More with Less

The Case for Precision Ag

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Ecological intensification

- Ecological intensification
  - Farm yields are approaching biophysical yield limits – yield plateaus
    - Yield plateaus are evident for rice in China, Japan, and Korea; wheat in northwest Europe; perhaps irrigated maize in USA
  - Crop response to applied nutrients follows a diminishing return function – use-efficiency falls off as yields approach the yield potential ceiling
- Precision agriculture is key to achieving EI in high-yield systems such that input rates are matched to crop demand in time and space

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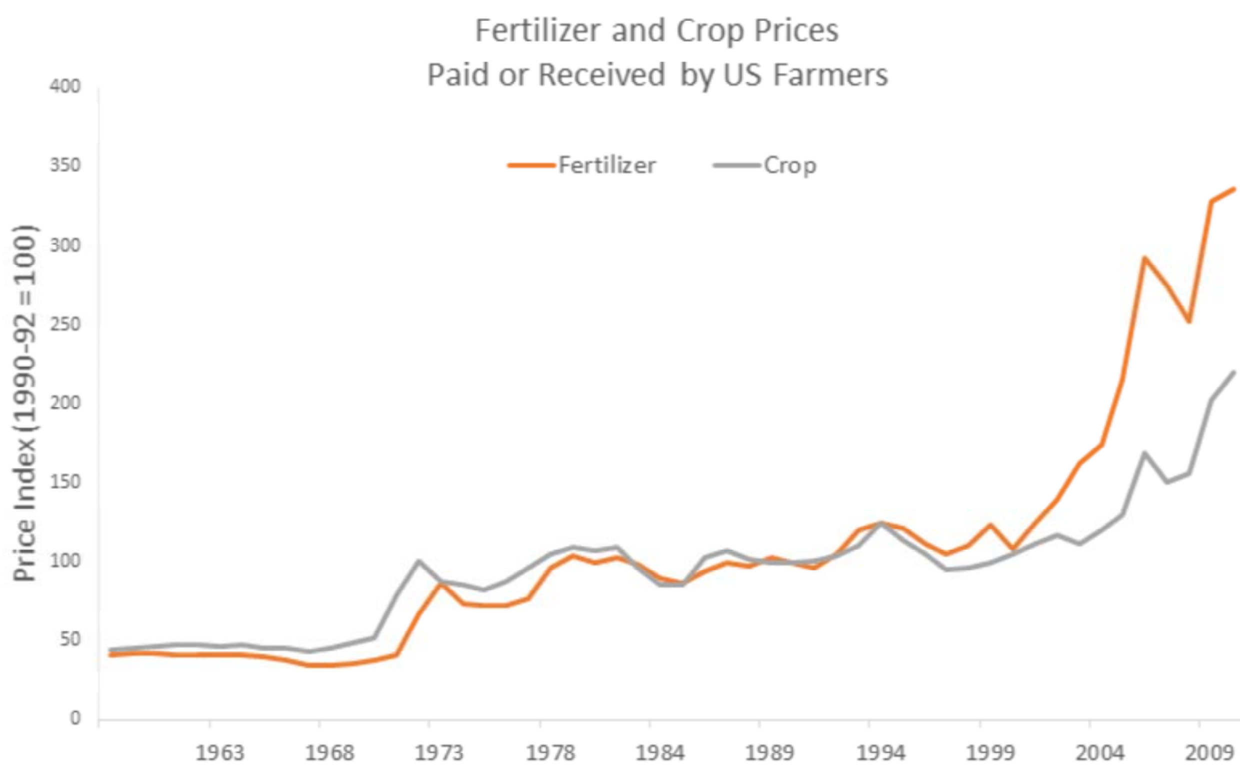
Fertilizer and Crop Prices over Time



Sources: National Agricultural Statistics Service and Bureau of Labor

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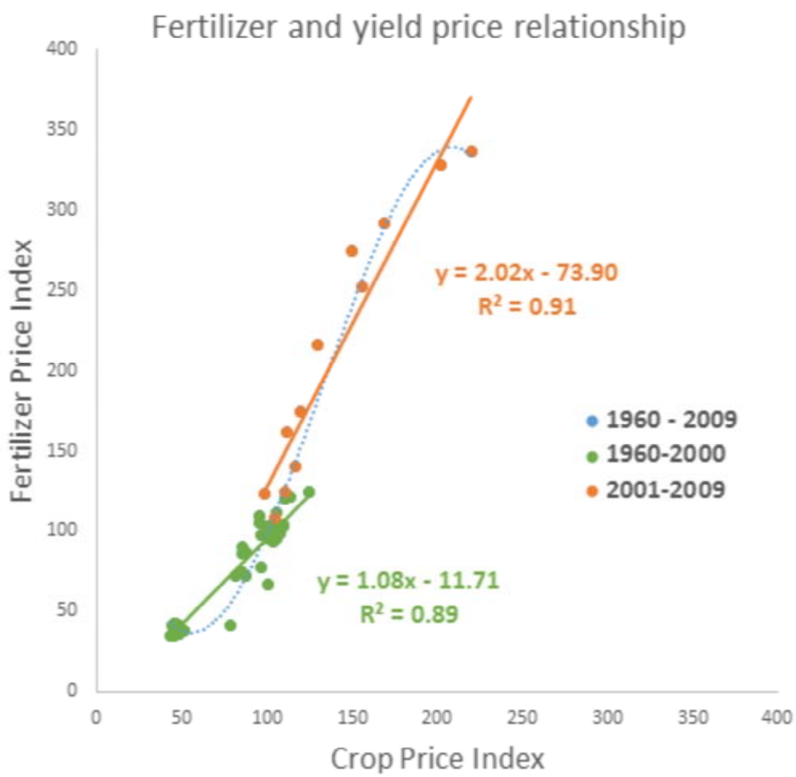

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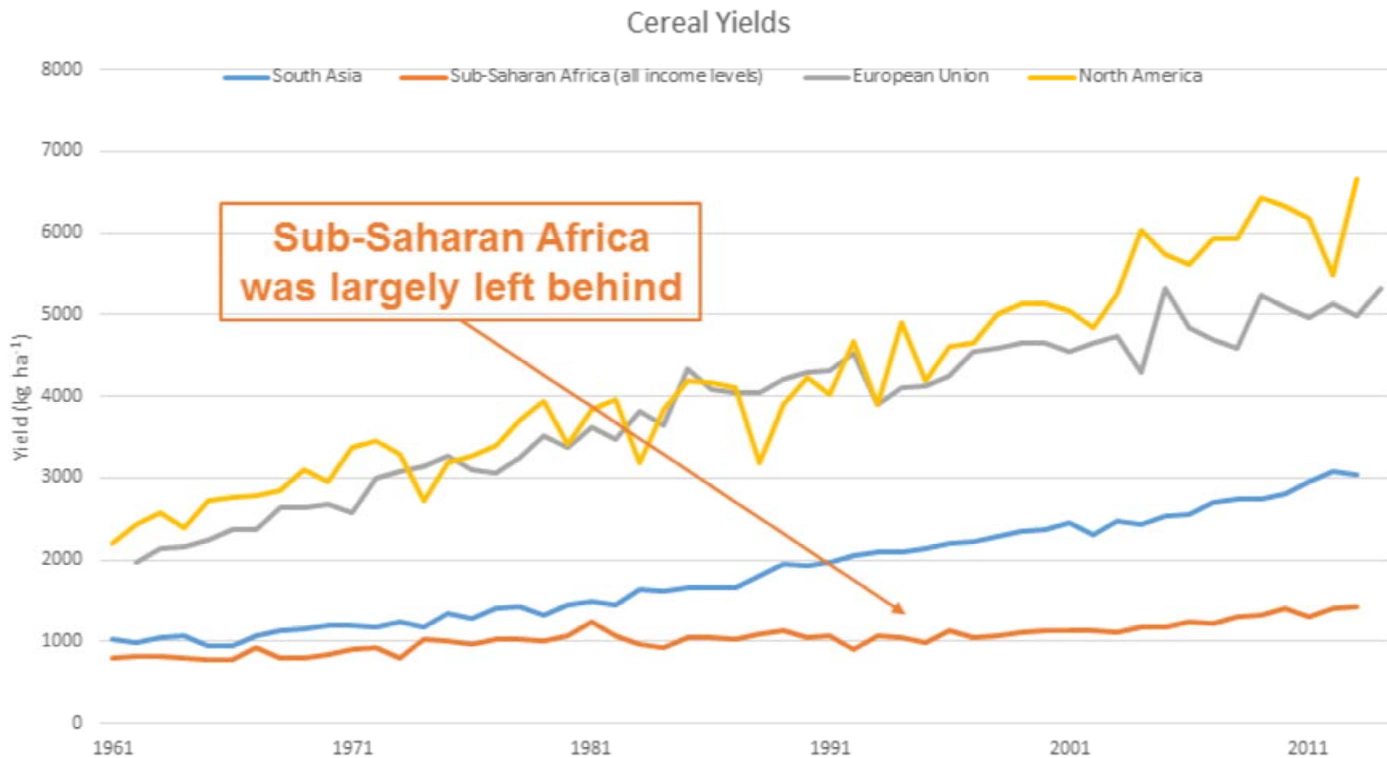
Yields Since the Green Revolution



Cereal yield, measured as kilograms per hectare of harvested land, includes wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains. Production data on cereals relate to crops harvested for dry grain only.

