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***Building Risk into
N Recommendations for Corn:
Understanding Insurance Applications***

Harold van Es



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College of Agriculture and Life Sciences
Department of Crop and Soil Sciences

Nitrogen Concerns in Corn Production Systems

Agronomic/Economic

- ~ \$5 billion/yr of N fertilizer applied to corn; large input costs for farmer
- N use efficiency low (30-70%)
- High uncertainty, and sensitivity to climate change

Environmental

- Largest energy input into cropping system
- Greenhouse gas emissions (esp. N_2O)
- High groundwater nitrate levels
- Hypoxia/anoxia in estuaries



Water Quality Concerns Not Improving

From: Dubrovsky et al., 2010,
based on NAWQA data:

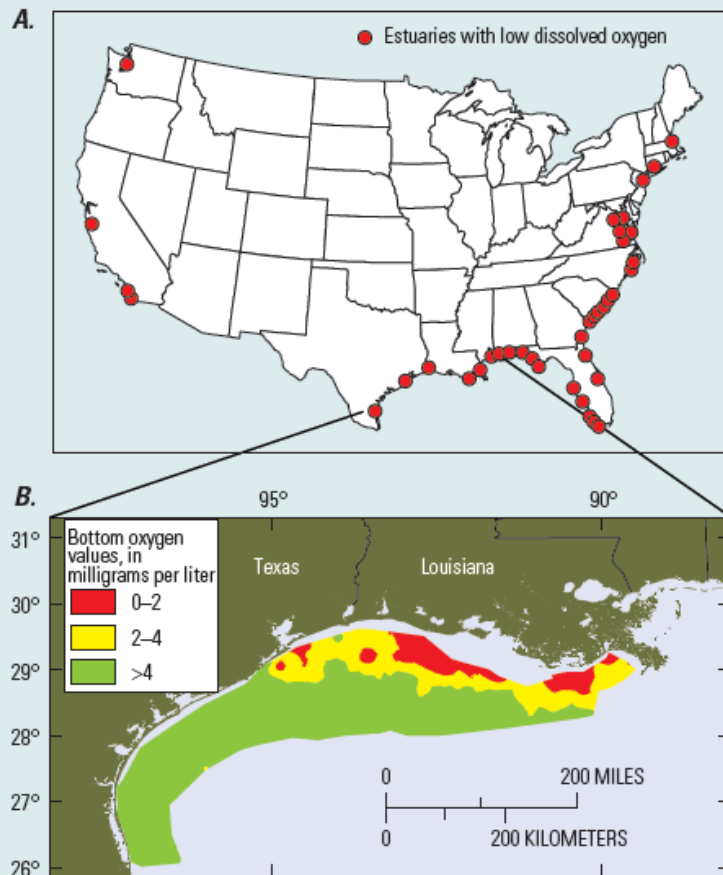
“Despite major Federal, State and local efforts and expenditures to control sources and movement of nutrients within our Nation’s watersheds, national-scale progress was not evident in this assessment”



Net Change in MRB Flow-Normalized Nitrate Concentration and Flux between 1980 and 2008 (Sprague et al., 2011)

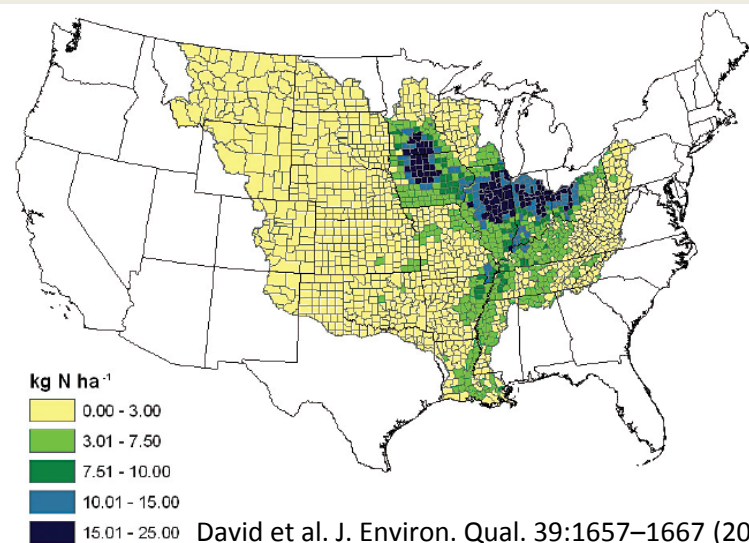
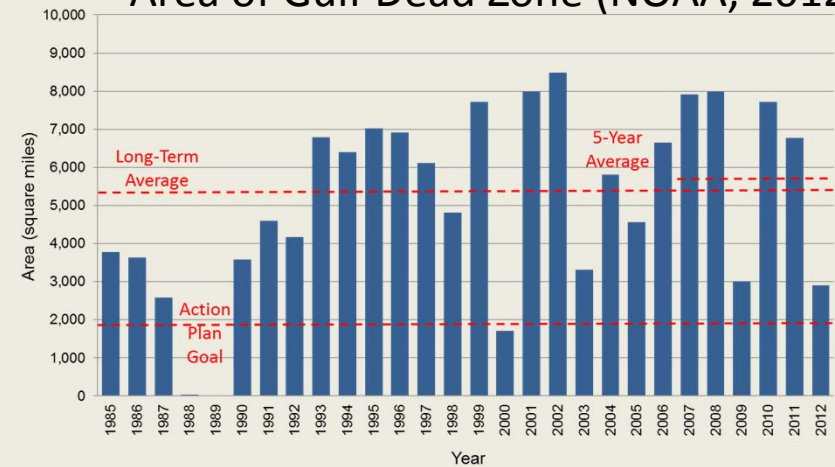
site	flow-normalized concentration of nitrate as N		
	annual mean flow-normalized concentration in 1980, mg/L	change, 1980–2008	
		mg/L	%
MSSP-CL	1.13	0.86	76
IOWA-WAP	5.02	0.17	3
ILLI-VC	3.81	−0.04	−1
MSSP-GR	2.56	0.49	19
MIZZ-HE	0.96	0.72	75
MSSP-TH	1.93	0.38	20
OHIO-GRCH	0.99	0.03	3
MSSP-OUT	1.25	0.13	10

Hypoxia Zones in USA



Riverine N Yield in the MRB

Area of Gulf Dead Zone (NOAA, 2012)



Agricultural GHG Emissions (2008)

■ CH₄
■ N₂O
■ CO₂

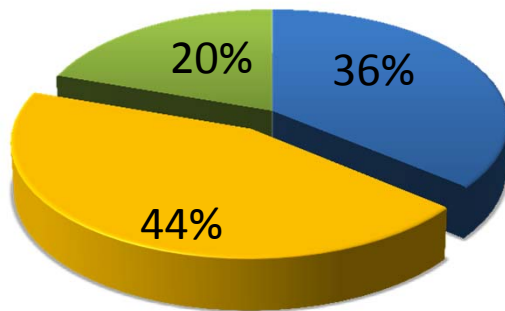
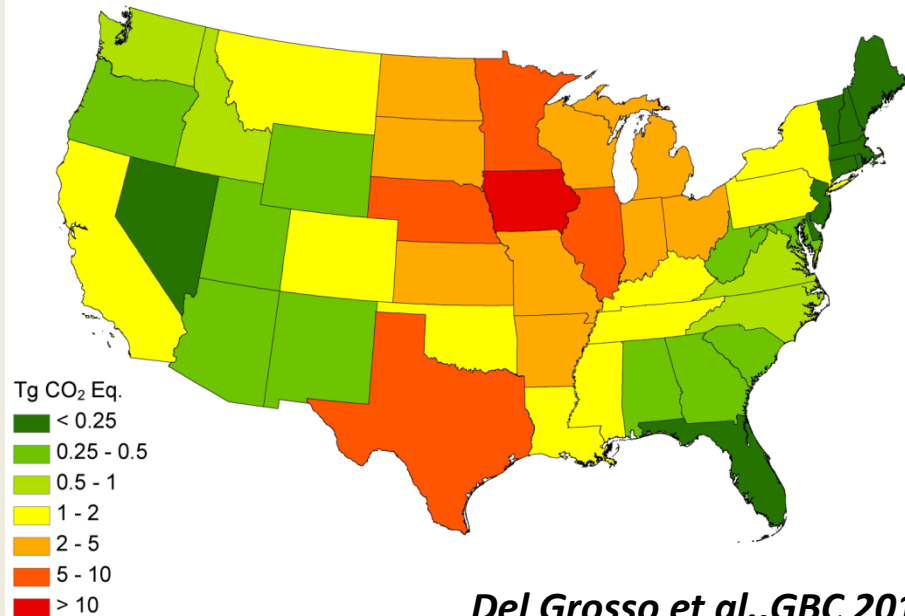


