EPRI Greenhouse Gas Offsets Workshop

Nov. 4, 2011, Washington, DC

Common and Evolving Practices for Nitrogen Management in U.S. Agriculture

Ron Gehl

Dept. of Soil Science

NC State University

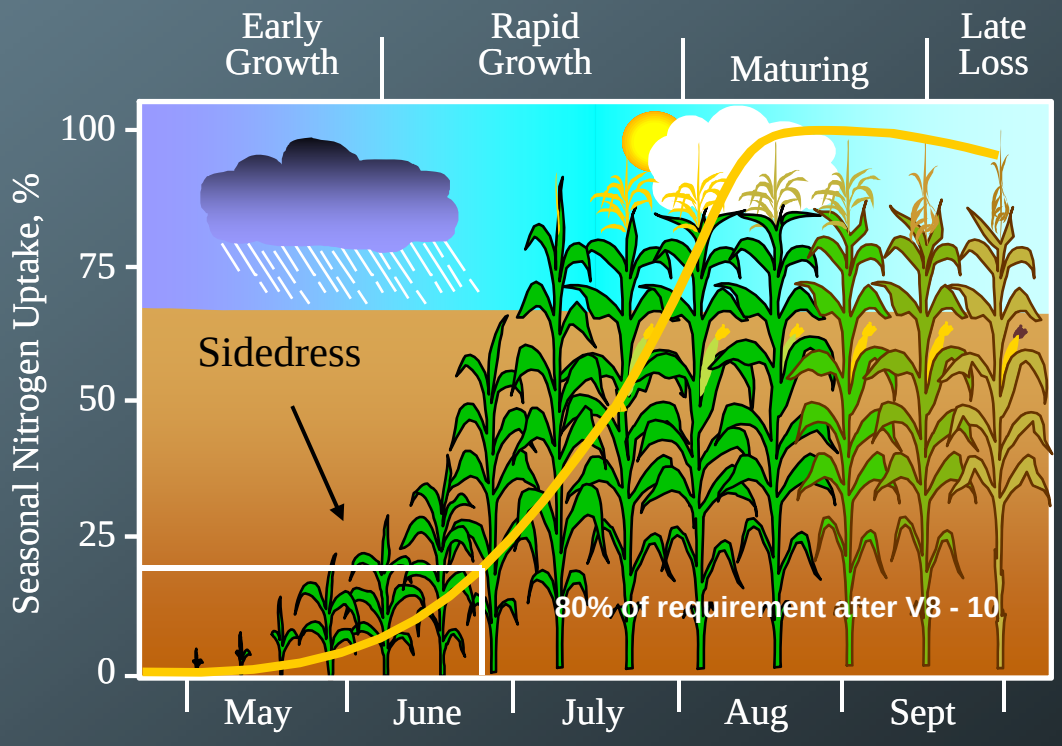
NC State University A&T State University COOPERATIVE EXTENSION Empowering People • Providing Solutions

NC STATE UNIVERSITY Department of Soil Science College of Agriculture and Life Sciences

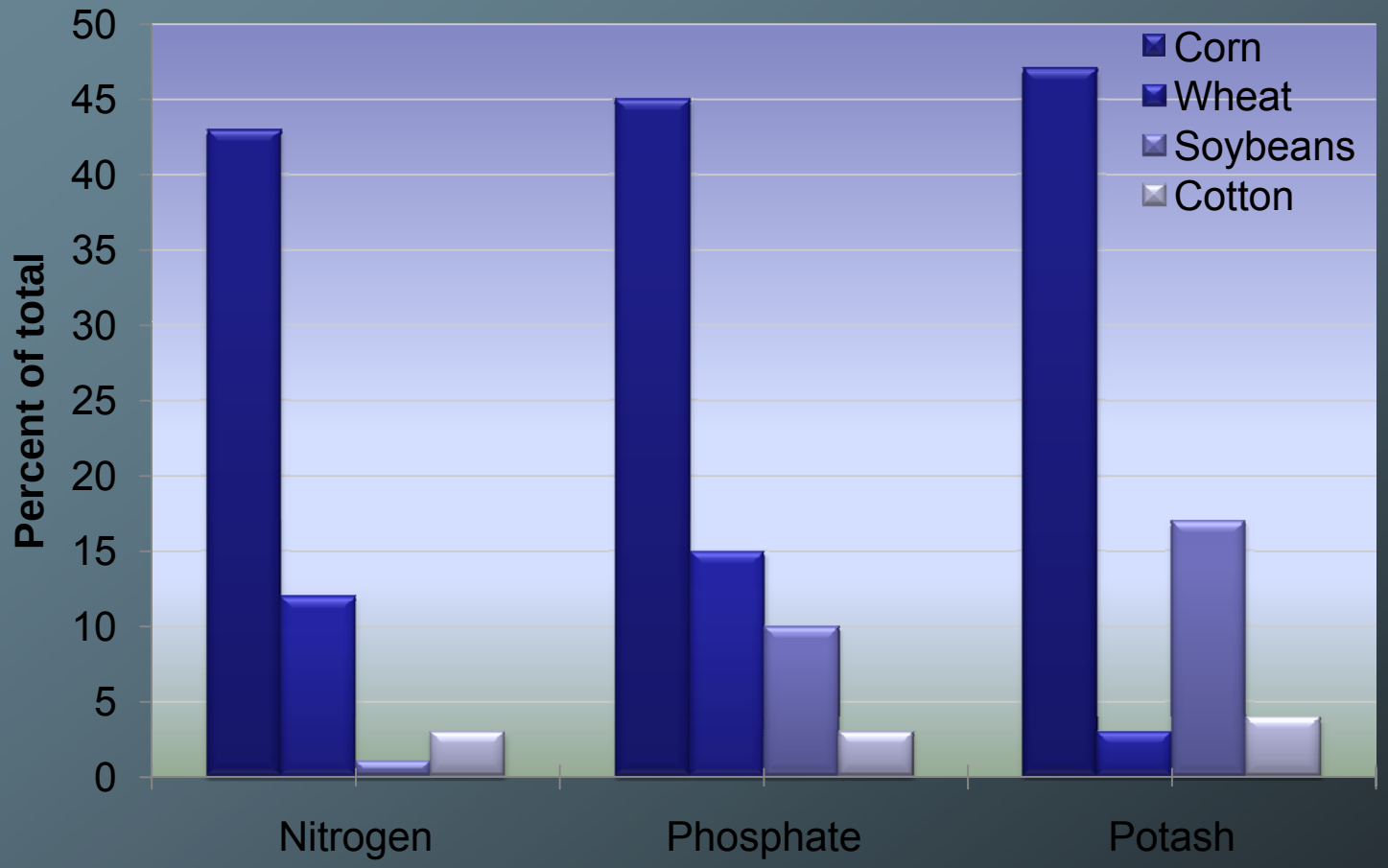
Nitrogen Management

Goals:

- Match crop need with fertilizer and/or manure applied
- Insure maximum nutrient use efficiency using rate, timing, and placement in such a way as *to reduce losses to the environment*

