Updates & Future Directions on Soil Phosphorus Testing: the Illinois context

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Thanks to the associations that make this work possible

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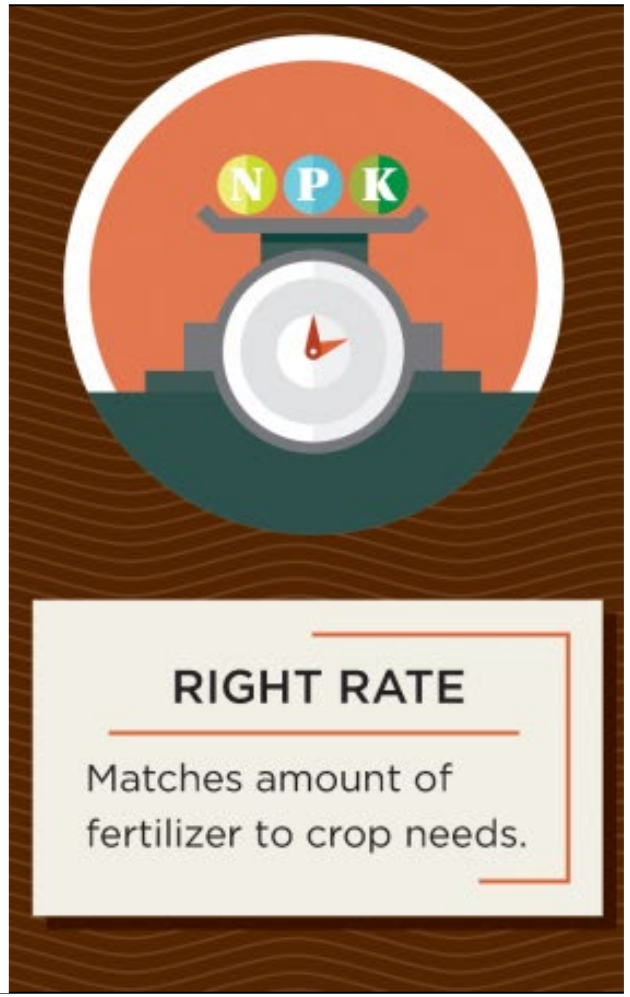
Overview

- Recent updates to Illinois Agronomy Handbook
  - Grain nutrient removal rates for P
  - https://farmdoc.illinois.edu/field-crop-production/uncategorized/new-grain-phosphorus-and-potassium-numbers.html
- Three areas for updating and adding to soil P management
  1. Soil test P
     - Updating critical values
     - Conversions for *Bray vs Mehlich*
     - Conversions for *Mehlich colorimetric vs ICP* conversions
  2. Subsoil P supply power
     - Is this concept still useful?
     - How much fertilizer P has been banked up in soils? (legacy P)
     - Safe drawdown for economic usage of P?
  3. Organic P mineralization: is there a soil P credit?

4 R’s of P Management



Right Rate: based on the "**Build and Maintain**" philosophy

Maintenance: a quantity of nutrient should be added to replace the amount removed by crop harvest

Build vs drawdown: factor in current soil test levels and exports (yield but also losses), as well as mineralization, to calculate how much of a given nutrient should be added (or not)

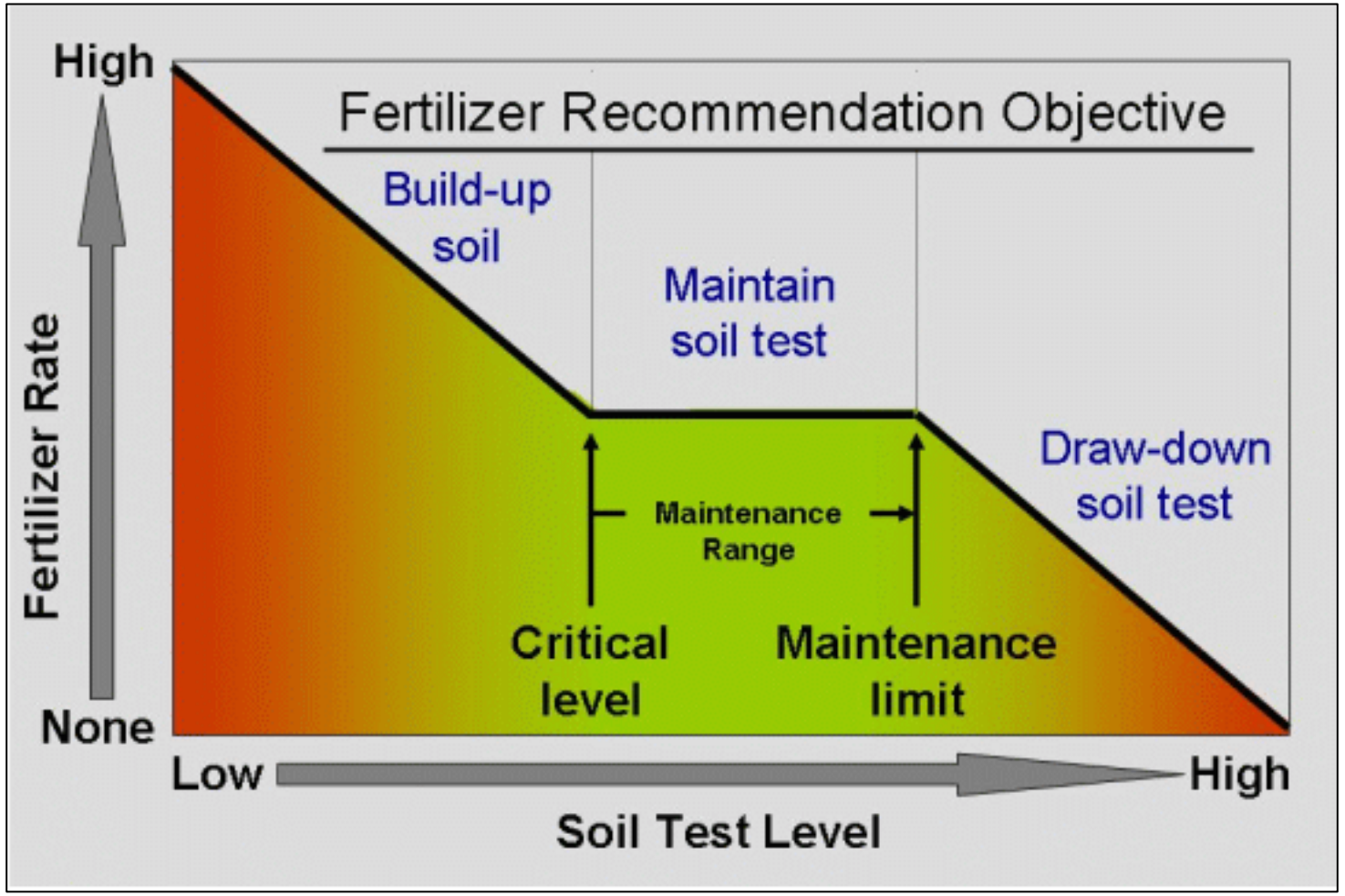


Table 8.6. Maintenance fertilizer required for various crops.

	P_2O_5	K_2O
Grains		
Corn	0.43 lb/bu	0.28 lb/bu
Oats	0.38 lb/bu[a]	0.20 lb/bu
Soybean	0.85 lb/bu	1.30 lb/bu
Grain sorghum	0.42 lb/bu	0.21 lb/bu
Wheat	0.90 lb/bu[a]	0.30 lb/bu
Biomass		
Alfalfa, grass, or alfalfa–grass mixes	12.0 lb/ton	50.0 lb/ton
Corn silage	2.7 (0.53)[b] lb/ton	7.0 (1.4)[b] lb/ton
Corn stover	7.0 lb/ton	30 lb/ton[c]
Wheat straw	4.0 lb/ton	30 lb/ton[c]

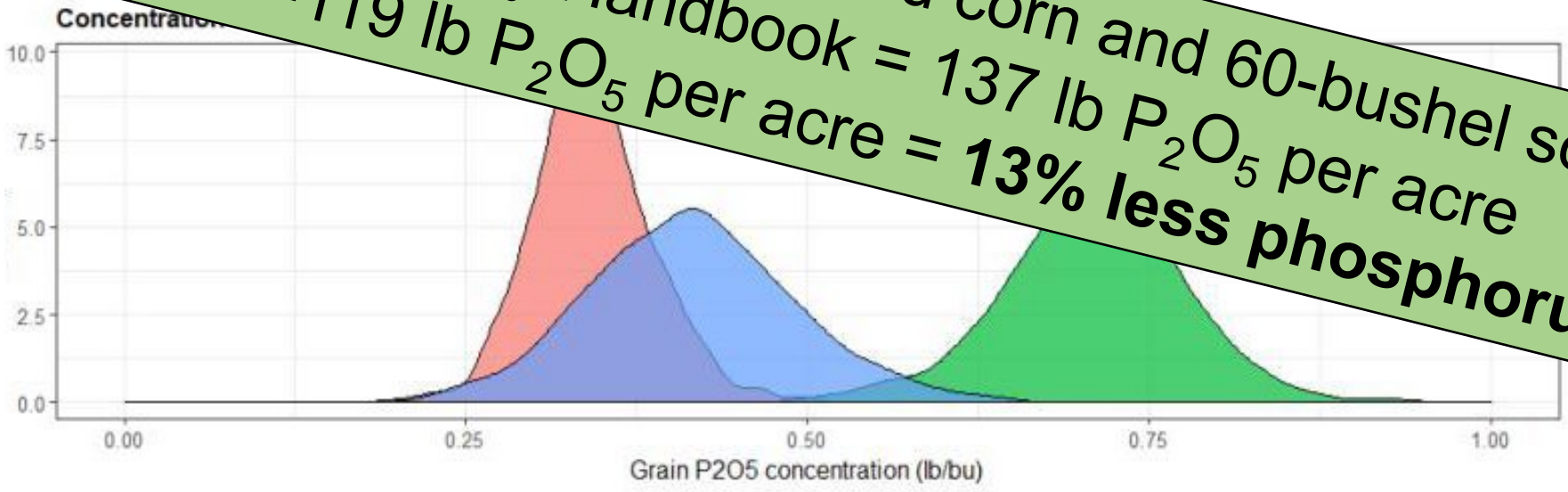
To obtain total nutrient removal by the crop (maintenance rate), multiply value by the expected yield.
[a]Values given are 1.5 times actual P_2O_5 removal for oats and wheat.
[b]Values in parentheses correspond to pounds per bushel.
[c]Value will vary depending on amount of precipitation received between the time of physiological maturity and the time the material was baled and by the potassium fertility level of the soil.

