Building Risk into N Recommendations for Corn: Understanding Insurance Applications

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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

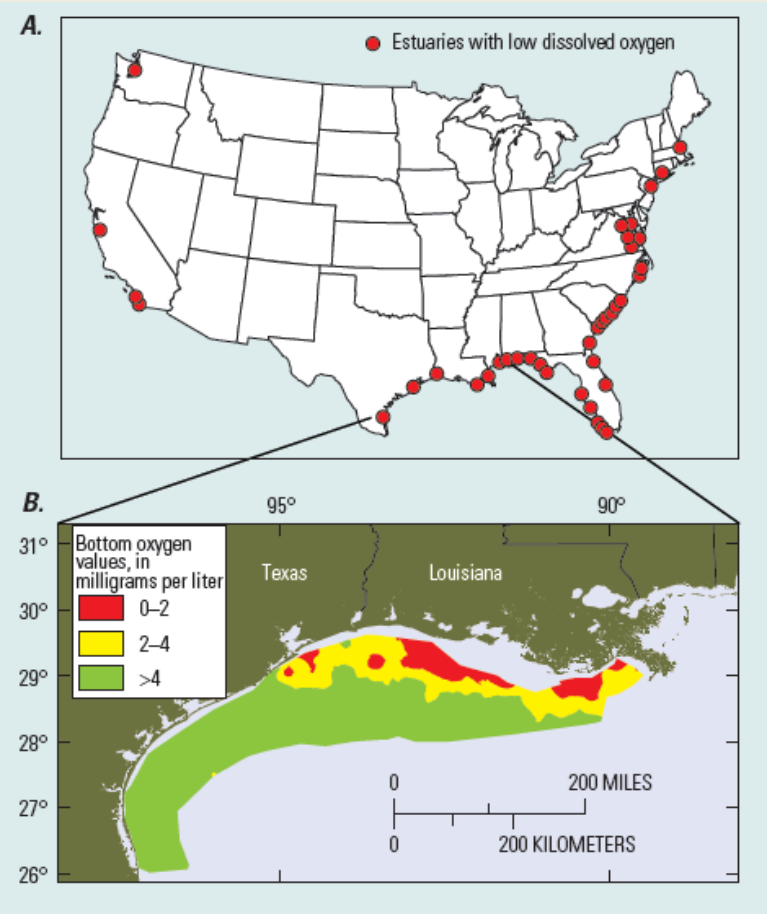
From: Dubrovsky et al., 2010, based on NAWQA data:

"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"

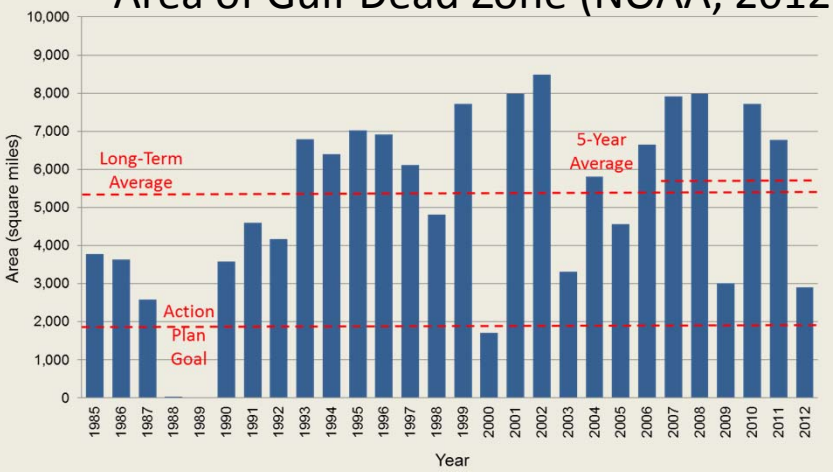
Net Change in MRB Flow-Normalized Nitrate Concentration and Flux between 1980 and 2008 (Sprague et al., 2011)

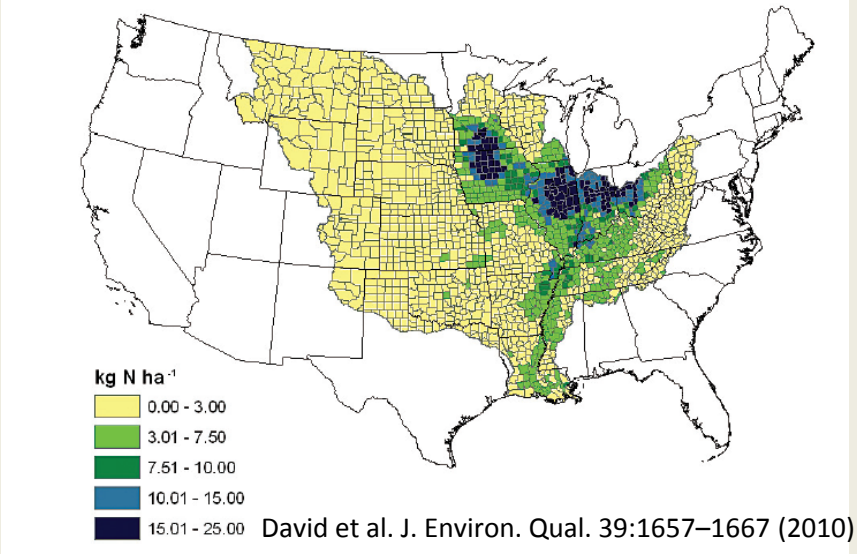
	flow-normalized concentration of nitrate as N		
		change, 1980–2008	
site	annual mean flow-normalized concentration in 1980, mg/L	mg/L	%
MSSP-CL	1.13	0.86	76
IOWA-WAP	5.02	0.17	3
ILLI-VC	3.81	−0.04	−1
MSSP-GR	2.56	0.49	19
MIZZ-HE	0.96	0.72	75
MSSP-TH	1.93	0.38	20
OHIO-GRCH	0.99	0.03	3
MSSP-OUT	1.25	0.13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

Hypoxia Zones in USA



Area of Gulf Dead Zone (NOAA, 2012)

