Nitrogen in Crop Production: Agronomics and Economics

Nitrogen Science Summit
Madison, WI
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University of Wisconsin-Madison

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Road Map

- Importance of N in crop production
- Developing N application rate guidelines
  - Influence of soil N supply
  - Influence of hybrid
- Meeting N needs with manure and legumes
- Relationship between N fertilizer application rate and residual N
- Summary

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Importance of N for plant growth

- Function in plant
  - Component of amino acids
  - Essential for cell division & plant growth
  - Basic component of chlorophyll
  - Necessary for enzymatic reactions
  - Component of nucleic acids

- Nutrient most often limiting crop yield
  - Especially for non-leguminous crops

2013 acreage of major crops requiring N in WI

Crop	Acreage
Corn (grain + silage)	4,030,000
Winter wheat	265,000
Oats	105,000
Potatoes	65,000

Source: USDA-NASS

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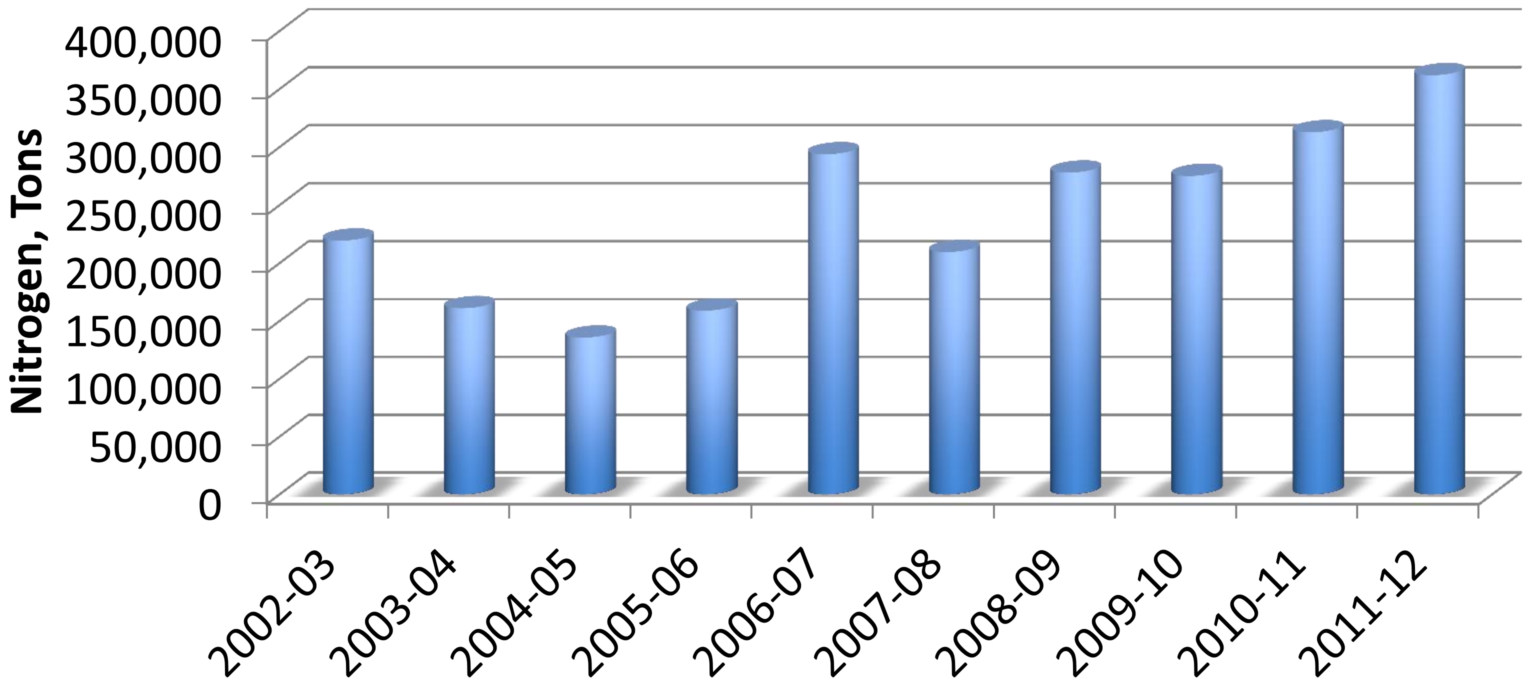
N fertilizer consumption in WI (2002-2012)



Includes all agricultural and non-agricultural fertilizer and fertilizer material (excluding fillers and secondary and micronutrients) in which N-P-K was reported. Source: WI DATCP

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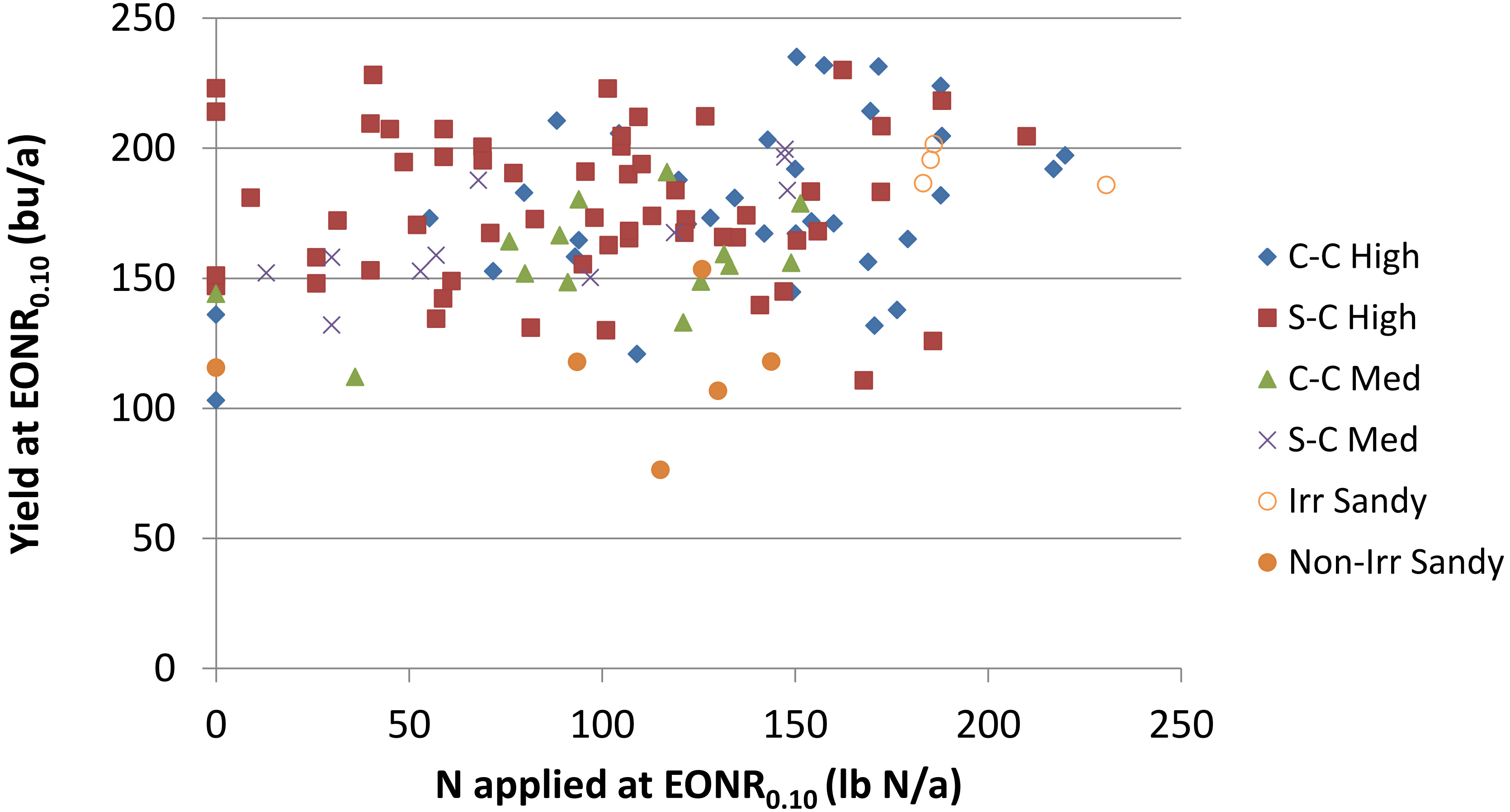
Determining Fertilizer N Need

$$\frac{\text{Crop N Need} - \text{Soil N Supply}}{\text{Fertilizer Efficiency Factor}} = \text{Fertilizer N Required}$$