- Nutrient removal values in Illinois Agronomy Handbook were outdated
- Revised for IL with NREC funding

Source	Grain P removal (lb P_2O_5/bu)		
	Corn	Soybean	Wheat
Handbook	0.43	0.85	0.9
	0.37	0.75	0.46
		12	-49

P removal over two seasons of 200 bu corn and 60-bushel soybean
Illinois Agronomy Handbook = 137 lb P_2O_5 per acre
New values =119 lb P_2O_5 per acre = **13% less phosphorus**

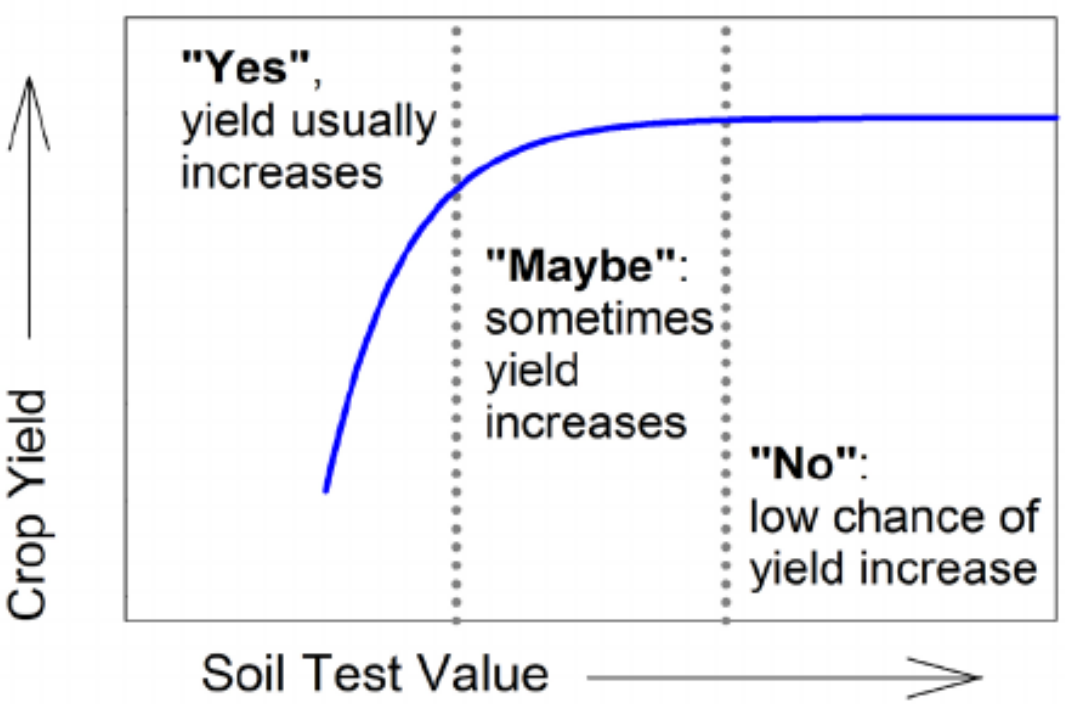
New values based on 6,000 grain samples across IL

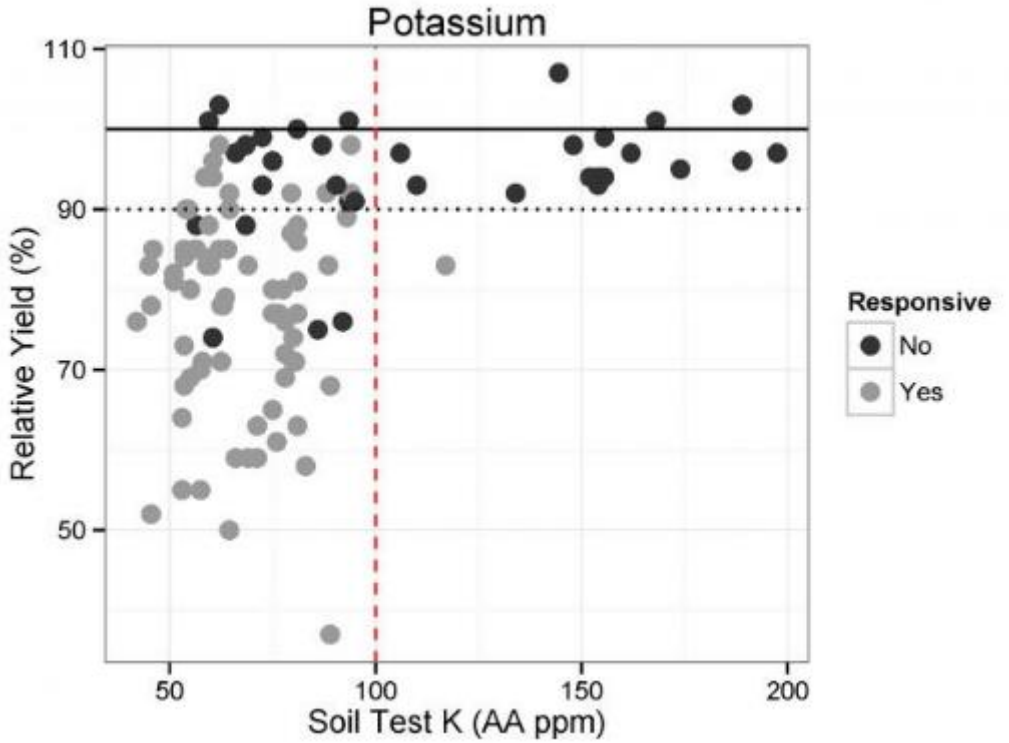


Villamil et al 2019 Crop, Forage Turfgrass Mgmt 5:180090

Soil test 101

- Soil tests provide the basis for a **critical value** or threshold based on <u>probability</u> of a crop response (usually yield)
- Calibrated to <u>relative yield</u>
    - Yield without the nutrient added to the soil as a % of yield obtained with the nutrient added
    - The relative yields, however, made it possible to include results of different climatic zones, soil types, cultivars, management, and weather
- Four major ways to calibrate soil test values to determine critical value (sorting vs regression)





Culman, 2020. OSU Extension.

Relative yield: determine by paired comparison of yield from treatment plots or strips with and without nutrient addition for relative yield

Residuality of P means that static check vs applied plots will be increasingly different

