Moving from Accurate to Precise

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PRECISION NUTRIENT MANAGEMENT

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A website to bridge the gap between Landlords and Leesses

How “we” Do N and P & K.

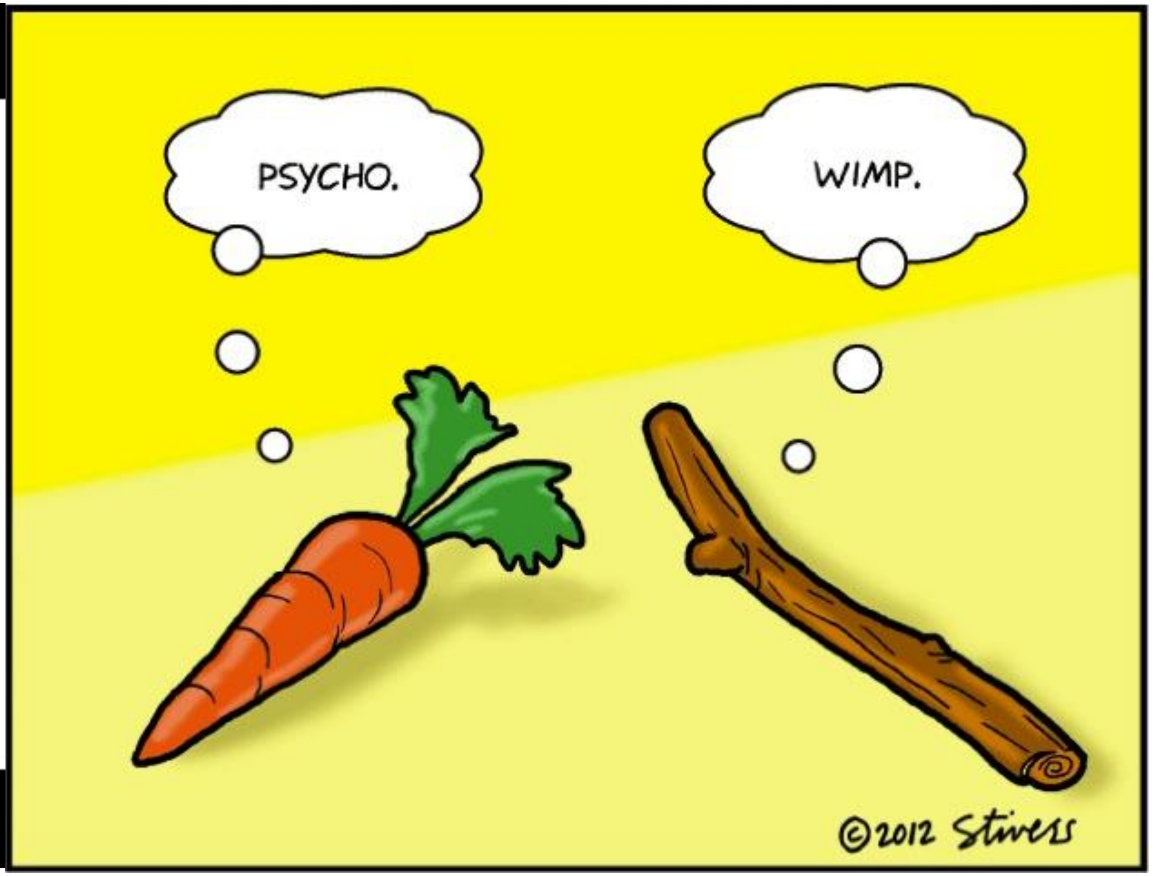
I am not, can not tell you how to do it right.

I am not going to say anyone is doing it wrong.

I do hope I make you think.

It just may not be today.

The Future "for others" will be either

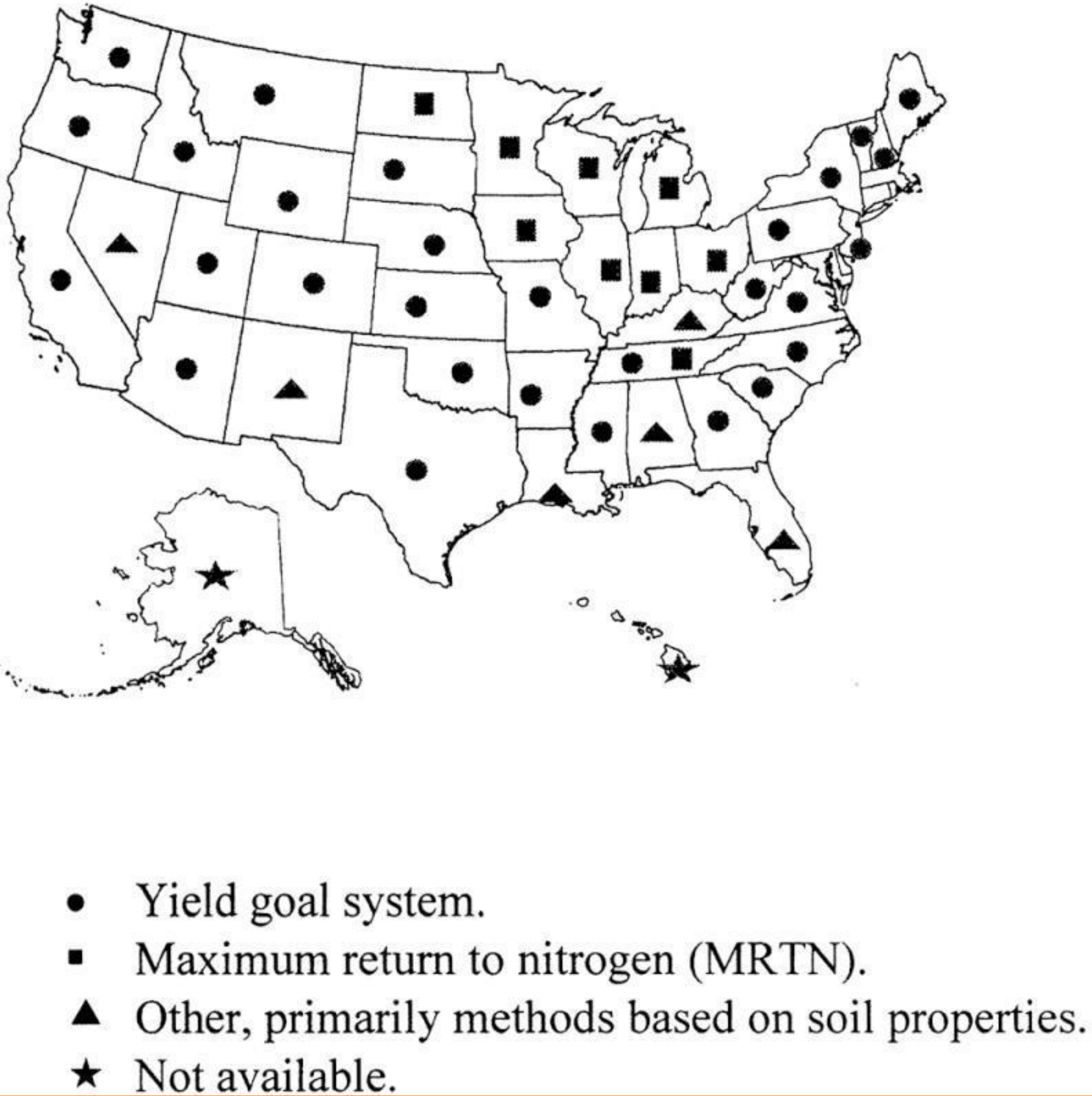


How N is done.

Yield goal * (factor)

+ or -

Soil and credits



Morris et al 2017

How N is done.

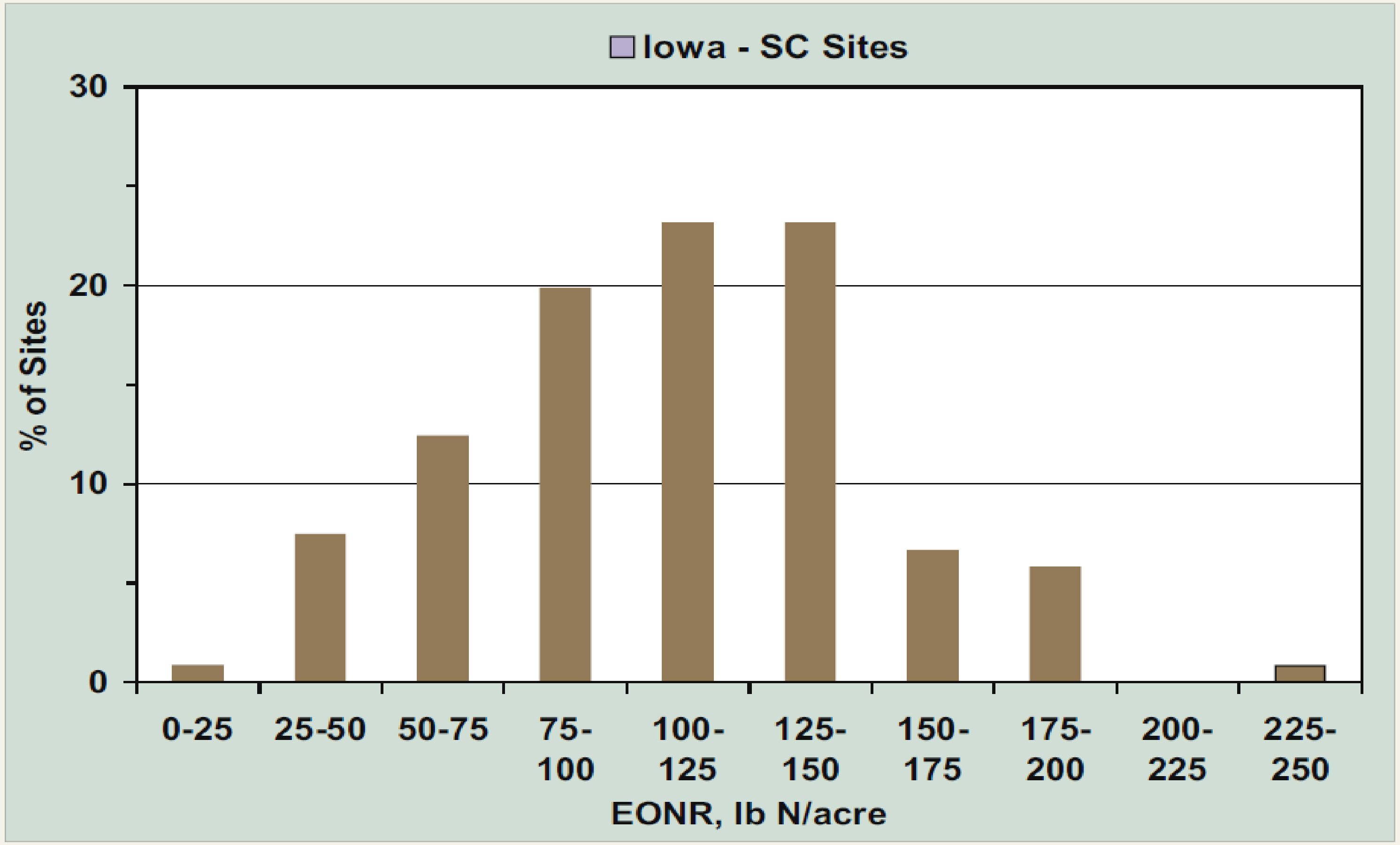


Figure 6. Frequency distribution of EONR (0.10 price ratio) for SC sites in Iowa.

How do recs Do.

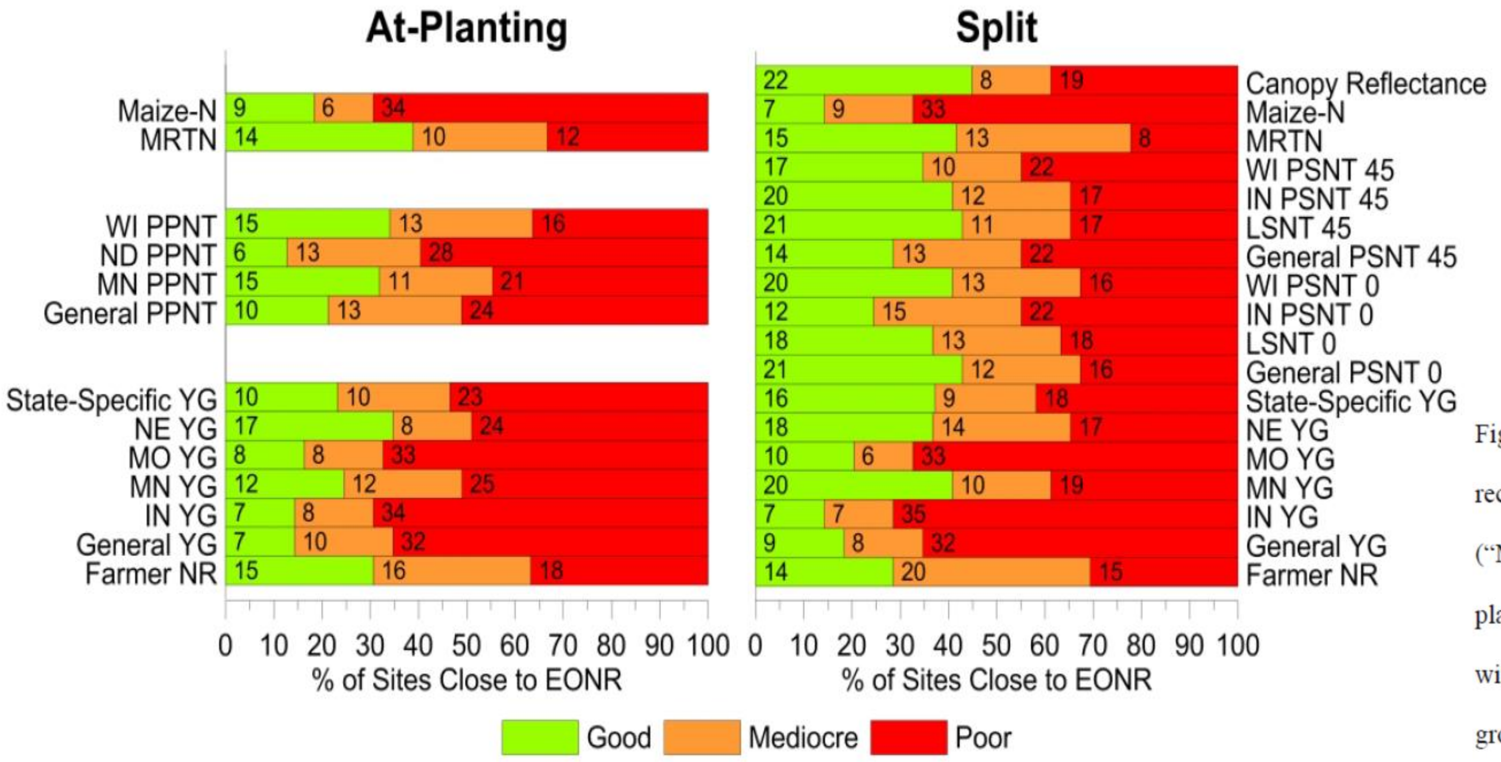
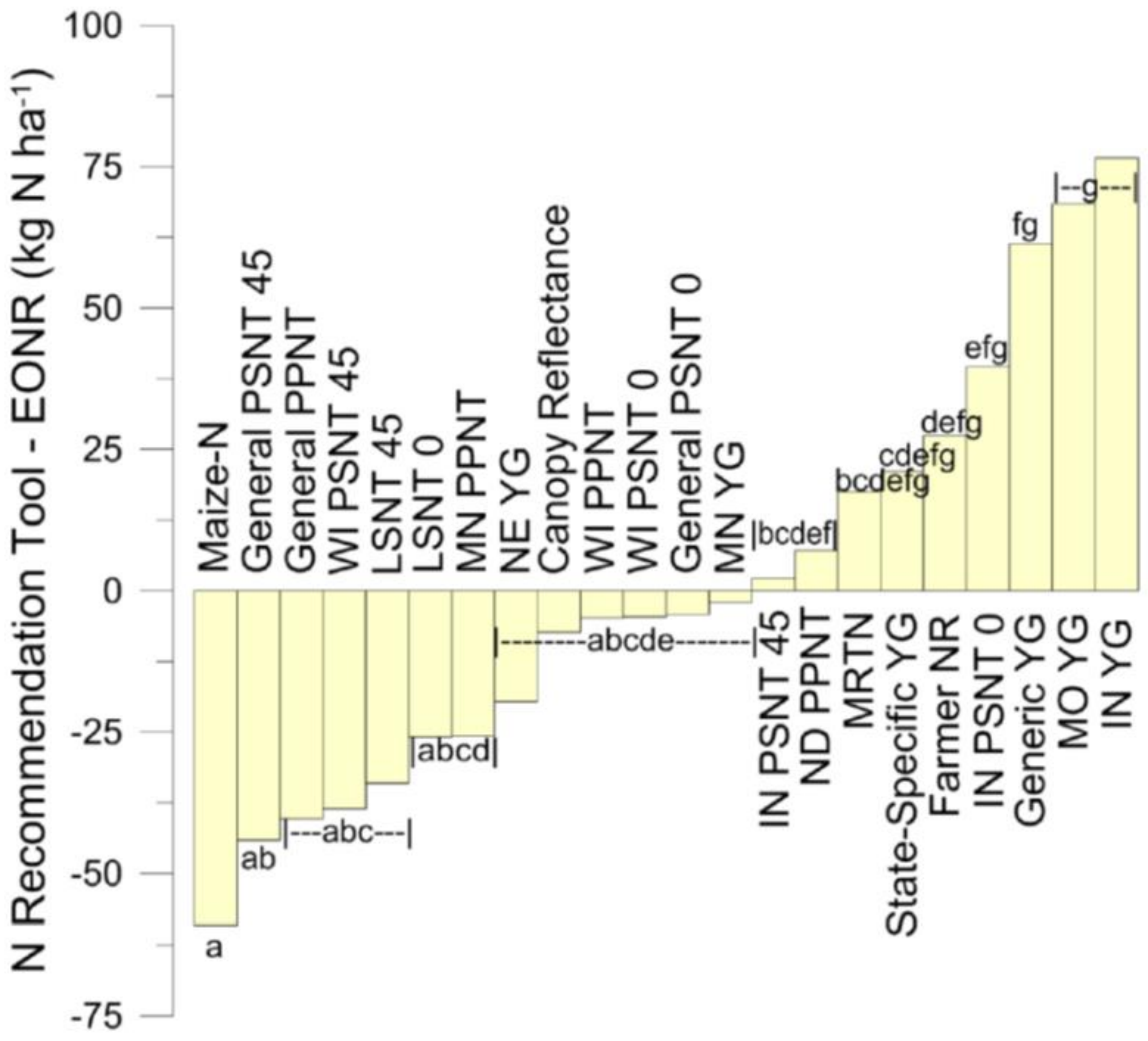


