WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Indiana CCA Conference

December 19, 2023

How Crop Nutrient Removal Trends Affect Agronomics and Economics of Nutrient Management

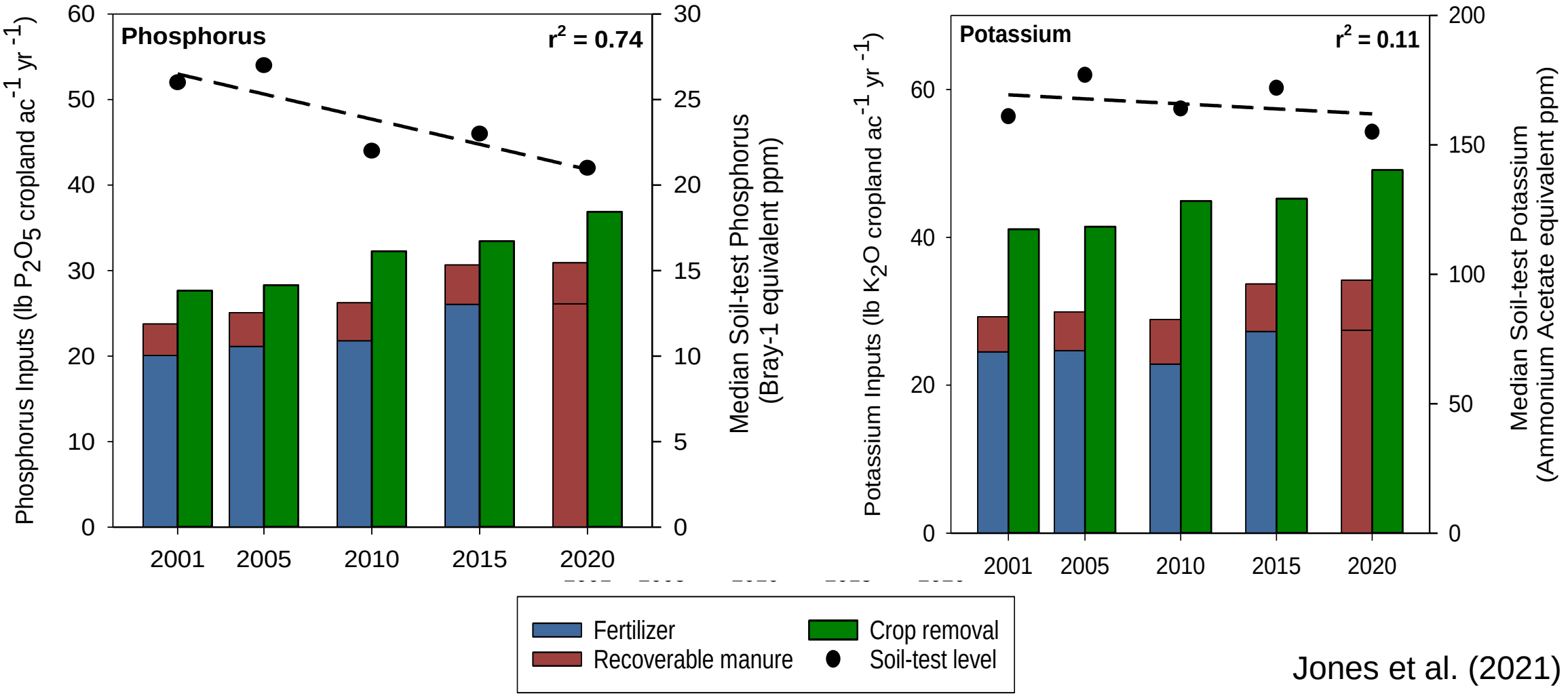
John Jones, PhD, CCA

Department of Soil Science, UW-Madison

First Step - brief definitions

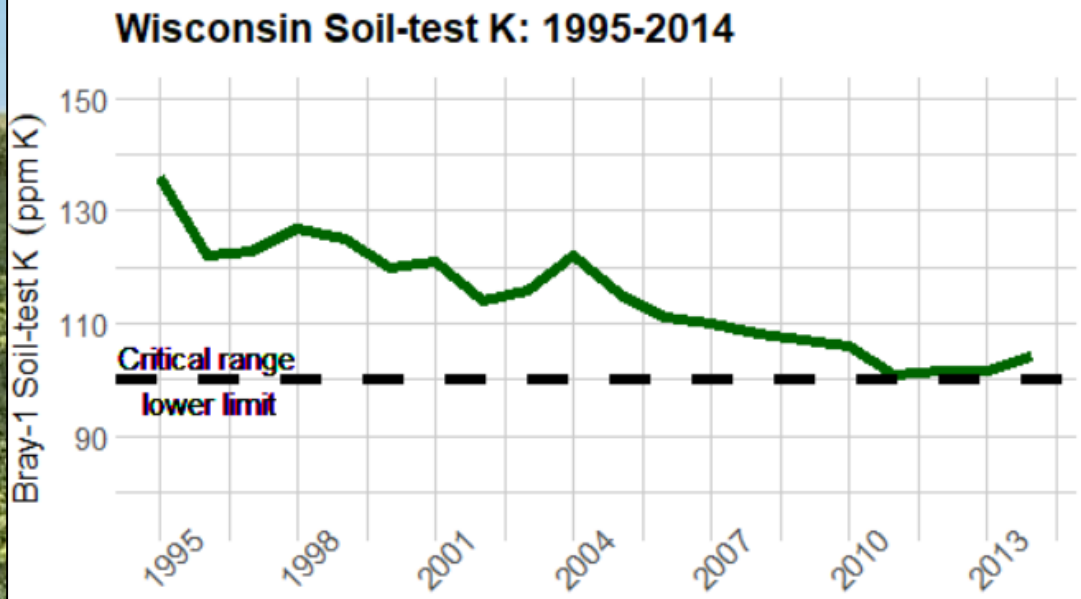
- **Grain nutrient concentration** – percentage (%) or part per million nutrient concentration in grain at physiological maturity (harvest)
- **Nutrient removal coefficient** – pounds of nutrient removed per unit of crop harvested (lb P_2O_5 per bushel of corn grain)
- **Nutrient removal** – pounds of nutrient removed per land area (ac or ha)
- **Soil-test level** – extractable nutrient value in ppm or mg/kg
- **Soil nutrient buffering capacity** – pounds of nutrient to increase soil-test levels one ppm (e.g., 7 pounds of K_2O to increase STK 1 ppm)

North Central U.S. Soil-test trends



Jones et al. (2021)