Equation seems easy, but is difficult in practice

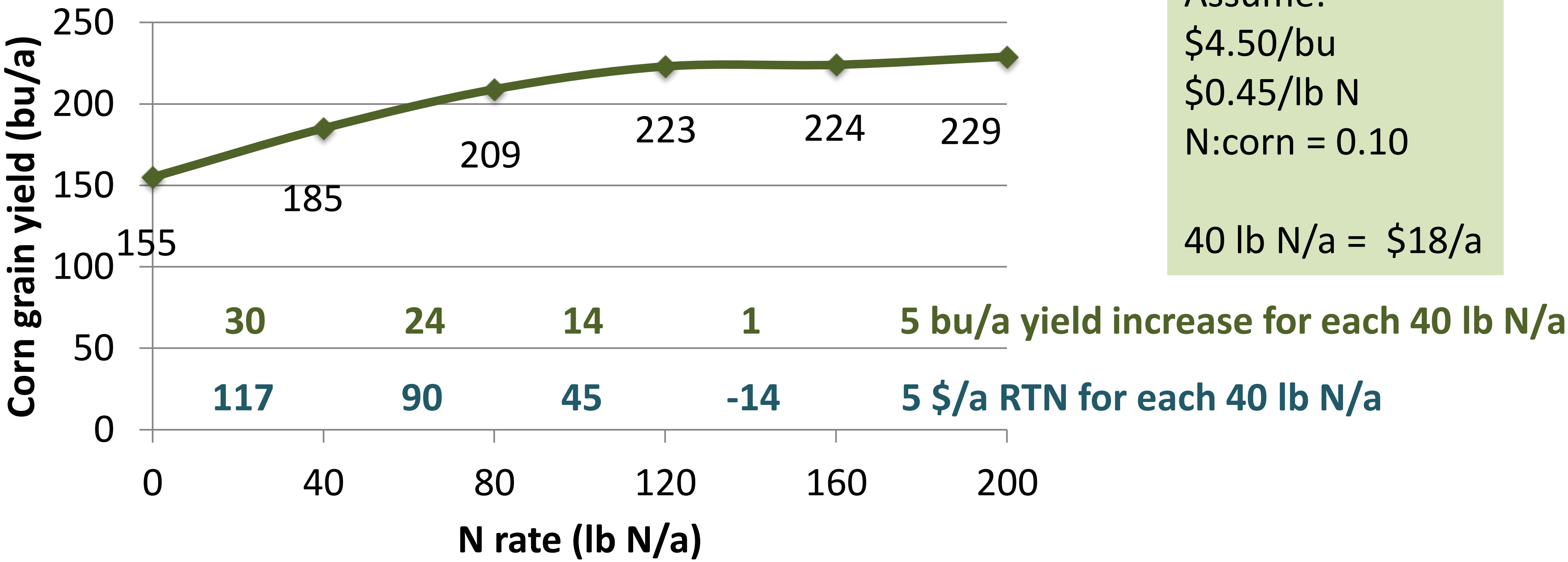
Simplified from Stanford, 1973

Relationship between N applied and corn yield achieved in WI at the $EONR_{0.10}$



Based on the 2012 MRTN database (1995-2011)

Crop response to N fertilizer



Assume:
$4.50/bu
$0.45/lb N
N:corn = 0.10

40 lb N/a = $18/a

- The **E**conomic **O**ptimum **N** Rate (EONR) is the N rate at which profit from N fertilizer is maximized
  - EONR will vary with prices of N and corn

N rate guidelines for corn: Maximum Return to N (MRTN)

- Uses a statewide database
  - Many soil types
  - Numerous counties
  - Many hybrids (traited and untraited)
- Based on replicated N response trials
  - Small plot and field strip
  - Where N was managed well
- Based on economics
  - Allows for fluctuating prices & risk tolerance
- Same basic philosophy used in:
  - MN, IA, IL, IN, MI, OH

Definition of soil yield potential (YP)

- The relative ranking of a soil's ability to produce high corn yields along with the responsiveness of corn yield to nitrogen (N) fertilizer

Soil yield potential (YP)

- All sandy soils are low (sandy YP)
  1. the upper 8 inches has a weighted average sand content greater than or equal to 75%,
  2. the subgroup or great group contains “Psam” and the weighted average sand content in the upper 8 inches is 65% or more, or
  3. the taxonomic particle size class matches sandy, and the weighted average sand content in the upper 8 inches is 65% or more
- Organic soils
  – High YP, if mesic
  – Medium YP, if frigid

Soil yield potential (YP)

- Loamy soils are medium or high YP
  - Defined by soil properties
  - If at least one of the properties is limiting, then the soil is medium YP

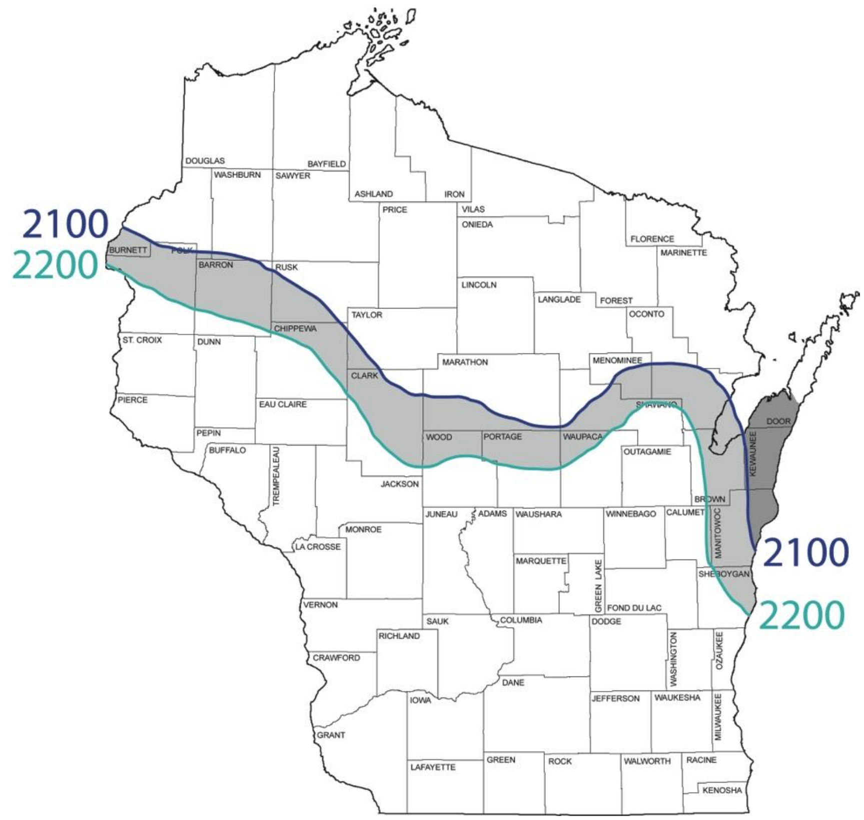
Soil Property	Interpretation that limits YP to medium
Drainage class	excessively drained somewhat excessively drained poorly drained very poorly drained
Available water in the top 60" of soil	Very low (< 3 inches) and low (3–6 inches)
Depth to bedrock (lithic contact)	<30"

  - Removing a limitation will place the soil in the high YP category

Additional criteria for loamy soil YP

- If a soil's location has, on average, <2100 GDD, it should be considered medium YP regardless of soil property limitations

- In the shaded transition area, if no limitation to YP, then growers & agronomists should choose the most appropriate YP based upon experience



Average accumulated (May 1 to Sept. 30) growing degree day (GDD) isolines for Wisconsin, 1997-2011. http://www.soils.wisc.edu/uwex_agwx/thermal _models

N:Corn Price Ratio Table

Price of Corn ($/bu corn)

Price of N* ($/lb N)	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00
0.20	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03
0.25	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04
0.30	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05
0.35	0.12	0.11	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06
0.40	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07
0.45	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.09	0.08	0.08	0.08
0.50	0.17	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08
0.55	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.10	0.09
0.60	0.20	0.18	0.17	0.16	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10	0.10
0.65	0.22	0.20	0.19	0.17	0.16	0.15	0.14	0.14	0.13	0.12	0.12	0.11	0.11
0.70	0.23	0.22	0.20	0.19	0.18	0.16	0.16	0.15	0.14	0.13	0.13	0.12	0.12
0.75	0.25	0.23	0.21	0.20	0.19	0.18	0.17	0.16	0.15	0.14	0.14	0.13	0.13