Fig. 2. The percentage and number of sites for the at-planting and sidedress tools' recommendations that came within: ±30 kg N ha^{-1} of EONR ("Good"), ±60 kg N ha^{-1} of EONR ("Mediocre"), and > 60 or < -60 kg N ha^{-1} of EONR ("Bad"). Tools include yield goal (YG), pre-plant nitrate test (PPNT), pre-sidedress nitrate test (PSNT) and late-spring nitrate test (LSNT) with 0 and 45 kg N ha^{-1} applied at-planting, Maximum Return to N (MRTN), Maize-N crop growth model, and canopy reflectance sensing using the Holland and Schepers algorithm.

Ransom CJ, Kitchen NR, Camberato JJ, Carter PR, Ferguson RB, Fernandez FG, Franzen DW, Laboski CAM, Nafziger ED, Sawyer JE, and Shanahan J. 2019. Corn nitrogen rate recommendation tools' performance across eight U.S. Midwest Corn Belt states. Agronomy Journal. doi: 10.2134/agronj2018.12.0776

Ransom Et al.

Fig. 3. Graph shows the mean difference (in kg N ha^{-1}) between each N recommendation tool and the economically optimal N rate (EONR). Tools used for both planting and split N application timing were not different ($P = 0.97$), and therefore recommendations shown are averaged across timings. Tools include yield goal (YG), pre-plant nitrate test (PPNT), pre-sidedress nitrate test (PSNT) and late-spring nitrate test (LSNT) with 0 and 45 kg N ha^{-1} applied at-planting, Maximum Return to N (MRTN), Maize-N crop growth model, and canopy reflectance sensing using the Holland and Schepers algorithm. Significance means separation was determined using Tukey's honest significant test with a significance threshold of 0.05.



Box and Whisker Plot

Here are the types of observations one can make from viewing a Box Plot:

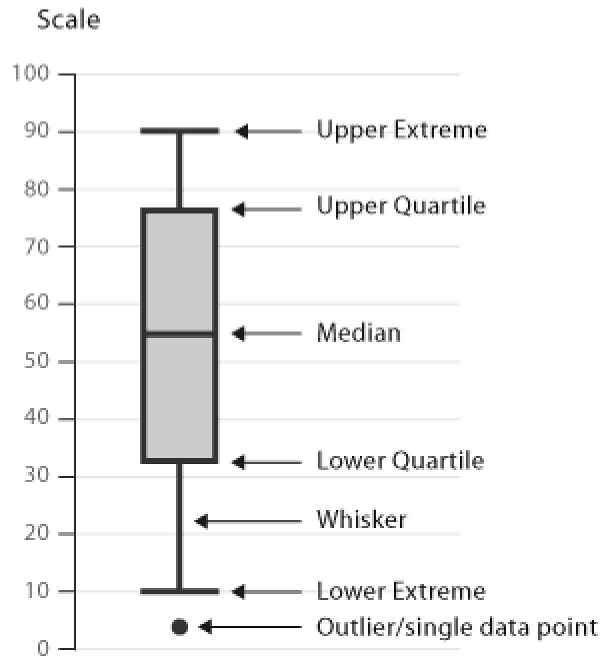
What the key values are, such as: the average, median 25th percentile etc.

If there are any outliers and what their values are.

Is the data symmetrical.

How tightly is the data grouped.

If the data is skewed and if so, in what direction.



Ransom Et al.

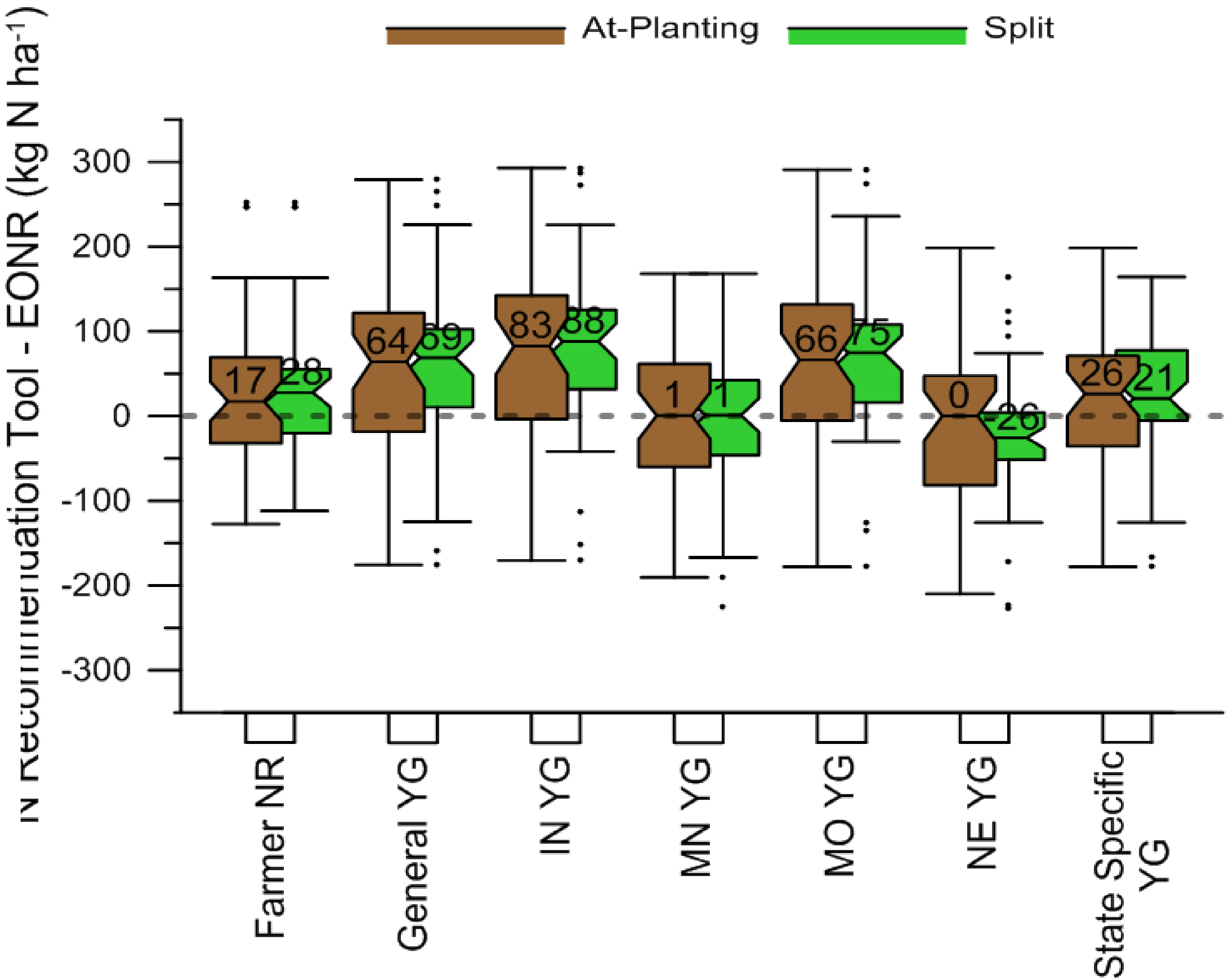


Fig. 4. Box and whisker plots showing the difference (in kg N ha^{-1}) between each yield goal (YG) based N recommendation and the economically optimal N rate (EONR) for both at planting and split N application timings. The median is reported by the value in the middle of the box. Notches on the side of each box indicate the 95% confidence interval around the median. Limits of the box indicate the first and third quartile, whiskers indicate 1.5 × interquartile range, and small circles indicate outliers.

Ransom Et al.

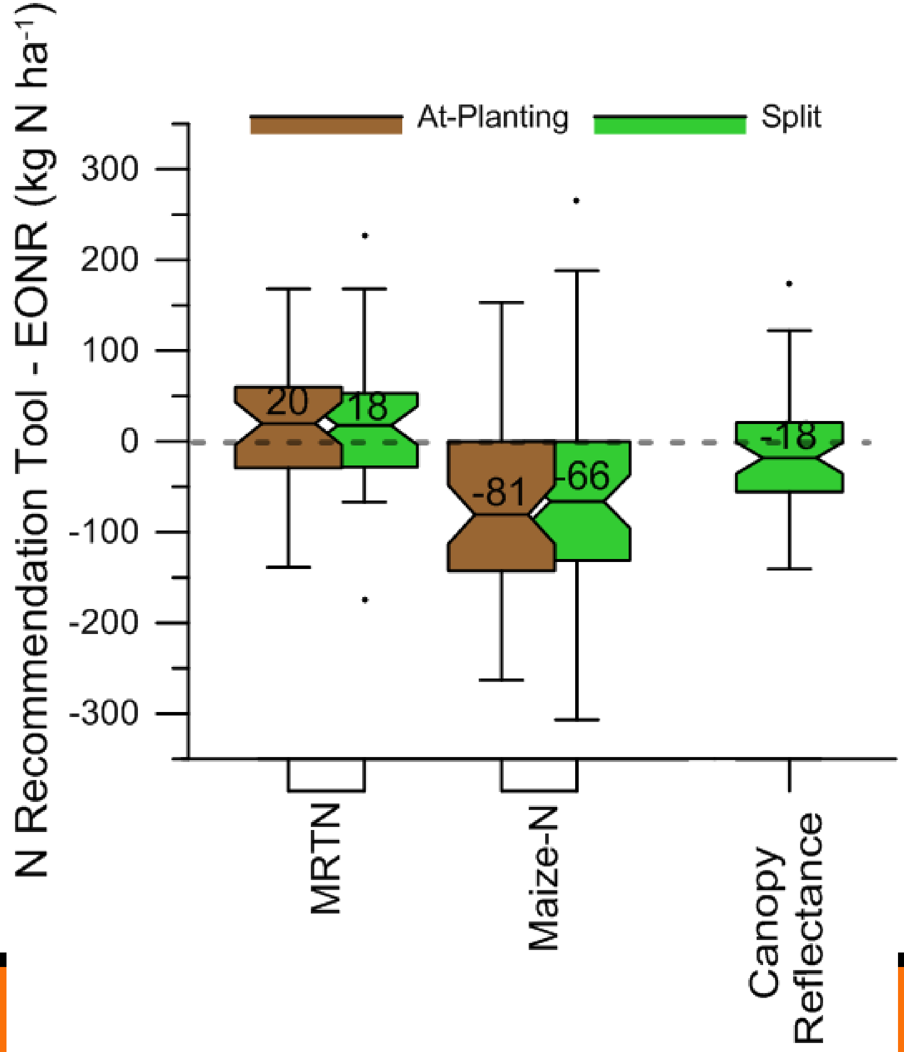
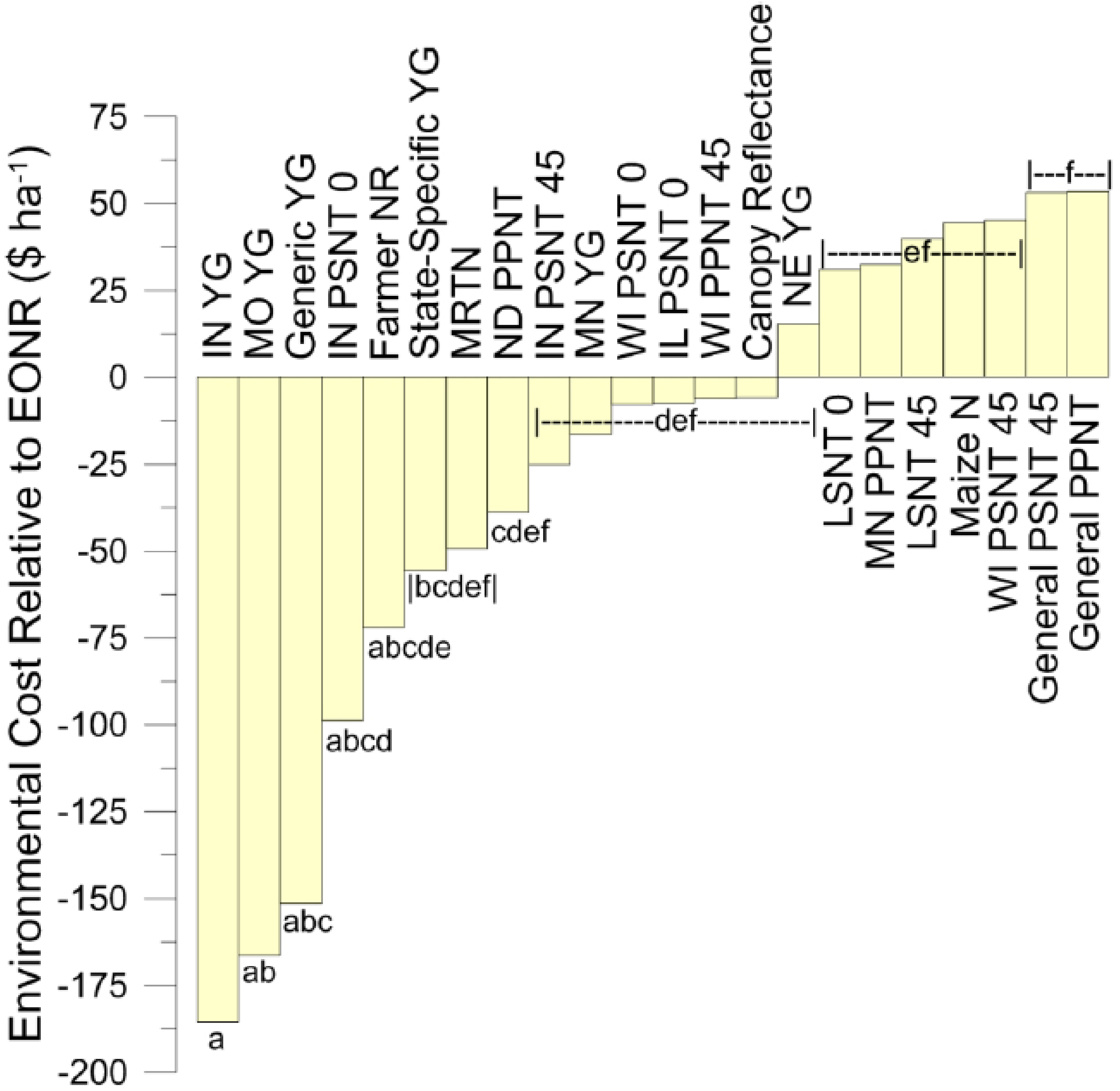


Fig. 7. Box and whisker plots showing the difference (in kg N ha^{-1}) between each of the tools' N recommendation and the economically optimal N rate (EONR) for both at-planting and split N application timings. Tools include Maximum Return to N (MRTN), Maize-N crop growth model, and canopy reflectance sensing using the Holland and Schepers algorithm. The median is reported by the value in the middle of the box. Notches on the side of each the box indicate the 95% confidence interval around the median. Limits of the box indicate the first and third quartile, whiskers indicate 1.5 × interquartile range, and small circles indicate outliers.

