How to pick a nitrogen rate?

Empirical, Mechanistic, or Faith-based?

Josh McGrath

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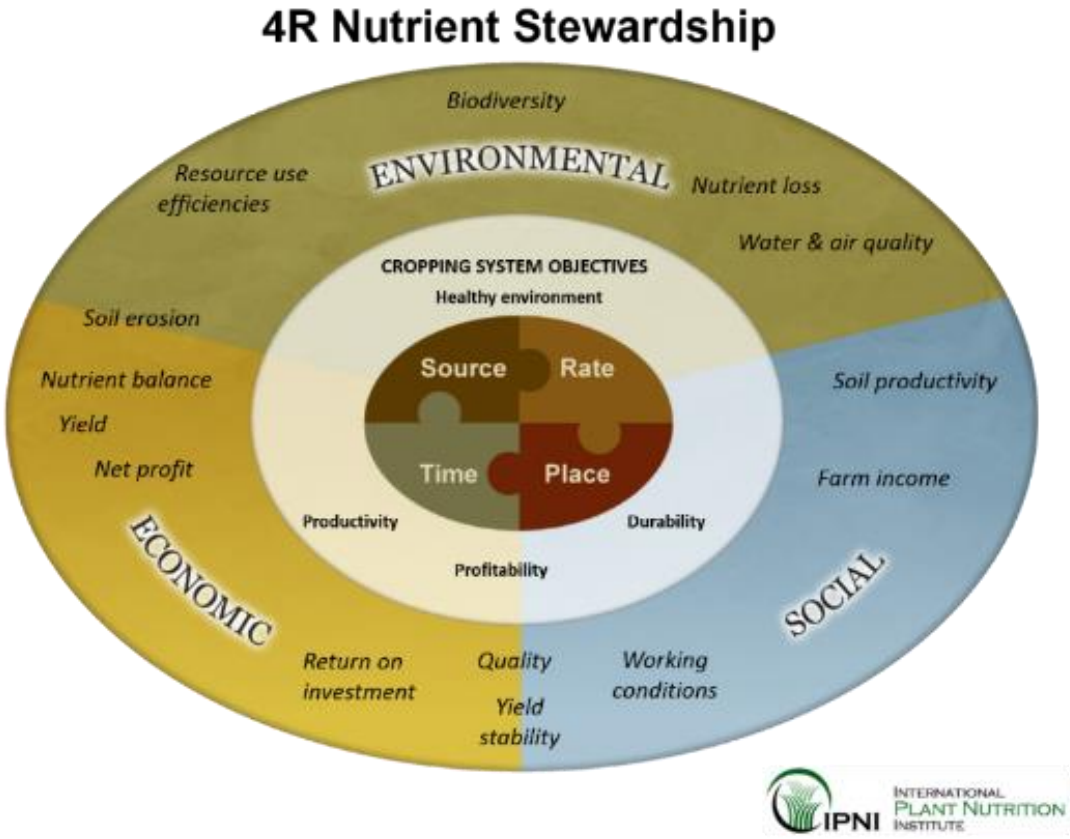
Thank you for funding our N research in KY and IL

4R performance objectives

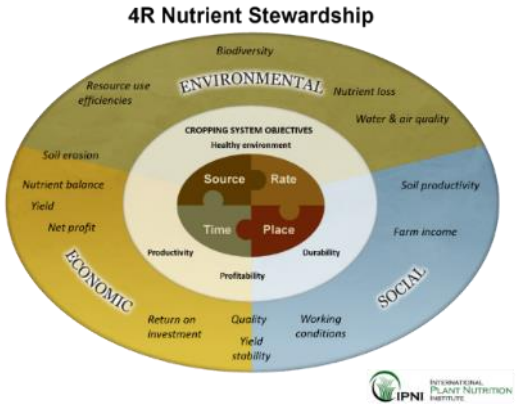
- Performance objectives define “Right”
- Competing objectives?
  - Optimized production
  - Minimize environmental impact
  - Maximize Economic Return



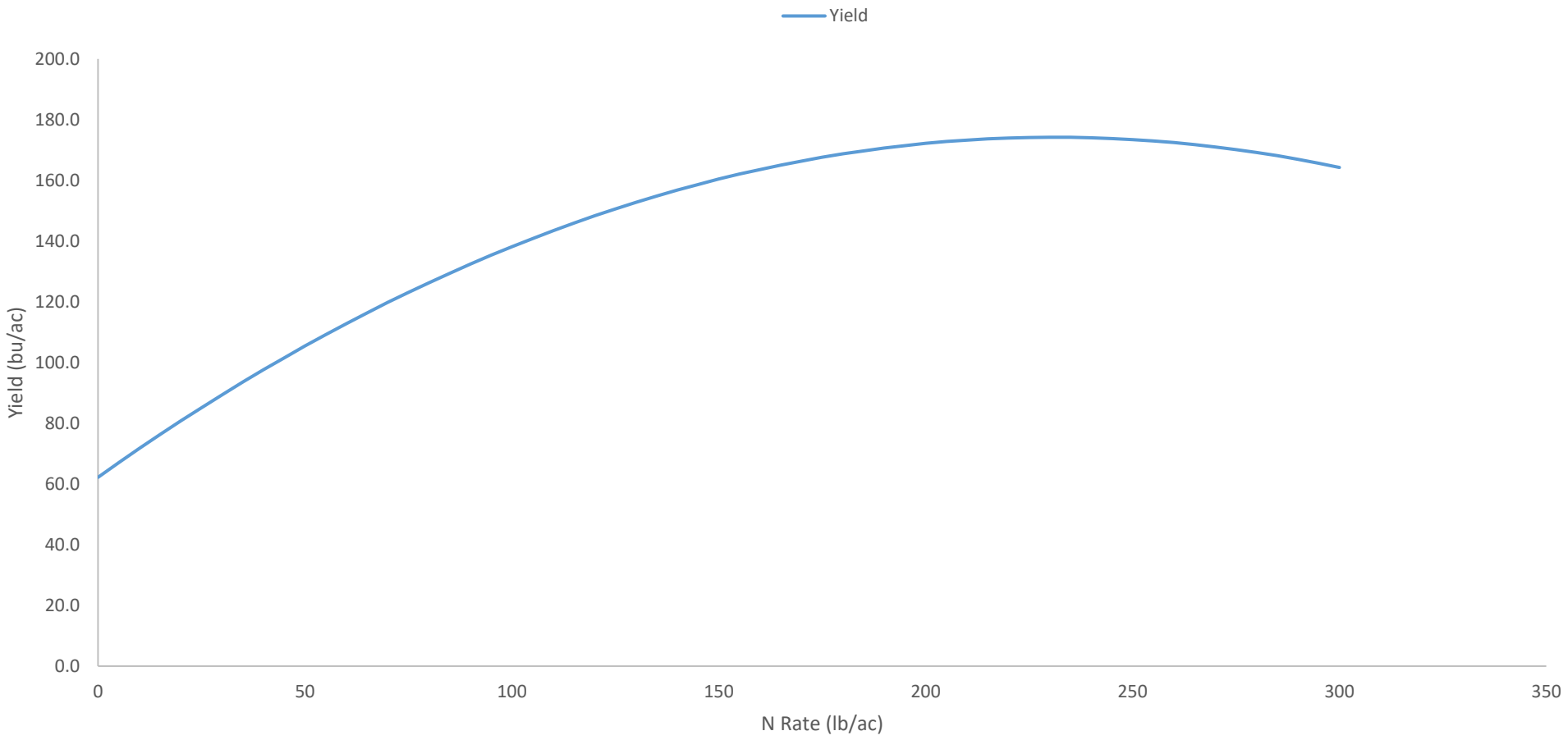
Balancing the “Right”

- Performance objectives define “Right”
- Competing objectives?
  - Optimized production
  - Minimize environmental impact
  - Maximize Economic Return

- How do we balance tradeoffs
  - Max yield ≠ max profit
  - Max profit ≠ environmental optimum
- The most profitable system will likely have some level of environmental impact

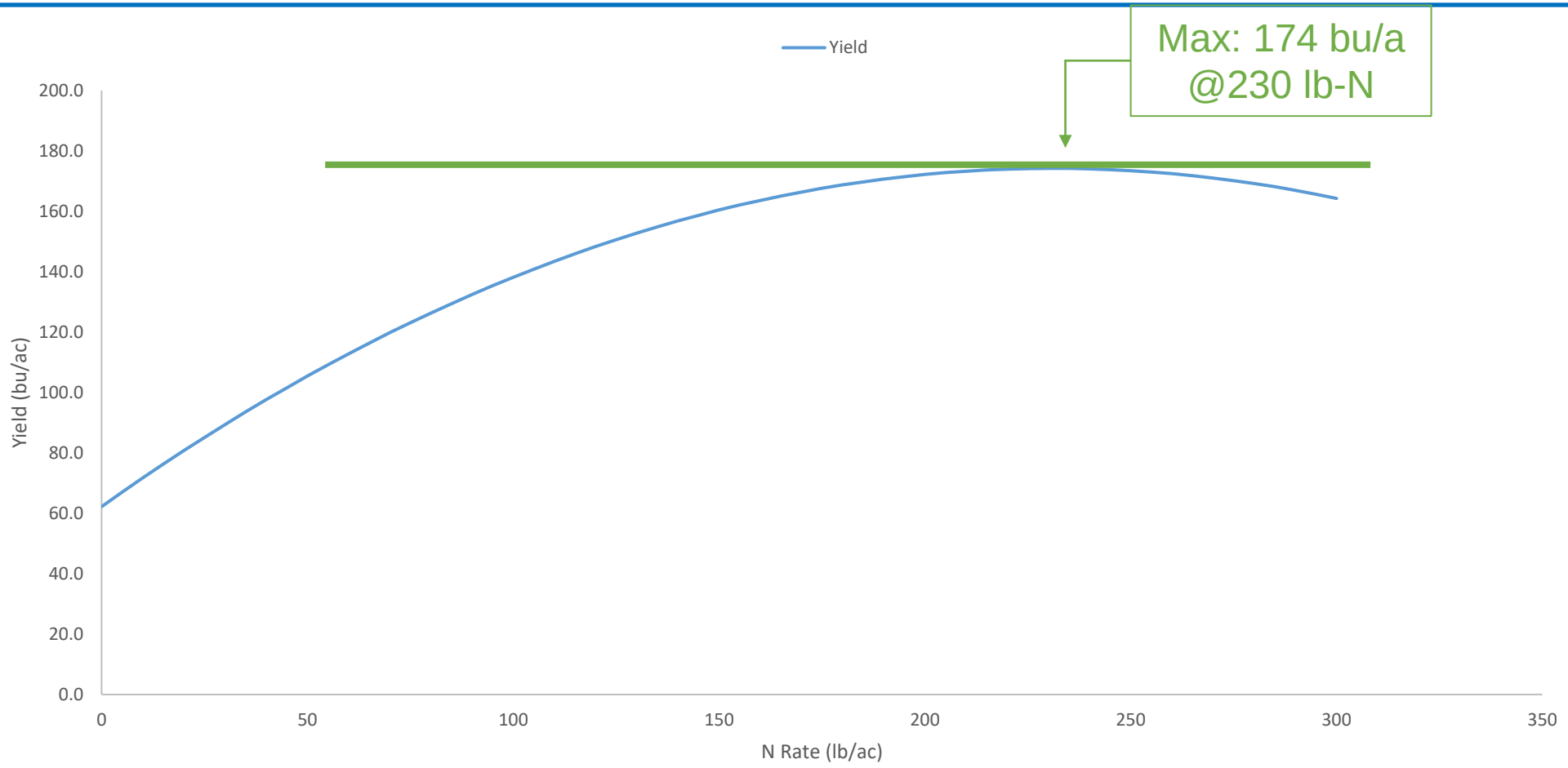


Why does precision matter?



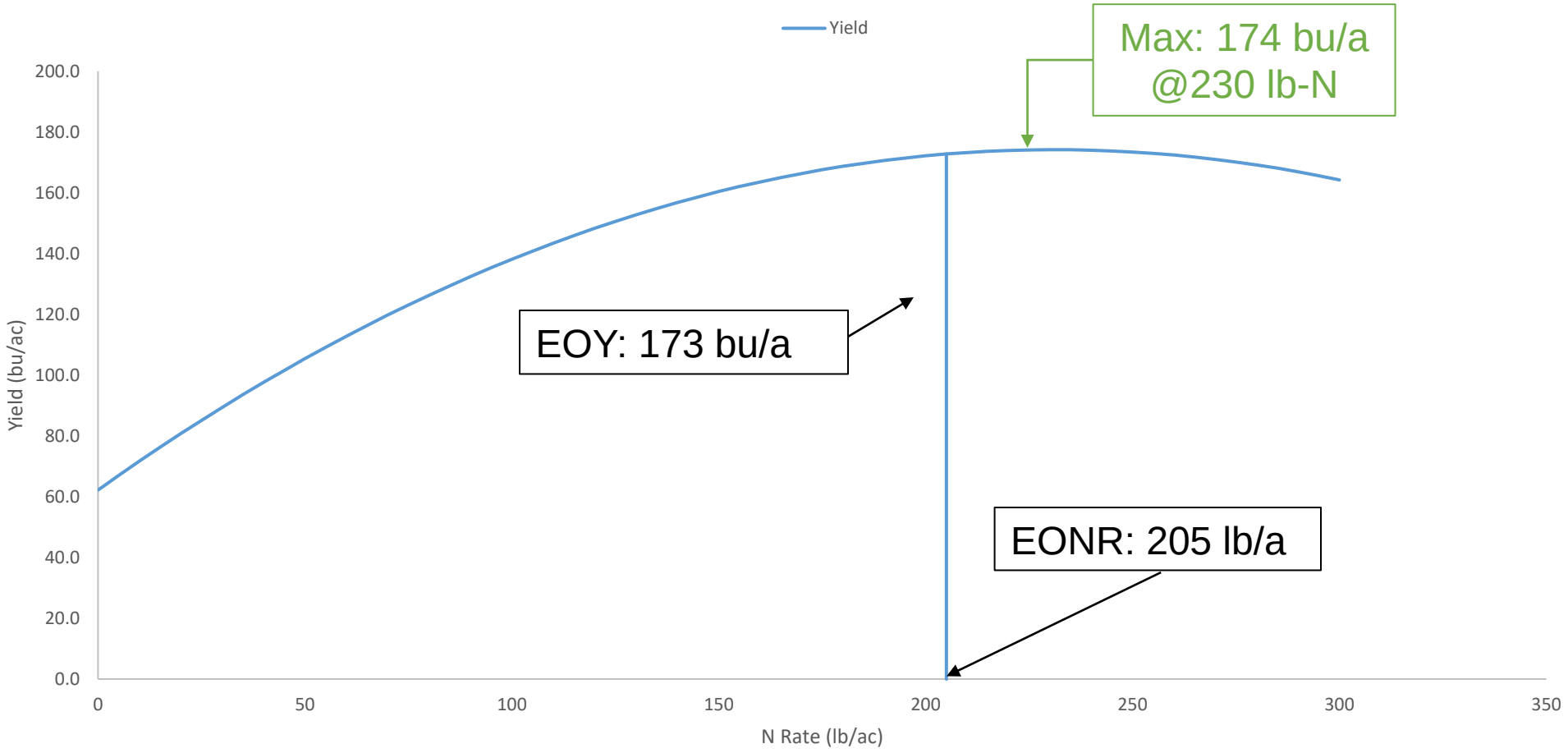
Data courtesy Frank Coale

Agronomic Optimum



Data courtesy Frank Coale

Agronomic ≠ Economic Optimum



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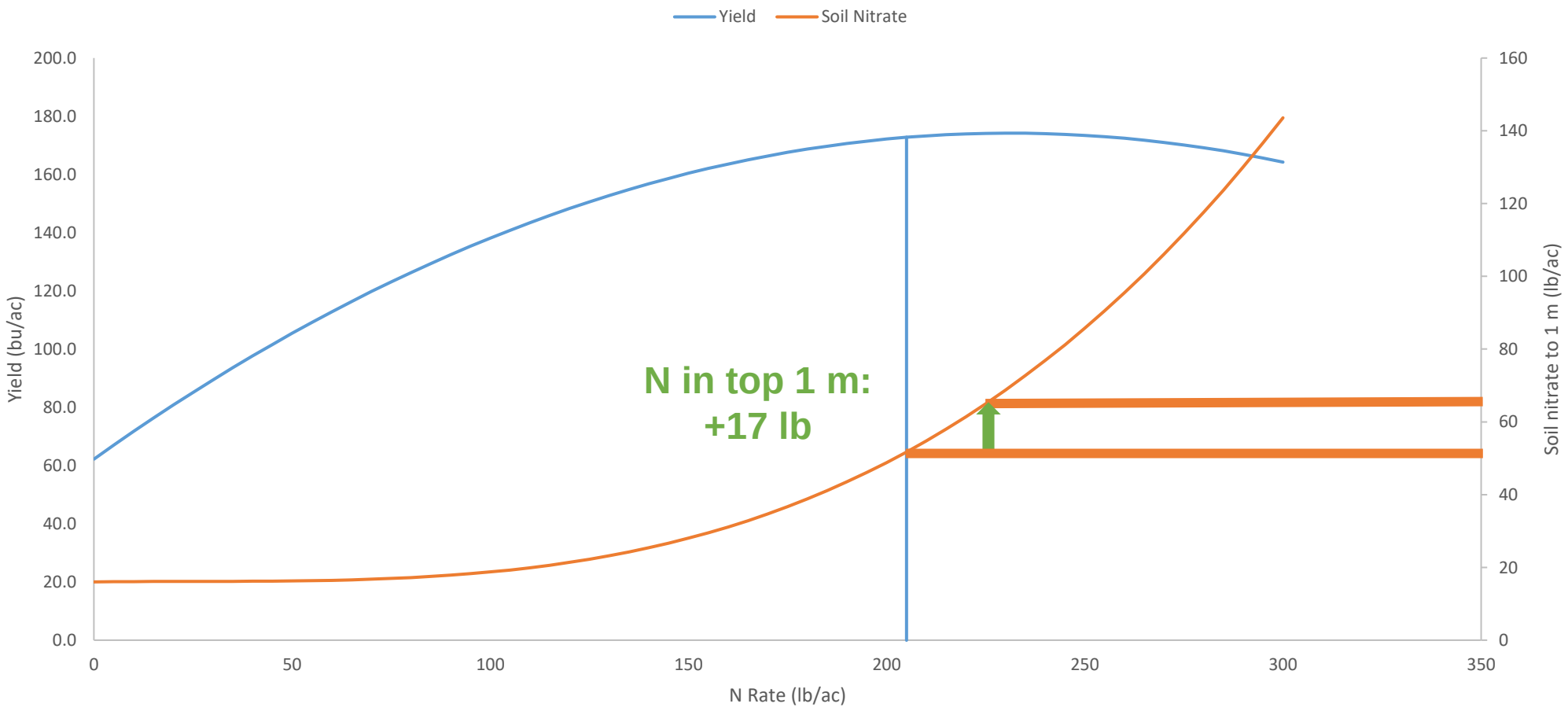
Agronomic ≠ Economic ≠ Environmentally Optimum

