Ecological Intensification of Corn-based Cropping Systems: *Soil Quality Changes Impact Yield*

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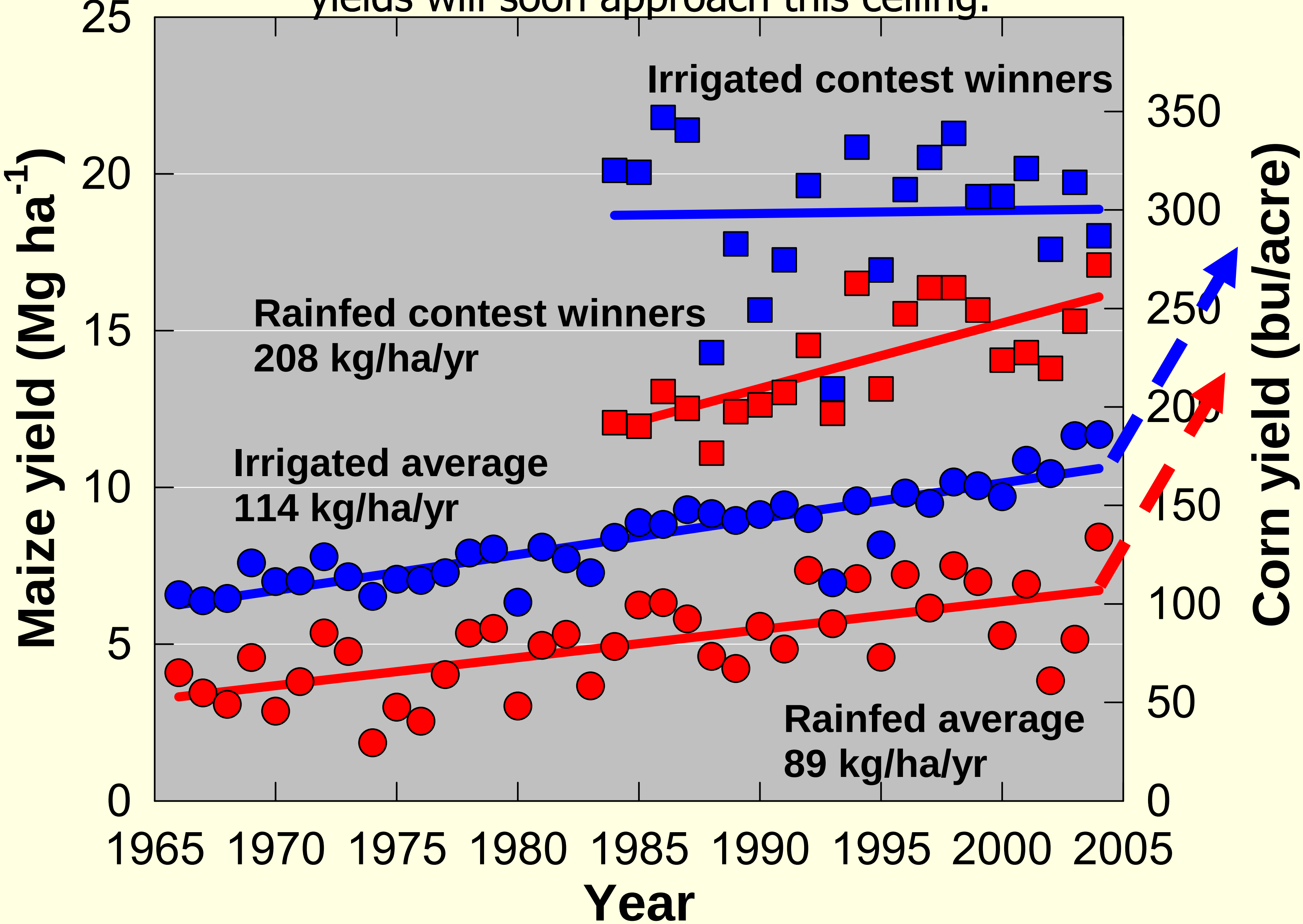
U.S. Rural Landscape Changes

- 360 million productive acres U.S.
- Currently 1.2 acres quality farmland per person
- Farmland loss 2 million acres per year.
- 1.1% increase population per year
- Year 2056, approximately 0.6 acres of farmland per person

(Source: Multifunctional Rural Landscapes for the Future 2007; Hansen, Francis, Esseks)