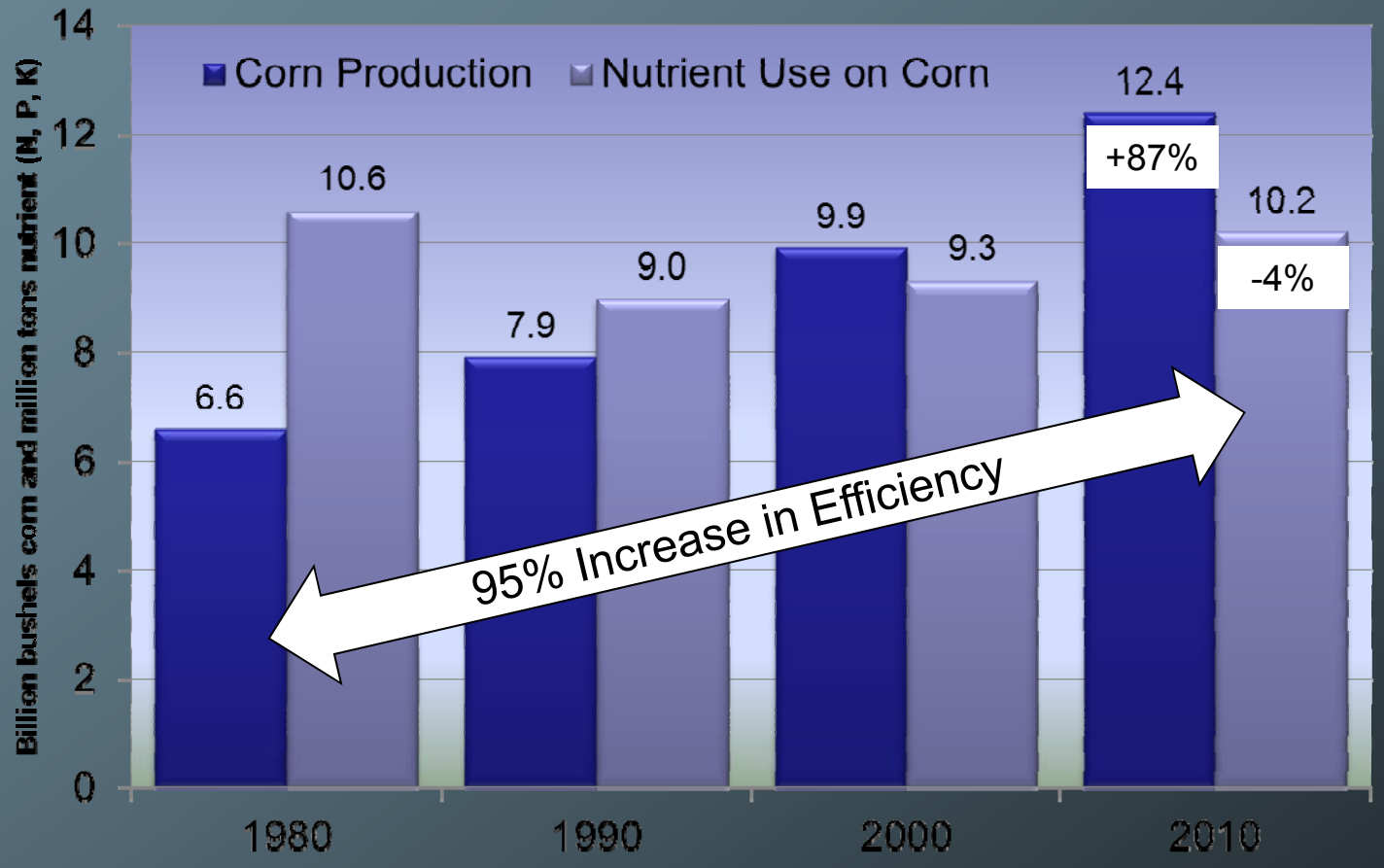


U.S. Nutrient Use by Crop, 2009



Source: USDA/NASS and AAPFCO/TFI

U.S. Corn Production and Nutrient Use on Corn



Slide adapted from TFI, computed from NASS data

Optimizing Nitrogen Use

- Determine optimum N rate
- Adjust rate for non-fertilizer N
  - Manure & legume N
  - Soil N contributions – Can be substantial!
    - Residual nitrate
    - Mineralized N
- Manage N to avoid losses
  - Source
  - Placement
  - Timing

Managing N to Avoid Losses

- **Placement**
  - Controlling ammonia volatilization losses
  - Increasing importance of urea as a fertilizer source
  - Increasing use of no-till cropping systems
  - Current practices include sidedress liquid N or anhydrous between rows, fall applications in some parts of Corn Belt (knifed-in anhydrous, broadcast urea preplant, 2x2 starter
  - Depending on source, critical to minimize ammonia volatilization losses

Managing N to Avoid Losses

- **Timing**
  - Consider soil characteristics and climate
  - Consider likely loss mechanisms
  - Consider timing of crop N demand

- **Sources**
  - Common sources in US include liquid solutions (43%), urea (21%), and anhydrous ammonia (16%)
  - Growing interest in controlled-release sources and fertilizer additives

Managing N to Avoid Losses

- **Rate**
  - Yield goal-based
    - Farmer experience
    - Traditional method for university/state recommendations
    - Typically includes other factors (e.g., previous crop, profile N)
    - Concept relies on per unit yield response to N
    - e.g. (Base N rate = (1.36 x YG) – 27-NC)
  - Soil-specific
    - Based on yield response to N in given soil; preplant profile soil N
  - Maximizing economic return to N
    - Based on economic return functions
    - Has gained popularity/adoption in recent years

How are Fertilizer Rate Recommendations Developed?

- Historic data and research experience as starting point
- Develop and perform experiments
  - Correlation: Relationship between soil test levels and crop response
  - Calibration: Relationship between applied fertilizer rate and crop response
- Multiple site-years required to improve accuracy across broad geographic ranges – the more specific, the better
- Must be updated to reflect current agricultural practices and improvements in crop varieties and production

Data fit to response models…..

PPI Crop Nutrient Response Tool — Ontario Corn N Edition v.2

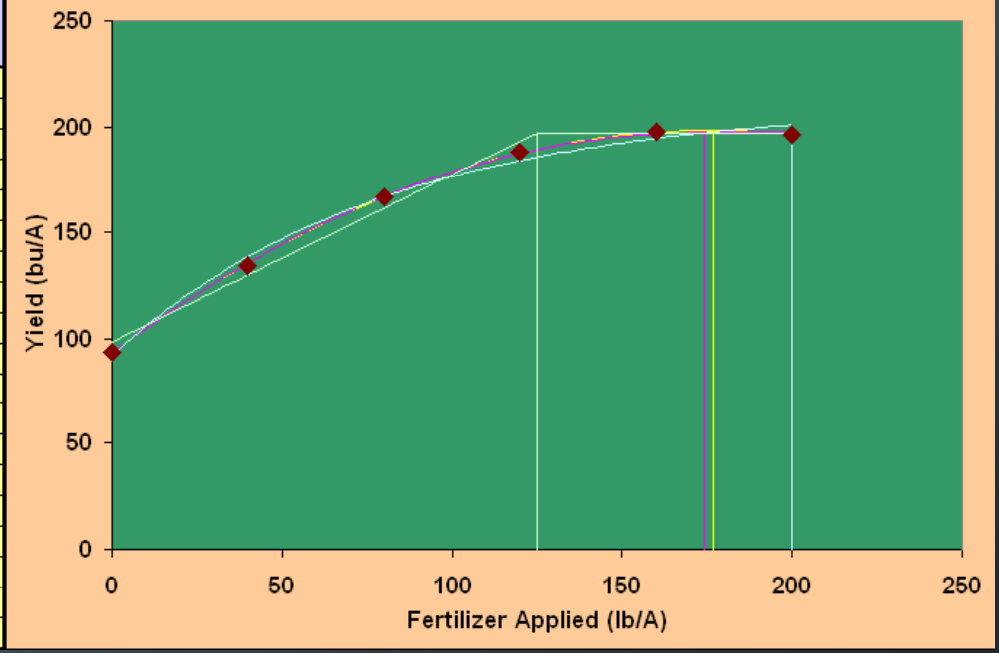
Step 1: Enter rate and yield data.
Step 2: Click the Fit button.
Step 3: Adjust crop and fertilizer prices.

Site Details	
Site Name:	Ingham CC
Cooperator:	MSU
County	Ingham
Township	
Soil texture class	Loam
Preceding crop	Grain Corn
Expected Yield (bu/A)	
Application timing	preplant incorporated
Tillage	fall chisel
Site OCHU	
Hybrid name	Pioneer37R80
PSNT (ppm)	
Manure N (lb/A)	
Planting date	9-May-2006
Harvest date	3-Nov-2006
Crop ($/bu):	$90.00
Fertilizer ($/lb):	$0.00
OCNDB MER (lb/A)	
Mean MERN (lb/A)	**169**
User-estimated MERN	
MERN (min)	
MERN (max)	
Mean NUE (response):	**71%**
Mean NUE (removal):	**91%**

Price Ratio:	Fit			
0.0	Quadratic (Q)	Quadratic-Plateau (QP)	Mitscherlich (M)	Linear-Plateau (LP)
A:	93	93	211	98
B:	1.19	1.20	-119	0.79
C:	-0.0034	-0.0034	-0.012	197
R^2:	100%	100%	99%	99%

	Q	QP	M	LP
MERN (lb/A):	177	174	200	125
Yield (bu/A):	198	197	201	197
NUE (response):	67%	67%	61%	89%
NUE (removal):	84%	85%	75%	118%

Fertilizer rate, lb/A	Crop Yield, bu/A
0	94
40	134
80	167
120	188
160	198
200	196



Developed by Tom Bruulsema, PPIC NE Region; Scott Murrell, PPIC NC Region
http://www.ipni.net/toolbox

Data fit to response models…..