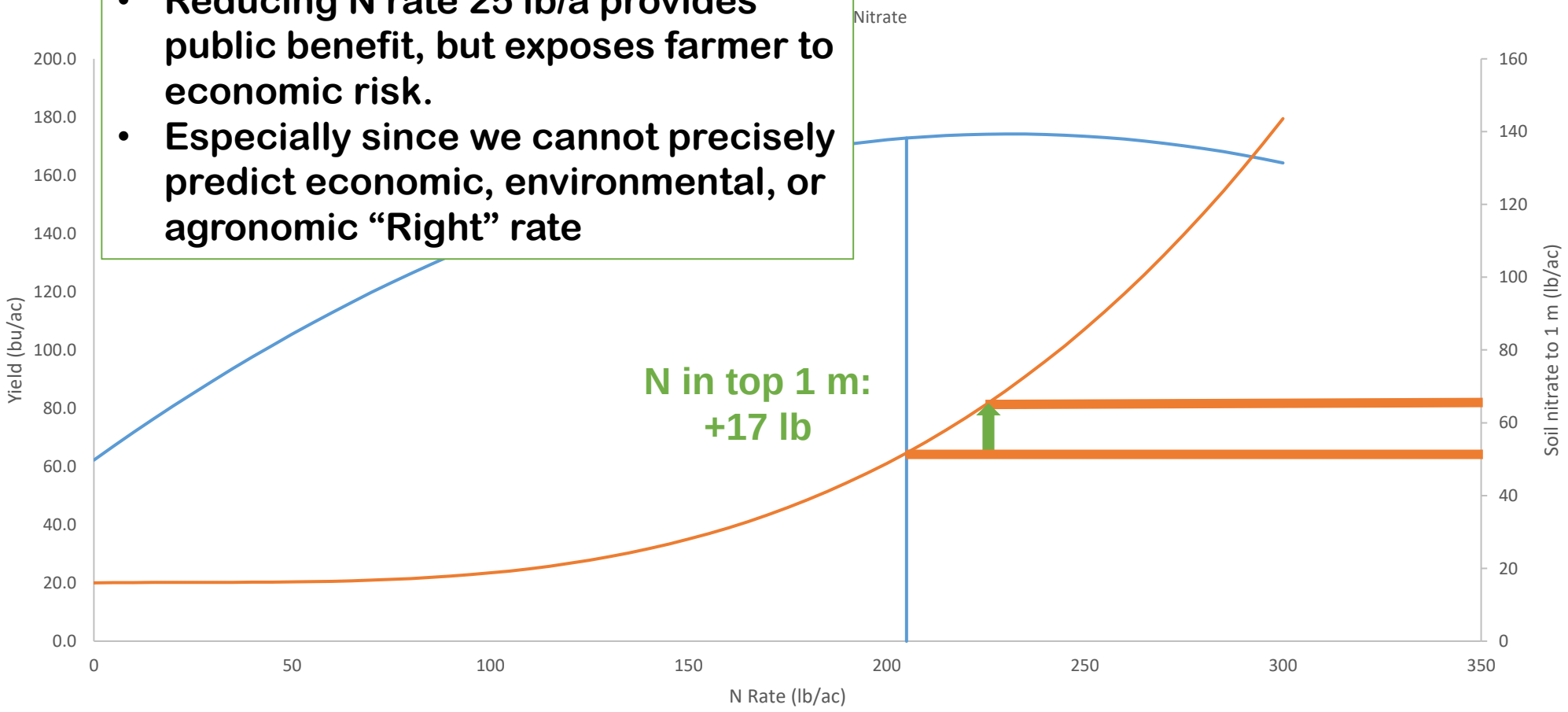


Data courtesy Frank Coale

Agronomic ≠ Economic ≠ Environmentally Optimum

Why precision matters:

- **Reducing N rate 25 lb/a provides public benefit, but exposes farmer to economic risk.**
- **Especially since we cannot precisely predict economic, environmental, or agronomic "Right" rate**

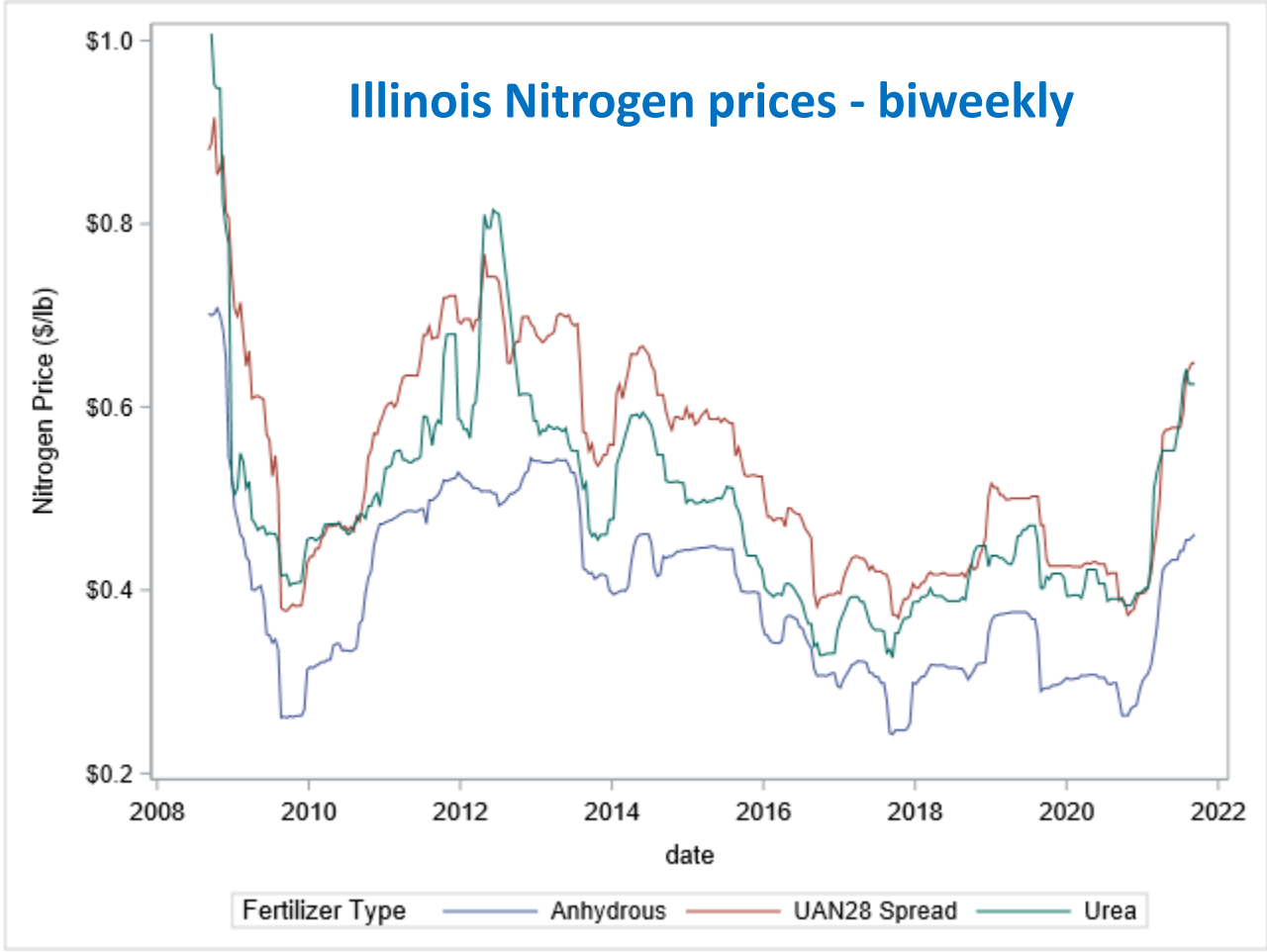


Data courtesy Frank Coale

Current nitrogen economics

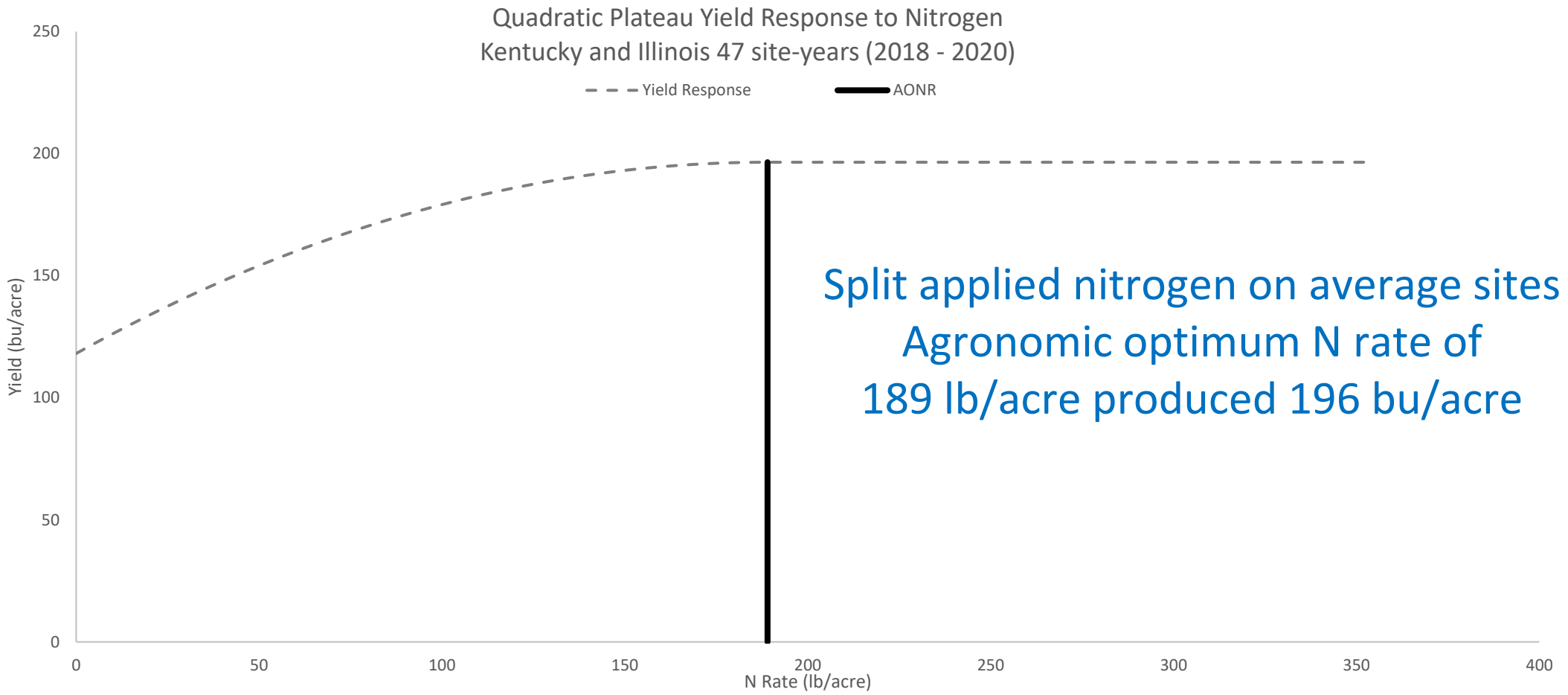
Adjusting for high prices

What's up with nitrogen prices?



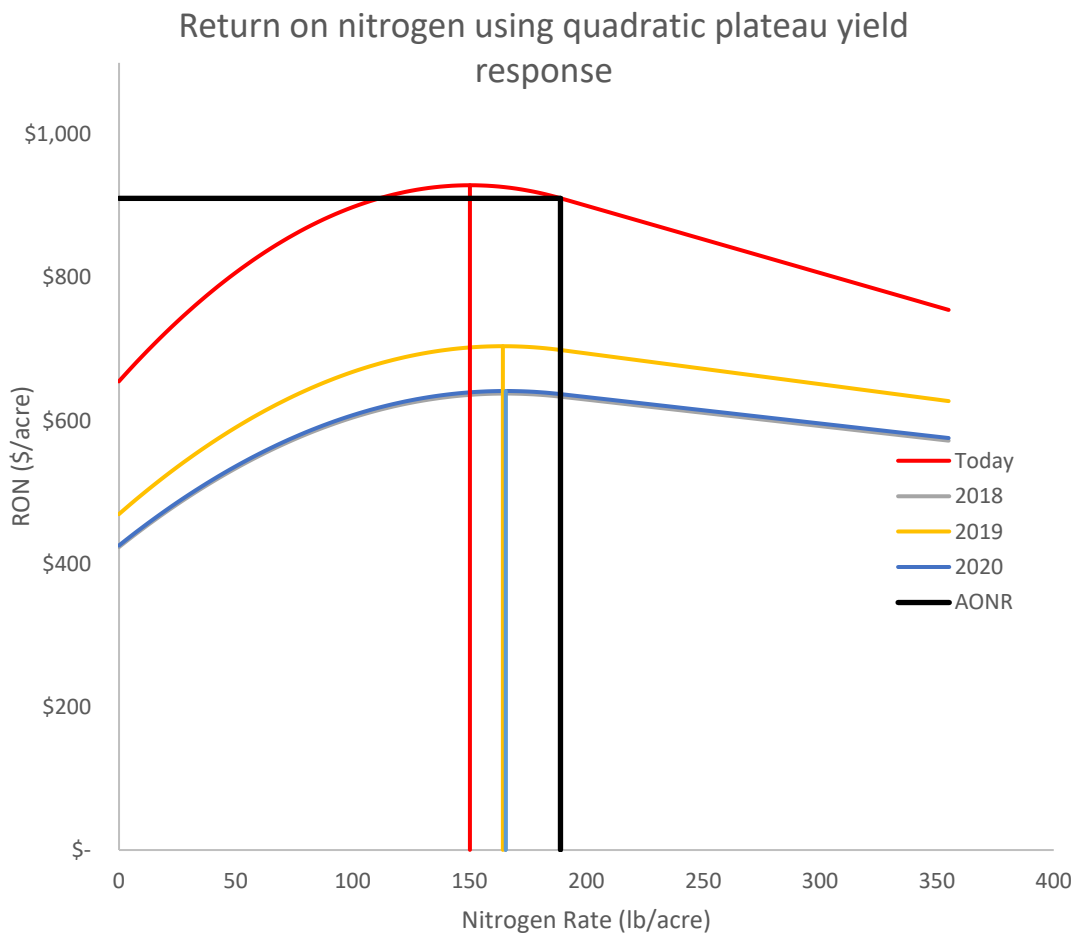
Source: USDA Agricultural Marketing Service. Illinois Production Cost Report (Bi-Weekly). https://www.ams.usda.gov/mnreports/gx_gr210.txt (accessed 22 September 2021).

How does price influence N rate?