Ransom Et Al.

Fig. 9. Mean environmental cost (in \$ ha^{-1}) for N recommendation tools relative to the economically optimal N rate (EONR). Tools used for both planting and split N application timing were not different (P = 0.98), and therefore recommendations shown are averaged across timings. Tools include yield goal (YG), pre-plant nitrate test (PPNT), pre-sidedress nitrate test (PSNT) and late-spring nitrate test (LSNT) with 0 and 45 kg N ha^{-1} applied at-planting, Maximum Return to N (MRTN), Maize-N crop growth model, and canopy reflectance sensing using the Holland and Schepers algorithm. Significance means separation was determined using Tukey honest significant difference test with a significance threshold of 0.05.

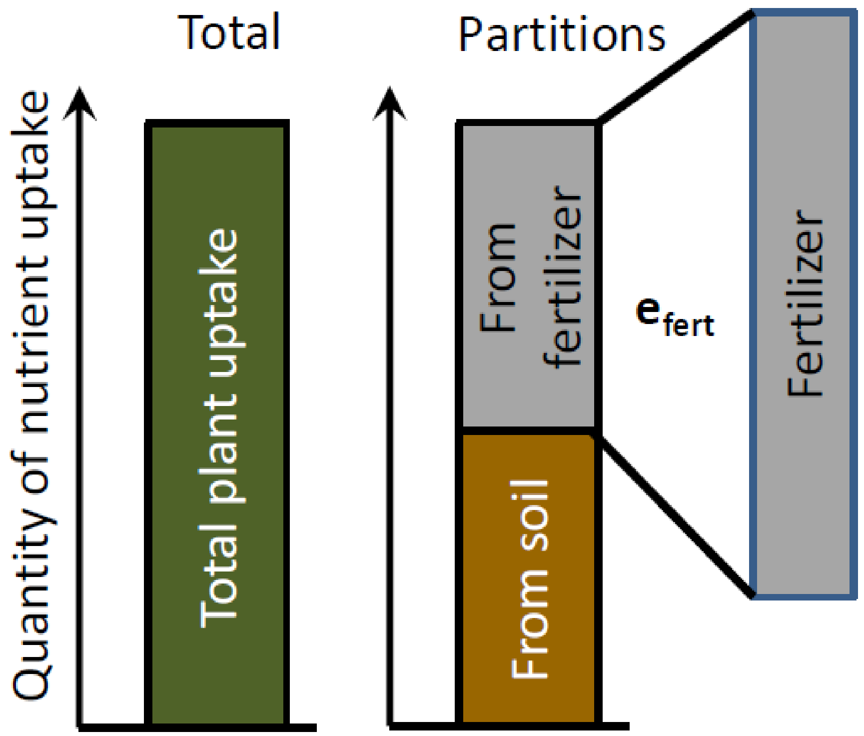


Stanford Equation

$$N_{fert} = (N_{crop} - N_{soil}) / e_{fert}$$

Douglas Beegle, Penn State University
Scott Murrell, International Plant Nutrition Institute

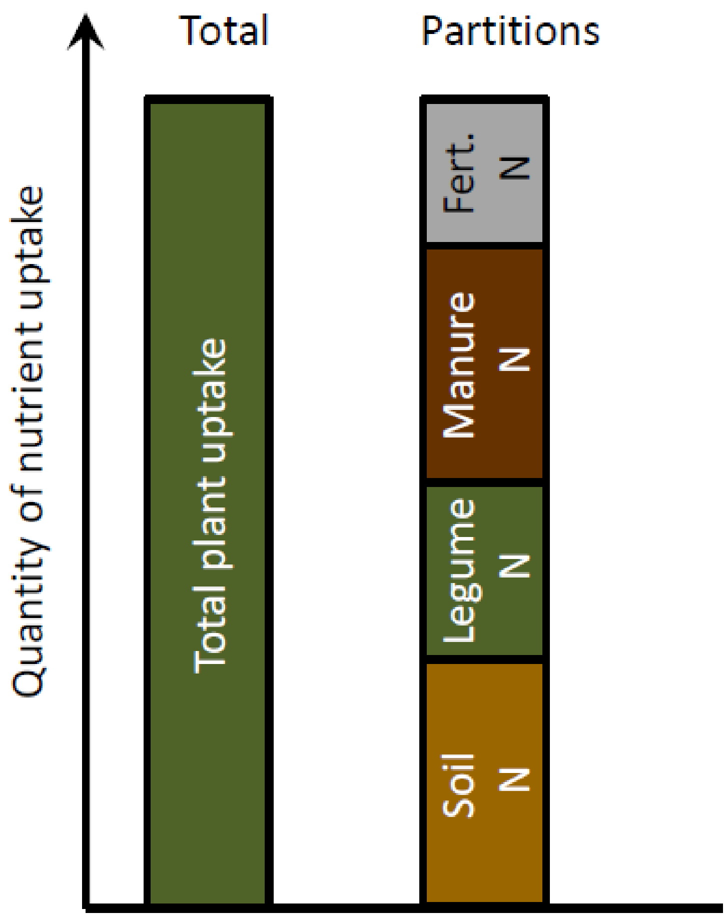
ASA Symposium
Agronomic Production Systems and Adaptive Nutrient Management Community
Strengths and Limitations of Methods, Tests, and Models for Making N Recommendations for Corn and a Framework for Improving N Recommendations



Stanford Equation

$$N_{fert} = (N_{crop} - N_{SIN} - N_{SON} - N_{CRN} - N_{manure\ RON} - N_{manure\ IN} - N_{manure\ ON} - N_{leg}) / e_{fert}$$

N_{fert} = Total fertilizer N required
N_{crop} = Total N in Crop
N_{SIN} = Available soil inorganic N
N_{SON} = Available soil organic N
N_{CR} = Available crop residue N
$N_{manure\ RON}$ = Available manure residual organic N
$N_{manure\ IN}$ = Available manure inorganic N
$N_{manure\ ON}$ = Available manure organic N
N_{leg} = Available legume N
e_{fert} = Fertilizer N efficiency



Theoretical Equation

$$N_{fert} = ([Yld \times N_{crop}] - [N_{SIN} \times e_{SIN} \times R_{SIN}] - [N_{SON} \times M_{SON} \times e_{SON} \times R_{SON}] - [N_{MRON} \times M_{MRON} \times e_{MRON} \times R_{MRON}]$$

$$- [N_{MIN} \times e_{MIN} \times R_{MIN}] - [N_{MON} \times M_{MON} \times e_{MON} \times R_{MON}] - [N_{LN} \times M_{LN} \times e_{LN} \times R_{LN}]) / e_{fert}$$

Yield Records

PPNT

Soil Quality, **Weather, Models**

Soil Quality

SOM Test, ISNT

Soil quality, **weather**, crop residues characteristics, tillage, **models**

Manure application records & manure analysis

Soil Quality, Weather, Tillage & characteristics of source, **Models**

Soil Quality

Manure application records & Manure analysis, PSNT

Soil Quality, weather, manure application timing and method, **models, PSNT, sensors**

Soil Quality

Manure application records & Manure analysis **PSNT**

Soil Quality, Weather, Tillage & characteristics of source, **PSNT, Sensors, Models**

Soil Quality

Assess Legume Stands

Soil Quality, Weather, termination, Tillage, characteristics of the source, **Models**

Soil Quality

Source, Method, timing of fertilizer application Weather

Nitrogen in the Crop

N_{Crop}

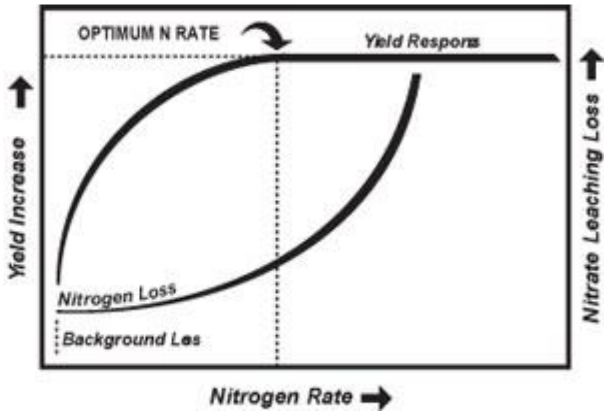
Yield Goal

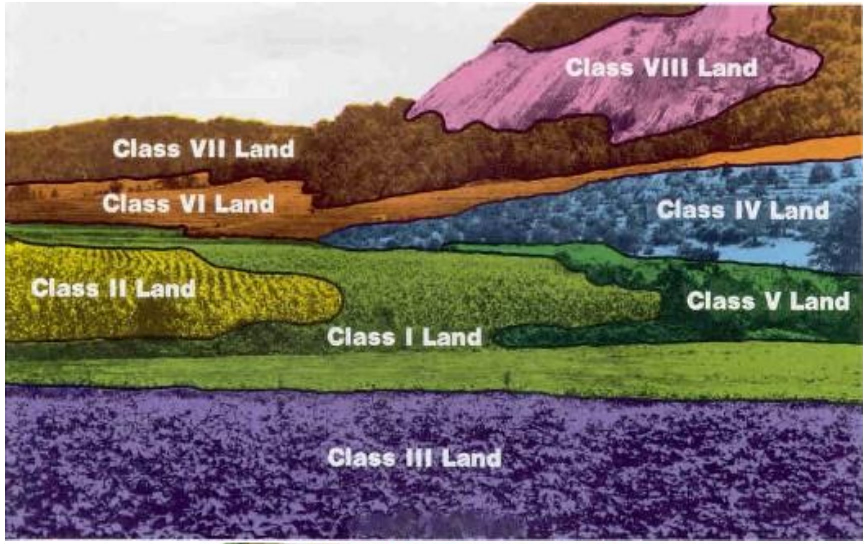
Soil Class

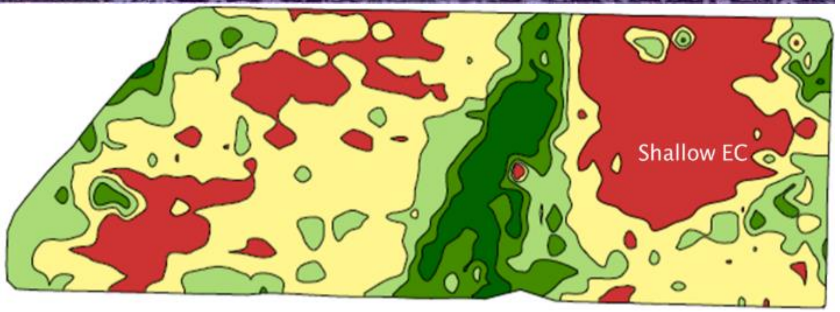
Yield Map

Biomass Map

Growth | Uptake Model







Nitrogen in the Crop – Yield Goal

N_{Crop}

Yield Goal

Soil Class

Yield Map

Biomass Map

Growth | Uptake Model

Nitrogen in the Crop - Removal

N_{Crop}

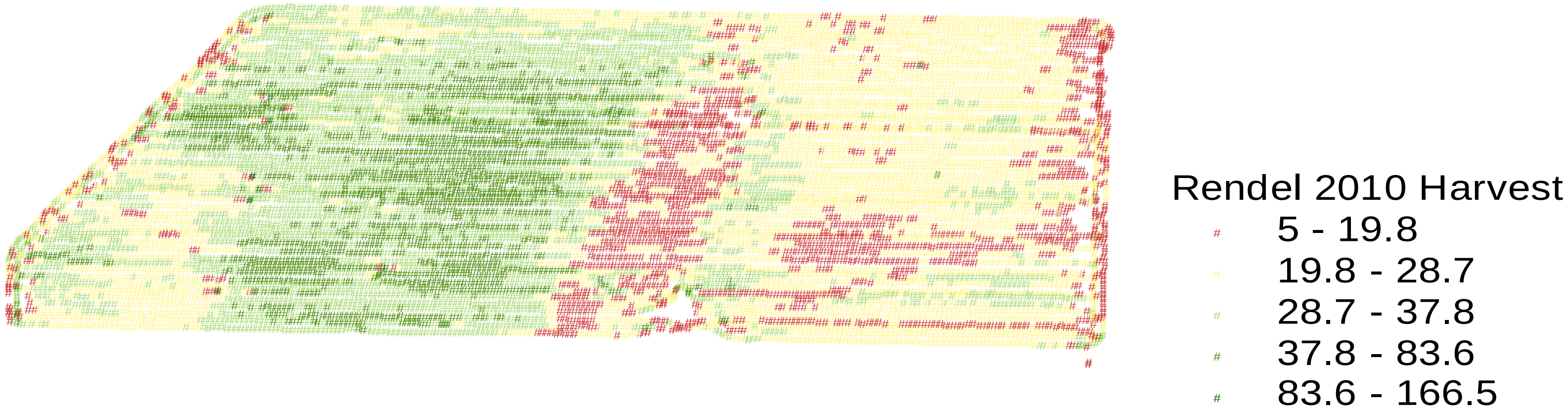
Yield Goal

Soil Class

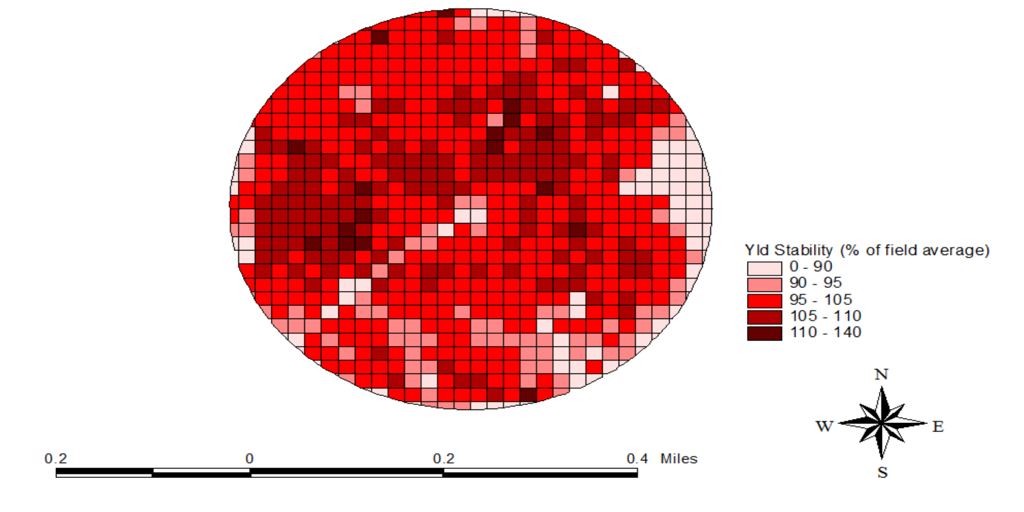
Yield Map

Biomass Map

Growth | Uptake Model



Field 3; Yield Stability 2006-2009



Nitrogen provide by the Soil

N_{Soil}

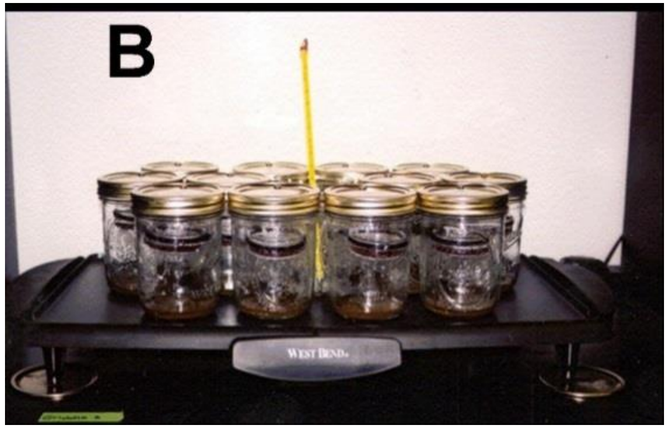
Soil Test

- Pre
- In-Season

Mineralization

Losses

N Addition and N Loss via Weather.