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Source: Food and Agriculture Organization. Downloaded 9/2/2015 from: http://databank.worldbank.org/

A Brief History of Soil Fertility

- Carl Sprengel
  - Malthusian Catastrophe (1798) influenced Sprengel and his contemporaries
  - Discovered plants require external nutrients
  - Liebig’s law of the minimum: Production is limited by the amount of the most limited nutrient relative to the plants need (Sprengel, 1828)
- Daniel Webster (1840): “It is upon this fundamental idea of constant production without exhaustion, that the system of English cultivation, and indeed, all good cultivation is founded”
- Green Revolution: 1960 – 2000 yields doubled, N use increased 7x, and P use increased 3.5x

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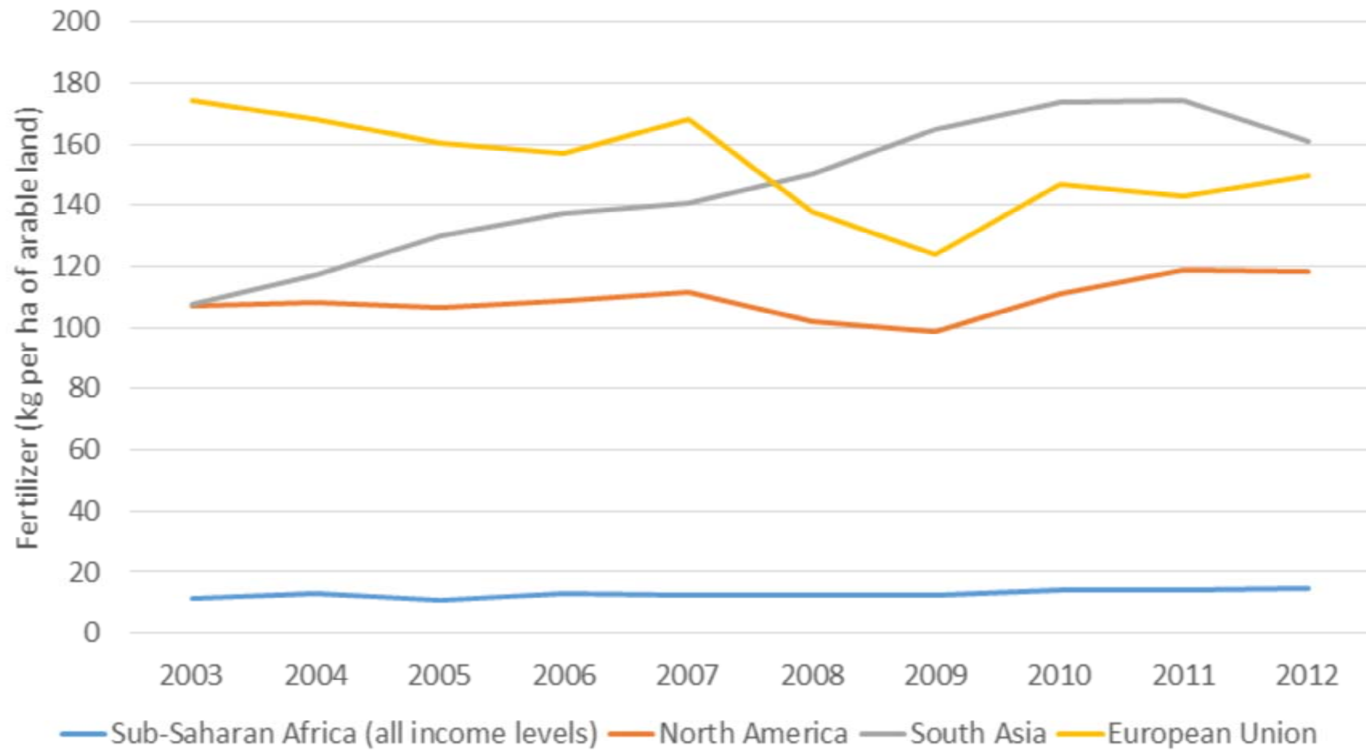
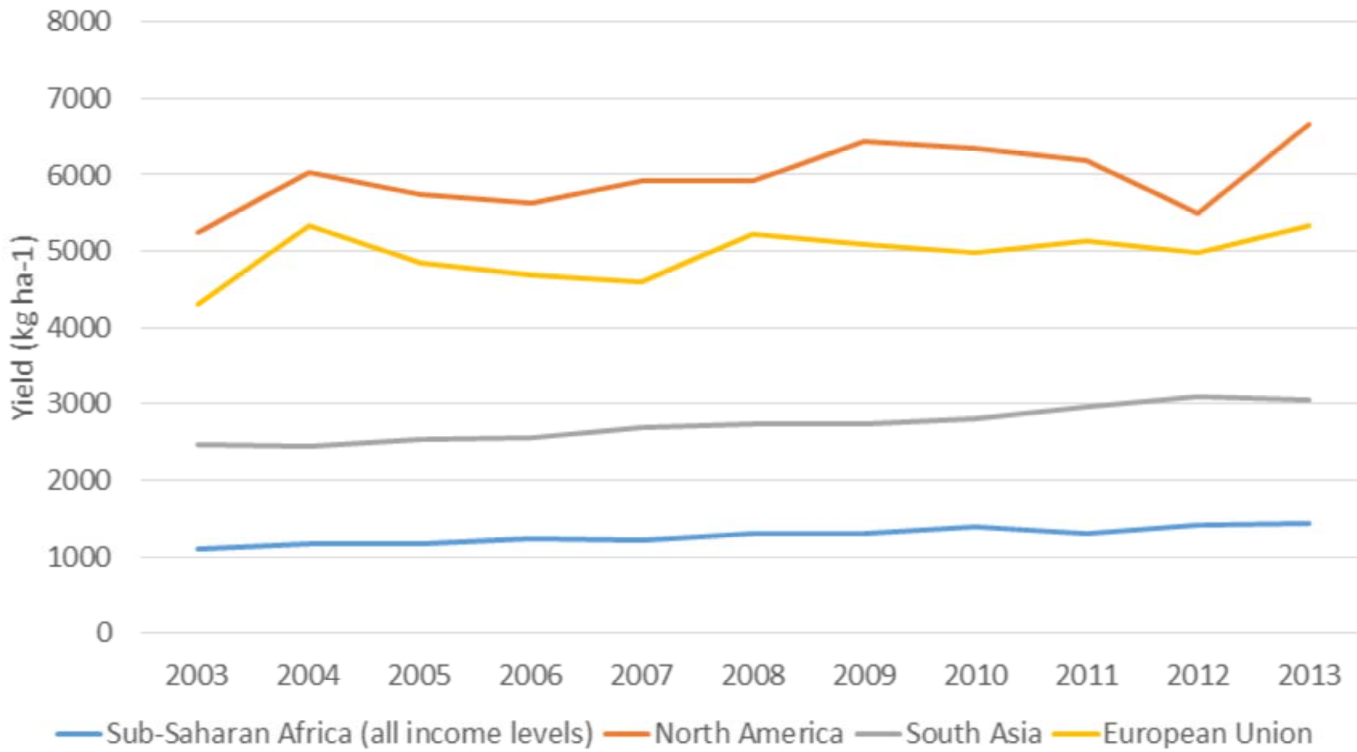
Agricultural technology has evolved in response to, or concomitantly with, population dynamics, continually avoiding Malthusian catastrophe. Foundation of green revolution built on fertilizer, crop genetics, and education of farmers.

Fertilizer Consumption



N, P, and K per unit arable land. Arable land = land under temporary crops
Source: FAO

Cereal Yields



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More with less (Nitrogen)?

- Partial factor productivity = units of yield per unit fertilizer: how productive is the system relative to inputs
  - Increases as fertilizer rates decrease below economic optimum
- Greater improvements come from yield increases
  - In US N rates rose by 24% but yield by 86%

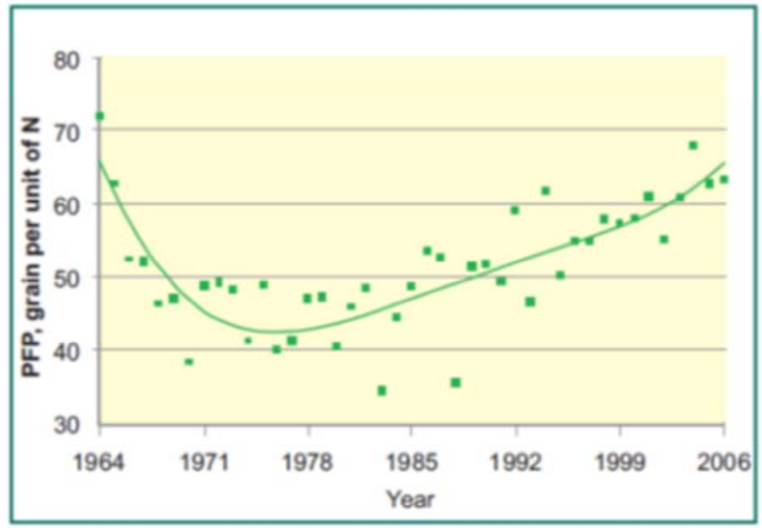

Figure 1. Corn grain produced in the U.S. per unit of N applied (PFP), 1964 to 2006[8].