Background for this work – Wisconsin K issues

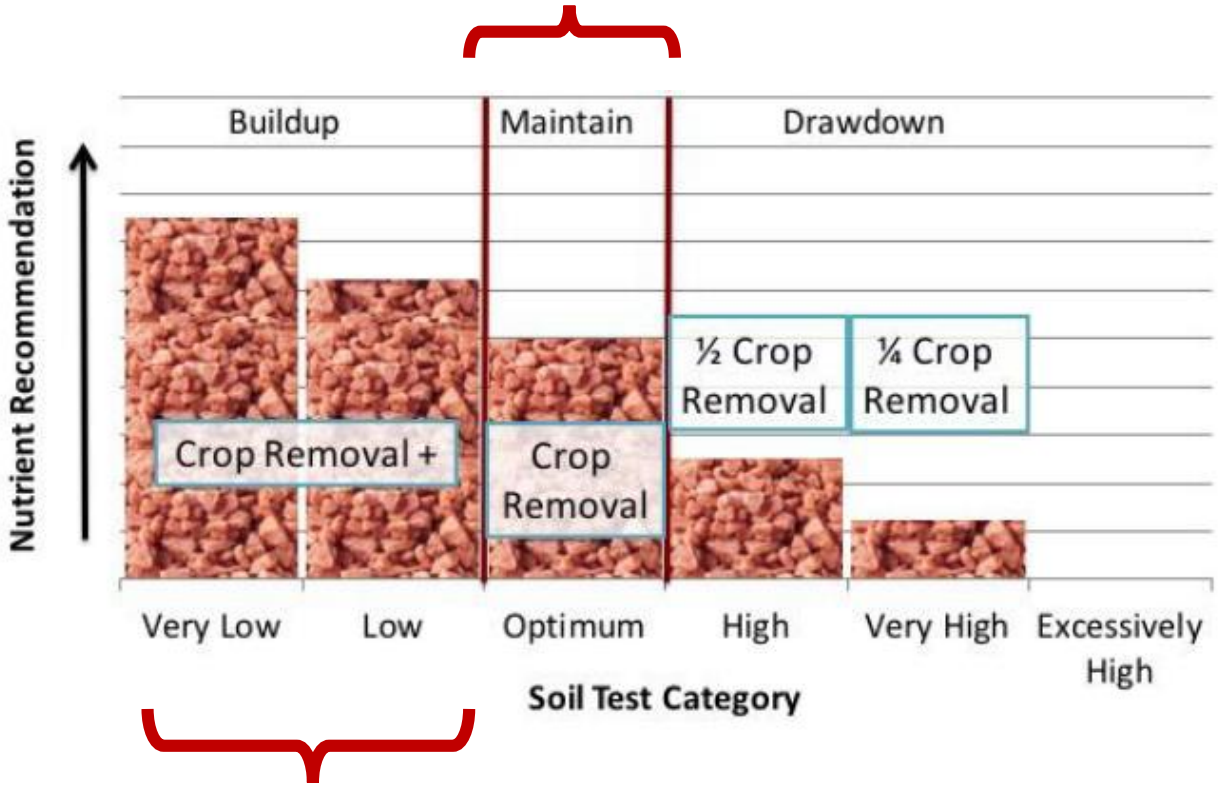


Adapted from J. Peters (2014)

Removal in WI rate recommendations

Critical concentration range

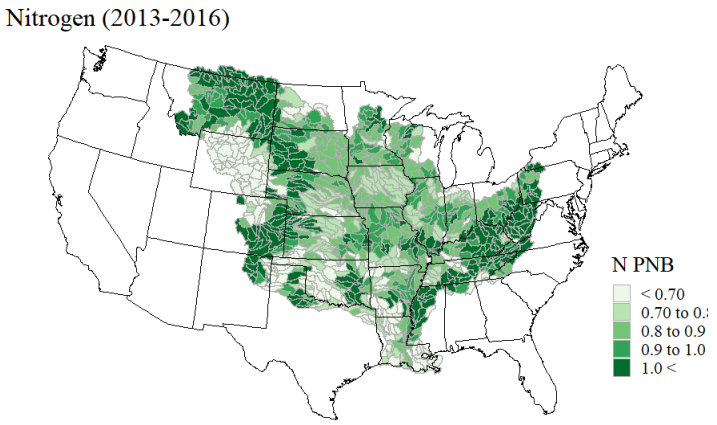
Soil group[a]	Soil test category: Very low (VL)	Low (L)	Optimum (O)	High (H)	Excessively high (EH)
	soil test P ppm[b]				
Demand level 1: corn grain, soybean, clover, small grains (but not wheat), grasses, oilseed crops, pasture					
Loamy	< 10	10–15	16–20	21–30	> 30
Sandy, Organic	< 12	12–22	23–32	33–42	> 42
Demand level 2: alfalfa, corn silage, wheat, beans, sweet corn, peas, fruits					
Loamy	< 12	12–17	18–25	26–35	> 35
Sandy, Organic	< 18	18–25	26–37	38–55	> 55
Demand level 3: tomato, pepper, brassicas, leafy greens, root, vine, and truck crops					
Loamy	< 15	15–30	31–45	46–75	> 75
Sandy, Organic	< 18	18–35	36–50	51–80	> 80
Demand level 4: potato					
Loamy	< 100	100–160	161–200	> 200	
Sandy, Organic	< 30	30–60	61–90	91–120	> 120

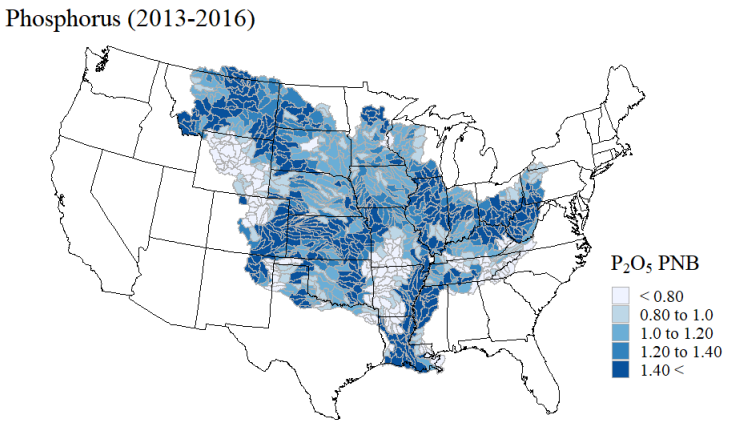


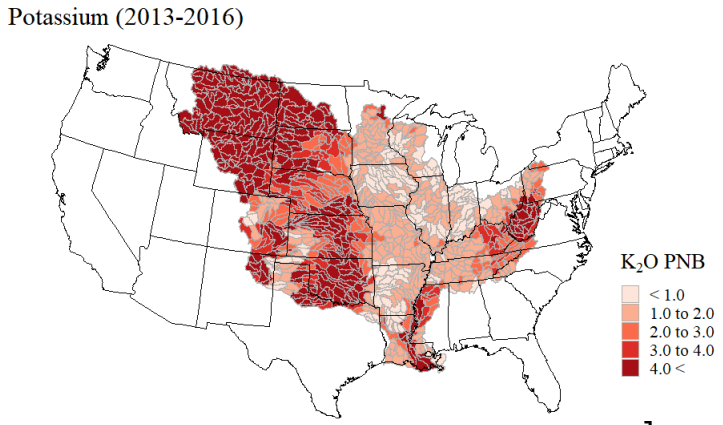
Maximizes economic return & builds over 4-yr Laboski (2012)

Removal estimates also affect…

- Assumed soil-test draw down values
  - E.g., 18 lb P_2O_5 to reduce soil-test P 1 ppm (Wisconsin number)
  - May be estimated from build-up rate
  - We will show later how this causes some complications
- Large-scale nutrient budgeting efforts
  - Support regional and national production and water quality estimates