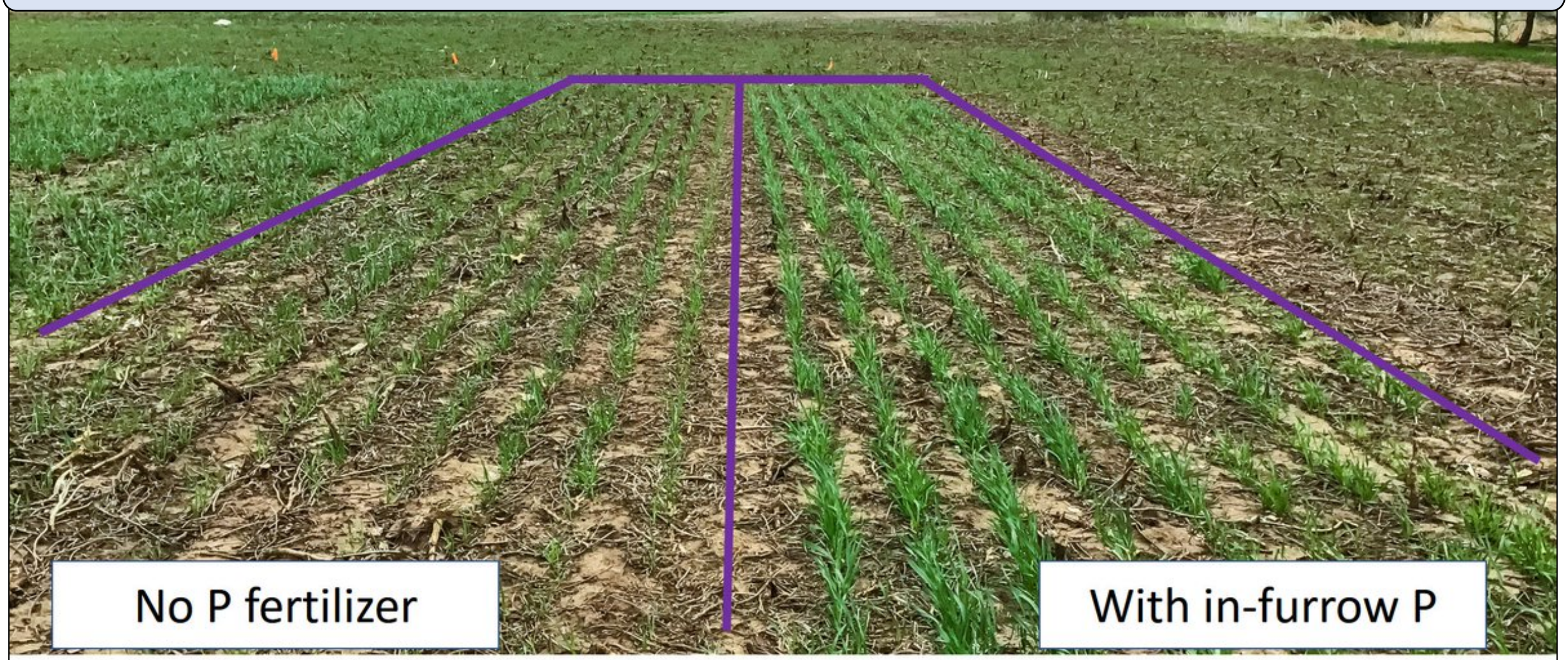
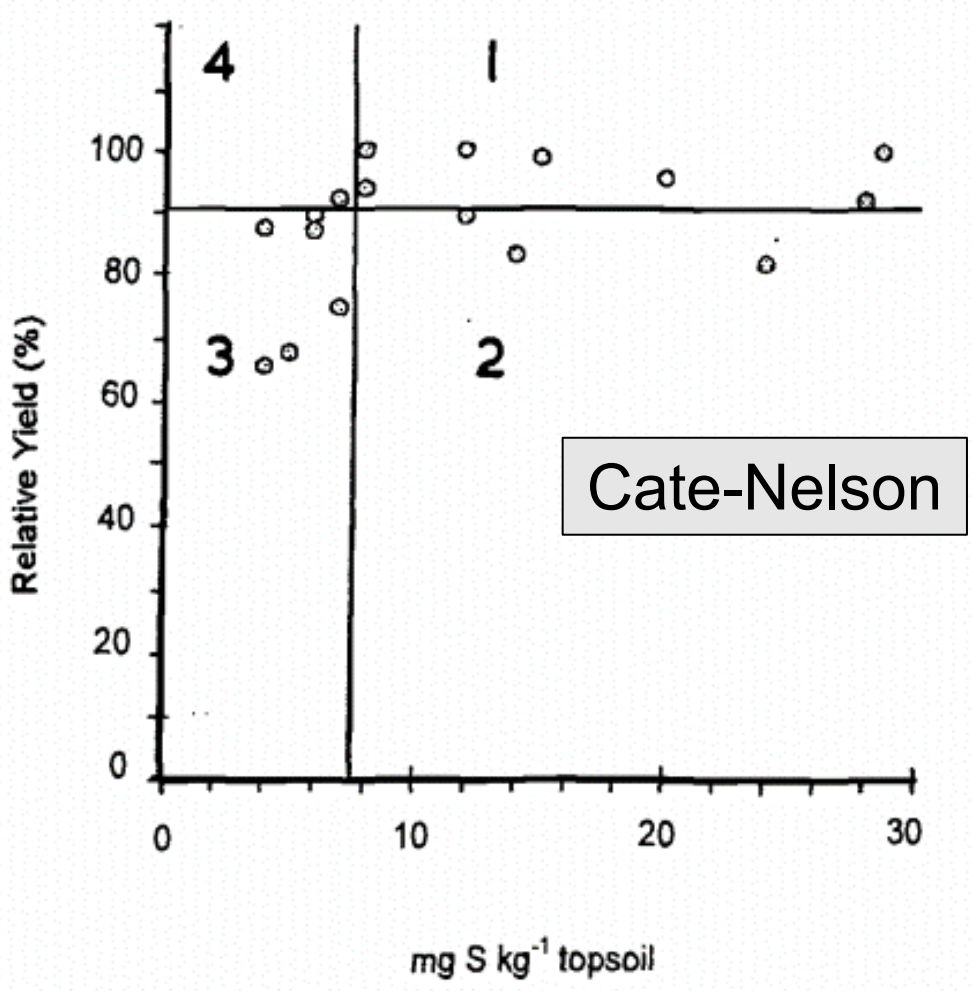


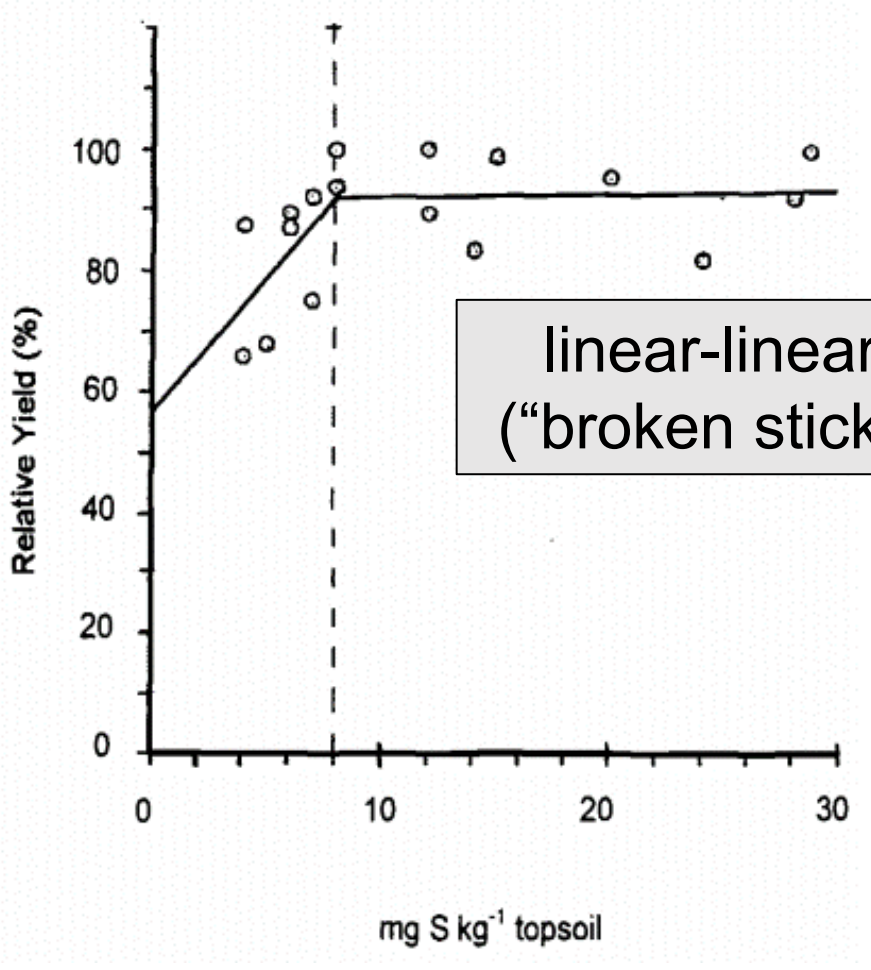
Photo courtesy of Dr. Ruiz Diaz, KSU

Sorting approaches

- Definite split = clear critical value
- Strongly influence by data distribution (e.g., outliers)