Snyder, C. S., & Bruulsema, T. W. (2007). Nutrient use efficiency and effectiveness in North America. *Indices of agronomic and environmental benefits.*

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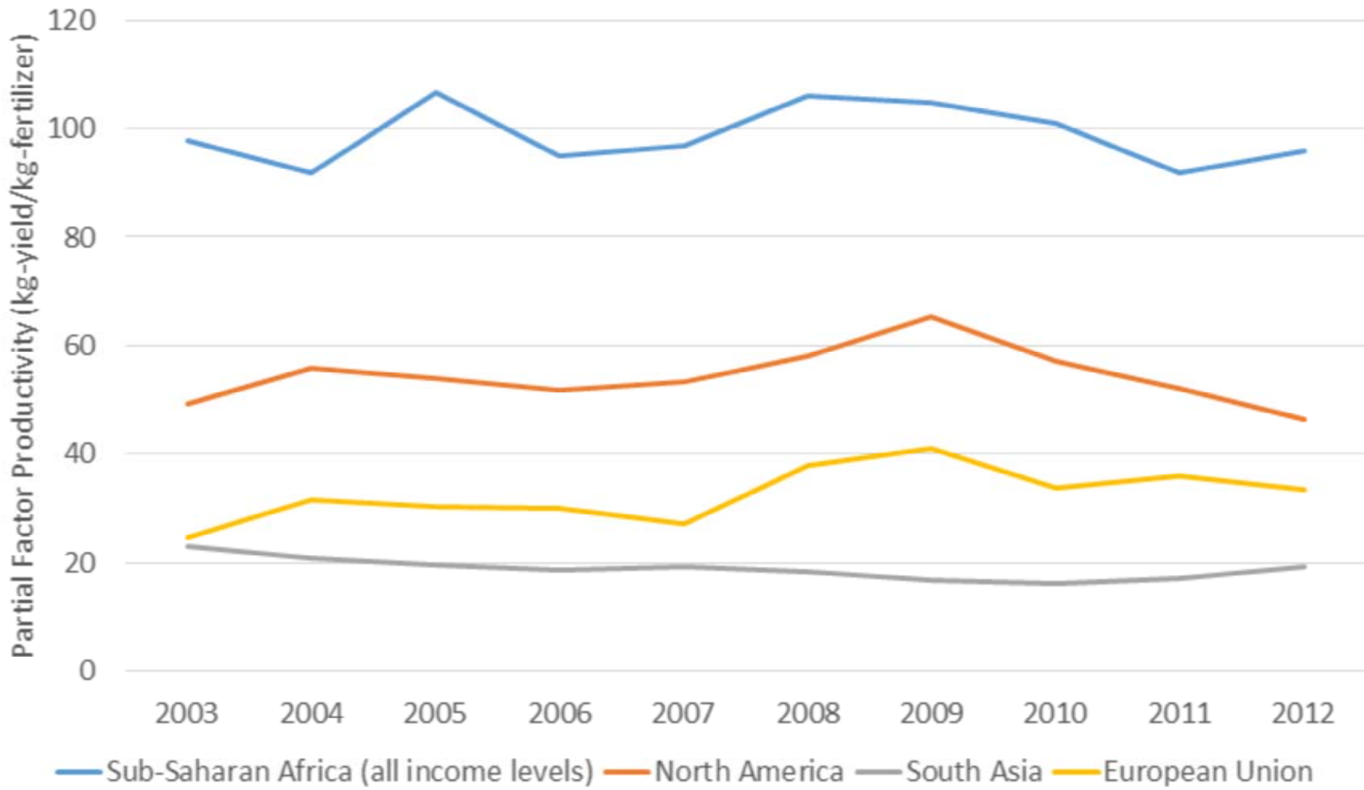
Productivity relative to fertilizer



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Sub Saharan Africa is operating will below production and economic optimum. Asia has focused on yields, but now looking towards efficiency.

Apparent Crop Recovery Efficiency

$$\text{NUE} = \frac{\text{N removed in grain} - (\text{soil N} + \text{atmospheric N})}{\text{Fertilizer N}}$$

- Worldwide NUE in cereals 33%
- Developed countries NUE's approximately 42%
- Current NUE for corn in US 30 – 60%

Raun and Johnson, 1999

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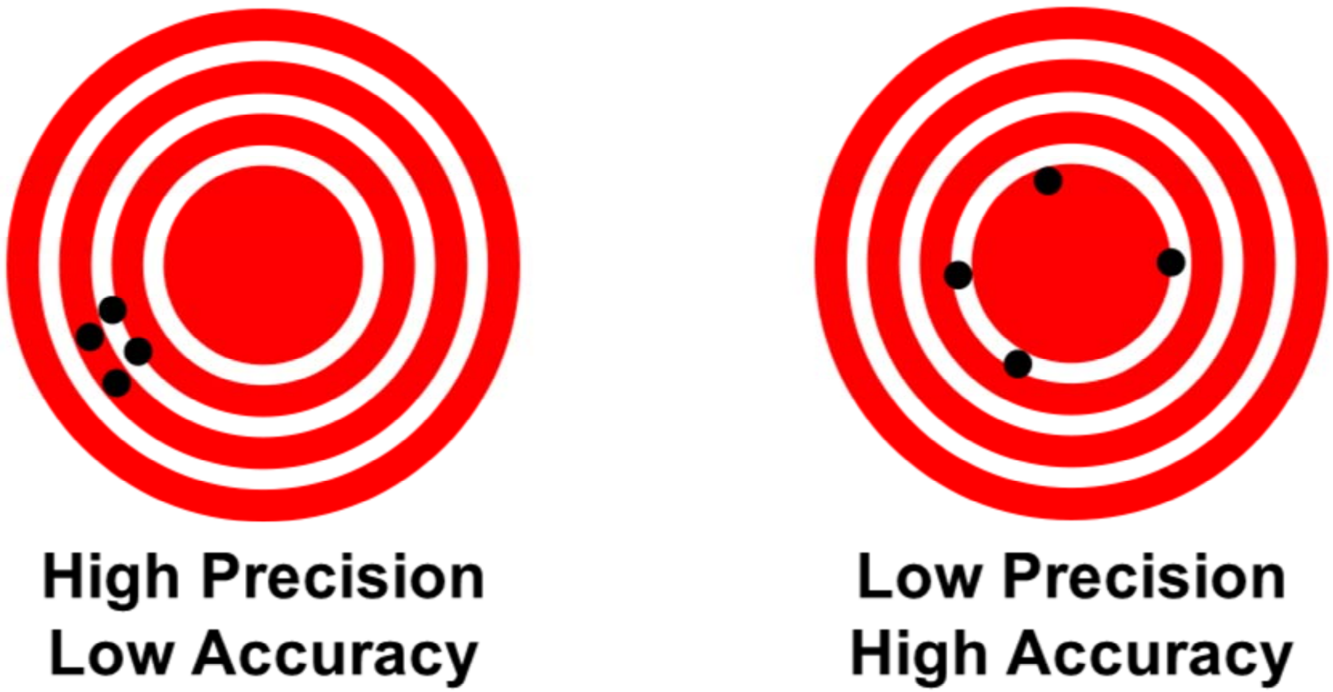
Nitrogen Requirement is Complex

- 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 due to our recommendations and seasonal and spatial variability in requirement

Modified from Raun et al., 2010

Accuracy versus Precision



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http://en.wikipedia.org/wiki/File:High_precision_Low_accuracy.svg