Fertilizer Use

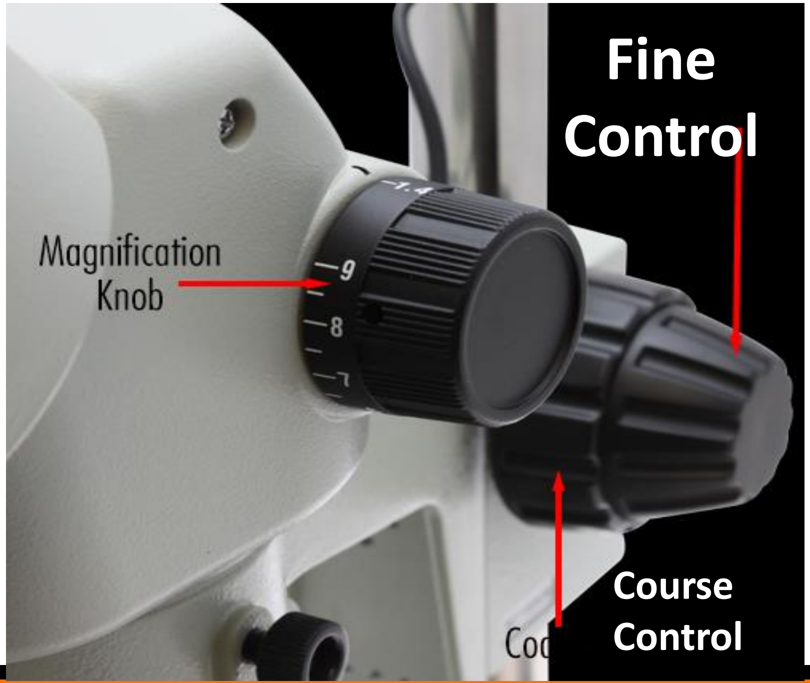
- e_{Fert}

- 4Rs
  - Source
  - Placement
  - Time
  - Rate
- NUE –
  Lbs of N per Bushel?????
  - Consistent low v high?

Fine and Course Control

- e_{Fert}
- N_{Crop}
  - Yield Map
  - Yield Goal N Recs 1.0-1.1-1.2* Yield

Making high resolution decisions using low resolution recs. Recommendation maps are at < 1 acre resolution and 1.2 Lbs N per bushel grain. How Precise is that.



Fine and Course Control

- e_{Fert}
- N_{Crop}
  - Yield Map
  - Yield Goal N Recs 1.0-1.1-1.2* Yield

Nitrogen Uptake $\mathbf{N_{crop}}$ is correlated with yield.

$\mathbf{N_{soil}}$ and $\mathbf{e_{Fert}}$ is Not correlated with yield

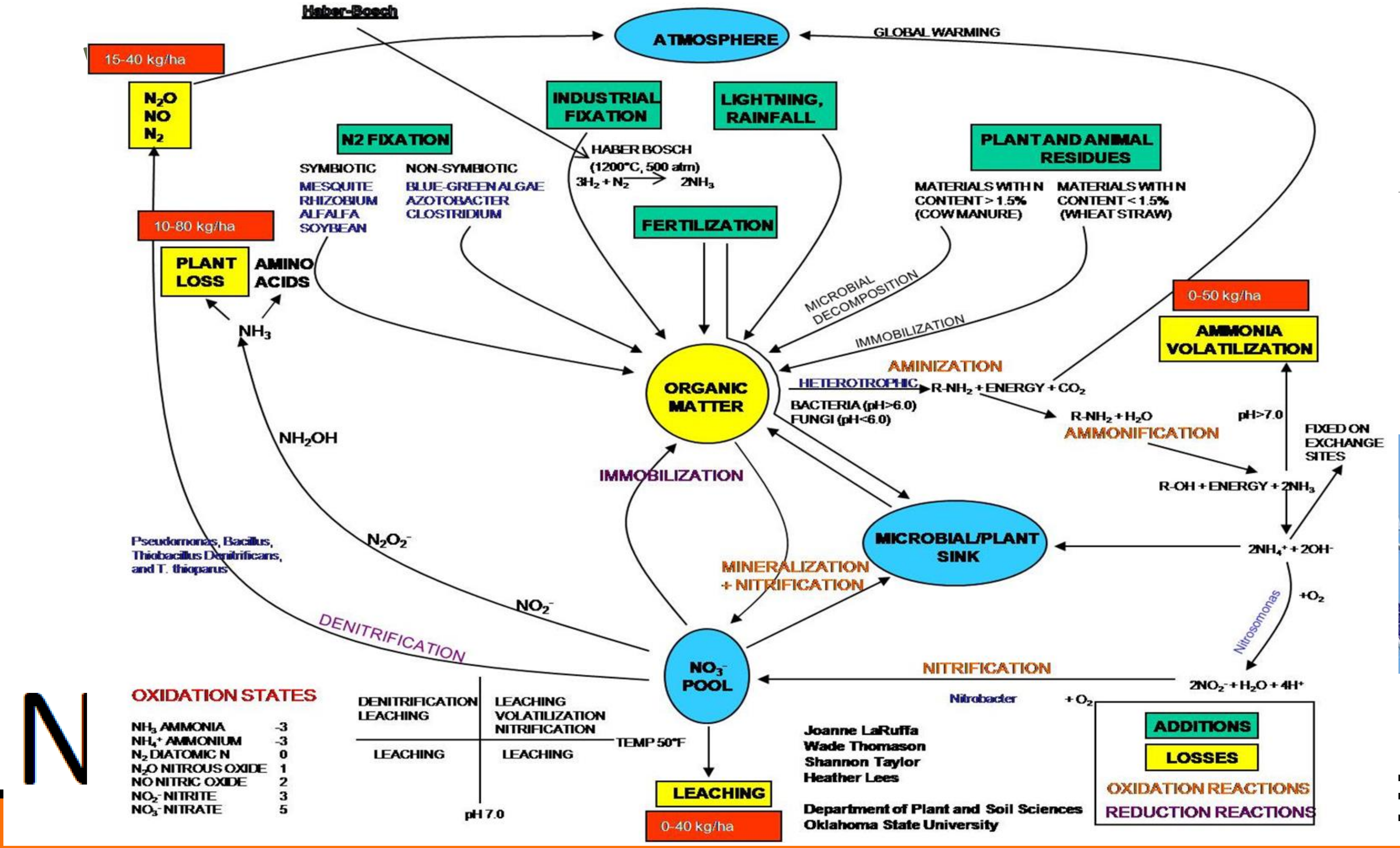
Therefore $\mathbf{N_{fert}}$ is Not Correlated with YIELD

Average of 68 lbs with 49 BPA, 1.5 lbs N per bushel

Combining the Components

- N_{Crop}
- N_{Soil}
- e_{Fert}

Wheat 1.3 lbs N bu^{-1} Corn .75 lbs N bu^{-1}


Haber-Bosch
ATMOSPHERE
GLOBAL WARMING
15-40 kg/ha
N2O
NO
N2
INDUSTRIAL FIXATION
LIGHTNING, RAINFALL
N2 FIXATION
HABER BOSCH
(1200°C, 500 atm)
3H2 + N2 → 2NH3
PLANT AND ANIMAL RESIDUES
SYMBIOTIC
MESQUITE
RHIZOBIUM
ALFALFA
SOYBEAN
NON-SYMBIOTIC
BLUE-GREEN ALGAE
AZOTOBACTER
CLOSTRIDIUM
MATERIALS WITH N CONTENT > 1.5% (COW MANURE)
MATERIALS WITH N CONTENT < 1.5% (WHEAT STRAW)
10-80 kg/ha
FERTILIZATION
PLANT LOSS
AMINO ACIDS
NH3
MICROBIAL DECOMPOSITION
IMMOBILIZATION
0-50 kg/ha
AMMONIA VOLATILIZATION
AMINIZATION
ORGANIC MATTER
HETEROTROPHIC
R-NH2 + ENERGY + CO2
BACTERIA (pH>6.0)
FUNGI (pH<6.0)
R-NH2 + H2O
AMMONIFICATION
pH>7.0
FIXED ON EXCHANGE SITES
NH2OH
IMMOBILIZATION
R-OH + ENERGY + 2NH3
MICROBIAL/PLANT SINK
2NH4+ + 2OH-
Pseudomonas, Bacillus, Thiobacillus Denitrificans, and T. thioparus
N2O2-
MINERALIZATION + NITRIFICATION
NO2-
Nitrosomonas
+O2
DENITRIFICATION
NO3- POOL
NITRIFICATION
2NO2- + H2O + 4H+
Nitrobacter
+ O2
OXIDATION STATES
NH3 AMMONIA -3
NH4+ AMMONIUM -3
N2 DIATOMIC N 0
N2O NITROUS OXIDE 1
NO NITRIC OXIDE 2
NO2- NITRITE 3
NO3- NITRATE 5
DENITRIFICATION LEACHING
LEACHING VOLATILIZATION NITRIFICATION
LEACHING
LEACHING
TEMP 50°F
pH 7.0
LEACHING
0-40 kg/ha
Joanne LaRuffa
Wade Thomason
Shannon Taylor
Heather Lees
Department of Plant and Soil Sciences
Oklahoma State University
ADDITIONS
LOSSES
OXIDATION REACTIONS
REDUCTION REACTIONS

N

ert

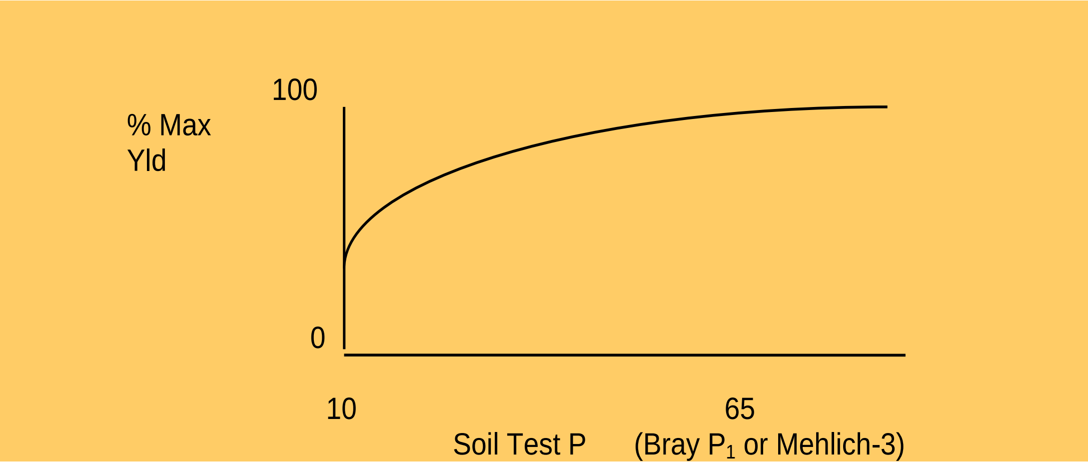
How we Do Phosphorus

Soil Testing was/is the basis

Determine immediately and potentially available P.

Relate back to Correlation Calibration work. (50s-60s)

“Critical” Values Est.



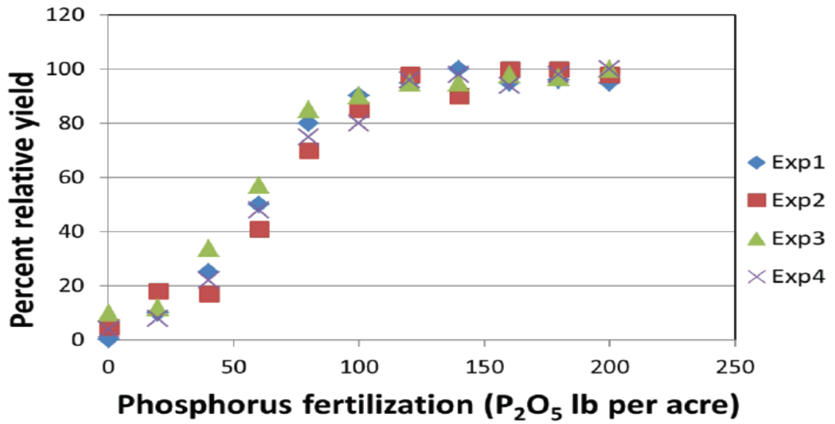


Figure 3. Crop response to P fertilization on a *low*-testing soil
Credits: Hochmuth, Mylavarapu, and Hanlon

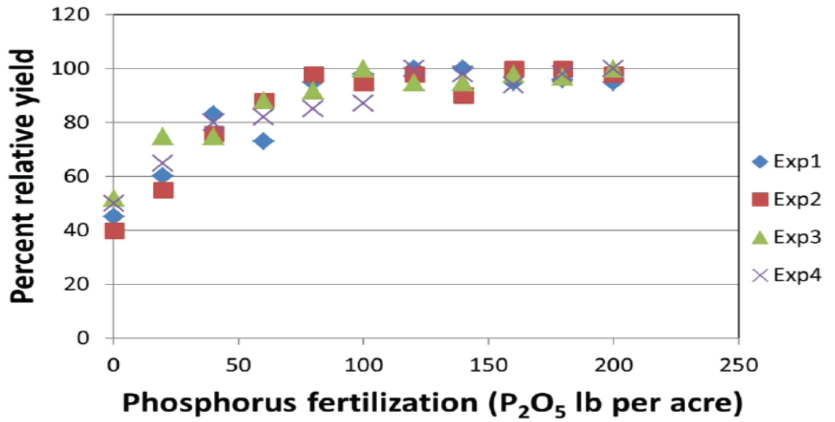


Figure 4. Crop response to P fertilization on a *medium*-testing soil
Credits: Hochmuth, Mylavarapu, and Hanlon

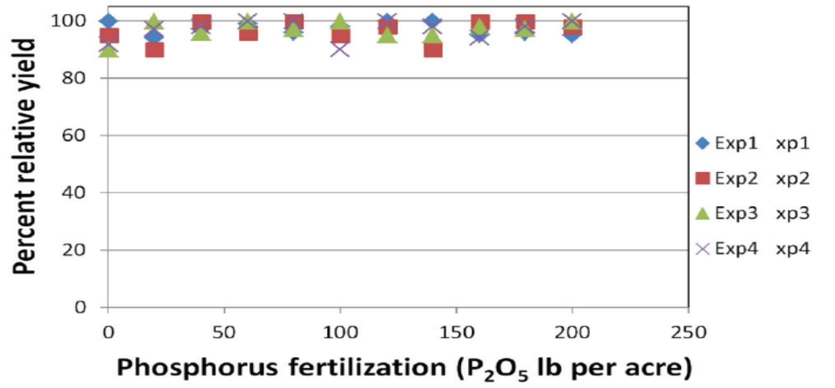


Figure 5. Crop response to P fertilization on a *high*-testing soil
Credits: Hochmuth, Mylavarapu, and Hanlon