Split applied nitrogen on average sites
Agronomic optimum N rate of
189 lb/acre produced 196 bu/acre

Price ratio of N:grain has a small influence on rate

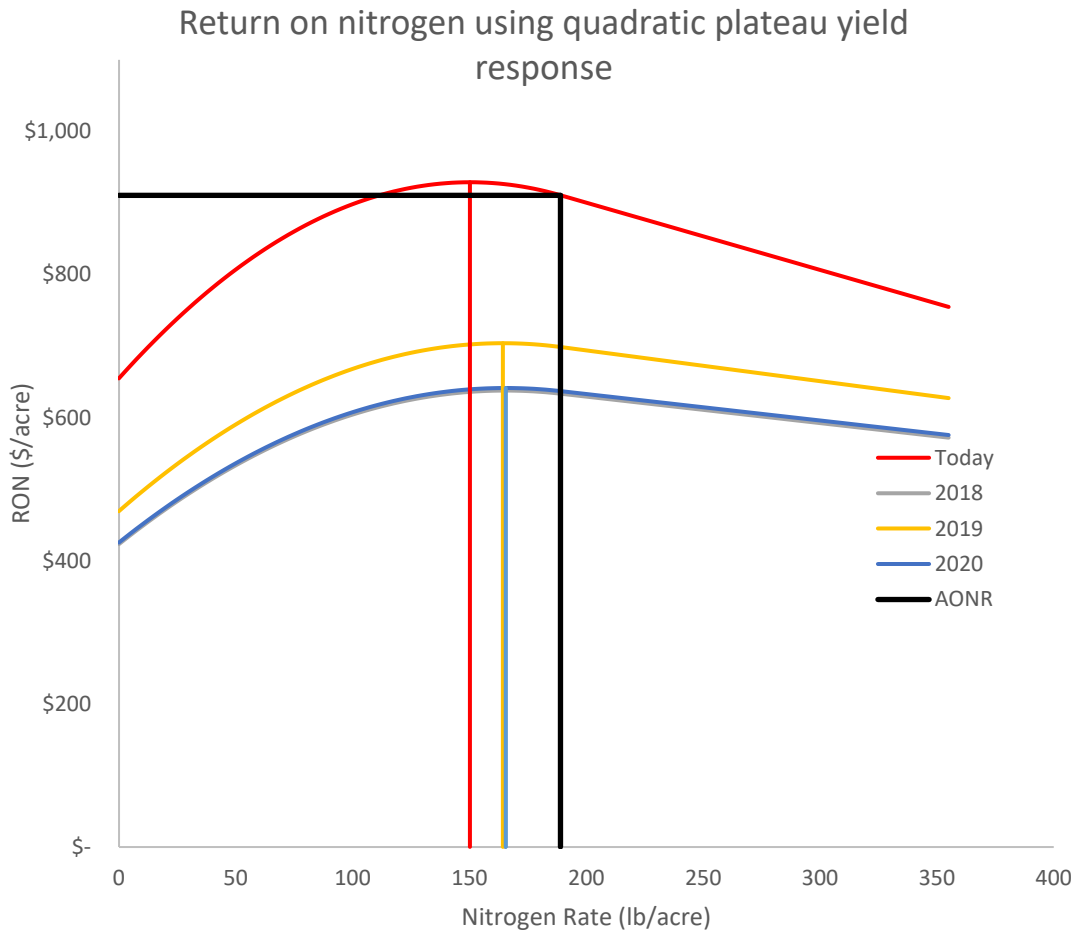


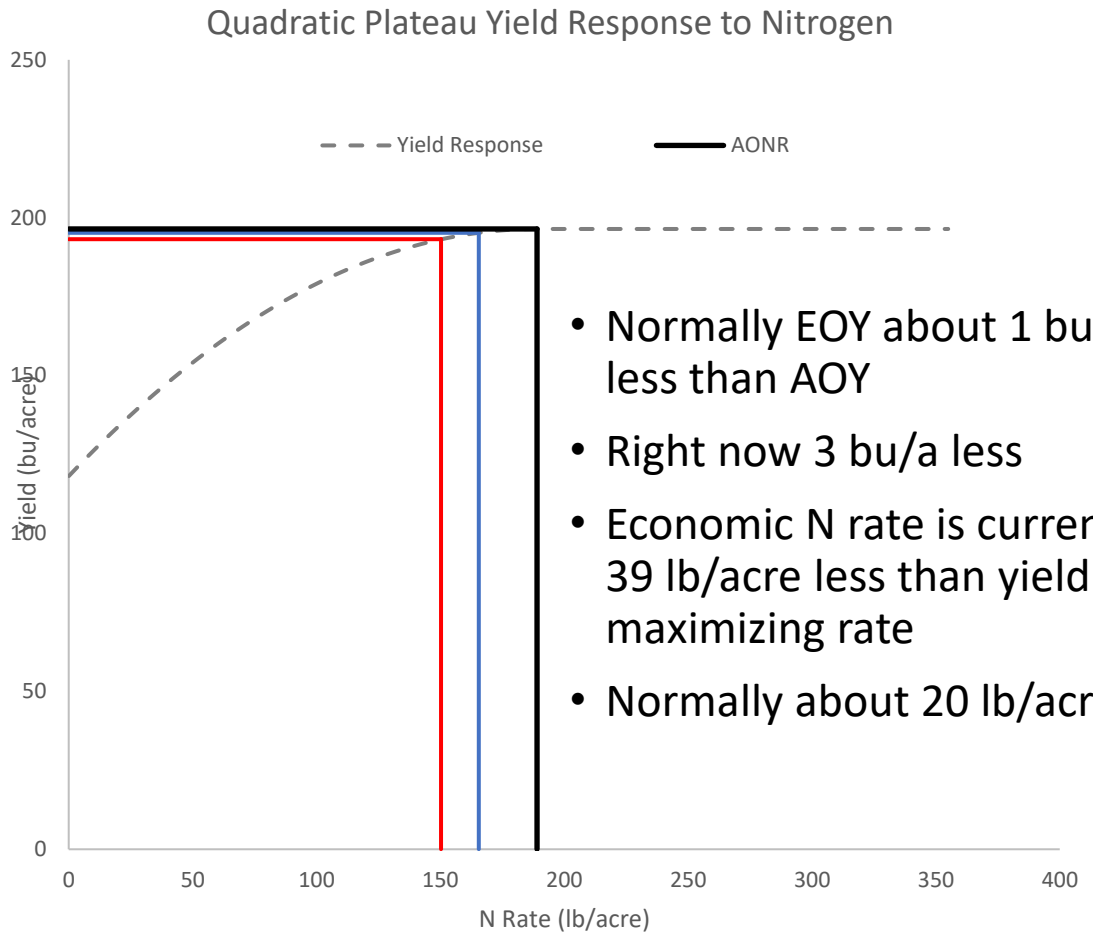
	Nov-21	Aug-18	Aug-19	Aug-20
Grain ($/bu)	$5.54	$3.58	$3.97	$3.60
N ($/lb)	$0.94	$0.37	$0.43	$0.37
Price Ratio	0.17	0.10	0.11	0.10
EONR (lb/a)	**150**	**165**	**164**	**166**
RON - EONR	$929	$638	$704	$642
RON - AONR	$911	$633	$699	$637
EOY (bu/a)	*193*	*195*	*195*	*195*
AOY (bu/a)	*196*			

- Price ratios stay steady - *mostly*
- Normally 5 lb/acre N rate swing
- Normally about $5 between yield max (AONR) and EONR
- What's our risk?

Grain Price data: USDA Agricultural Marketing Service. State Grain Reports | Agricultural Marketing Service. https://www.ams.usda.gov/market-news/state-grain-reports#Kentucky (accessed 22 November 2021).

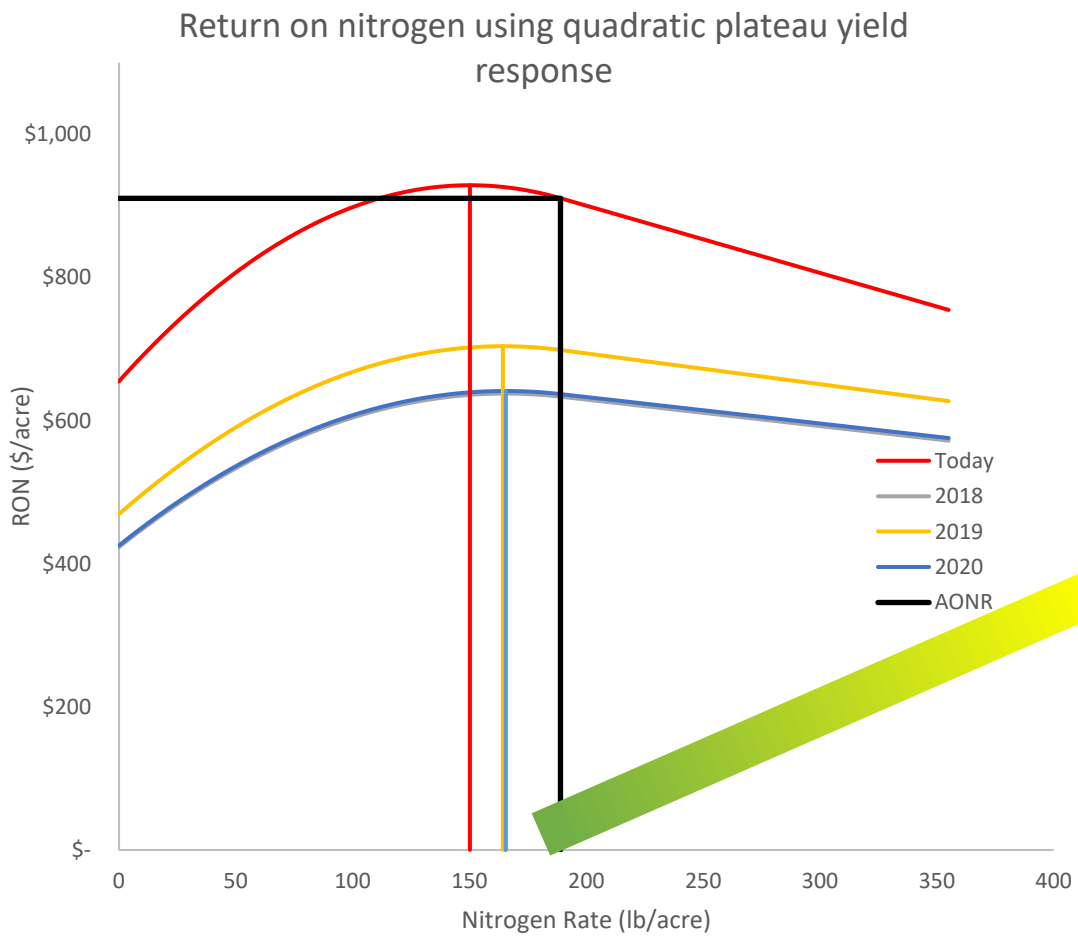
Price ratio of N:grain has a small influence on rate

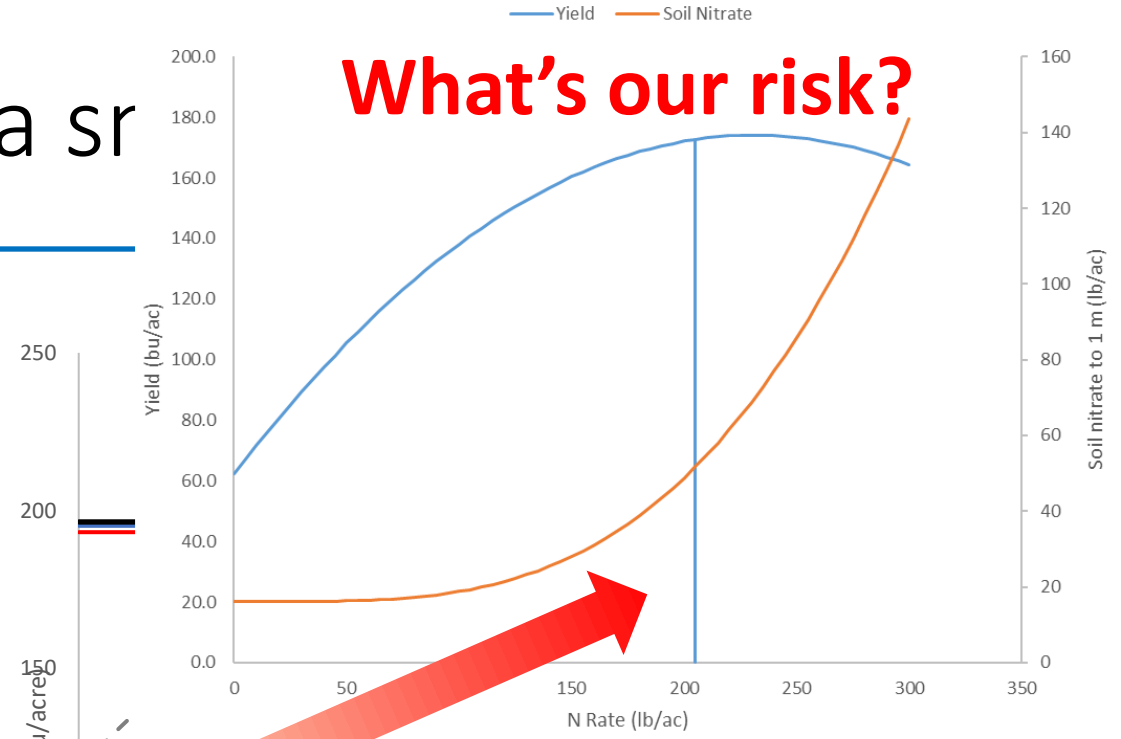




- Normally EOY about 1 bu/a less than AOY
- Right now 3 bu/a less
- Economic N rate is currently 39 lb/acre less than yield maximizing rate
- Normally about 20 lb/acre

Price ratio of N:grain has a sr





What's our risk?

a

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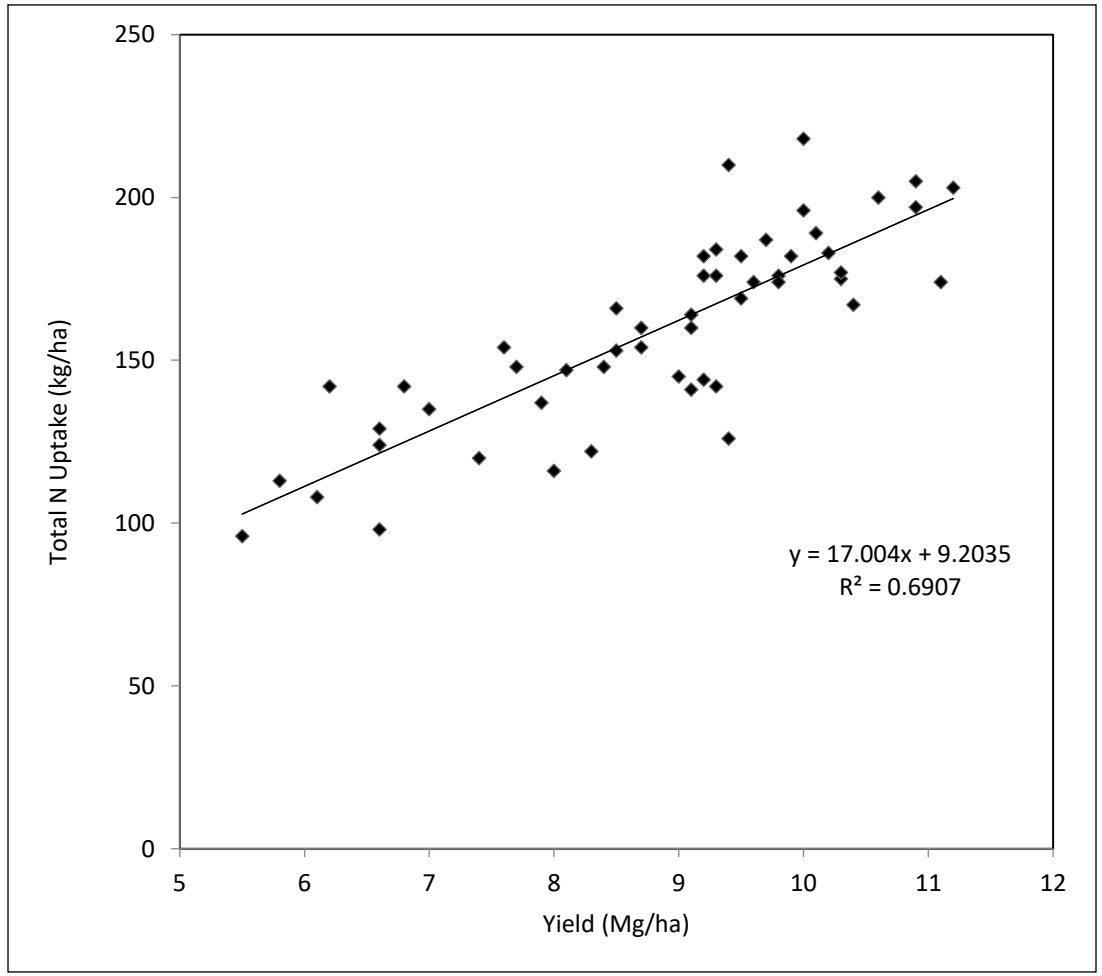
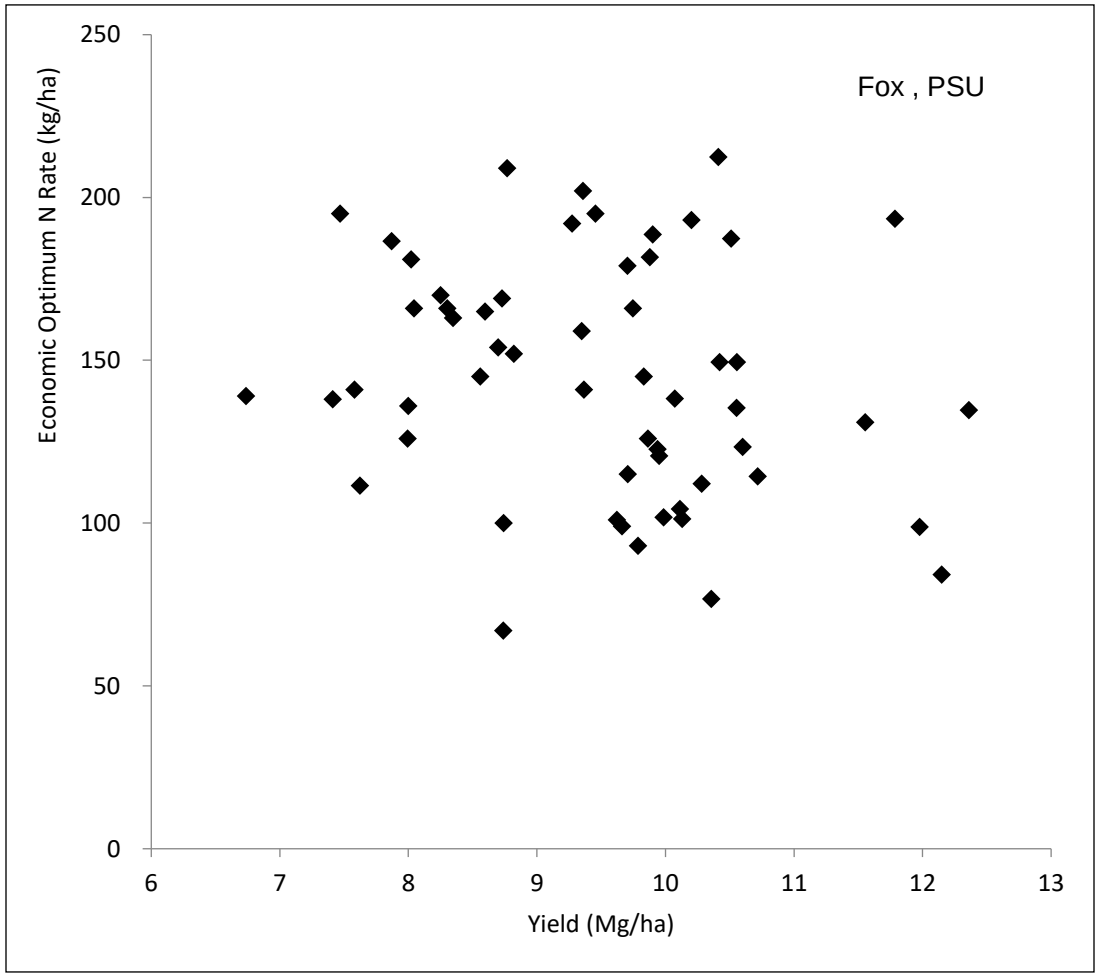
Components of nitrogen requirement