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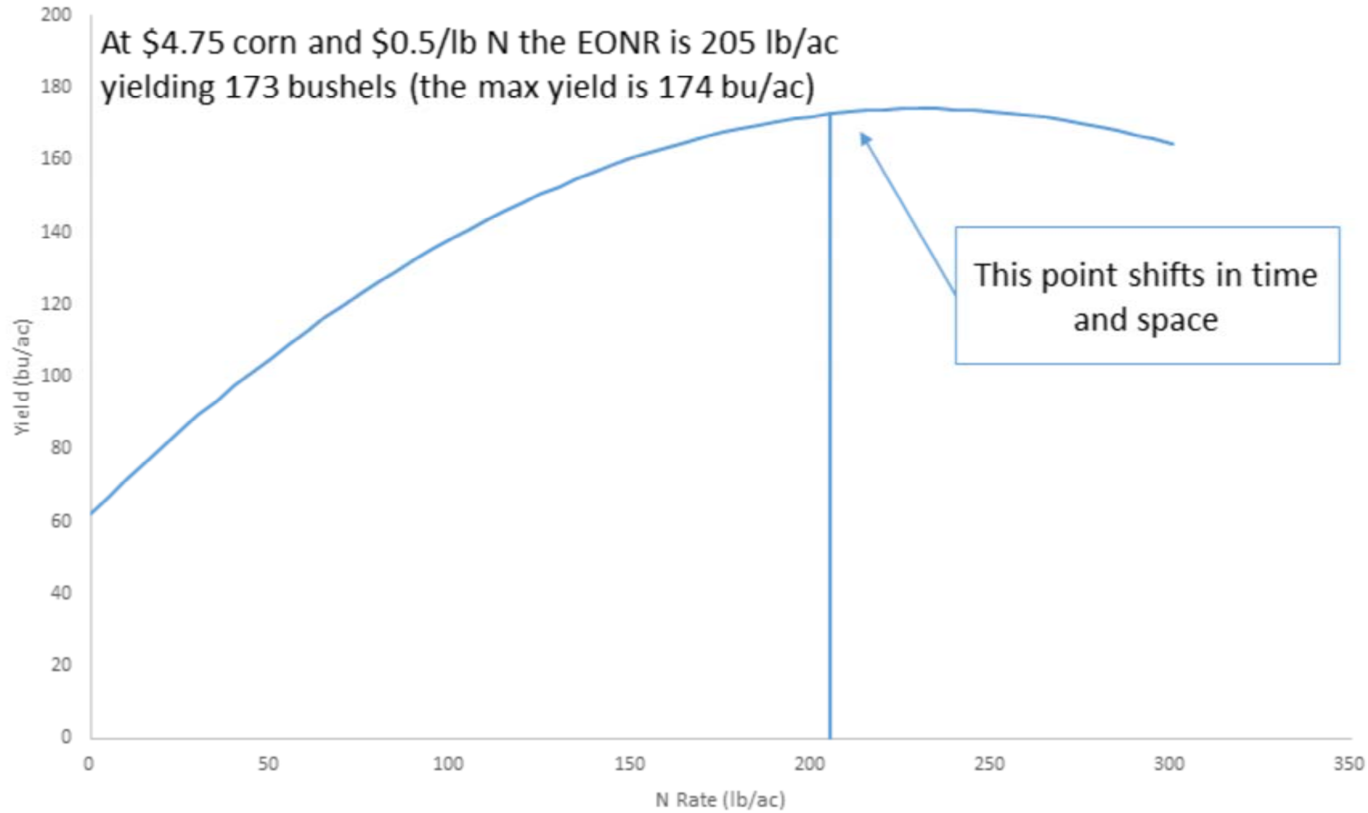
When we talk about precision ag most people just think technology and many people are confusing accuracy with precision. Our current fertilizer recommendations tend to be accurate, but imprecise. Better management along with technology (at various scales) might allow future efficiency increases.

What effect does lack of precision have?



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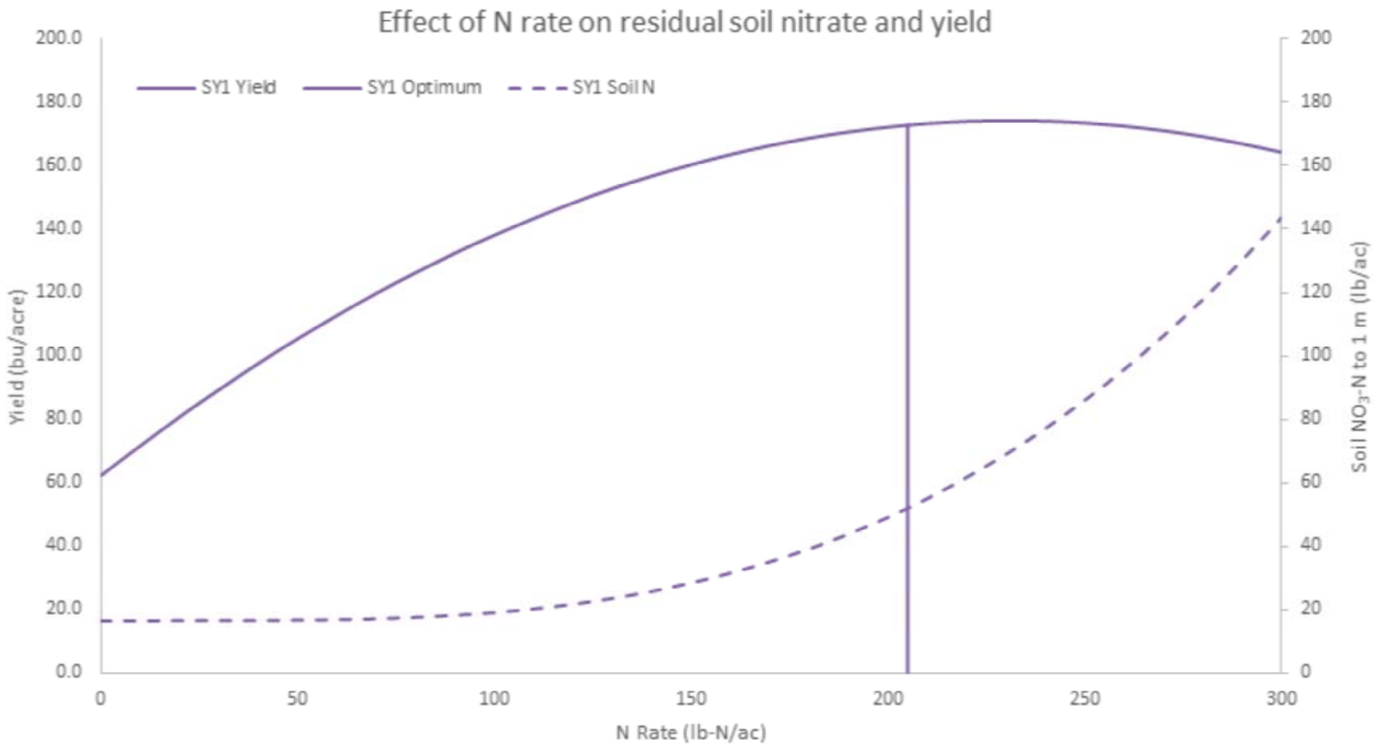
This an example of potential yield response to N based on MD data. Our recommendations are based on average yield response, but there is huge variability around that average – lack precision.

Small changes in requirement or rate have a large impact



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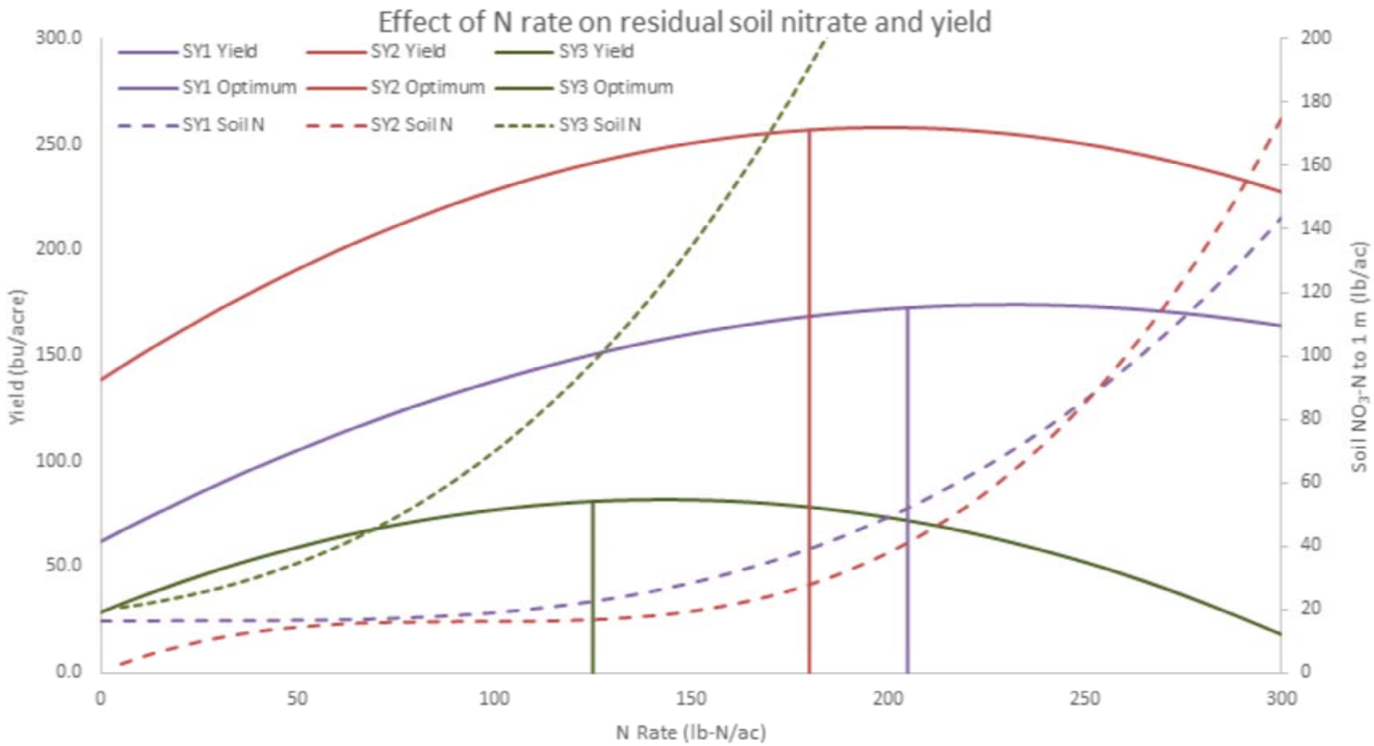
Soil nitrate and yield data from Coale et al. (personal communication)