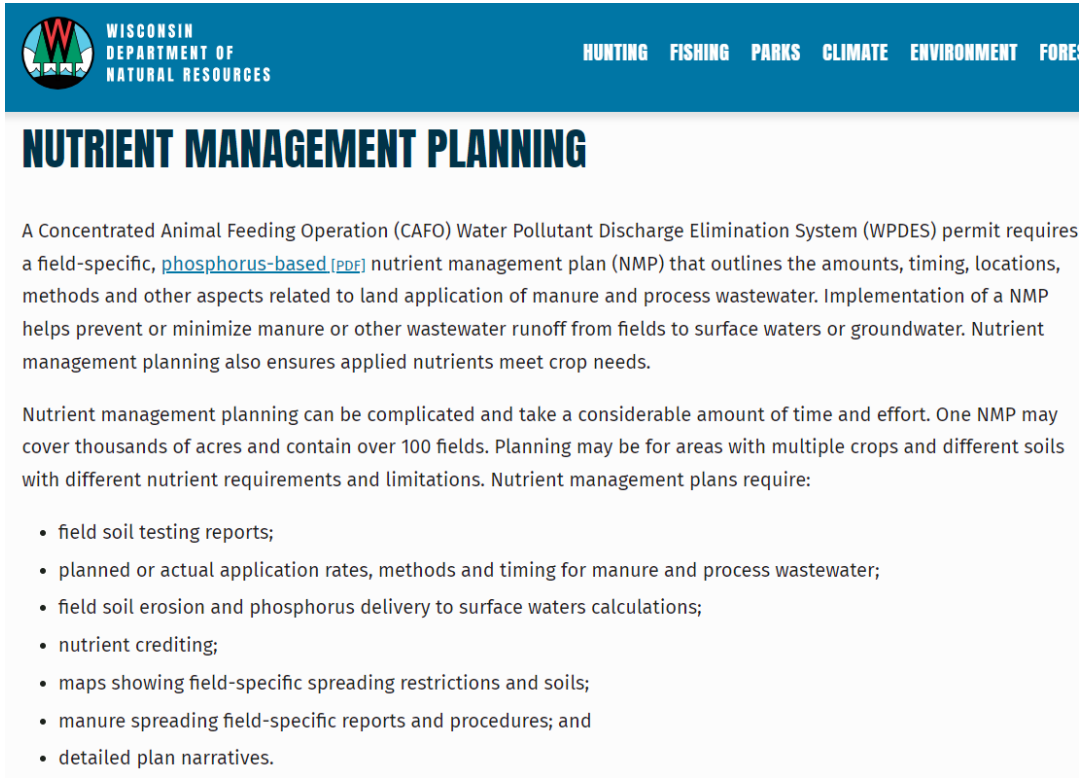




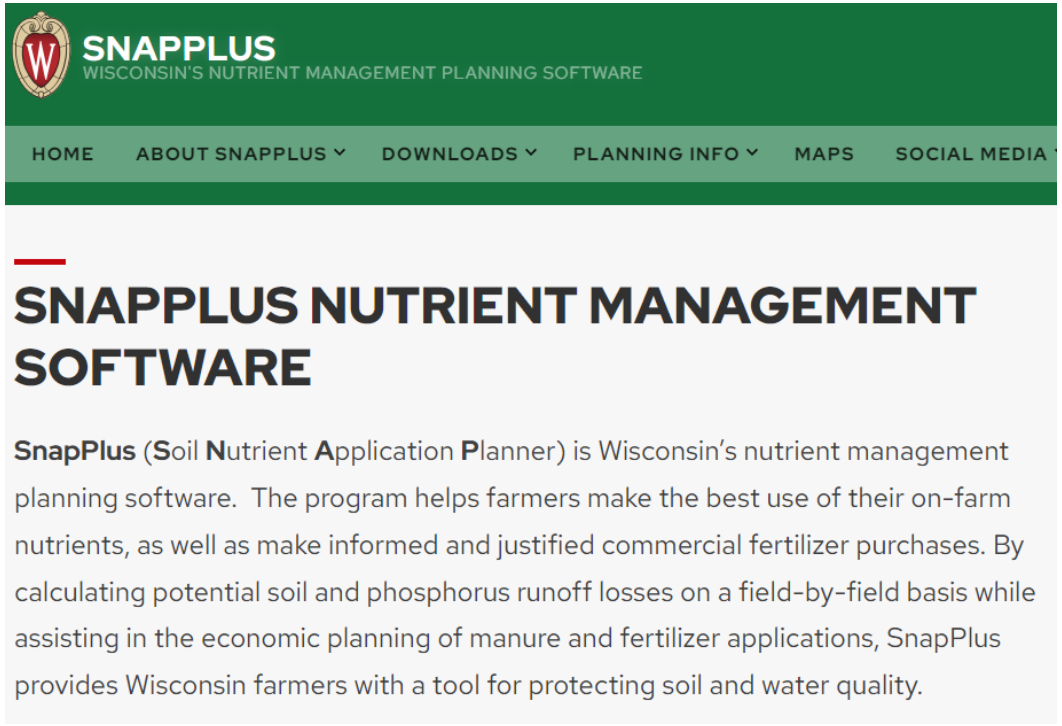
Jones (2021)

Specific importance with manure planning
(Wisconsin examples)

- Crop nutrient removal and soil buffering capacities embedded in:



https://dnr.wisconsin.gov/topic/CAFO/NutrientManagementPlan.html



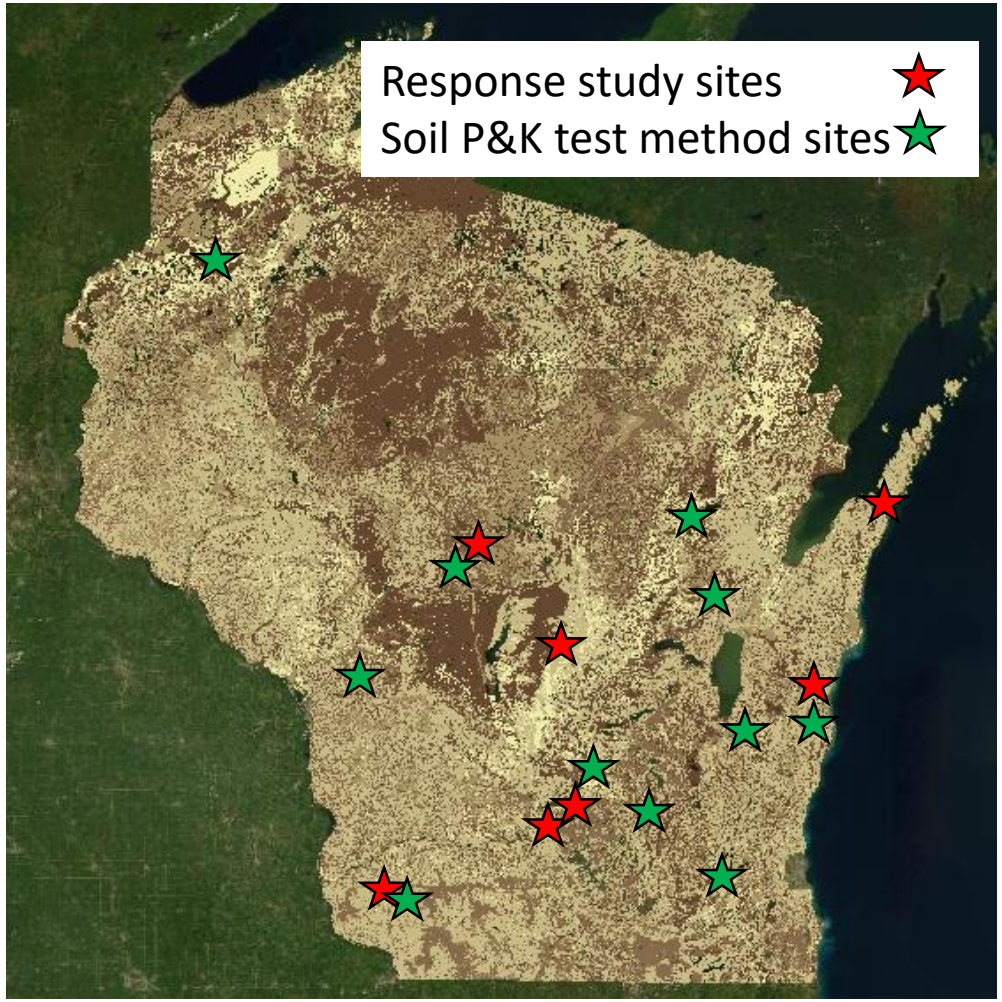
https://snapplus.wisc.edu/

Big three questions to address today

1. What happens to removal as crop yield and fertility status change?
2. What are economic implications of changing removal estimates?
3. How will varying removal rates affect soil-test levels?