Stanford's push towards mechanistic recommendations

Stanford's Equation as a framework for N recommendations





Stanford's Equation for N

Stanford has been much maligned and often misrepresented. His critics assert that Stanford simply proposed to multiply 1.2 by the expected or even targeted yield. Quite to the contrary Stanford proposed a mechanistic approach to counter the prevailing empirical approach of his time.

What Stanford actually wrote (1966):

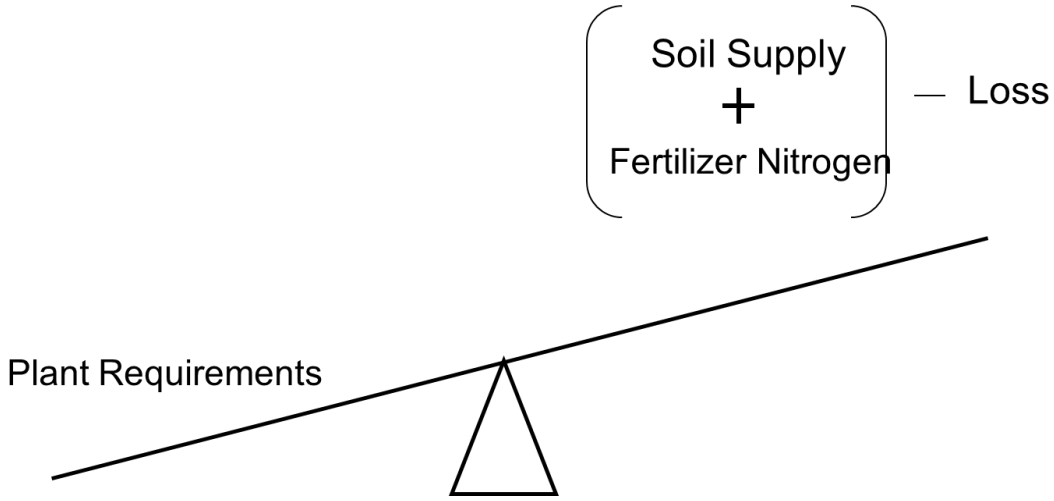
> *"In formulating recommendations for nitrogen fertilizer use, agronomists and soil scientists have relied mainly on experience and interpretations of the numerous field and associated laboratory studies conducted over the years…Future progress, however, demands that less empirical means be developed for predicting and meeting the nitrogen needs of crops."*

Stanford, George. "Nitrogen Requirements of Crops for Maximum Yield." In Agricultural Anhydrous Ammonia Technology and Use, 237–57. Madison, WI: American Society of Agronomy, Soil Science Society of America, 1966. https://doi.org/10.2134/1966.nh3agricultural.c13.

Stanford's equation: basic mass balance

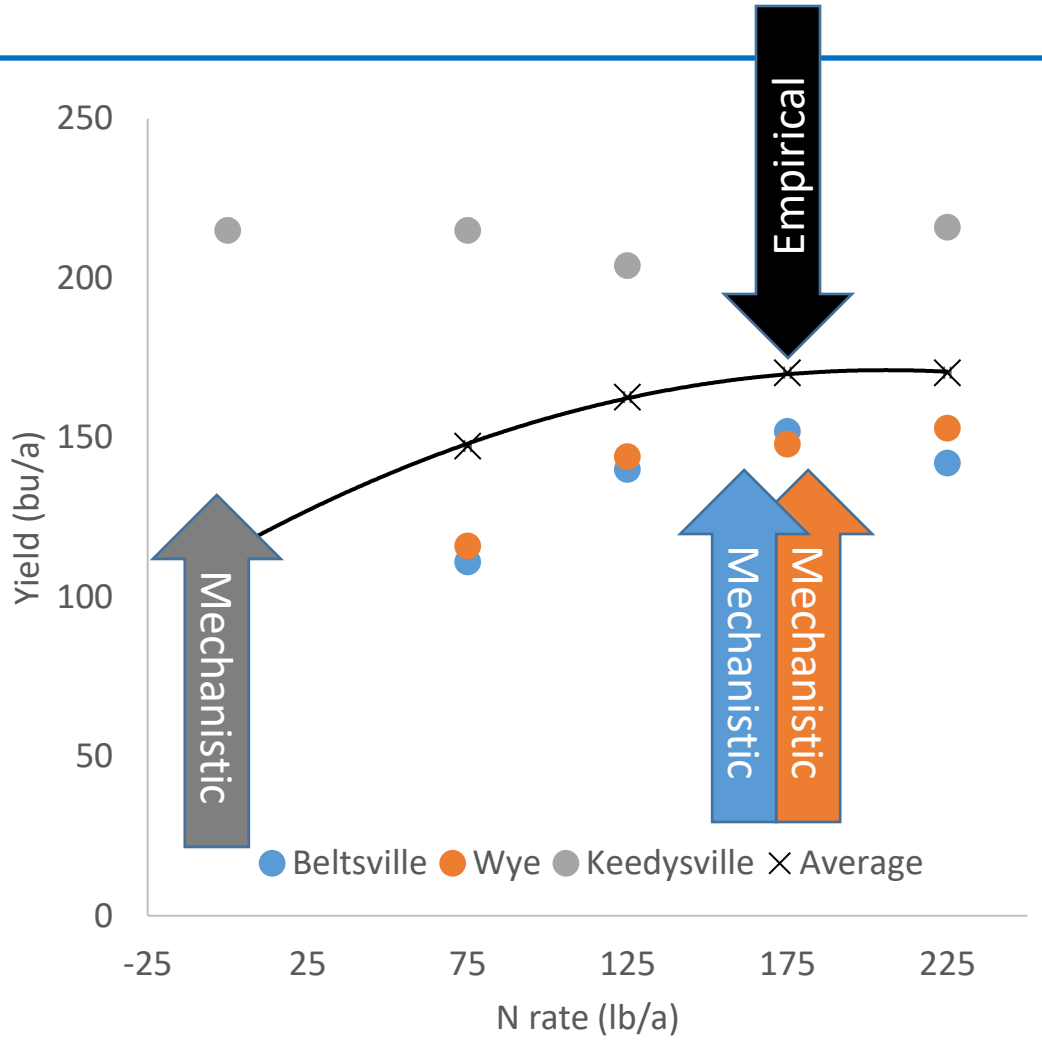
$$Fertilizer = \frac{Plant\ Need - Soil\ Supply}{e_{fert}}$$

- How much does the plant need?
- How much does the soil supply?
- e_{fert} is the fertilizer efficiency or percentage applied that gets to the plant



Mechanistic versus empirical models

- It is a challenge to estimate the components of Stanford's equation
  - Size of soil N pools
  - Rate and timing of transformations – particularly organic N mineralization
  - Efficiency of N supply from those pools
- We need to continue to strive towards more mechanistic approaches



Nitrogen Requirement is Complex

- Nitrogen requirement to achieve maximum yield for cereal grains is determined by N responsiveness, N availability, and potential yield.
  - All three factors vary spatially and temporally
  - All three factors are independent of each other and independent of time.
- Soil type, climate, and previous management vary in space and time and influence yield potential, N availability, and N responsiveness independently.
- **N surpluses exist because our recommendations don't *precisely* match seasonal and spatial variability in requirement and loss**

Modified from Raun et al., 2010

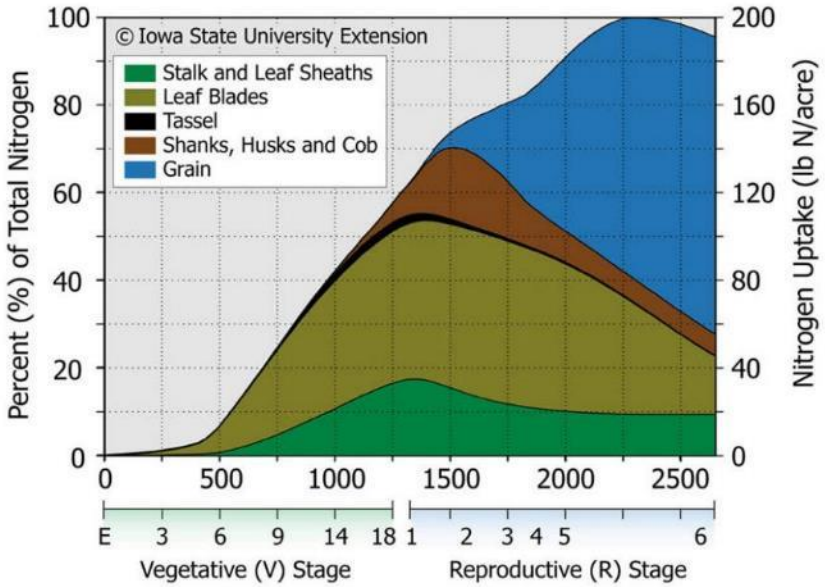
Basic tools to help us do a little better

Adding mechanisms to our model

Use tools to adjust to conditions

- Pre-sidedress Soil Nitrate Test (PSNT)
  - Best for manured soils
  - 12” soil sample when corn is 12” tall
- Chlorophyll meter
  - 6 leaf stage
  - Reference area
- NDVI Sensor
  - Handheld GreenSeeker
  - Effective V6 – V10
  - Reference area

- Late season stalk nitrate test
  - Assessment of N management program
  - Between ¼ milk-line (before silage harvest) to about 3 weeks after black layer formation
  - 8-inch segment starting 6 inches above ground
- Reference Strip
  - In field assessment (visual or with optical device)
  - Overlaid on producer practices
  - Incorporates seasonal influences on N availability



Total N Requirement =

Starter + Pre + In-season

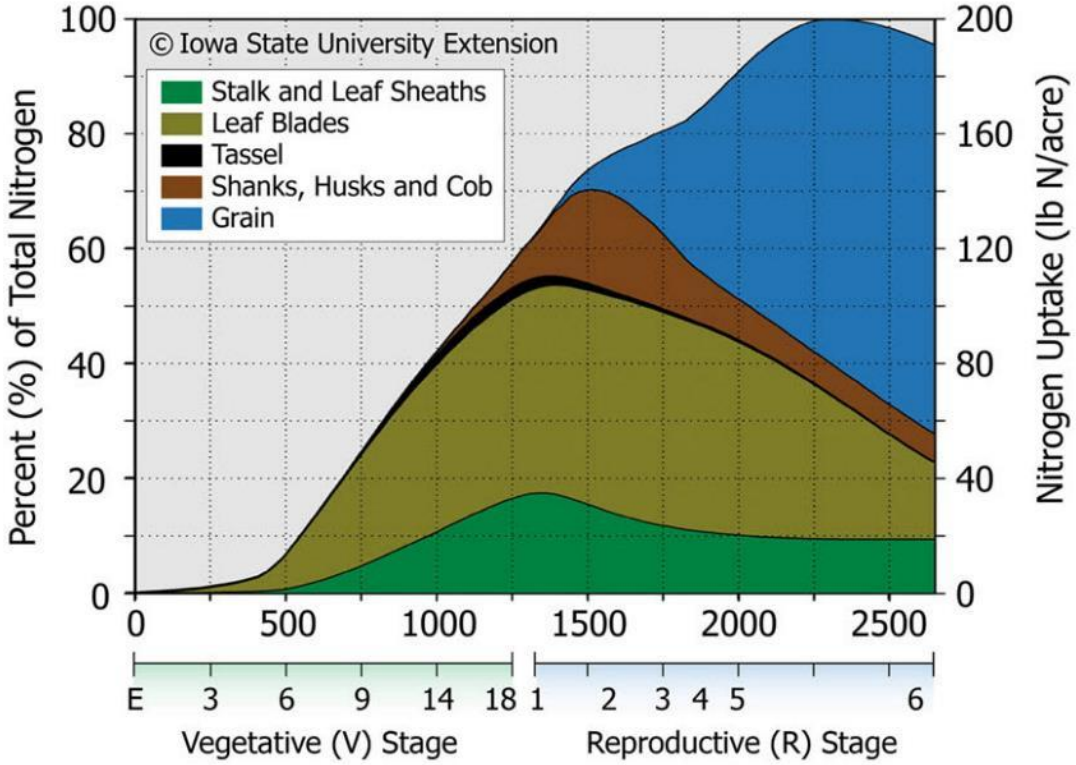
Predictive & Reactive

How do we adjust N management?

- Predictive approach
  - Adjustments made based on historic or temporally fixed data (e.g. yield history, soil zone)
  - Data intensive – Data driven
  - Basis for zones?
- Reactive approach
  - Reacts to need expressed by crop
  - Requires a crop in the field
  - Still need information and interpretation to make decision

Nitrogen 4Rs: **Timing is the big lever!**

- If the N is not yet applied, it can't be lost
- Apply the N when it is required by the crop
- Split application gives us the opportunity to assess the situation and adjust our plan
  - **Predictive + Reactive**



Total N Requirement =
Starter + Pre + In-season

What is side-dressing?

- In-season N application as rapid growth starts (V4 or later).

