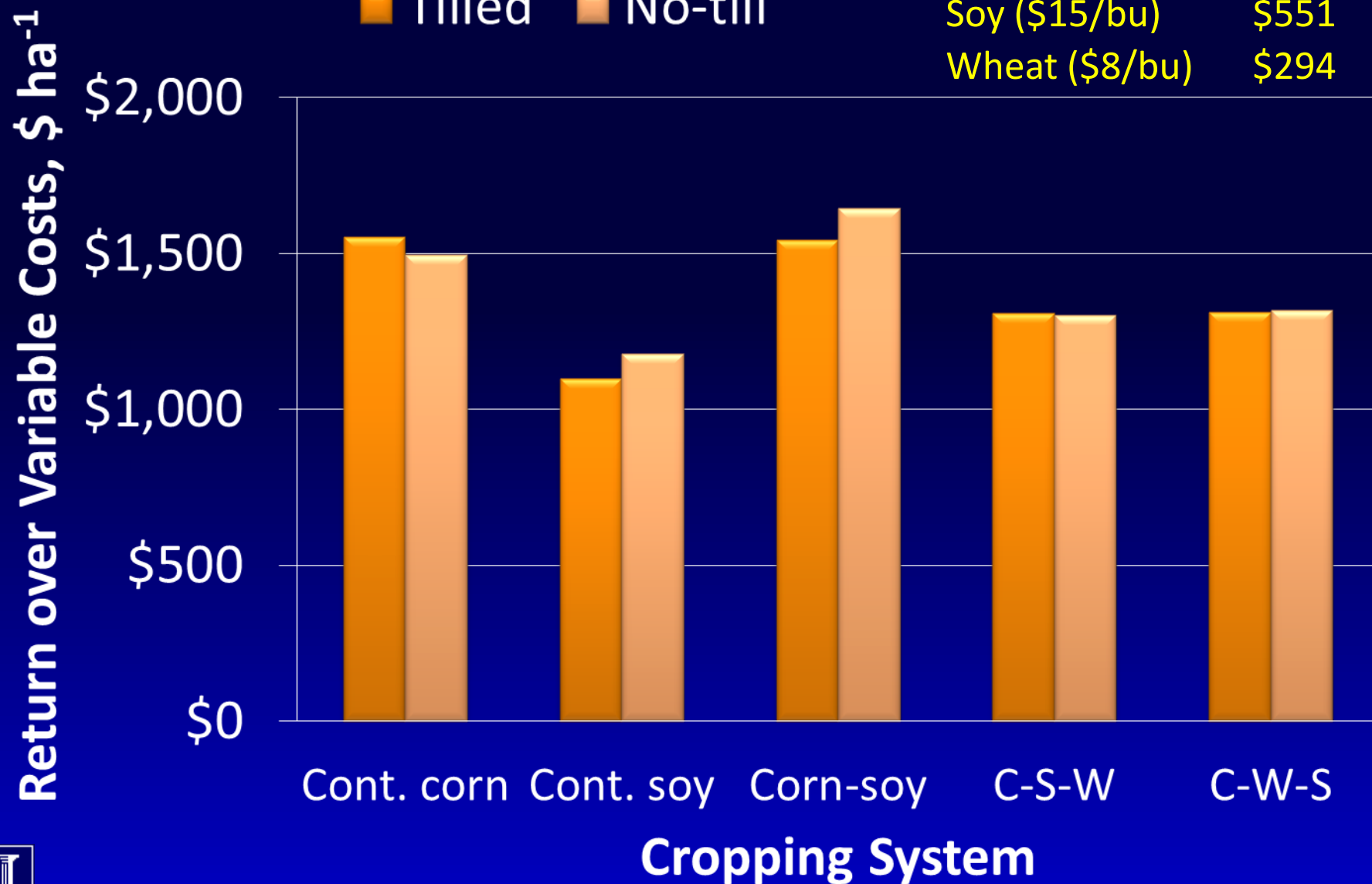
■ Tilled ■ No-till



Perry, 1998-2012

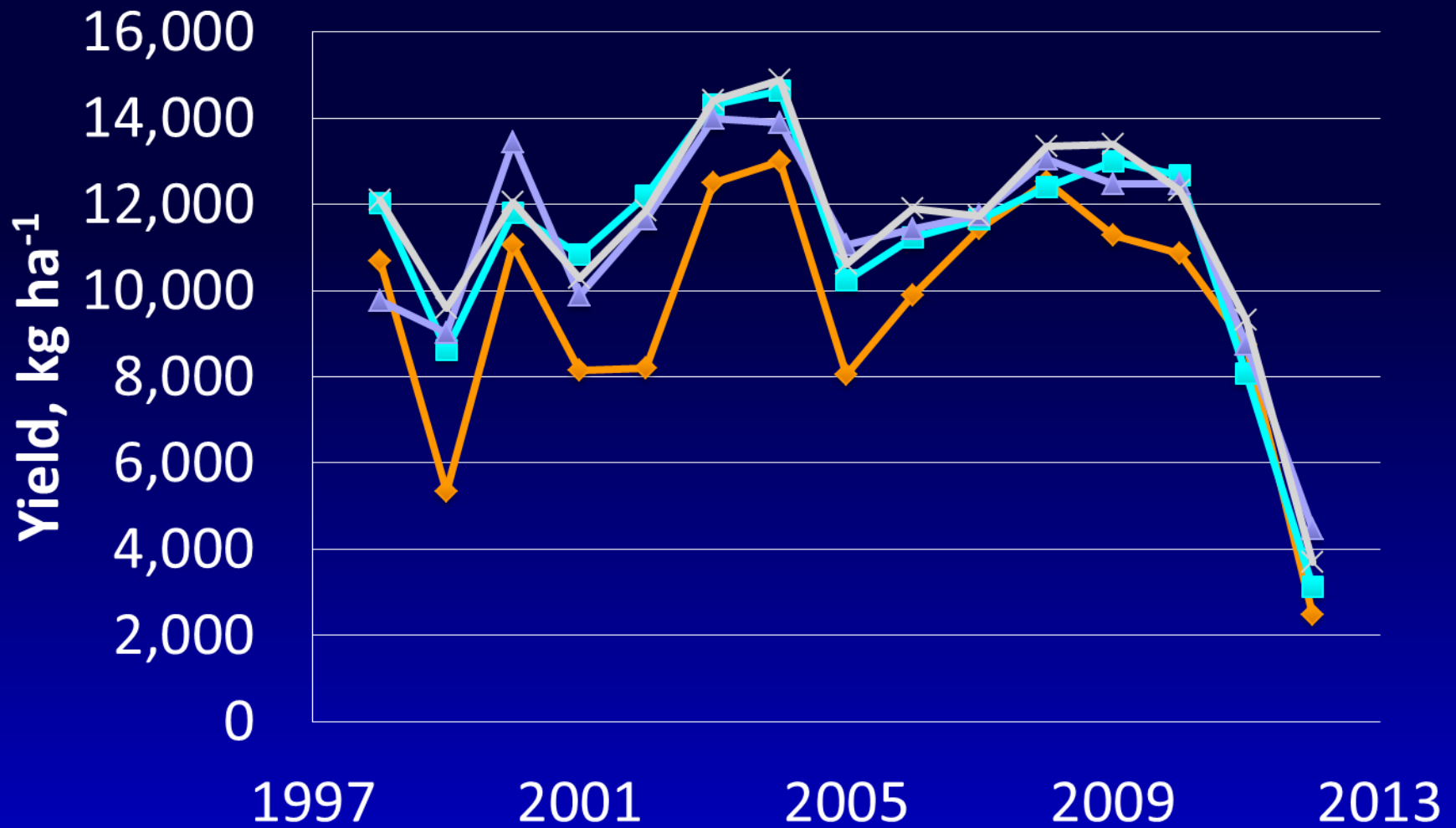
■ Tilled ■ No-till

<u>Price</u>	<u>\$/Mg</u>
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Wheat (\$8/bu)	\$294