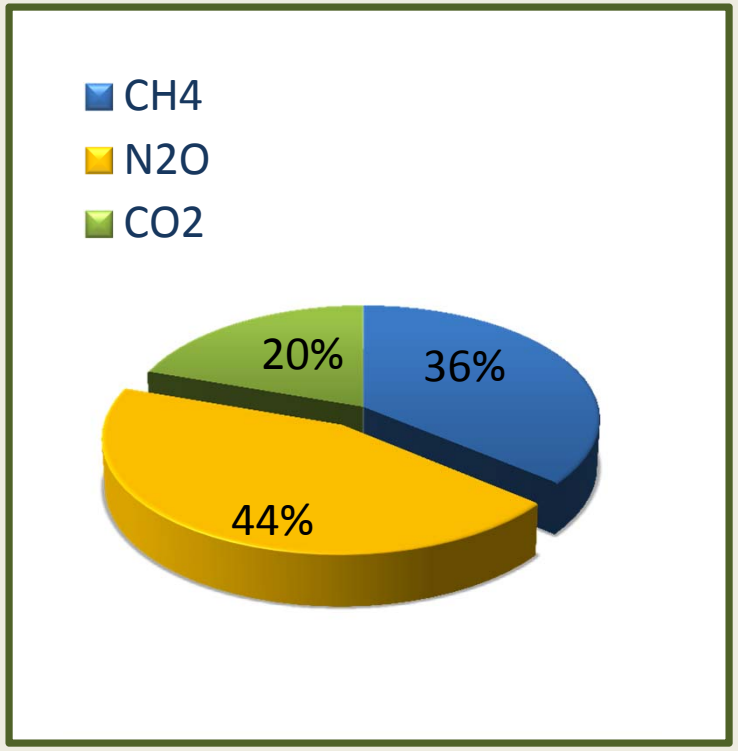


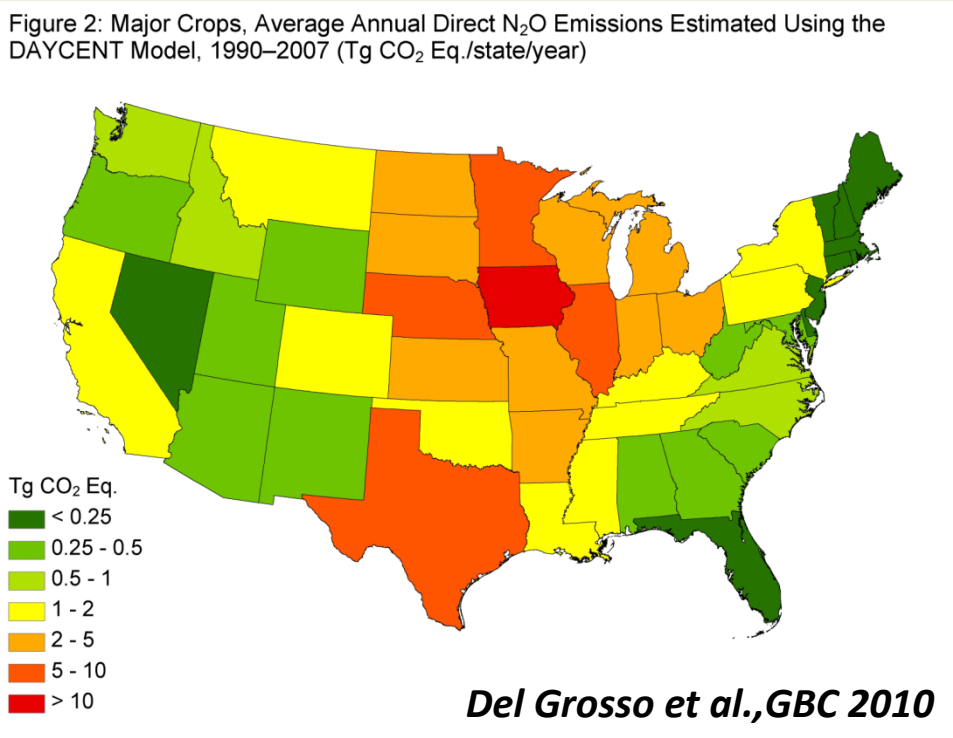


David et al. J. Environ. Qual. 39:1657–1667 (2010)

Riverine N Yield in the MRB

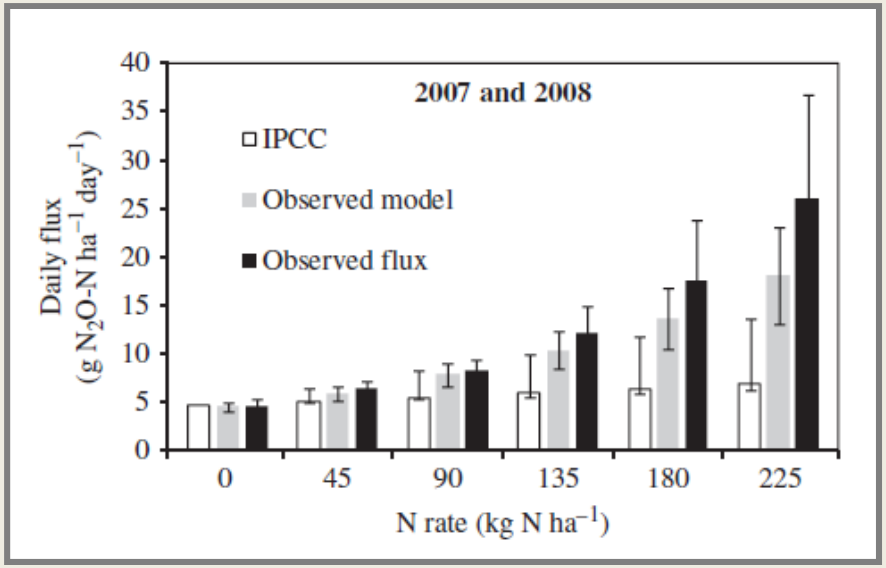
Agricultural GHG Emissions (2008)



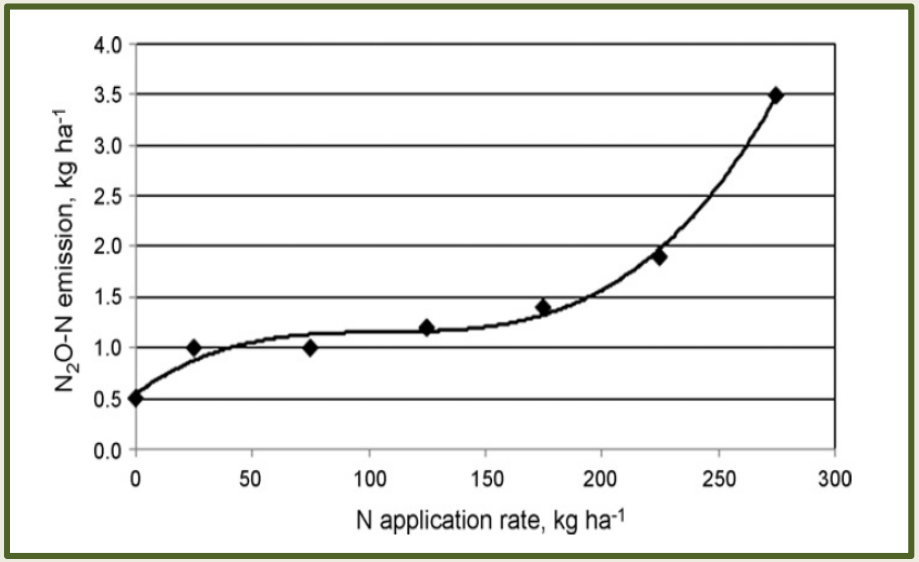


Nitrogen application to US agricultural lands in 2008 had a greater global warming impact than the entire US aviation industry **(EPA, 2010)**