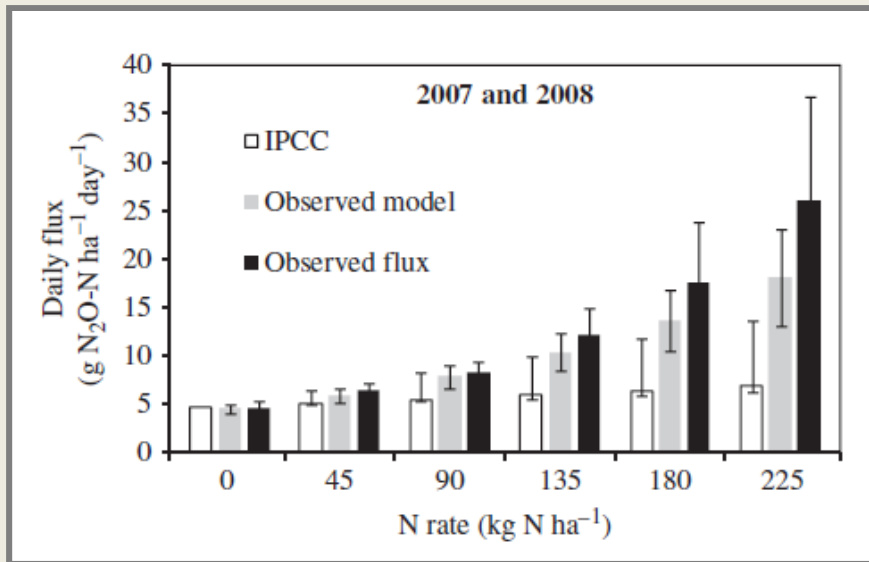
Figure 2: Major Crops, Average Annual Direct N₂O Emissions Estimated Using the DAYCENT Model, 1990–2007 (Tg CO₂ Eq./state/year)



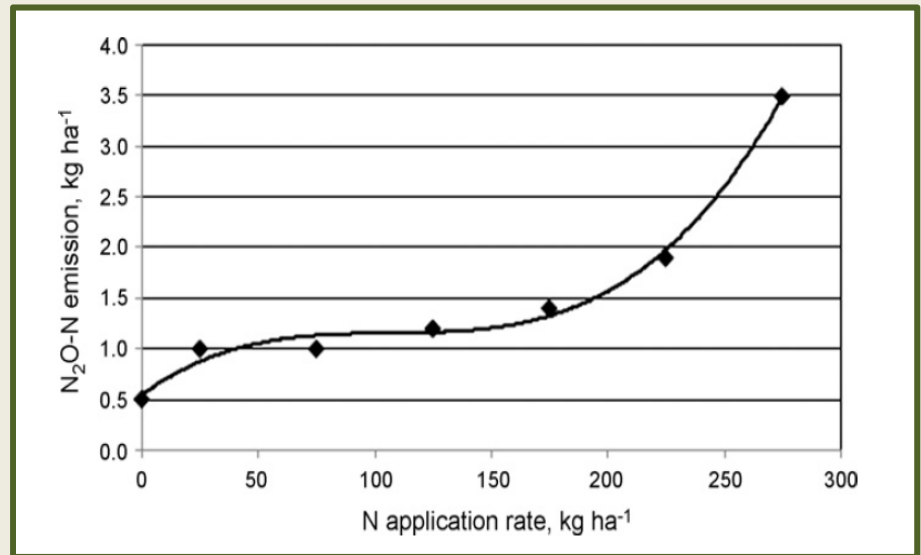
Nitrogen application to US agricultural lands in 2008 had a greater global warming impact than the entire US aviation industry (EPA, 2010)



Nitrous Oxide Losses Increase Exponentially With N Rate Beyond a “Critical” Value



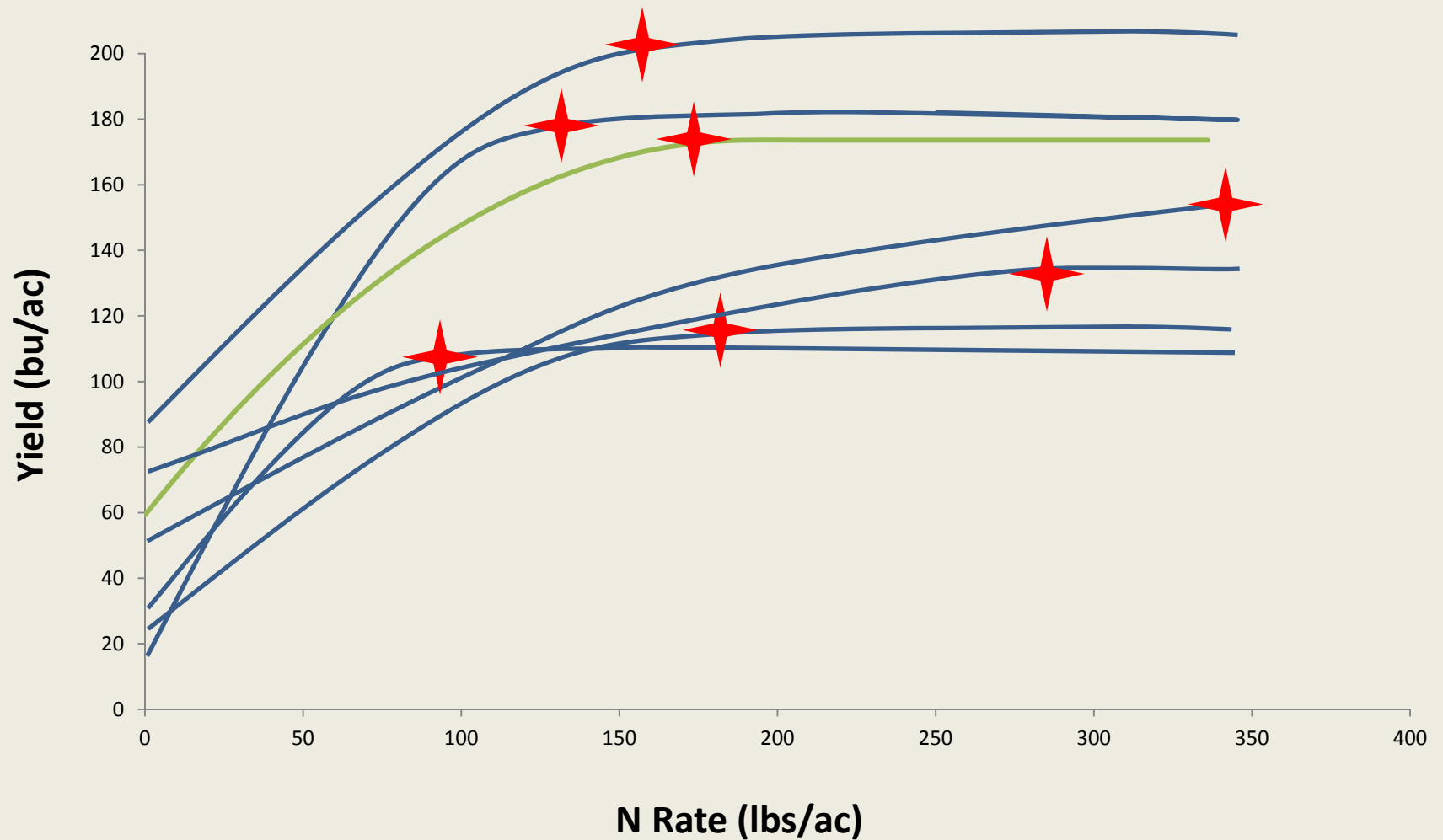
Hoben et al, 2010.



Snyder et al., 2009, based on data by
Bouwman et al., 2002

A common perception is that farmers over-apply N fertilizer, and it has been suggested that they can reduce N rates by 30-50 lbs/ac