How we Do Phosphorus

Soil Testing

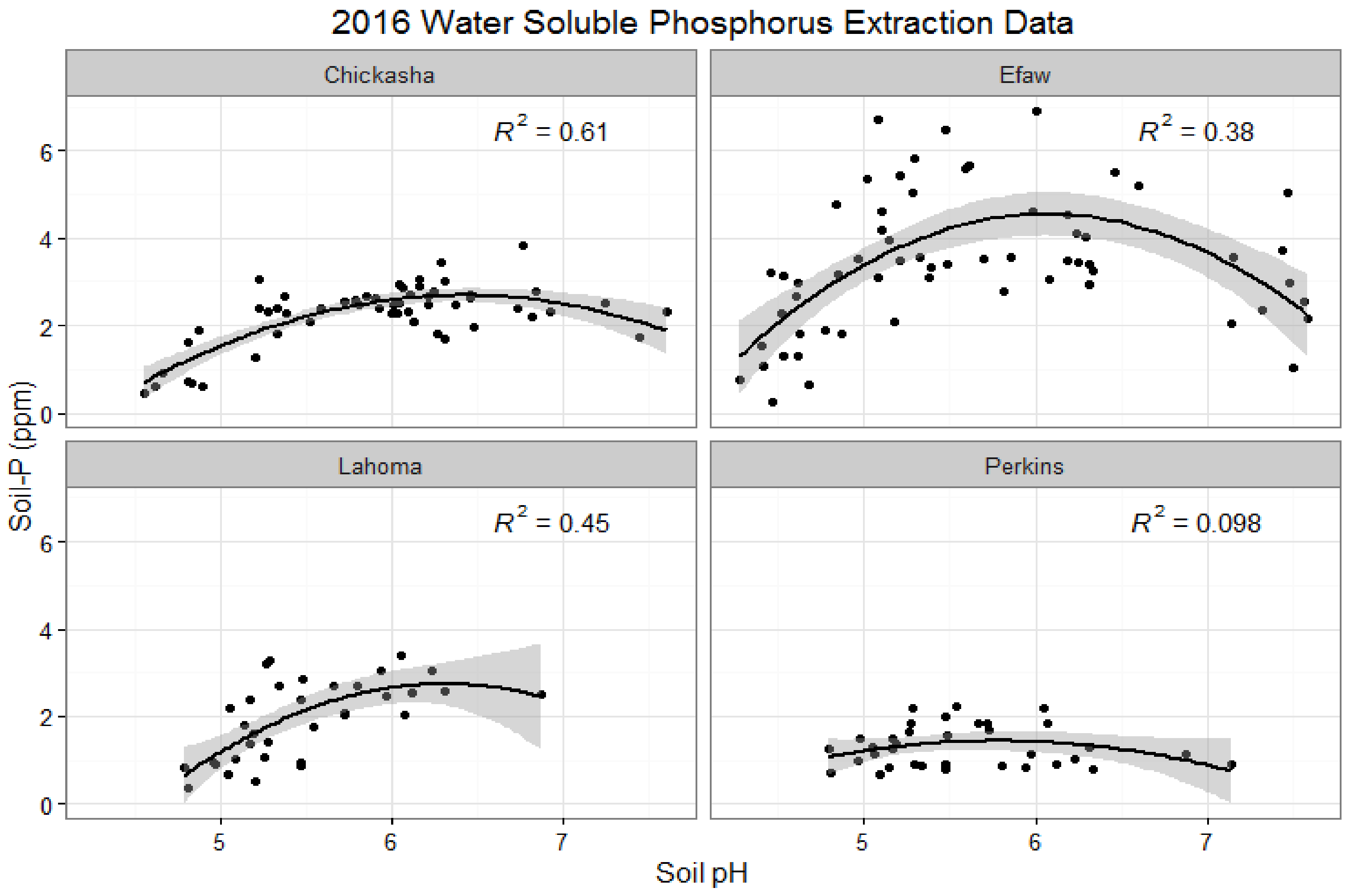
Multiple Extractions because of pH

Bray

Olsen

Mehlich

Resin



How we Do Phosphorus Recs

Sufficiency program

Feed the Plant

- Intended to estimate the long-term average amount of fertilizer P required to, on average, provide optimum economic return in the year of application. There is little consideration for future soil test values

	Phos Removal Per Bus.	90% Suff. ppm	Starter Rate lbs p2O5 ac -1 *Low*	*High*	P205 Rec at 90% Suff.
Wheat	0.5	18	23	40	25
Canola	0.4	20	12	25	20
Corn	0.38	18	17	25	25
Sorghum	0.42	18	17	34	25

Phosphorus Recs – Suff Does work

Year	Location	OSU Rate	Applied Phosphorus (kg P ha^{-1}) OSU	0	4.9	9.8	14.7	19.6	24.5	29.4	34.3	39.2	44.1	48.9
		kg P ha^{-1}	yield Mg ha^{-1}											
2014														
	Stillwater	36.2	2.93	2.84	2.71	2.57	3.01	2.85	2.88	2.43	3.02	3.00	2.86	2.50
	Red Rock 1	19.5 *	2.02 abc	1.34 c	1.46 c	1.44 c	2.02 abc	2.30 abc	1.81 bc	3.06 a	2.79 ab	2.37 abc	2.98 ab	2.84 ab
	Red Rock 2	11.3 *	3.52 abcd	2.87 d	2.99 cd	3.38 bcd	3.40 abcd	3.71 abc	3.58 abcd	3.59 abcd	4.16 a	3.83 ab	3.59 abcd	3.99 ab
	Red Rock 3	10.2 *	3.46 abcd	2.97 de	2.84 e	3.19 bcde	3.21 cde	3.93 ab	3.59 abcde	3.39 abcde	3.75 a	3.83 abc	3.68 abcd	3.76 ab
	Waukomis1	0 *	2.06 ab	1.86 b	2.39 a	1.94 b	2.06 ab	2.02 ab	2.22 ab	1.92 b	2.05 ab	2.08 ab	2.16 ab	1.98 ab
	Waukomis 2	19.6	1.82 abc	1.29 d	1.58 cd	1.68 bc	1.72 bc	1.84 abc	1.81 abc	2.03 a	1.83 abc	1.84 abc	1.97 ab	1.95 ab
2015														
	Garber	0	3.33	3.20	3.13	3.19	3.30	3.47	3.79	3.21	3.20	3.14	3.20	3.25
	Stillwater	29.4	2.23	2.34	2.53	2.24	2.75	2.60	3.74	2.72	2.68	2.97	2.84	3.03
	Waukomis 3	7.4 *	3.31	3.24	3.57	3.29	3.48	3.41	3.72	3.59	3.65	3.56	3.80	3.69

Means in each row with different lettering beneath are significantly different at $p \leq 0.05$.
OSU Rate with * indicates that current recommendations would have required an additional 14.68 kg P ha^{-1} application due to soil pH.

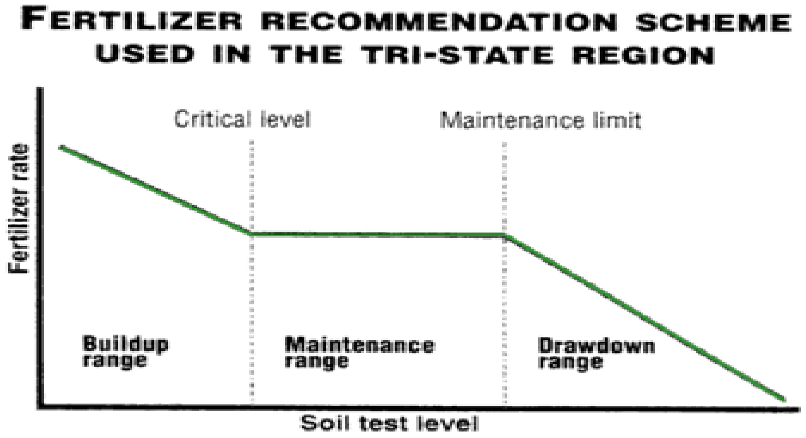
How we Do Phosphorus Recs

Build-Maintain (Replacement)

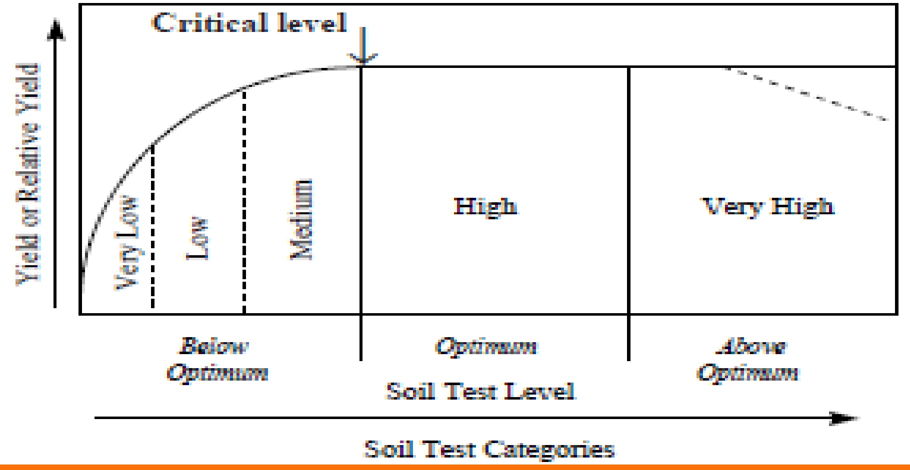
Sounds good and makes sense right.

If we are using this approach.

Does rate matter.



Build-up maintain fertilizer scheme suggested by the Ohio State University.



Nutrient response curve based on soil test, Rutgers Cooperative Extension.

How we Do Phosphorus Recs

Build-Maintain (Replacement)

Apply enough P to or K to build soil test values to a target soil test value over a planned timeframe (e.g. 4-8 years), then maintain based on crop removal and soil test levels

NOT intended to provide optimum economic returns in a given year, but minimize the probability the P or K will limit crop yields while providing for near maximum yield potential

Crop	Harvest unit	P in yield
Corn	Bushel	.38
Soybean	Bushel	.8
Wheat	Bushel	.5

How we Do VRT Phosphorus Recs

How is it done?

Soil : Yield : Soil x Yield: Yield : Soil

Grid/Zone Sample, Yield Goal 3-5 yr

Grid/Zone, Multi Year Yield, 3 yr

Grid/Zone, Update Yield each year.

How we Do VRT Phosphorus Recs

Equation for soils below optimum is:

P Rec = (Optimum P – Observed P) *16 / build years + Crop Removal

For soils test in the optimum range:

Prec = Crop Removal

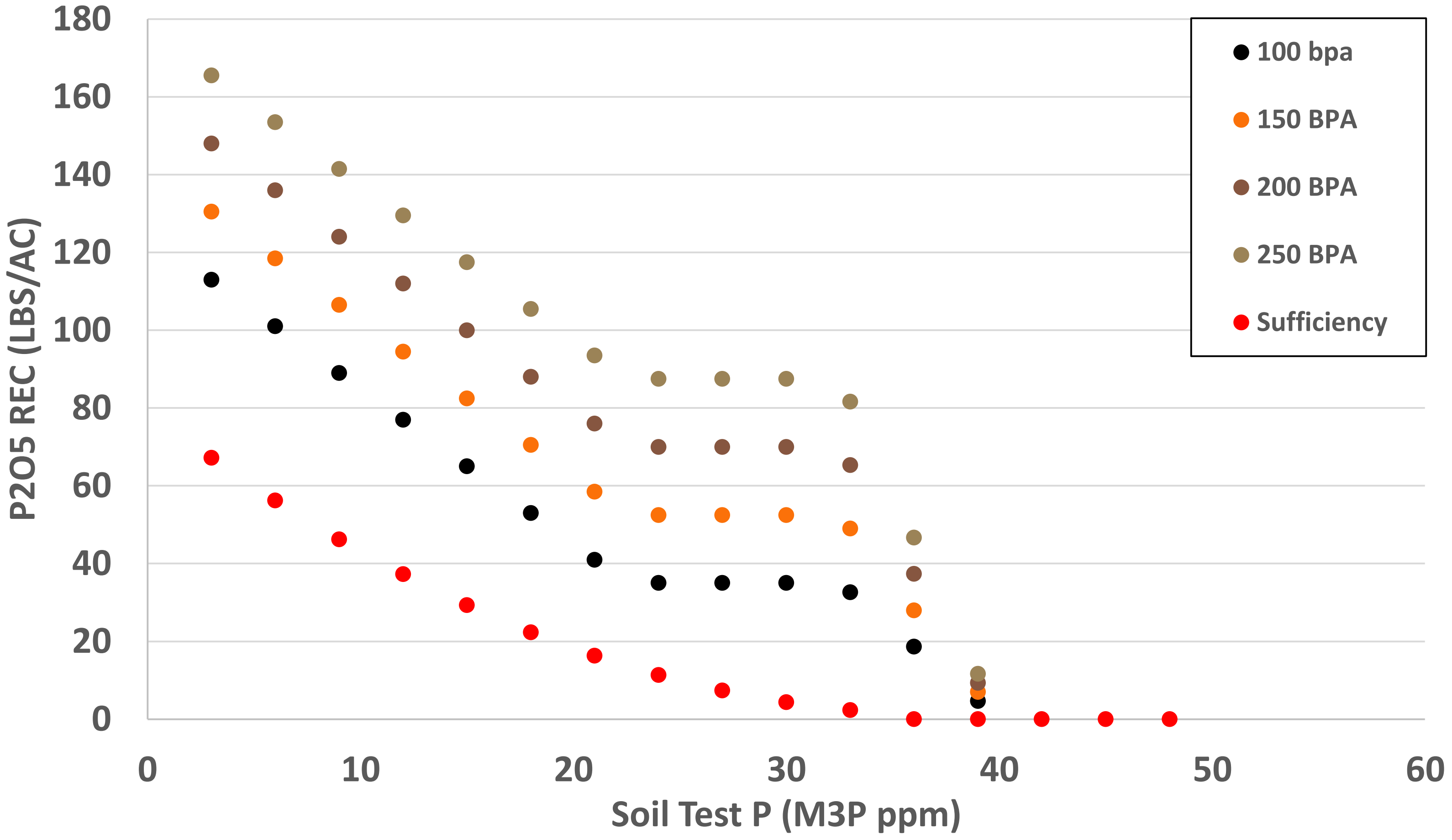
For Soils in High Range

Prec = Crop Removal *(((Optimum P level + 12.5) – observed P)/7.5)

- This gradually tapers the rec to 0 once we are 12.5 ppm above optimum

Optimum Range is 22.5-27.5 ppm for Row Crops , 20-25ppm for cool season grass and similar, 15-20ppm for Warm Season grass and similar