Changes across time really mess us up



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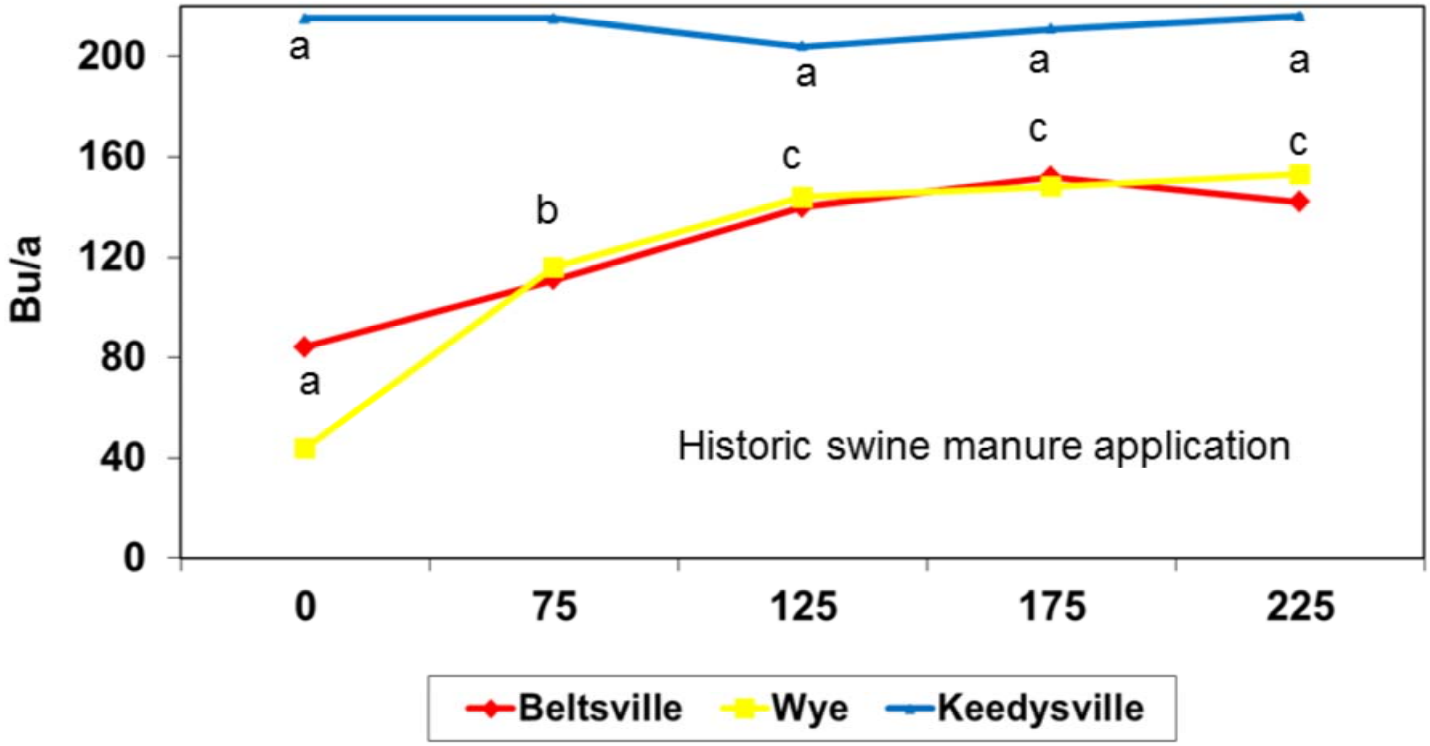
This stretches the data a little further to use soil nitrate data from Coale to predict based on yield response for other site years. Not very accurate or sophisticated model, but demonstrates potential impact of getting the wrong N rate. Soil nitrate concentration in top meter strong predictor of potential nitrate leaching.

No response to N



Average for 8 hybrids: R. Kratochvil, 2008

Sometimes we can achieve maximum yields without fertilizer N. This typically occurs in dry years – drought is yield limiting, but can coincide with high soil organic matter and warm wet spring. In this example Keedeysville had not had manure for 18 years, but warm wet spring generated inorganic N for crop.

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
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- Soil type, climate, and previous management vary in space and time and influence yield potential, N availability, and N responsiveness independently.
- N surpluses exist due to our recommendations and seasonal and spatial variability in requirement

What can we do?

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Modified from Raun et al., 2010

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Example: Sensor Based N Management

Constant Rate – Hand Held

Variable Rate Application

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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

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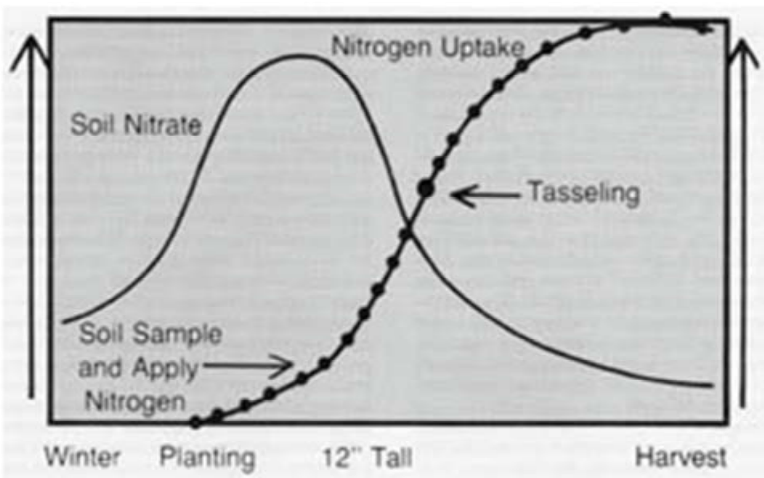
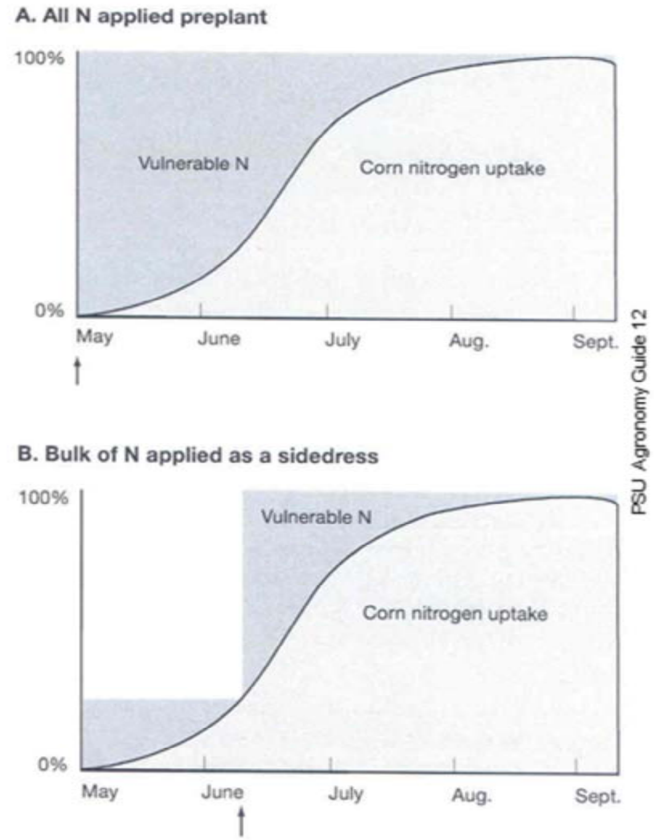
Split Application of N is starting point

- If the N is not yet applied, it can't be lost
- Apply the N when it is required by the crop



Bandel et al. UMD FS-559



Note: Arrows indicate when fertilizer is applied.