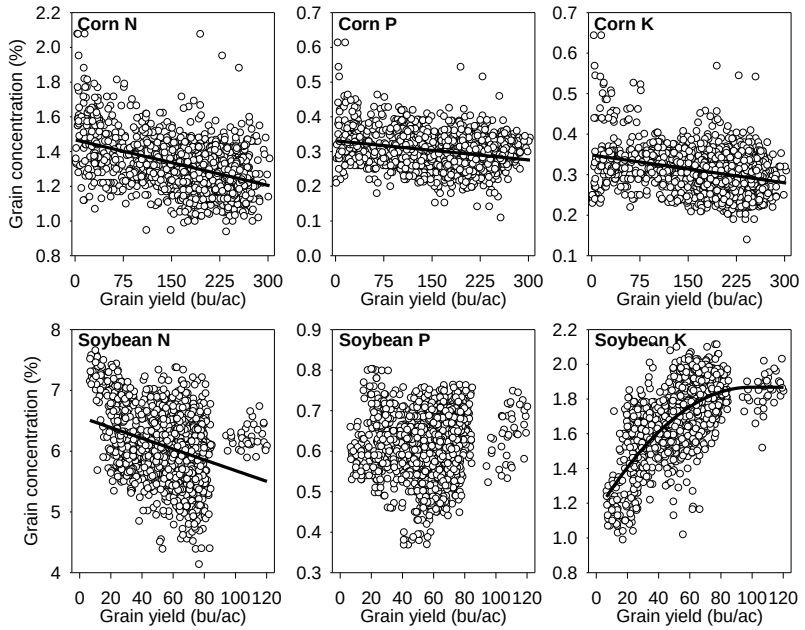
Studies to examine P&K in Wisconsin

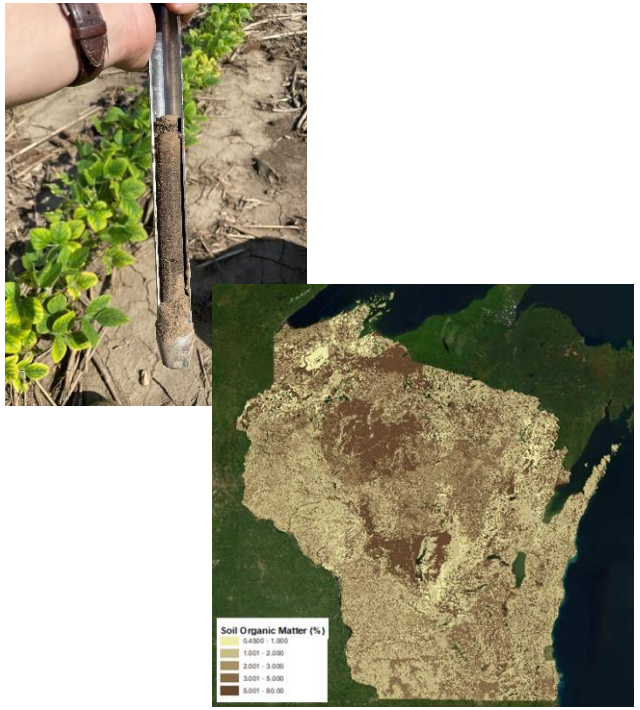
- 12 sites/year across Wisconsin
- Corn, soybean, corn silage each year
- No-till and disk/chisel-plow
- 0.7 to 5.8% SOM, silty clay loam to sand surface textures, pH 5.5 to 7.4 (6”)
- Full factorial of P & K treatments