How we Do VRT Phosphorus Recs



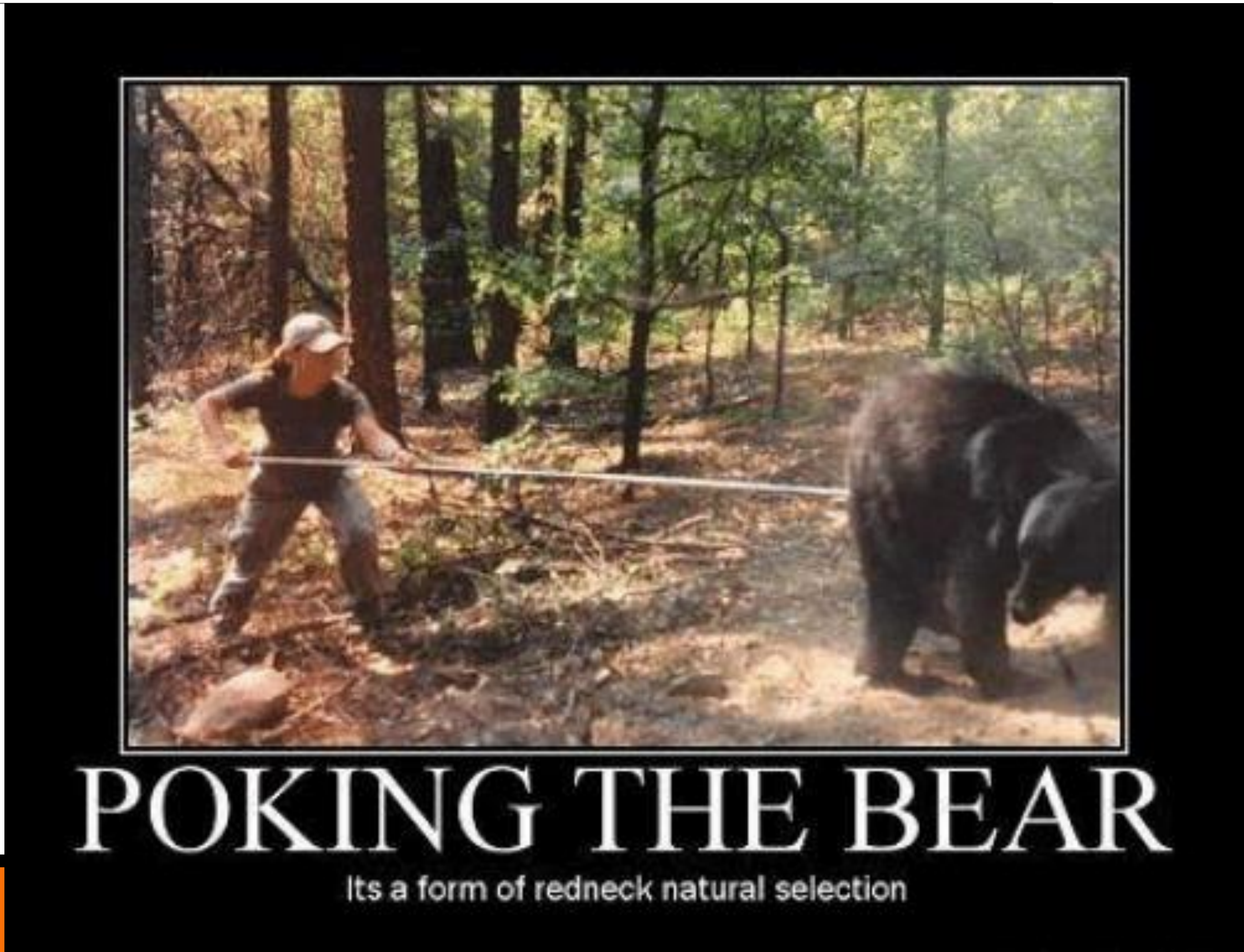
Time to Poke holes, or the Bear

CAUTION: Remember the point of this discussion.

Current Methods are VERY Accurate.

Current Methods are not Very Precise.

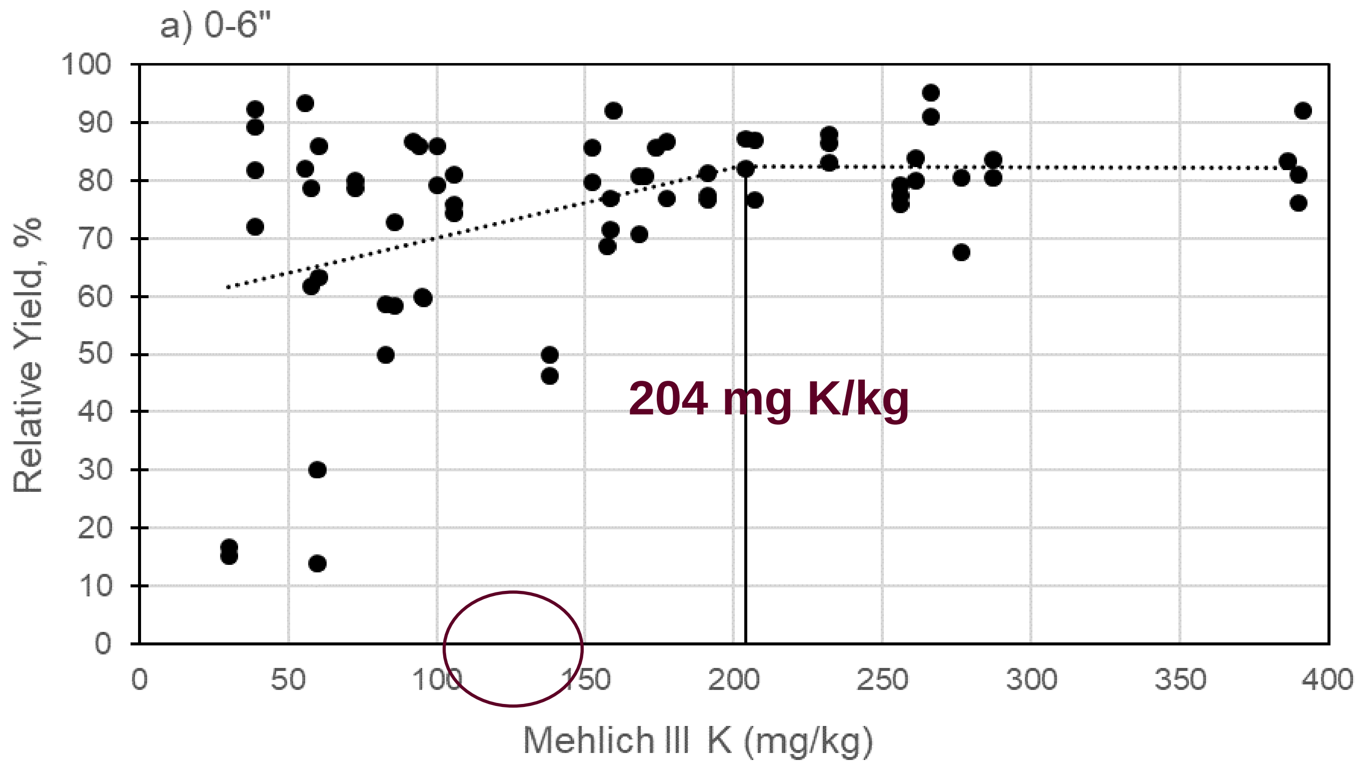
Lets Break it down.



Soil Test Correlation

Data & Slide highjacked from Dr. Katie Lewis TAMU

Mehlich III K critical level in Texas is currently 125 mg/kg



Observations	Plateau	Joint	*P*-value
68	83%	204 mg/kg	0.001

Relative Yield = mean of check lint yield divided by highest numerical treatment lint yield; multiplied by 100.

Lbs per Bushel.

Table 1. Fertility Removal by Crop (lbs/Bu).

	P2O5	K2O
Corn Grain	0.43	0.28
Soybean Grain	0.85	1.3

Source: Illinois Agronomy Handbook

Crop	Harvest unit	P in yield
Corn	Bushel	.38
Soybean	Bushel	.8
Wheat	Bushel	.5

Nutrient removal rates (pounds per bushel) of three Michigan grain crops

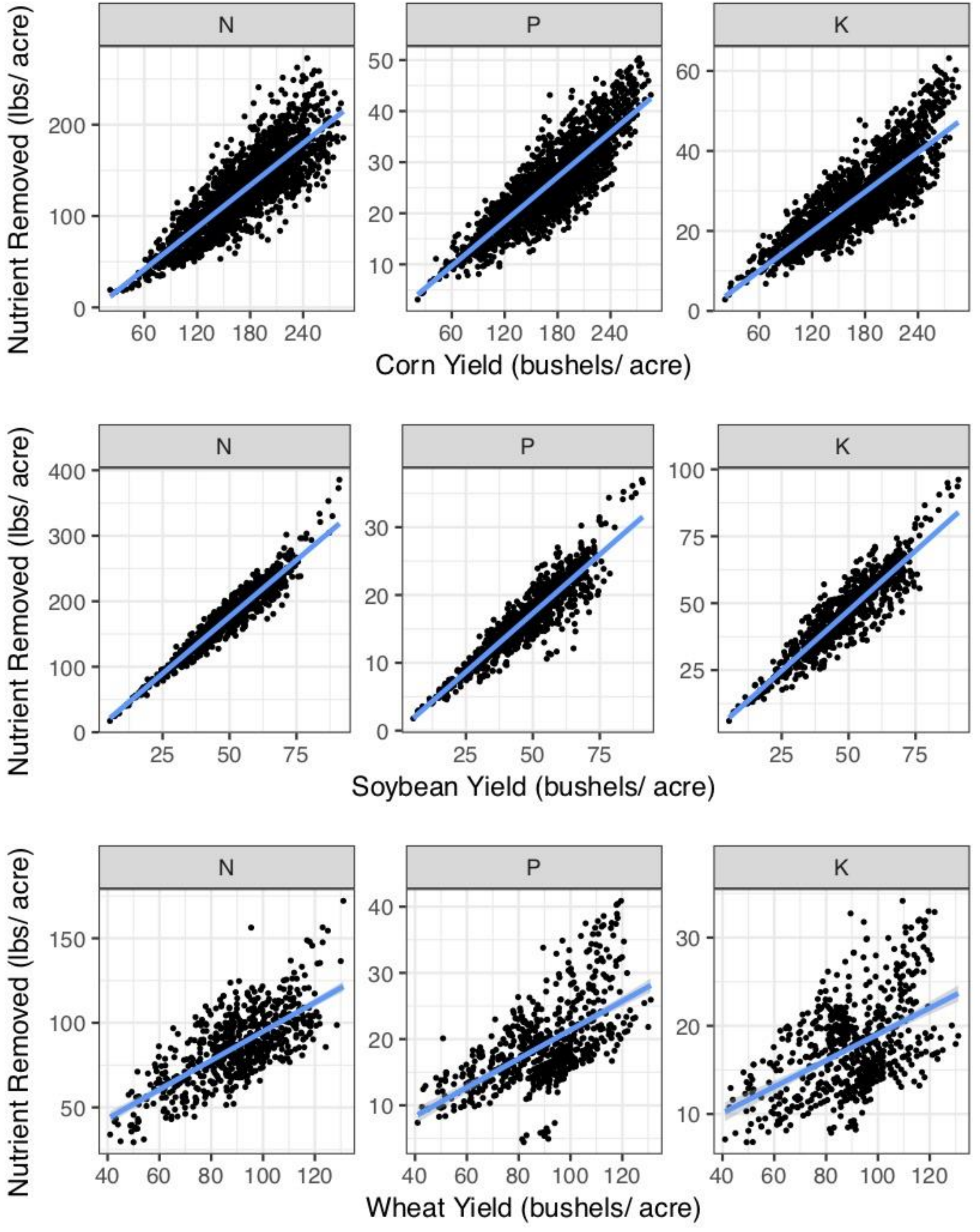
Crop	N removal pounds per bushel	P2O5 removal pounds per bushel	K2O removal pounds per bushel
Corn	0.9	0.37	0.27
Soybean	3.8	0.80	1.40
Wheat	1.2	0.63	0.37

Table 1. Grain Nutrient Removal Rates (lb/bushel) and Total Grain Nutrient Removed (lb/acre) For Corn, Soybean, and Wheat. Total grain nutrient removed is based on 180 bushel corn, 60 bushel soybean, and 80 bushel wheat.

	Grain nutrient removal rates			Total grain nutrient removed at harvest		
	Corn	Soybean	Wheat	Corn (180 bu)	Soybean (60 bu)	Wheat (80 bu)
	(lb of nutrient/bushel grain)			(lbs of nutrient/acre)		
N	0.74	3.55	0.96	134	213	77
P_2O_5	0.35	0.79	0.49	62	47	39
K_2O	0.20	1.14	0.24	36	68	19
Ca	0.06	0.22	0.08	11	13	6
Mg	0.05	0.14	0.07	9	8	6
S	0.05	0.18	0.07	9	11	6

Lbs per Bushel

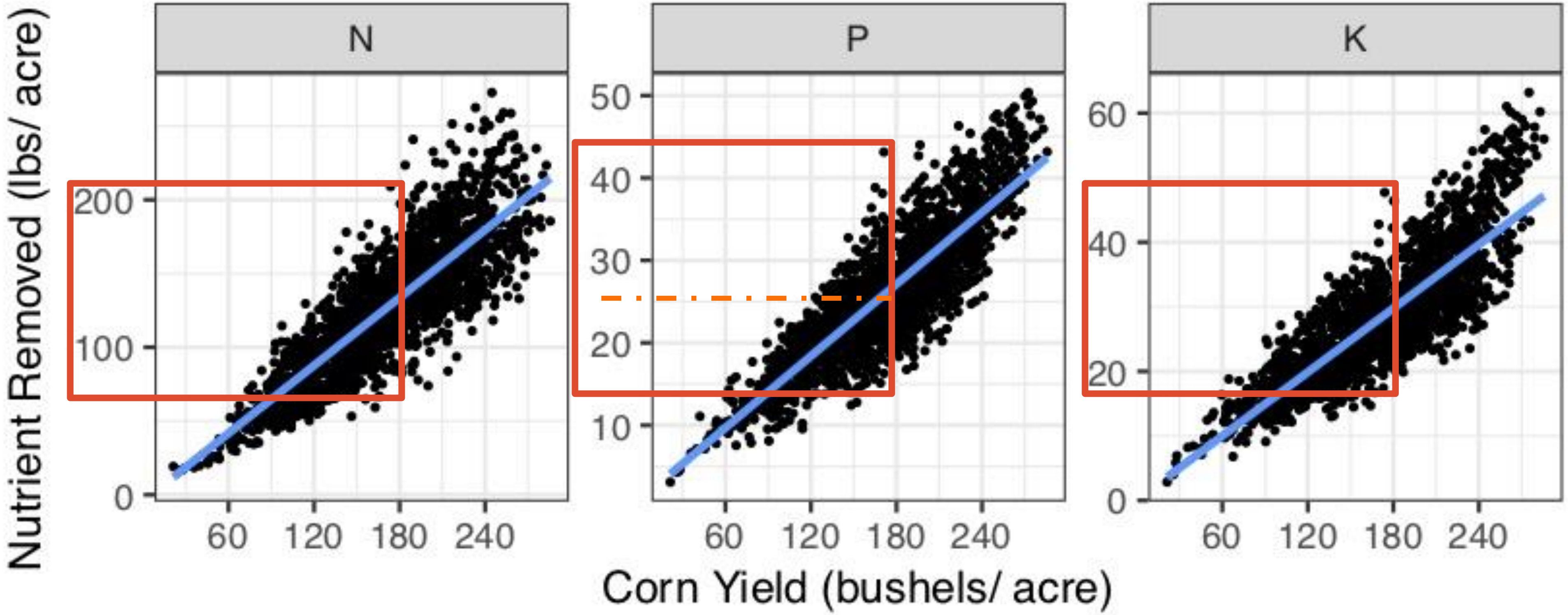
Where does it come from.