PSNT performs extremely well on manured fields

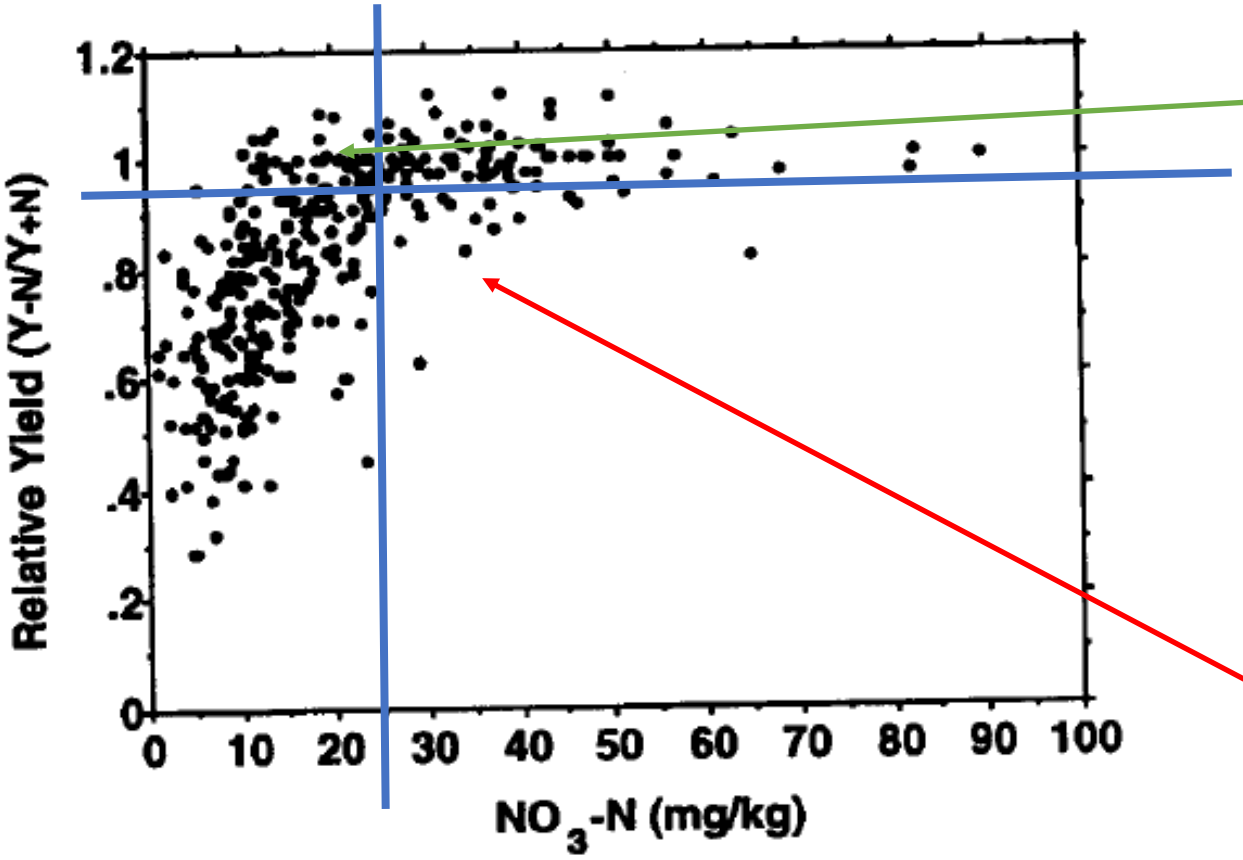
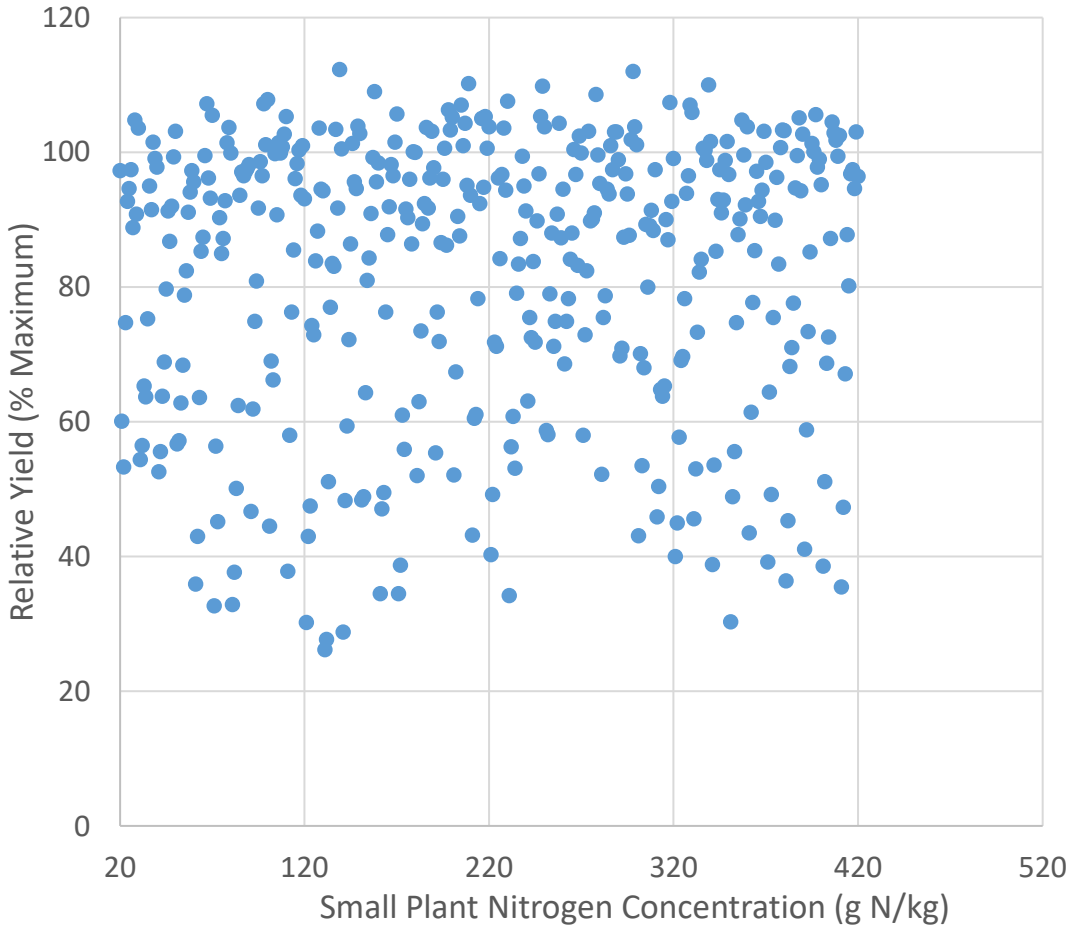
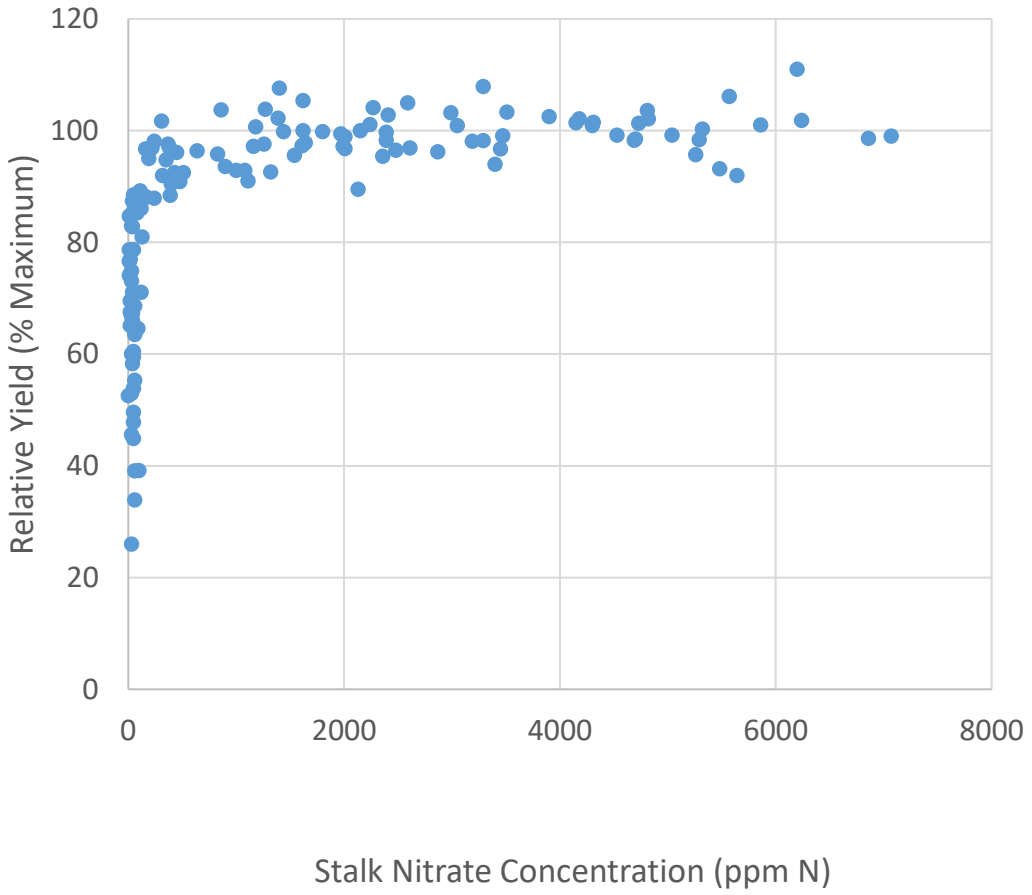


Fig. 3. Relationship between PSNT soil test levels and relative yields (341 year-site response situations include data in Magdoff et al., 1990, plus data from New York through 1991)

- False positive:
  - Leaching of NO_3-N from surface 12" prior to sampling, but significant amounts remain
  - Cool wet (or sometimes very dry) weather before sampling
  - Much better conditions for mineralization after sampling
- False negative:
  - Excessive leaching after sampling

What about tissue testing?!





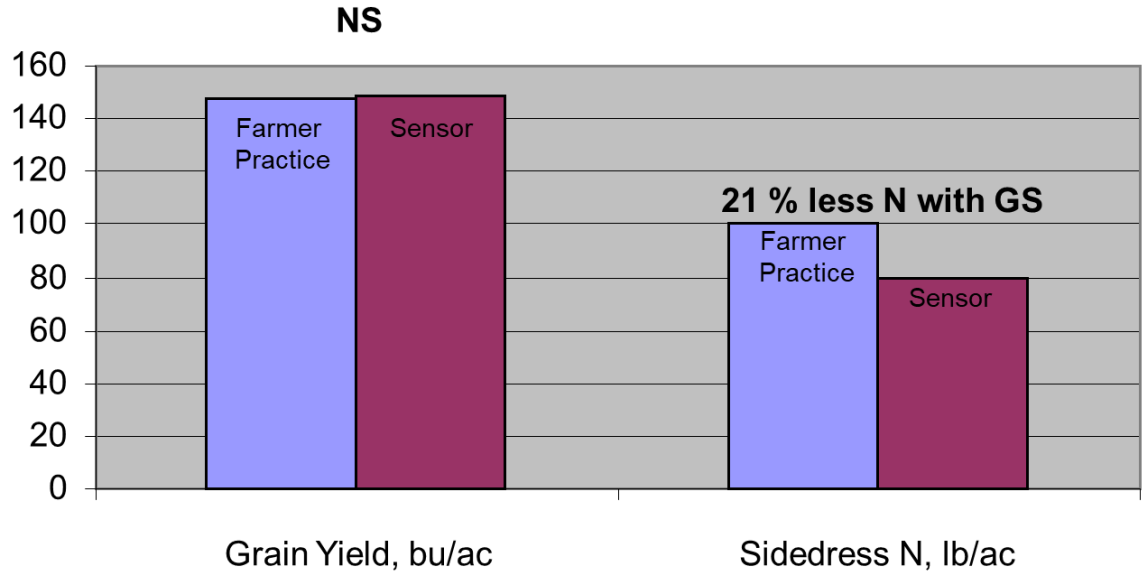
Courtesy Greg Binford

Active Optical Sensors

- Emit light in the red and near infrared wavelength (60/sec)
- Average reflectance measurements calculated every second
- Calculates simple ratio or NDVI
  - NDVI = (NIR – Red)/(NIR + Red)
- Correlate sensor reading to crop vigor and N need
- Not affected by:
  - Light conditions
  - Atmospheric conditions
  - Variety

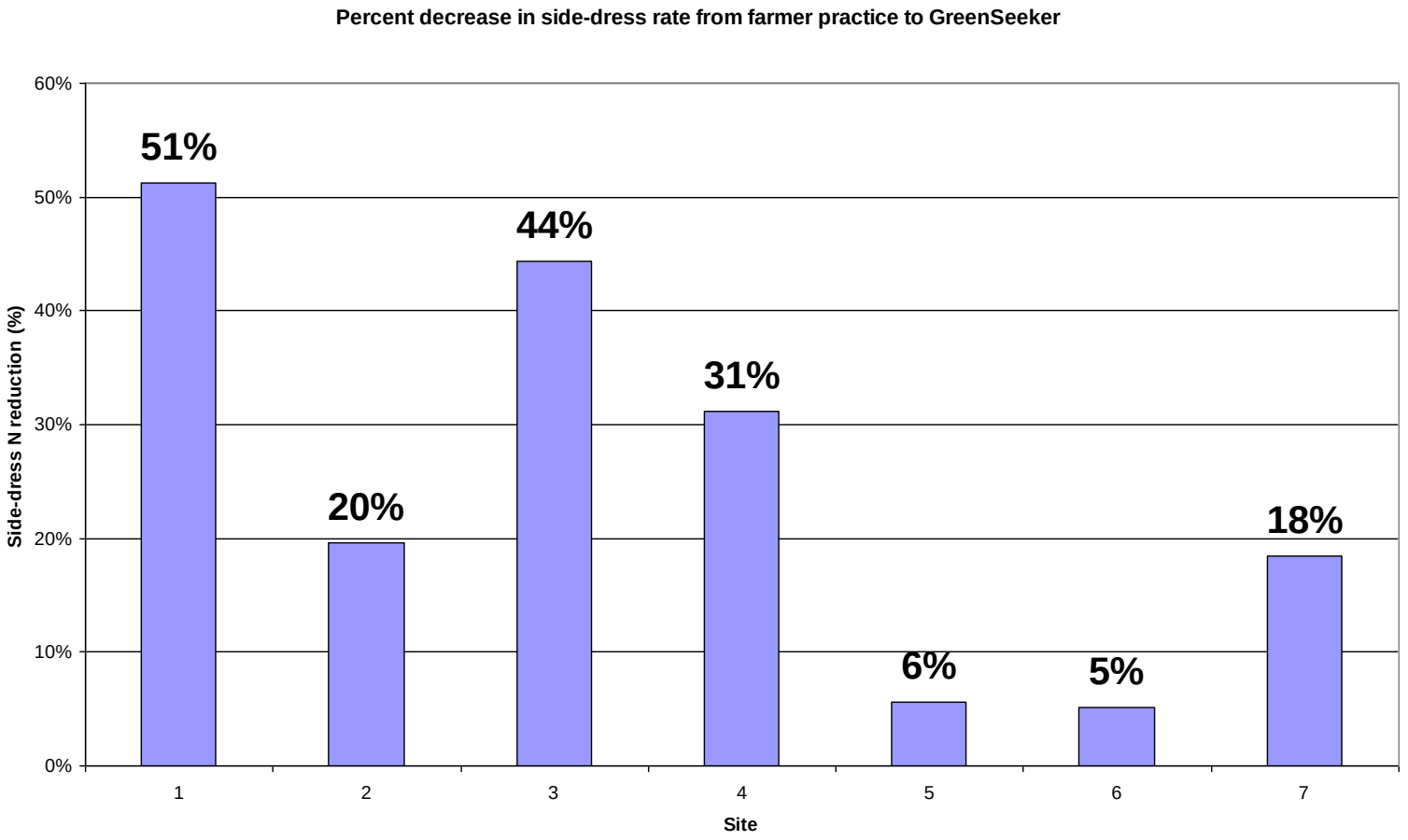
We need new methods for rate decisions

- Sensors can use models and plant response to early growing conditions to adjust rate ***spatially*** and ***temporally***
- Some models address yield potential and N responsiveness independently
- There are two distinct approaches to N rate calculations.
  - Use of Yield Prediction and Response
  - Use of Response only



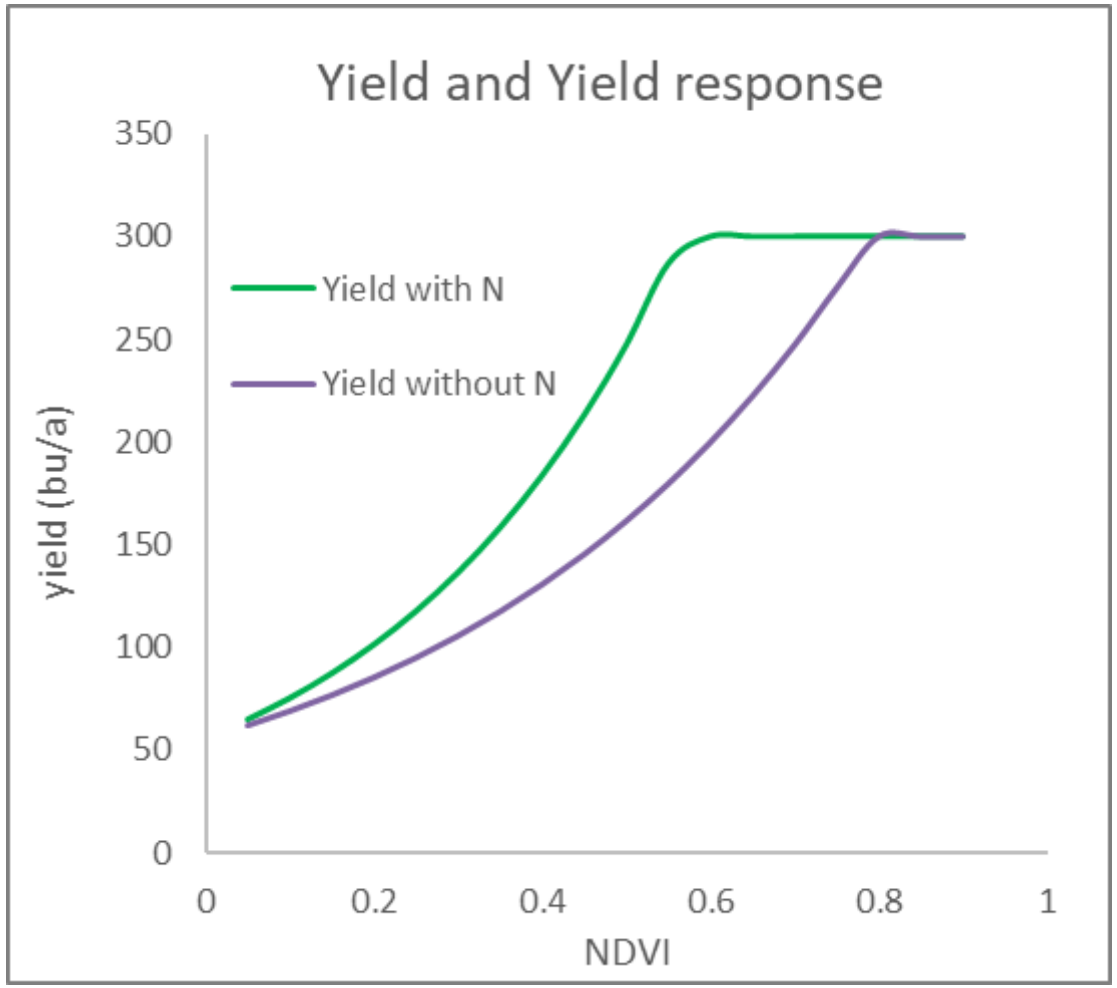
To be precise…

2010 Average Reduction = 25%



Response

- Response is thought of in two ways.
  - RI: Ratio of high N reference to standard or low pre-plant N
    - Increase in yield due to N
    - RI 1.2, Expect an increase in yield of 20% w/ N
  - SI: Percent of high level low/high <1.0
    - Sufficiency of standard practice
    - Typically uses a Base N rate
    - SI of .75, Expected N need 200 FP = 150
- Can be calculated using NDVI or SR