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



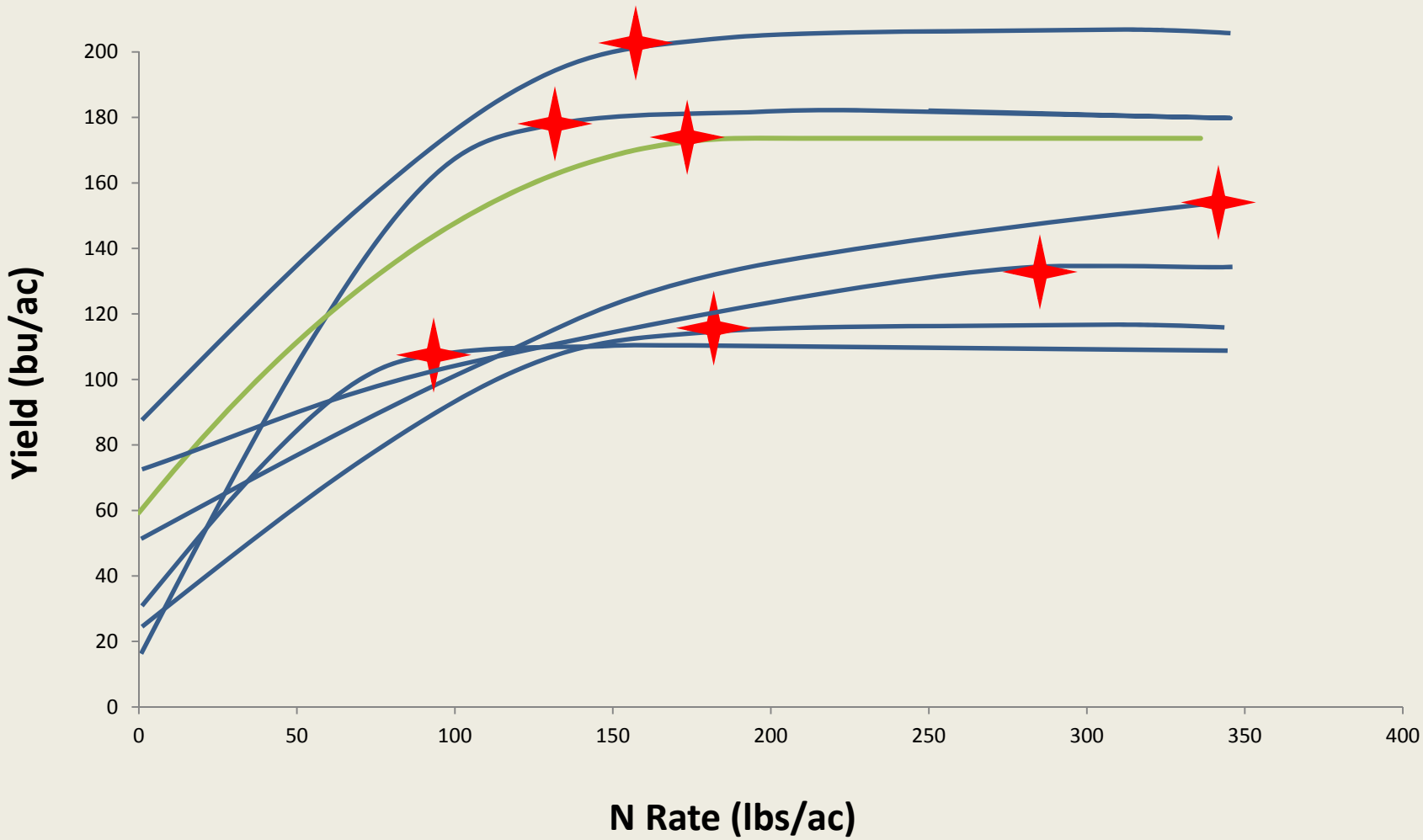
Hoben et al, 2010.



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

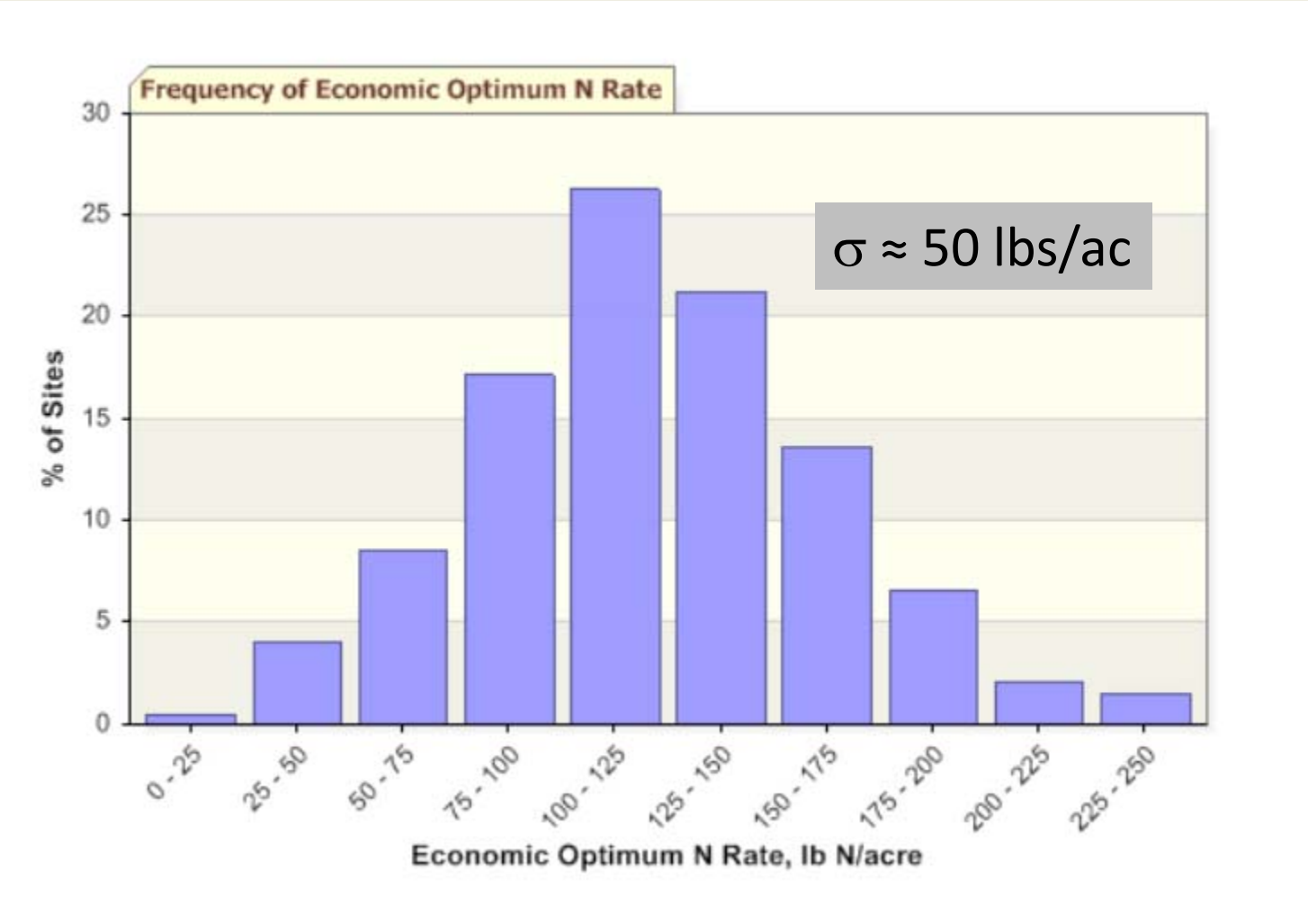
Corn N Response and Agronomic Optimum N Rate