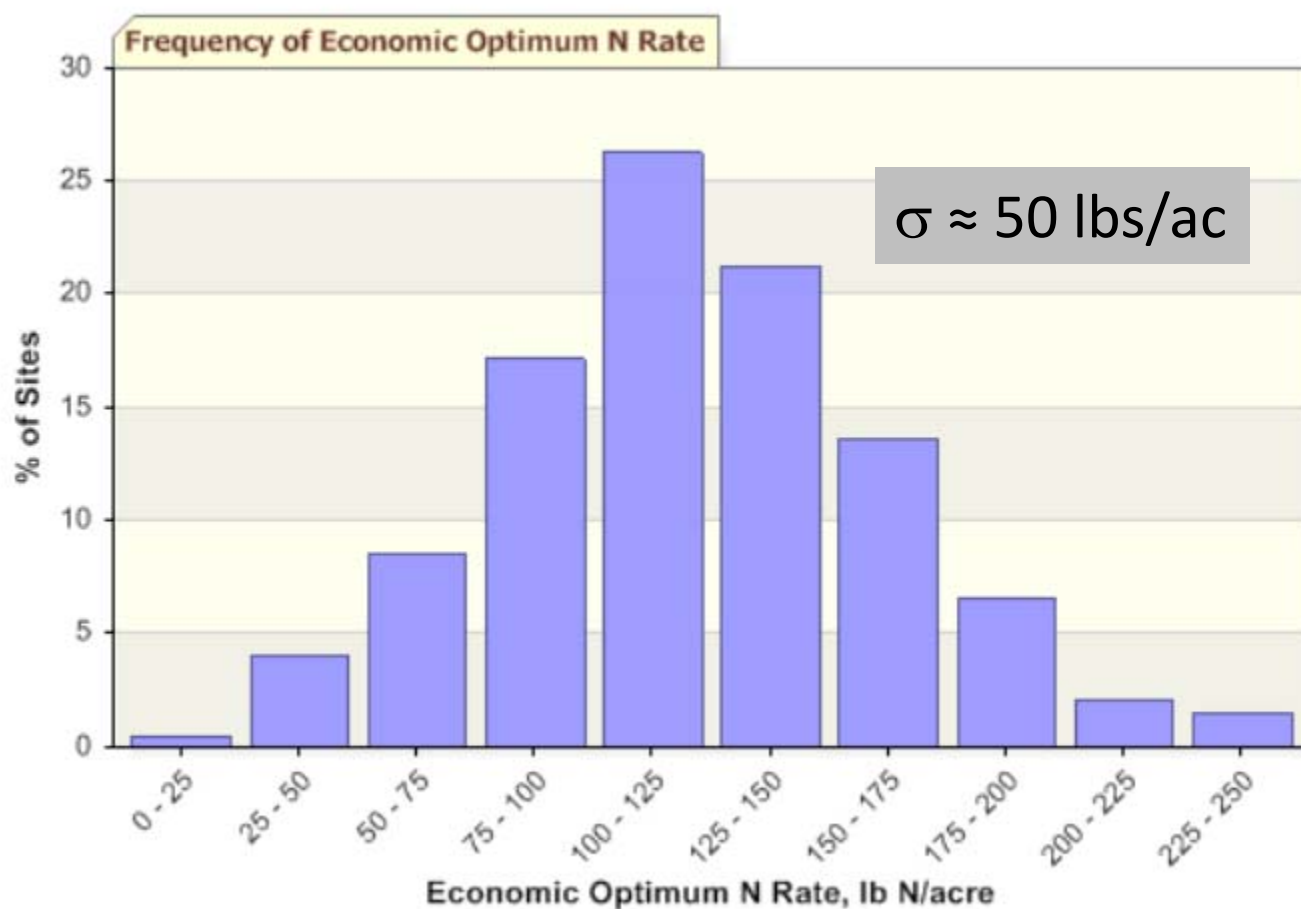
Corn N Response and Agronomic Optimum N Rate



Distribution of Economic Optimum N Rates

fertilizer = \$0.60/lb; corn = \$6/bu

from: <http://extension.agron.iastate.edu/soilfertility/nrate.aspx>



Many sources of variation in N availability and crop needs

→ generalized recommendations are too simplistic

- Organic amendments (manure, compost, etc.)
- Crop rotations
- Soil type differences
- Soil organic matter contents
- Soil and crop management (tillage, planting date, etc.)
- **Weather:**
 - Temperature
 - Precipitation!



Interactions are complex and nonlinear!

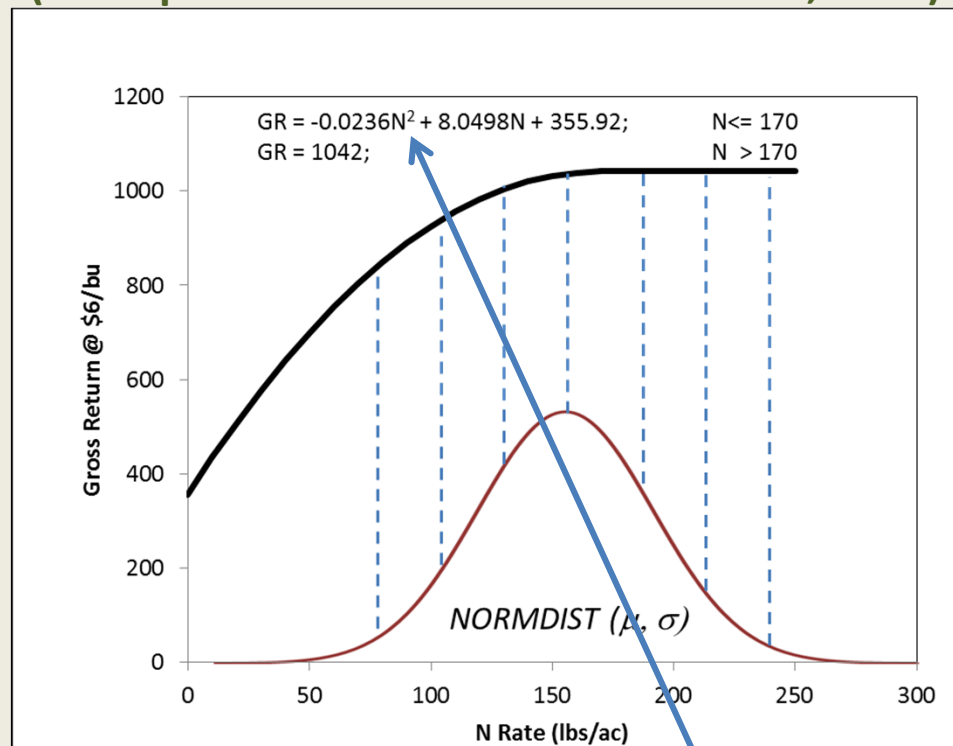
Reasons for Farmer Tendency to Over-Fertilize: Coffee Shop Wisdom on Risk and Risk Perception

- With uncertainty around the optimum N rate, the profit losses from under-fertilizing (yield penalty) are greater than those from over-fertilizing (unnecessary fertilizer expense).
- Under-fertilization results in highly visible leaf yellowing, while over-fertilization is not noticeable.
 - Farmers tend towards the highest rate
 - Consultants cannot afford to under-recommend
- Fertilizer dealers have additional incentives to suggest high rates



Gross Return

Differential Impact of Under and Over-Fertilization due to Nonlinear-Asymmetrical Yield Response to N (concept after Kachanoski and Fairchild, 1996)

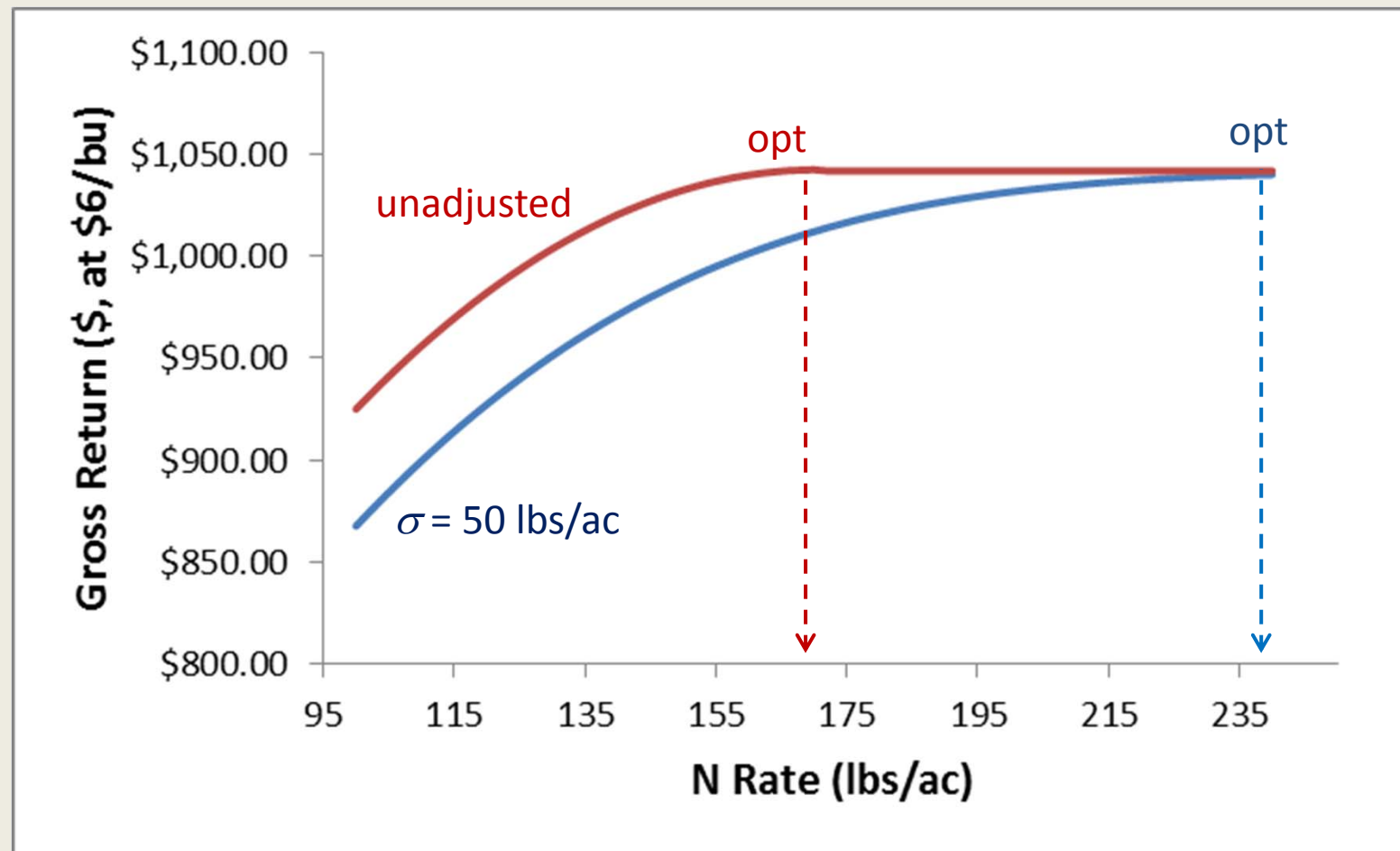


Stochastic Gross Returns:

$$E[f(Y)] = \left(\int_{-\infty}^{\infty} \left(\frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} * f(Y)dY \right) \right)$$