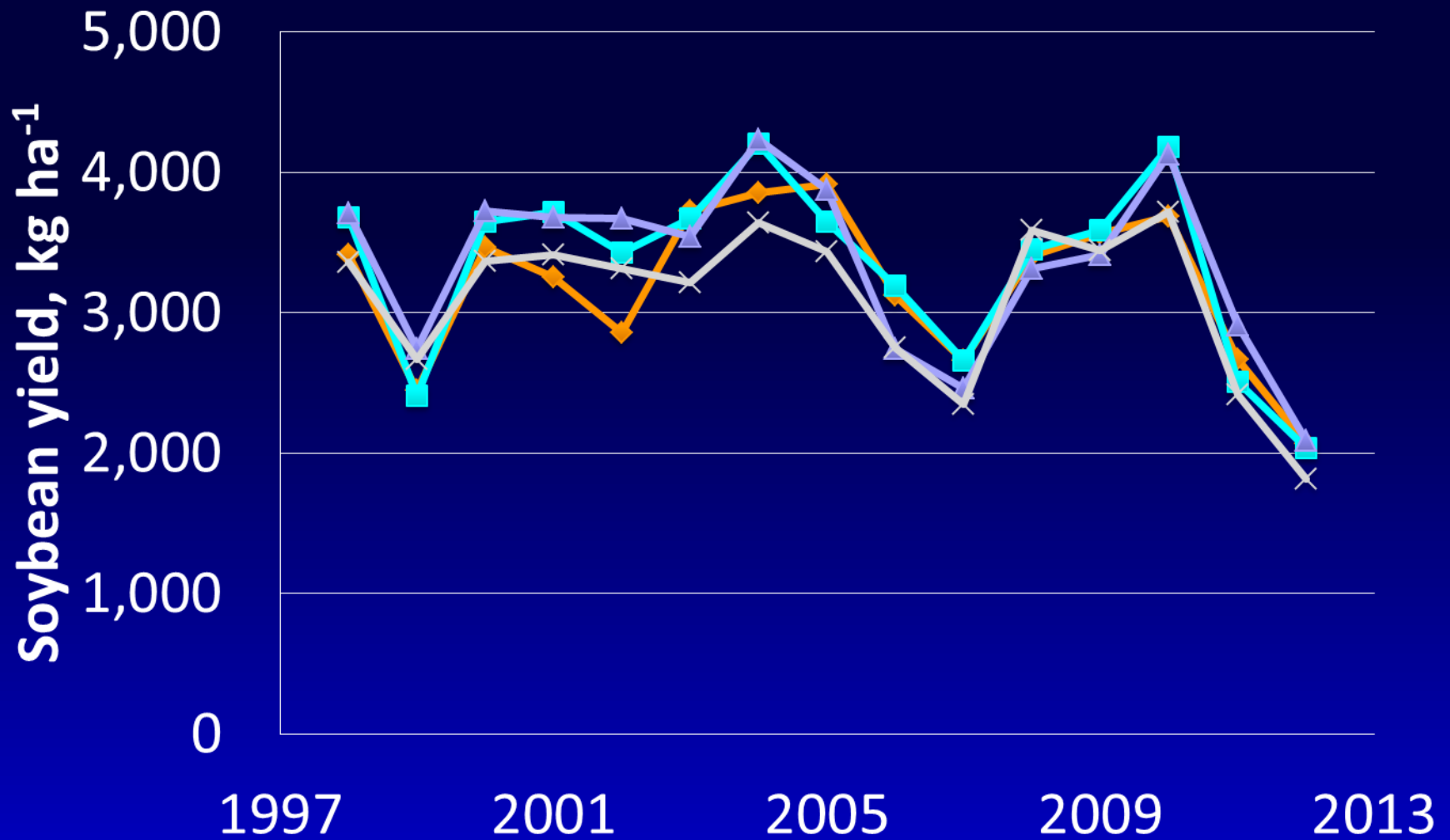
Perry Corn

—◆— CCC —■— CS —▲— CSW —×— CWS



Perry Soybeans

—◇— CS —■— CSW —▲— CWS —×— SSS



Perry Summary - Rotation

- Corn in rotation yielded significantly (17%) more than continuous corn; the rotations CS, CSW, CWS did not yield differently
- Soybean yield was not affected by rotation
- Wheat yield was not affected by rotation



Perry Summary - Tillage

- In corn, CT yielded 402 kg ha^{-1} (4%) more than NT
 - Rotation x tillage interaction was due to CT>NT by 476 kg ha^{-1} in continuous C; 929 kg ha^{-1} in CSW; no tillage effect in CS or CWS
- Tillage did not affect soybean yields
- In wheat, CT>NT by 144 kg ha^{-1} (3%); larger effect in CWS than in CSW



Perry Summary - Returns

- Return to inputs: Corn-Soy=Continuous C > CSW=CWS > Cont Soy
- CT>NT in continuous corn; NT>CT in continuous soybean and in CS; little difference due to tillage in CSW or CWS
- Yield trends over years were similar for different rotations
 - Continuous corn yielded less than rotated corn consistently except under severe stress (2011, 2012), when both yielded about the same



Conclusions

- Rotating maize with soybean increases maize yield, sometimes dramatically so, even in productive environments
- The stabilizing effect of rotation on soybean yield was found to be less than in maize
- Adding wheat to produce a 3-year rotation increased yield modestly compared to maize-soybean
- Tillage had only moderate effects on maize and soybean yields and on profitability
- Maize is typically the most profitable crop in the systems tested and wheat the least profitable, with the maize-soybean rotation the most consistent with regard to returns to inputs





Thank you for your attention