Cate-Nelson

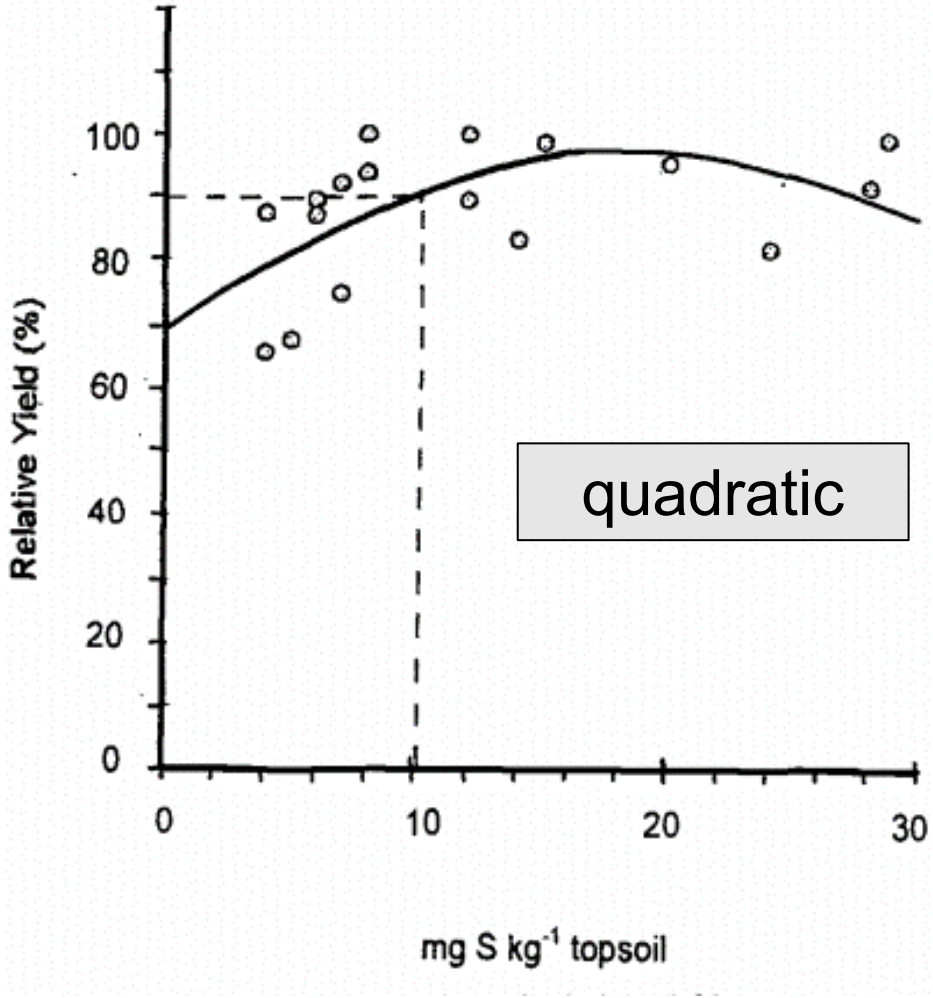


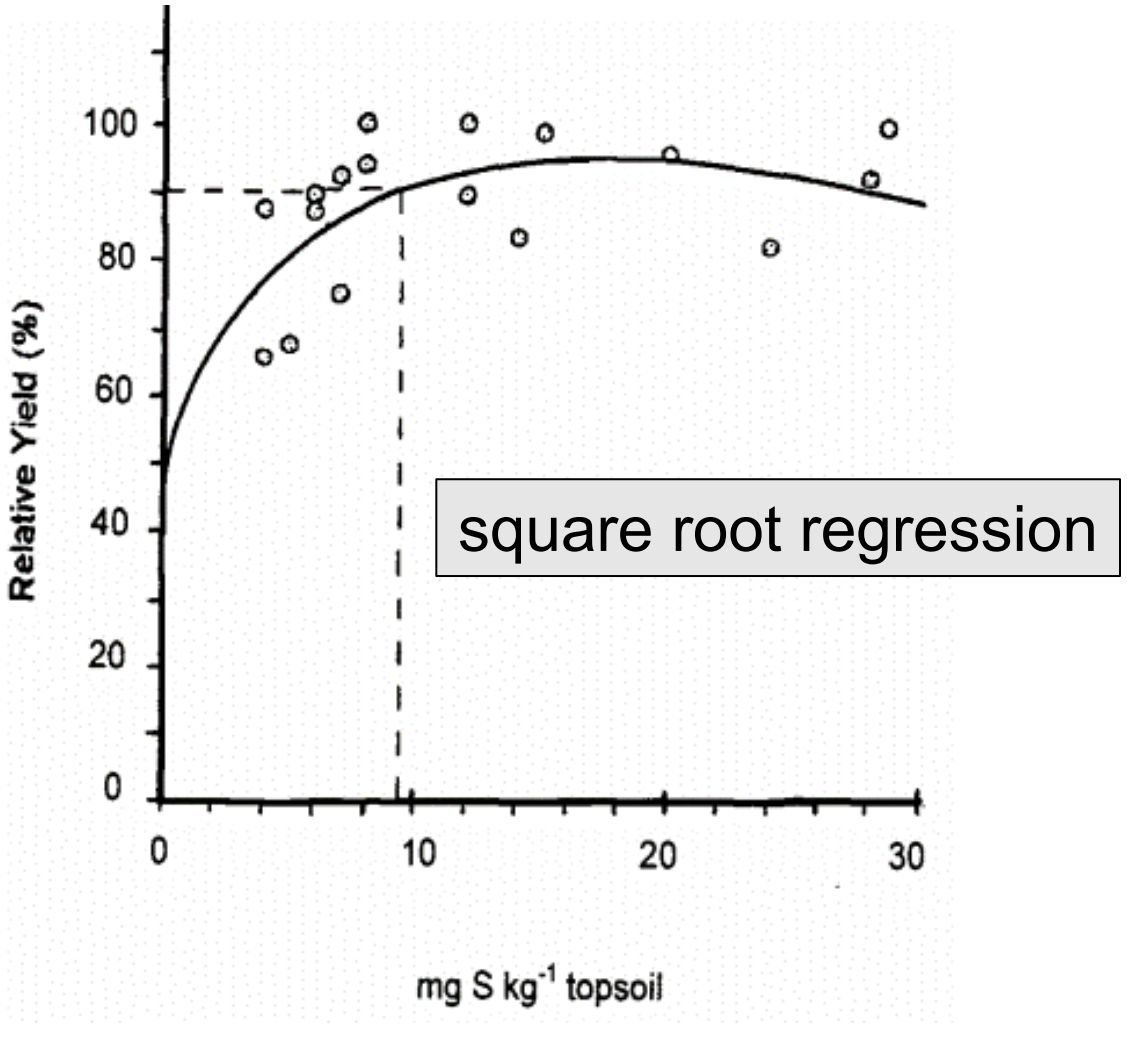
linear-linear
("broken stick")

van Biljon et al 2004 *South African Journal of Plant and Soil* 21:152

Regression approaches

- *Models* the data
- No inflection point as a justification for making a division
- Must determine what % relative yield is the basis for back-calculating a critical value (90-95% is common)



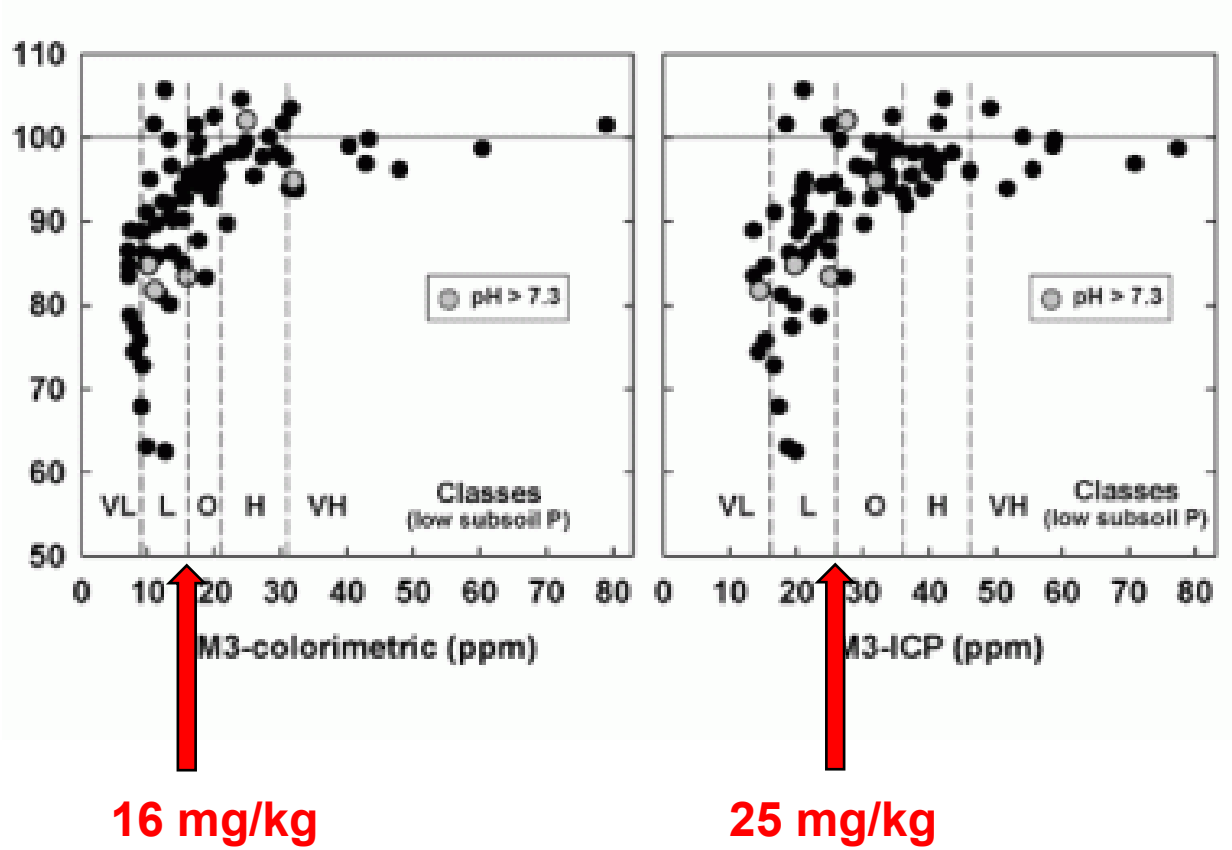


van Biljon et al 2004 *South African Journal of Plant and Soil* 21:152

Soil test P: (1) extraction and (2) method of quantification

- Bray vs Mehlich-3
- **Colorimetric**
  - Measures inorganic P only
  - Used for Bray and Mehlich-3
- **I**nductively **c**oupled **p**lasma (**ICP**)
  - Measures inorganic and organic P in the extract
  - Usually only used for Mehlich-3
- ICP values are equal to or higher than colorimetric values, and this depends on soil type (soil organic P content)
- Critical value is *35-50% higher* for Mehlich-3 by ICP than for Bray (colorimetric) in OH and IA, respectively

*Example from Iowa: Mehlich-3 P determined by ICP is (~50%) **higher** than by colorimetry*