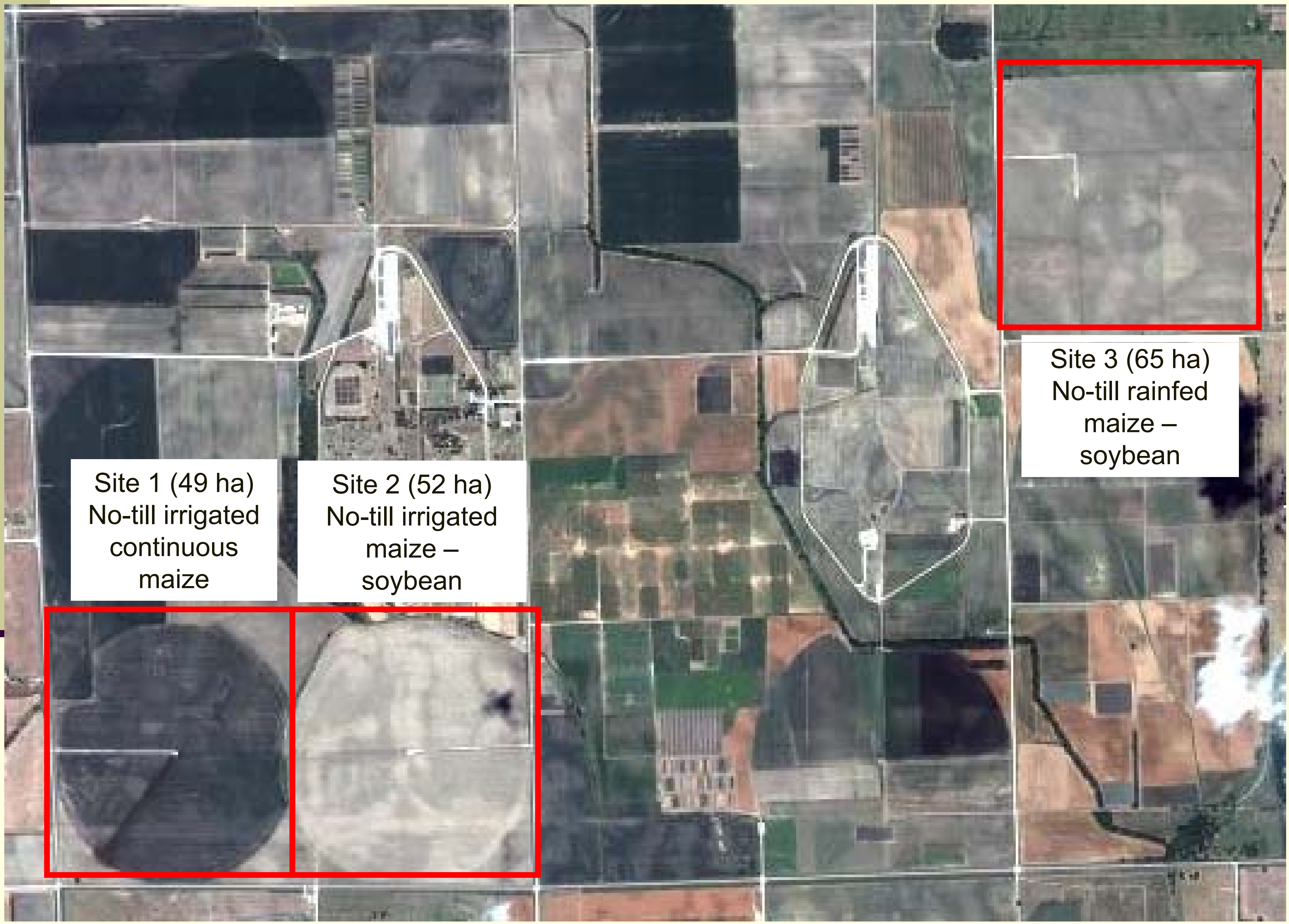
Nebraska contest-winning and average yield trends

No increase in yield potential ceiling since the 1980s; average yields will soon approach this ceiling.



Carbon Sequestration Research Facility

at the UNL Agricultural Research and Development Center, Mead, NE



Landscape-Level Measurements of Carbon Dioxide Exchange

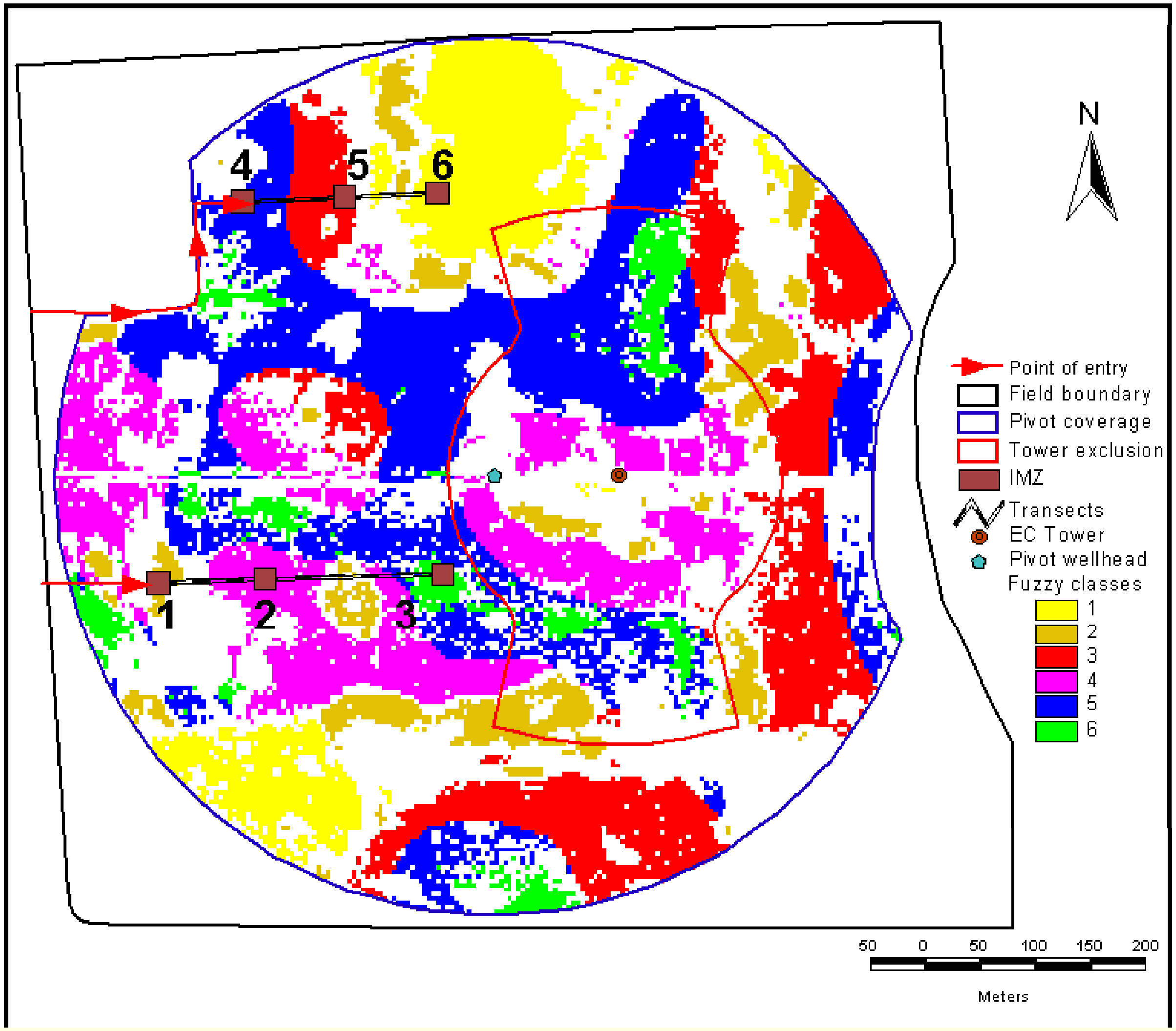
Eddy Covariance Measurements of Carbon Dioxide and Other Fluxes