Gross Return

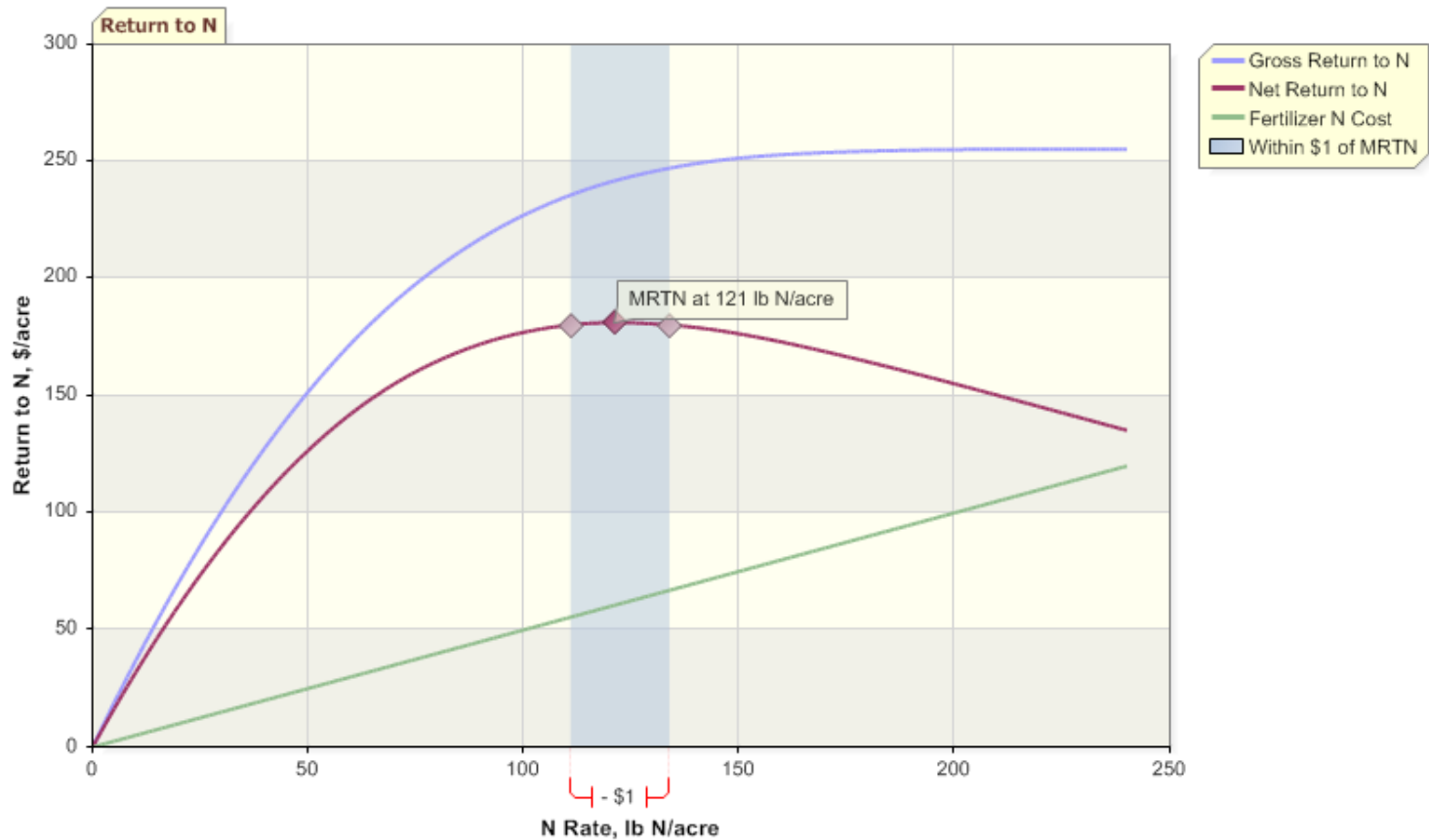
stochastic ($\sigma = 50$ lbs/ac) and unadjusted (corn=\$6.00/bu)
no consideration for cost of fertilizer



Factoring in Price of Grain and Fertilizer

fertilizer = \$0.60/lb; corn = \$6/bu

from: <http://extension.agron.iastate.edu/soilfertility/nrate.aspx>



Maximum Return to N Fertilizer Input

Economic Optimum N Rate accounting for cost of fertilizer

Accounting for Fertilizer Cost only:

$$\text{Max } \{GR - FC\}$$

Accounting for Fertilizer Cost and Variability (uncertainty):

$$\text{Max} \left(\int_{-\infty}^{\infty} \left(\frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} * GR \right) - FC \right)$$