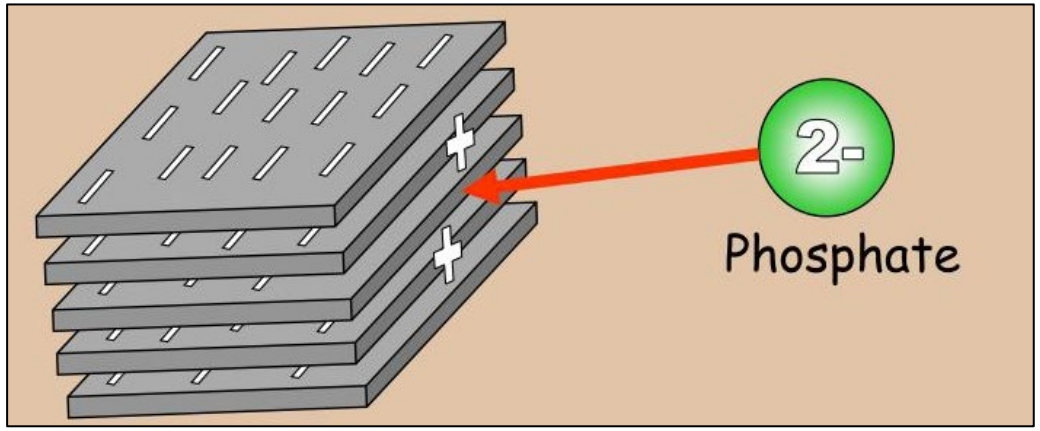


Q1. (a) Do critical values need to be updated? How does this differ by extractant × quantification?

Mallarino et al. 2003 *SSSAJ* 67:1928
Culman, 2020. OSU Extension.

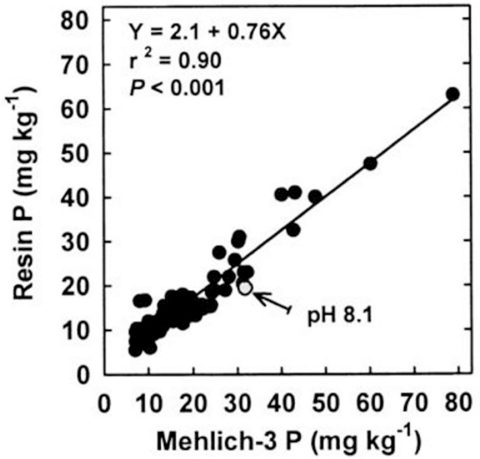
Soil test P testing by sink-based approaches: the resin test

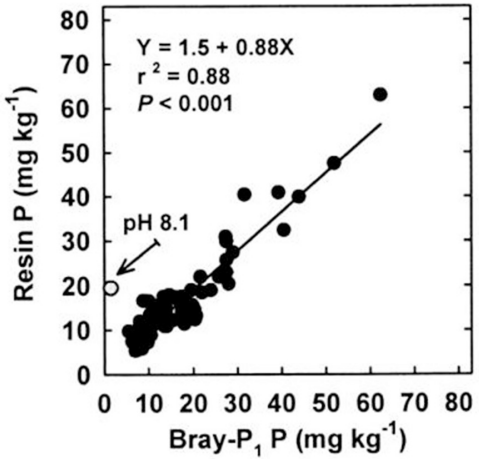
- Resin beads or membrane strips
- Anion-exchange material with bicarbonate counterion: mimic root as a ‘sink’
- Long equilibration time (16-18 h)



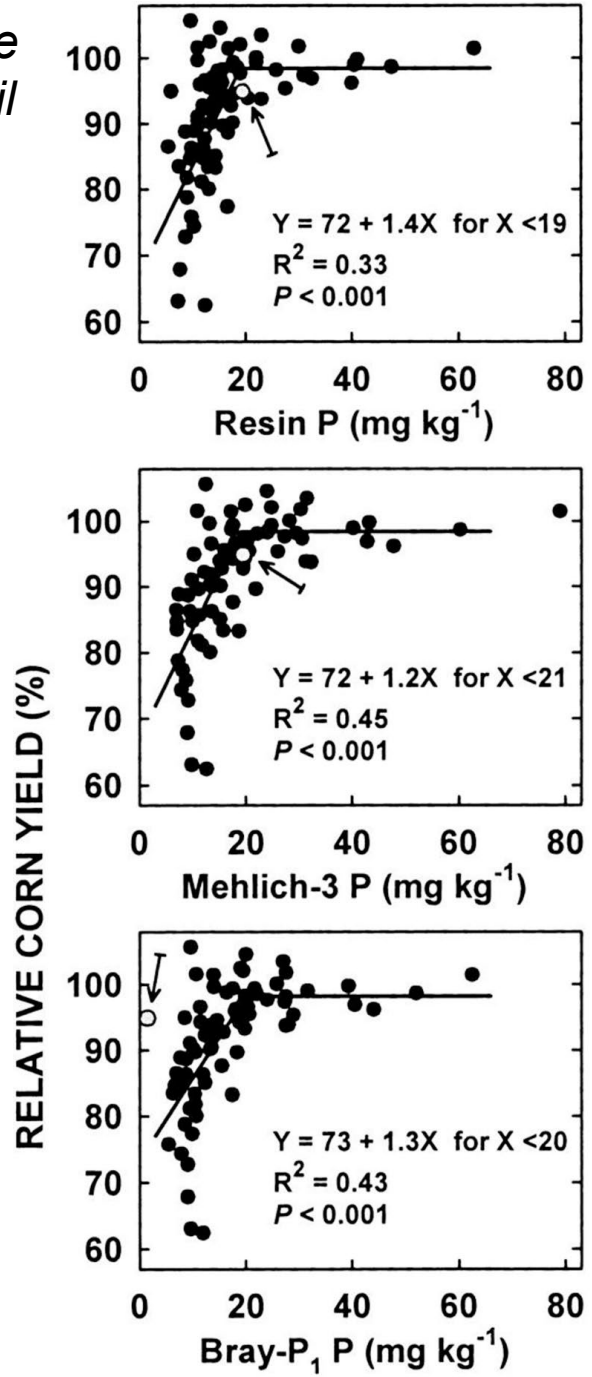
Mallarino 2005 *SSSAJ* 69:266

Relationships between relative yield response of corn and soil P extracted by four soil P tests, linear-plateau model

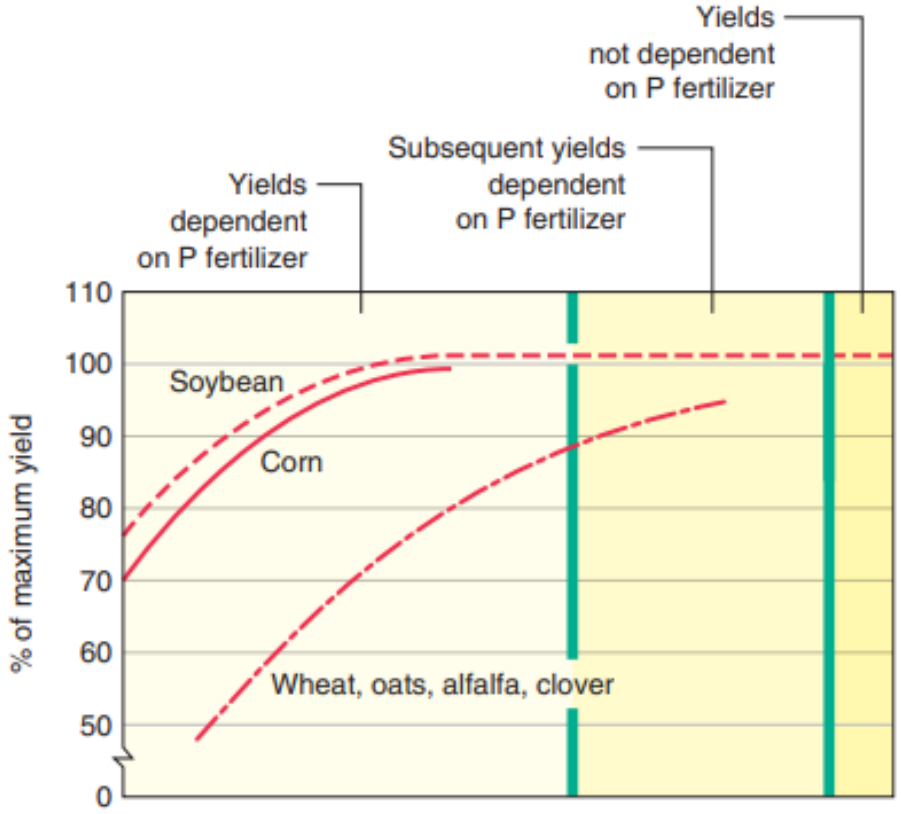




Resin and Bray/Mehlich tests are generally well-correlated



Illinois Agronomy Handbook recommendations based on Bray…



P test (lb/A) for different subsoil phosphorus-supplying power regions

High	7	15	20	40	60
Medium	10	20	30	45	65
Low	20	30	38	50	70

Figure 8.5. Relationship between expected yield and soil P, measured colorimetrically by the Bray P_1 or Mehlich-3 procedures on neutral-to-acid soils, or by the Mehlich-3 procedure on soils with pH > 7.3