Graph of SI

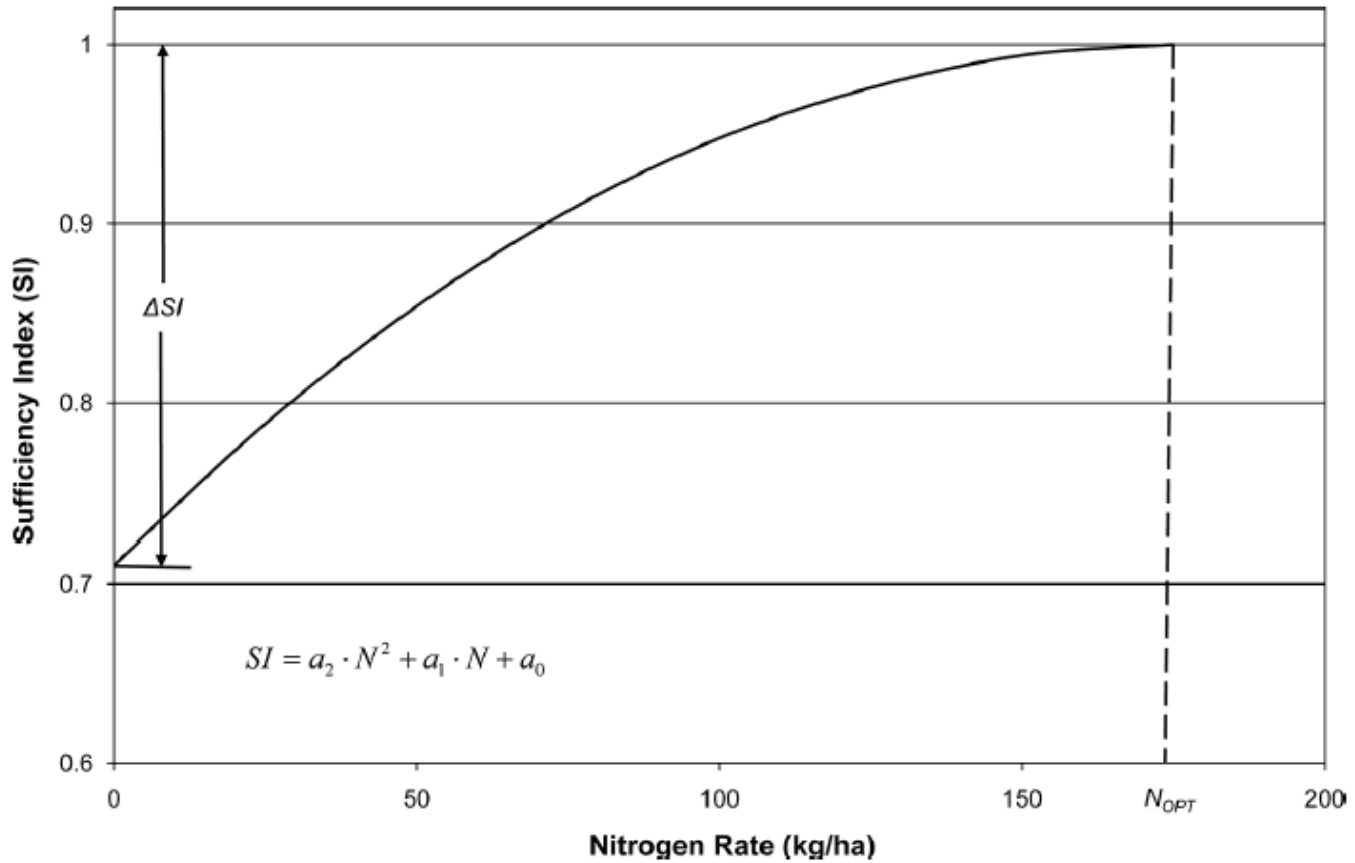
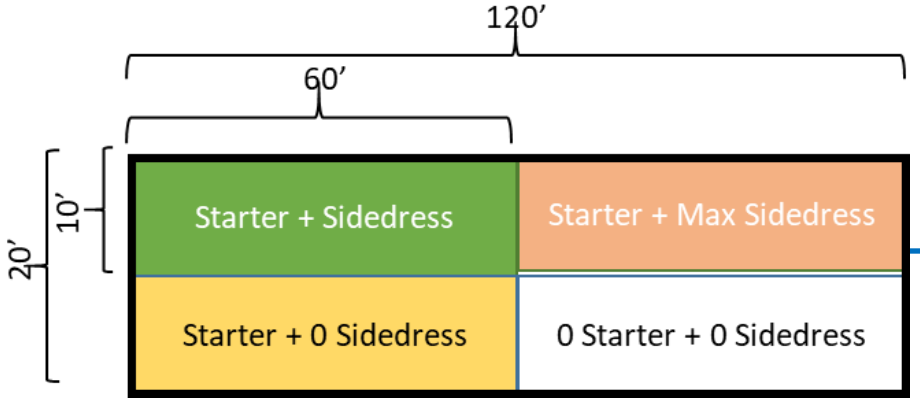


Figure from Holland and Schepers: 2010 Agronomy Journal.

Current research

Plot design – repeated 400 – 500 times per field



Preseason-only study rates.
Subplots received 0 or 100 lb/a

----------lb-N/a----------

105	154	204	253	302	352

Sidedress nitrogen rate

----------lb-N/a----------

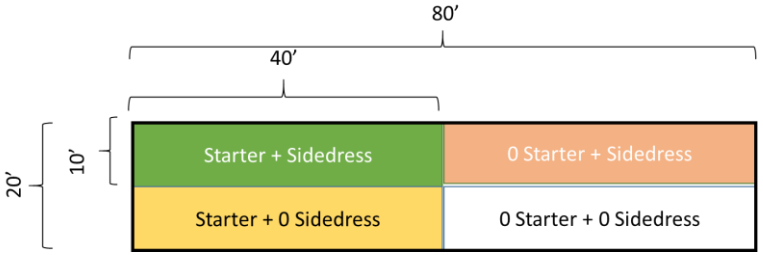
100	100	100	100	100	100

Total final rate

----------lb-N/a----------

105	154	204	253	302	352
205	254	304	353	402	452

Prior to 2021



At planting nitrogen rate

----------lb-N/a----------

18.5	37.0	55.5

Sidedress nitrogen rate

----------lb-N/a----------

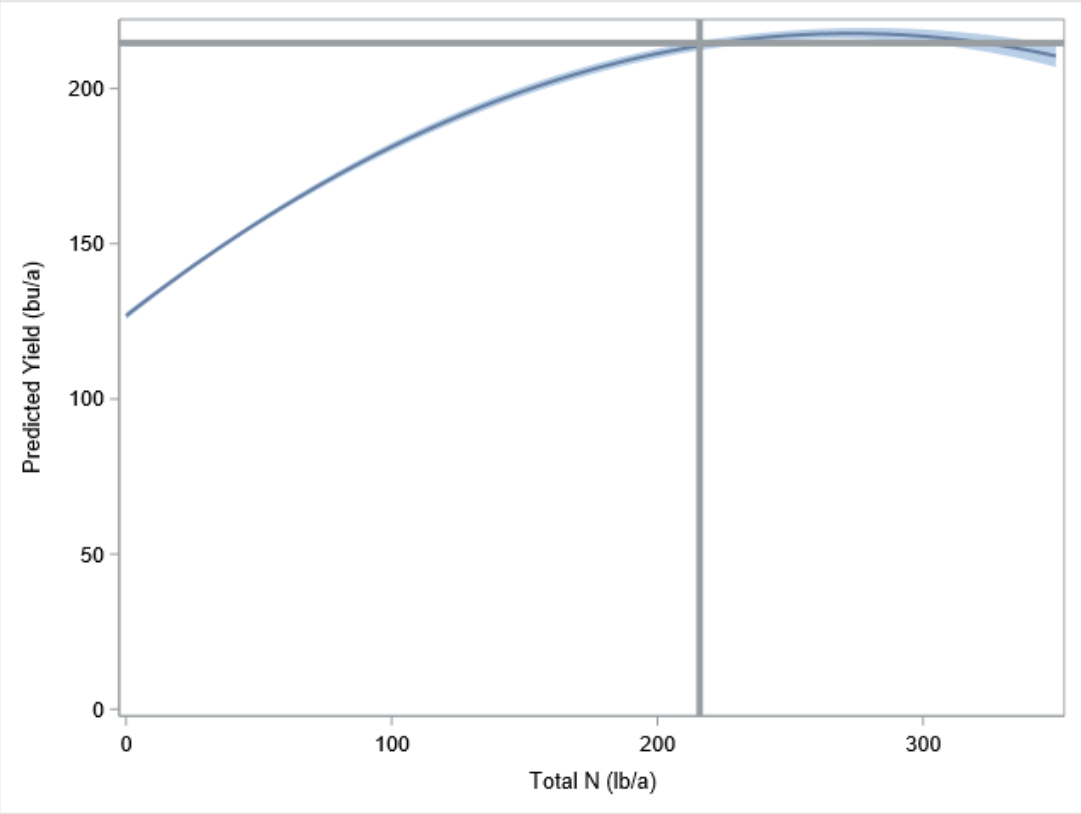
48	45	42
95	90	85
143	135	127
190	180	169
238	225	212
286	269	254
333	314	296

Total final rate

----------lb-N/a----------

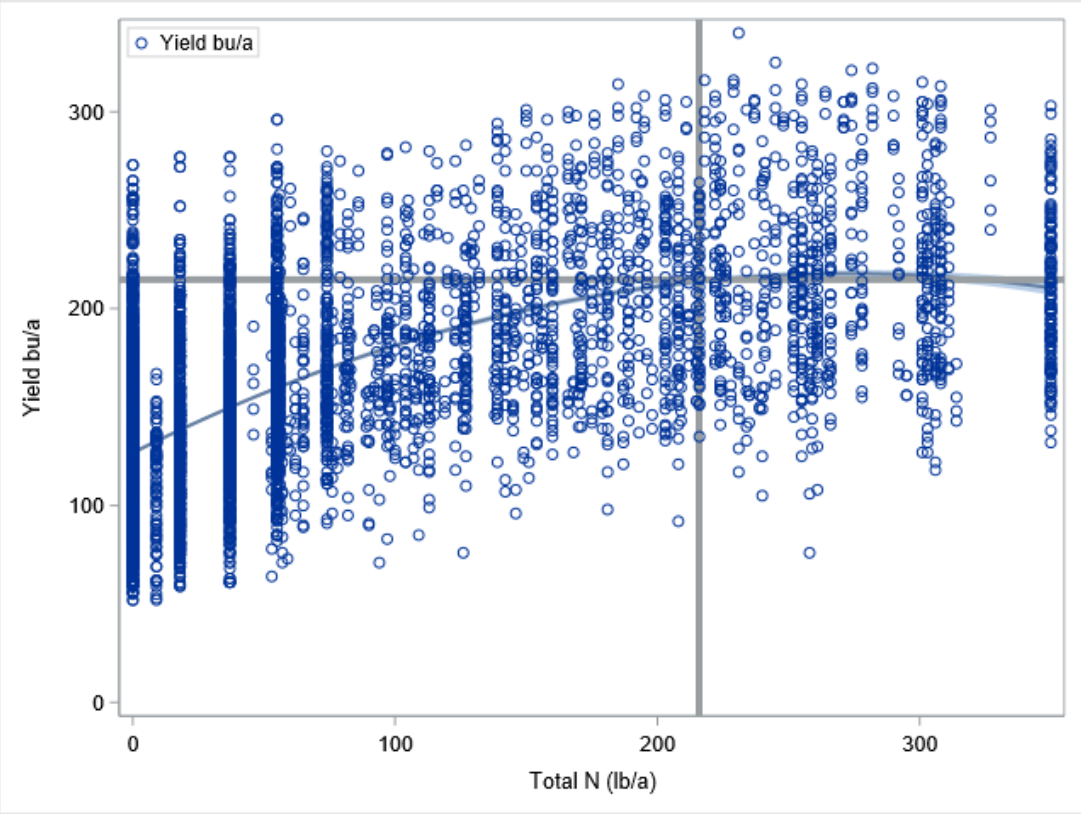
66	82	98
114	127	140
161	172	182
209	217	225
257	262	267
304	306	309
352	351	352

Average, empirical recommendation



- Over 7,000 data points
- 64 site years
- Across site, rotation, cover crop, irrigation, etc.
- Average recommendation
  - 37-55 lb/a starter N
  - 216 lb/a total N
  - 214 bu/a
  - 1 lb/expected bushel recommendation
  - *Current UKY rec ~185 lb/a*