Distribution of Economic Optimum N Rates

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

<u>from:</u> 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!**

<u>Interactions are complex and nonlinear!</u>

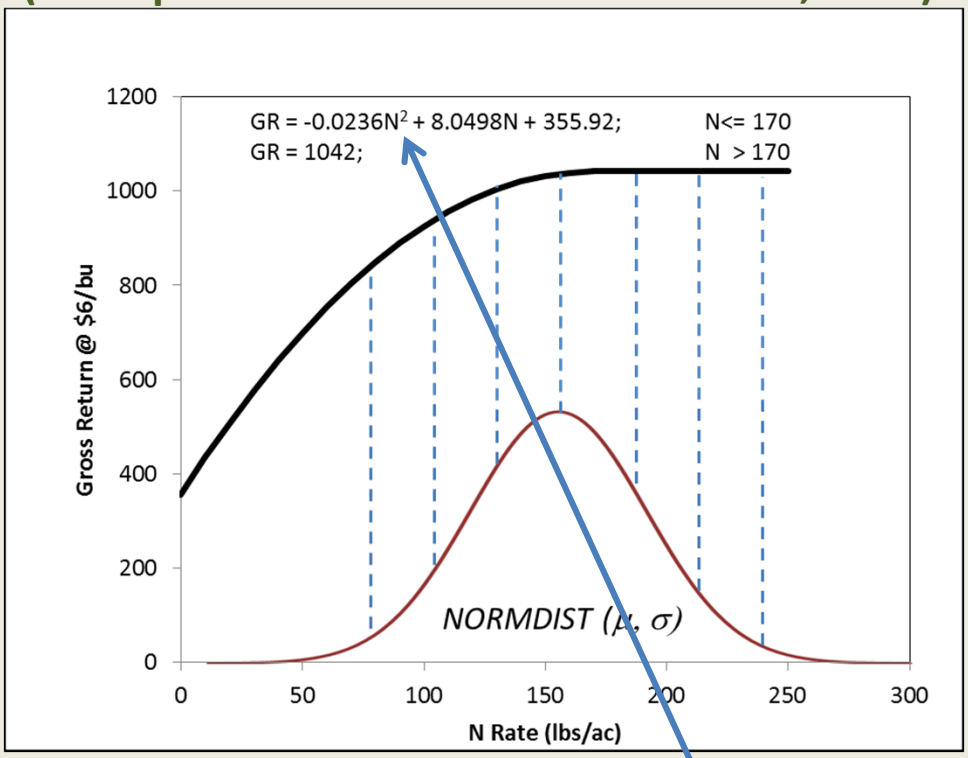
Reasons for Farmer Tendency to Over-Fertilize: Coffee Shop Wisdom on Risk and Risk Perception

- 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)

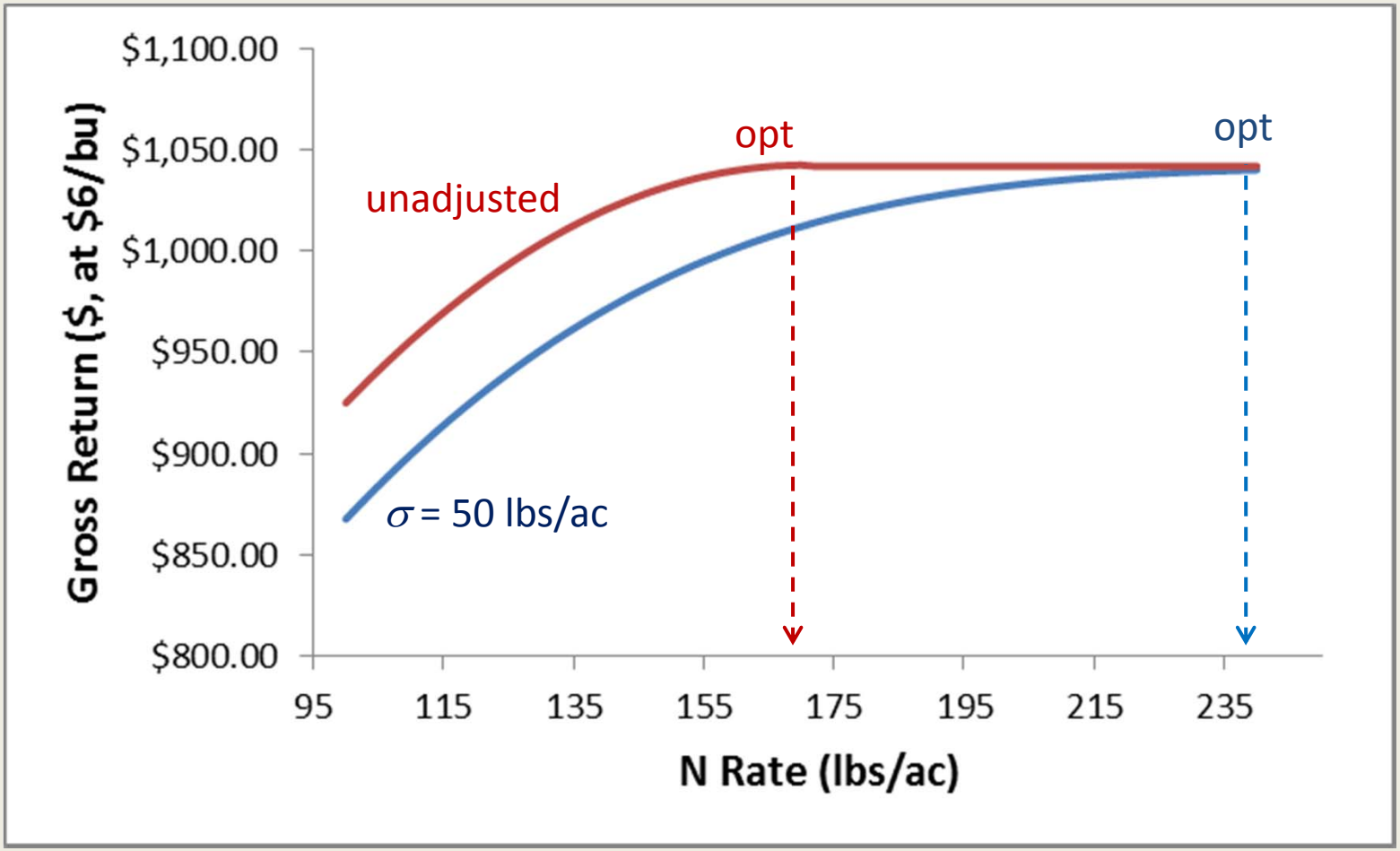


Stochastic Gross Returns:

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

Gross Return

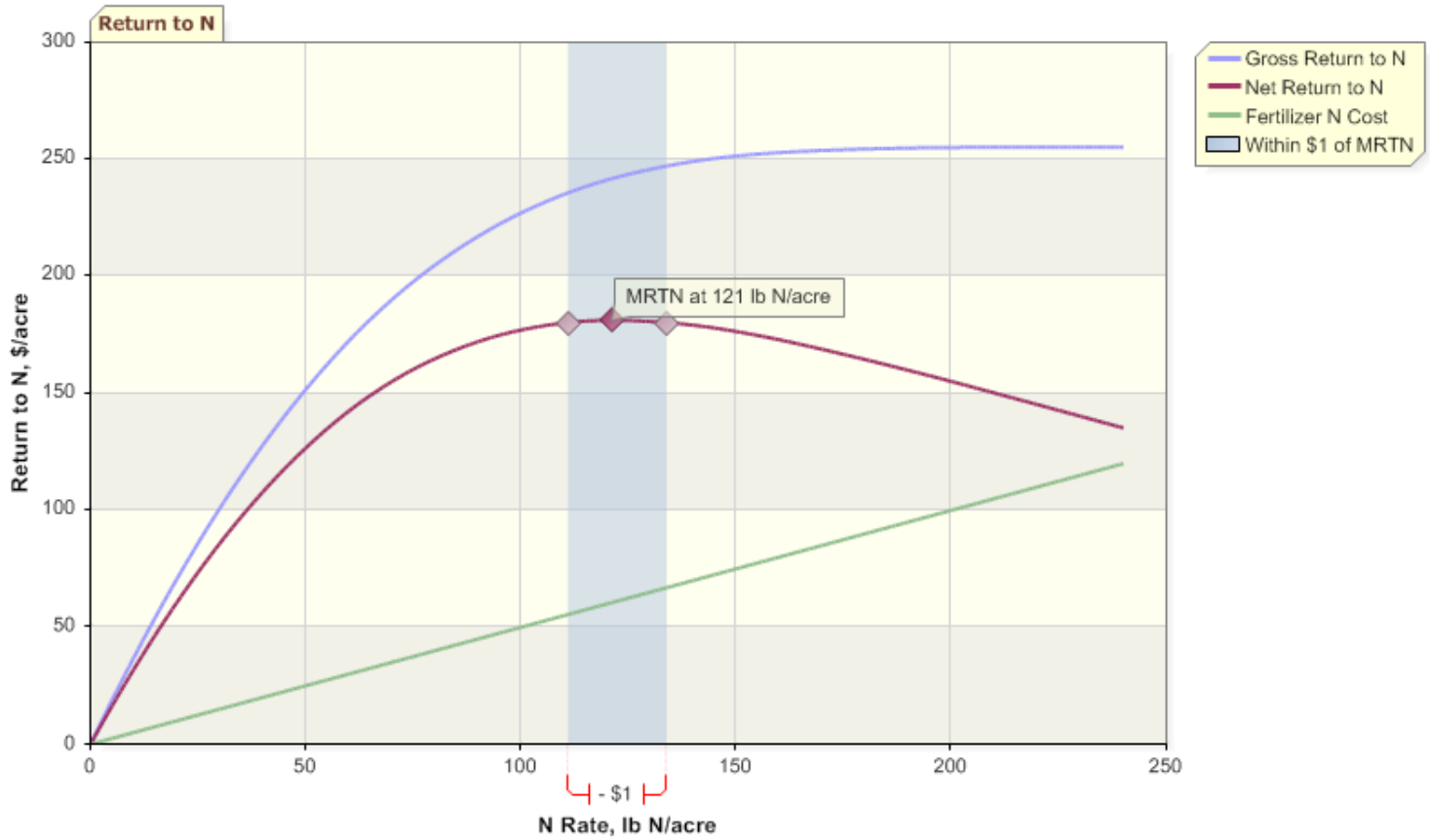
stochastic (σ = 50 lbs/ac) and unadjusted (corn=$6.00/bu)
no consideration for cost of fertilizer