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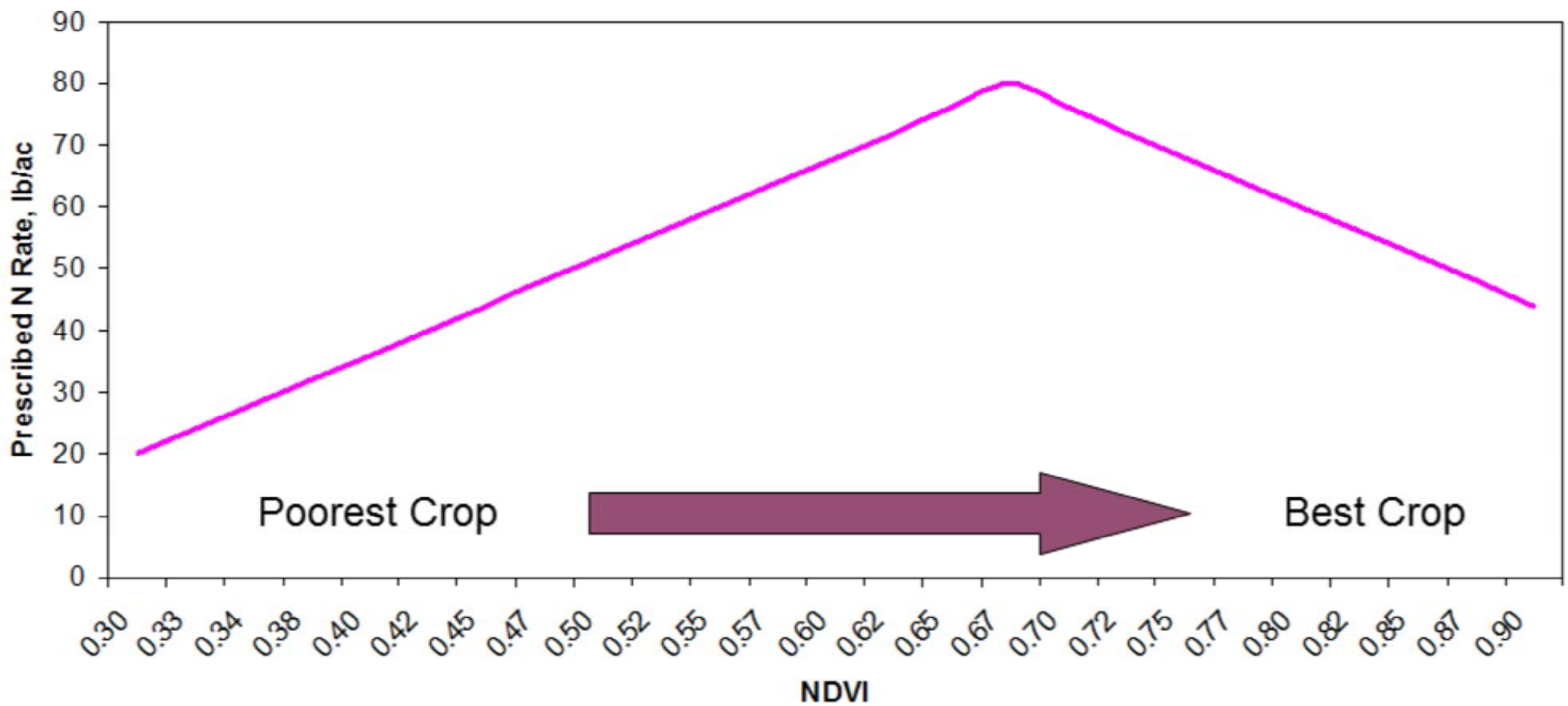
General Algorithm Approach



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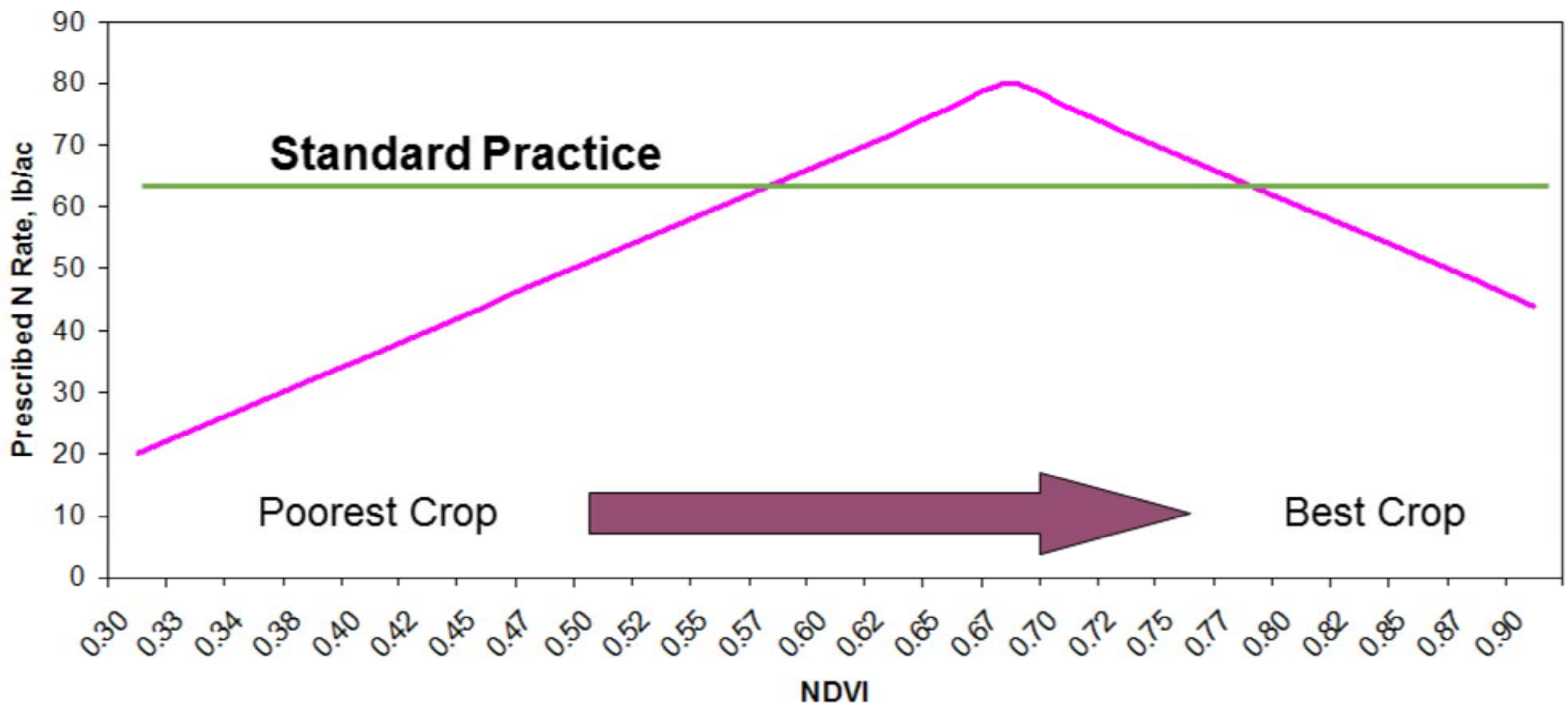
The response index was approach developed at Oklahoma State University. Nitrogen rate adjusts for yield potential and yield responsiveness.