PPI Crop Nutrient Response Tool

Ontario Corn N Edition v.2

Potash & Phosphate Institute | Potash & Phosphate Institute of Canada

Step 1: Enter rate and yield data.
Step 2: Click the Fit button.
Step 3: Adjust crop and fertilizer prices.

Price Ratio:	5.6

Site Details

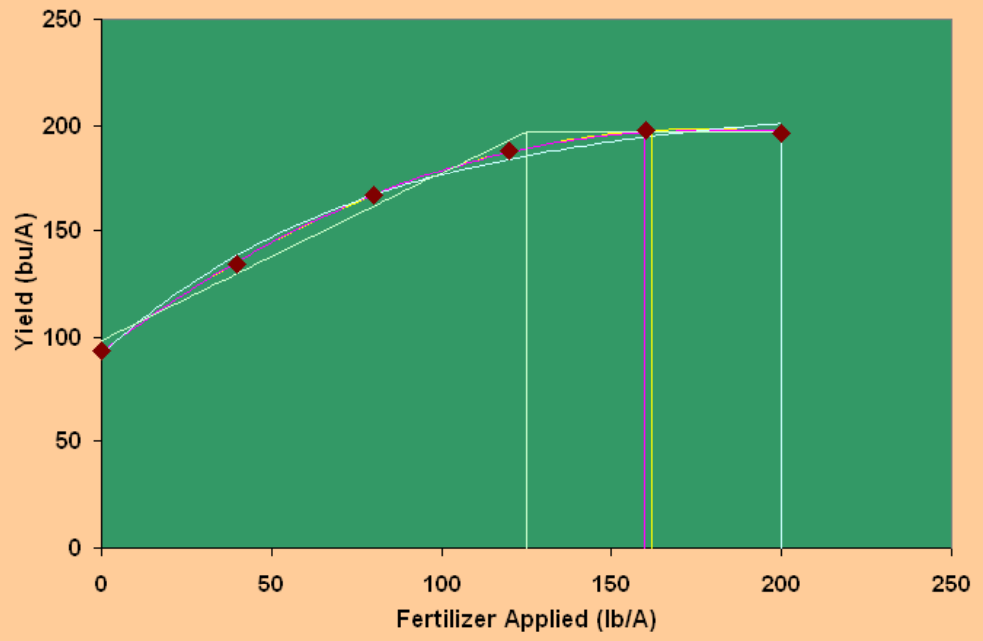
Site Name:	Ingham CC
Cooperator:	MSU
County	Ingham
Township	
Soil texture class	Loam
Preceding crop	Grain Corn
Expected Yield (bu/A)	
Application timing	preplant incorporated
Tillage	fall chisel
Site OCHU	
Hybrid name	Pioneer37R80
PSNT (ppm)	
Manure N (lb/A)	
Planting date	9-May-2006
Harvest date	3-Nov-2006
Crop ($/bu):	$3.00
Fertilizer ($/lb):	$0.30
OCNDB MER (lb/A)	
Mean MERN (lb/A)	**162**
User-estimated MERN	
MERN (min)	
MERN (max)	
Mean NUE (response):	**74%**
Mean NUE (removal):	**94%**

Fit

	Quadratic (Q)	Quadratic-Plateau (QP)	Mitscherlich (M)	Linear-Plateau (LP)
A:	93	93	211	98
B:	1.19	1.20	-119	0.79
C:	-0.0034	-0.0034	-0.012	197
R^2:	100%	100%	99%	99%

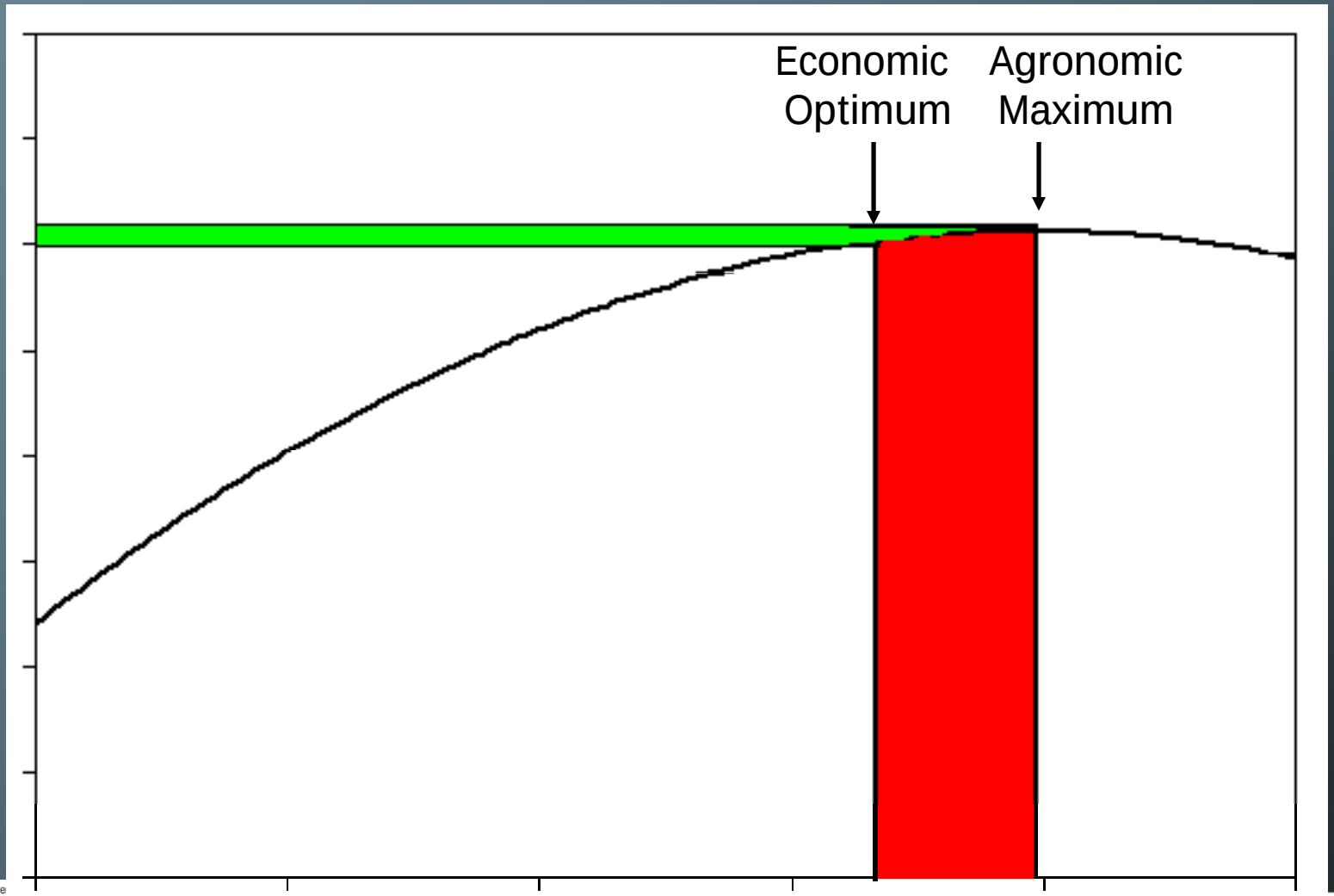
	Q	QP	M	LP
MERN (lb/A):	162	160	200	125
Yield (bu/A):	198	197	201	197
NUE (response):	73%	73%	61%	89%
NUE (removal):	92%	92%	75%	118%

Fertilizer rate, lb/A	Crop Yield, bu/A
0	94
40	134
80	167
120	188
160	198
200	196