Measuring Components of Solar Radiation

Close Up of Eddy Covariance Flux Sensors

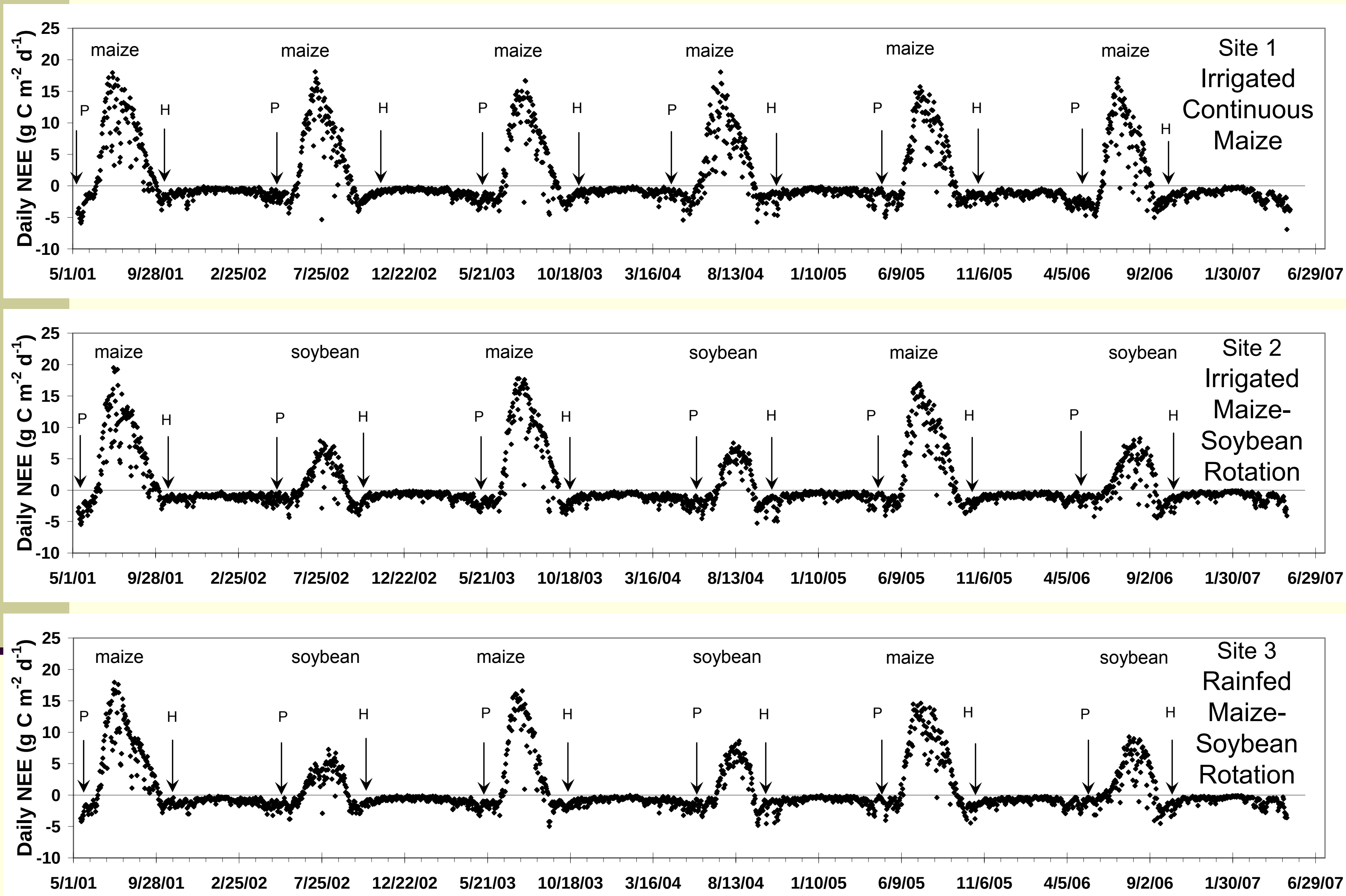
Carbon Sequestration Program

Site 1: Irrigated Continuous Maize



Fuzzy Classes, Intensive Measurement Zones
For scaling to whole field

Net Ecosystem CO_2 Exchange (NEE)



CROP Carbon Balance

Mead, NE

Crop / Syst.	Gross Primary Product. GPP	Growing Season Respir. RE_{GS}	RE_{GS} / GPP	Annual Respir. RE_{ANN}	Net Ecosystem Exchange NEE
	------------------------------Mg C ha^{-1}------------------------------				
Corn / Irr.	17.7	11.4	0.65	13.3	4.4
Corn / Rainfed	15.7	9.2	0.58	11.2	4.5
Soy / Irr.	10.0	8.6	0.86	10.9	-0.9
Soy / Rainfed	8.9	8.6	0.81	9.2	-0.3

+ positive value is net flux to the soil   - negative value is flux to the atmosphere

Corn/Soybean Productivity Ratio

- Photosynthetic Mechanism:
  Corn **C4** system *versus* Soybean **C3** system.
  - C4 more productive in high light intensities.
  - C3 less productive due to photorespiration.
- Seed Constituents (Typical Percentages):

	Carbohydrate	Protein	Lipid
Corn:	84%	10%	05%
Soybean:	38%	38%	20%
PSG Equiv*:	0.83	0.40	0.33

- Corn thus always yields 3X more than Soybean!