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:

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

Accounting for Fertilizer Cost <u>and</u> Variability (uncertainty):

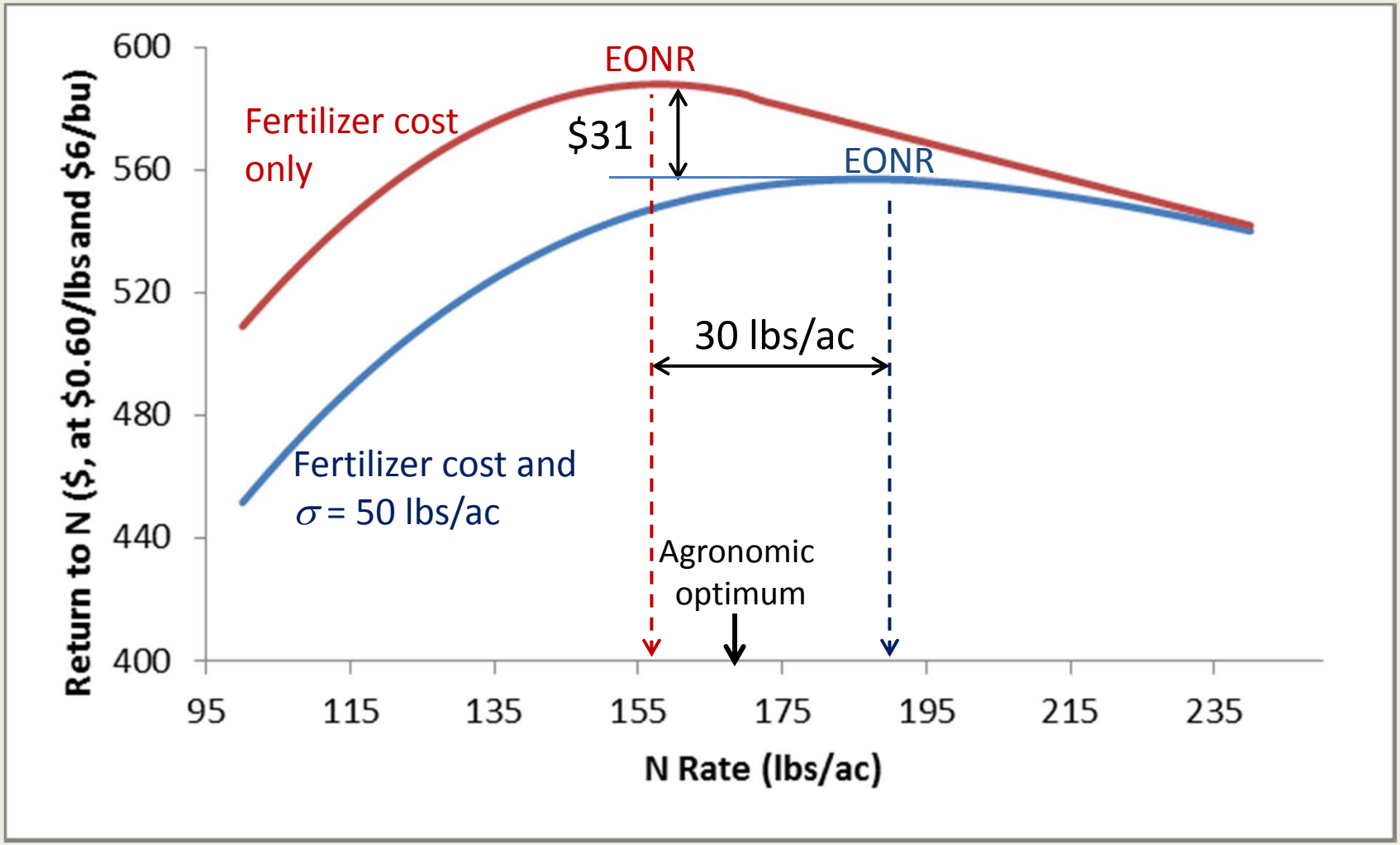
$$Max\left(\int_{-\infty}^{\infty}\left(\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(x-\mu)^2}{2\sigma^2}} * GR\right) - FC\right)$$