Corn, soybean, and wheat grain nutrient removal rates for nitrogen (N), phosphorus (P), and potassium (K). The blue trend lines represent average grain nutrient removal rates.

https://ohioline.osu.edu/factsheet/anr-74

Lbs per Bushel

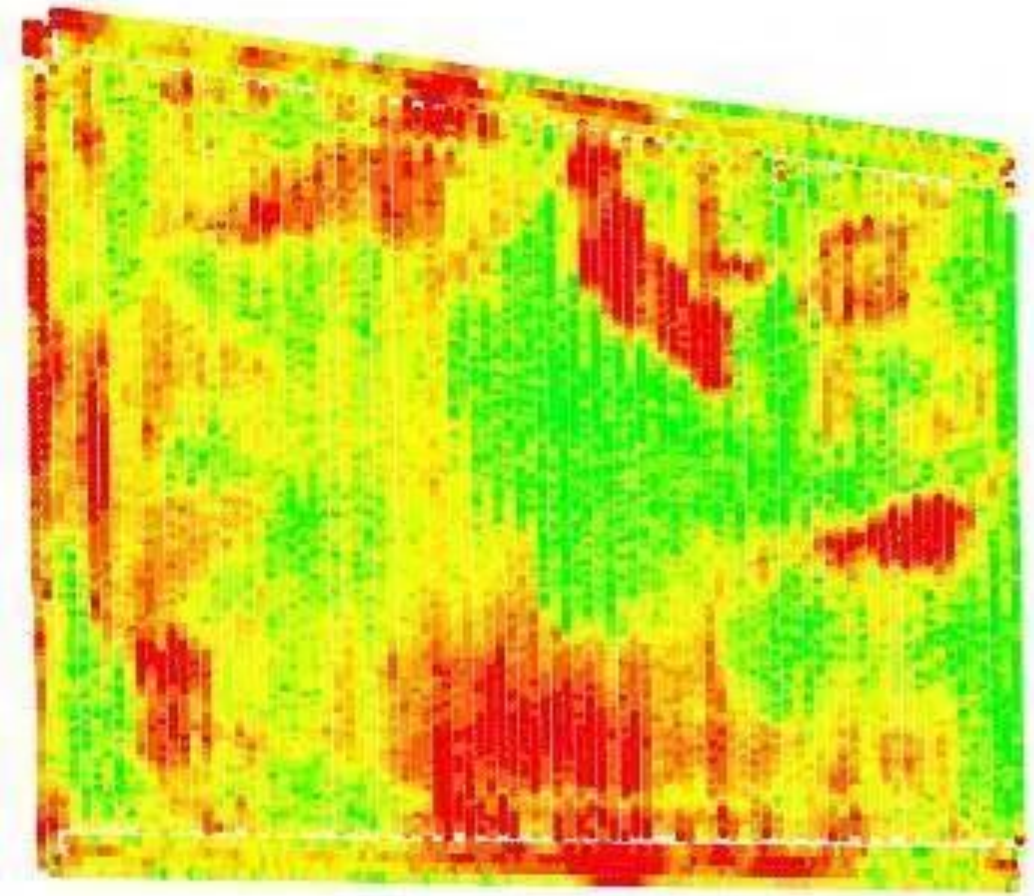


Removal Based on..

Yield Goal

3-5 Year Yield Maps

Last years Yield Map



Spatial Variance….

I requested grid sample data straight from producers.

Have entered 400 fields

The data you see is 268

Goal 500+ fields

Multiple Labs

Still Requesting data

Soil Test Results

Grower: Knoche Farms
Farm: Craig
Field: BK
Area: 78.41 ac
Event Date(s): 3/6/2015

Min:	4.7	6.4	20.0	105.0	0.2
Max:	6.7	7.2	43.0	244.0	0.4
Avg:	5.3	6.6	33.2	184.7	0.3

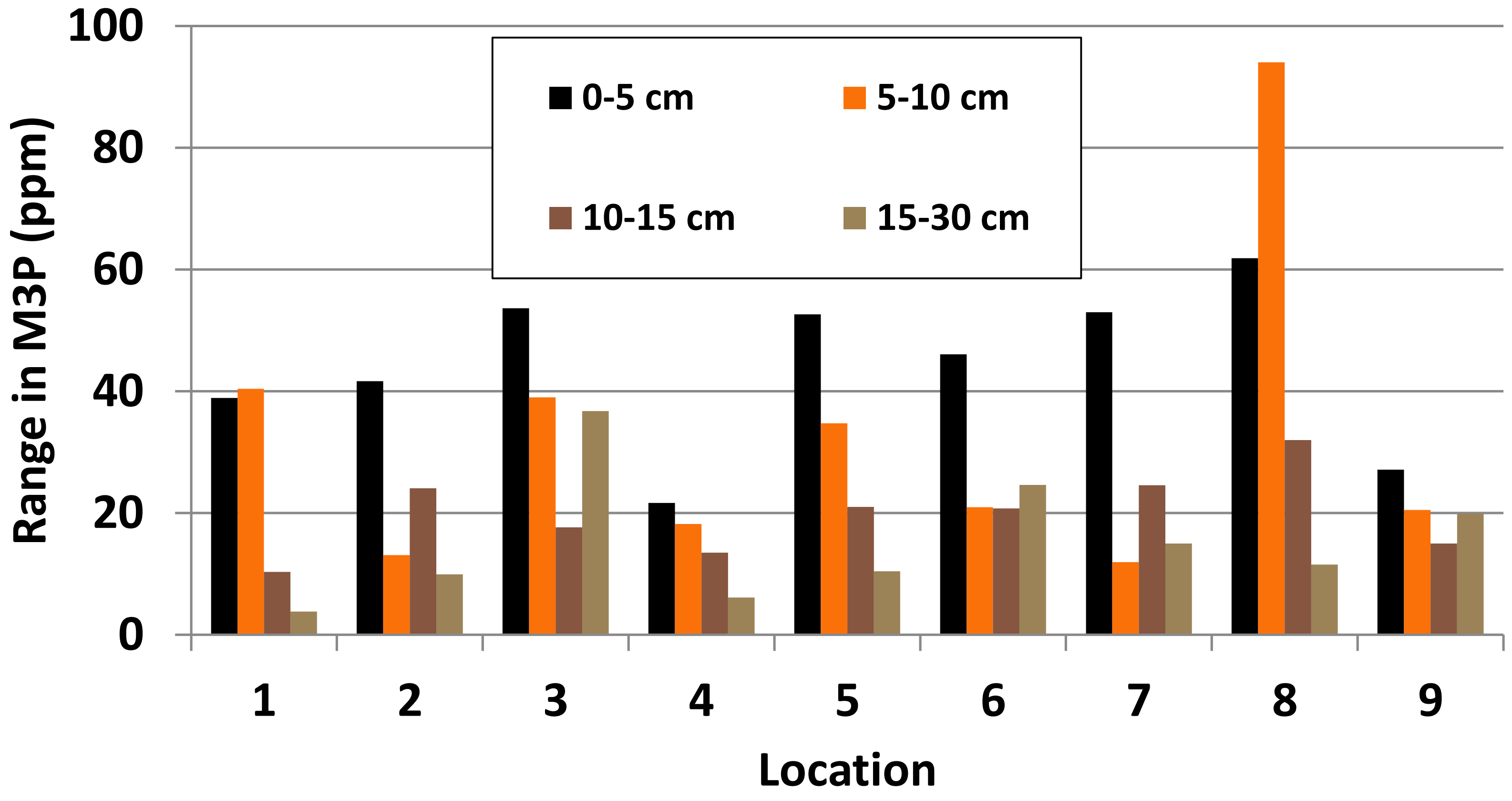
Sample ID	pH	BpH	P Mehlich III	K	Zn
1	5.4	6.7	37.0	175.0	0.3
2	5.9	6.7	27.0	204.0	0.3
3	5.1	6.6	40.0	192.0	0.3
4	4.7	6.4	39.0	171.0	0.2
5	5.5	6.6	31.0	201.0	0.2
6	6.7	7.2	40.0	184.0	0.3
7	5.2	6.6	28.0	156.0	0.2
8	5.3	6.5	35.0	208.0	0.3
9	4.8	6.4	36.0	193.0	0.2
10	5.3	6.9	20.0	105.0	0.2
11	5.1	6.5	30.0	178.0	0.3
12	5.0	6.6	31.0	175.0	0.2
13	5.5	6.7	27.0	164.0	0.3

Spatial Variance….

	Soil pH		CEC		P		K	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
# fields	371		313		360		360	
Average	6.0	1.8	13	11	30	58	194	193
Min	4.6	0.3	2.7	.6	4.0	4.0	28	14
Max	8.1	3.8	27.3	85	93	365	544	673

	OM		Ca		Mg		S	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Count	255		292		336		181	
Average	1.8	1.2	1569	1952	288	320	15	27
Min	0.5	.3	396	15	20	20.0	5.9	2
Max	3.5	7.0	5099	16746	1208	1201	87	597

How we Do VRT Phosphorus Recs

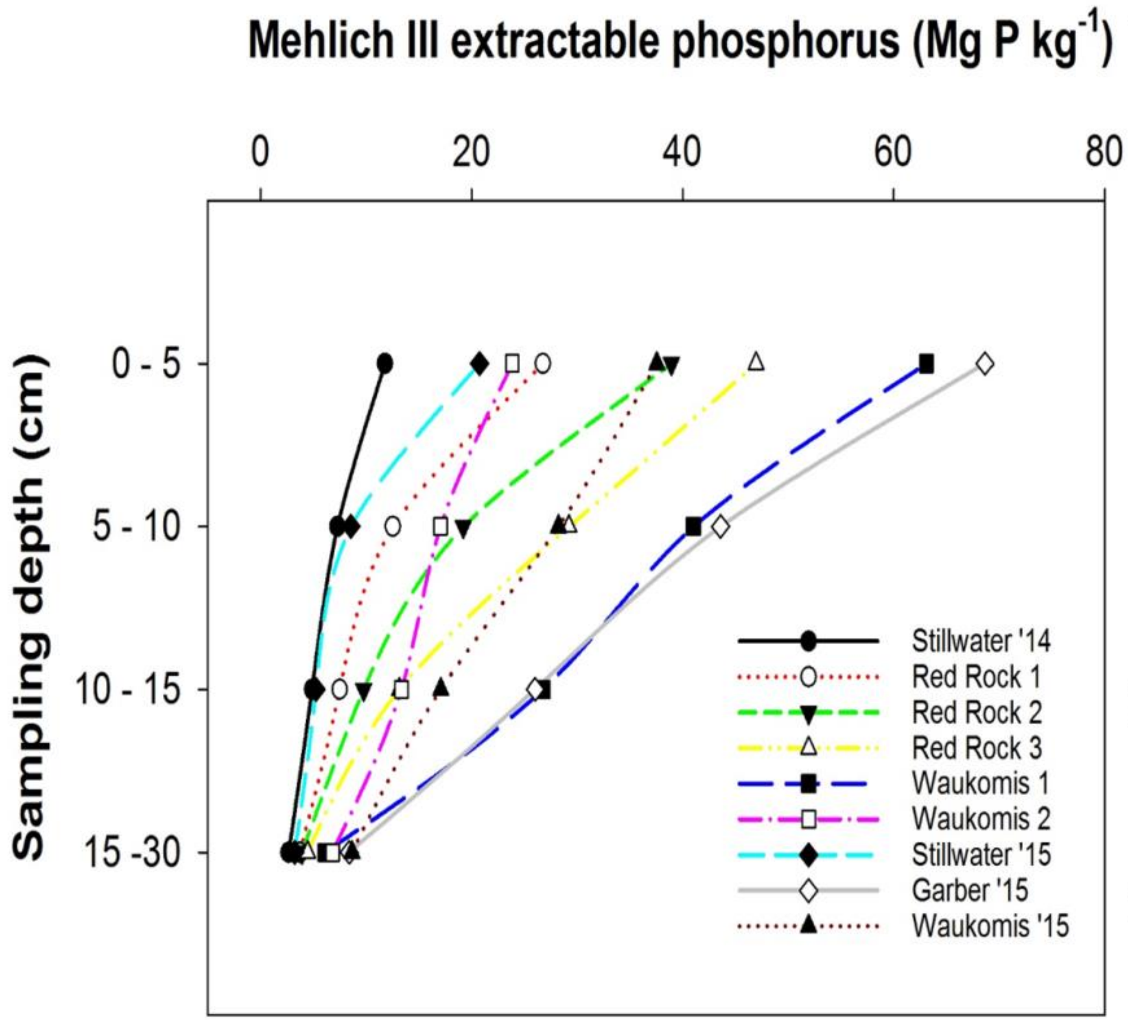


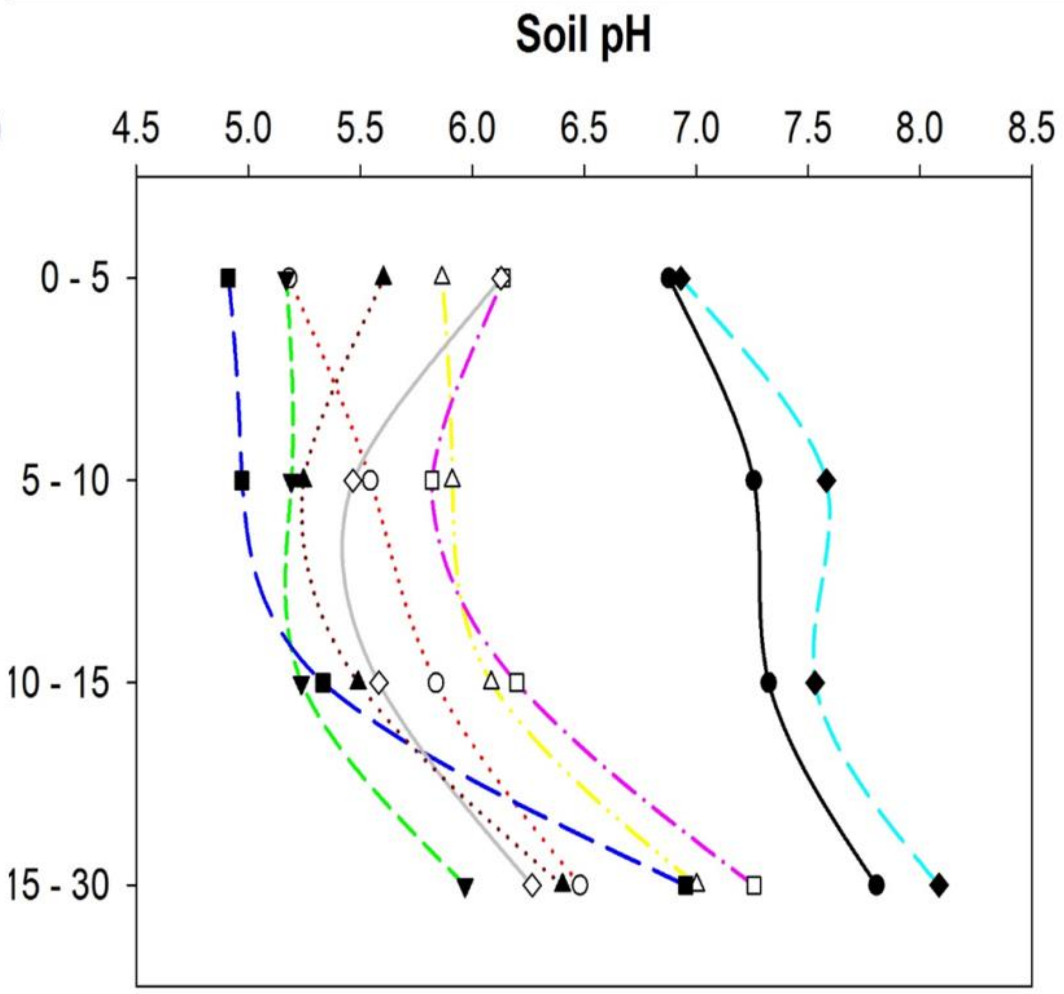
Year	Location	Sampling Depth	Mehlich III Extractable P			Soil pH		
			Min	Max	Ave	Min	Max	Ave
		cm	Mg P kg^{-1}					
2014	**Stillwater**	0 -5	***2.2***	***41.1***	11.8	***5.9***	***8.1***	6.9
		5 -10	***2.9***	***43.3***	7.3	***6.3***	***8.2***	7.3
		10 -15	2.3	12.7	4.9	6.2	5.2	7.3
		15 -30	1.5	5.3	2.7	6.6	9.1	7.8

Spatial Variance….

Microvariability in Soil Test, Plant Nutrient, and Yield Parameters in Bermudagrass. 1997
W. R. Raun et al.
Vol. 62 No. 3, p. 683-690

Spatial Variance….





Why is Lime most Accurate VRT?

Buffer Index

- It measures soil response

P Buffer???

Change Soil Sampling intensity from Spatial to Temporal

Adjust P rate based on expected response and soil response.

Arnall's Adaptive Sampling Strategy

I am not saying to Stop soil sampling.