*Price of N = [$/ton fertilizer x (100 / % N in fertilizer)] / 2000

Corn N rate guidelines: Maximum Return to N (MRTN)

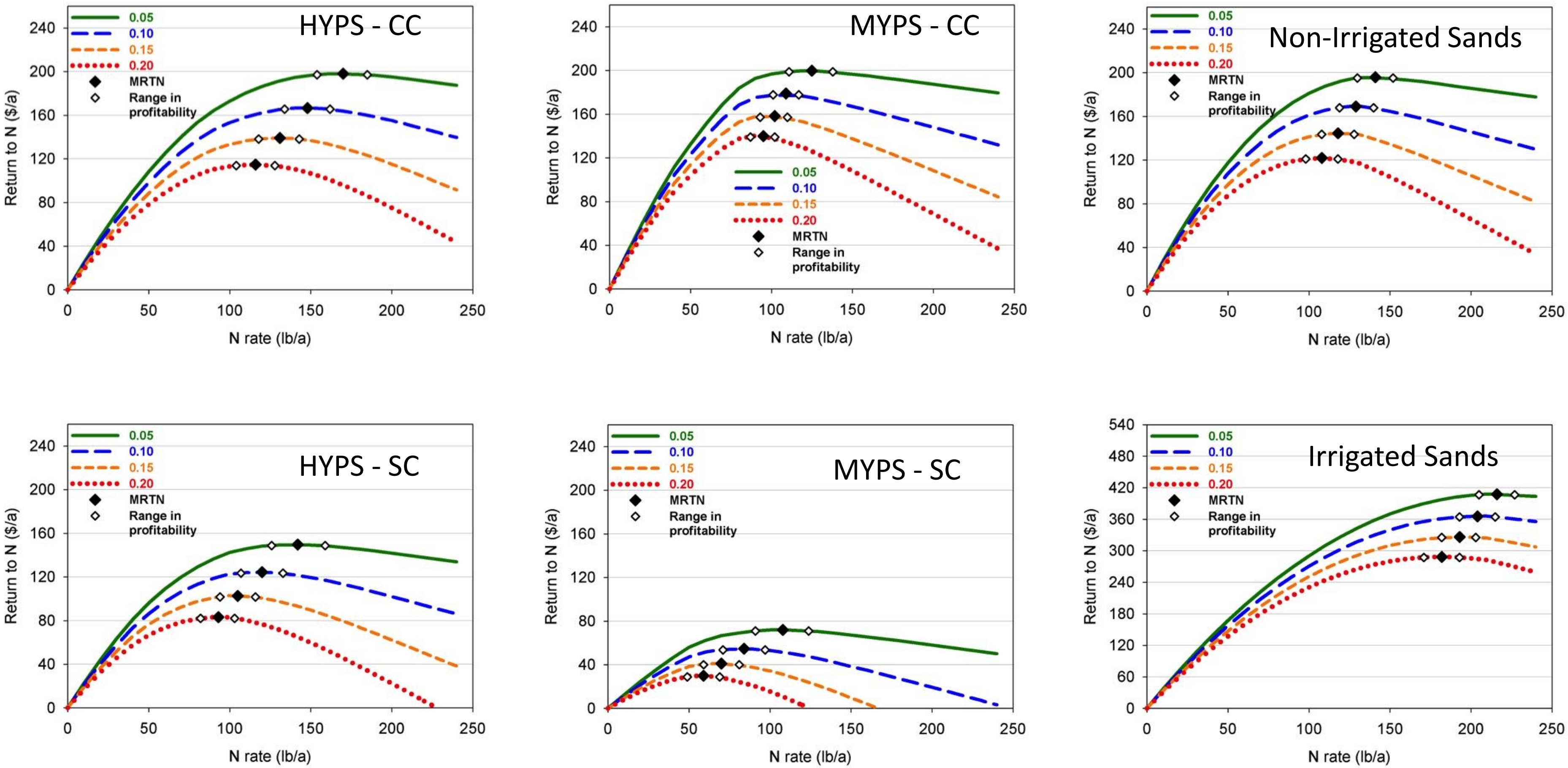
University of Wisconsin Nitrogen Guidelines for Corn

Soil[1]	Previous Crop	N:Corn Price Ratio (see table on other side): 0.05	0.10	0.15	0.20
		lbs N/acre (total to apply)[2]			
loamy: high yield potential soils	**Corn**, Forage legumes, Legume vegetables, Green manures[5]	**190**[3] 170-------210[4]	**165** 155----180	**150** 140---160	**135** 125----150
	Soybean, Small grains[6]	**140** 125------160	**120** 105----130	**105** 95--115	**90** 80----105
loamy: medium yield potential soils	**Corn**, Forage legumes, Legume vegetables, Green manures[5]	**145** 130-----160	**125** 115----140	**115** 105---125	**105** 95--110
	Soybean, Small grains[6]	**130** 110-------150	**100** 85------120	**85** 70---95	**70** 60---80
sands/ loamy sands	Irrigated—**All crops**[5]	**215** 200-----230	**200** 185----210	**185** 175---195	**175** 165---185
	Non-irrigated—**All crops**[5]	**140** 130---150	**130** 120---140	**120** 110---130	**110** 100---120

Several footnotes – important to read them!!!

Must still take N credits for forage legume, legume vegetable, green manure and animal manure

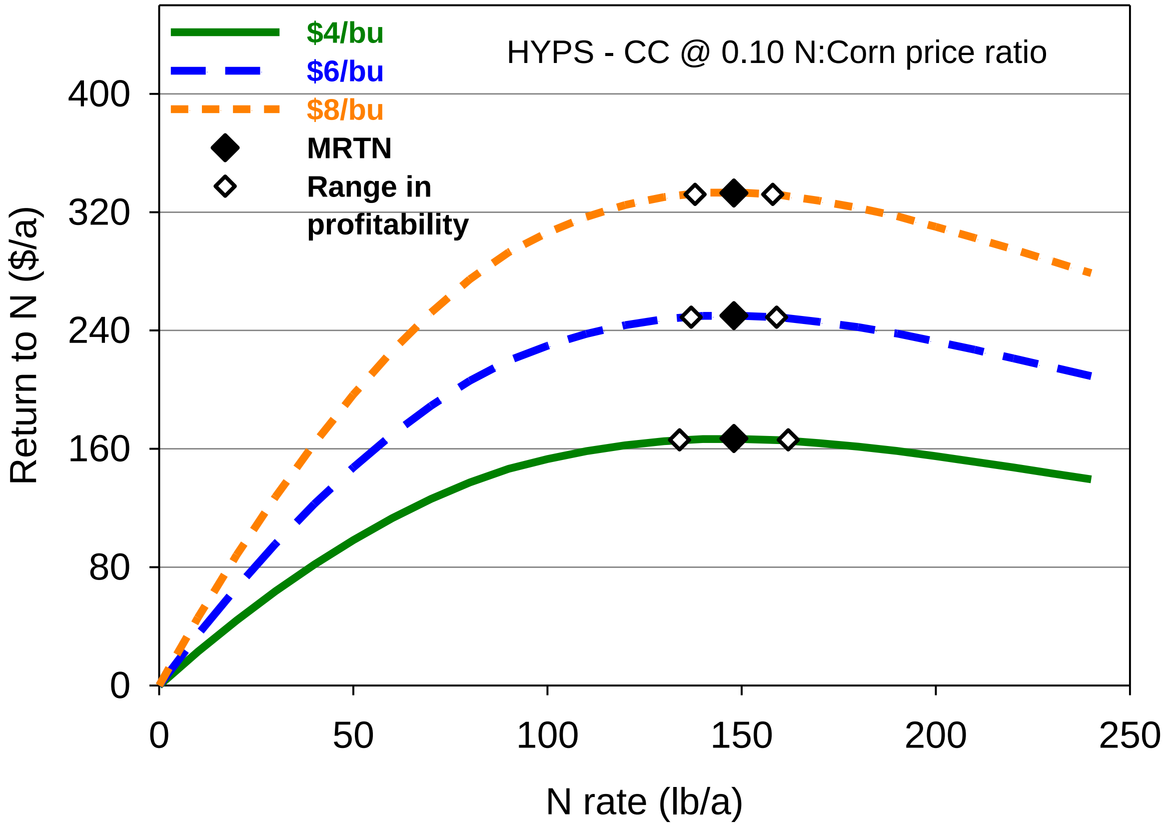
Effect of N:corn price ratio on MRTN



As N:corn price ratio decreases (lower cost N and/or higher value corn), MRTN rate increases