Developed by Tom Bruulsema, PPIC NE Region; Scott Murrell, PPIC NC Region
http://www.ipni.net/toolbox

Maximum and Optimum Levels for Yield Response to Applied N



N Recommendations

- Since 2006, several states have adopted a new regional approach to N recs. for corn
  - Iowa, Illinois, Indiana, Ohio, Michigan, Wisconsin, Minnesota
  - ~55% planted corn acres in 2011
- Why?
  - Diverse N rate recommendation systems across states
  - Lack of optimum N rate relationship with corn yield
  - Concerns about N rates with corn yields at record levels (and N use at high yield levels)

Fundamentals of the regional approach

- Similar analysis of data for each state
  - Uses state-specific data to calculate individual state N recommendations
  - Data from recent N response trials

- Determine economic response and most profitable N rates directly from trials in N response database
  - Maximum Return To Nitrogen (MRTN)

Previously described by Nafziger, Sawyer, and Hoeft (2004)

Reasons for the Regional Approach

- Diverse N rate recommendation systems across states
- Lack of optimum N rate relationship with corn yield
- Concerns about N rates with corn yields at record levels (and N use at high yield levels)

N Recommendations

- Yield goal based
  - Illinois
    - lb N/A = (1.2 x YG) – N credits; soybean credit = 40 lb/A
  - Michigan/Indiana/Ohio
    - lb N/A = (1.36 x YG) - 27 – N credits; soybean credit = 30 lb/A
  - Minnesota

		---------- Expected Yield (bu/A) ----------				
PC	OM*	100-124	125-149	150-174	175-199	200+
		---------- N to apply (lb N/A) ----------				
Corn	Low	130	160	190	210	230
Corn	Med/High	100	130	160	180	200
Soybean	Low	90	120	150	170	190
Soybean	Med/High	60	90	120	140	160

* Low OM < 3.0%; Med/High OM ≥ 3.0% soybean credit = 40 lb/A

N Recommendations

- Non- yield goal based
  - Iowa

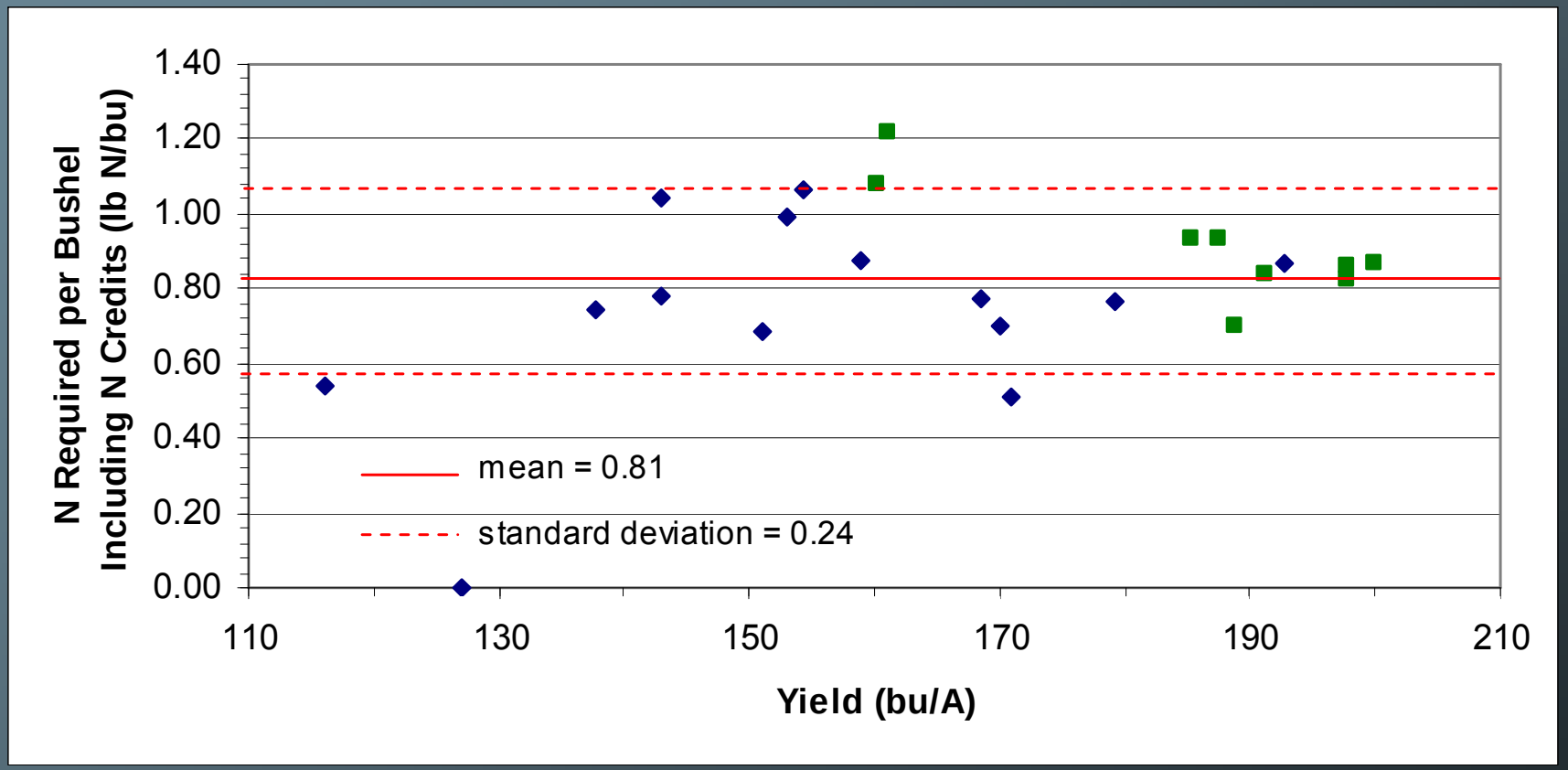
PC	N rec. (lb N/A)
Corn	150 to 200
Soybean	100 to 150

  - Wisconsin

	--- Sands/loamy sands ---		---------- Other soils ----------	
OM	Irrigated	Non-irrigated	Low/Med YP	High/Very High YP
%	---------- lb N/A ----------			
< 2	200	120	150	180
2-9.9	160	110	120	160
10-20	120	100	90	120
> 20	80	80	80	80

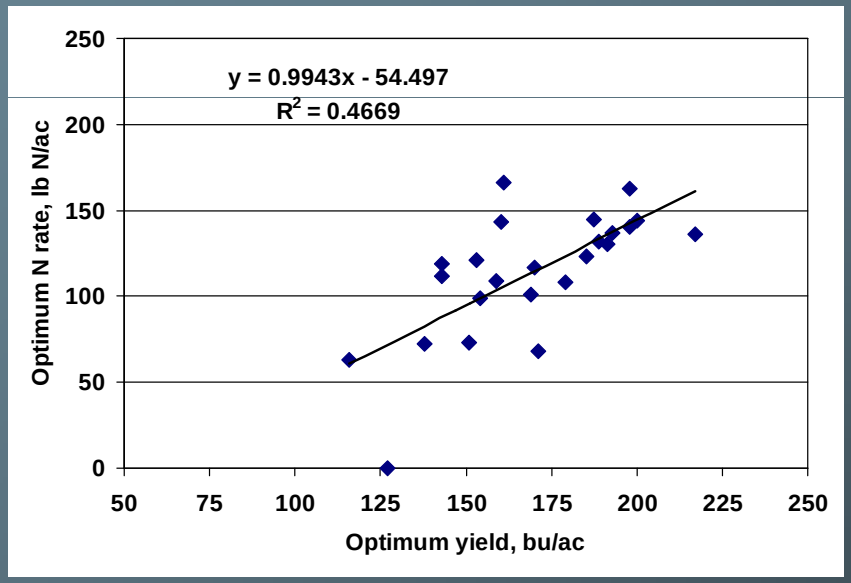
(soybean credit = 40 lb N/A)