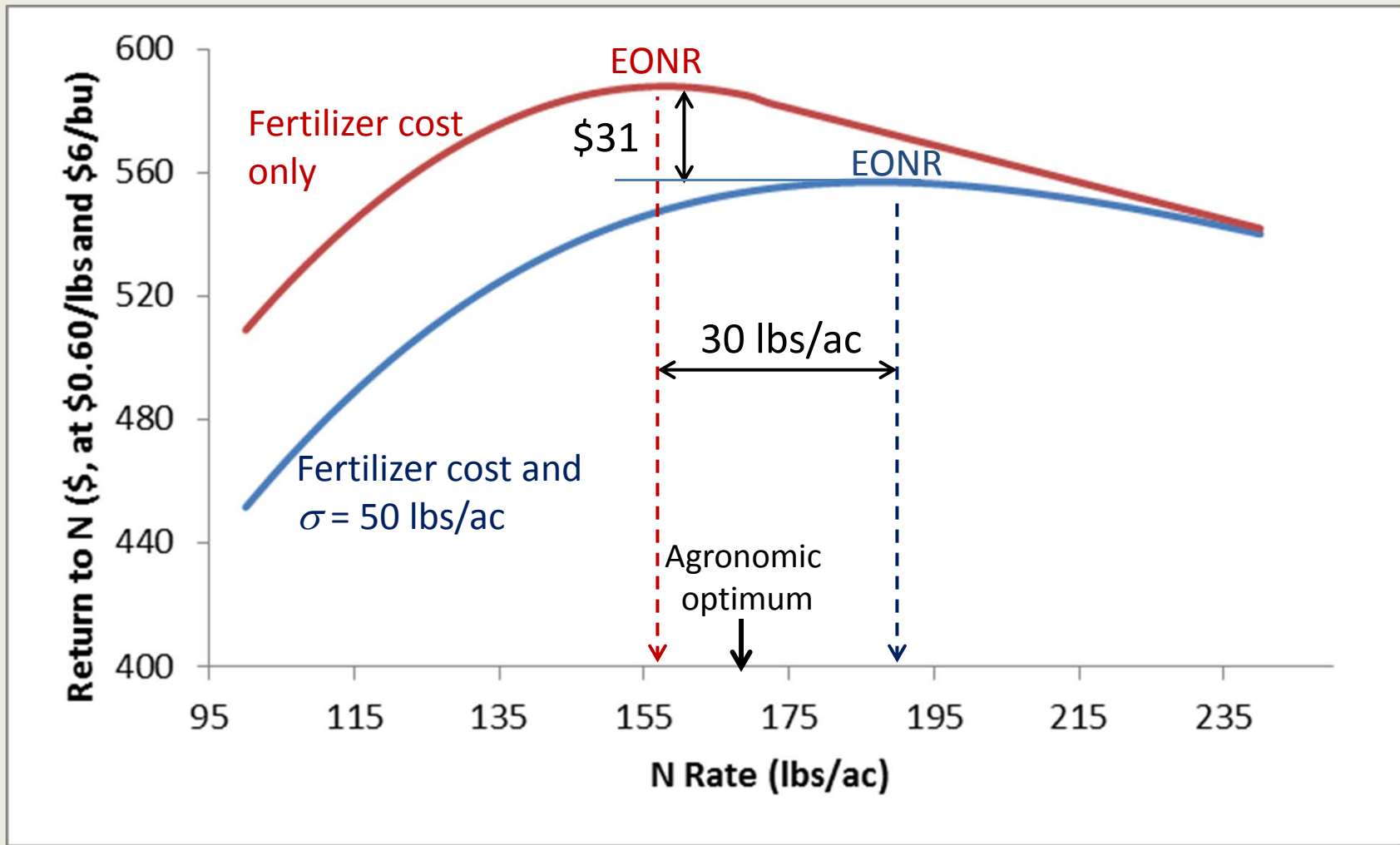
where

GR is the gross return

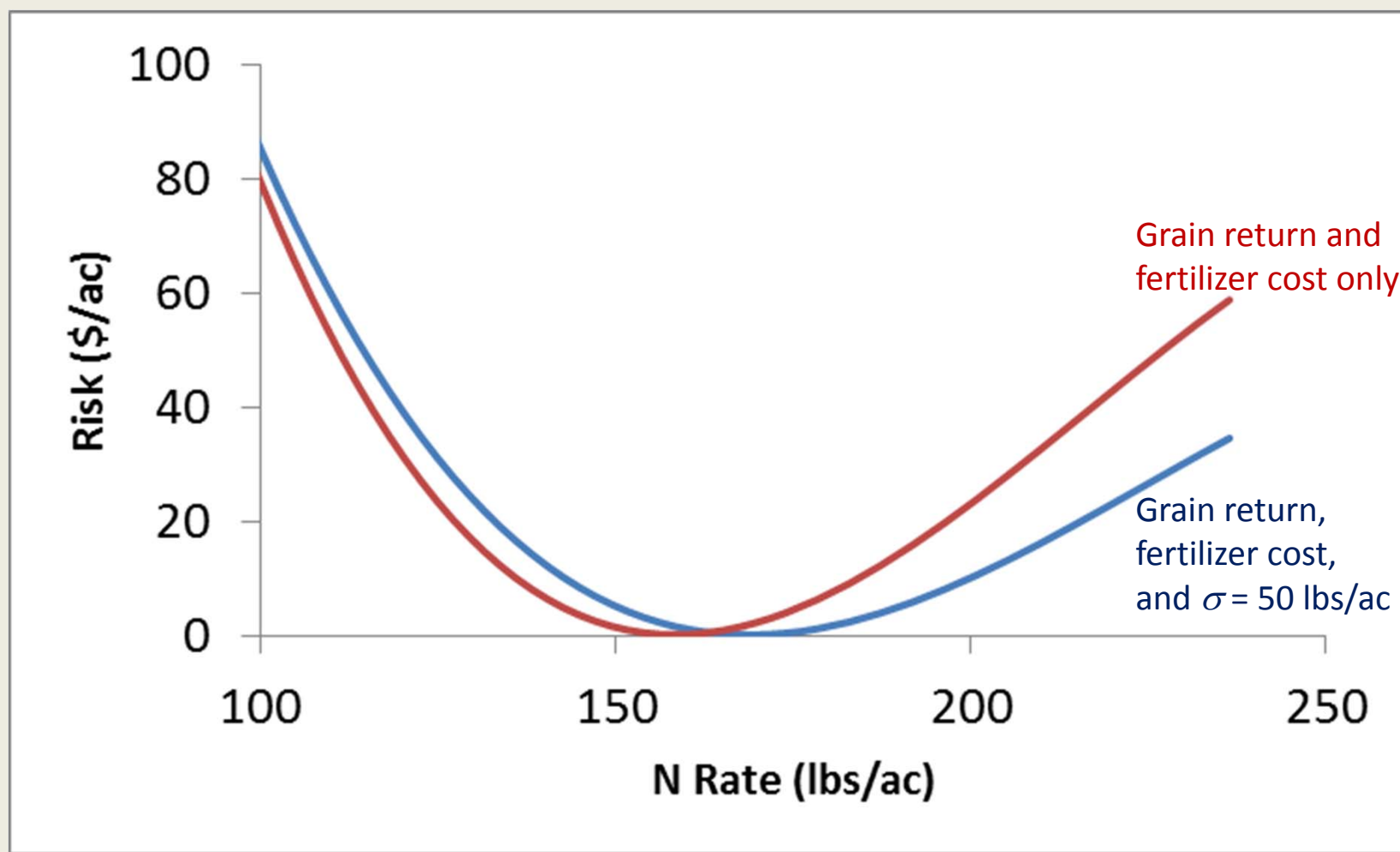
FC is the fertilizer cost

Return from N Application

unadjusted ($\sigma = 0$) and stochastic ($\sigma = 50$ lbs/ac)
(fertilizer=\$0.60/lb; corn=\$6.00/bu)



Relative Risk From Erroneous N Fertilizer Application



Reasons for Farmer Tendency to Over-Fertilize: Coffee Shop Wisdom on Risk and Risk Perception

- With uncertainty around the optimum N rate, the profit losses from under-fertilizing (yield penalty) are greater than those from over-fertilizing (unnecessary fertilizer expense).
- Under-fertilization results in highly visible leaf yellowing, while over-fertilization is not noticeable.
 - Farmers tend towards the highest rate
 - Consultants cannot afford to under-recommend
- Fertilizer dealers have additional incentives to suggest high rates



Most farmers \pm rationally manage the risks associated with N fertilization based on the imperfect information and tools available to them

Different Fertilizer-Grain Price-Ratios Methods

- Gross return to N application function defined for Floyd silt loam soil in Iowa for \$6/bu corn (Graham et al., 2010):
$$\text{GR (\$)} = 355 + 8.05N - 0.0236 N^2 \quad \text{for } N \leq 170 \text{ lbs/ac}$$
$$\text{GR (\$)} = 1042 \quad \text{for } N > 170$$
- Stochastic simulations were performed at N rate intervals of 2 lbs/ac using
 - fertilizer:corn price ratios of 0.0033, 0.05, 0.067, 0.083, 0.10, 0.125, 0.15, and 0.20
 - Agronomic N rate uncertainty levels of $\sigma = 0, 20, 30, 40,$ and 50 lbs/ac.
- Returns to N and needed corrections were determined

Return to N application associated with the economic optimum N rate (EONR)

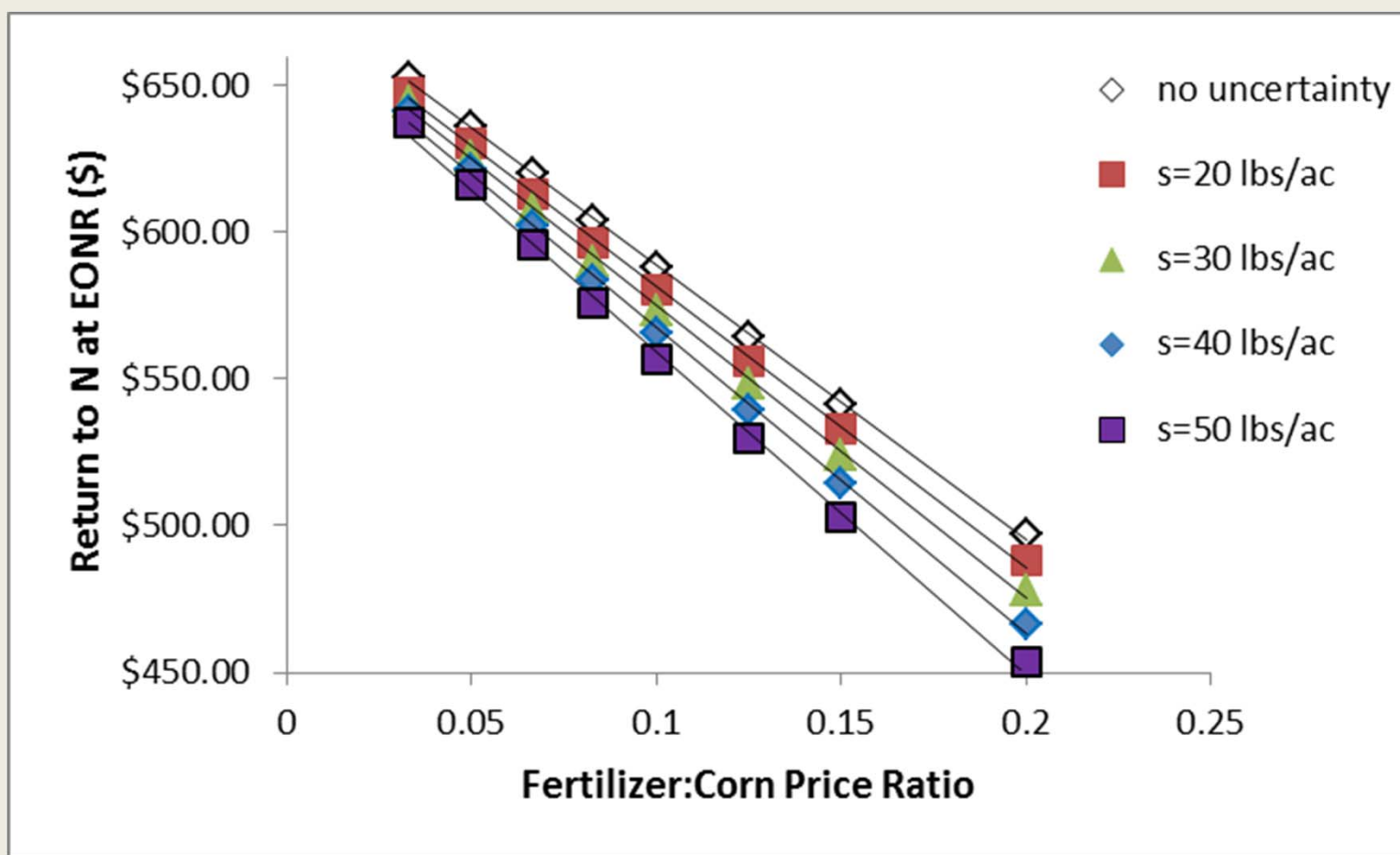
Price Ratio	Return to N at EONR for \$6/bu corn \$/ac				
Fertilizer : Corn	no uncertainty	σ =20 lbs/ac	σ =30 lbs/ac	σ =40 lbs/ac	σ =50 lbs/ac
\$1.20 : \$6 (0.20)	\$497.01	\$487.88	\$478.15	\$466.46	\$453.43
\$0.90 : \$6 (0.15)	\$541.52	\$532.78	\$524.21	\$514.20	\$503.15
\$0.75 : \$6 (0.125)	\$564.47	\$556.11	\$548.29	\$539.30	\$529.47
\$0.60 : \$6 (0.1)	\$587.92	\$580.08	\$573.18	\$565.36	\$556.90
\$0.50 : \$6 (0.083)	\$603.81	\$596.44	\$590.27	\$583.34	\$575.9
\$0.40 : \$6 (0.067)	\$619.91	\$613.16	\$607.82	\$601.88	\$595.54
\$0.30 : \$6 (0.05)	\$636.22	\$630.28	\$625.90	\$621.07	\$615.96
\$0.20 : \$6 0.033)	\$652.75	\$647.89	\$644.62	\$641.07	\$637.34
Equation	Profit = -935.16PR + 682.4	Profit = -959.8PR + 677.52	Profit = -998.23PR + 674.88	Profit = -1046.7PR + 672.3	Profit = -1102.4PR +669.8