Based on the 2010 MRTN database

Effect of price level on MRTN



As price level increases:

- MRTN does not change
- Range in profitable N rates narrows

Based on the 2010 MRTN database

MRTN rate guideline for wheat

University of Wisconsin
Nitrogen Guidelines for Wheat

N:Wheat Price Ratio (see table on other side to determine ratios)

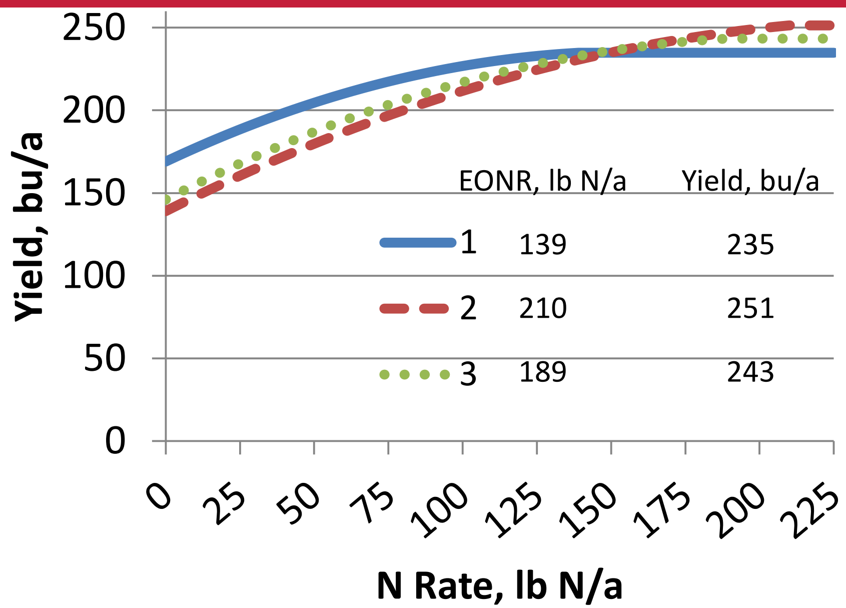
Soil Group	Previous Crop	PPNT (lb NO_3- N/a)	0.050	0.075	0.100	0.125
			lbs N/acre (total to apply)[1]			
LOAMY	Corn	< 50 or no PPNT	**75** 65 -------- 85	**70** 55 -------- 80	**60** 50 -------- 70	**55** 40 --------65
		51 to 100	**45** 35 -------- 55	**40** 30 -------- 50	**35** 25 -------- 40	**30** 20 --------35
		> 100	**0** 0 -------- 0	**0** 0 -------- 0	**0** 0 -------- 0	**0** 0 --------0
	Soybean, small grain	All results[2] or no PPNT	**55** 45 -------- 65	**50** 40 -------- 60	**45** 35 -------- 50	**40** 35 -------- 45
SANDY	All crops	PPNT is not recommended on sandy (sand and loamy sand) soils.	**105** 95 -------- 115	**100** 95 -------- 110	**90** 80 -------- 100	**85** 70 --------95

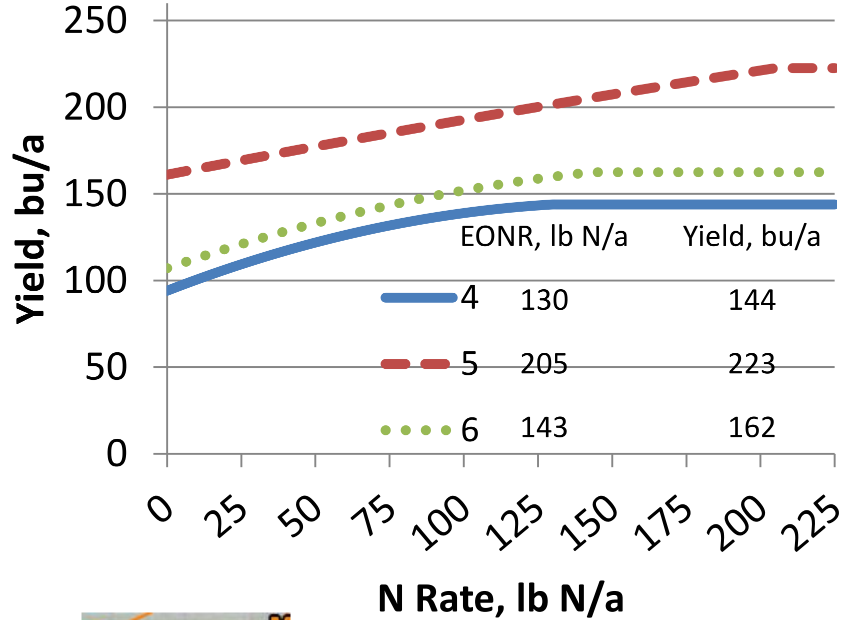
[1] On loamy soils with < 2% organic matter, add 30 lb N/a to all rates. On soils with more than 10% organic matter, reduce rates by 30 lb N/a.

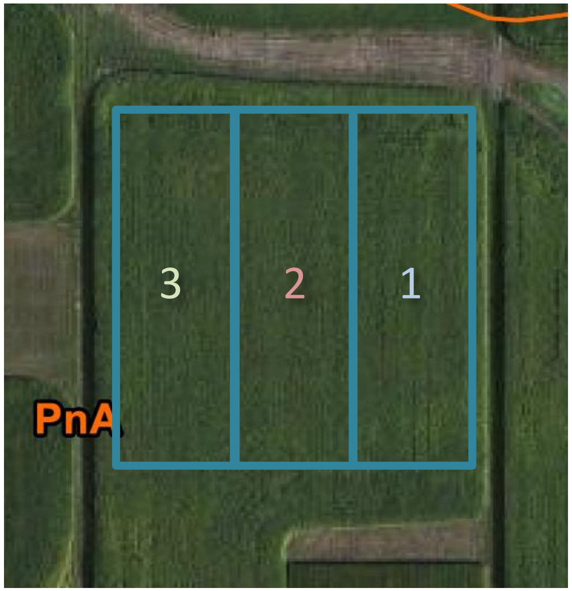
[2] If the PPNT is < 50 lb N/a, use the top end of the profitable range; if the PPNT is 51 to 100 lb N/a, use the bottom end of the profitable range; if the PPNT is > 100 lb/a, no additional N is needed.

See other side for more guidelines.

