ILLINOIS
Crop Sciences
COLLEGE OF AGRICULTURAL, CONSUMER
& ENVIRONMENTAL SCIENCES

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TESTING ASSOCIATION

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Differing Soil-test P & K Build-up & Drawdown Rates

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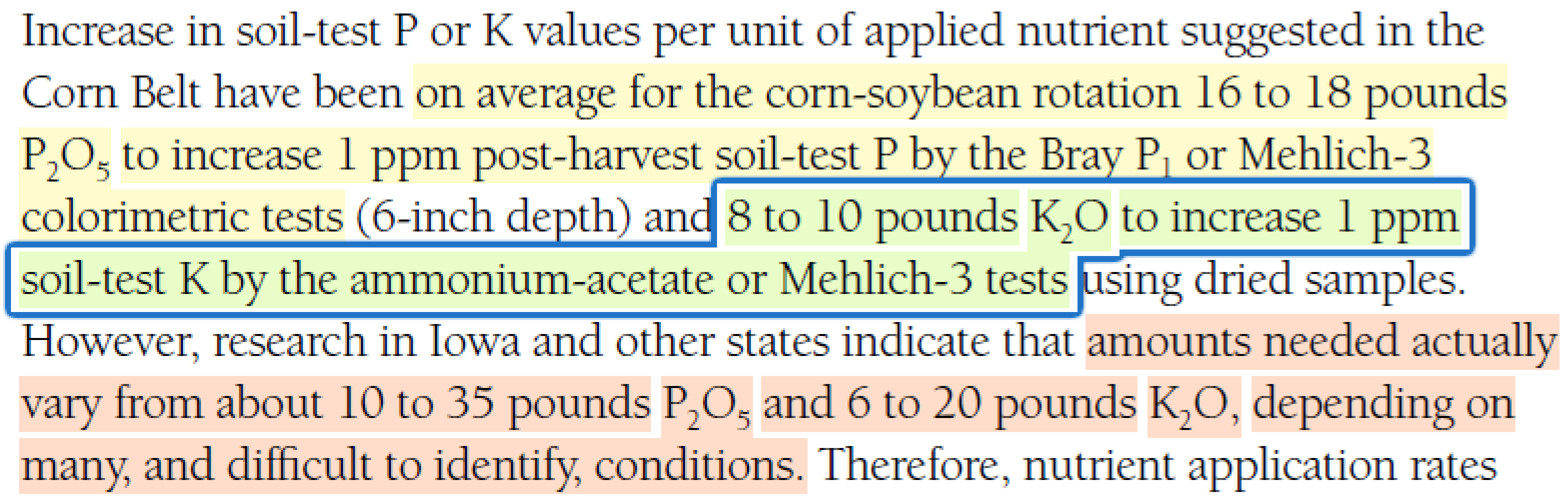
Personal introduction

Common Definitions – buffer capacity

- **Buffer power:** “The ability of solid phase soil materials to resist changes in ion concentration in the solutions phase.” -SSSA glossary (2024)
- “The **buffer capacity (BC)** represents the ability of the soil to resupply an ion to the soil solution” – Soil Fertility & Fertilizers (Havlin et al.)
- Today: **amount of fertilizer (P_2O_5 or K_2O) required to increase the soil-test value by one part per million (mg/kg) <u>and</u> the amount of crop removal required to decrease the soil-test value.**

Buffering capacity is embedded in most north central region fertility guidelines

Iowa State PM 1688



Increase in soil-test P or K values per unit of applied nutrient suggested in the Corn Belt have been on average for the corn-soybean rotation 16 to 18 pounds P_2O_5 to increase 1 ppm post-harvest soil-test P by the Bray P_1 or Mehlich-3 colorimetric tests (6-inch depth) and 8 to 10 pounds K_2O to increase 1 ppm soil-test K by the ammonium-acetate or Mehlich-3 tests using dried samples. However, research in Iowa and other states indicate that amounts needed actually vary from about 10 to 35 pounds P_2O_5 and 6 to 20 pounds K_2O, depending on many, and difficult to identify, conditions. Therefore, nutrient application rates

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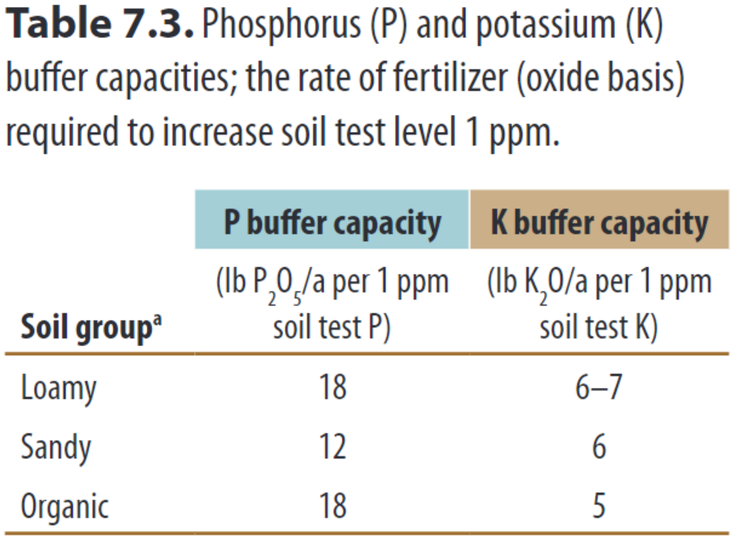
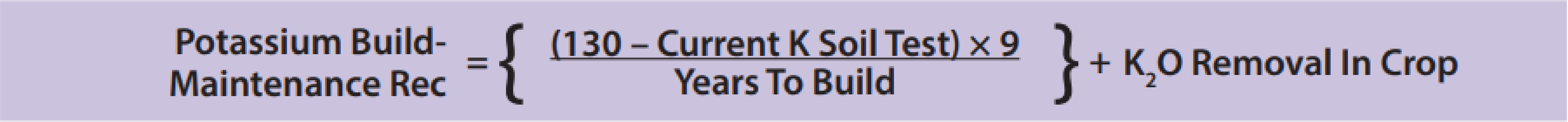


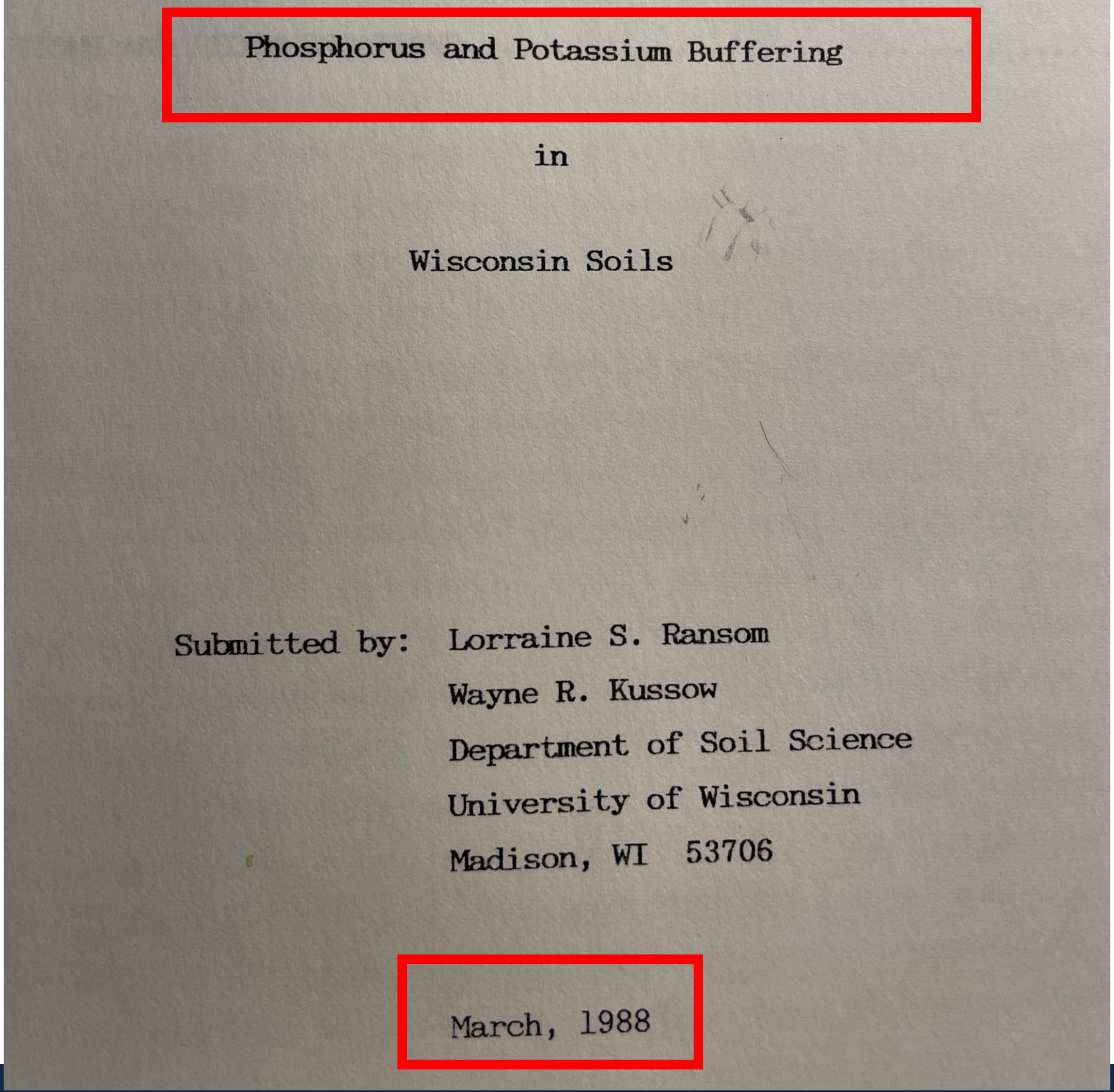
Table 7.3. Phosphorus (P) and potassium (K) buffer capacities; the rate of fertilizer (oxide basis) required to increase soil test level 1 ppm.

Soil group[a]	**P buffer capacity** (lb P_2O_5/a per 1 ppm soil test P)	**K buffer capacity** (lb K_2O/a per 1 ppm soil test K)
Loamy	18	6–7
Sandy	12	6
Organic	18	5

Kansas State Research and Extension



$$\text{Potassium Build-Maintenance Rec} = \left\{ \frac{(130 - \text{Current K Soil Test}) \times 9}{\text{Years To Build}} \right\} + K_2O \text{ Removal In Crop}$$



Phosphorus and Potassium Buffering

in

Wisconsin Soils

Submitted by: Lorraine S. Ransom
Wayne R. Kussow
Department of Soil Science
University of Wisconsin
Madison, WI 53706