Average, empirical recommendation



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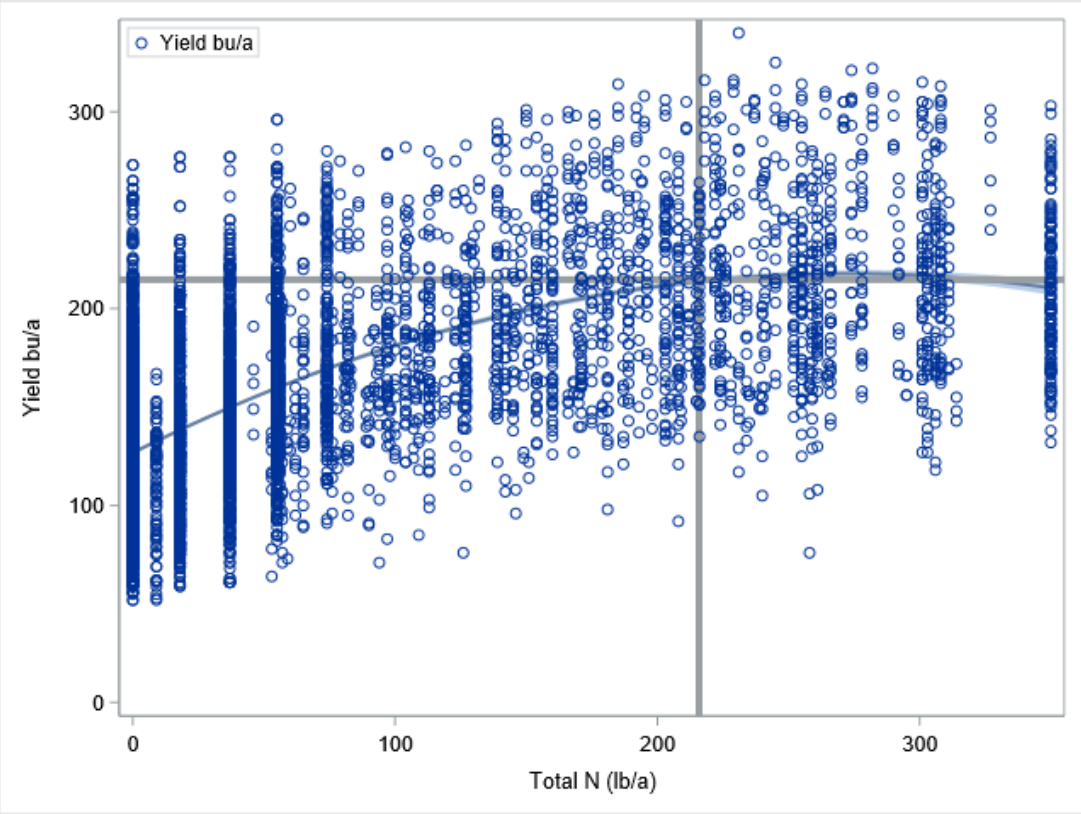
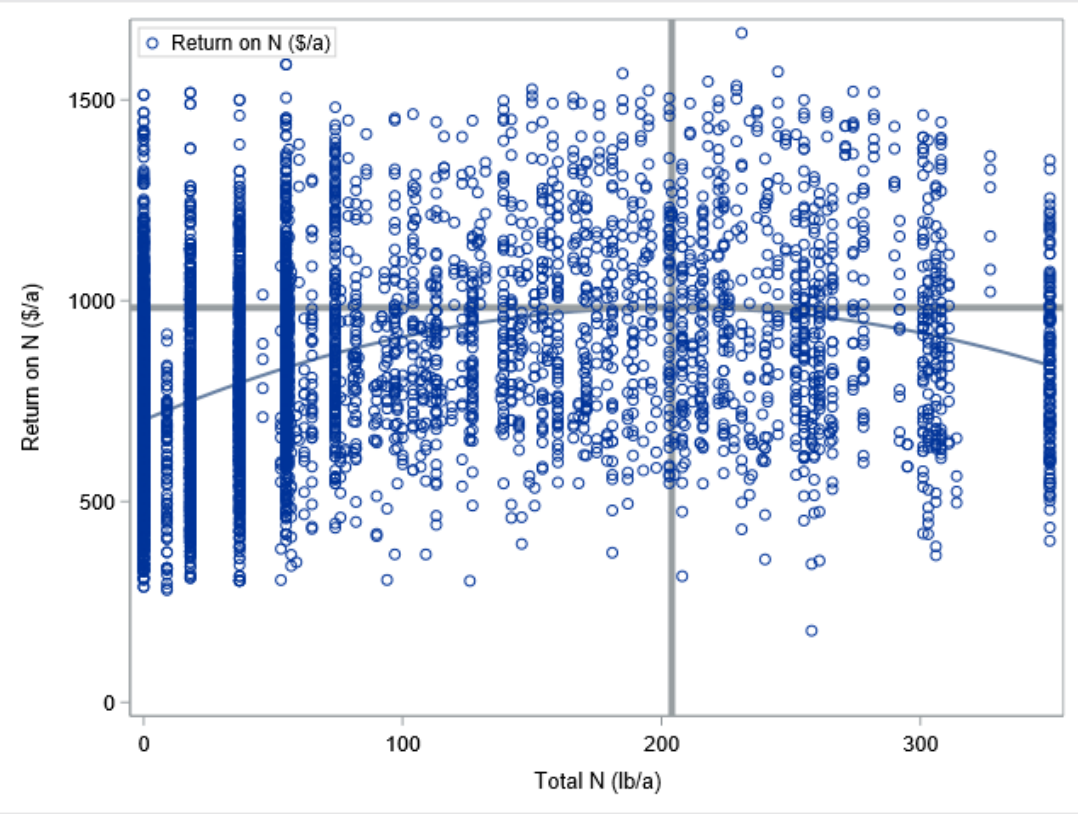
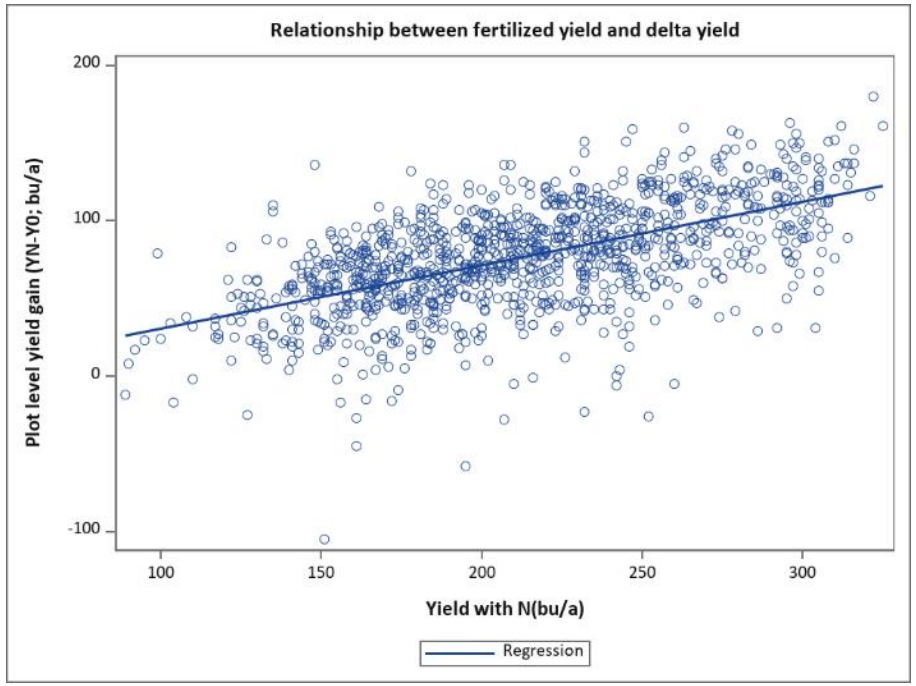
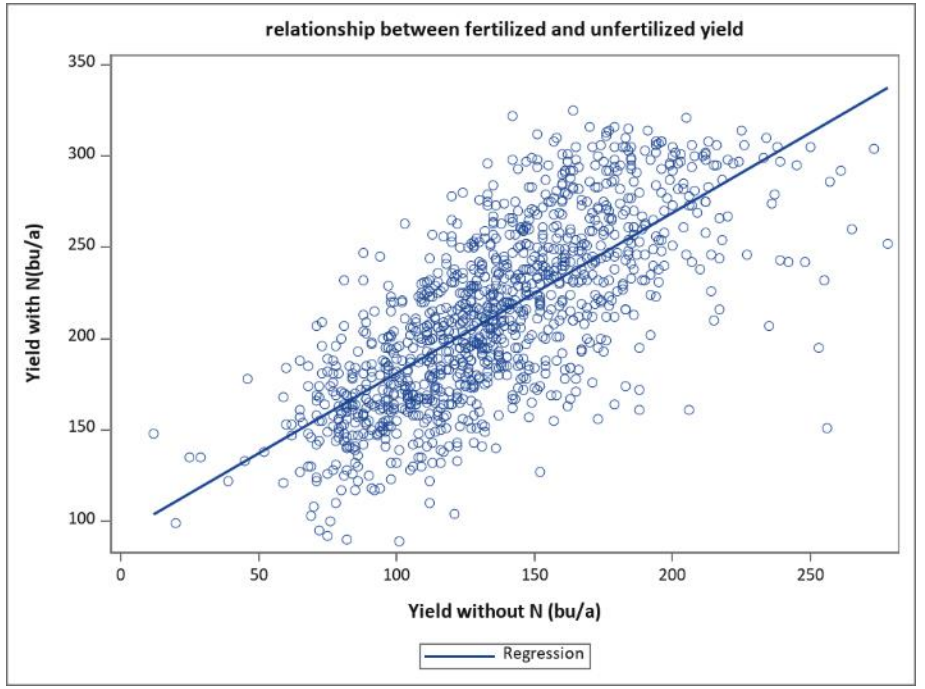
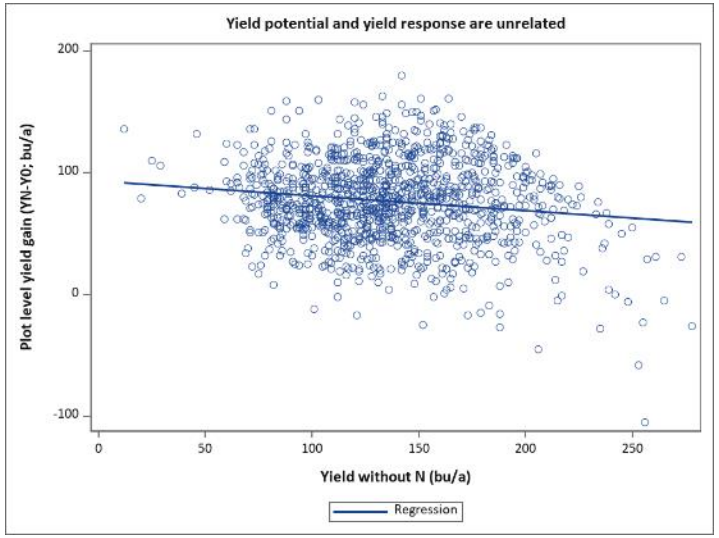




N rate = Yield Response & Yield Potential



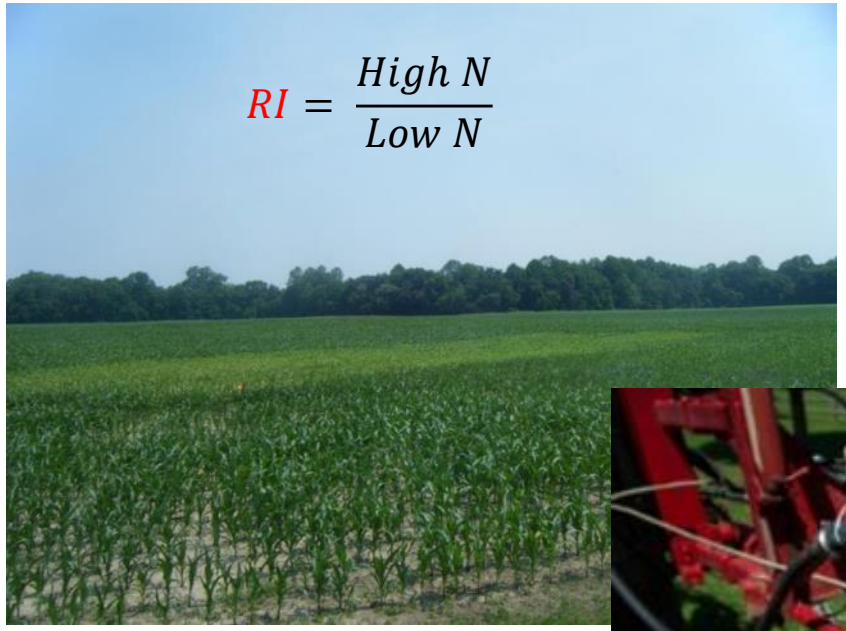




Yield potential independent of Yield response

KY's first corn VRN equation

$$RI = \frac{High\ N}{Low\ N}$$



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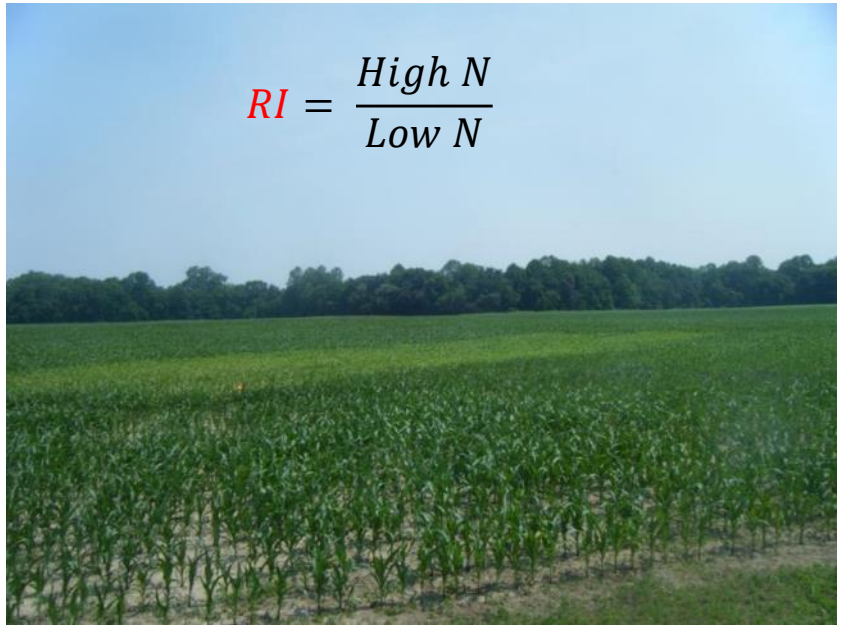
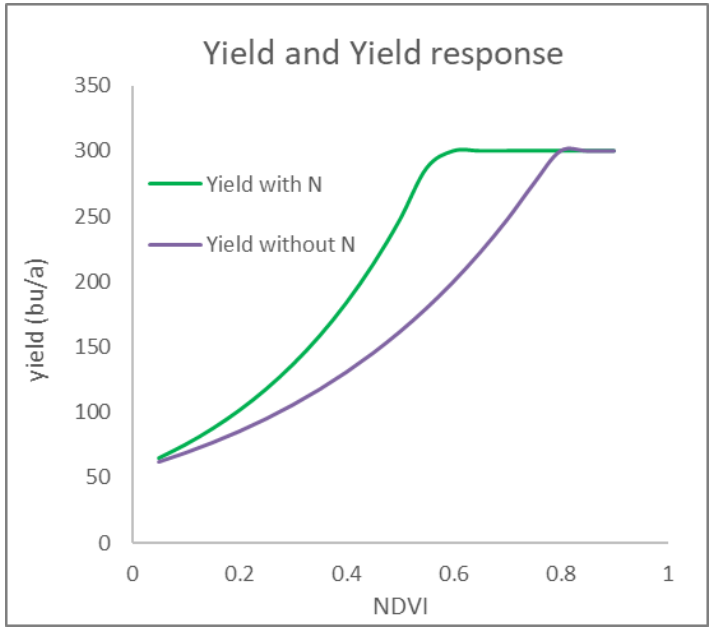


$$RI = \frac{High\ N}{Low\ N}$$

$$YPN \sim RI * \frac{NDVI}{Days\ from\ Planting}$$

$$YP0 \sim \frac{NDVI}{Days\ from\ Planting}$$



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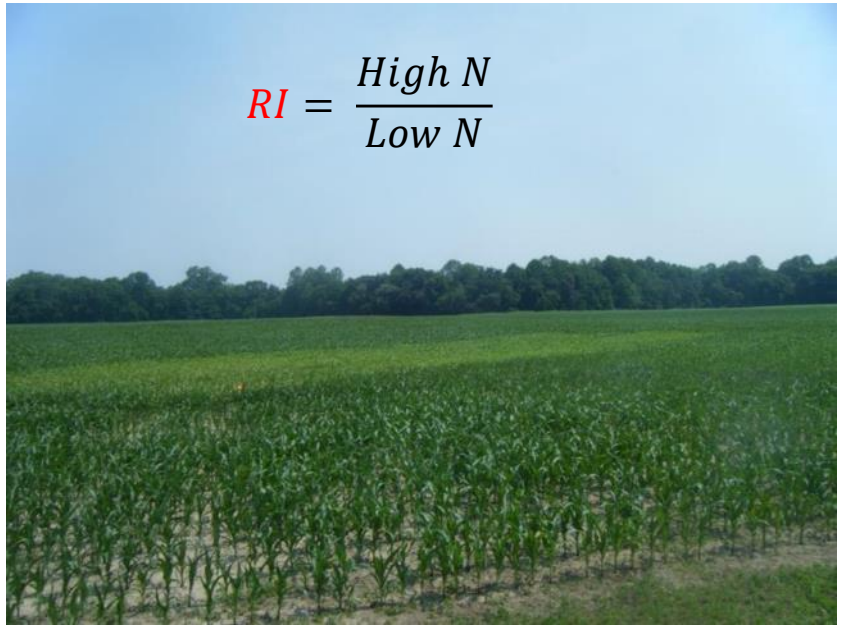

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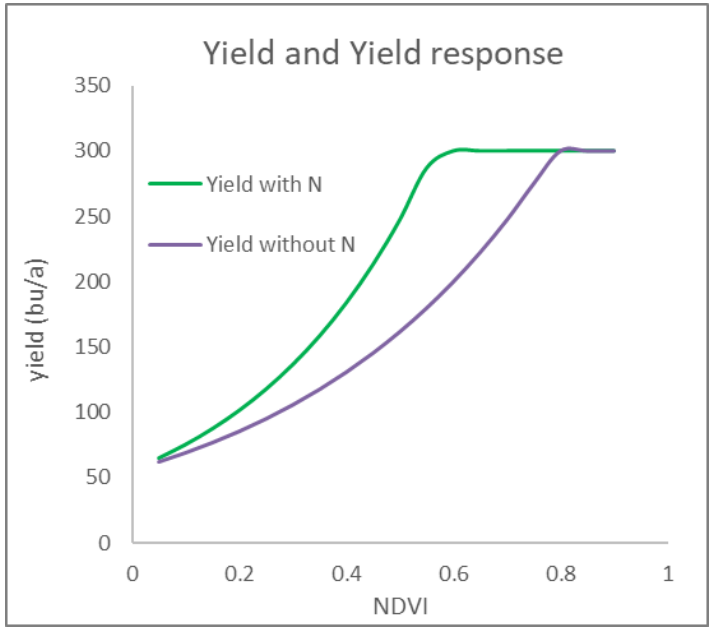
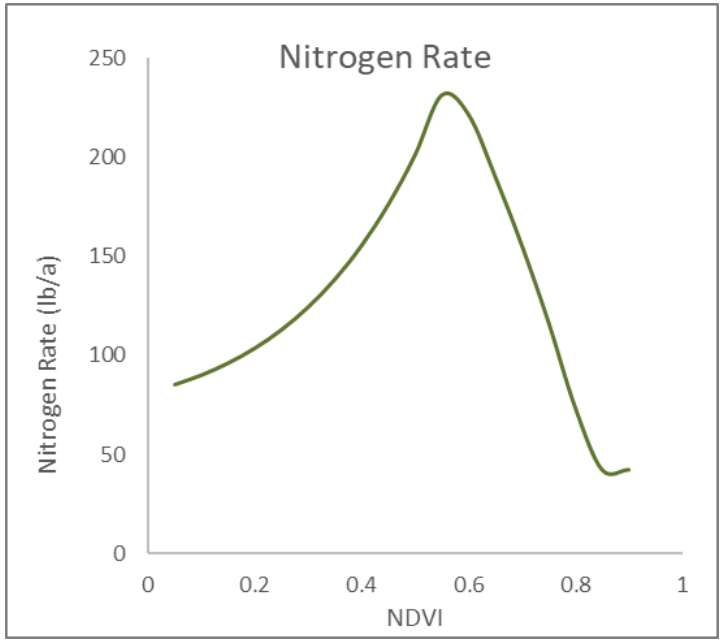