(*photosynthetic glucose equivalent. The fractional number indicates how much constituent is obtainable from a glucose molecule of six carbons, so it is a measure of the cost to the plant to produce one unit of the given constituent)

Annual Net Ecosystem Exchange of CO_2-C for a Variety of Ecosystems

Annual NEE g C m^{-2}	Biome and location	Reference
300 to 500	Maize, Nebraska, USA	Verma, et al., 2005
200	Temp. deciduous forest, Mass. USA	Barford, et al., 2003
174	Temp. coniferous Forest, Mass., USA	Hollinger et al., 2004
80 to 170	U. Michigan Biological Station Forest	Schmidt et al., 2003
-100 to 200	Temp. coniferous forest, Wash. USA	M. Falk personal comm.
270 to 420	Douglas Fir forest, West Coast Canada	Morgenstern, et al., 2004
50 to 275	Tall grass prairie, Oklahoma, USA	Suyker et al., 2003
-18 to 20	Temperate grassland, Alberta, Canada	Flanagan et al., 2002
-30 to 130	Mediterranean grassland	Xu and Baldocchi, 2003

System Level

Net Annual Carbon Sequestration

average of four years

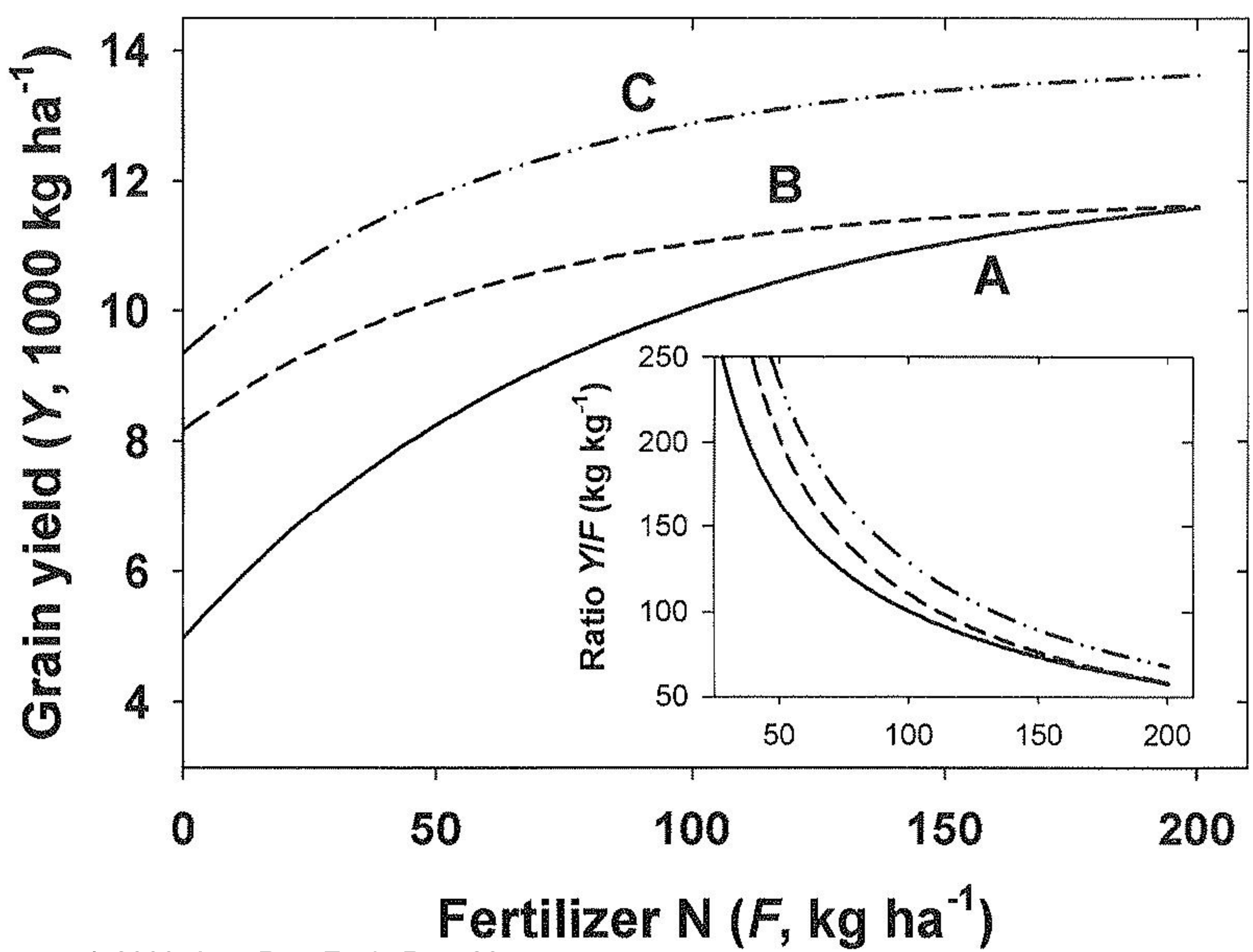
Mg C ha^{-1} yr^{-1}

Mead, NE

	Site 1 Irrigated Cont. Maize	Site 2 Irrigated Maize-soybean	Site 3 Rainfed Maize-soybean
Annual Net Ecosystem Exchange (NEE)	4.40	2.44	2.19
Grain C removal at Harvest	-4.91	-3.52	-2.35
Net carbon Sequestration	**-0.51**	**-0.92**	**-0.16**