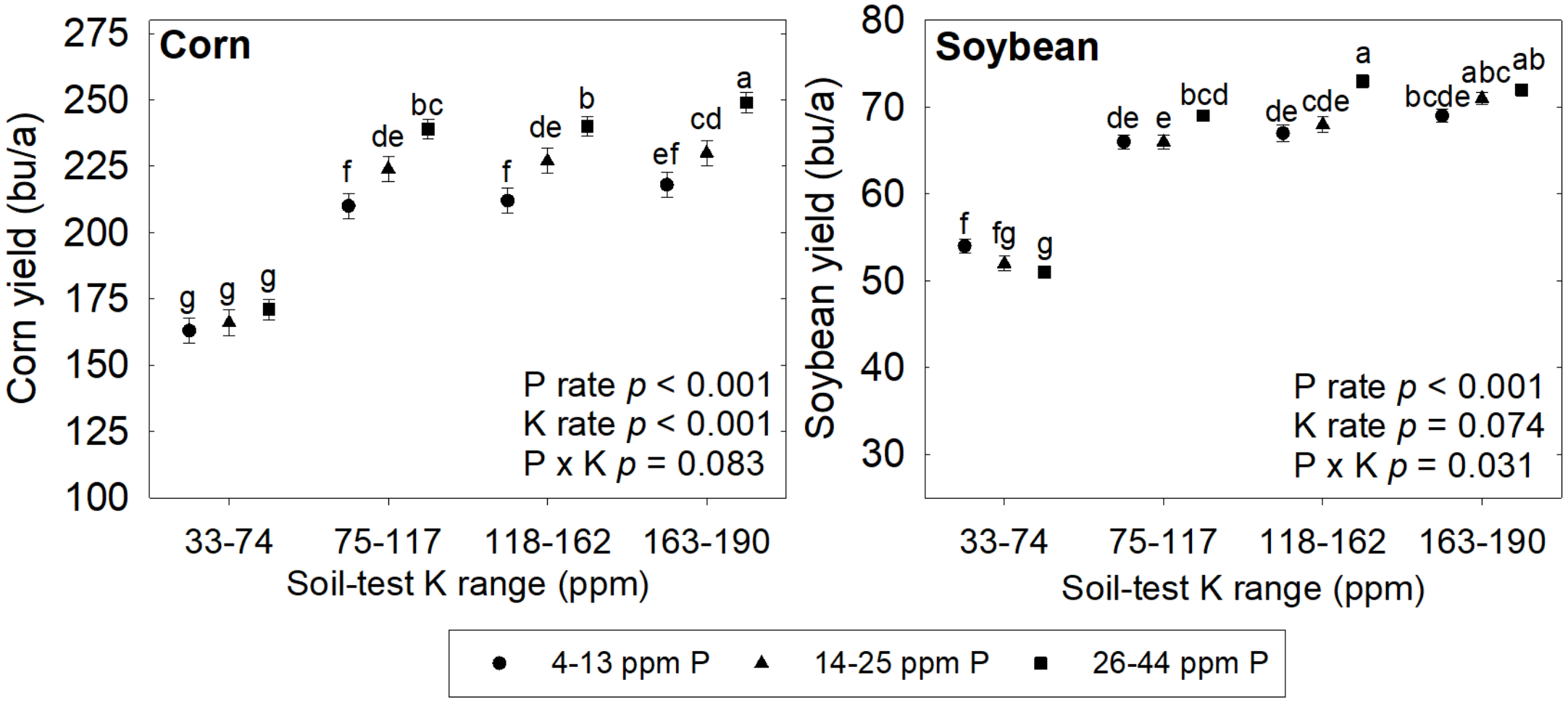
General discussion direction today

Data trends → Quantify variability → Management implications





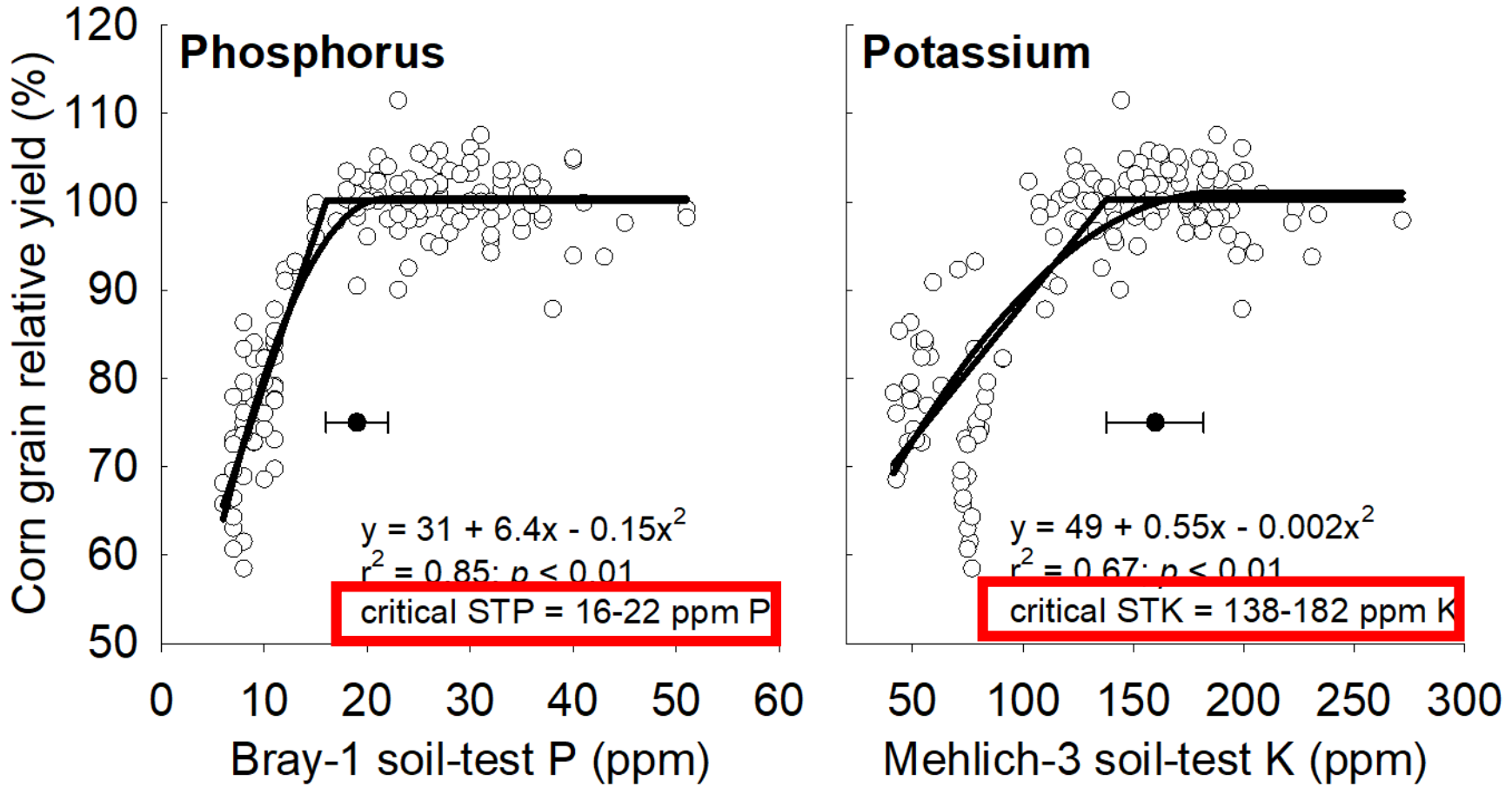
Yield response to soil-test P and K



- Corn and soybean yield affected by P rate, K rate, and P x K interaction

Jones (2023)

Critical soil-test P&K – fine textured WI sites

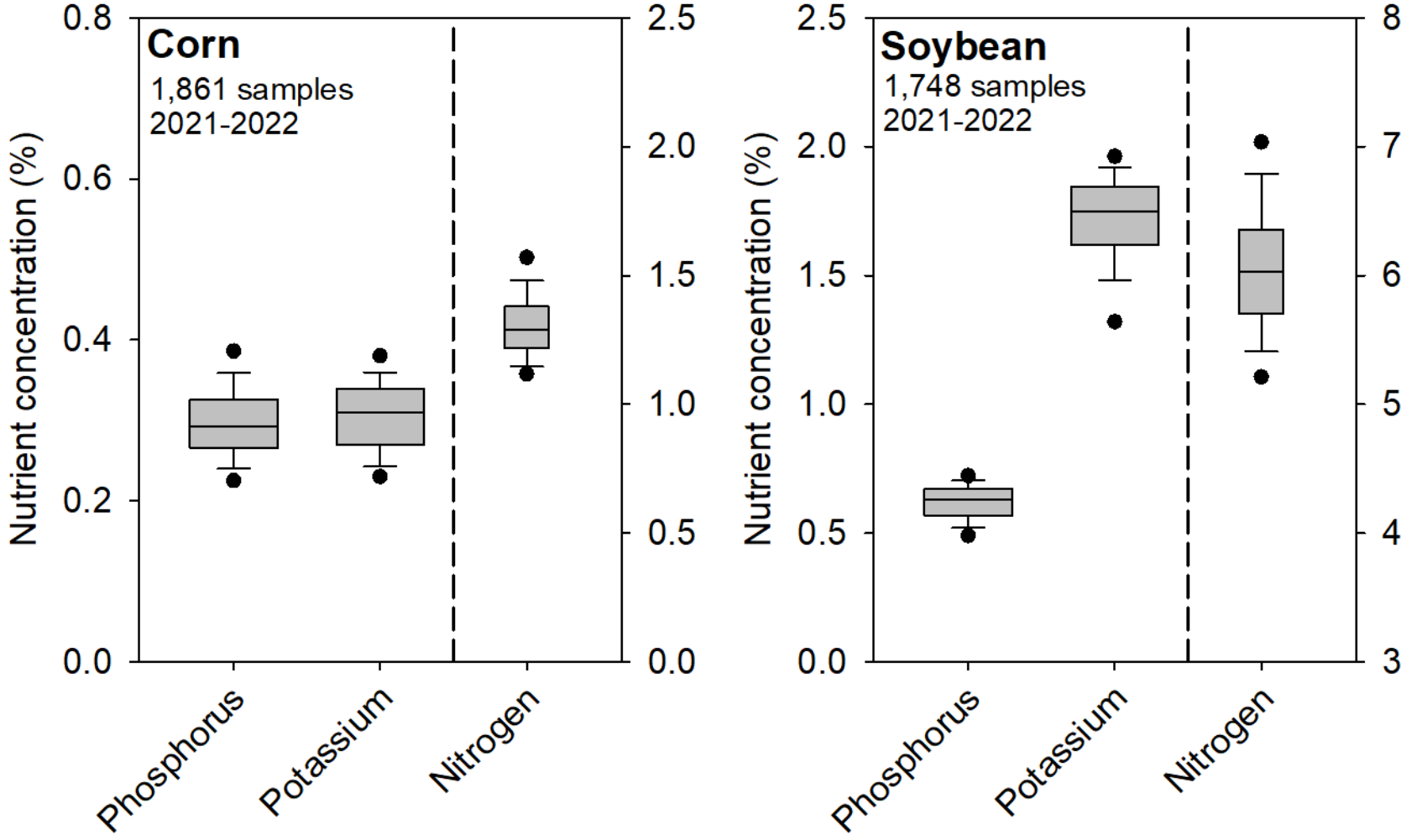


Slightly higher than current interpretation class “optimum” for P&K

Jones et al. (2023)