field corn

sweet corn - FM

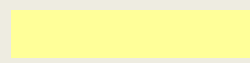
Return to N at EONR (\$/ac)

Combined Price Ratio and Stochastic Corrections
based on \$6/bu corn



Corrections from Agronomic Optimum N rate to Maximize Returns (lbs N/ac)

Price Ratio	Price Ratio Only	Price Ratio + Stochastic			
Fertilizer : Corn	$\sigma=0$ lbs/ac	$\sigma=20$ lbs/ac	$\sigma=30$ lbs/ac	$\sigma=40$ lbs/ac	$\sigma=50$ lbs/ac
\$1.20 : \$6 (0.20)	-24	-24	-20	-16	-10
\$0.90 : \$6 (0.15)	-18	-16	-12	-6	+2
\$0.75 : \$6 (0.125)	-16	-12	-6	0	+8
\$0.60 : \$6 (0.1)	-12	-8	-2	+6	+18
\$0.50 : \$6 (0.083)	-10	-4	+2	+12	+24
\$0.40 : \$6 (0.067)	-8	0	+8	+18	+30
\$0.30 : \$6 (0.05)	-6	+4	+14	+26	+38
\$0.20 : \$6 0.033)	-4	+10	+20	+34	+48
Equation	Corr = $50.55PR^2 - 132.73PR + 0.50$	Corr = $529.07PR^2 - 319.94PR + 19.25$	Corr = $787.27PR^2 - 418.57PR + 32.63$	Corr = $1062.80PR^2 - 540.63PR + 50.16$	Corr = $1059.2PR^2 - 587.4PR + 65.41$



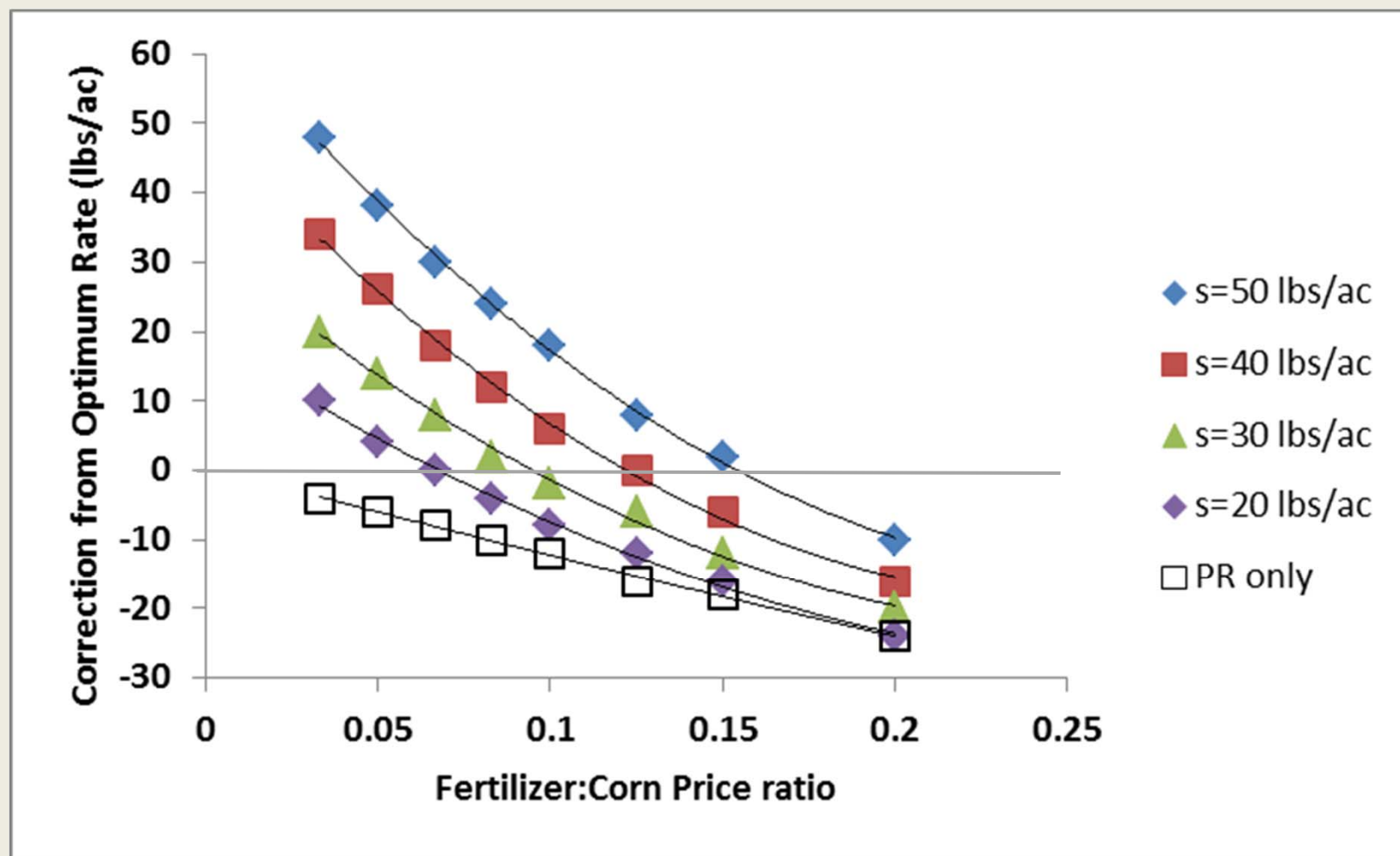
field corn



sweet corn - FM

Correction from Agronomic Optimum Rate to Obtain Economic Optimum N Rate (lbs/ac of fertilizer)