N Required per Bushel in MI 2002-2006

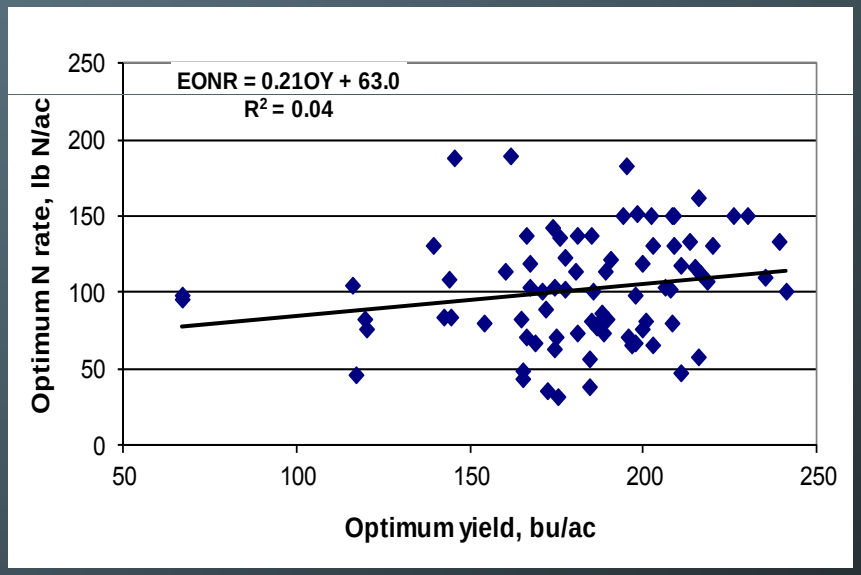


Relationship Between Optimum N Rate and Yield

Michigan 2002-06
24 site years; pc varies

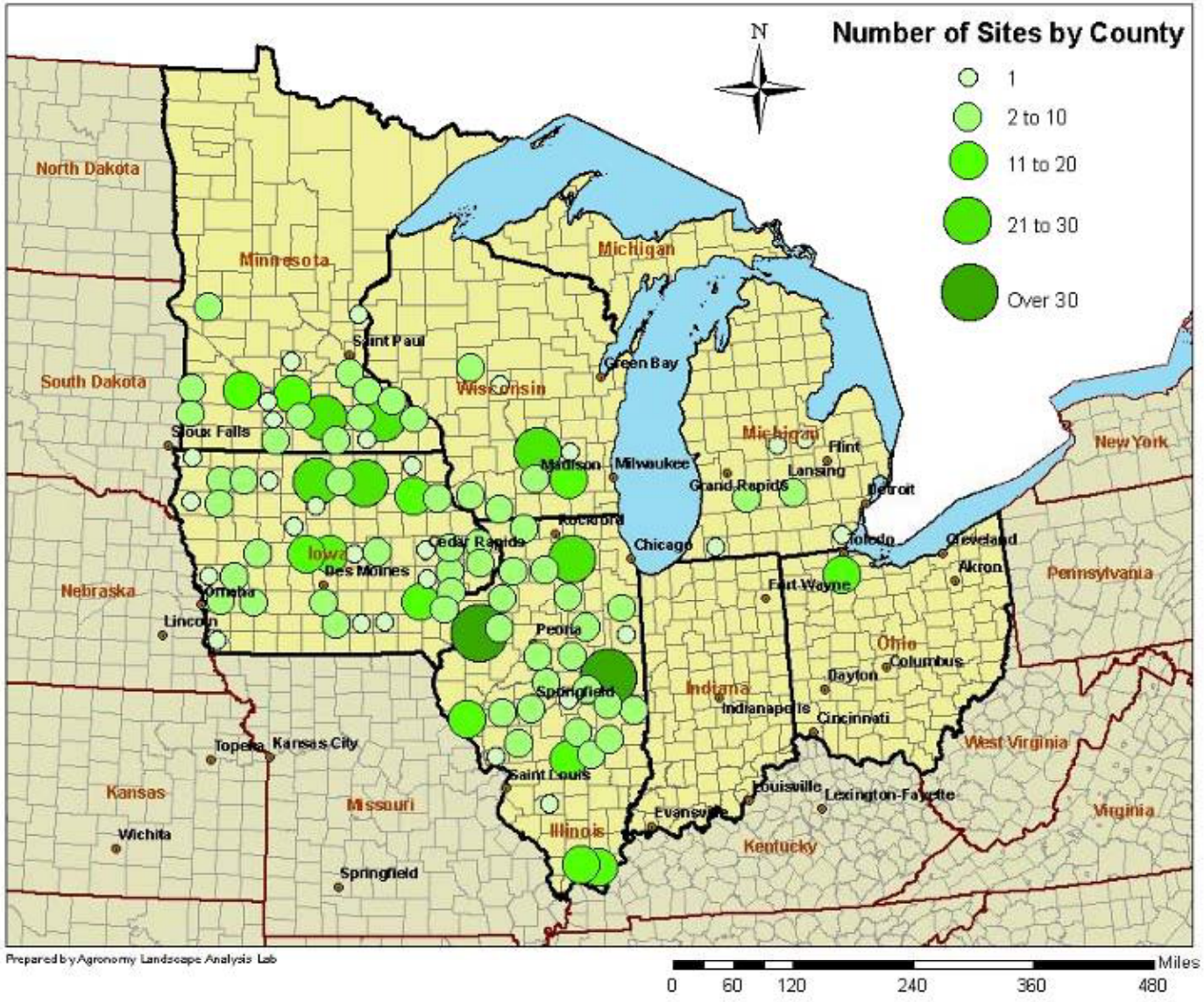


Iowa
81 site years; pc soybean



From Nafziger et al., 2004

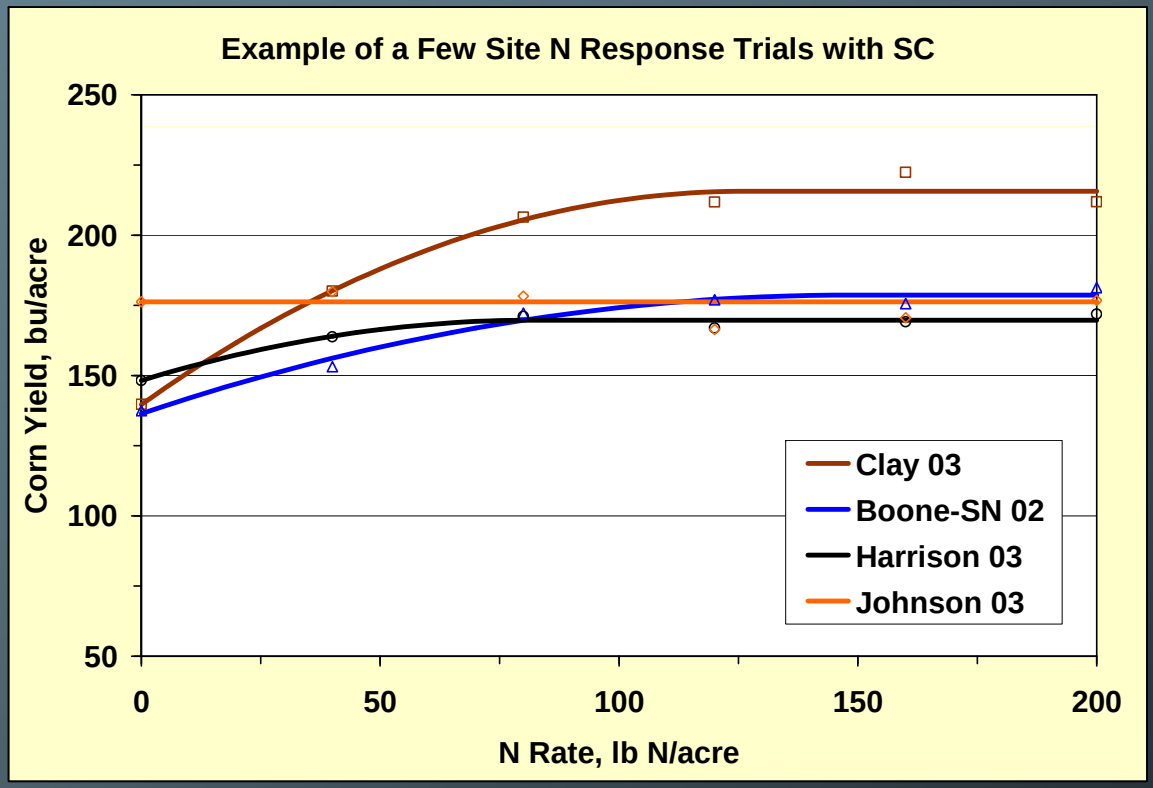
Regional N Rate Database



Sawyer et al., 2006

Calculation of MRTN

- Database from corn yield N response trials for various crop rotations and soil yield potentials
- Response model calculated for each site