where
GR is the gross return
FC is the fertilizer cost

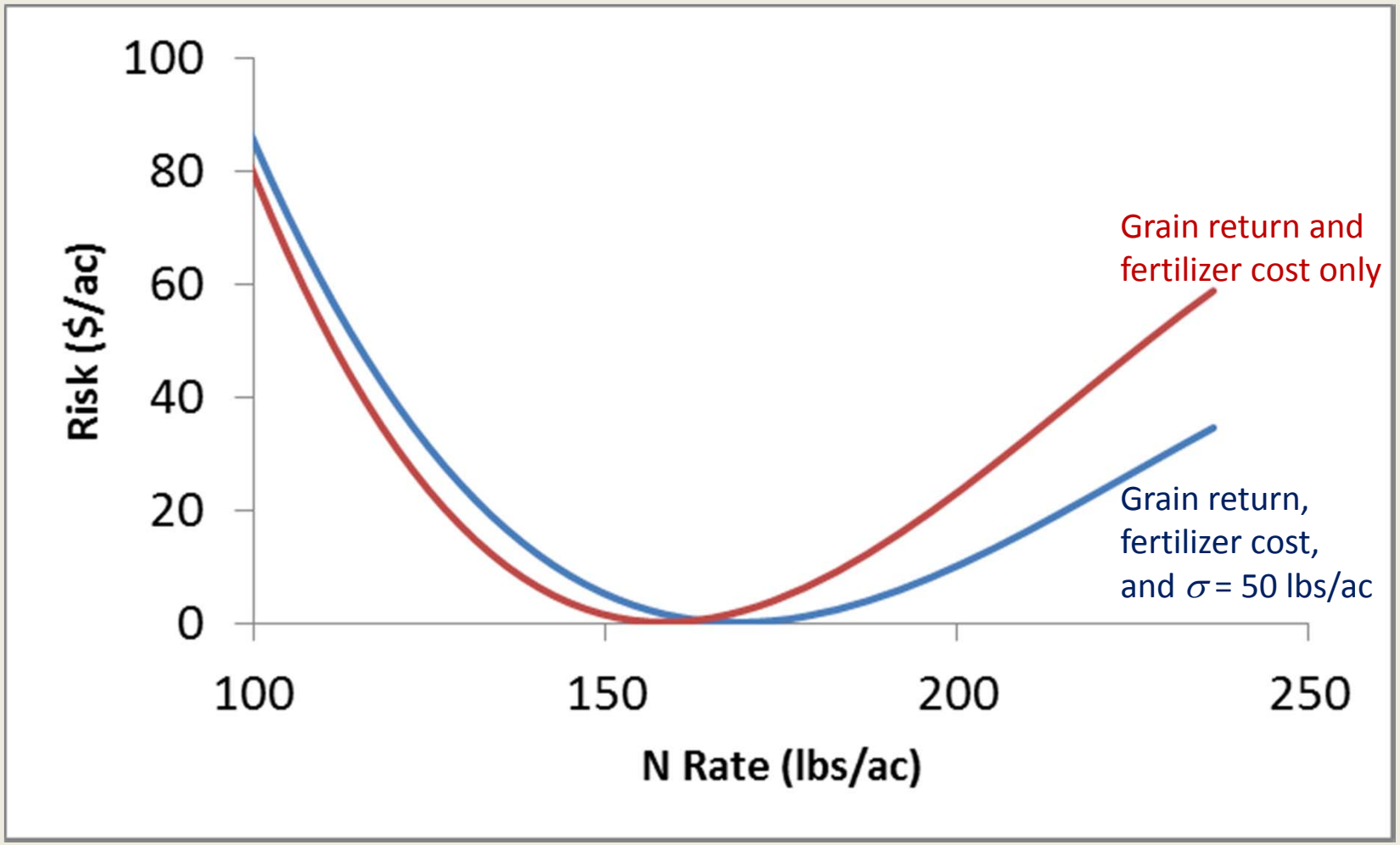
Return from N Application

unadjusted (σ = 0) and stochastic (σ = 50 lbs/ac)

(fertilizer=$0.60/lb; corn=$6.00/bu)



Relative Risk From Erroneous N Fertilizer Application



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Most farmers ± 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):

  $GR (\$) = 355 + 8.05N - 0.0236 N^2$ for $N \leq 170$ lbs/ac

  $GR (\$) = 1042$ 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 σ = 0, 20, 30, 40, and 50 lbs/ac.
- Returns to N and needed corrections were determined

Graham, C.J., H.M. van Es, J.J. Melkonian, and D.A. Laird. 2010. Improved nitrogen and energy use efficiency using NIR estimated soil organic carbon and N simulation modeling. In: D.A. Clay and J. Shanahan. GIS Applications in Agriculture – Nutrient Management for Improved Energy Efficiency. pp 301-325, Taylor and Francis, LLC.

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

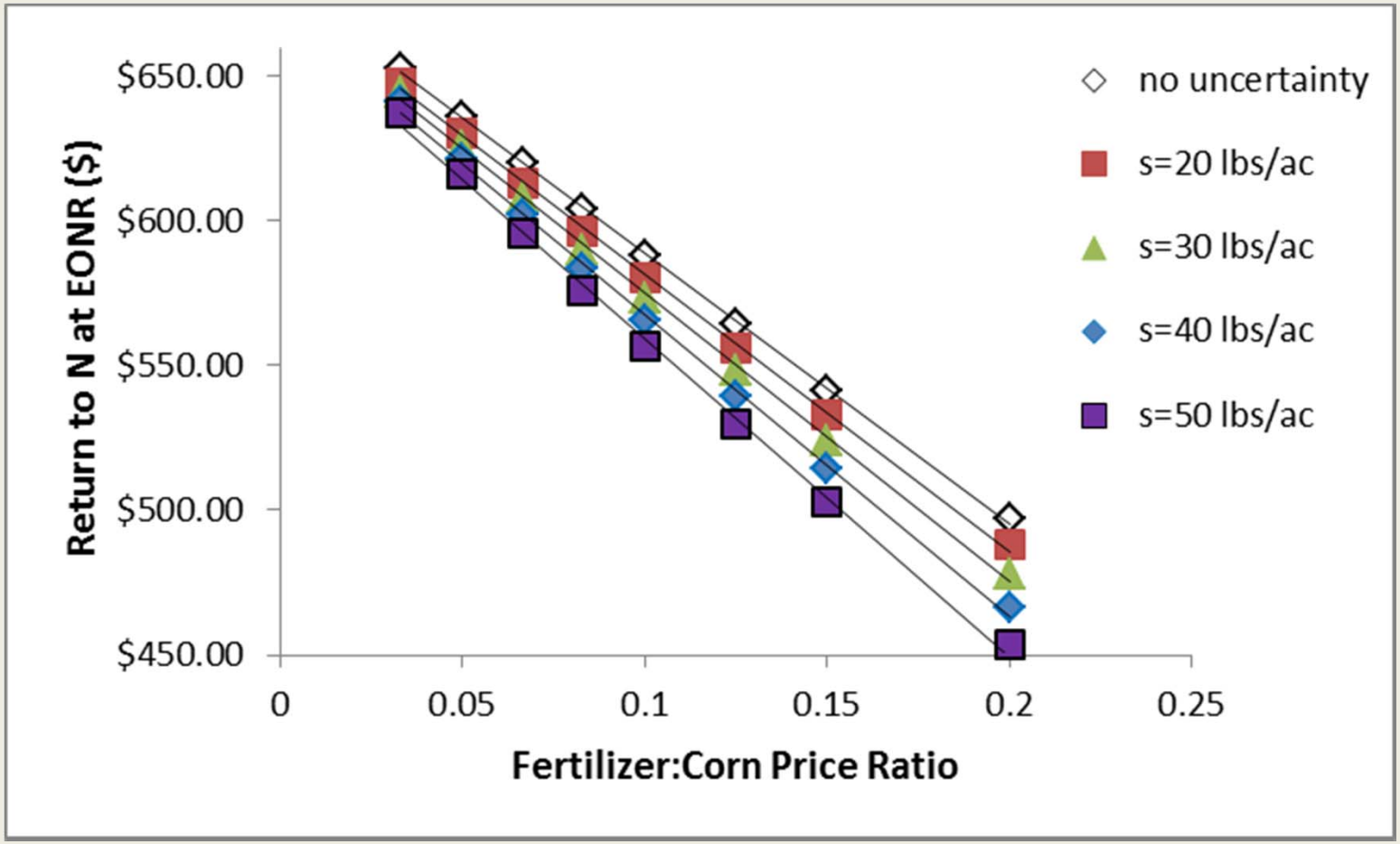
Price Ratio	Return to N at EONR for $6/bu corn $/ac				
Fertilizer : Corn	**no uncertainty**	**σ=20 lbs/ac**	**σ=30 lbs/ac**	**σ=40 lbs/ac**	**σ=50 lbs/ac**
$1.20 : $6 (0.20)	$497.01	$487.88	$478.15	$466.46	$453.43
$0.90 : $6 (0.15)	$541.52	$532.78	$524.21	$514.20	$503.15
$0.75 : $6 (0.125)	$564.47	$556.11	$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	**σ=0 lbs/ac**	**σ=20 lbs/ac**	**σ=30 lbs/ac**	**σ=40 lbs/ac**	**σ=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 = $1059.2PR^2 - 587.4PR + 65.41$**