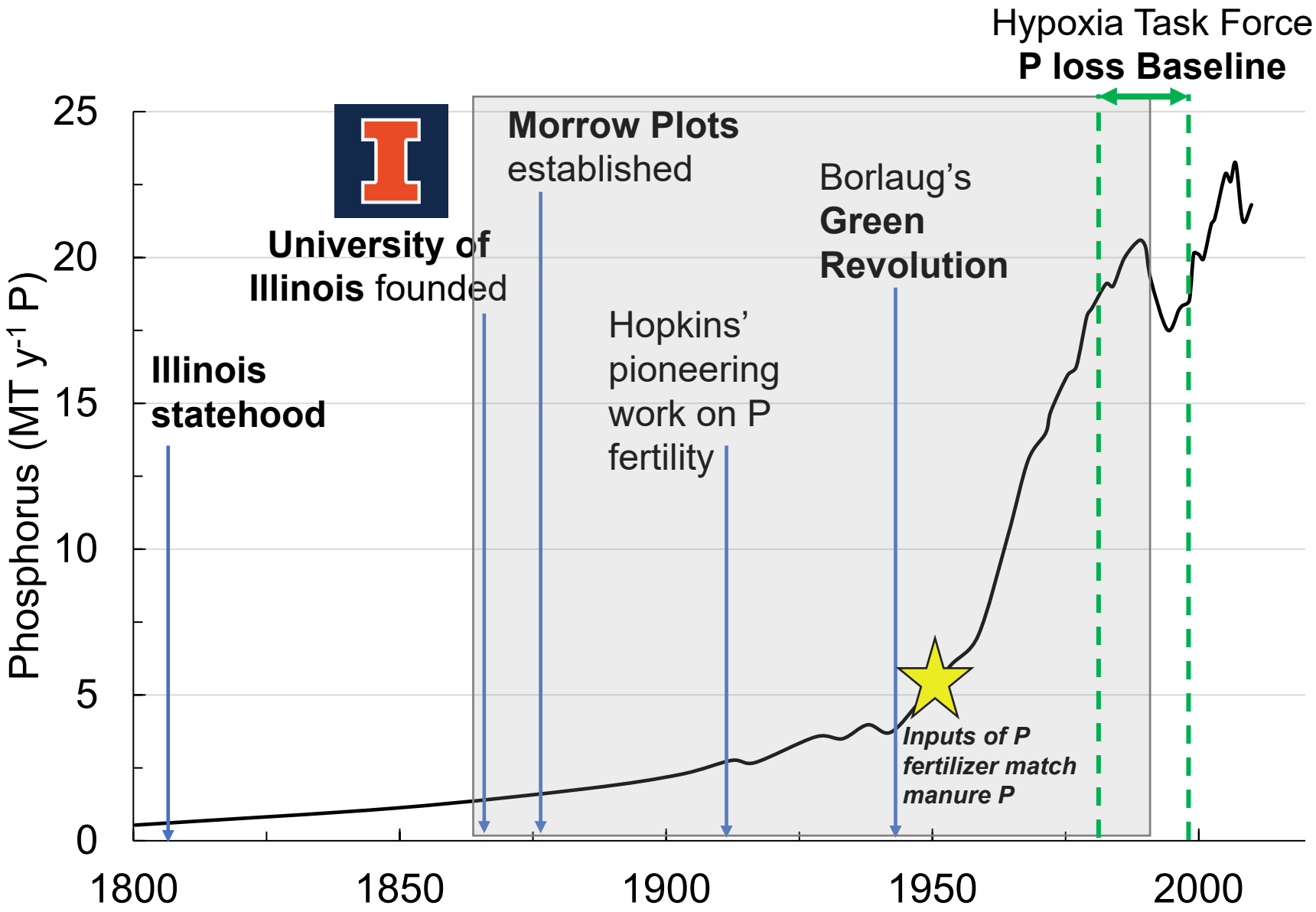
…and subsoil supply power

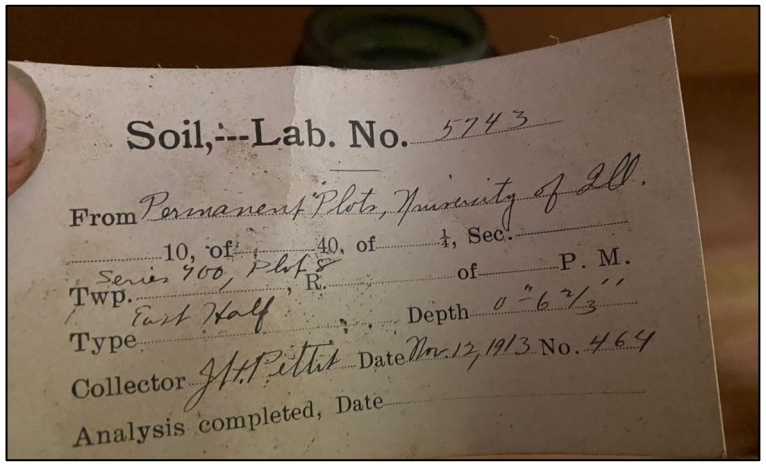
Figure 8.4. Subsoil phosphorus-supplying power in Illinois.

- Subsoil P supplying power moderates interpretation
- Removed from neighboring states (WI, IA)
- Under evaluation in NREC project (2021-2025)

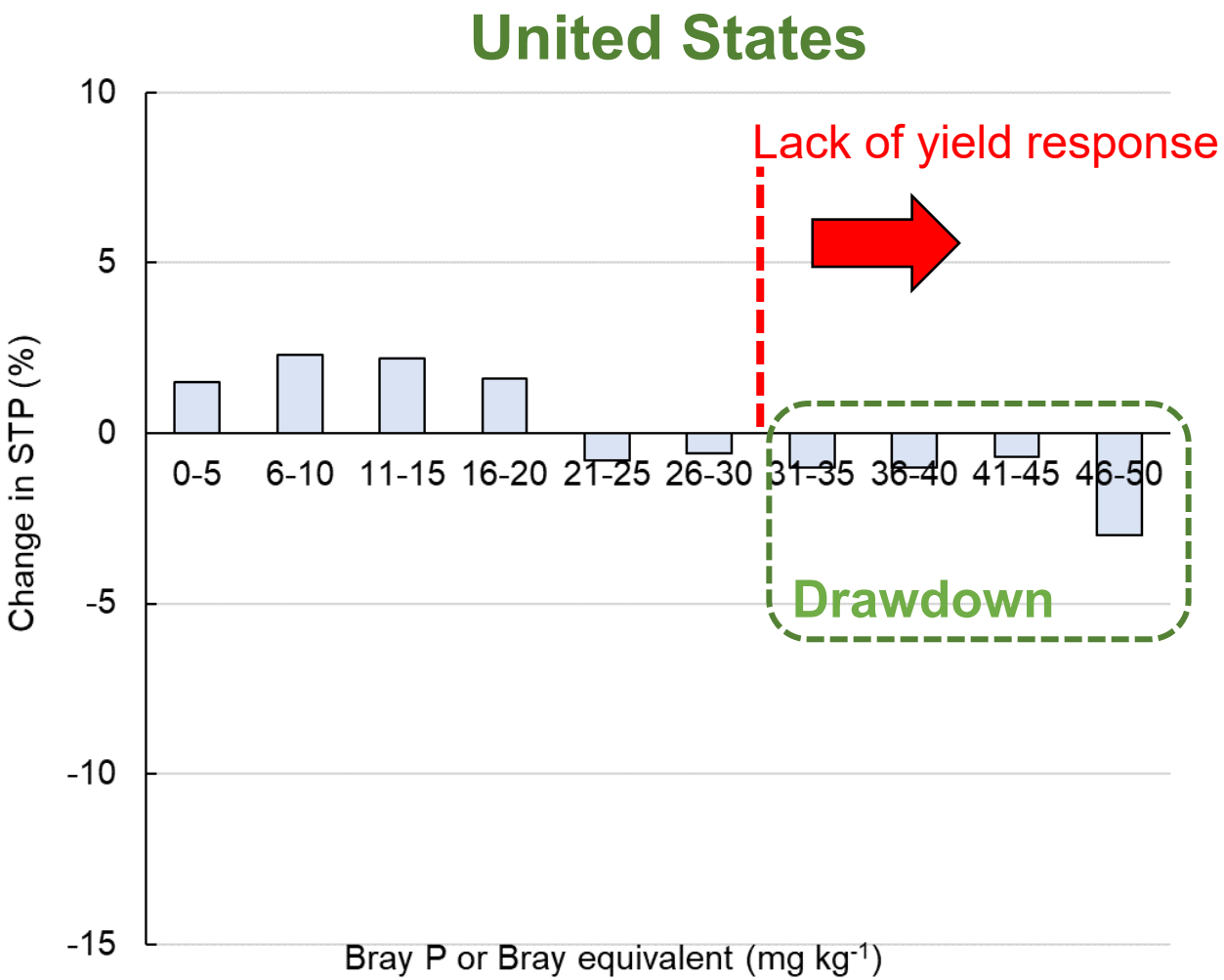
Q2. Is subsoil P supply power still valid/useful?