Observed grain nutrient concentration ranges – P, K, & N

- Small increases in soybean yield can greatly affects removal
- Though not used for fertilization planning, large amounts of N leave the system in grain



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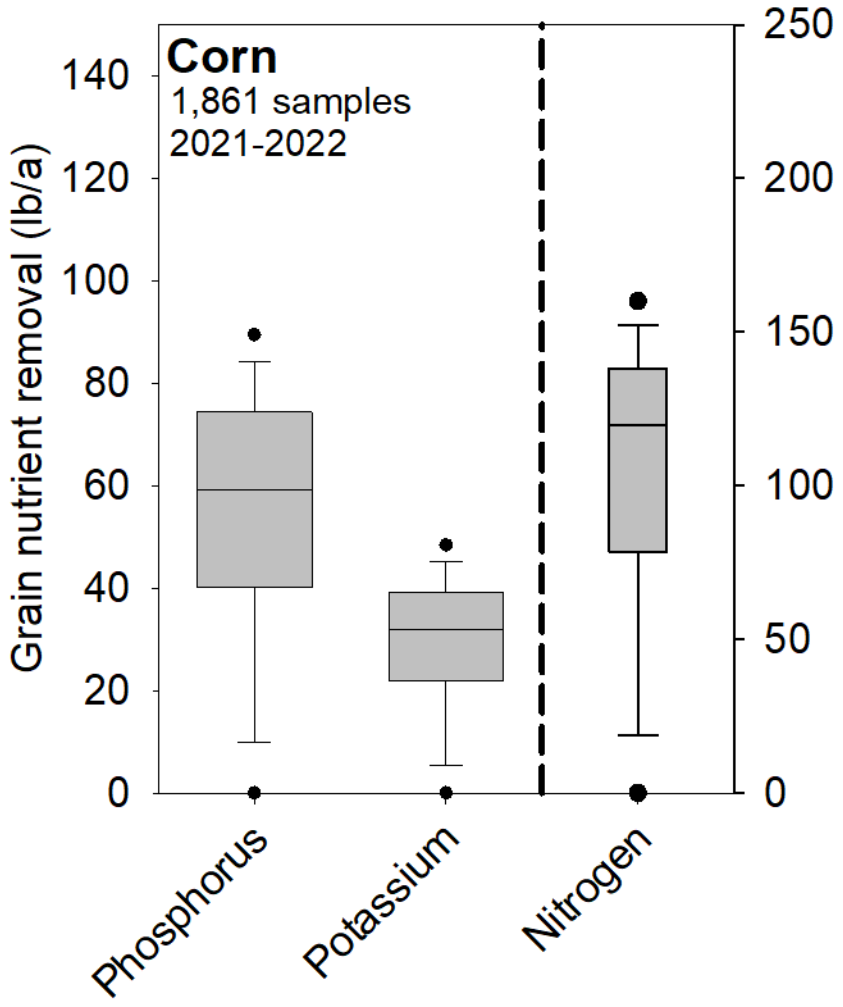
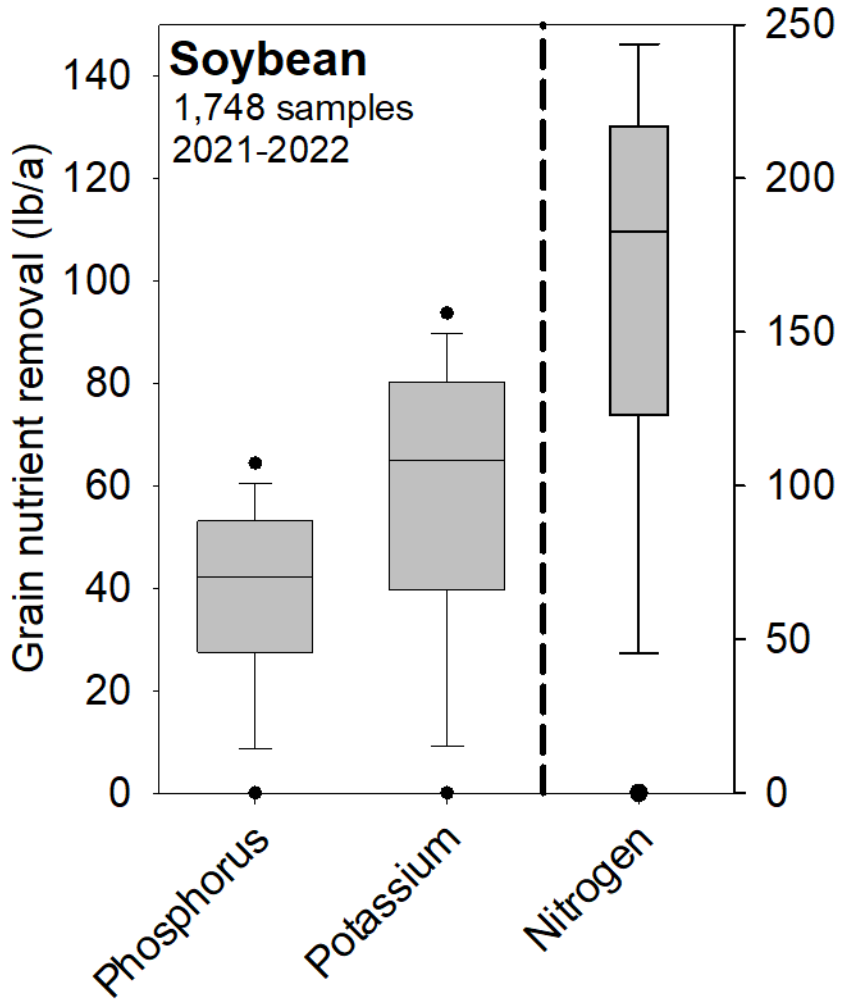
Observed grain nutrient removal ranges

- Total removal variability is driven in part by fertility, but also any stress that affects yield