March, 1988

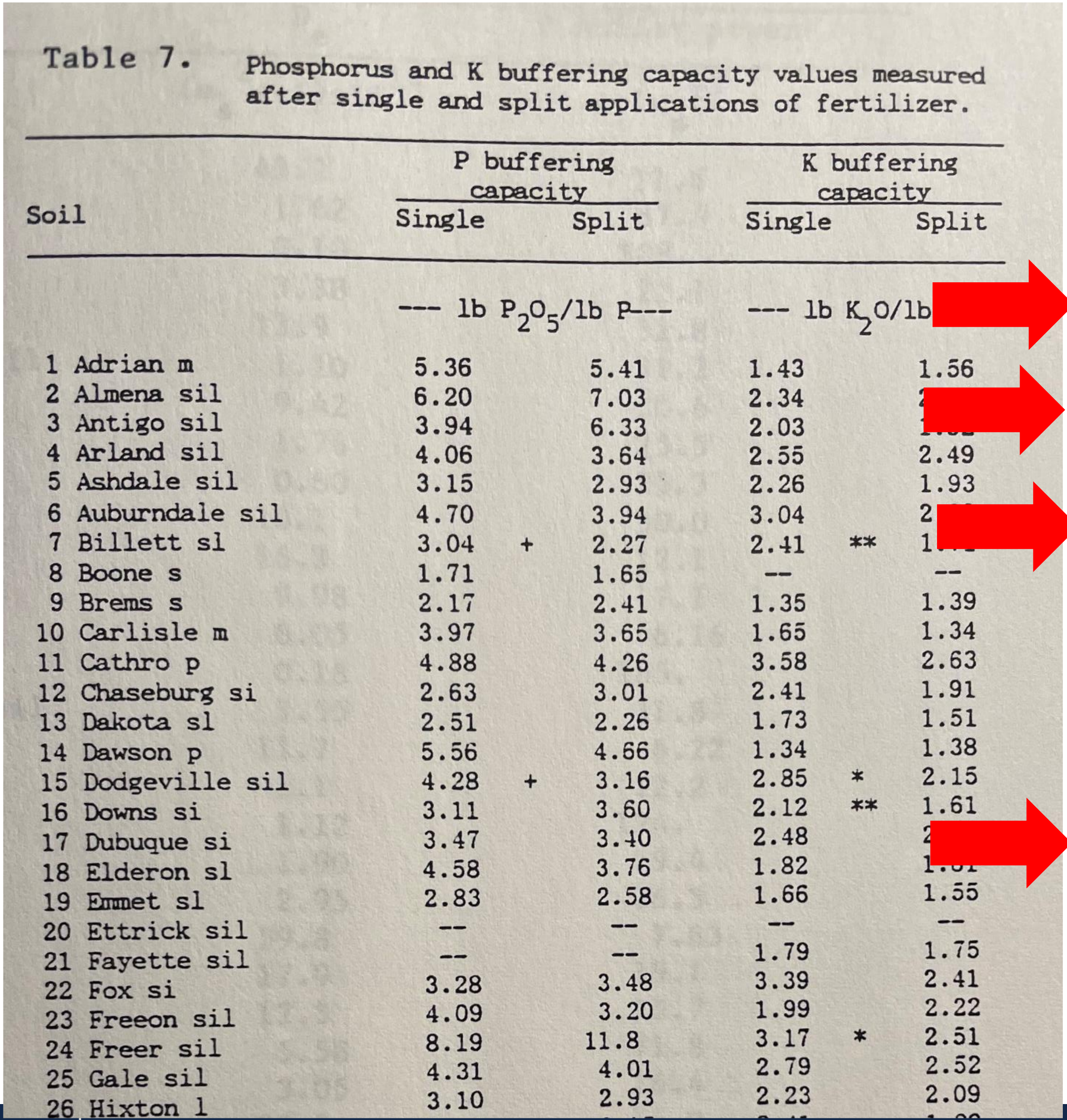
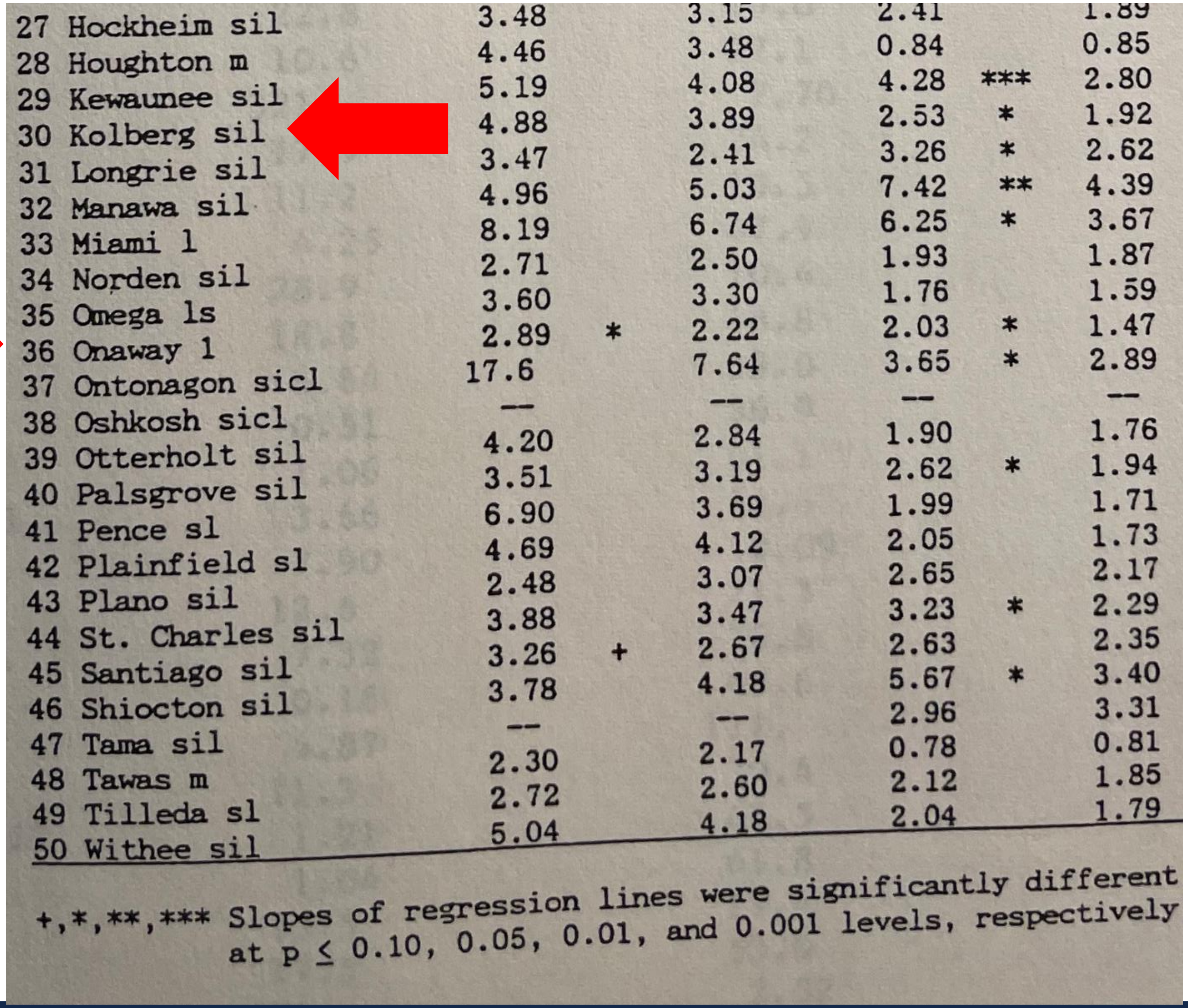


Table 7. Phosphorus and K buffering capacity values measured after single and split applications of fertilizer.

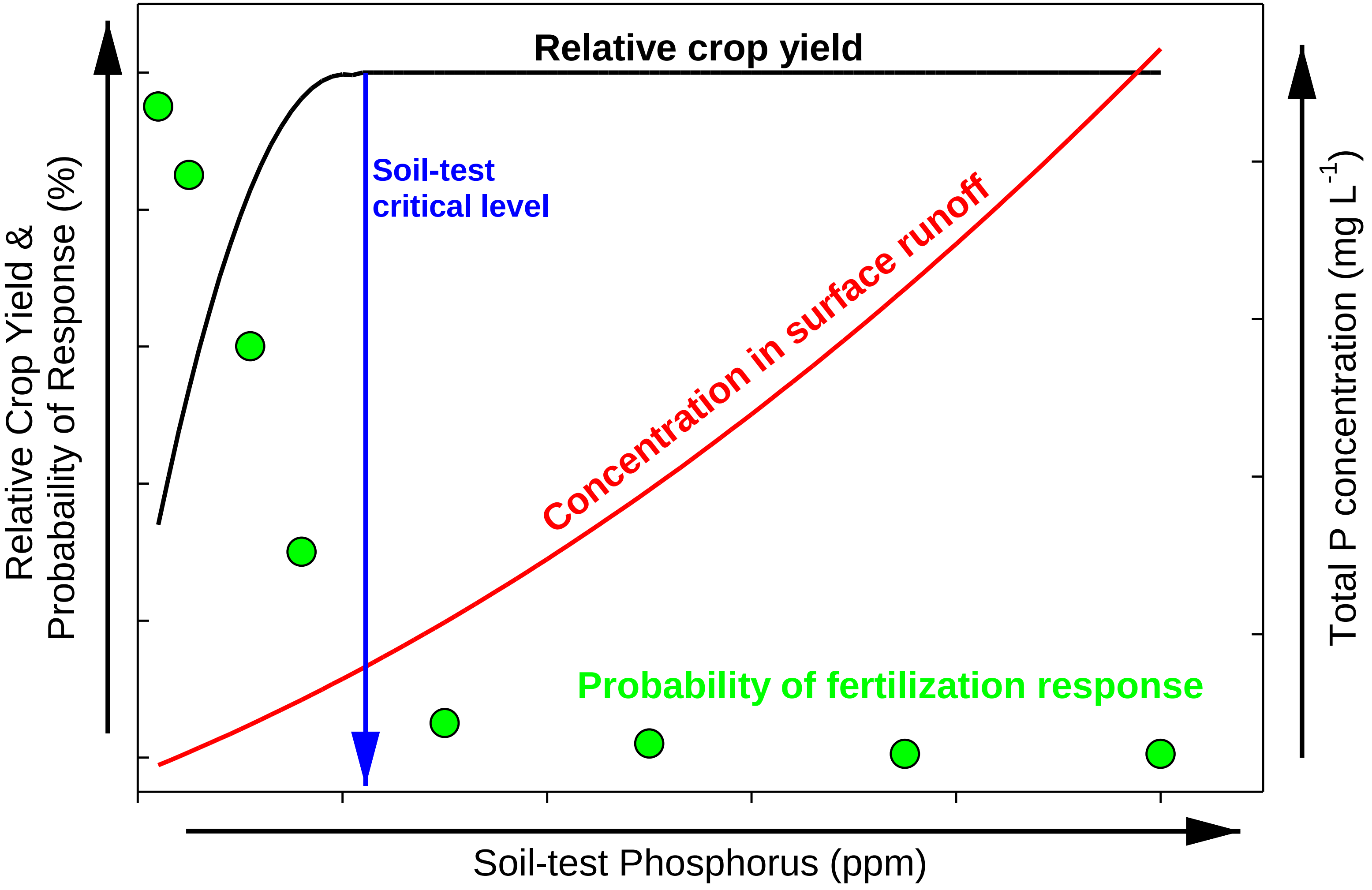
Soil	P buffering capacity			K buffering capacity		
	Single		Split	Single		Split
	--- lb P_2O_5/lb P---			--- lb K_2O/lb		
1 Adrian m	5.36		5.41	1.43		1.56
2 Almena sil	6.20		7.03	2.34		[illegible]
3 Antigo sil	3.94		6.33	2.03		[illegible]
4 Arland sil	4.06		3.64	2.55		2.49
5 Ashdale sil	3.15		2.93	2.26		1.93
6 Auburndale sil	4.70		3.94	3.04		[illegible]
7 Billett sl	3.04	+	2.27	2.41	**	[illegible]
8 Boone s	1.71		1.65	--		--
9 Brems s	2.17		2.41	1.35		1.39
10 Carlisle m	3.97		3.65	1.65		1.34
11 Cathro p	4.88		4.26	3.58		2.63
12 Chaseburg si	2.63		3.01	2.41		1.91
13 Dakota sl	2.51		2.26	1.73		1.51
14 Dawson p	5.56		4.66	1.34		1.38
15 Dodgeville sil	4.28	+	3.16	2.85	*	2.15
16 Downs si	3.11		3.60	2.12	**	1.61
17 Dubuque si	3.47		3.40	2.48		[illegible]
18 Elderon sl	4.58		3.76	1.82		[illegible]
19 Emmet sl	2.83		2.58	1.66		1.55
20 Ettrick sil	--		--	--		--
21 Fayette sil	--		--	1.79		1.75
22 Fox si	3.28		3.48	3.39		2.41
23 Freeon sil	4.09		3.20	1.99		2.22
24 Freer sil	8.19		11.8	3.17	*	2.51
25 Gale sil	4.31		4.01	2.79		2.52
26 Hixton l	3.10		2.93	2.23		2.09