Calculation of MRTN

- Return To N (RTN) calculated for each site in the dataset
  - For every 1 lb N/acre applied from 0 to 240 lb N/a, calculate the yield increase over the yield obtained with 0 lb N/a
  - RTN = yield increase times price of corn minus the cost of N
- MRTN is the N rate with the greatest average economic return to N
- A range is determined where returns to N are within $1.00/acre of MRTN
  - This provides a range of most profitable N rates

Calculation of MRTN

- 4th - Find the N rate with the greatest average return to N, this is the MRTN and N rate at the MRTN

Site	Return to N at various N rates (lb/acre)						
	80	90	100	110	120	130	140
	$/acre						
1	113.96	115.43	115.10	113.16	110.96	108.76	106.56
2	63.80	70.18	76.56	82.94	89.32	87.98	85.78
3	79.20	81.31	82.37	82.37	81.31	79.29	77.09
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
92	94.60	98.98	102.43	104.96	106.57	107.25	107.01
Average	69.24	72.00	72.59	72.98	72.44	72.03	71.05

MRTN

Calculation of MRTN

- 5th - Find the N rates with returns to N within $1.00/acre of MRTN
  - This provides a range of most profitable N rates

LOW HIGH

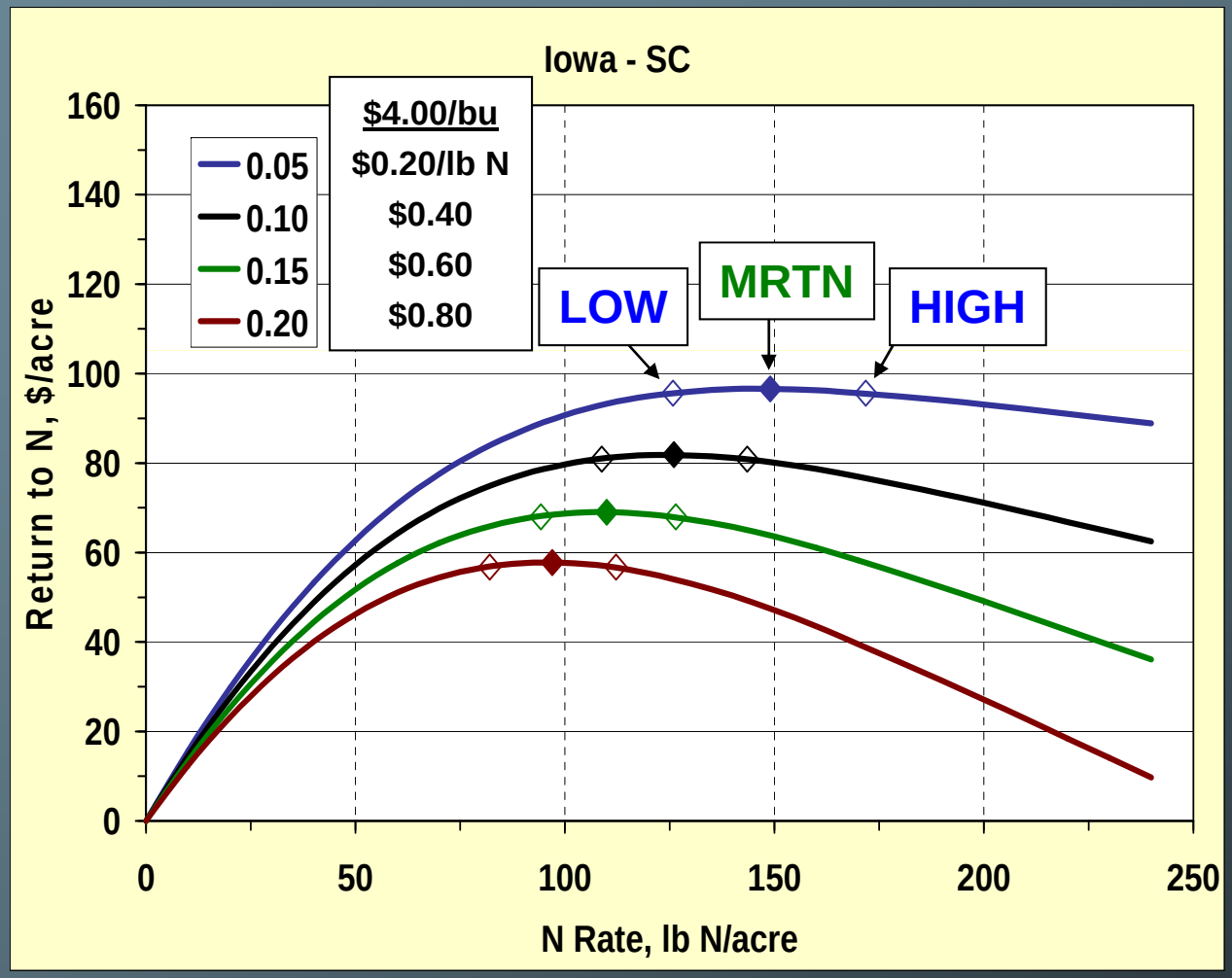
Site	Return to N at various N rates (lb/acre)						
	80	90	100	110	120	130	140
	$/acre						
1	113.96	115.43	115.10	113.16	110.96	108.76	106.56
2	63.80	70.18	76.56	82.94	89.32	87.98	85.78
3	79.20	81.31	82.37	82.37	81.31	79.29	77.09
⋮	⋮	⋮	MRTN	⋮	⋮	⋮	⋮
92	94.60	98.98	102.43	104.96	106.57	107.25	107.01
Average	69.24	72.00	72.59	72.98	72.44	72.03	71.05

Calculation of MRTN

LOW HIGH

Site	Return to N at various N rates (lb/acre)						
	80	90	100	110	120	130	140
	$/acre						
1	113.96	115.43	115.10	113.16	110.96	108.76	106.56
2	63.80	70.18	76.56	82.94	89.32	87.98	85.78
3	79.20	81.31	82.37	82.37	81.31	79.29	77.09
⋮	⋮	⋮	MRTN	⋮	⋮	⋮	⋮
92	94.60	98.98	102.43	104.96	106.57	107.25	107.01
Average	69.24	72.00	72.59	72.98	72.44	72.03	71.05