+ positive value is net flux to the soil   - negative value is flux to the atmosphere

HYPOTHESES



Cassman et al. 2003. Ann. Rev. Envir. Res. 28


Corn - Soybean
44,000 Plants/acre
M2

Site: Lincoln, NE, UNL East Campus (1999 – 2005)

Crop rotation (main plots)

CC	Continuous corn
CS	Corn – Soybean (corn in odd years)
SC	Soybean – Corn (corn in even years)

Plant Population (subplots)

P1	Corn: 30k	28-31,000 plants/acre
P2	Corn: 37k	35-41,000 plants/acre
P3	Corn: 44k	38-47,000 plants/acre)

Management Intensity (sub-subplots)

M1	recommended fertilizer management based on soil testing. Maize: UNL recommendation for 200 bu/acre yield goal
M2	intensive management aimed at yields close to yield potential. Maize yield goal 300 bu/acre, higher NPK rates, micronutrients, N in 3-4 splits

Simulated Yield Potential (Hybrid-Maize) vs. Actual Yield (bu/a)

Population[1]	Simulated Yield Potential[2]		EI Trial 30" rows		Row Spacing Trial 15" rows	
	Long-term mean	2005	Actual Yield[3] bu/a	% Yield Potential	Actual Yield[4] bu/a	% Yield potential
P1 (28 k)	258	239	221	**92**	229	**96**
P2 (37 k)	282	257	219	**85**	252	**98**
P3 (41 k)	290	264	200	**76**	-	-

1. Number in parenthesis is final plant population
2. Hybrid-Maize simulation using observed dates of emergence, silk and maturity.
3. Refers to CS-M2 treatments, EI trial P31G68
4. Refers to 15" row corn, Row-spacing trial, P31G68

Site: Lincoln, NE, UNL East Campus (2006 – 2007)

Crop rotation (main plots)

CC	Continuous corn
CS	Corn – Soybean (corn in odd years)
SC	Soybean – Corn (corn in even years)

Plant Population (subplots)

P1	Corn: 30k - 30” rows
P2	Corn: 40k - 30” rows
P3	Corn: 40k - 15” rows

Management Intensity (sub-subplots)

M1	recommended fertilizer management based on soil testing. Maize: UNL recommendation for 200 bu/acre yield goal
M2	intensive management aimed at yields close to yield potential. Maize yield goal 300 bu/acre, higher NPK rates, micronutrients, N in 3-4 splits

2007 crop lost to severe windstorm @ R3 stage of growth

CC & CS systems: Corn yields Lincoln EI

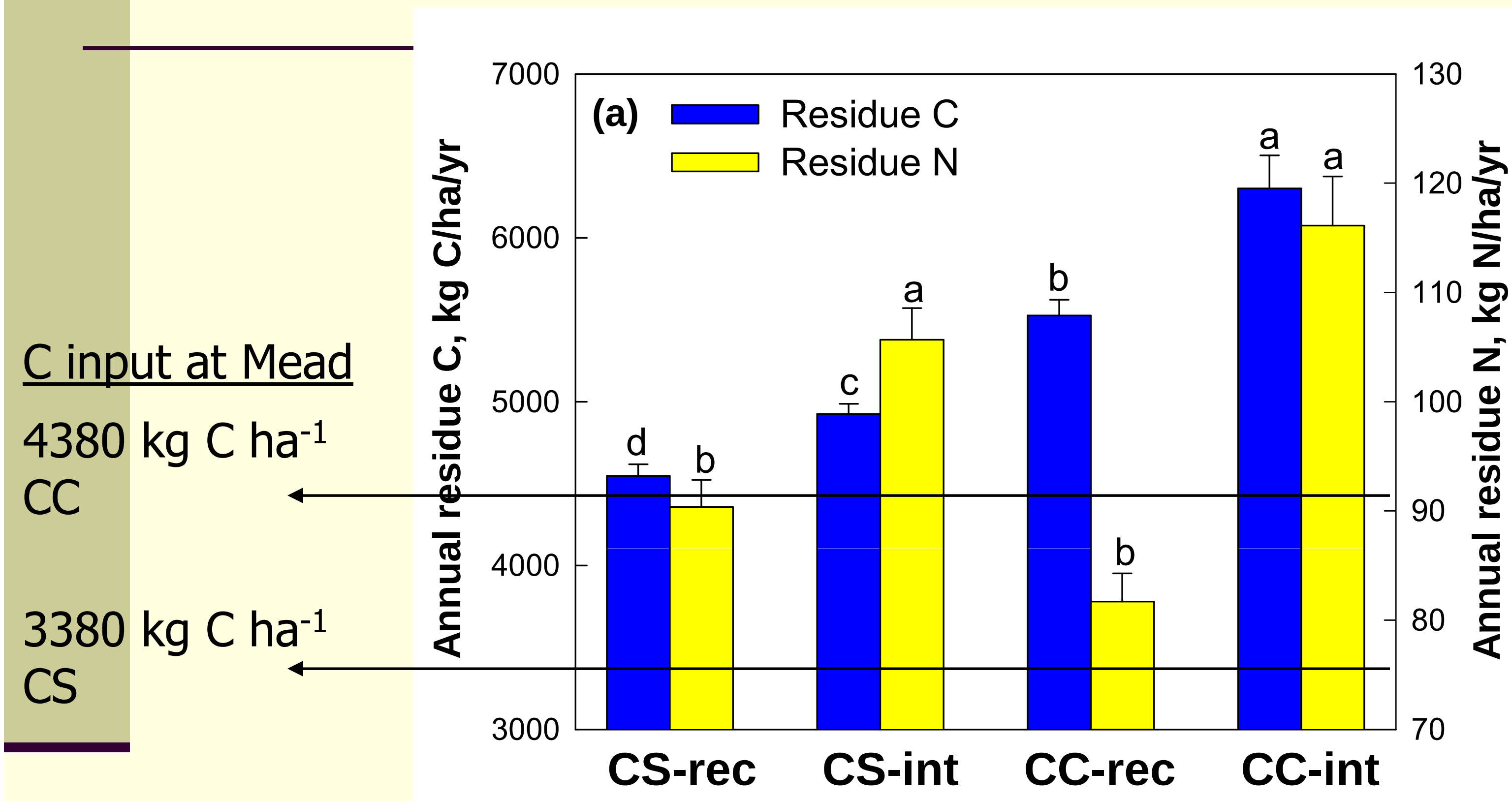
Treatments		Corn grain yield (bu/acre)[2]							
Density[1]	**Fertilizer**	**Avg[3]**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Continuous Corn									
P1	**M1**	**223**	-	214	223	178	255	**247**	**221**
P2/3	**M2**	**244**	-	229	252	242	265	**266**	**208**
Corn / Soybean									
P1	**M1**	**235**	219	225	230	221	268	**261**	**223**
P2/3	**M2**	**256**	257	248	249	243	285	**287**	**220**