Soil	P buffering capacity			K buffering capacity		
	Single		Split	Single		Split
27 Hockheim sil	3.48		3.15	2.41		1.89
28 Houghton m	4.46		3.48	0.84		0.85
29 Kewaunee sil	5.19		4.08	4.28	***	2.80
30 Kolberg sil	4.88		3.89	2.53	*	1.92
31 Longrie sil	3.47		2.41	3.26	*	2.62
32 Manawa sil	4.96		5.03	7.42	**	4.39
33 Miami l	8.19		6.74	6.25	*	3.67
34 Norden sil	2.71		2.50	1.93		1.87
35 Omega ls	3.60		3.30	1.76		1.59
36 Onaway l	2.89	*	2.22	2.03	*	1.47
37 Ontonagon sicl	17.6		7.64	3.65	*	2.89
38 Oshkosh sicl	—		—	—		—
39 Otterholt sil	4.20		2.84	1.90		1.76
40 Palsgrove sil	3.51		3.19	2.62	*	1.94
41 Pence sl	6.90		3.69	1.99		1.71
42 Plainfield sl	4.69		4.12	2.05		1.73
43 Plano sil	2.48		3.07	2.65		2.17
44 St. Charles sil	3.88		3.47	3.23	*	2.29
45 Santiago sil	3.26	+	2.67	2.63		2.35
46 Shiocton sil	3.78		4.18	5.67	*	3.40
47 Tama sil	—		—	2.96		3.31
48 Tawas m	2.30		2.17	0.78		0.81
49 Tilleda sl	2.72		2.60	2.12		1.85
50 Withee sil	5.04		4.18	2.04		1.79

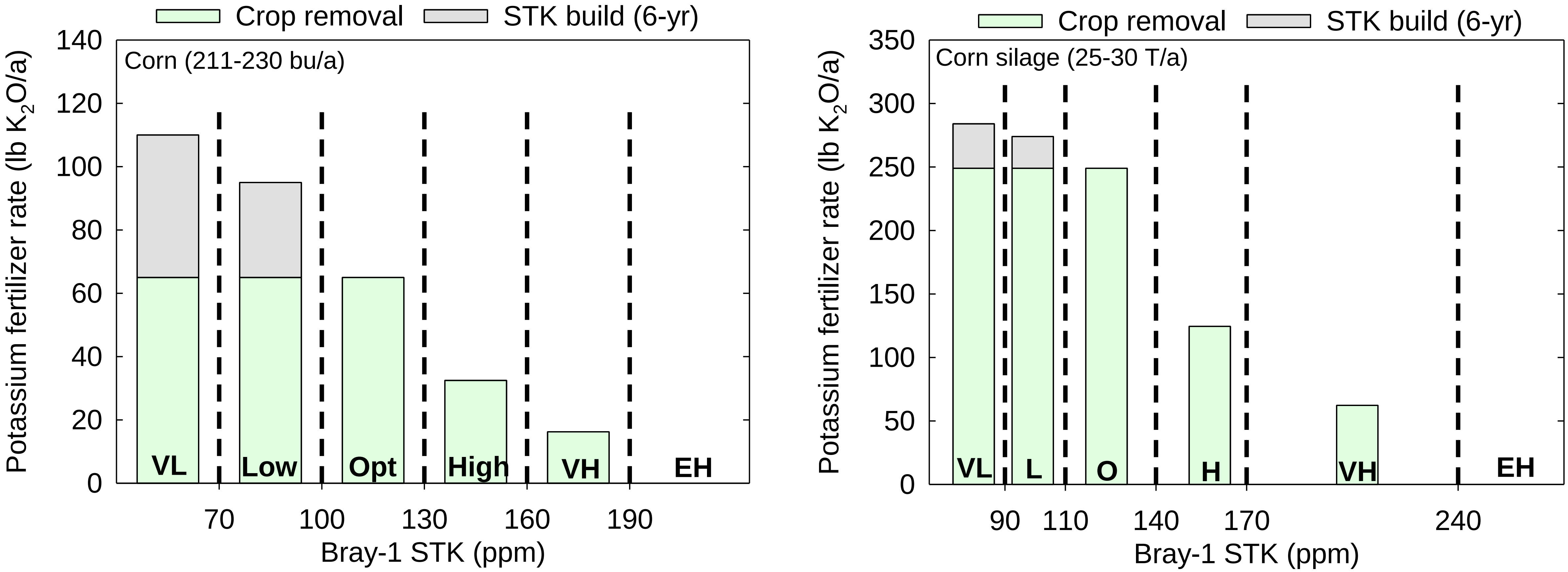
+,*,**,*** Slopes of regression lines were significantly different at p ≤ 0.10, 0.05, 0.01, and 0.001 levels, respectively

Drawdown rates & reducing P losses



Jones et al., 2021

Buffering capacity then affects recommended rates



Fertilization rates where the build component is large are more affected by assumed buffering capacity

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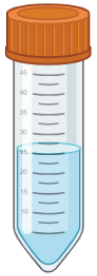
Measuring buffering capacity

Laboratory/
incubation

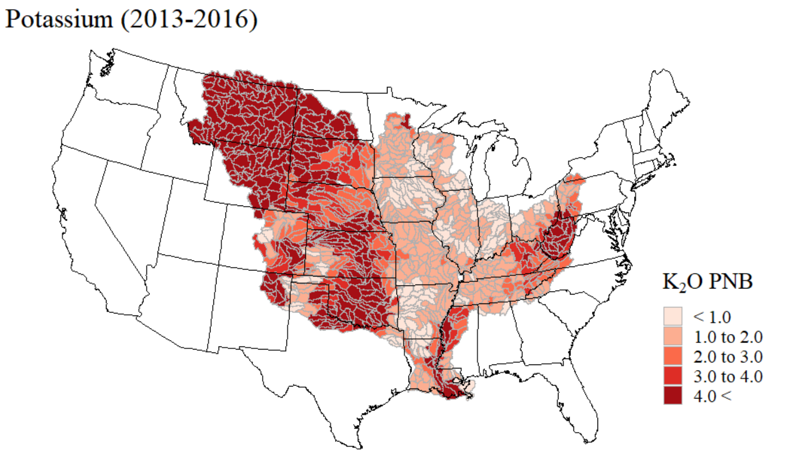


Greenhouse

Data shared today

Research plot or
field scale

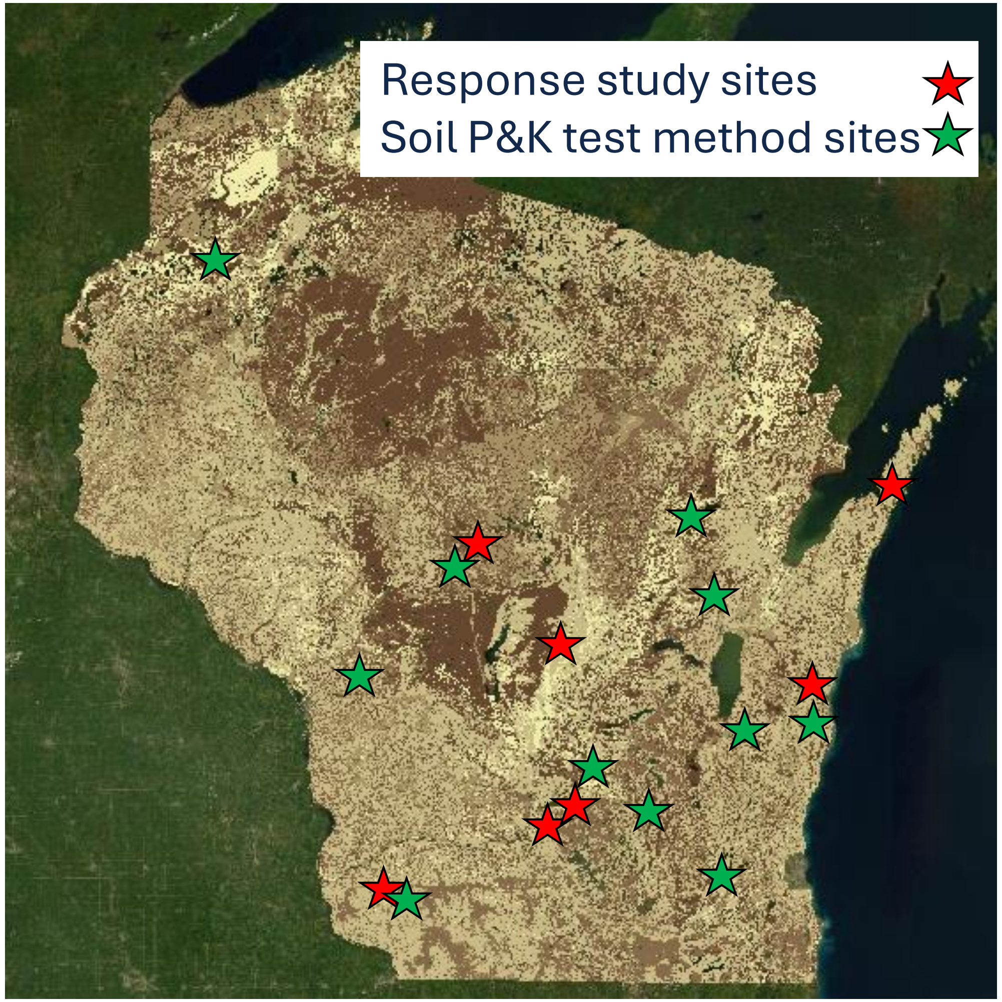
Regional scale



Sources & magnitude of error/uncertainty increase with scale

P & K research in Wisconsin (2021-2024)

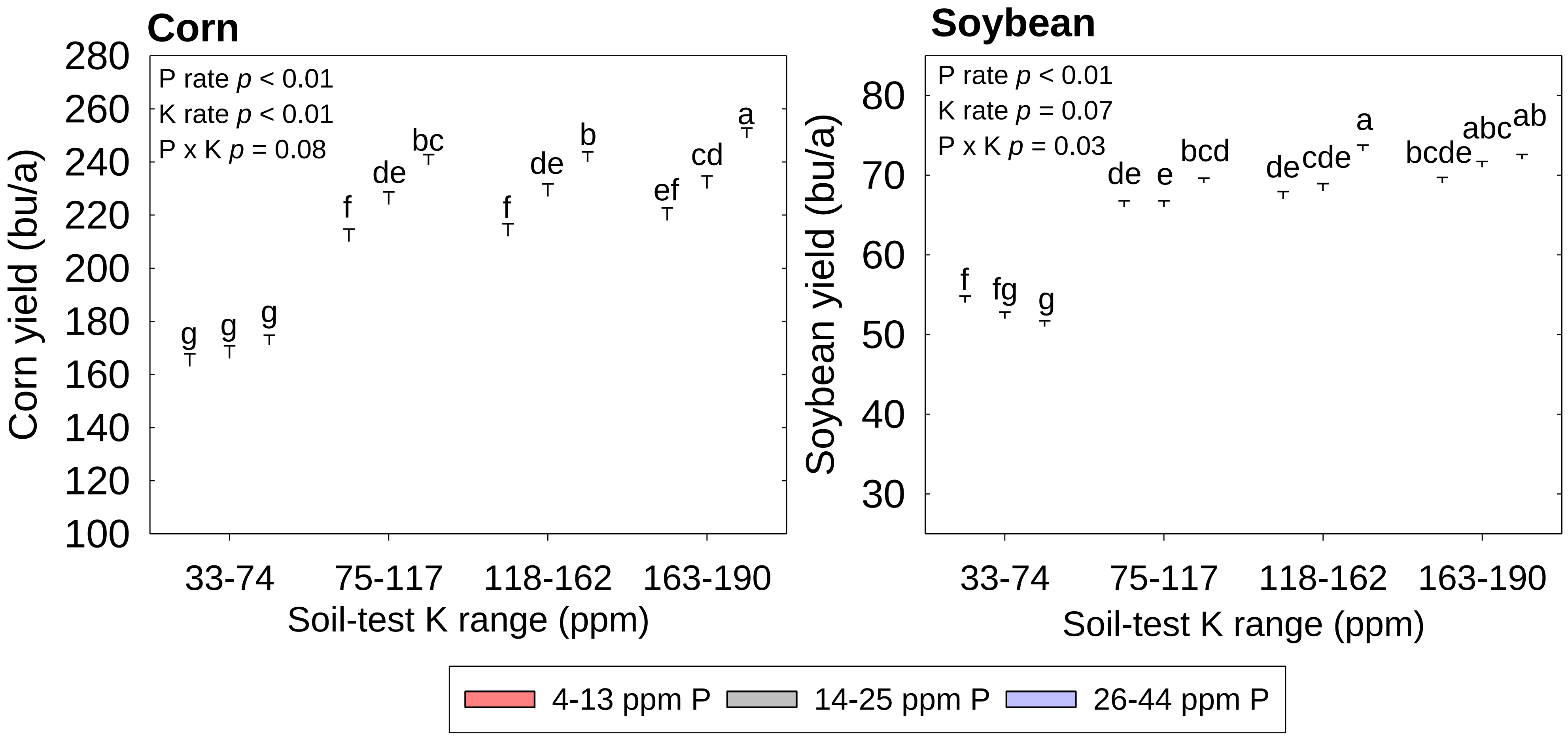
- 18 sites/year (corn & soybean combined)
- No-till and disk/chisel-plow
- 0.7 to 5.8% SOM, silty clay loam to sand surface textures, pH 5.5 to 7.4 (6”)
- Full factorial of P & K treatments