Combined Price Ratio and Stochastic Corrections





Adapt-N: A Tool for Precision Nitrogen Management in Corn

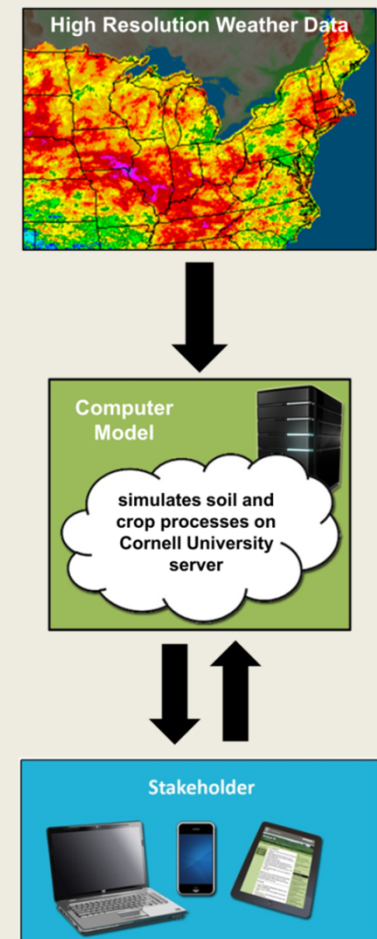


Adapt-N

A tool for adaptive nitrogen management in corn

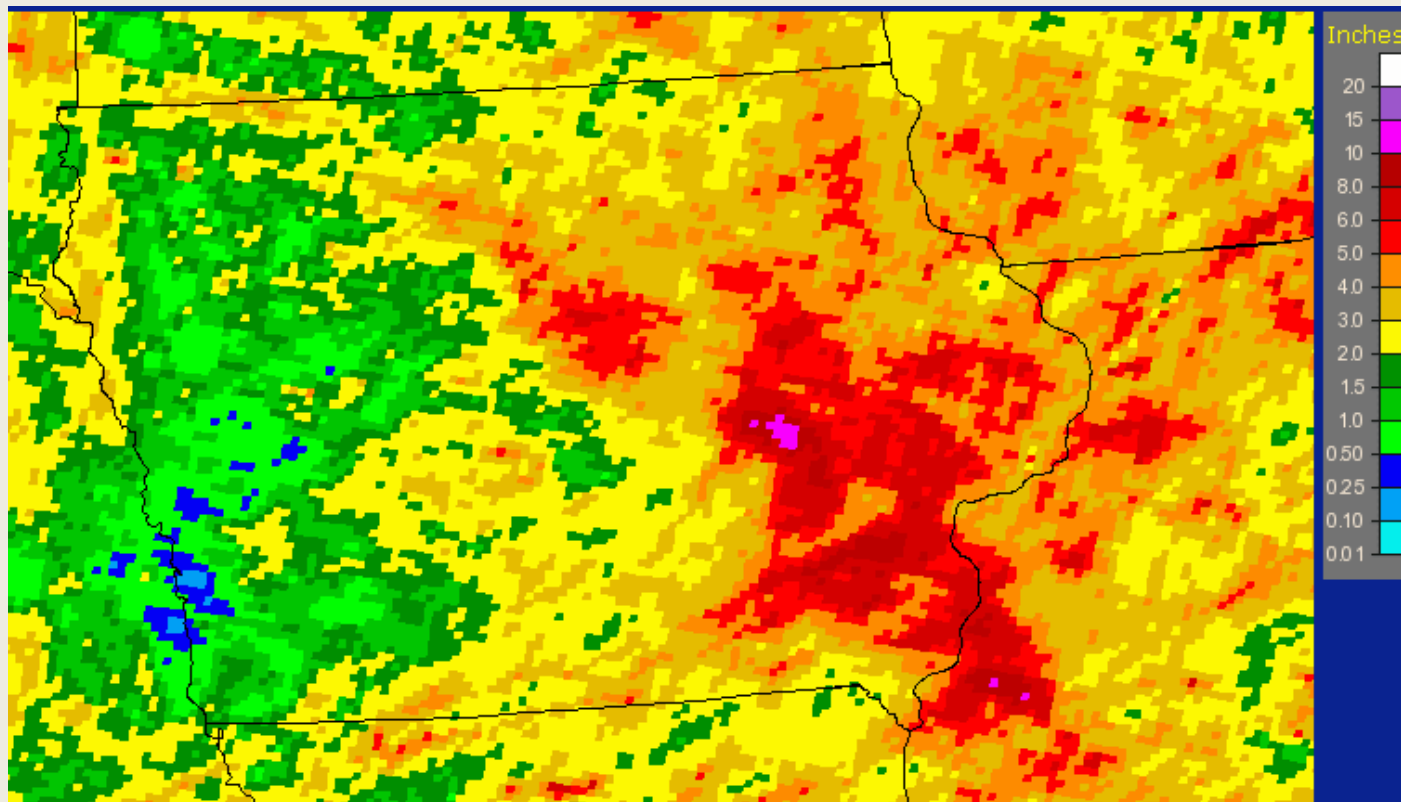
- Provides nitrogen rate recommendations for corn (grain, silage, sweet)
- Is server-based (“cloud computing”), and accessible through multiple devices
- Its core is the PNM model, built from well-calibrated dynamic simulation models and based on decades of field and modeling research
- Uses daily 3x3 mile near-real time weather data (areas East of 100 W Meridian)
- Uses NRCS soil database information

Adapt-N Infrastructure



High Resolution Climate Data (5 x 5 km) Critical Input to Adapt-N Tool

Precipitation is highly localized and seasonal....



June 2007 Precipitation Iowa

Adapt-N

A tool for adaptive nitrogen management in corn



- Simulates crop and soil processes
 - Crop management, rotation, tillage, soil type, OM, organic/inorganic nutrient additions, etc.
- Field or subfield management scale
- Incorporates fertilizer grain-price ratio, and uncertainty corrections
- Provides additional information on:
 - Environmental impact - nitrate leaching and (soon) N_2O losses
 - Additional diagnostic information
 - End-of season situation analysis and “what-if” scenarios

Adapt-N Interface: Manage Locations

Adapt-N: *A tool for adaptive nitrogen management in corn production.*

LoginMineral Nitrogen/CultivarSoil/TillageManure/Sod/SoybeanAdd ApplicationResultsManage Locations

Adapt-N Home

☐ Select Location

☐ Modify Location

☒ Set Up New Location

Please identify the region, the season and the location name. You may also identify the group name if you wish.

Northeast

2011

Select Group (optional)

Location Name

Please identify the latitude and longitude. You can use the map to do this; If you wish to enter latitude and longitude without using the map, you can click on the clear Lat./Lon. button

Latitude (e.g. 42.443)

42.556447050


Longitude (e.g. -76.502)

-73.99192535

clear Lat./Lon.

Submit New Location

Cancel



Adapt-N Interface: entering Mineral N/Cultivar info

Adapt-N: *A tool for adaptive nitrogen management in corn production.*

Login	Manage Locations	Alert Settings	N Rec. Alerts	Mineral Nitrogen/Cultivar
Soil/Tillage	Manure/Rotations	Irrigation	Add Application	Results
Season End Date				Adapt-N Home

Nitrogen Fertilizer Applications for this Growing Season

Application	Name	lbs N/acre	Placement Depth	Date	Delete	Edit
					Button	Button
starter (fertilizer banded with seed)	monoammonium phosphate	30	2"-4"	n/a	Delete	Edit
preplant/sidedress	urea	100	2"-4"	04/10/2012	Delete	Edit

You may enter one starter and up to four preplant/sidedress applications. Preplant applications can start as early as 10/1/2011.

Crop Information

Grains: 110 d crm

Planting Date

Grain Cultivars: Expected Yield (bu/acre)

Adapt-N Interface: entering Soil/Tillage info

Adapt-N: *A tool for adaptive nitrogen management in corn production.*

Login	Manage Locations	Alert Settings	N Rec. Alerts	Mineral Nitrogen/Cultivar	Soil/Tillage
Manure/Rotations	Irrigation	Add Application	Results		
Season End Date <input type="text"/>					Adapt-N Home

Soil Information

Please select a soil texture class that best describes the soil in the field.

Canisteo ▼

Please select the estimated rooting depth. > 38 inches ▼

Please select the approximate slope (%) of the field. less than 3% ▼

Was there a soil test? There was a soil test in the last 3 years. ▼

If you know the sample depth, please enter it in inches.

Otherwise, please enter 6 inches. (inches)

soil organic matter: (%)

Tillage System Information

Please select the tillage system for this field.

Conservation tillage ▼

50% ▼

Adapt-N Interface: entering irrigation info

Adapt-N: *A tool for adaptive nitrogen management in corn production.*

Login	Manage Locations	Alert Settings	N Rec. Alerts
Mineral Nitrogen/Cultivar	Soil/Tillage	Manure/Rotations	Irrigation
Add Application	Results		
Season End Date	<input type="text"/>	Adapt-N Home	

Irrigation: *Please identify irrigation date and the total irrigation amount. Then click on the 'Submit Irrigation' button.*

Irrigation Date

Amount in inches ▼

Submit Irrigation

Cancel Irrigation

Adapt-N Interface: entering Manure/Sod/Soybean info

Adapt-N: *A tool for adaptive nitrogen management in corn production.*

LoginManage LocationsAlert SettingsN Rec. AlertsMineral Nitrogen/CultivarSoil/Tillage

Manure/RotationsIrrigationAdd ApplicationResults

Season End Date [Adapt-N Home](#)

Manure N Applications

Date	Added	Unit	Organic N	Ammonia N	Depth	Solids	Delete Button	Edit Button
04/10/2012	8000	gal./acre	8.00	9.00	incorporated/injected immediately	5	Delete	Edit

You may enter up to three applications for 2012. Manure can be applied as early as 10/1/2011.

Select Manure Application ▼

N from Sod Rotation

Previous sod crop in the past three years? ▼

Previous Crop

Please select the previous crop for this location.

▼

When you've entered all your information, please click the submit button

When done entering all field info, click 'Submit' to run the simulation.