[1] M2 treatment with highest yielding plant density: P2 in 2000, 2003 and 2005;
P3 in 1999, 2001, 2002 and 2004.

[2]Hybrid: P33A14 (113 d) in 1999-2000
P33P67 (114 d) in 2001-2002
P31N28 (119 d) in 2003-2004
P31G68 (119d) in 2005

[3] Average of 2000-2005

C & N input with crop residues, Lincoln, NE



Averages for corn and soybean crops grown during 2000-2005

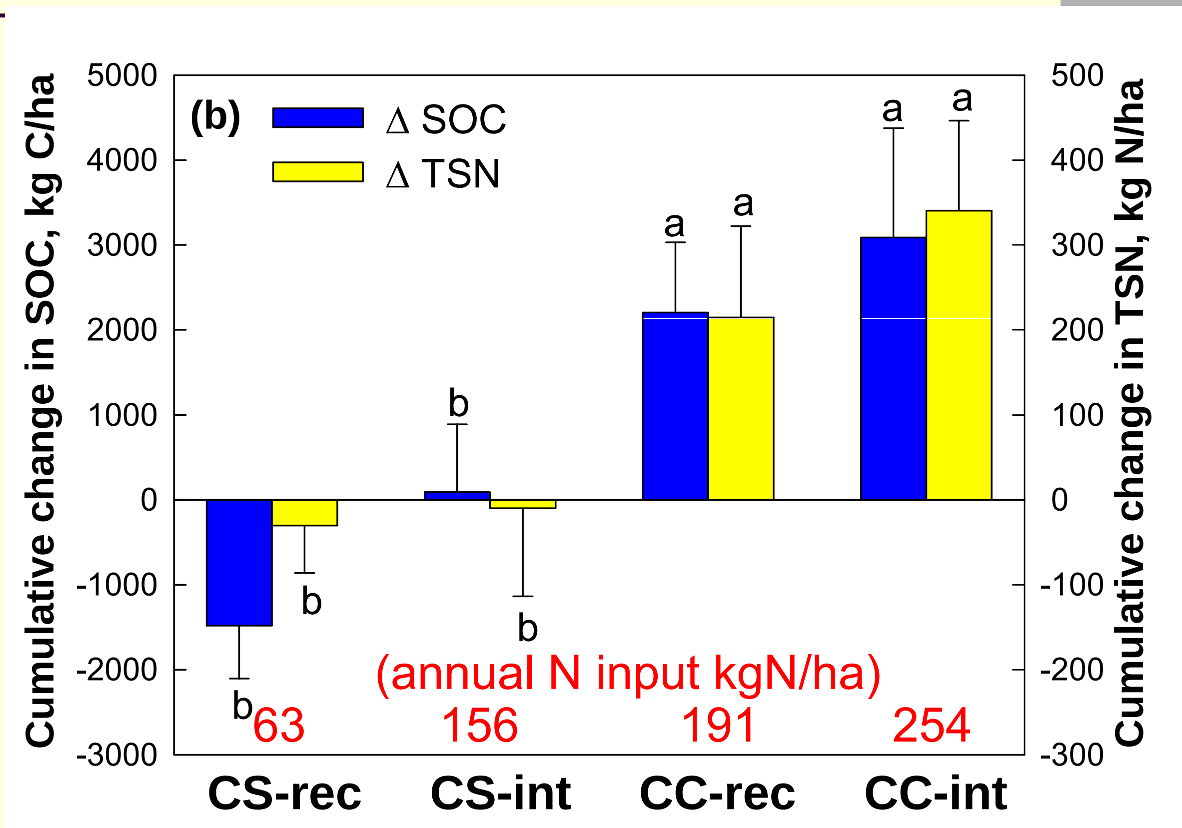
CS-rec Maize-soybean rotation, recommended management