General Algorithm Approach



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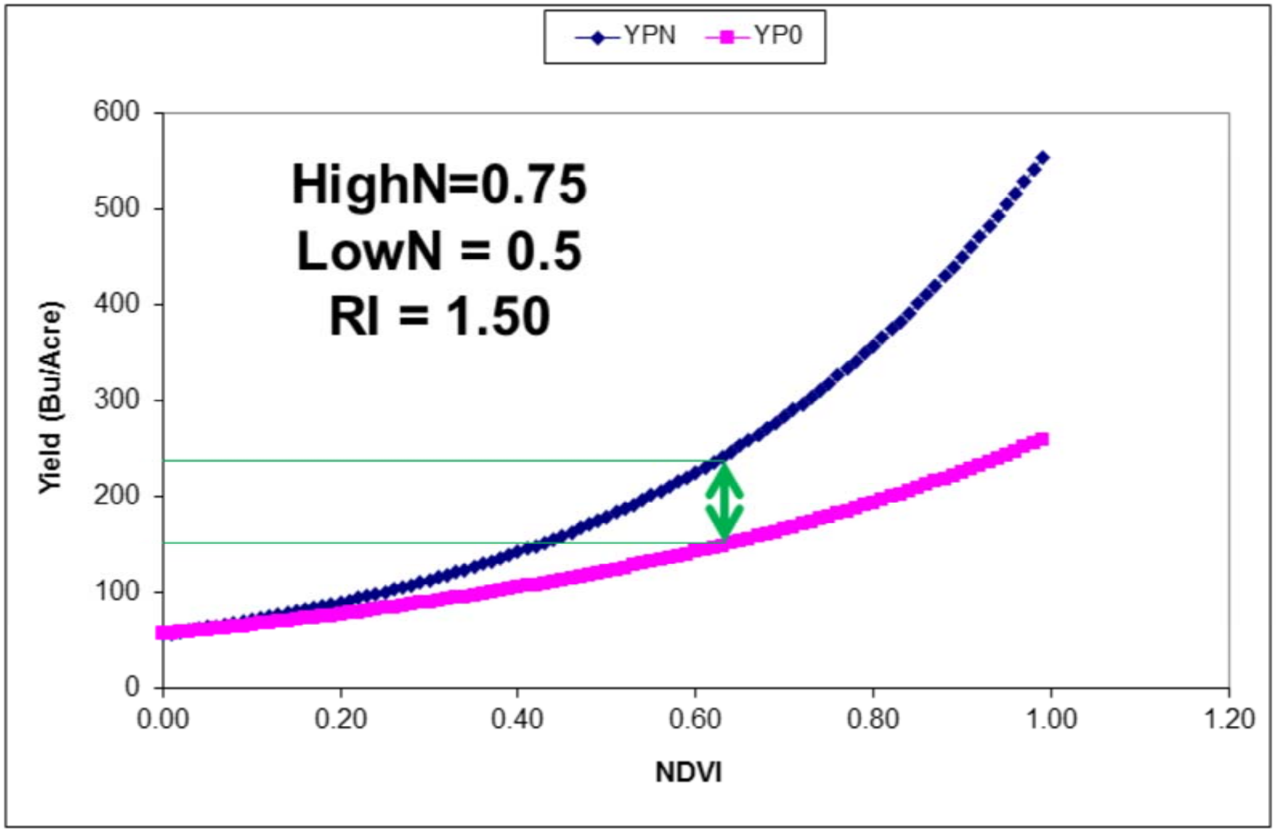
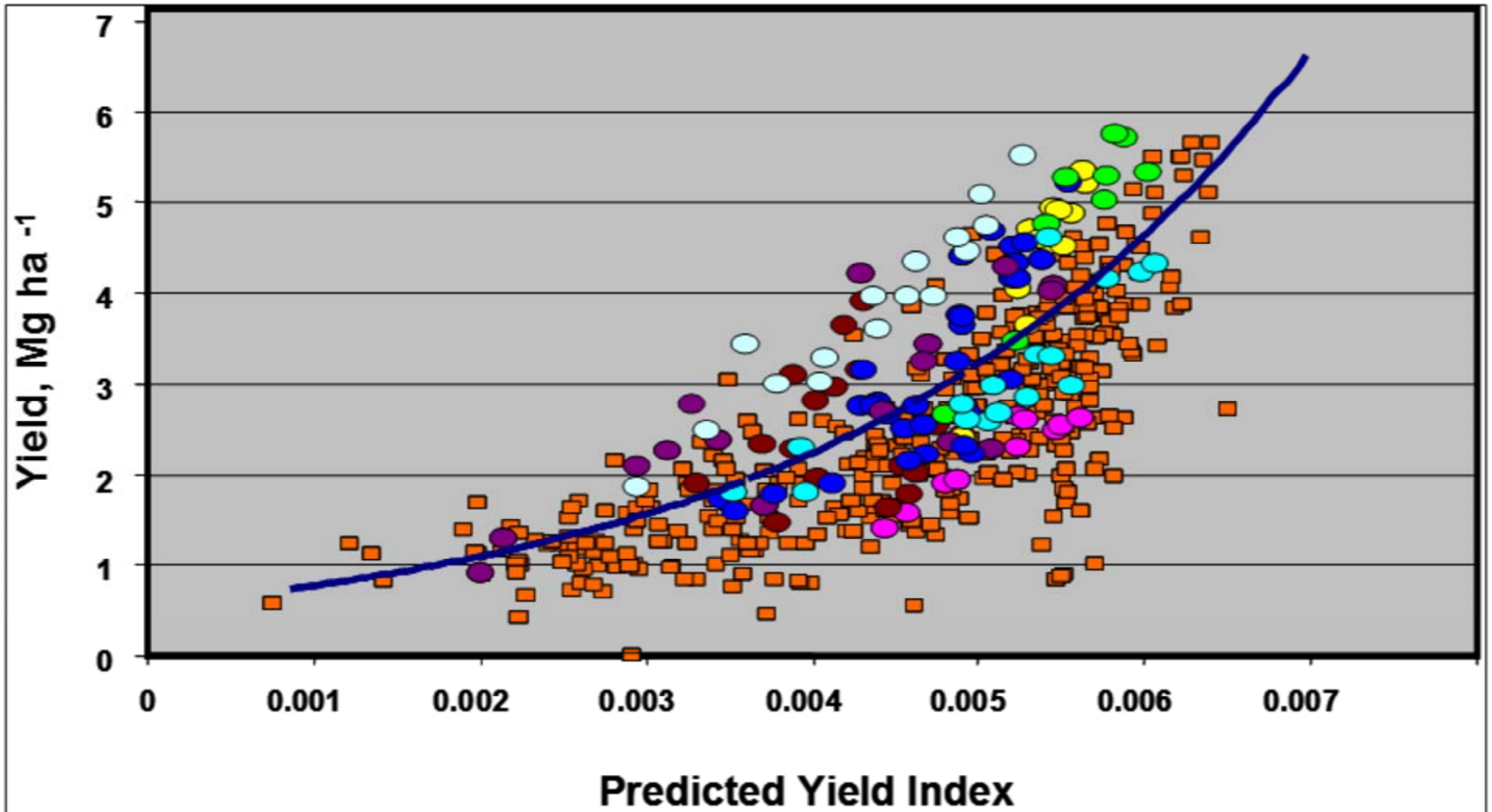
Ultimately you should end up applying the right rate in the right place in the field. Typically you end up applying less in the poor areas of the field and potentially in the very best areas of the field. Mid-range areas, that should yield close to maximum expected yield for the field, receive more nitrogen than under a flat rate strategy.

Varies N rate according to yield potential and N responsiveness



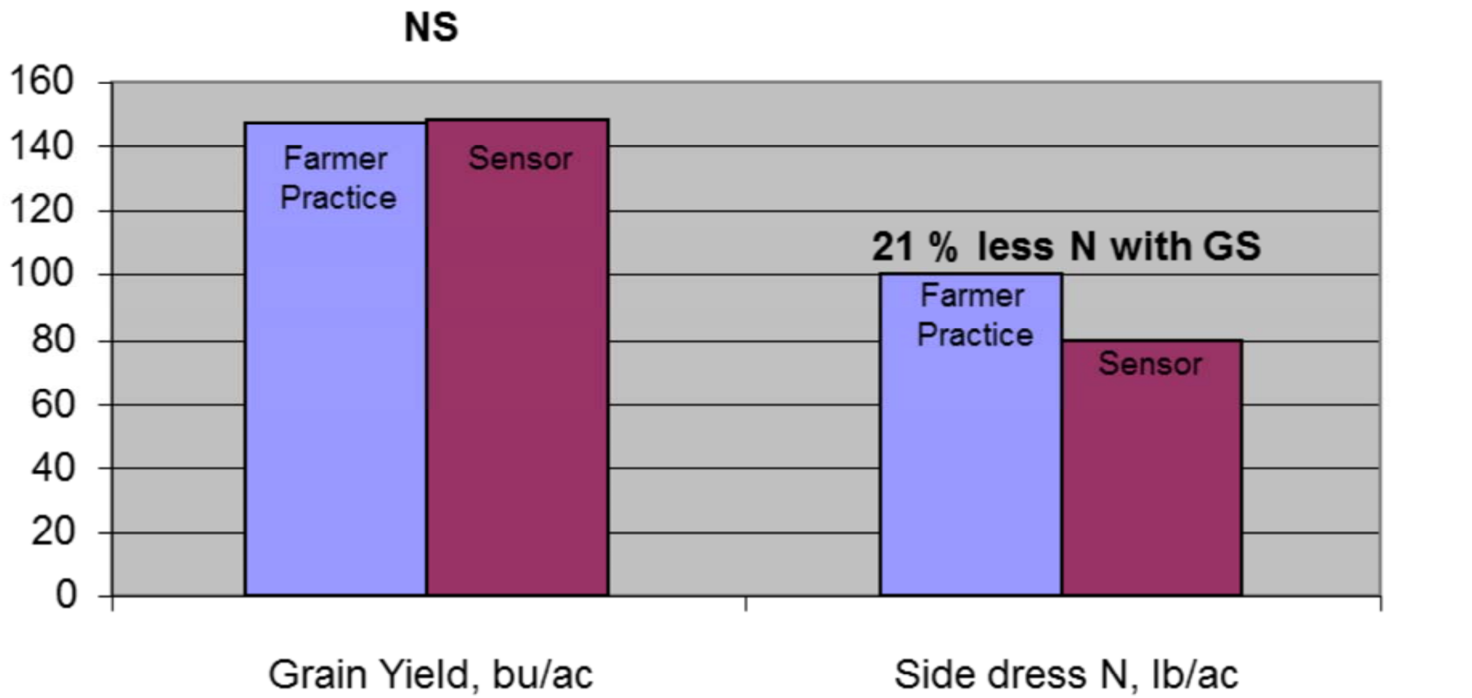
Predicted yield with added N (YPN) and yielded with no N (YPO). Used to calculated N rate when YPN<yield goal. Predicted yield increases exponentially to unrealistic rate. Therefore, the user enters a maximum yield value that replaces YPN in the equation if YPN>Max yield.