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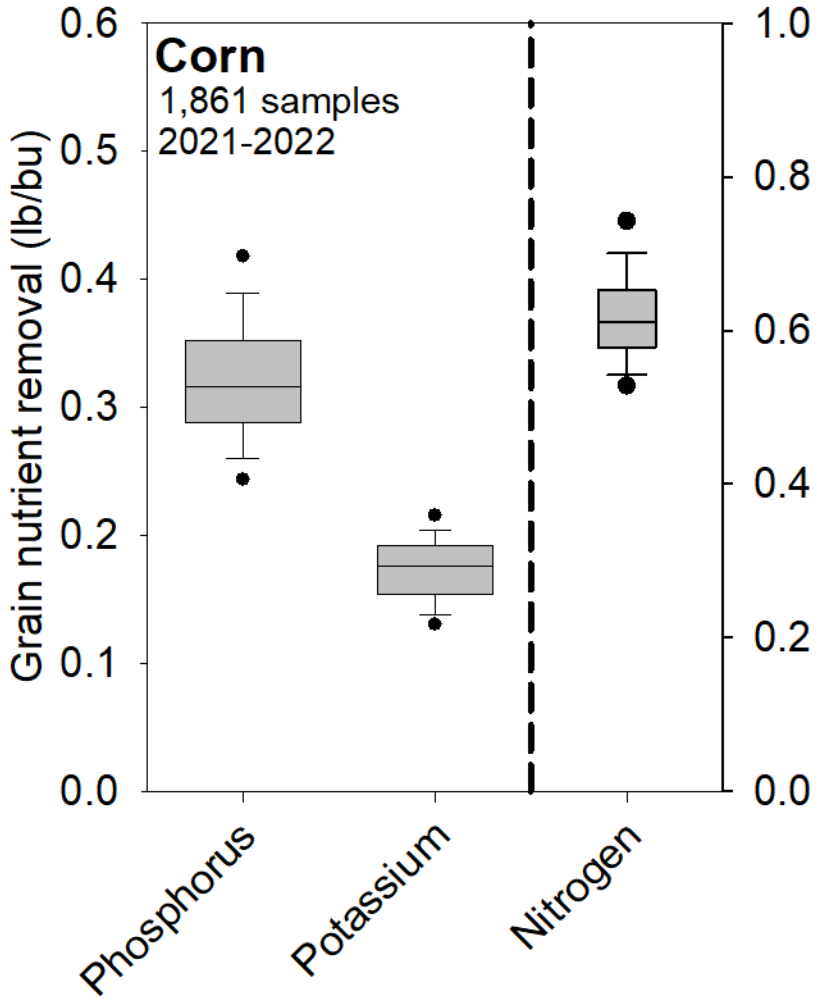
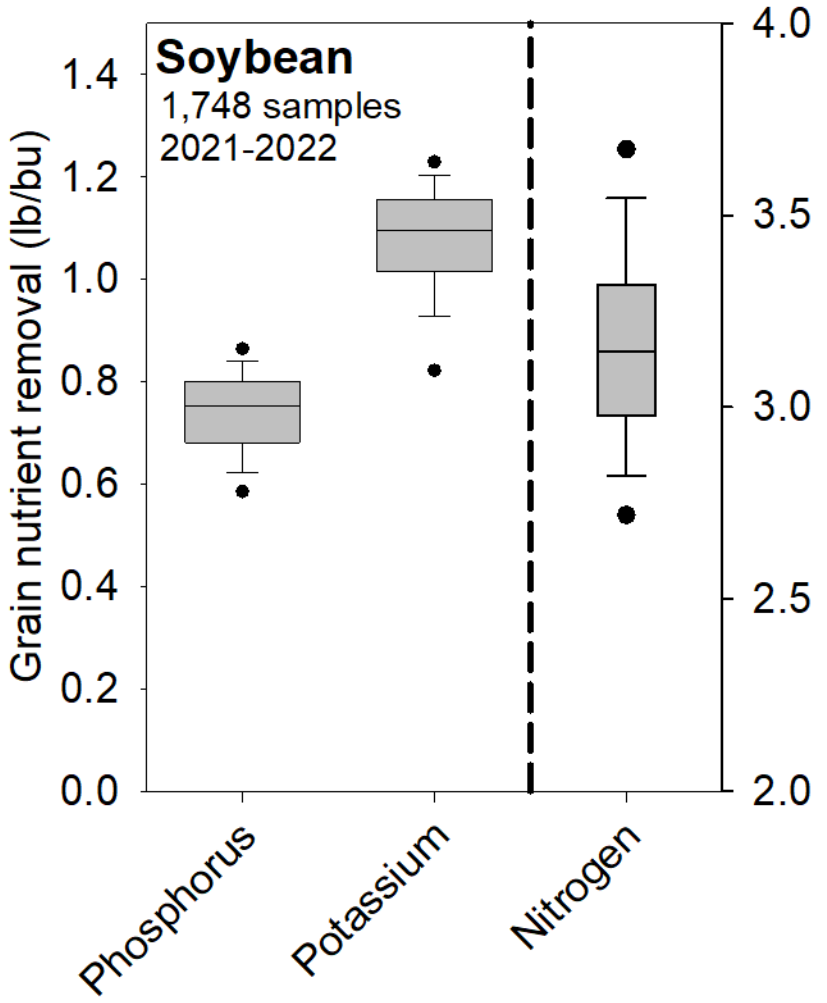
Variability in removal coefficients

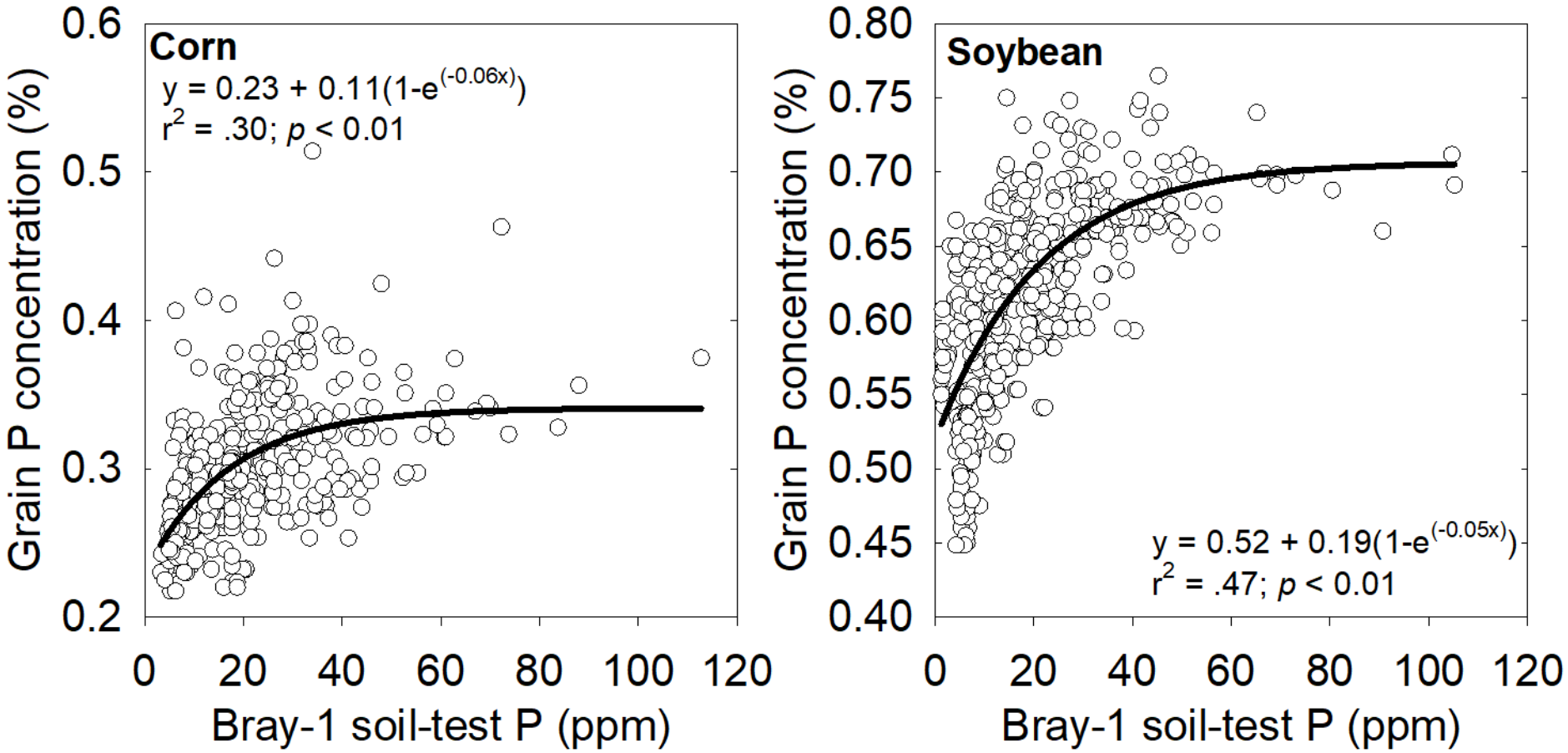
- Both yield and grain composition affecting this variability
- Upper 75th percentiles near or slightly changed from current UW values