CS-int Maize-soybean rotation, intensive management

CC-rec Continuous maize, recommended management

CC-int Continuous maize, intensive management

Change in soil C and N, Lincoln, NE



Soil samples collected in June 2000 and 2006, 0-30 cm

CS-rec maize-soybean rotation, recommended management

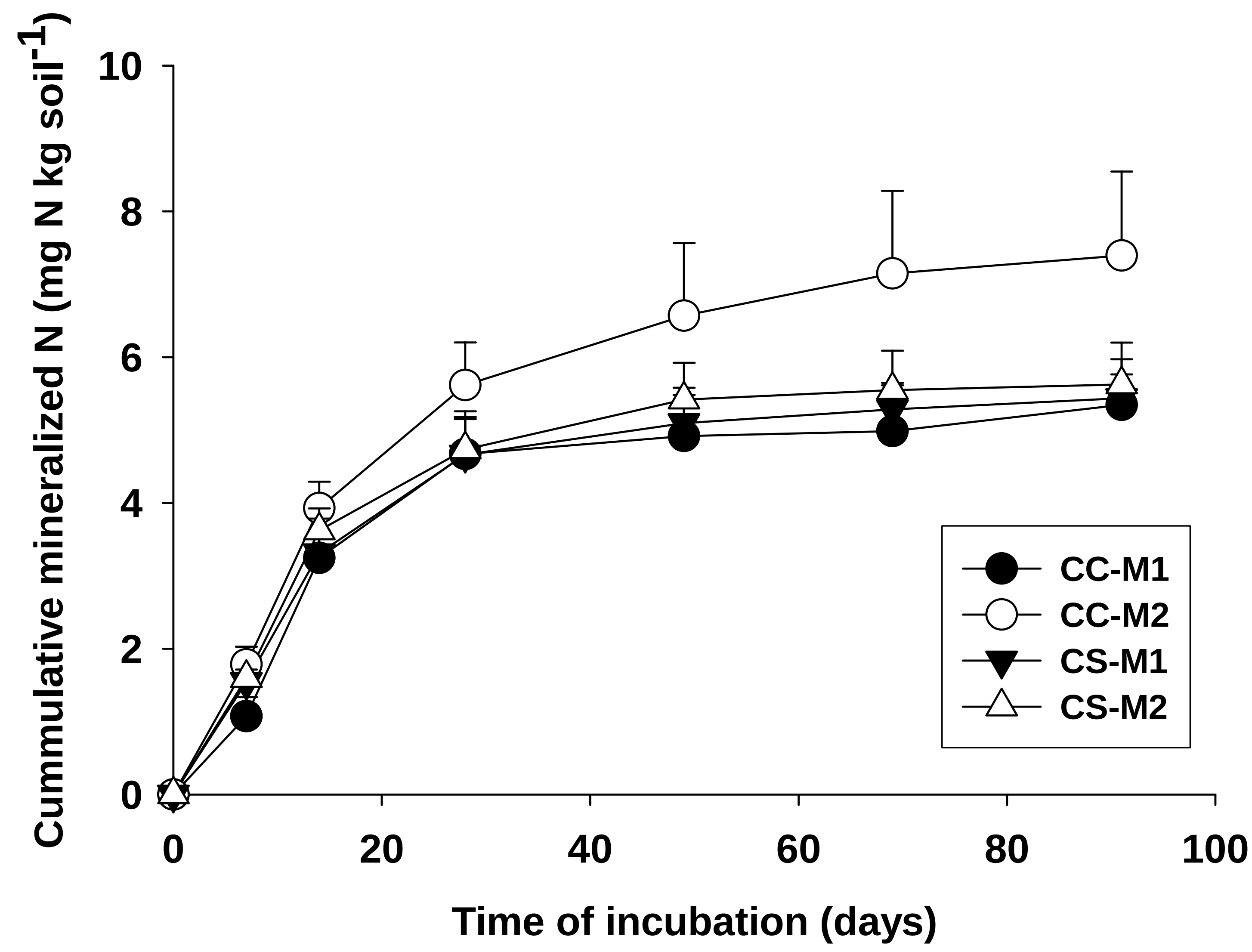
CS-int maize-soybean rotation, intensive management

CC-rec continuous maize, recommended management

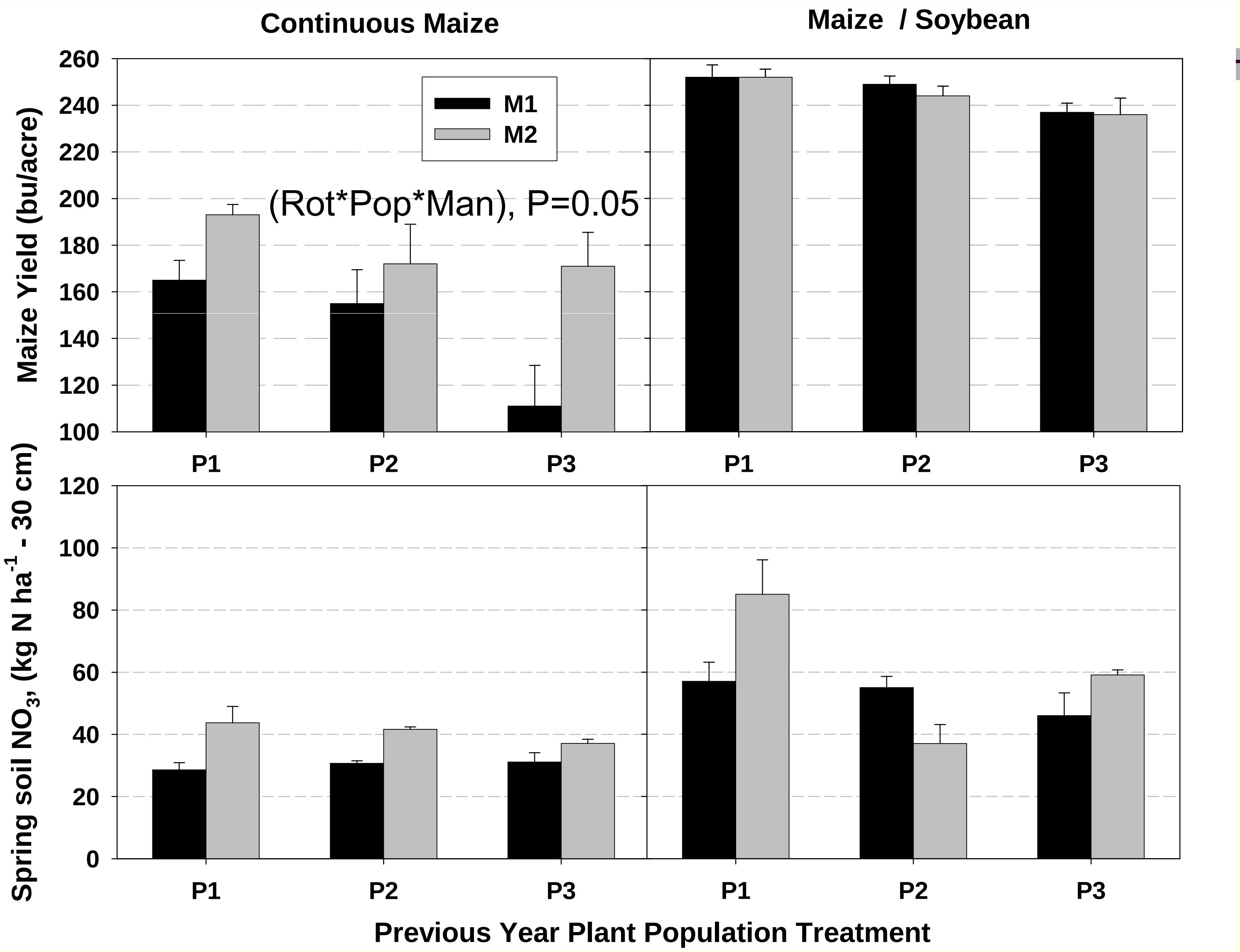
CC-int continuous maize, intensive management