But let me present

Option B^2

Adaptive Sampling Strategy

Same number of samples from Grid.

- Decrease Spatial increase Temporal
  - We cant sample for space

Sample the same 20’ x 20 foot area every year.

In a Build/Maintain we are fertilizing to or for a goal.

- Target STP

Watch what the soil test values are doing in the sampled area.

Adaptive Sampling Strategy

Watch what the soil test values are doing in the sampled area.

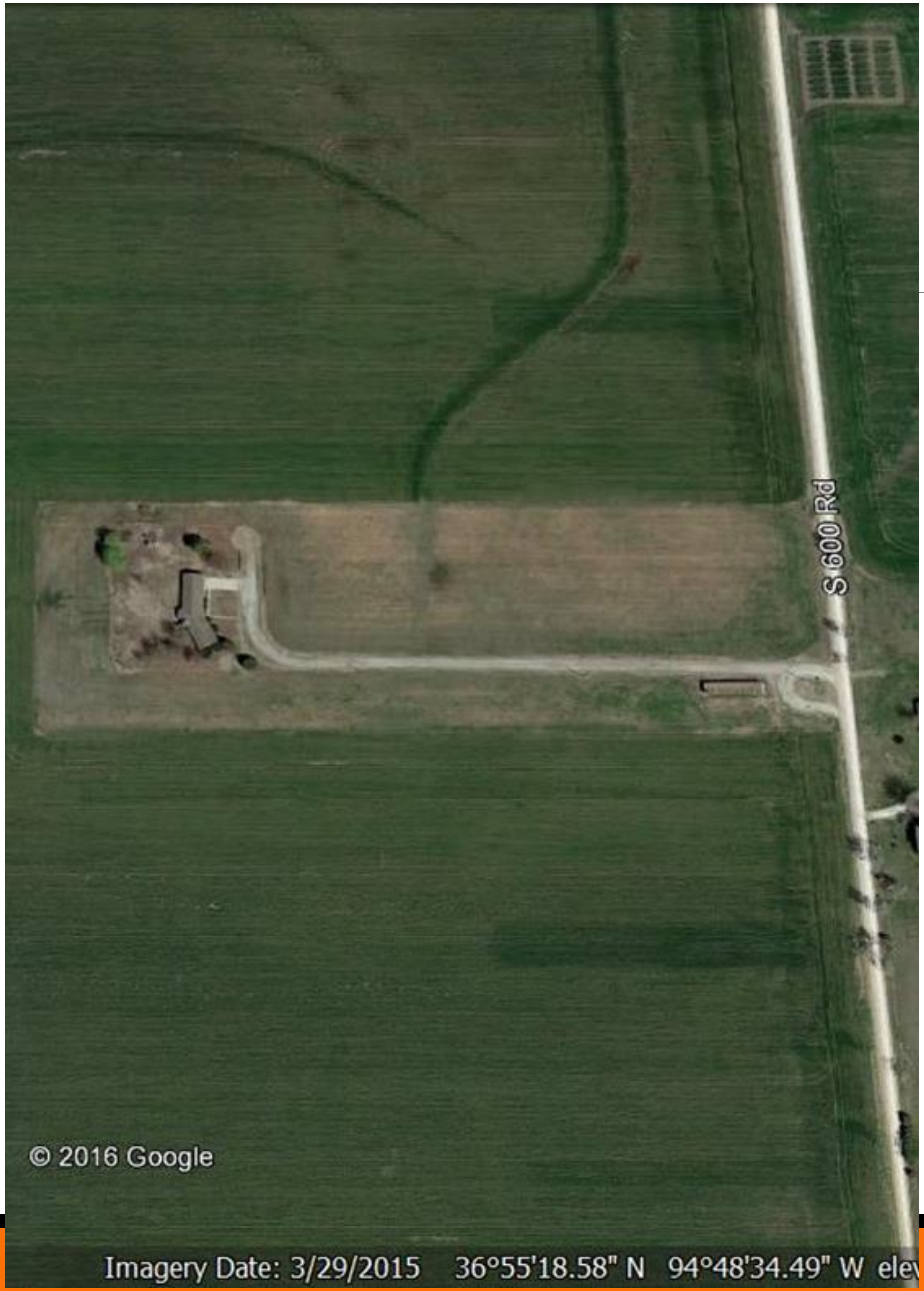
- If Rate of decrease or increase is out side of planned rate
- Change the rate.

All soils don’t hold or release nutrients at the same rate.

If you can figure out and area, change to a new spot, check original from time to time.

More things at the wall

Why not Check/Reference Strips.



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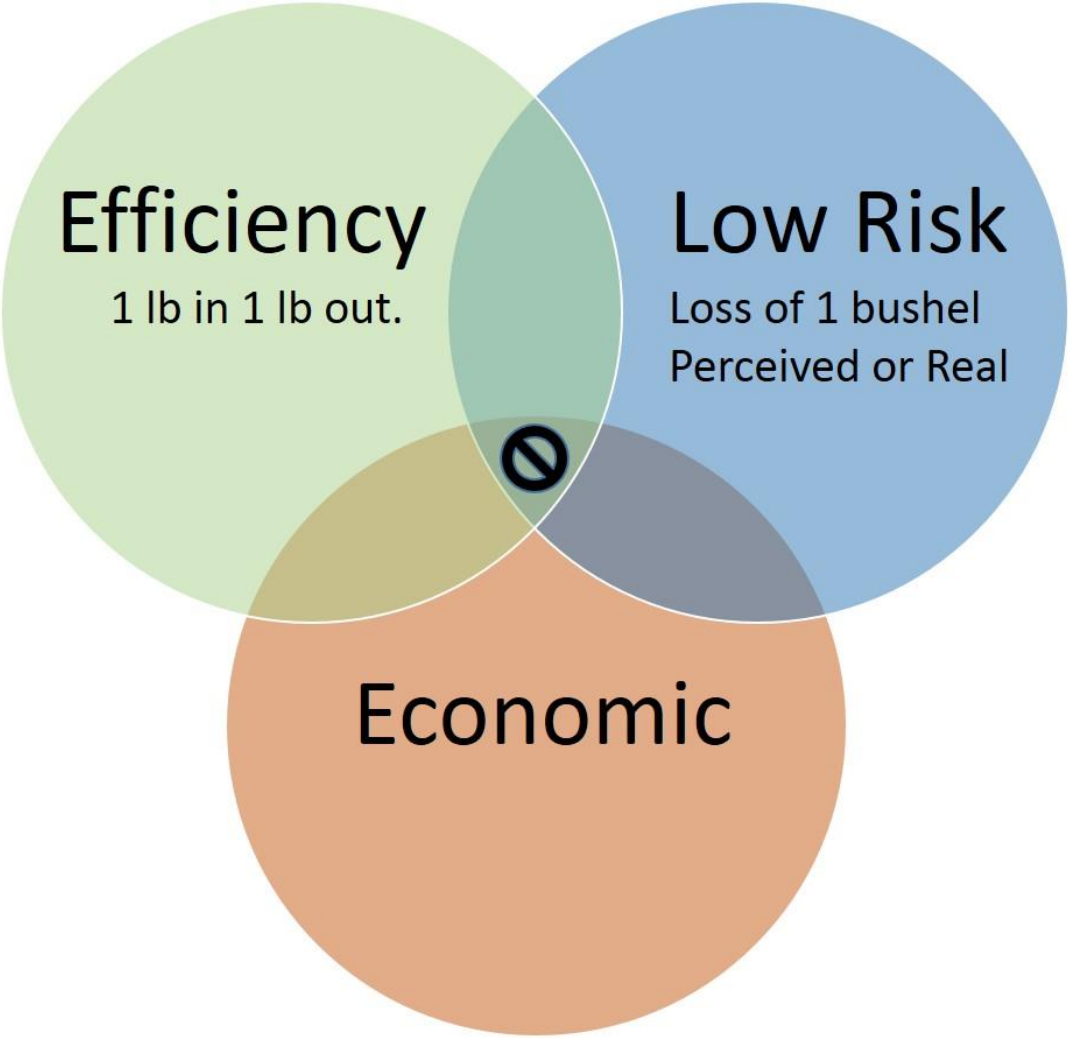
Pick 2 Nitrogen



Pick 2,
The Nitrogen Conundrum

Efficiency: Economic ->
Limit N up front, use in-season cues/measurement. This will often create a perceived sense of risk.

Low Risk: Economic ->
Pre-plant yield goals, proven to be economical

Efficiency: Low Risk ->
Spoon feeding, high data, high cost N.

Nitrogen provide by the Soil - NRS

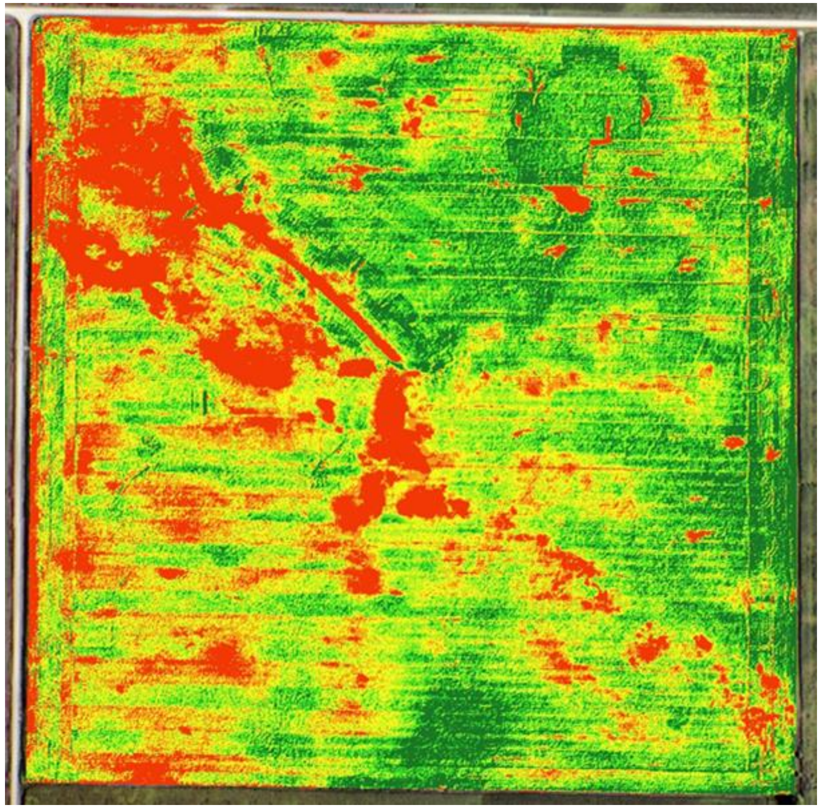
N_{Soil}

Let the crop tell you.

Nitrogen in the Crop - Removal

N_{Crop}

Biomass Map



Biomass is a Proxy for Yield

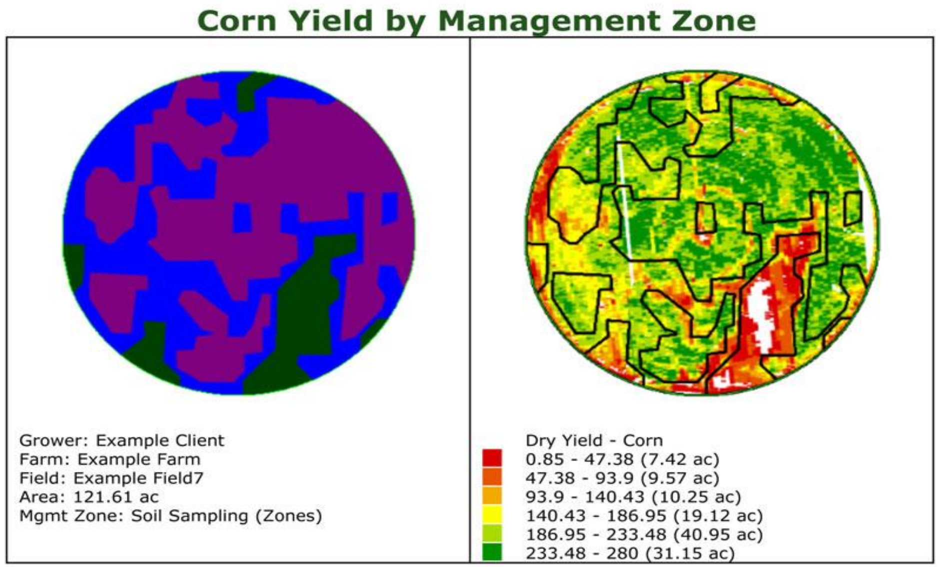
NDVI is a Proxy for Biomass

Therefore NDVI is a Proxy for Yield.

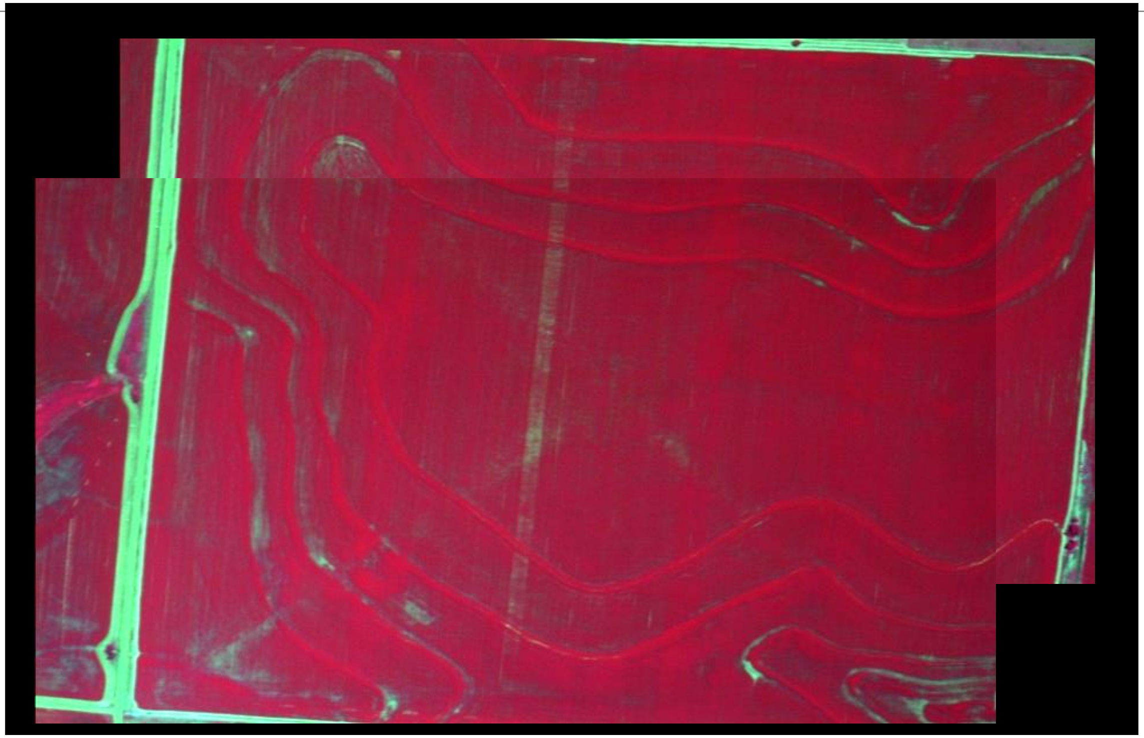
Combining the Components

- N_{Crop} — NDVI plus a +/- Reference Strip.
- N_{Soil} — Yield + Soil (Environment)

What is Your Missing Component



Legend	Management Zone	Dry Yield Avg	Min	Max	Avg Moisture	Total Bushels	Acres
	3 High	214.90	1.20	280.00	17.40 %	12,867.27	59.87
	2 Med	173.77	0.87	280.00	17.20 %	7,789.04	44.82
	1 Low	84.79	0.85	280.00	15.75 %	1,166.43	13.76
	N/A	87.21	87.21	87.21	15.54 %	0.19	0.00
	All	184.23	0.85	280.00	16.47 %	21,822.92	118.46



$$N_{fert} = (N_{crop} - N_{soil}) / e_{fert}$$

Spatial Variance….