Soil spatial variability can influence EONR

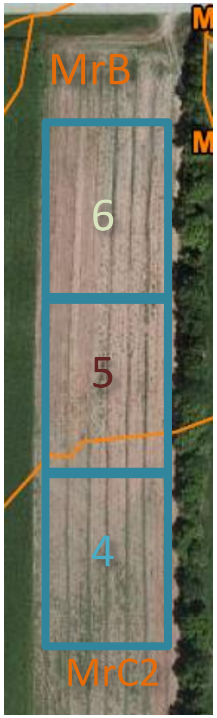






Arlington ARS

Waterloo



2013
Both sites high yield potential

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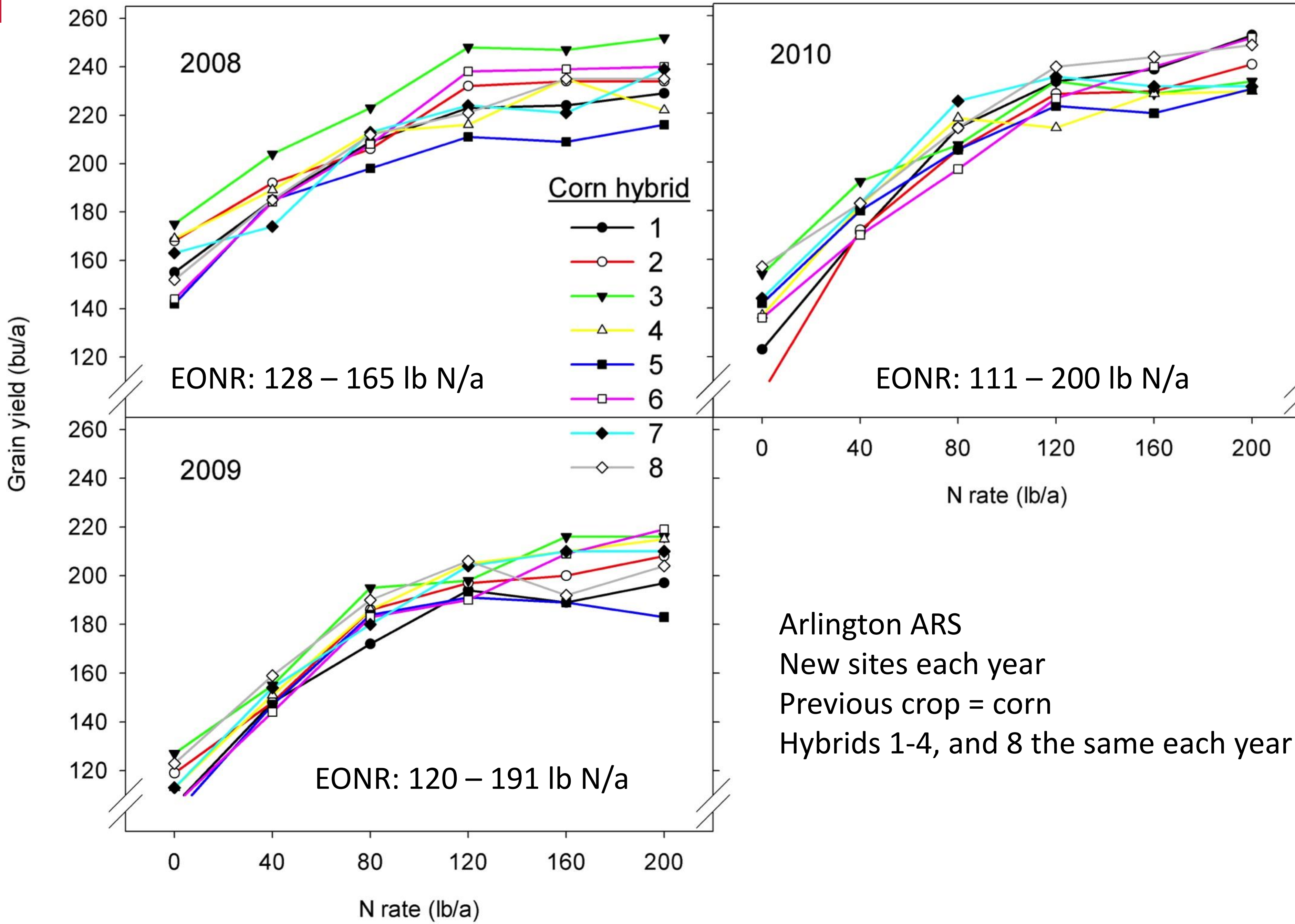
Effect of corn hybrid on N use efficiency (NUE)



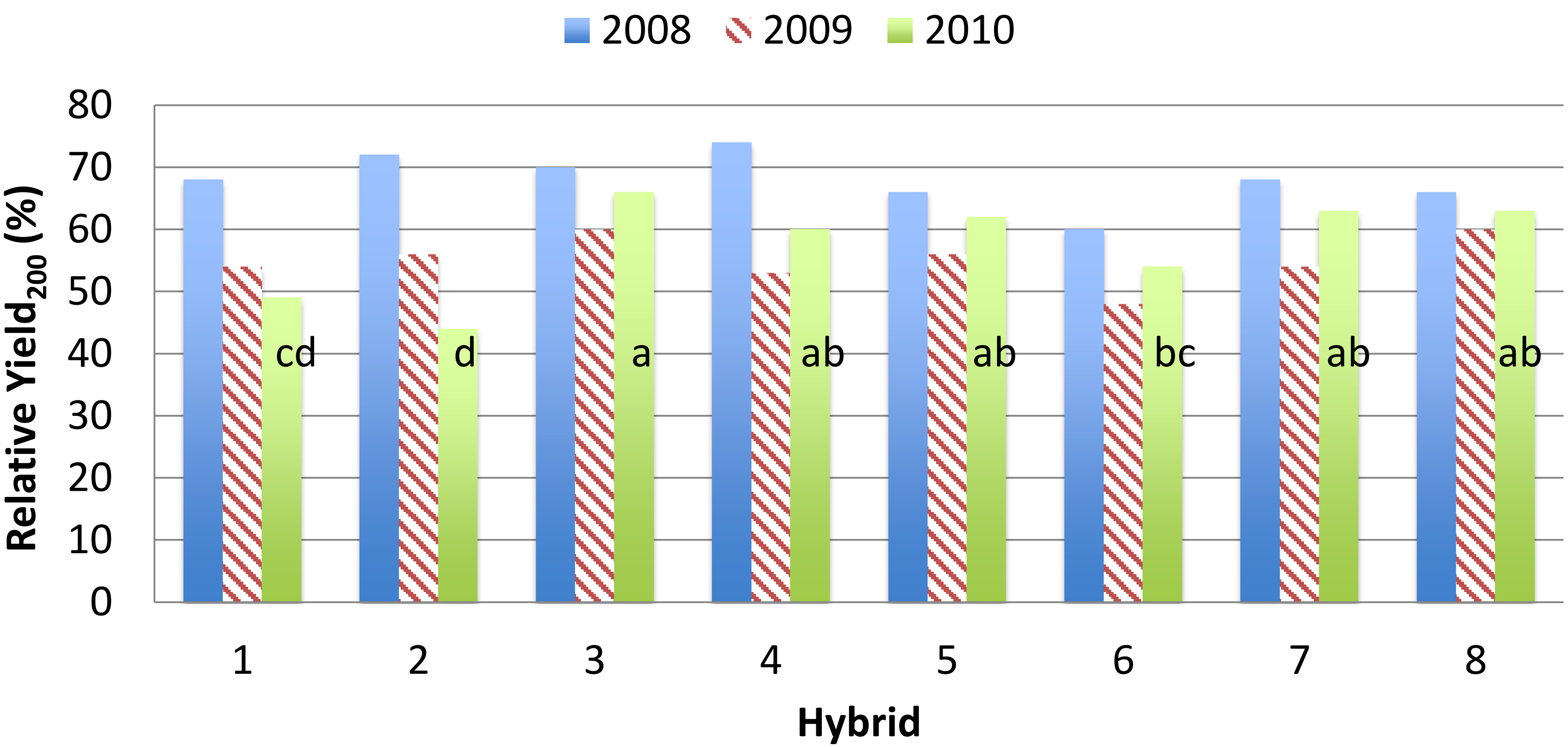
Arlington ARS

New sites each year

Previous crop = corn

Hybrids 1-4, and 8 the same each year

In Wisconsin, soil N's contribution to yield is significant!!



	HYPS Corn	MYPS Corn	HYPS Soybean	MYPS Soybean	Irrigated Sands	Non-Irrg Sands
Relative Yield, %	59	61	73	83	43	52

Based on the 2012 MRTN database (1995-2011)