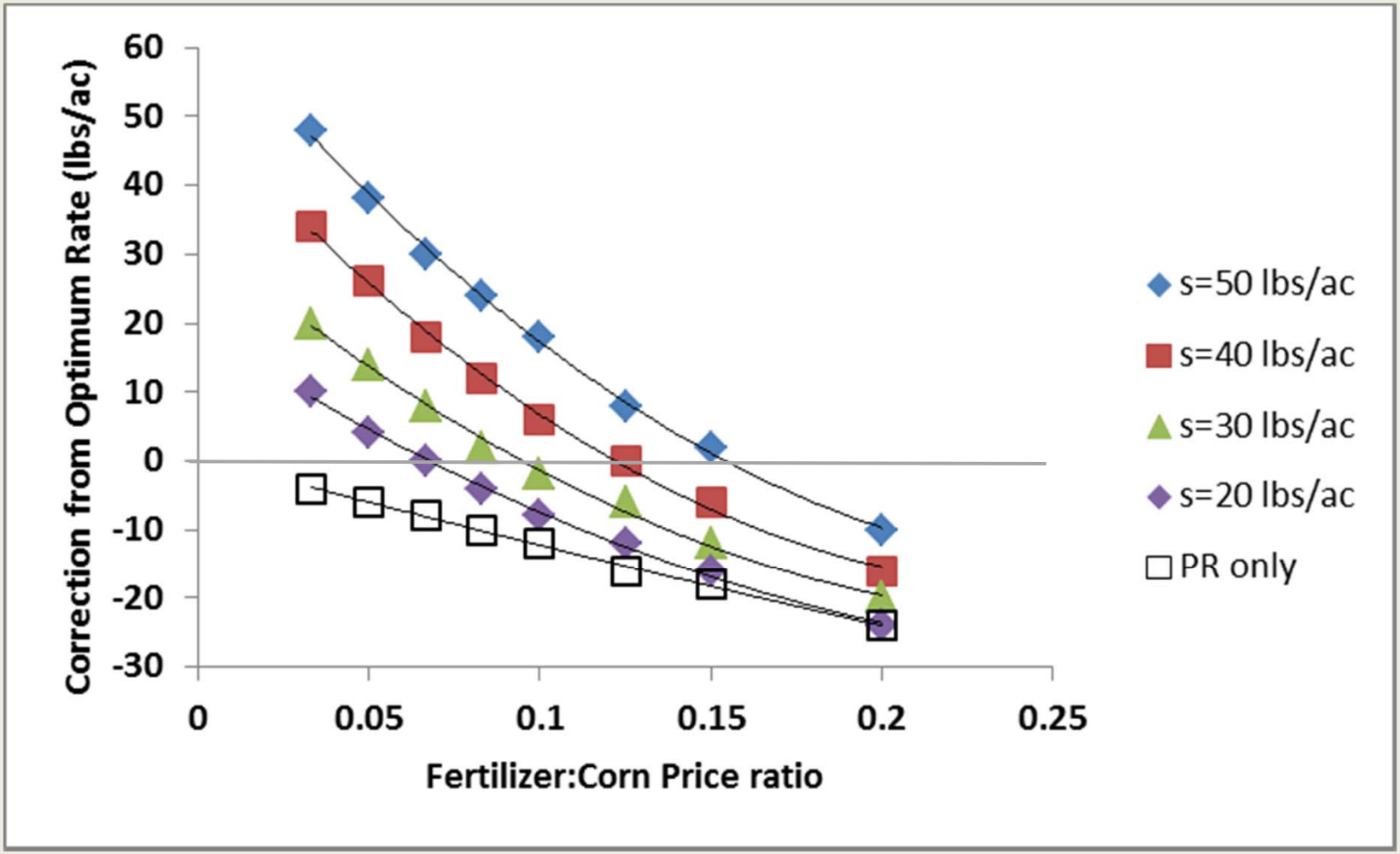
field corn

sweet corn - FM

Correction from Agronomic Optimum Rate to Obtain Economic Optimum N Rate

(lbs/ac of fertilizer)

Combined Price Ratio and Stochastic Corrections



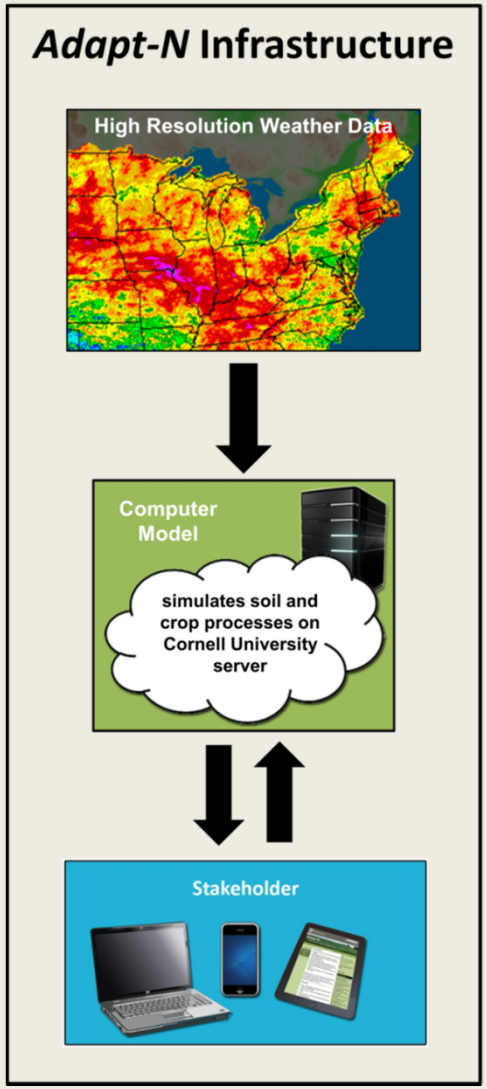
Adapt-N: A Tool for Precision Nitrogen Management in Corn