MRTN and Most Profitable N Rate Range

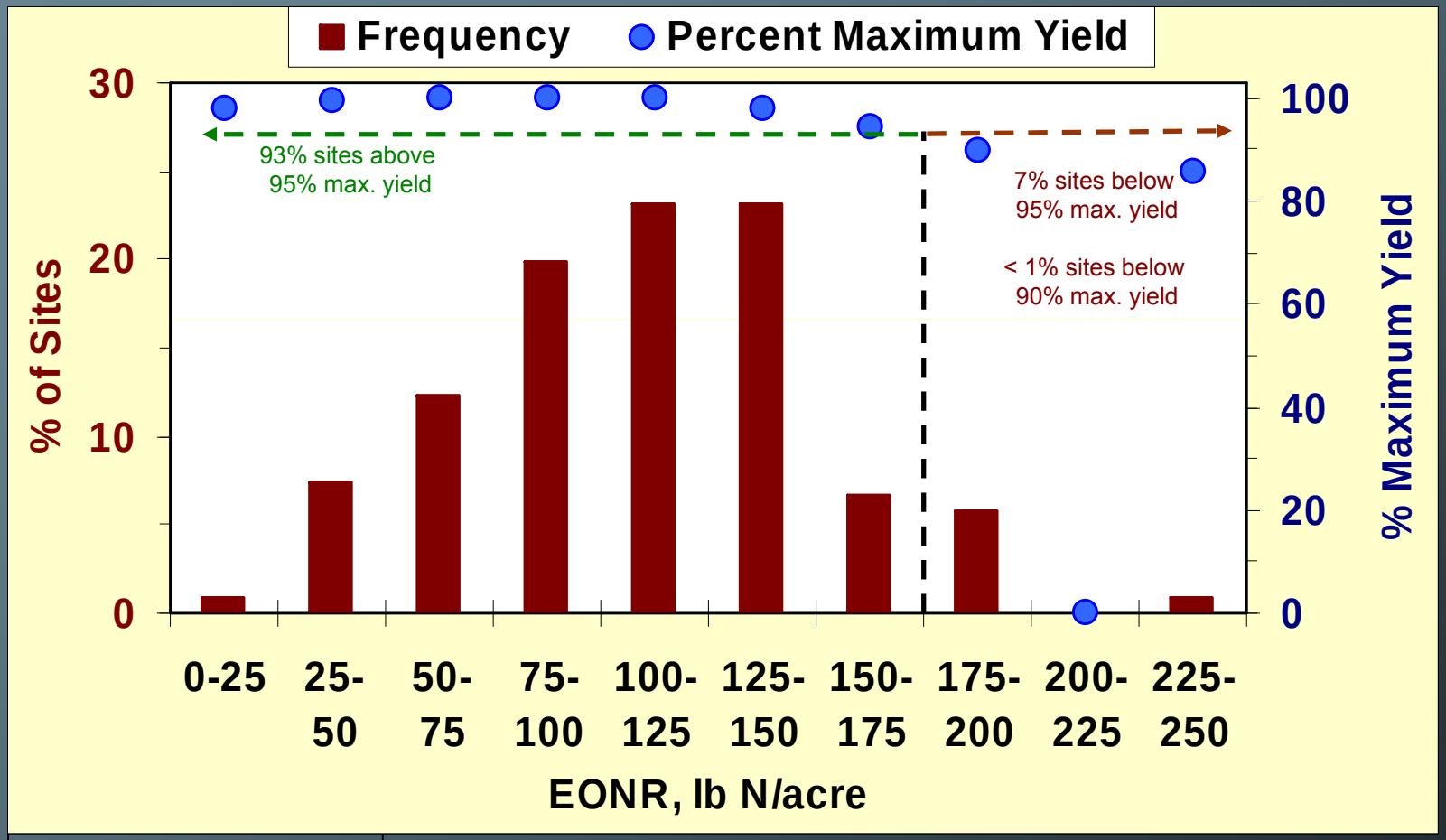


- A range of N rates can produce profitable yields
- Economics clearly drives the profitable N rate

MRTN and N Risk Management

- Although may want to be 100% certain of N sufficiency, being that certain is not necessarily most profitable
  - The risk of lower N rates is a decrease in profitability due to lost yield
  - The risk of higher N rates is a decrease in profitability and environmental concerns due to unneeded N
  - Most profitable N rate range helps “protect” these risks

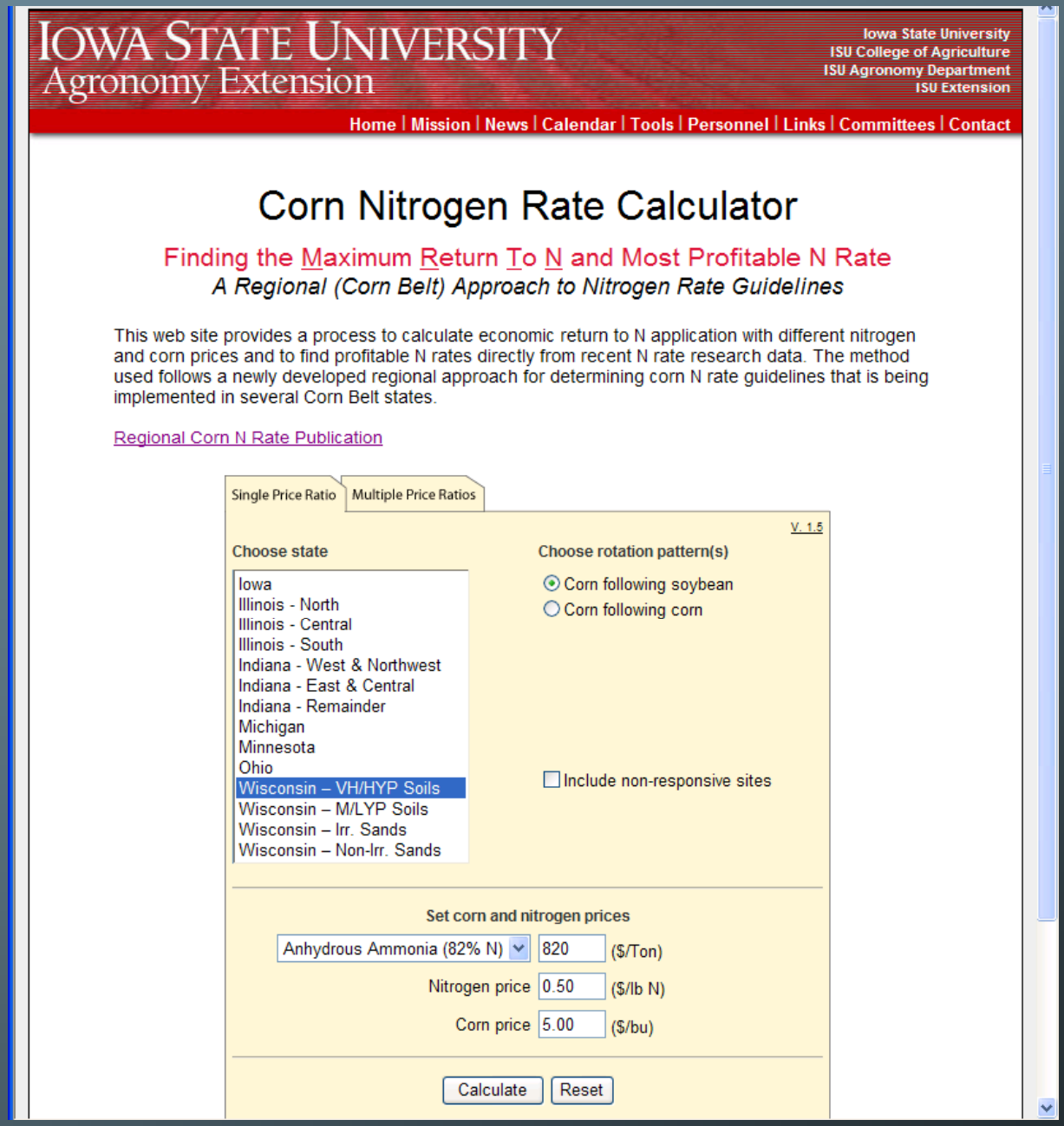
Risk from Applying MRTN Rate
(123 lb N/acre for IA - SC)



0.10 Price Ratio
$0.40/lb N:$4.00/bu

Source: Sawyer

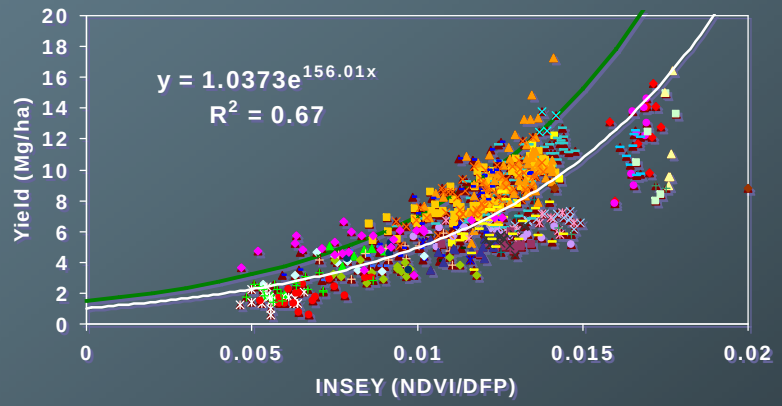
http://extension.agron.iastate.edu/soilfertility/nrate.aspx



Future?