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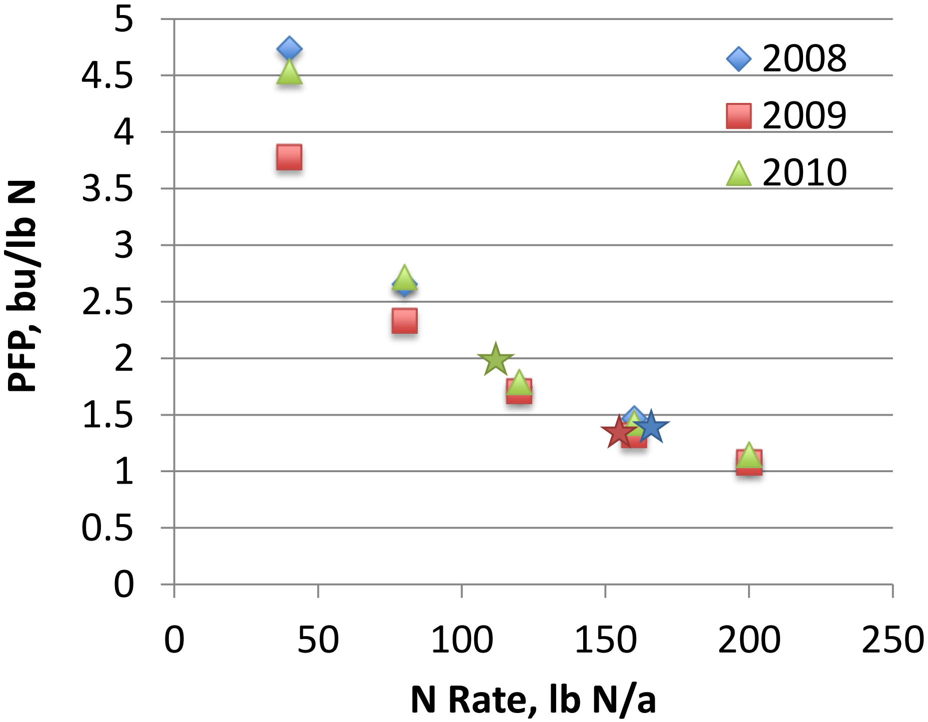
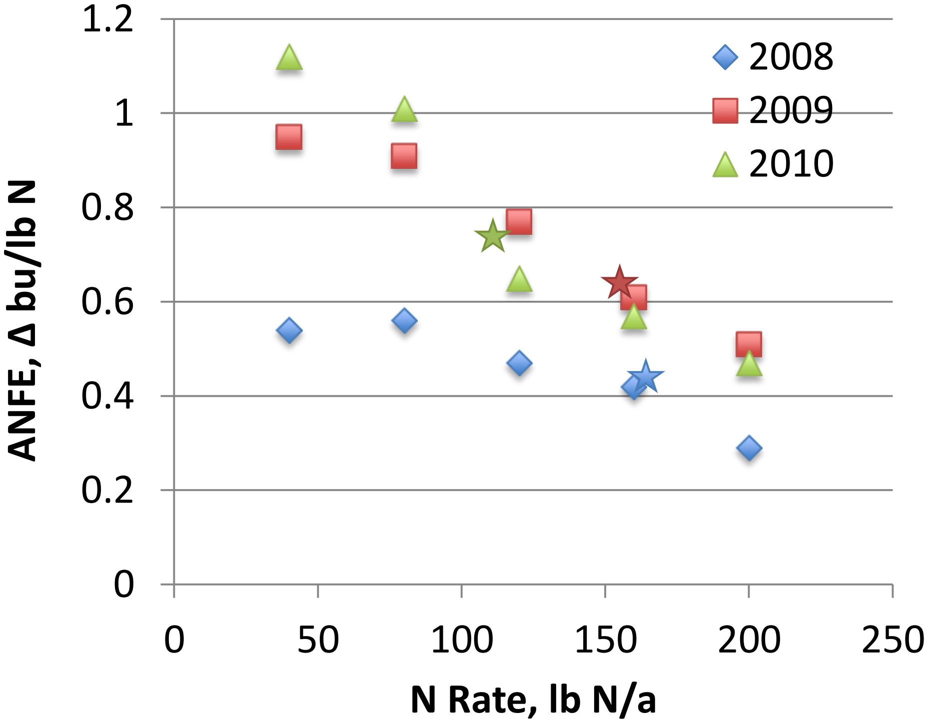
Effect of N rate and year on partial factor productivity (PFP) and agronomic N fertilizer efficiency (AFNE) for hybrid 4





PFP = Yield ÷ N rate

ANFE = (Yield – $Yield_0$) ÷ N rate

- Stars represent the NUE parameter at the EONR
- ANFE is a better measure of NUE (effect of fertilizer alone)

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Effect of hybrid and year on partial factor productivity (PFP), agronomic N fertilizer efficiency (AFNE), and fertilizer N recovery efficiency (FNRE) at the EONR

Hybrid	PFP			ANFE			FNRE		
	2008	2009	2010	2008	2009	2010	2008	2009	2010
	bu/ lb N			Δ bu/ lb N			Δ lb N uptake/ lb N		
1	1.37	1.28	1.37	0.45	0.63	0.73	0.63	0.66	0.74
2	1.54	1.33	1.53	0.61	0.63	0.90	0.50	0.65	0.91
3	1.77	1.17	1.43	0.63	0.54	0.53	0.61	0.57	0.73
4	1.31	1.22	1.93	0.42	0.65	0.76	0.53	0.62	0.78

PFP = Yield ÷ N rate

ANFE = (Yield – Yield_0) ÷ N rate

FNRE = (N Uptake – N Uptake_0) ÷ N rate

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NUE is not simple

- How it is defined will impact interpretation
- Effected by:
  - Hybrid/traits
  - Soil
    - OM content
    - N mineralization potential
    - Environmental conditions for N mineralization
  - Weather
    - Conditions for N loss (eg excessive rainfall shortly after N application)

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On-farm N sources

- What are they?
  - Manure, Forage legumes, Leguminous vegetables, Green manures
- N in these materials can be in both inorganic and organic form
  - Organic forms need to decomposed before they are available for plant uptake
- *The fertilizer bill can be reduced when N credits from on-farm sources are properly accounted for*

Nutrient Availability Coefficients

Multiply Total N content of manure by coefficient to obtain estimated N availability

	N: Time to incorporation: > 72 hours or not incorporated	N: Time to incorporation: 1 to 72 hours	N: Time to incorporation: < 1 hour or injected	P_2O_5	K_2O	S
First-year availability			% of total			
Beef: liquid (≤ 11.0% DM)[a]	30	40	50	80	80	55
Beef: solid (> 11.0% DM)	25	30	35	80	80	55
Dairy: liquid (≤ 11.0% DM)[a]	30	40	50	80	80	55
Dairy: solid (> 11.0% DM)	25	30	35	80	80	55
Goat	25	30	35	80	80	55
Horse	25	30	35	80	80	55
Poultry (chicken, duck, and turkey)	50	55	60	80	80	55
Sheep	25	30	35	80	80	55
Swine	40	50	65	80	80	55
Veal calf	30	40	50	80	80	55
Second-year availability			% of total			
All species	10	10	10	0	0	10
Third-year availability			% of total			
All species	5	5	5	0	0	5

[a] If dry matter (DM) is < 2.0% and NH_4-N is > 75% of total N, the following equation for first-year N availability may be used in an effort to better account for the high concentration of NH_4-N that may be found in these manures: first-year available N = NH_4-N + [0.25 x (Total N – NH_4-N)], assuming manure is injected or incorporated in < 1 hour.

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Estimated 1st year Nutrient Availability

	N					
	------Time to incorporation------			P_2O_5	K_2O	S
	> 72 hours or not incorporated	1 to 72 hours	< 1 hour or injected			
Solid manure	------lb/ton------					
Beef	3	4	5	6	10	1
Dairy: semi-solid (11.1–20.0% DM[b])	2	2	3	3	5	1
Dairy: solid (> 20.0% DM)	2	3	3	3	6	1
Goat	3	4	5	6	8	1
Horse	2	3	4	5	6	1
Poultry: chicken	24	27	29	35	26	2
Poultry: duck	6	7	7	8	7	1
Poultry: turkey	26	28	31	35	25	2
Sheep	5	6	7	7	19	1
Swine	7	9	12	10	8	1
Liquid manure	------lb/1000 gal------					
Beef	5	6	8	6	12	1
Dairy: liquid (< 4.0% DM)	4	6	7	3	11	1
Dairy: slurry (4.1–11.0% DM)	7	10	12	6	17	1
Goat	4	5	6	6	15	1
Poultry	6	7	7	6	7	1
Swine: finish (indoor pit)	17	22	28	14	22	2
Swine: finish (outdoor pit)	7	9	12	6	8	1
Swine: (farrow-nursery, indoor pit)	8	10	14	6	10	1
Veal calf	3	4	4	2	13	1

[a] These estimates are based on the typical total nutrient contents of manures tested in Wisconsin (Table 9.2) multiplied by the estimated first-year nutrient availability (Table 9.1).