Calibration Model



Courtesy Wade Thomason VT

Average Corn Performance

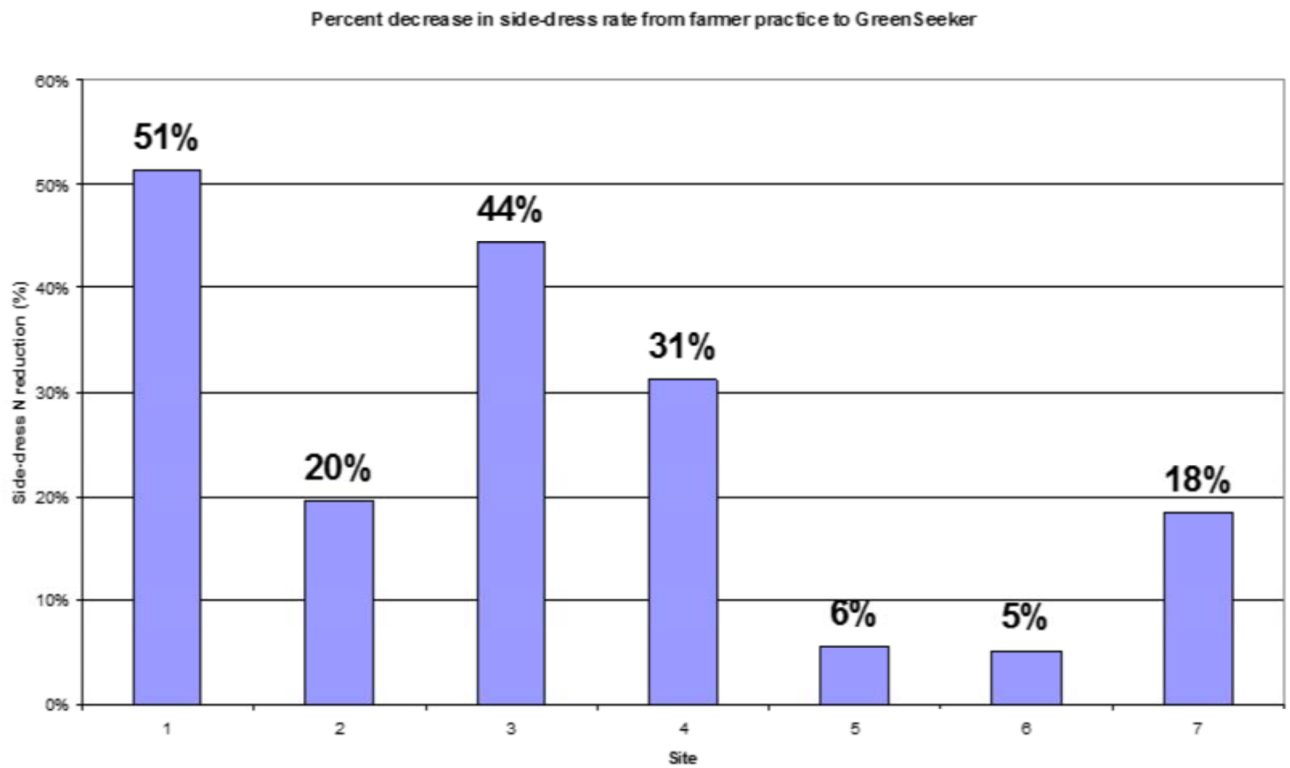


Courtesy Wade Thomason VT

VT validation showed about 20% reduction in side-dress N rate using sensor guided variable rate, with same yield.

2010 Percent N Reduced

Average Reduction = 25%



Be cautious when talking about average performance.

Policy – Science Disconnect

- New tools needed to achieve N balance and water quality goals
  - Adapt to temporal and spatial variation in N requirement
- Current policy is prescriptive instead of performance based
  - Dynamic nature of N lends itself to adaptive approach with flexibility to adjust to this variation
  - Rigid focus on individual BMP efficiency overlooks systemic issues
- Is lack of implementation our problem?
  - There are important questions left unanswered

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System Nutrient Balance

- Nutrient balances can be addressed through inputs and OUTPUTS
- N requirement as a system (crop rotations)
  - Manage the N cycle
  - Maximize recovery of applied N.
  - Convert as much fertilizer N as we can into grain and then conserve the balance as SOM
  - We tend to focus on one crop and tightening NUE
    - How does this impact yield in good years?

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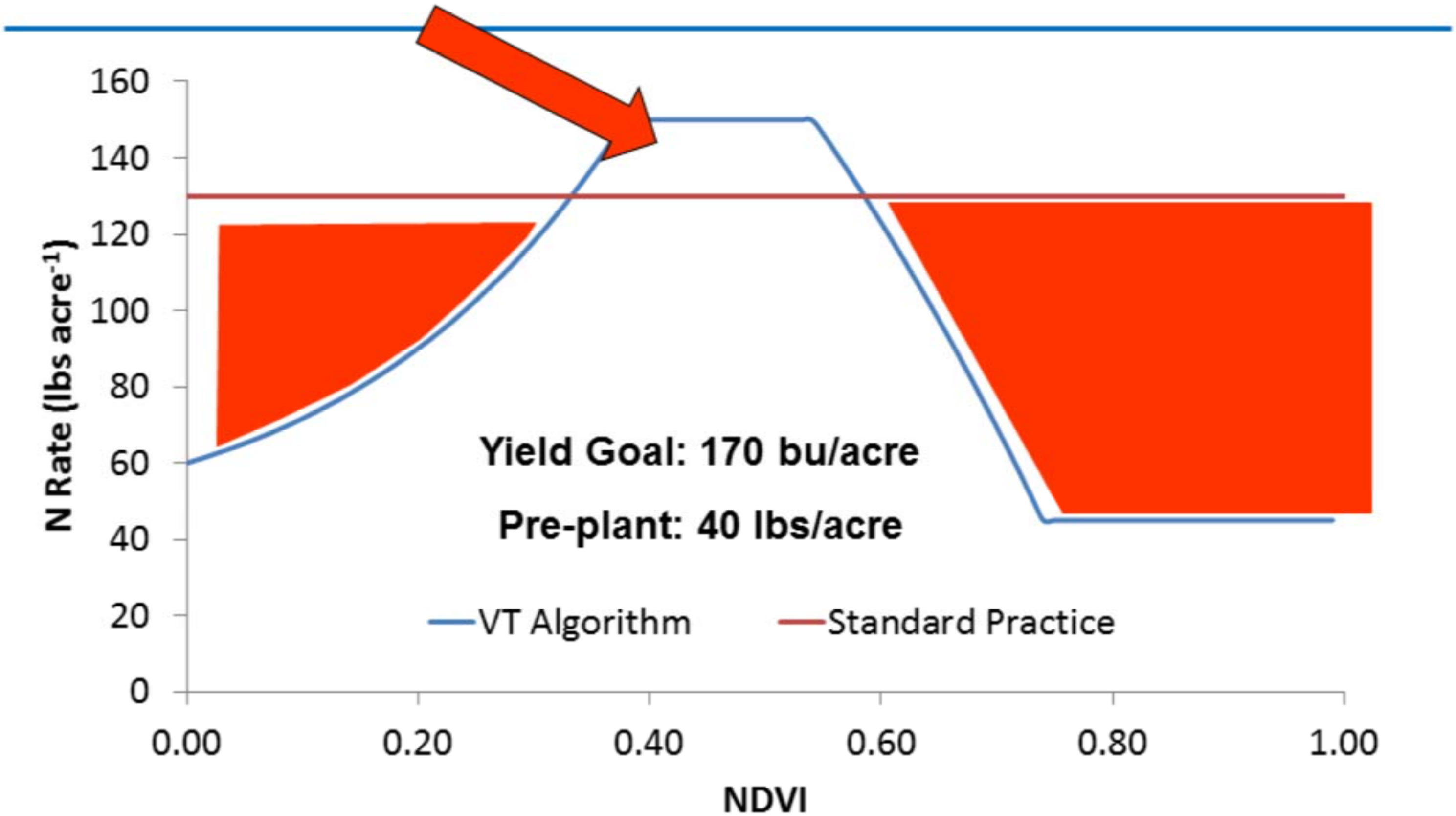
Trust the Research



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If we trust the technology we need to trust it when it says we need more or less than standard flat rate practice. Often farmers don't want to apply less and environmental groups don't want to apply more, but the technology should be applying the right rate in the right place.

Closing Thoughts

- Precision ag addresses variability through scalable technology
  - Social
  - Economic
  - Environmental
  - Temporal
  - Spatial
- Adjusting N rate for spatial and temporal variability is one way forward
- A new mouse trap is needed – ***implementing current best practices is not enough***
  - Fertilizer technology
  - Application equipment
  - Improved recommendation systems

The handheld sensor is an example of scalable tech. It is a "precision" N recommendation system scaled to socio-economic conditions. Similarly OSU is working on more precise hand planter. A lot of crops are planted by hand globally. A better hand planter is still precision ag.

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