P & K research in Wisconsin

- Samples collected after harvest and before fertilizer application in the fall; and in the spring prior to planting
- 6-inch depth (15 core composite sample per plot)
- **Bray-1**, Mehlich-3 (colorimetric & ICP), Olsen phosphorus
- **Bray-1**, Ammonium acetate, Mehlich-3 potassium
- Grain samples collected & analyzed for total nutrients
- Plot size between 450 and 650 sq ft (0.015ac)
- Annual rates of TSP and KCl (during build phase) applied with Gandy drop spreader

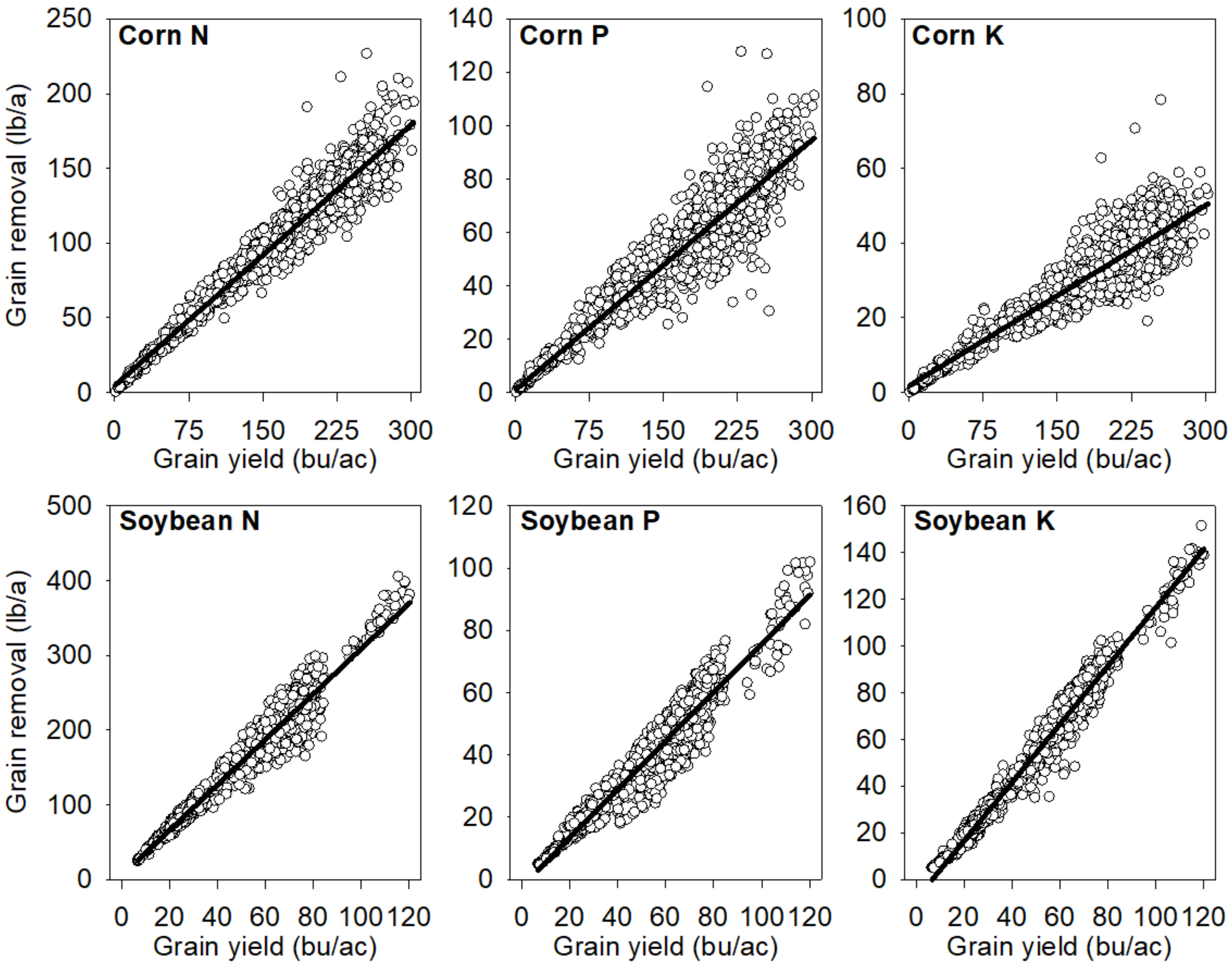
Study soil-test levels & yield responses



Corn and soybean yield affected by P rate, K rate, and P x K interaction (2021-2023)

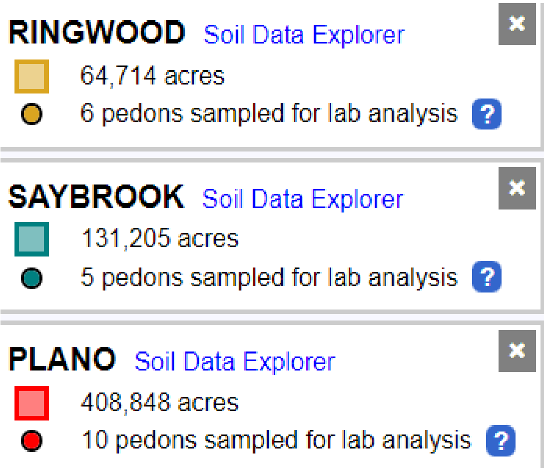
Jones (2023)

Yield levels & nutrient removal



Jones (2023)

Consider associated soils: Plano/Ringwood/Saybrook



RINGWOOD Soil Data Explorer ✕

🟨 64,714 acres

● 6 pedons sampled for lab analysis ?

SAYBROOK Soil Data Explorer ✕

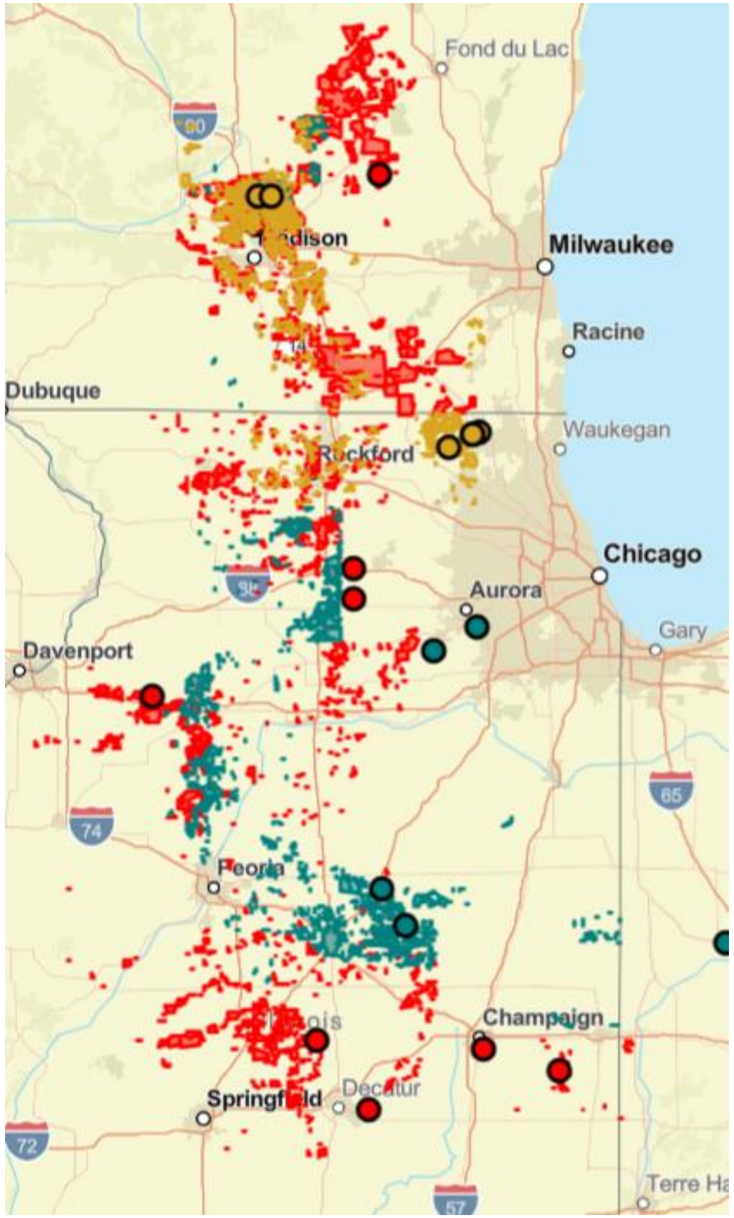
🟦 131,205 acres

● 5 pedons sampled for lab analysis ?