[b] DM = dry matter

Forage legume N credits

Crop/stand density	Medium-/fine-textured soils > 8″ regrowth	Medium-/fine-textured soils < 8″ regrowth	Sands/loamy sands > 8″ regrowth	Sands/loamy sands < 8″ regrowth
First-year credit	-----------------	lb N/a to credit	-----------------	
Alfalfa				
Good (70–100% alfalfa, > 4 plants/ft^2)	190	150	140	100
Fair (30–70% alfalfa, 1.5–4 plants/ft^2)	160	120	110	70
Poor (0–30% alfalfa, < 1.5 plants/ft^2)	130	90	80	40
Red clover, birdsfoot trefoil	-----------------	80% of alfalfa credit for similar stands	-----------------	
Vetch	160	90	110	40
Second-year credit	-----------------	lb N/a to credit	-----------------	
All crops, good or fair stand	50	50	0	0

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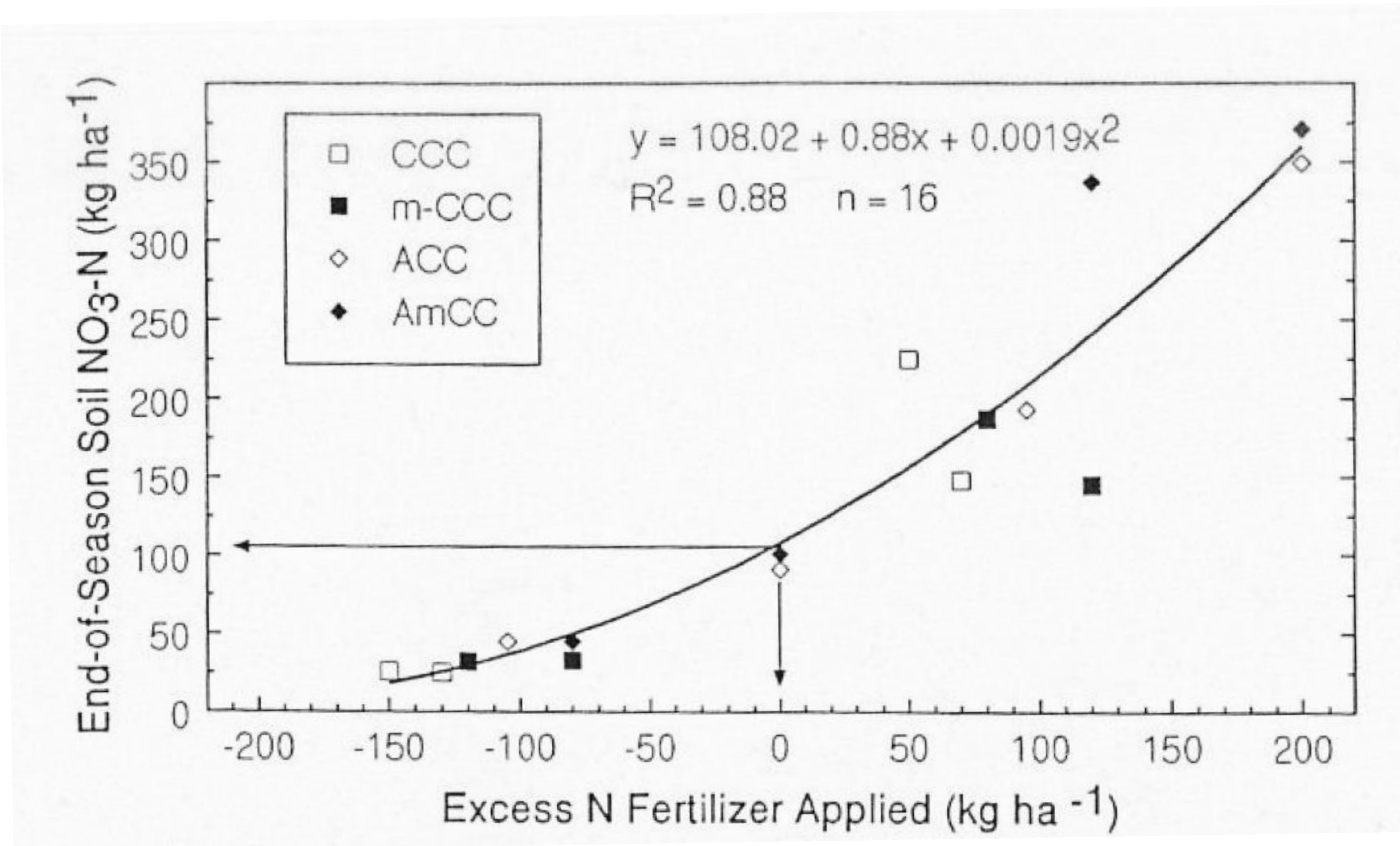
Relationship between excess N fertilizer applied to corn and 0-3' end-of-season (fall, residual) soil nitrate content



Plano silt loam, Arlington, WI
Andraski et al., 2000

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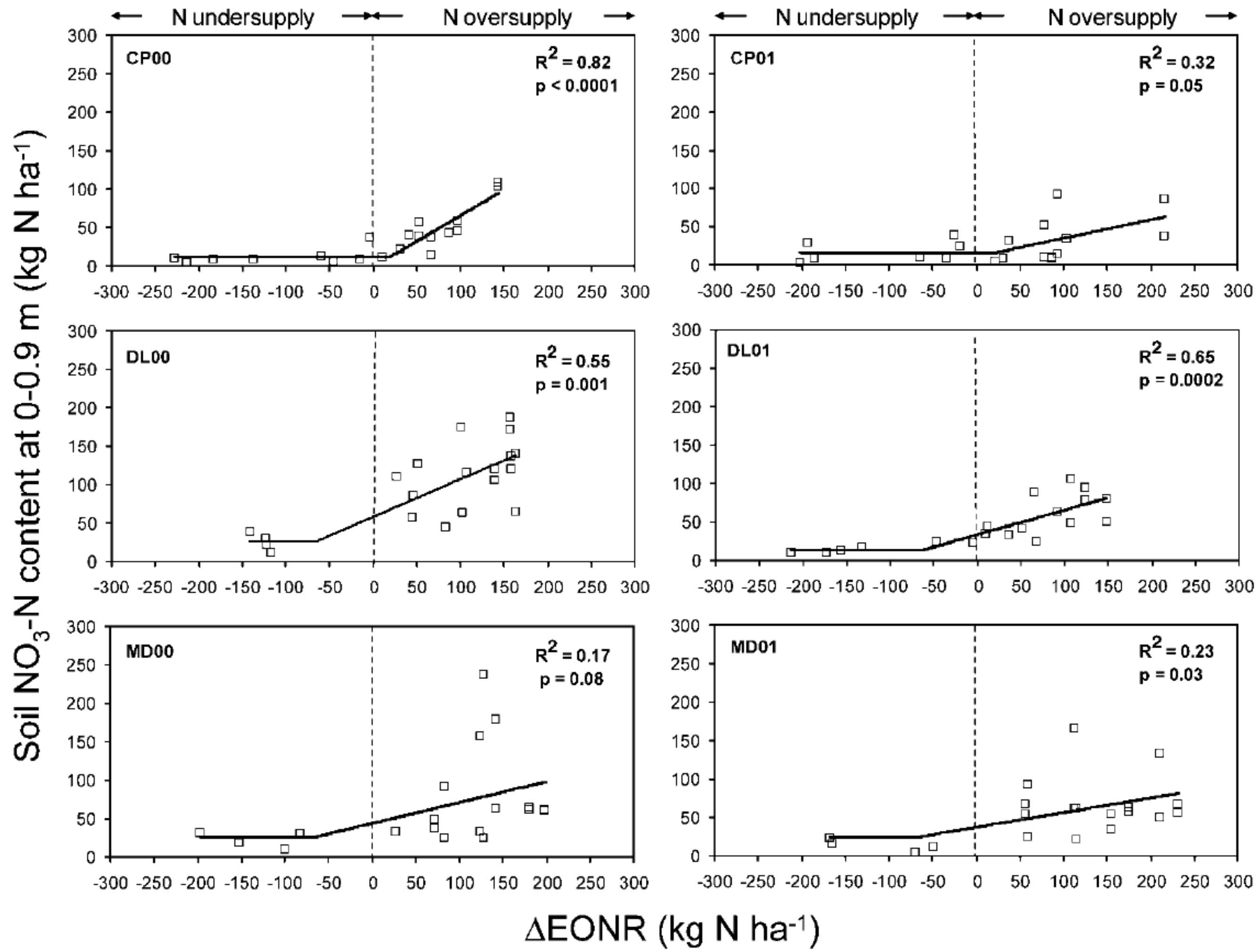