90-d Aerobic Incubation of Soil

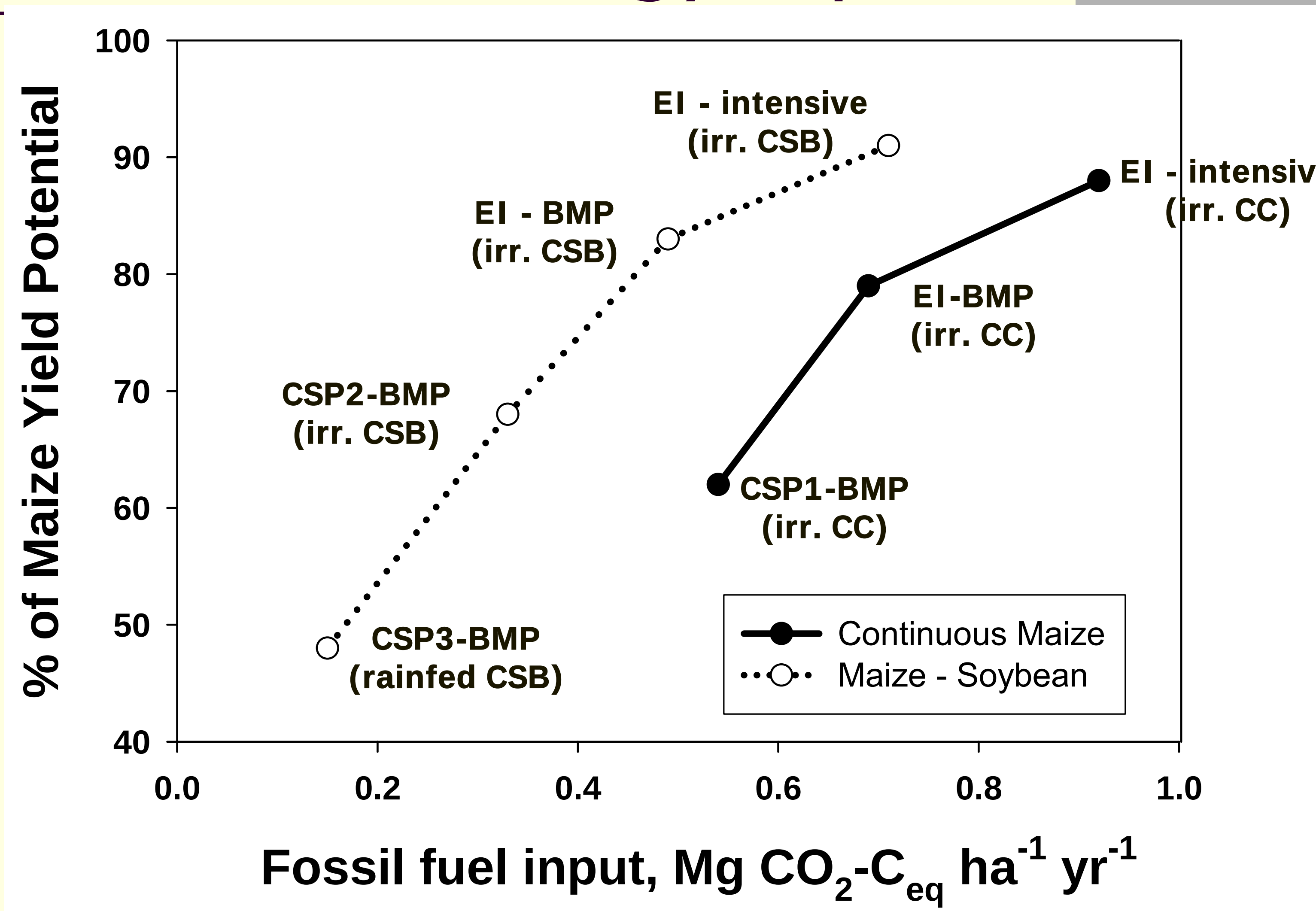
(25°C @ Θ_v/ε=0.6), Lincoln EI 2006



2008 Residual Yield – Lincoln EI



Dependence of Intensification on Energy Input



Summary

- Modern corn production is one of the most productive crops in terms of net energy harvest.
- There is a considerable yield gap that can be exploited through intensification but it requires added energy input.
- Long-term sustainability will require that we consider *C-management* as well as N,P,K etc.

Summary

- Exploitation of yield potential (intensification) can be achieved without loss in energy use efficiency but this requires more information intensive management.

- Improvements in soil quality (carbon ***and nitrogen*** sequestration) from intensification may also reduce global warming potential by improving efficiency of N use.