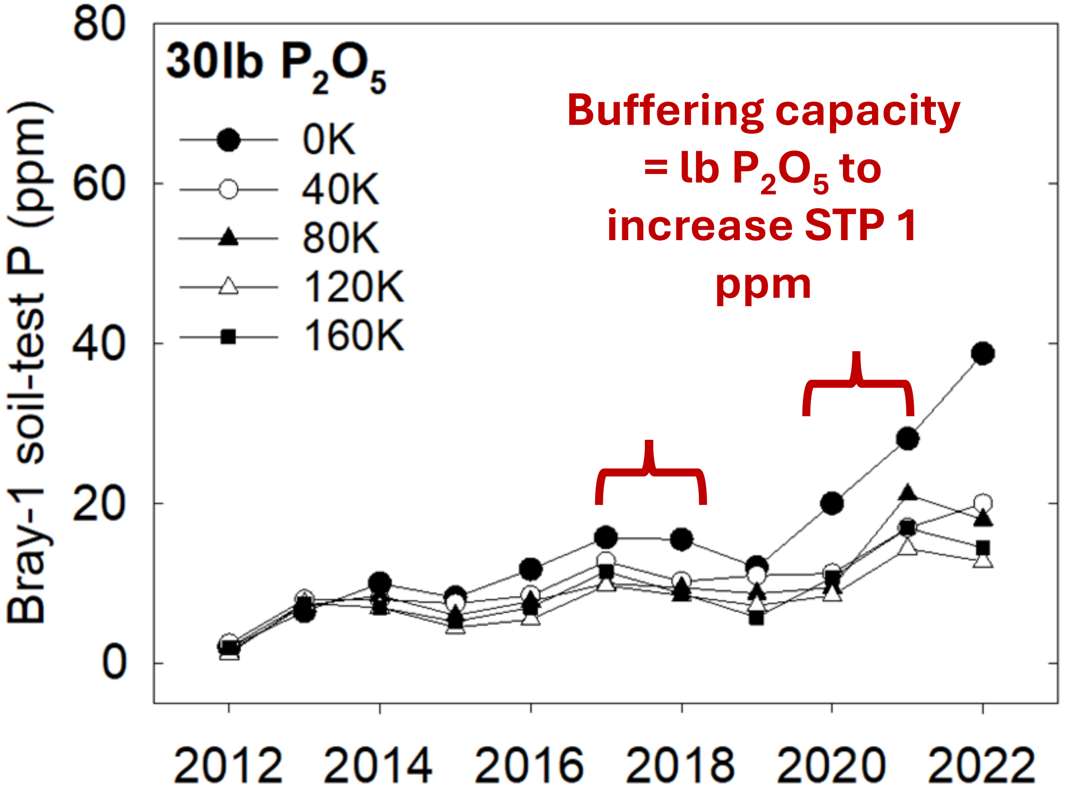
PLANO Soil Data Explorer ✕

🟥 408,848 acres

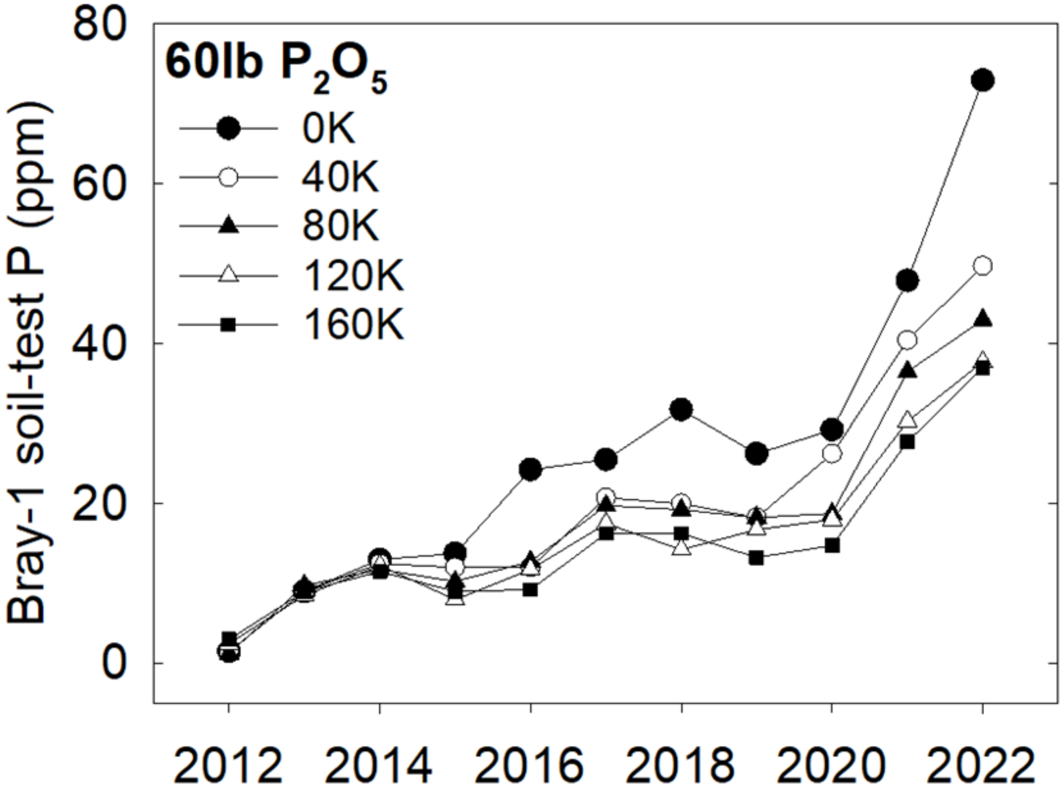
● 10 pedons sampled for lab analysis ?



Changes in soil-test level over time



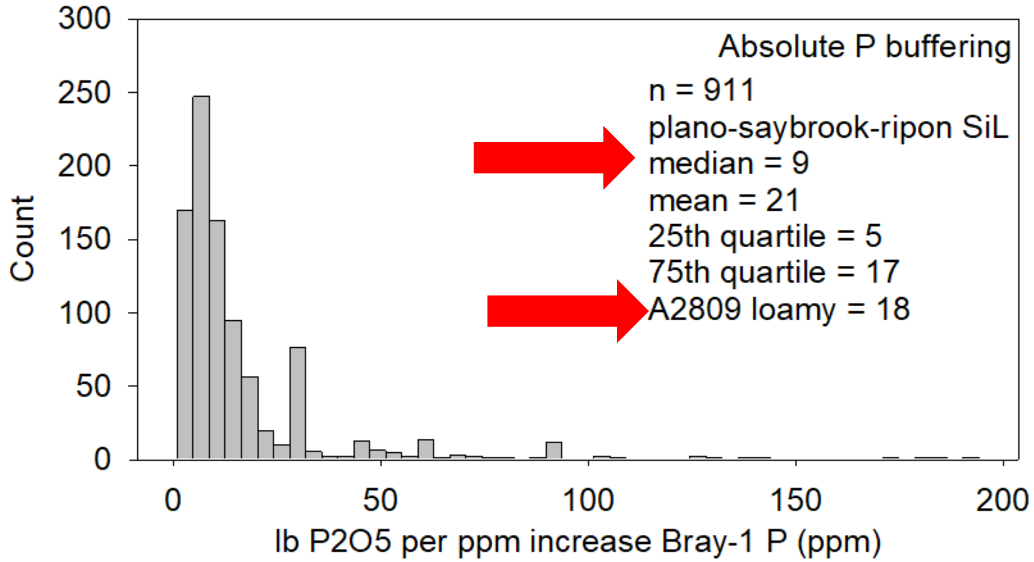
Buffering capacity = lb P_2O_5 to increase STP 1 ppm

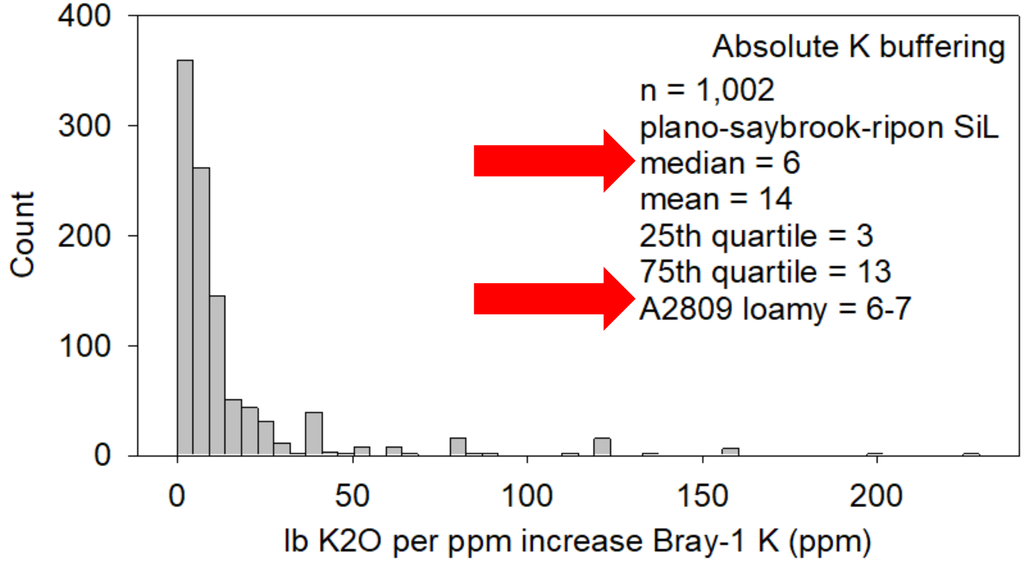


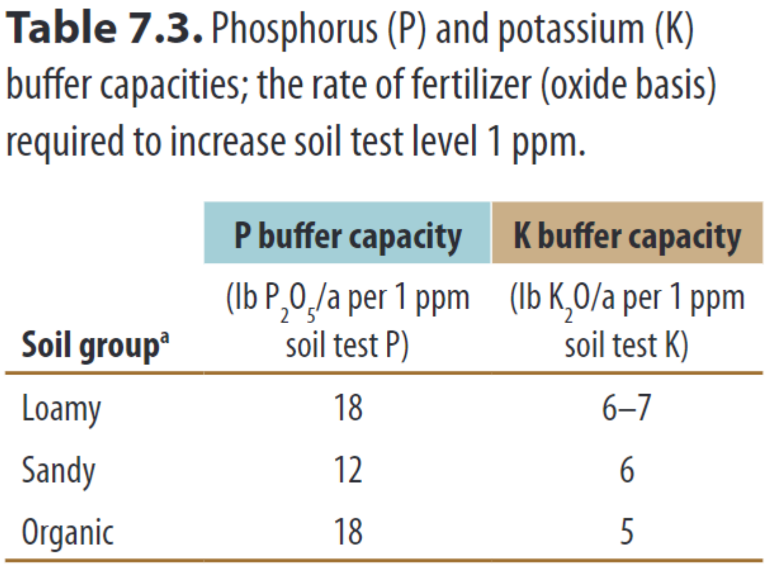
Maintaining optimum STP (16-20 ppm P) was affected by K nutrition

Jones (2022)

Buffering capacities (build-up)







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Loamy	18	6–7
Sandy	12	6
Organic	18	5

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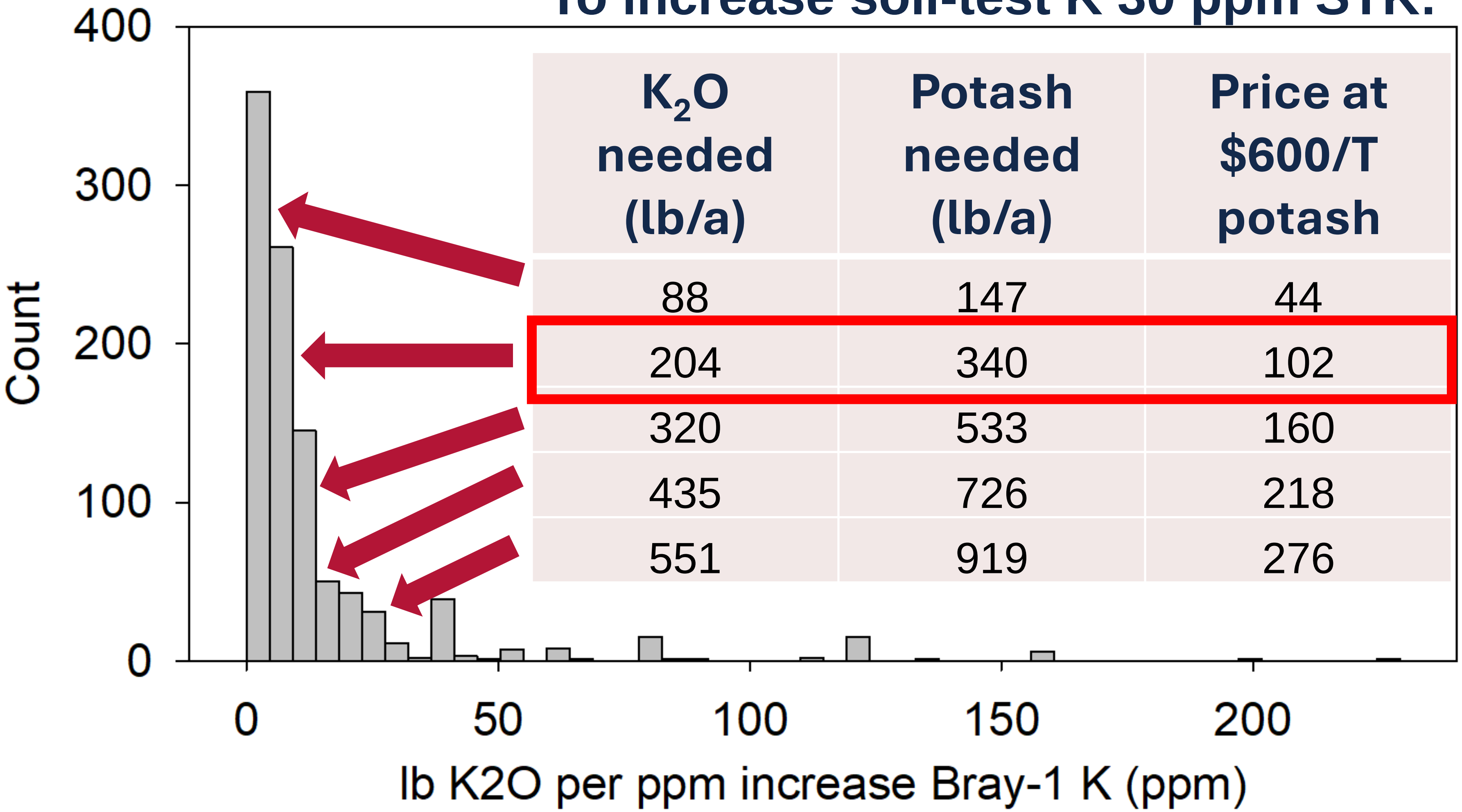
- Well represented soils in recommendation dataset

Jones (2022)

Building soil-test levels

To increase soil-test K 30 ppm STK:

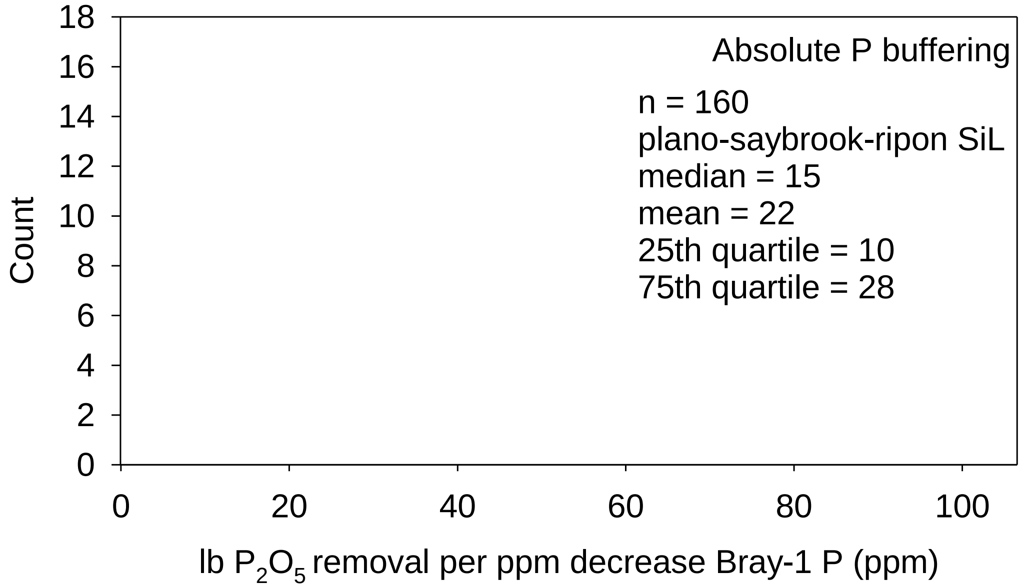
K_2O needed (lb/a)	Potash needed (lb/a)	Price at $600/T potash
88	147	44
204	340	102
320	533	160
435	726	218
551	919	276

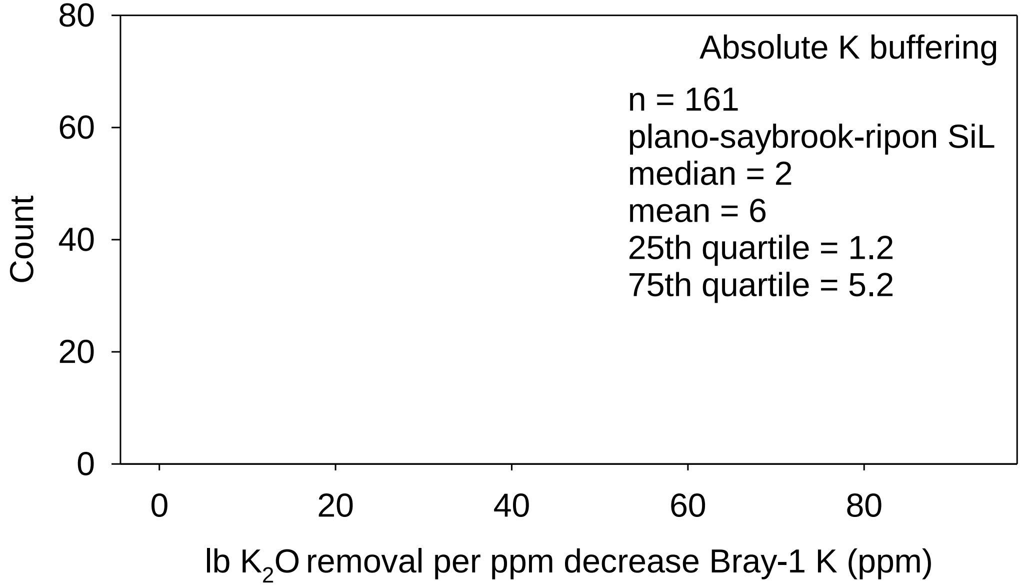


Jones (2022)

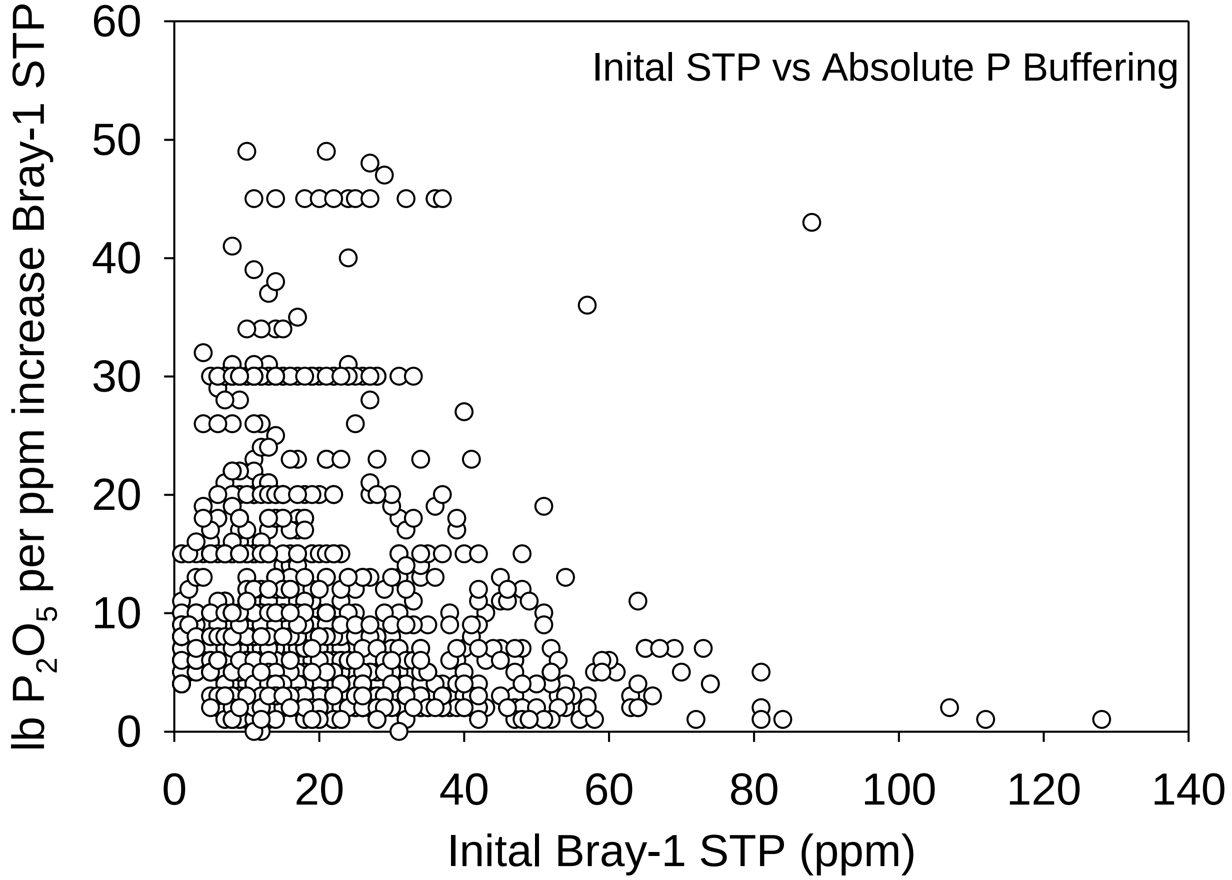
Only drawdown

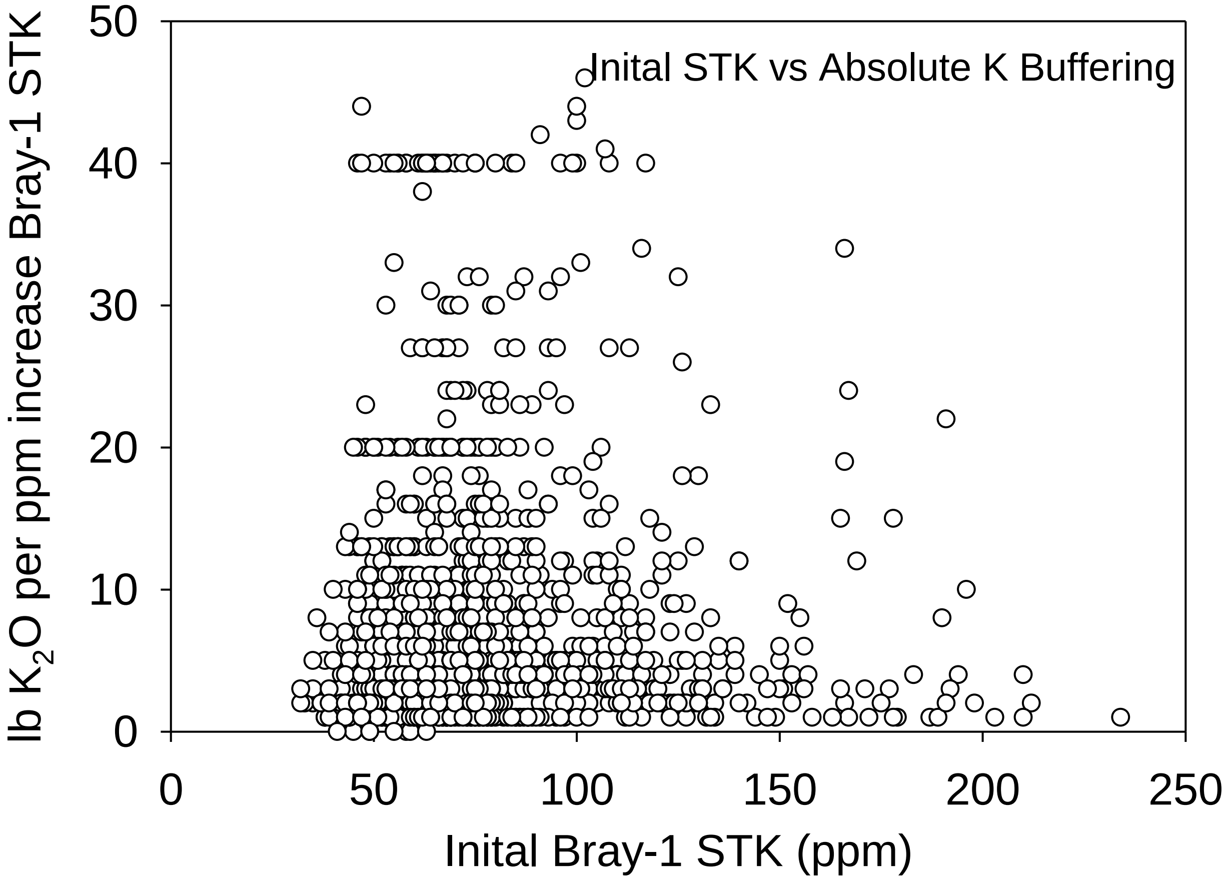
- Greater P removal to reduce STP
- More difficult and slower to drawdown high testing soils
- Lower K removal to reduce STK
- Easier to drop into optimum or low testing categories with high removal rates





Buffering capacity & initial soil-test level





Messy data reflects the variability out there…

Dynamic buffering capacities make sense, in practice

- “My K levels just won’t increase”
- “Soil P has barely budged after high-yielding corn”
- Work referenced from Kentucky observed similar trends