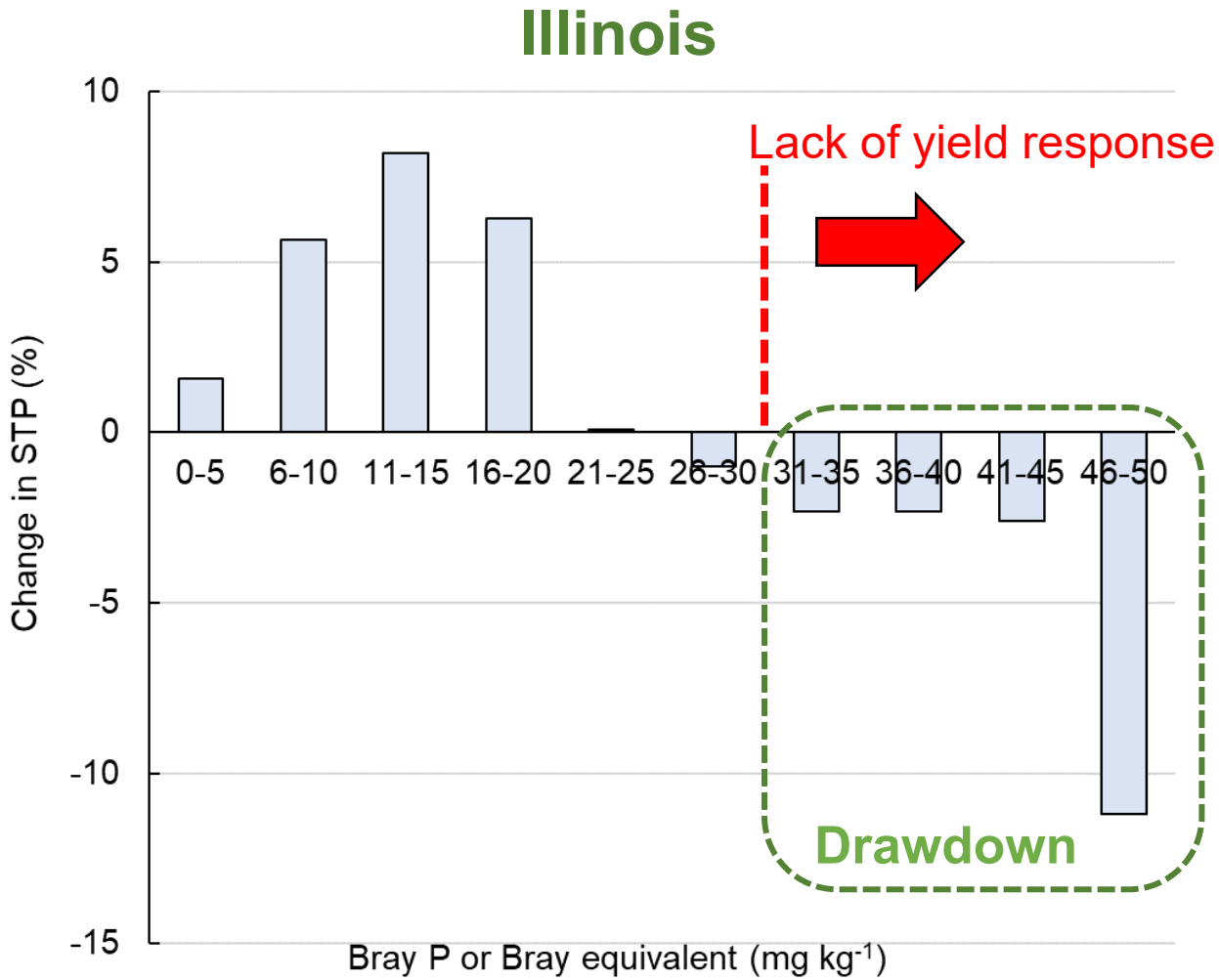
Approach: use archive of soil samples extending to 1861 through 2021, with re-sampling of relic sites to establish 150-year chronosequence





Illinois has seen greater decrease in ‘very high’ soil test values from 2001 to 2015 than the national average

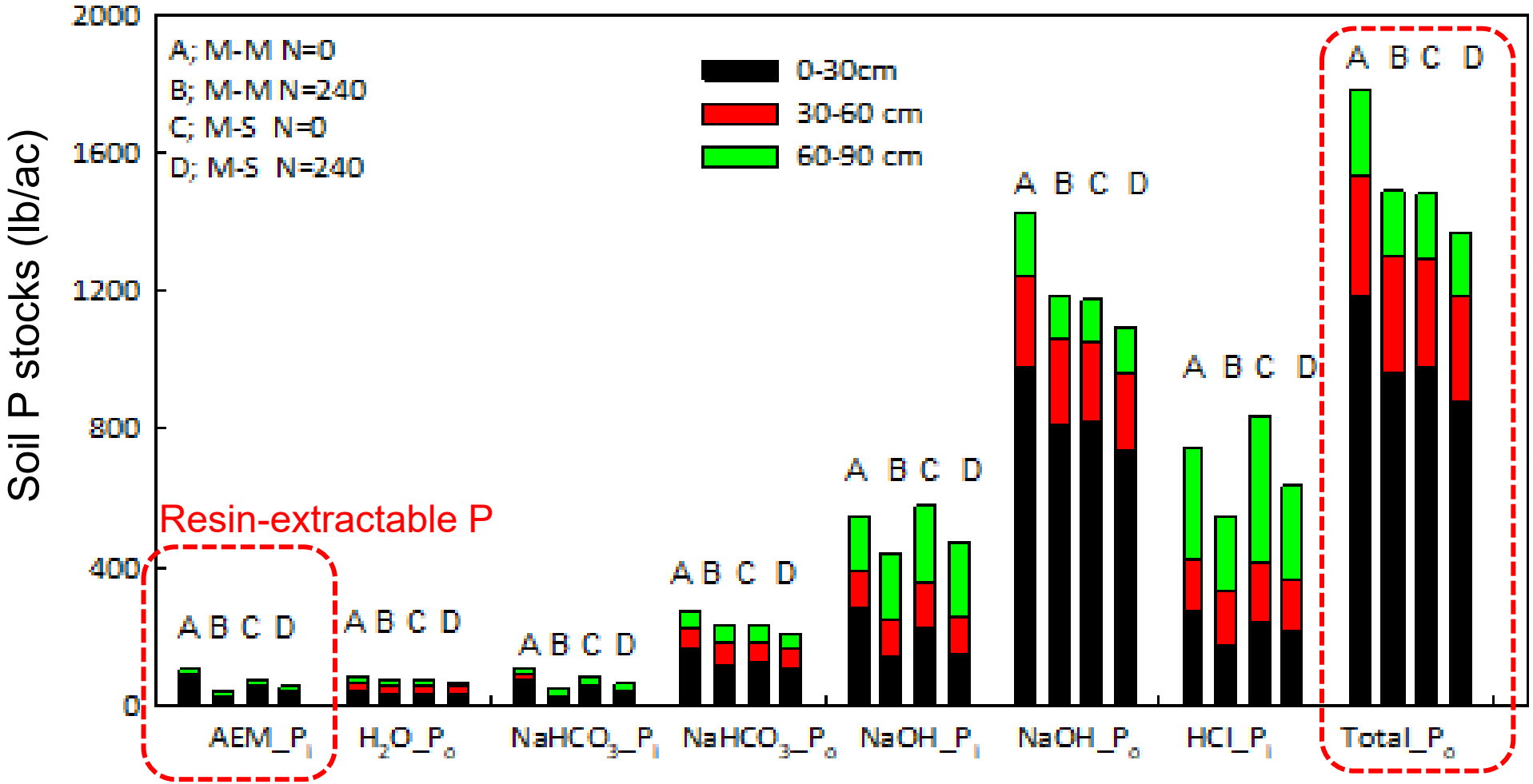




Calculated from IPNI data

Soil test P is a small fraction of total P: what about the other P?

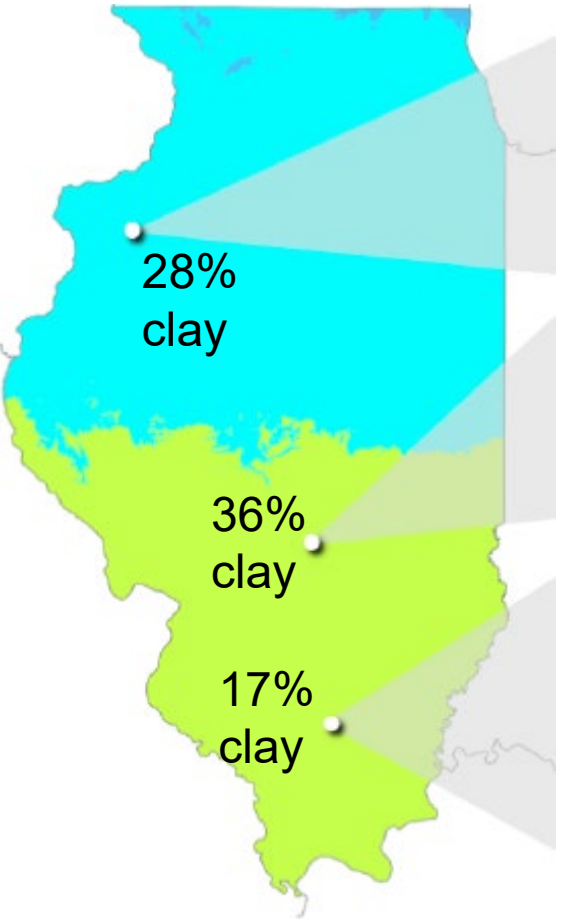
Quantity and **quality**: Soil P stocks under long-term (27 year) management at UI Northwestern Illinois Agricultural Research and Demonstration Center in Monmouth, IL



Organic P: over 1600 lb/ac in the top 3 feet

Sun, Margenot et al. In review.