EONR =
Economic
Optimum
N
Rate

Hong et al., 2007

6 sites in Missouri

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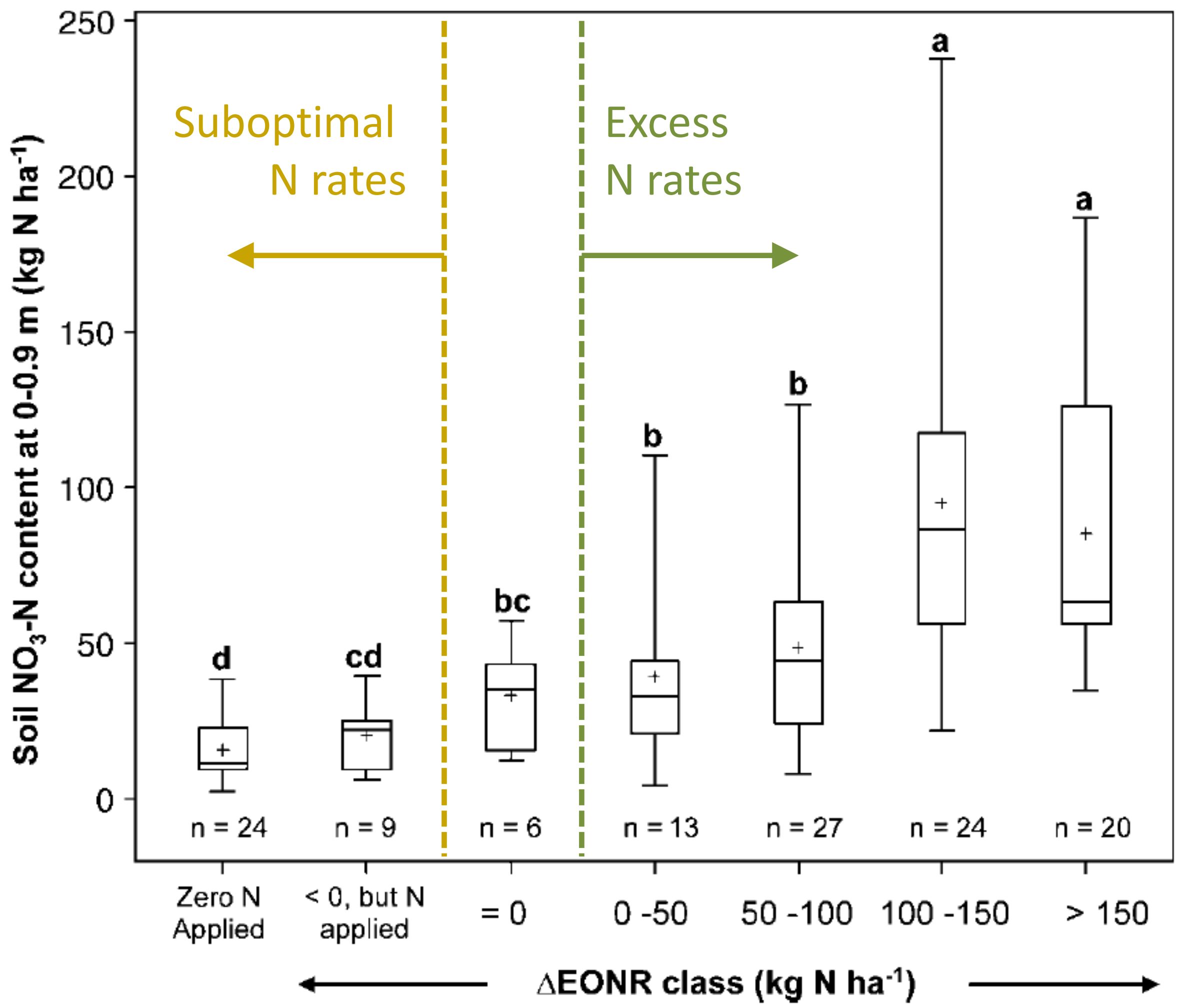
Relationship between excess N fertilizer applied to corn and 0-3' end-of-season (fall, residual) soil nitrate content



N:corn price ratio = 0.12

Hong et al., 2007

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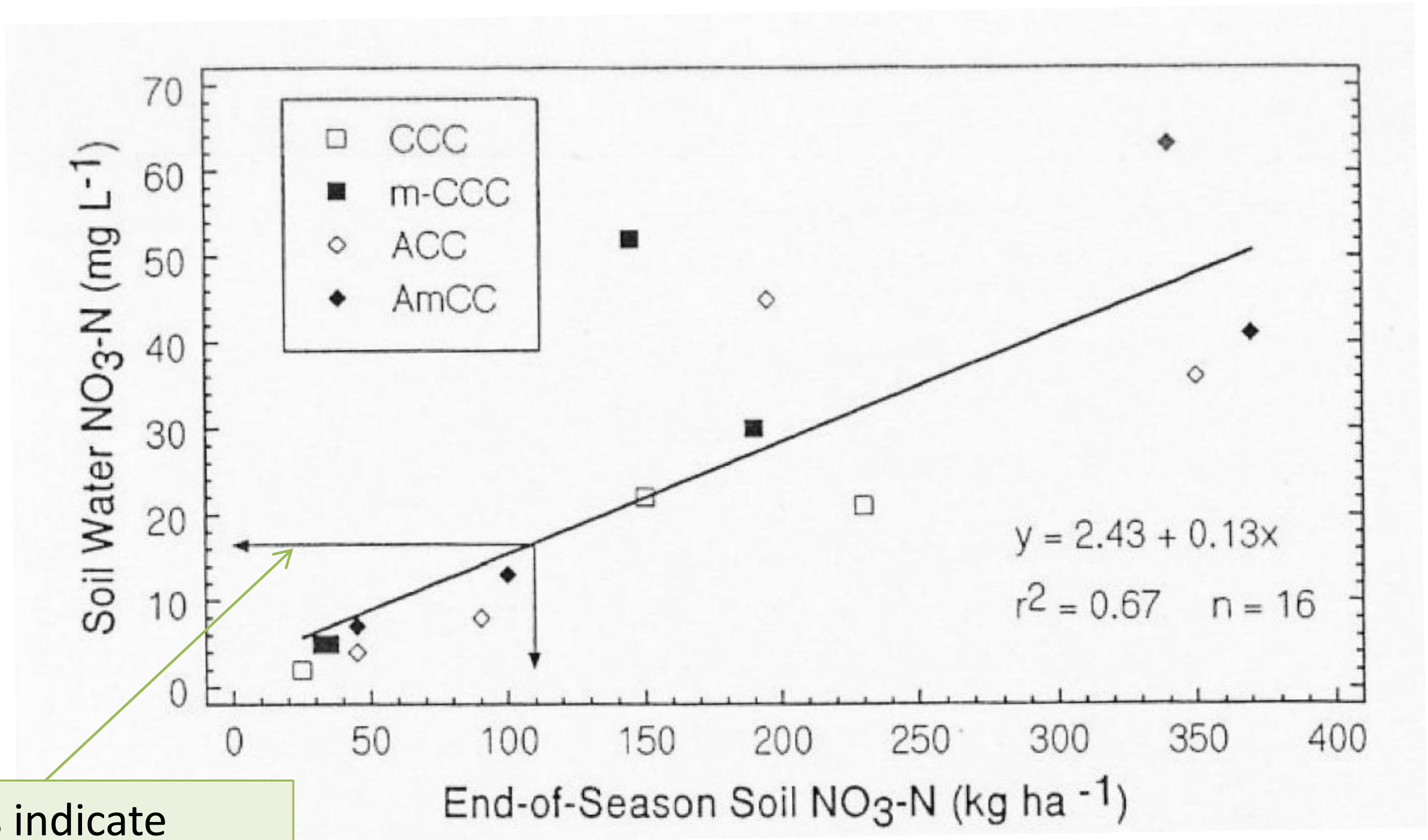
Relationship between 0-3' end-of season (fall, residual) soil nitrate content and soil water nitrate concentrations the following April



Arrows indicate relationship at EONR

Plano silt loam, Arlington, WI
Andraski et al., 2000

Bottom line:

Reducing over application of N is a key step in reducing the potential for excess N loss to the environment

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Summary

- N is required for sustainable crop production
- Supplying N (fertilizer, manure, legumes) at economically optimum N rates reduces potential for N loss to the environment
- Selecting an appropriate N is not easy
  - Crop N need varies with hybrid & environment
  - Soil N supply varies with OM, soil N mineralization potential
  - N availability from manure & legumes varies
- After a N rate is selected, then N must be managed to reduce the potential for N loss

Thank You!

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