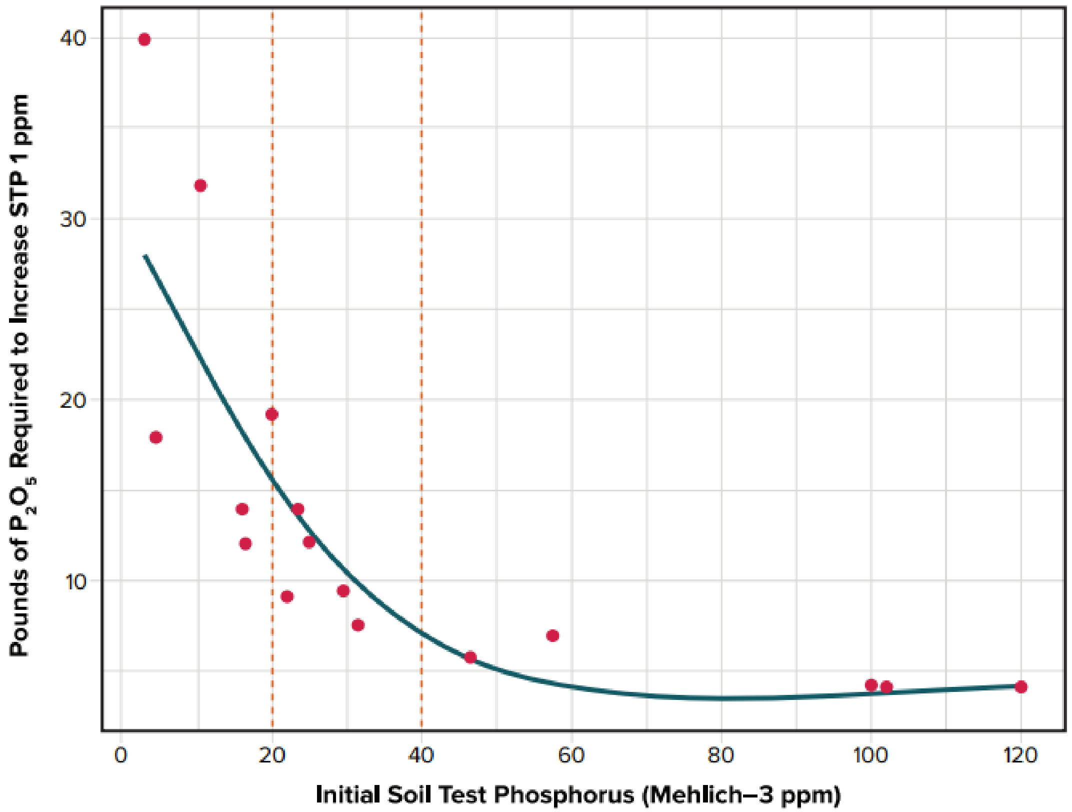
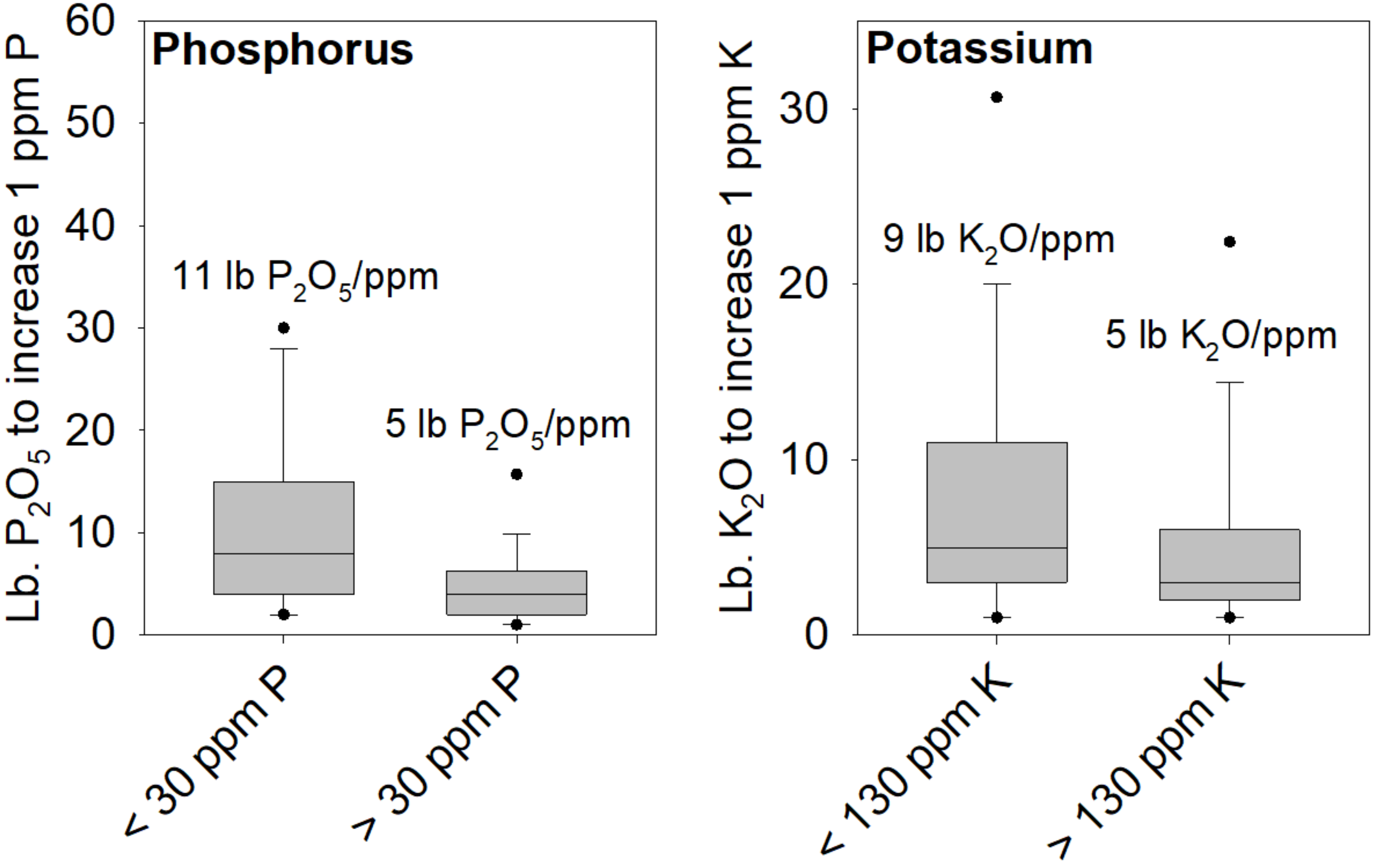


Figure 3. Pounds of P_2O_5 fertilizer required to increase soil test phosphorus levels by 1 part per million in 16 Kentucky soils (Adapted from Thom and Dollarhide, 2002). Red vertical, dashed lines indicate the tri-state maintenance range for corn and soybean.

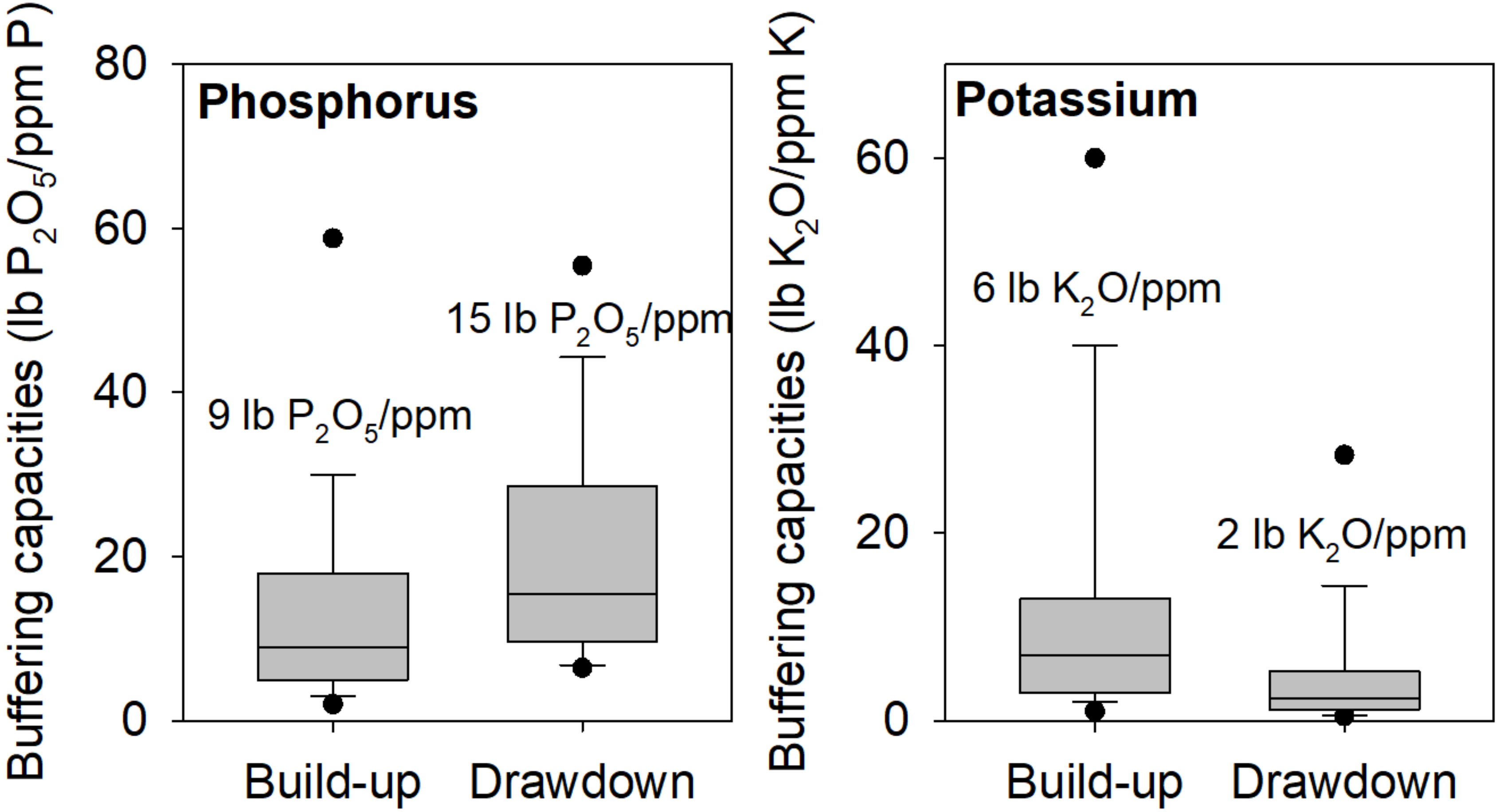
Tri-state guidelines

Splitting the data near the soil-test critical concentration range

- More fertilizer is required to increase soil-test levels if the initial level is low
- Remember: this is based on extractable nutrient amounts
- Finding true fate of applied nutrients at higher levels needs other tactics (lab methods)



Are build-up and drawdown equivalent?

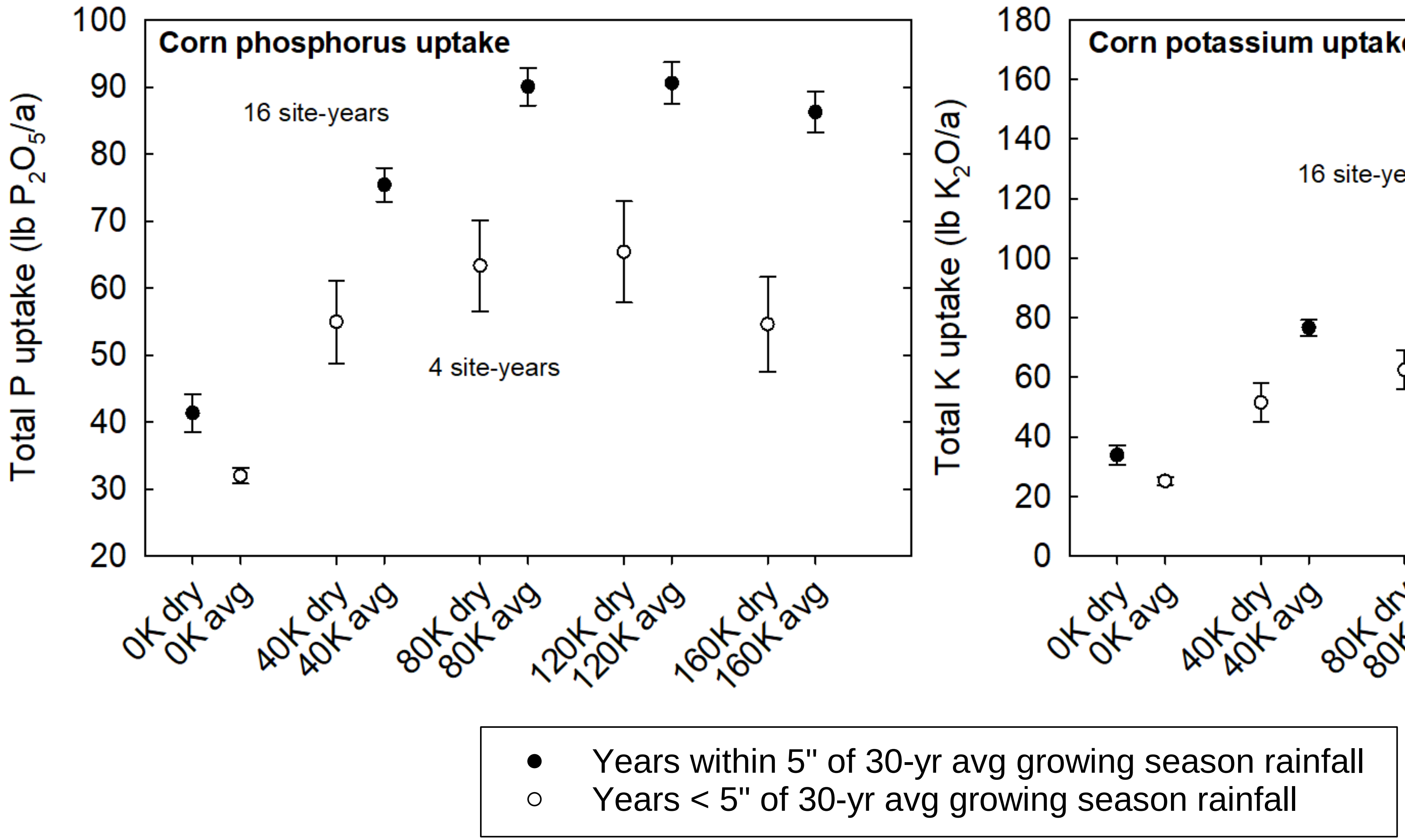


Suggests that they might not be...