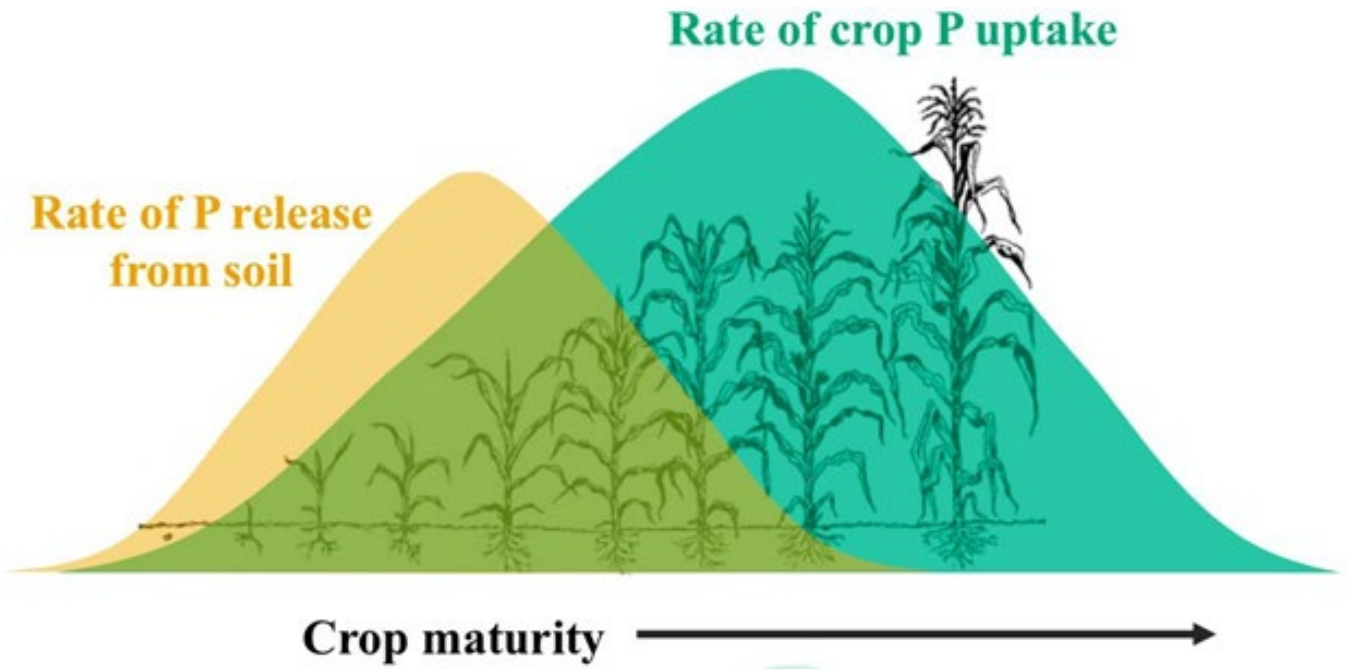
Most of the total P in soils is in *organic* form: mineralizable?



site	treatment	SOC (%)	C:N	pH	total P (mg/kg)	Organic P (mg/kg)	Organic P (% of toal)
Monmouth	no N	2.3	12.8	6.9	637.7	501.3	78.6
Monmouth	high N	2.5	12.4	5.5	629.0	591.6	94.1
Monmouth	till	2.7	12.4	6.9	635.5	539.0	84.8
Monmouth	no till	2.3	13.5	7.2	602.5	446.2	74.1
Dudley Smith	high N no cover crop	1.7	11.3	5.8	666.1	418.8	62.9
Dudley Smith	high N and cover crop	1.8	12.0	5.9	731.9	443.5	60.6
Dudley Smith	no N	1.8	11.7	5.8	762.3	451.5	59.2
Dudley Smith	pasture	2.0	11.1	6.3	546.4	375.9	68.8
Ewing	no lime no P	1.0	9.4	4.6	233.4	189.8	81.3
Ewing	no lime and P	1.1	9.3	4.7	556.4	487.6	87.6
Ewing	lime no P	1.0	8.7	5.3	203.3	191.8	94.3
Ewing	lime and P	1.3	9.4	5.0	568.4	497.0	87.4

Q3. Can a “P credit” help refine recommendations or at least explain supplying power?

How much P mineralizes from SOM in IL production systems?

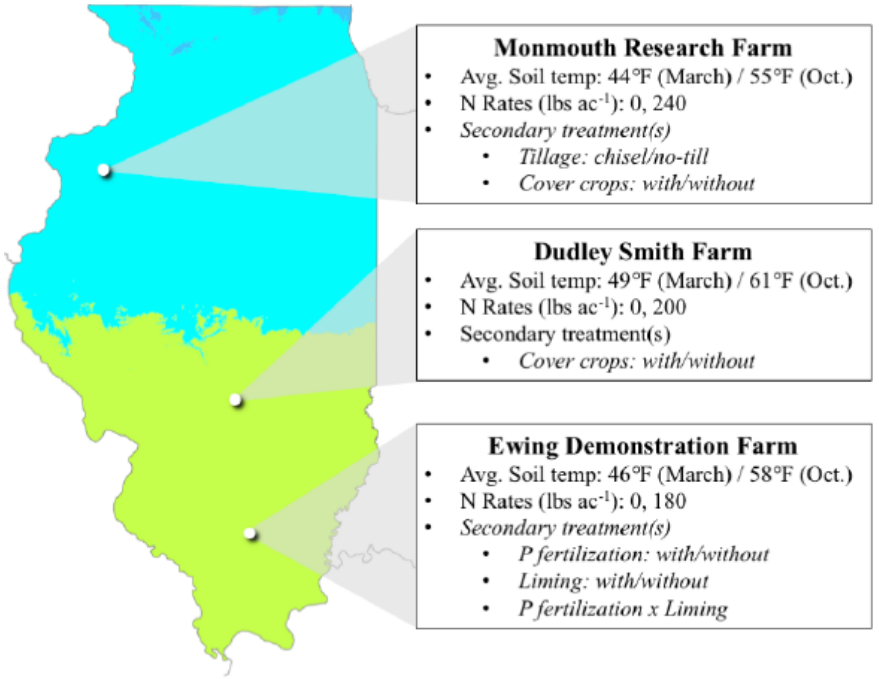


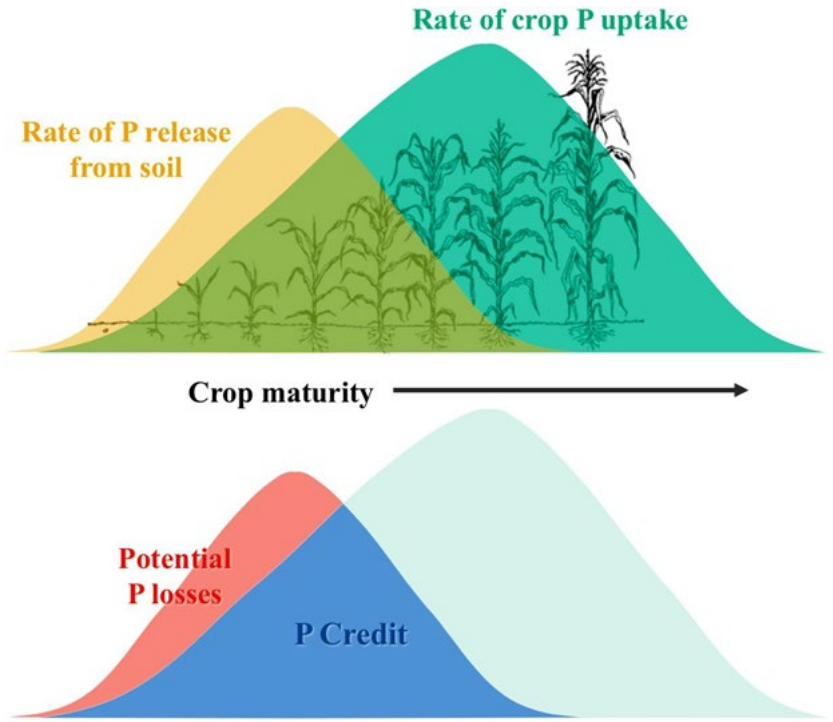
A soil P credit can help fine-tune P fertilization recommendations to increase nutrient use efficiency…..

….and make the most of our soils' natural capital

Preliminary findings

- Is there a basis for a P credit for Illinois?
  - **Yep:** *max <u>potential</u>* of up to 54 lb/ac over a growing season
  - Temperature sensitive
    - Similar to other biological processes in soils that influence the N credit
  - Management sensitive
    1. Most sensitive to tillage, P *and* N application
    2. Somewhat sensitive to cover cropping
    3. Not sensitive to liming
  - Differs by soil type *beyond* 'just' OM, organic P and soil test P





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- Three areas for updating and adding to soil P management
  1. Soil test P
     - Updating critical values: **data transparency**
     - Updating *Bray vs Mehlich* discussion
     - Conversions for *Mehlich colorimetric vs ICP* conversions
     - Other soil tests? Sink-based (resin)
  2. P **subsoil supply** power
     - Is this concept still useful?
     - How much fertilizer P has been banked up in soils? (legacy P)
     - Safe drawdown for economic usage of P?
  3. Organic P mineralization: is there a **soil P credit**?

Questions?

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