Adapt-N Results Page: Example with need for sidedress N

Adapt-N: *A tool for adaptive nitrogen management in corn production.*

Login	Manage Locations	Alert Settings	N Rec. Alerts	Mineral Nitrogen/Cultivar	Soil/Tillage
Manure/Rotations	Irrigation	Add Application	Results		

[Adapt-N Home](#)

Sidedress Nitrogen Recommendation for IA Storm Lake: **115 lbs N/Acre (101 - 128 lbs N/Acre)**

This recommendation is based on an "Expected Yield" entry that is assumed to be the economically optimum yield for this field. The recommended range reflects the uncertainty with post-application fertilizer losses for the remainder of the growing season due to unknown future weather events.

1. Calculation of Sidedress N Rate

Sidedress N rate estimated by AdaptN = $\text{CropN}_{\text{Harvest}} - \text{CropN}_{\text{Current}} - \text{SoilN}_{\text{Current}} - \text{SoilN}_{\text{postsidedress}} - \text{SoybeanNCredit} + \text{Loss}_{\text{postapplication}} - \text{Correct}_{\text{profit}}$

CropN _{Harvest}	205 (lbs N/acre)
CropN _{Current}	65 (lbs N/acre)
SoilN _{Current}	28 (lbs N/acre)
SoilN _{postsidedress}	7 (lbs N/acre)
SoybeanNCredit	0 (lbs N/acre)
Loss _{postapplication}	17 (lbs N/acre)
Correct _{profit}	8 (lbs N/acre)

Root Zone Crop Available Water

Note that these estimates are for non-irrigated corn production.

Current root zone crop available water:	0 inches
Crop available water at field capacity	6 inches

- [Full Report and Graphs \(pdf file\)](#)
- [Sidedress N Definitions](#)

Email/text alert system for chosen fields

Sidedress Notifications

To setup email and/or text message notification, please complete the Notification and Monitoring sections. You will only receive information about locations for which all Adapt-N input has been provided. Email addresses and cell phone numbers will be kept confidential.

Notification

Select email notification and/or text message notification by checking the appropriate boxes. Please insure that your email address and cell phone information is correct.

☐ **Email:**

Email Address on record: bnm5@cornell.edu

[Update Email](#)

☐ **Text Messages:**

Cell Phone number on record: missing Cell Phone Carrier:

[Update Cell Phone Information](#)

Monitoring

You will get daily simulation updates for all farm locations that are checked.

Group Name

Locations in this Group

**Adapt-
NProjects2011**

☒ Aurora.NT

☐ Aurora.NT.A

☐ Aurora.NT.G

☐ Aurora.PT

☐

☐

☐

☐

N Recommendation Methodology: deterministic-stochastic mass balance at sidedress

Input:
Expected Yield

Near-Real-Time
Simulation at Sidedress

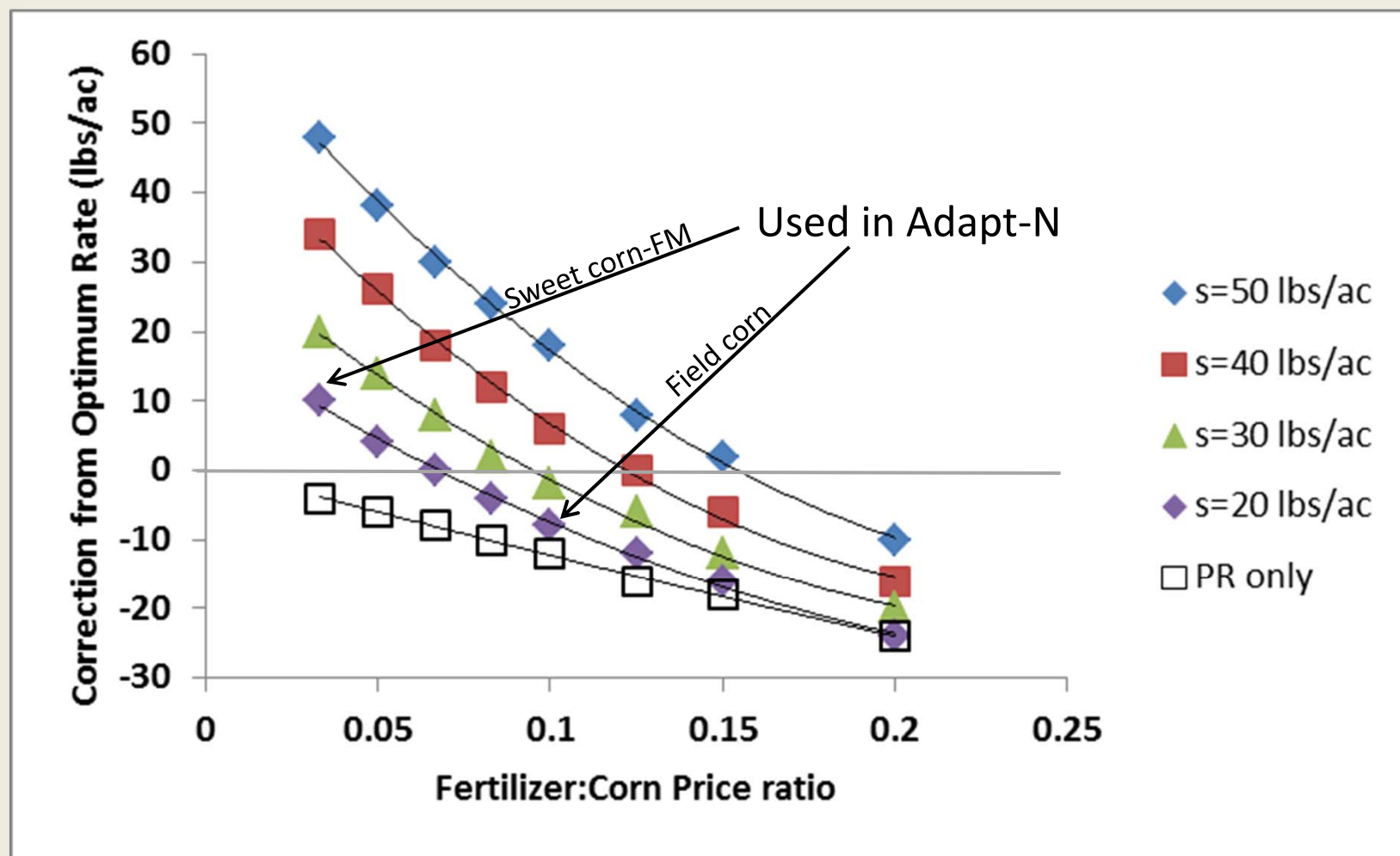
$$\text{SidedressNrate} = \text{CropN}_{\text{Harvest}} - \text{CropN}_{\text{Current}} - \text{SoilN}_{\text{Current}} - \text{SoilN}_{\text{postsidedress}} -$$
$$\text{SoybeanN}_{\text{credit}} + \text{NLoss}_{\text{postapplication}} - \text{Correct}_{\text{profit}}$$

Now: simulated &
partial fixed credit

Probabilistic
simulations

Correction from Agronomic Optimum Rate to Obtain Economic Optimum N Rate (lbs/ac of fertilizer)

Combined Price Ratio and Stochastic Corrections



Question: Does Adapt-N work?

- **Agronomic:** Does Adapt-N provide an accurate N recommendation at sidedress time?
- **Economic:** Can Adapt-N save growers money in comparison to their current practices?
- **Environmental:** Can Adapt-N decrease N losses?

Overall Adapt-N Performance 2011-2012, IA and NY

Treatment comparison (Adapt-N) – (grower practice)	Iowa		New York		Grand Mean
	2011	2012	2011	2012	(weighted)
	(n=9)	(n=19)	(n=14)	(n=18)	(n=60)
N fertilizer input (lb ac ⁻¹)	-25	-36	-61	-38	-41
Yield (bu ac ⁻¹)	+2	-1	-3	+2	0
Profit (\$ ac ⁻¹)	+\$26	+\$17	+\$26	+\$29	+\$24
Trials with greater profit	78%*	74%*	86%*	83%*	81%

*Most “misses” were associated with wrong data inputs

Environmental:

N losses decreased by 45 kg/ha; N leaching losses by 34 kg/ha (NY, 2011)

Summary

- Variability (uncertainty) in corn N yield response, combined with a nonlinear-asymmetrical corn response relationship implies that the returns to N application are maximized at higher rates than the average economic optimum N rate.
- This explains farmer tendencies for “insurance” fertilizer applications, and their reluctance to reduce N rates for environmental purposes.
- Economic optimum N rates need to be corrected to address underlying uncertainty (farmer’s risk).
- Needed corrections are smaller with lower uncertainty - when N rate recommendations are more precise, but depend on fertilizer and product prices.
- Corrections have been incorporated into Adapt-N tool with varying price ratios for field vs. sweet corn.



Thank you! Questions?

Adapt-N.cals.cornell.edu



Thanks to our funders

- New York Farm Viability Institute
- USDA-NRCS Conservation Innovation Grants program
- USDA-NIFA Agriculture and Food Research Initiative
- USDA-NIFA Special Grant on Computational Agriculture
- Hatch – Smith Lever Funds
- Northern NY Agricultural Development Program
- International Plant Nutrition Institute
- Walton family Foundation
- McKnight Foundation