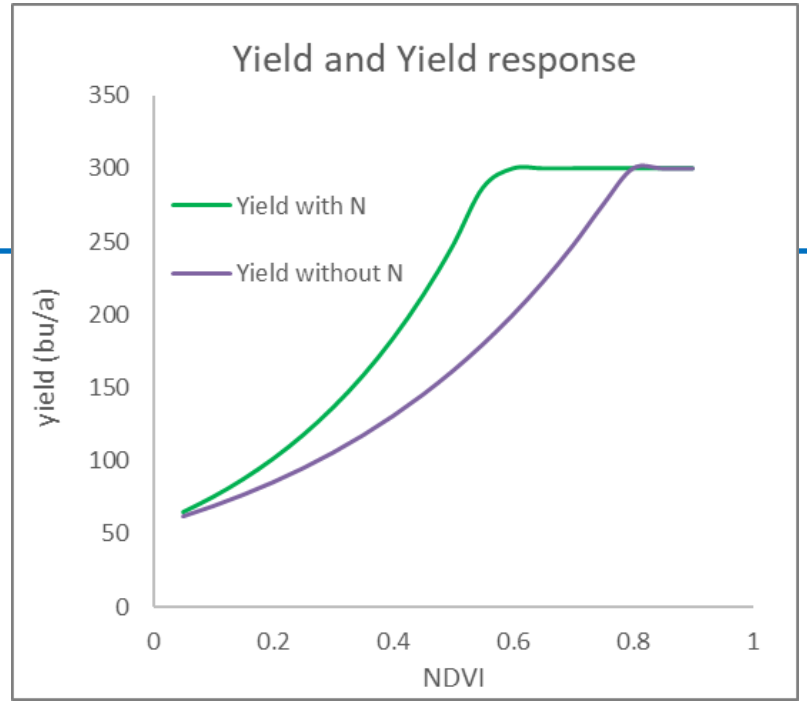
$$Fertilizer \sim \frac{(YPN - YP0) * Grain\ N}{e_{fert}}$$

Mechanistic

- Identify components of nitrogen requirement
  - Yield potential
  - Nitrogen response
  - Loss (efficiency)

$$Fertilizer = \frac{Plant\ Need - Soil\ Supply}{e_{fert}}$$

Mechanistic



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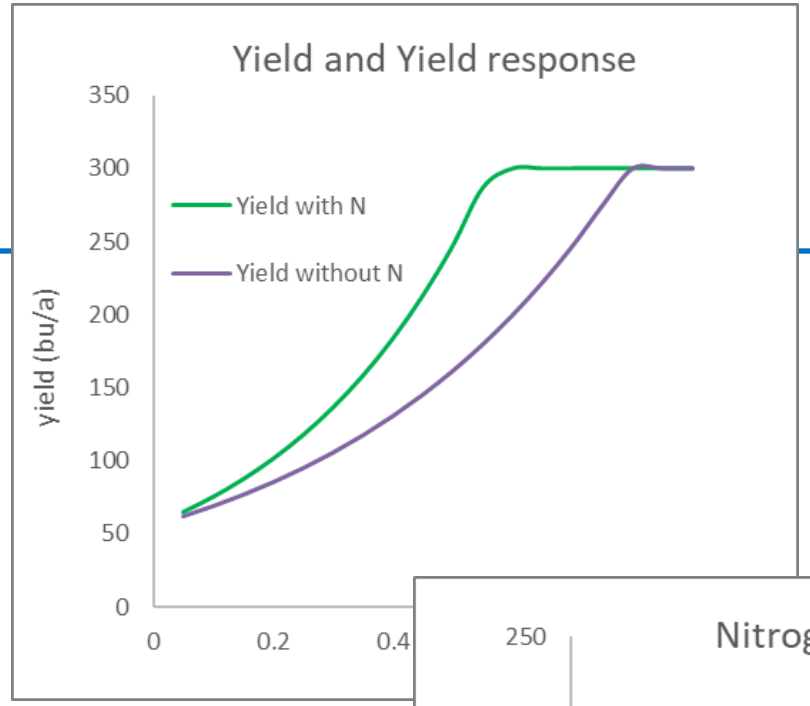

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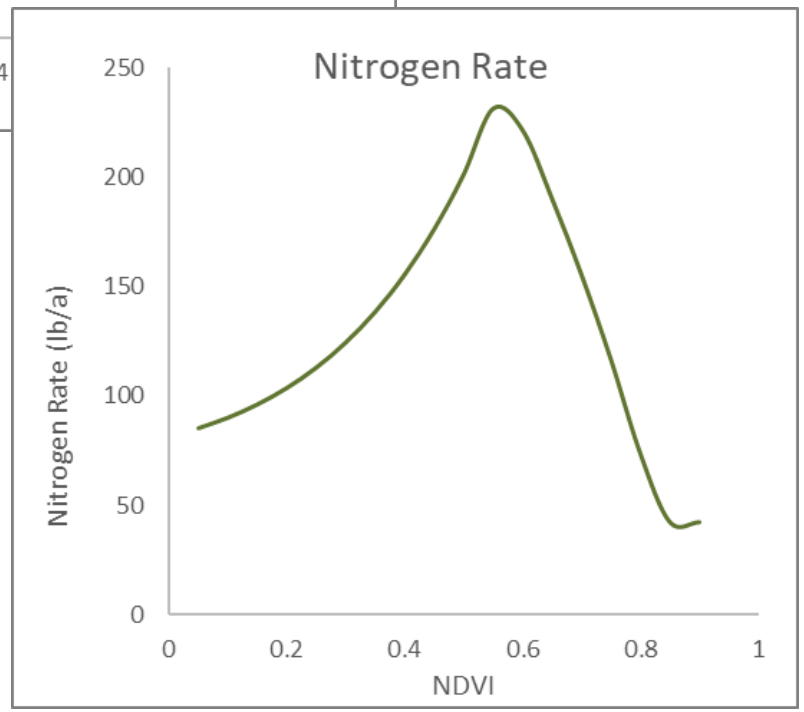
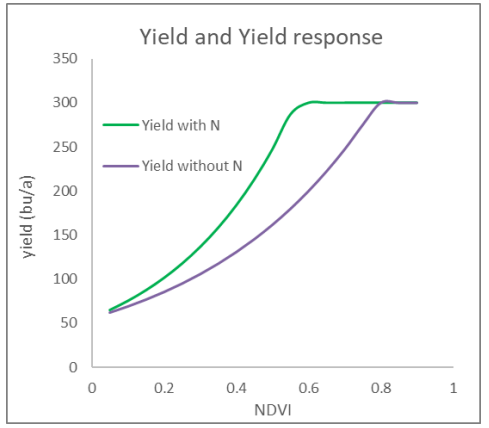
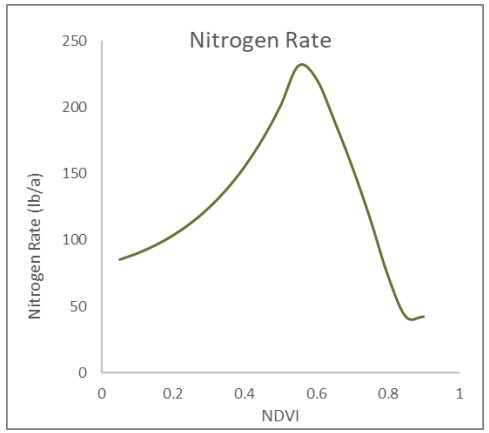


Mechanistic

$$Fertilizer \sim \frac{(YPN - YP0) * Grain\ N}{e_{fert}}$$

- Potential and response are independent and change year-to-year or site-to-site
- Normalized Difference Vegetation Index (NDVI) measures plant vigor and correlates strongly to biomass.
- Sense corn V6 – V10ish. Too early and plants are too small – everything looks the same. Too late and plants saturate the image – everything looks the same.
- Use NDVI to calculate an in-season estimate of yield (INSEY or YP0)
- Reference strips with extra N (High N) and no N (Low N) established at planting are sensed the day of sidedress to calculate Response Index (RI)
- INSEY predicts yield with zero in-season N (YP0). RI multiplied by INSEY predicts yield with nitrogen (YPN) – *Requires local coefficients!*



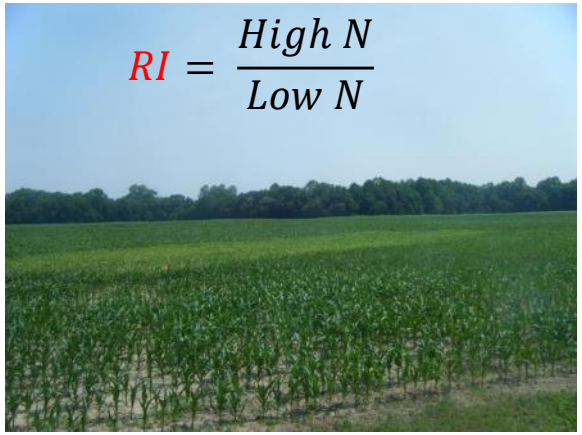


Figures show output from Kentucky-Southern Illinois algorithm that was tested for the first time in 2021.

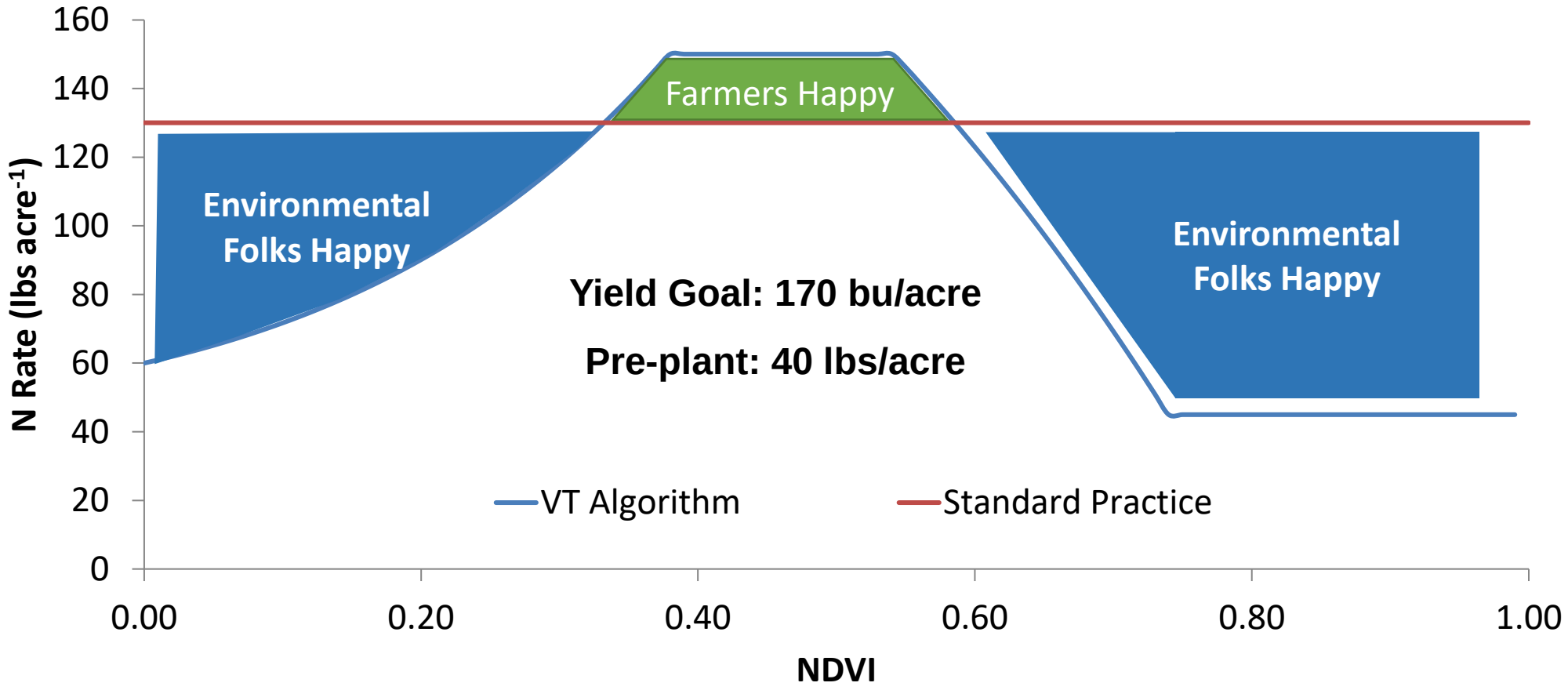
$$YP0 \sim \frac{NDVI}{Days\ from\ Planting}$$

$$YPN \sim RI * \frac{NDVI}{Days\ from\ Planting}$$

$$RI = \frac{High\ N}{Low\ N}$$

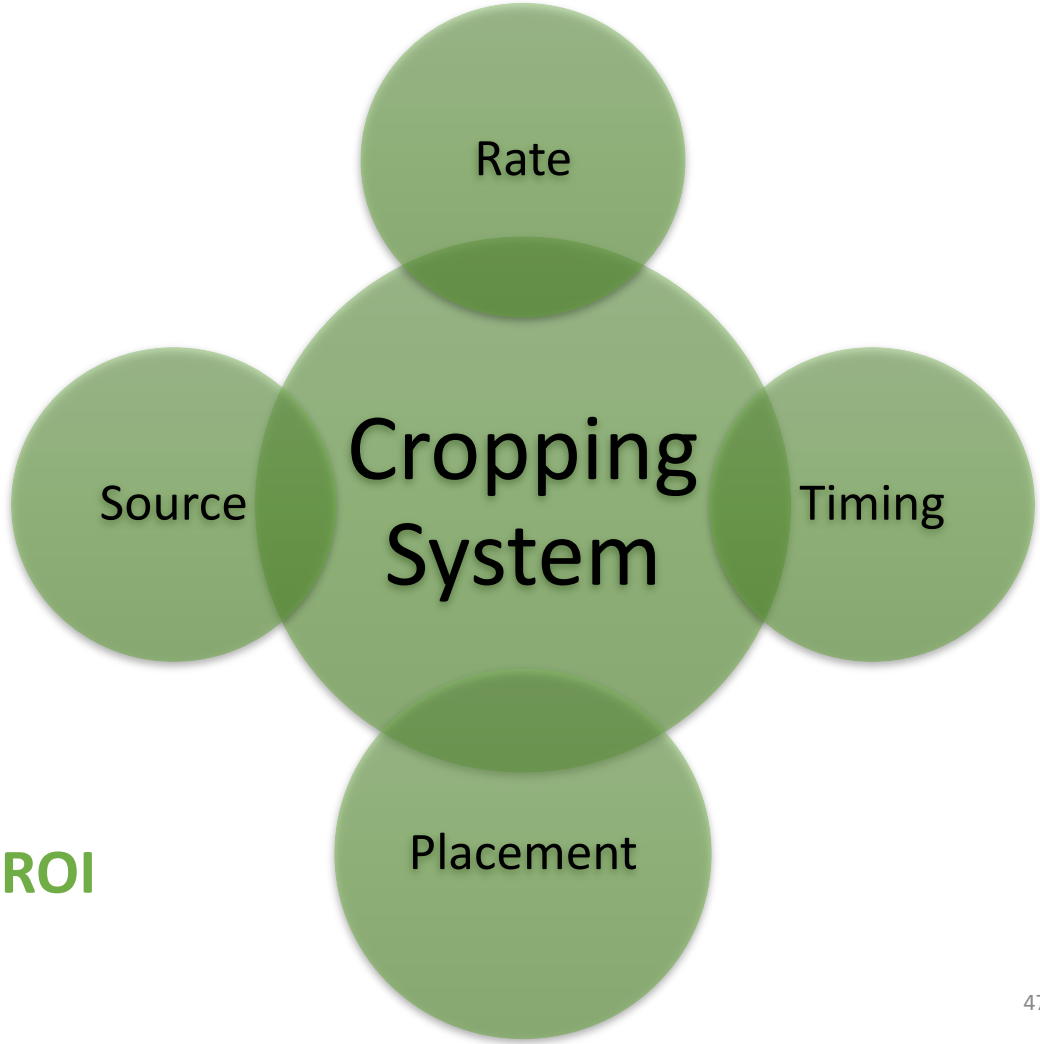


Suspending disbelief (personal bias)



Strategies to improve input efficiency

- Most people are probably in a position to improve average economic returns
- Moving to ***proven*** precision technologies can increase returns $15 – 20/acre
- Overall uncertainty drives decision to apply rates above absolute economic optimum rate (stochastic risk assessment)
- We can control uncertainty through management practices that improve NUE



Consistent NUE → confidence in rate → improve ROI

Basic N recommendations

- To do better we have to take active approach and use available diagnostic tools
- What factors influence N requirement?
  - ***Yield and Response***
  - Crop system, Timing, Placement, Source
  - Soil, topography, weather
- Timing is **top concern** – only N already applied can be lost
  - After rapid growth probability of loss decreases significantly
- **Risk** that weather will delay timely application
  - Invest in equipment and tools to offset this risk
  - Some products provide a measure of insurance against unexpected weather

P and K

- ***DOLLARS PER ACRE*** Cut the extras – don't waste $/acre on biologicals, unnecessary – or worse unproven – additives
- Soil testing provides solid basis for lime, P, and K
- Now is the time to pencil out manure if you have cheap source and can spring apply
  - Check out Budget and Decision Tools
  - https://agecon.ca.uky.edu/budgets
- With high prices stick to recommendations and forget about maintenance rates for now
  - Don't lose the money invested in MAP or DAP Nitrogen

Thanks!

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