The Future of N Management?
Optical Sensing/Diagnostic Tools

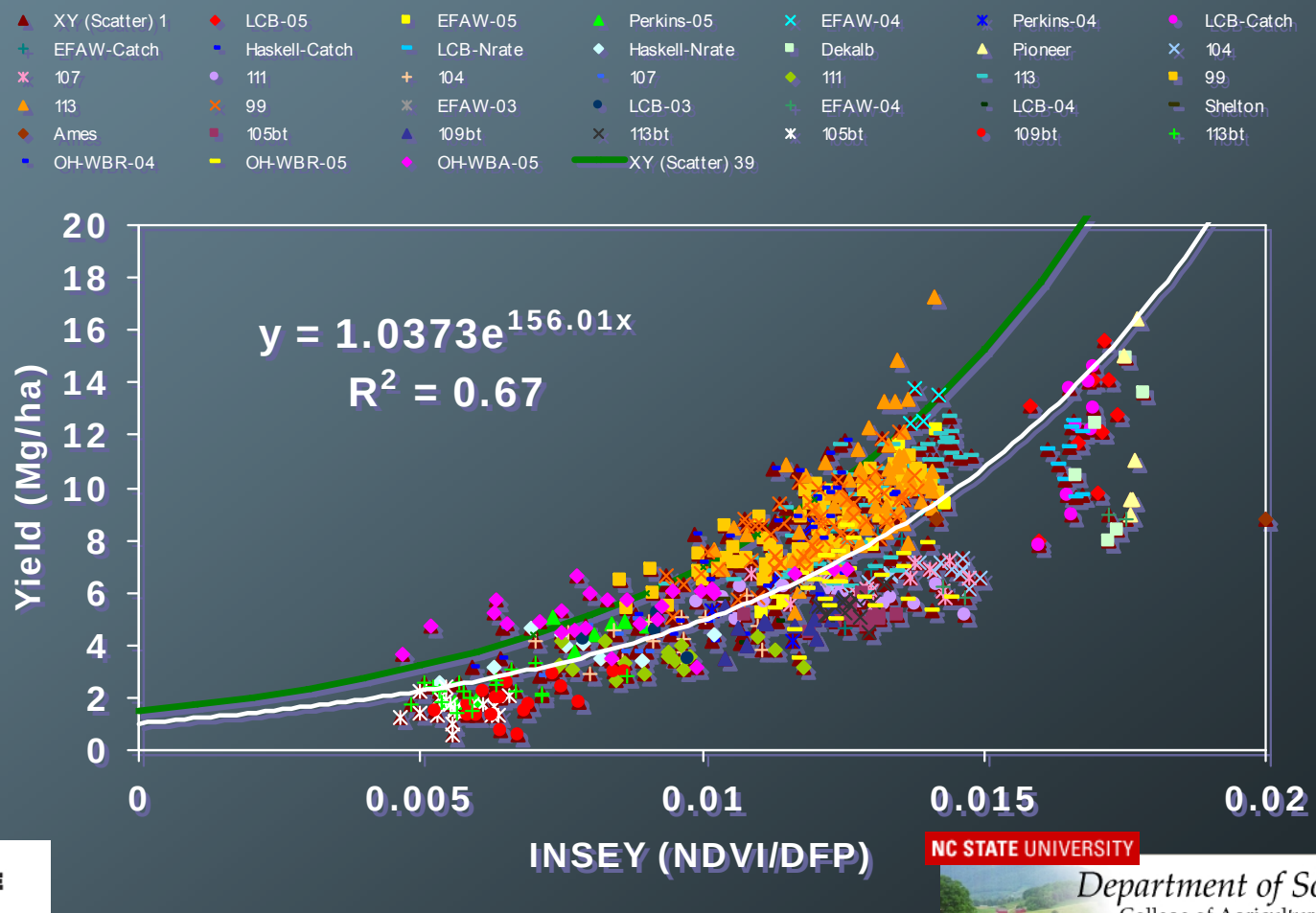
- Non-destructive methods of evaluating plant status
- Measurement of canopy reflectance/ relative plant greenness
- Crop canopy sensors used to determine optimal N rates (in season), crop-dependent response
- Algorithm development



Yield prediction for corn (Source: Raun, OSU)

N Algorithms

- Yield prediction for corn



NC State University A&T State University COOPERATIVE EXTENSION Empowering People • Providing Solutions

NC STATE UNIVERSITY Department of Soil Science College of Agriculture and Life Sciences

Oklahoma State University, CIMMYT, INTA, Australian Farmers, The Noble Foundation, Ohio State University, Virginia Tech, USDA-ARS, National Soil Tilth Lab, Ag Canada, Kansas State University

Sensor-Based Nitrogen Rate Calculator

Accurate Mid-Season Crop Fertilizer N Recommendations

1. Winter Wheat (US Grain Belt)
2. Spring Wheat-Rainfed (US, Canada, Mexico)
3. Spring Wheat-S.Australia D. Cox
4. Spring Wheat-E.Australia R.Heath
5. Spring Wheat-India
6. Trigo Bajo-Riego (Mexico)
7. Trigo-Región Pampeana Central y Norte (Argentina)
8. Winter Wheat (China)
9. Corn-Rainfed (US Grain Belt)
10. Corn-Irrigated (US Grain Belt)
11. Maíz sin Riego (Argentina)
12. Maíz bajo Riego (Argentina)
13. Maíz bajo Riego-Siembra de Segunda (Argentina)
14. Canola (Canada)
15. Spring Wheat (Canada)
16. Bermudagrass-Forage
17. Bermudagrass-Turf-coming soon
18. Sorghum-Great Plains
19. Sorghum-Kansas
20. Rice-India
21. Cotton-coming soon

NC State University A&T State University COOPERATIVE EXTENSION Empowering People · Providing Solutions

http://www.soiltesting.okstate.edu/SBNRC/SBNRC.php

NC STATE UNIVERSITY Department of Soil Science College of Agriculture and Life Sciences

Sensor-Based Nitrogen Rate Calculator

Developed by Oklahoma State University, INTA, and CIMMYT

Inputs

Crop:	Winter Wheat (US Grain Belt)
Planting Date (mm/dd/yyyy):	10 / 01 / 2006
Day Prior To Sensing (mm/dd/yyyy):	01 / 30 / 2007
Location: (click to select from map)	Stillwater
NDVI Farmer Practice (FP)	0.2
NDVI N-Rich-Strip (NRS)	0.25
Maximum Yield for Region, bu/ac	50
(This is generally 2 times the Average yield)	
Expected Grain Price, $/bu	4.5
Fertilizer Cost, $/lb actual N	0.35

○ English Units ● Metric Units
● Within Oklahoma ○ Outside Oklahoma

Outputs

Response Index (RI):	1.41
Days,GDD>0:	80
Yield Potential YP0, bu/ac	25.5
Yield Potential YPN, bu/ac	36
Yield Potential YPNRS, bu/ac	27.56
N Rate Recommendation, lb/ac	25.1
Gross Return (no N fertilizer), $/ac:	114.6
Gross Return (using N Rec), $/ac:	153.1

(Cost of N fertilizer is already subtracted from this estimate)

Submit Clear Form

(*) Yield Prediction and N Fertilization Rates are Based on Sensor Measurements Collected between Feekes 4 and 6 (pre dormancy to pre first node)
(@)Number of Days where GDD>0: Days from planting to sensing where the average daily temperature exceeds 40F or 4.4C

(1) YP0 : Yield Potential Achievable with no Added N Fertilization
(2) YPN : Yield Potential Achievable with Added N Applied (using the rate recommended)
(3) YPNRS : Yield Potential Achievable in the Nitrogen Rich Strip with No N Applied
(4) This is generally 2 times the Average yield

Oklahoma Agweather

NC State University
A&T State University
COOPERATIVE EXTENSION
Empowering People · Providing Solutions

NC STATE UNIVERSITY
Department of Soil Science
College of Agriculture and Life Sciences

Future

- N rate research will be needed to:
  - Accompany educational delivery
  - Fill in gaps where data are limited
    - Geographic, soil productivity, rotation
  - Monitor the role of soil N and N use efficiency
  - Assess the effect of improved genetics and higher corn yield potential
- Web based MRTN calculation tool
  - http://extension.agron.iastate.edu/soilfertility/nrate.aspx
- IPNI Crop Nutrient Response Tool and Rate Reduction Calculator
  - http://www.ipni.net/toolbox

Photo courtesy J. Camberato, Purdue Univ.