Two important pieces to this story...

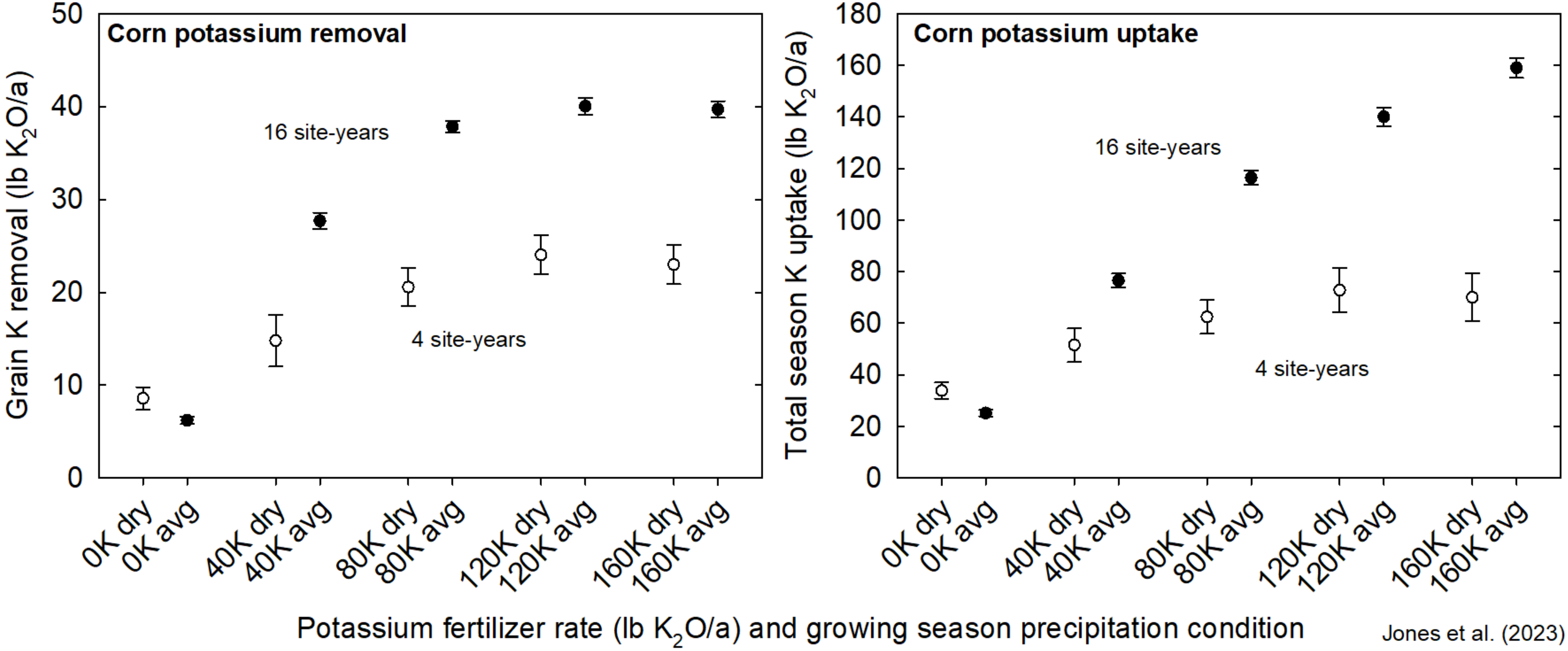
- Does applying harvest removal maximize grain yield?
  - Consider what applying only 100% of removal means physiologically and for fertilizer use efficiency...
- Does the assumption that drawdown rates are equivalent to build-up rates hold true?
  - Consider the fate of applied P or K and diffusion/uptake mechanisms during the growing season
  - Contrasting soil conditions (moisture and temperature)?

Weather conditions & removal/drawdown



Jones et al. (2023)

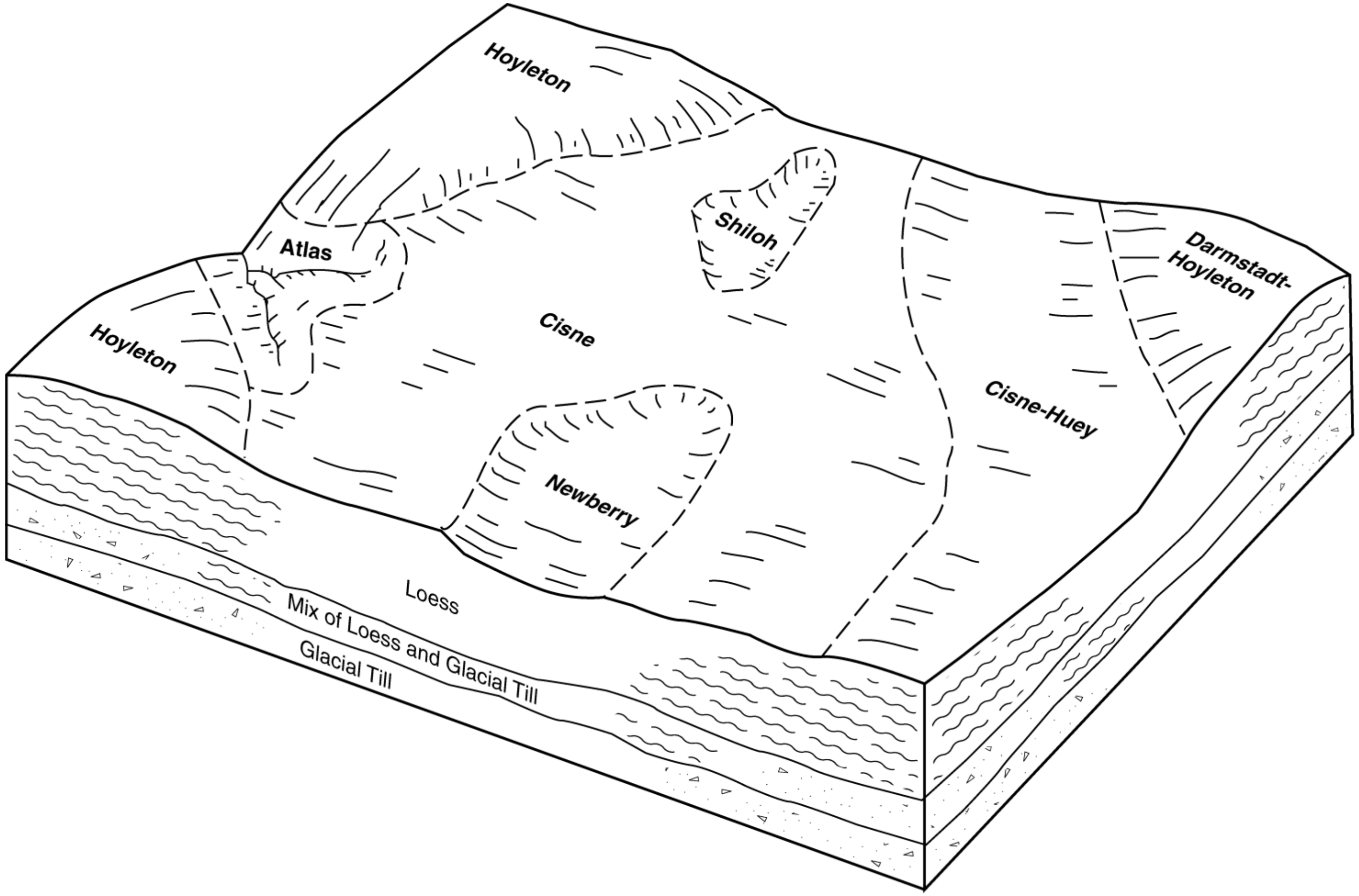
Weather conditions & removal/drawdown



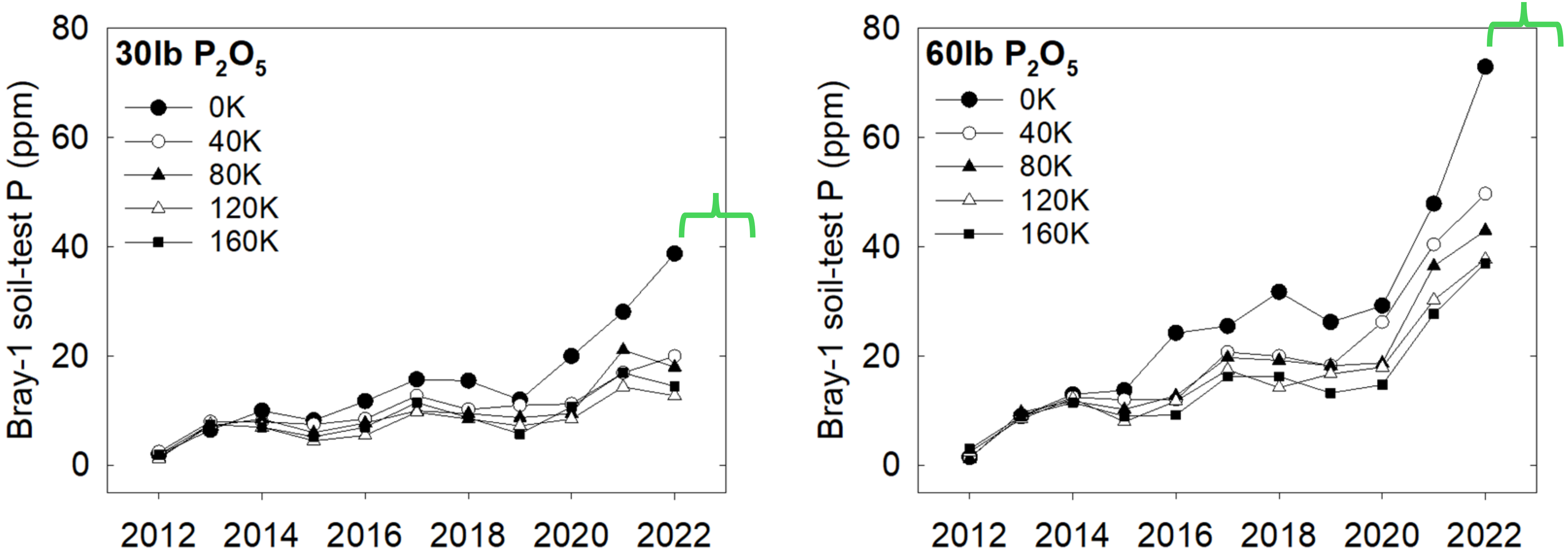
Jones et al. (2023)

- ● Years within 5" of 30-yr avg growing season rainfall
- ○ Years < 5" of 30-yr avg growing season rainfall

Would soil-specific buffering capacities be *consistent* enough to assign across a landscape?



Can build or drawdown components of fertility recommendations be dynamic?



Where can this analysis take us?

- Build-up and drawdown rates identified for major IL soil associations
- Only extractable nutrient levels were assessed
- Quantifying P or K within the continuum of solution-exchangeable-moderately available will provide clearer guidance
- Realistic building program, and even more important, realistic drawdown timelines.
- Long-term studies around IL complemented by on-farm trials for regional calibration & spatial response assessment.

Thank you!

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