AG PROFESSIONAL Weekly

2012 NEW PRODUCT OF THE YEAR AWARDS

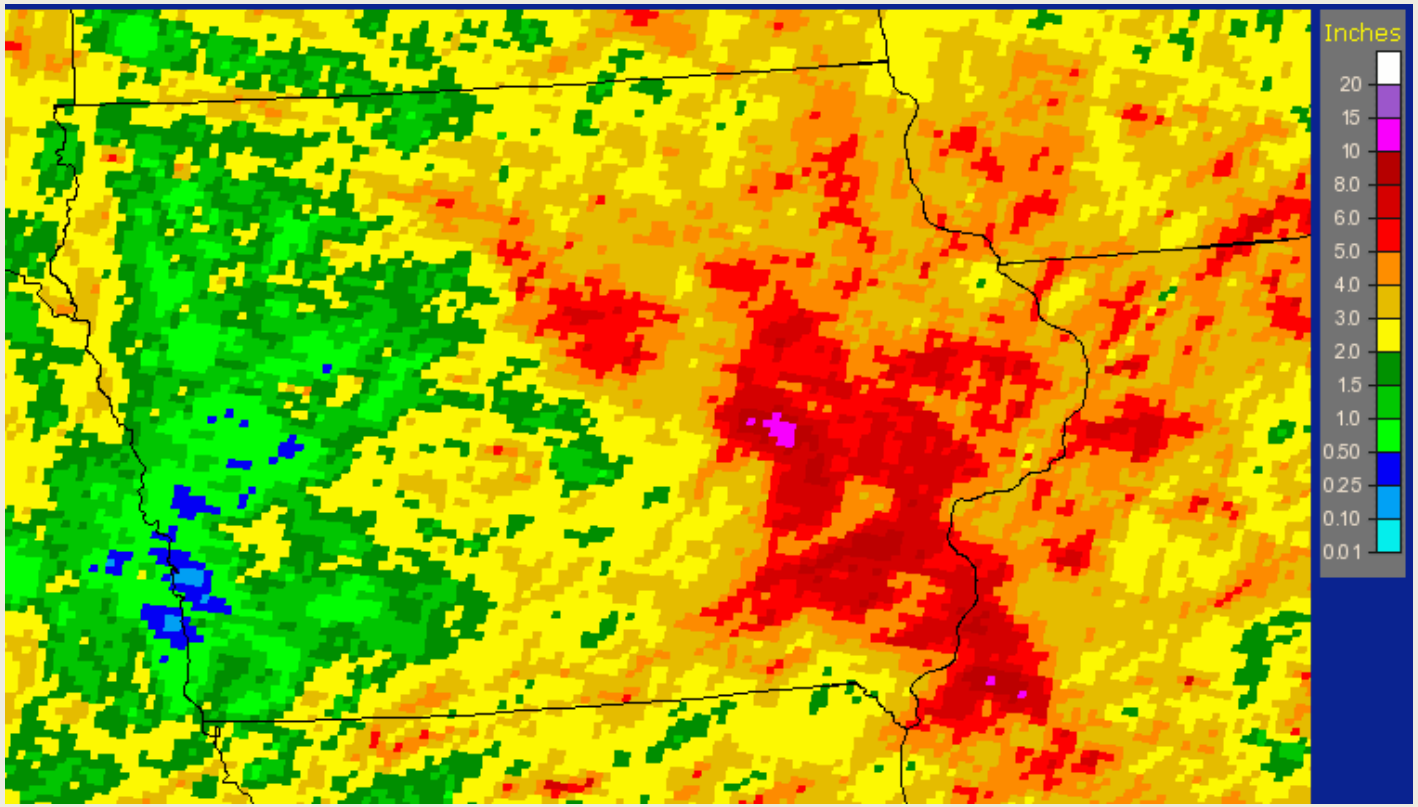
AgProfessional Readers' Choice

- 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



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

Precipitation is highly localized and seasonal….



June 2007 Precipitation Iowa

- 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.***

Login | Mineral Nitrogen/Cultivar | Soil/Tillage | Manure/Sod/Soybean | Add Application | Results | **Manage 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 to remove any information provided by the map.

Latitude (e.g. 42.443) 42.55644705C 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 Button	Edit 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. Select Fertilizer Application

Crop Information

Grains: 110 d crm

Planting Date 04/15/2012 32,500 plants/acre

Grain Cultivars: Expected Yield (bu/acre) 190 - 210

Adapt-N Interface: entering Soil/Tillage info

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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

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)* 6

soil organic matter: *(%)* 3.5

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

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.***

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

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? sod not applied

Previous Crop

Please select the previous crop for this location.

soybean

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

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 = $CropN_{Harvest}$ - $CropN_{Current}$ - $SoilN_{Current}$ - $SoilN_{postsidedress}$ - $SoybeanN_{Credit}$ + $Loss_{postapplication}$ - $Correct_{profit}$

$CropN_{Harvest}$	205 *(lbs N/acre)*
$CropN_{Current}$	65 *(lbs N/acre)*
$SoilN_{Current}$	28 *(lbs N/acre)*
$SoilN_{postsidedress}$	7 *(lbs N/acre)*
$SoybeanN_{Credit}$	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

$$\mathbf{SidedressNrate = CropN_{Harvest} - CropN_{Current} - SoilN_{Current} - SoilN_{postsidedress} - SoybeanN_{credit} + NLoss_{postapplication} - Correct_{profit}}$$

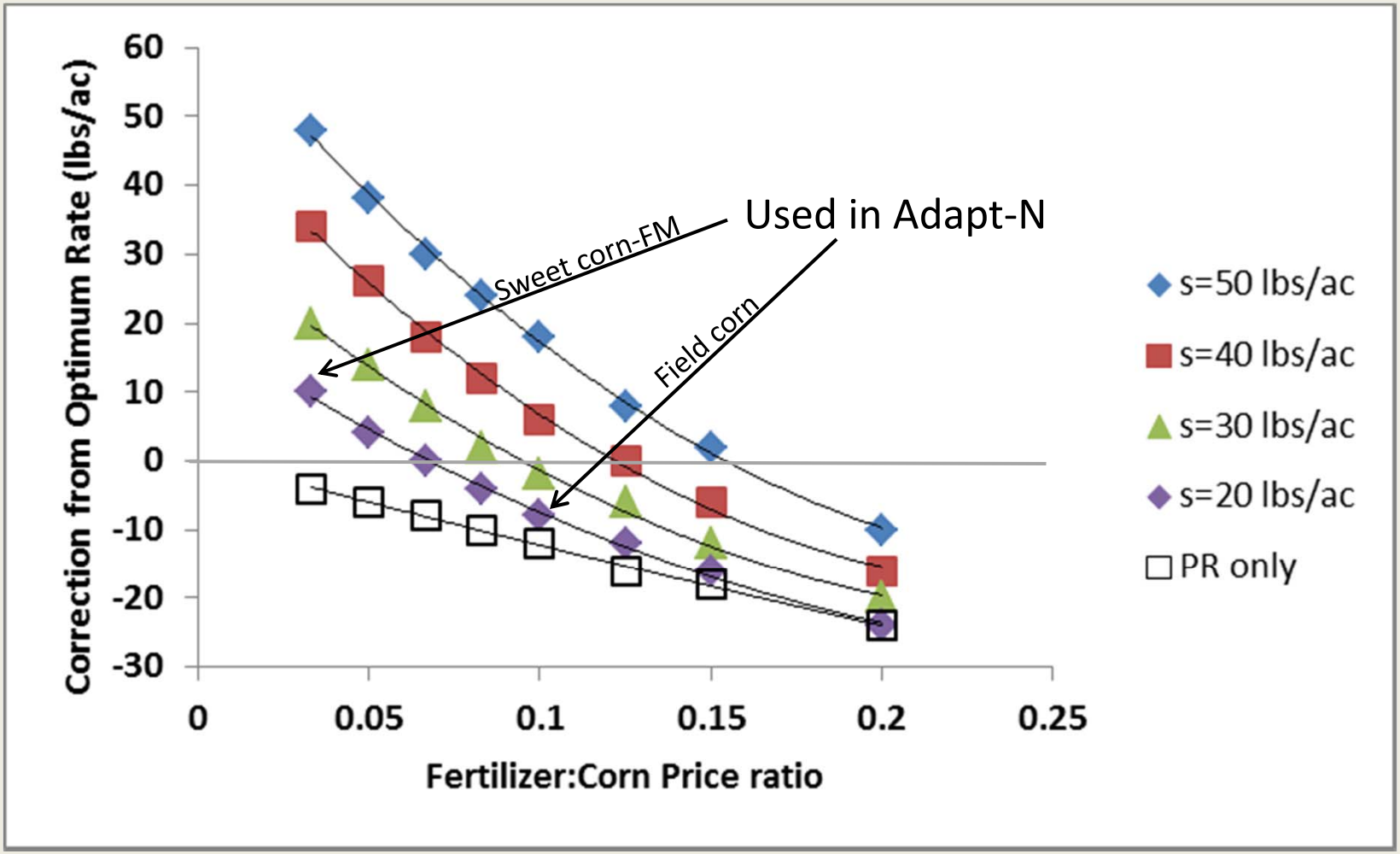
Now: simulated & partial fixed credit

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 <u>higher</u> rates than the <u>average</u> 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