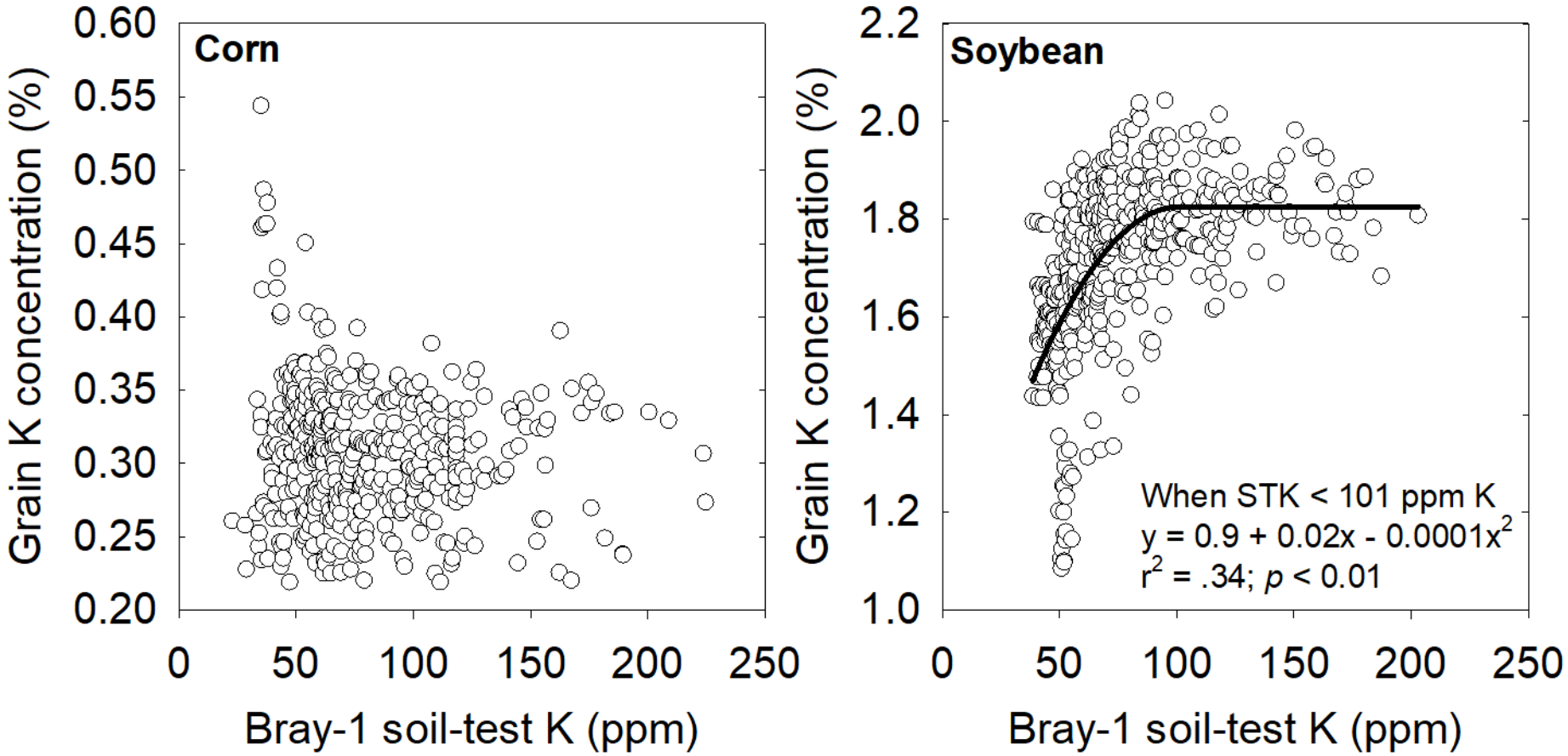
Jones (2023)

Soil-test level and grain P



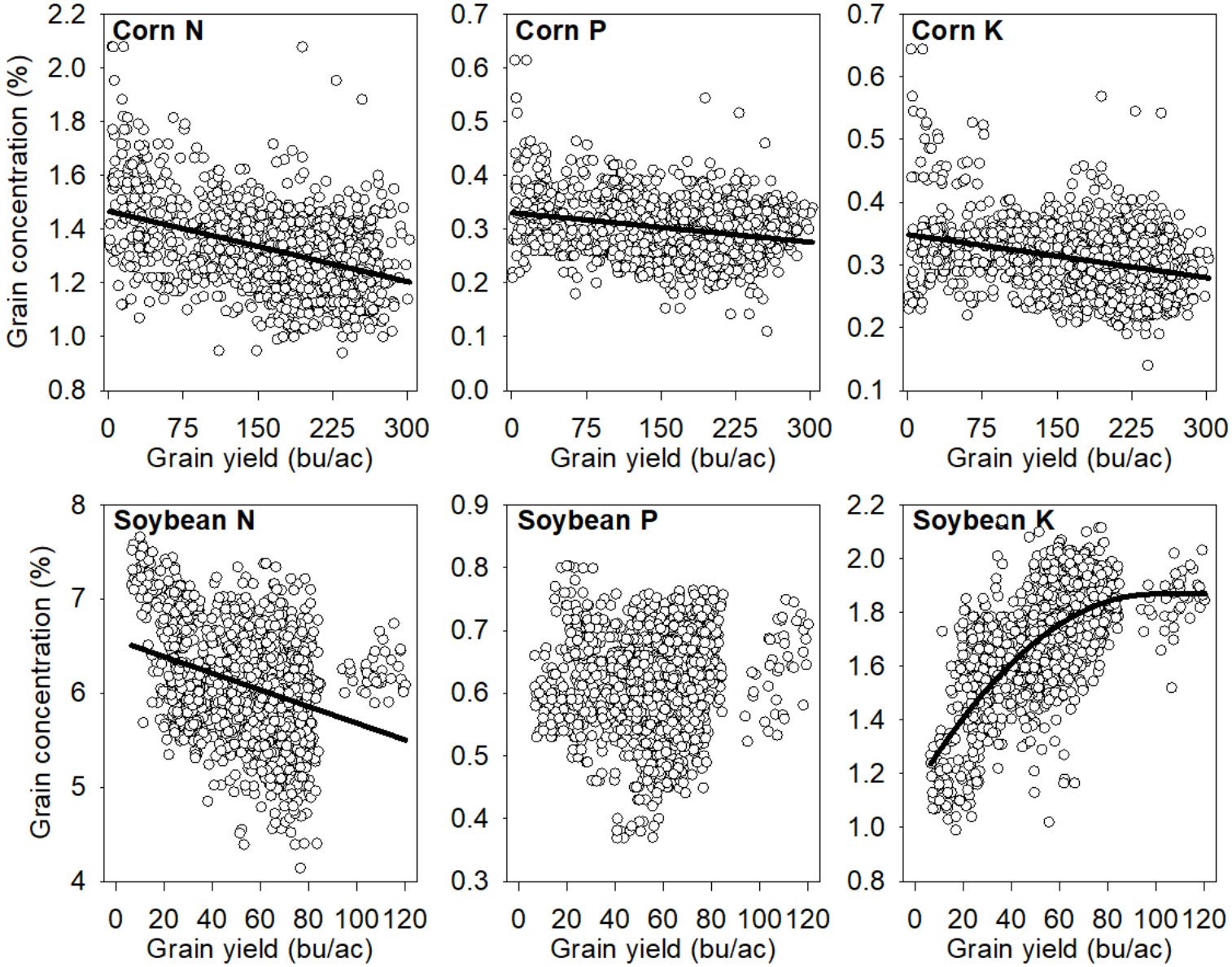
Jones (2023)

Soil-test level and grain K



Jones (2023)

Yield level and grain concentration



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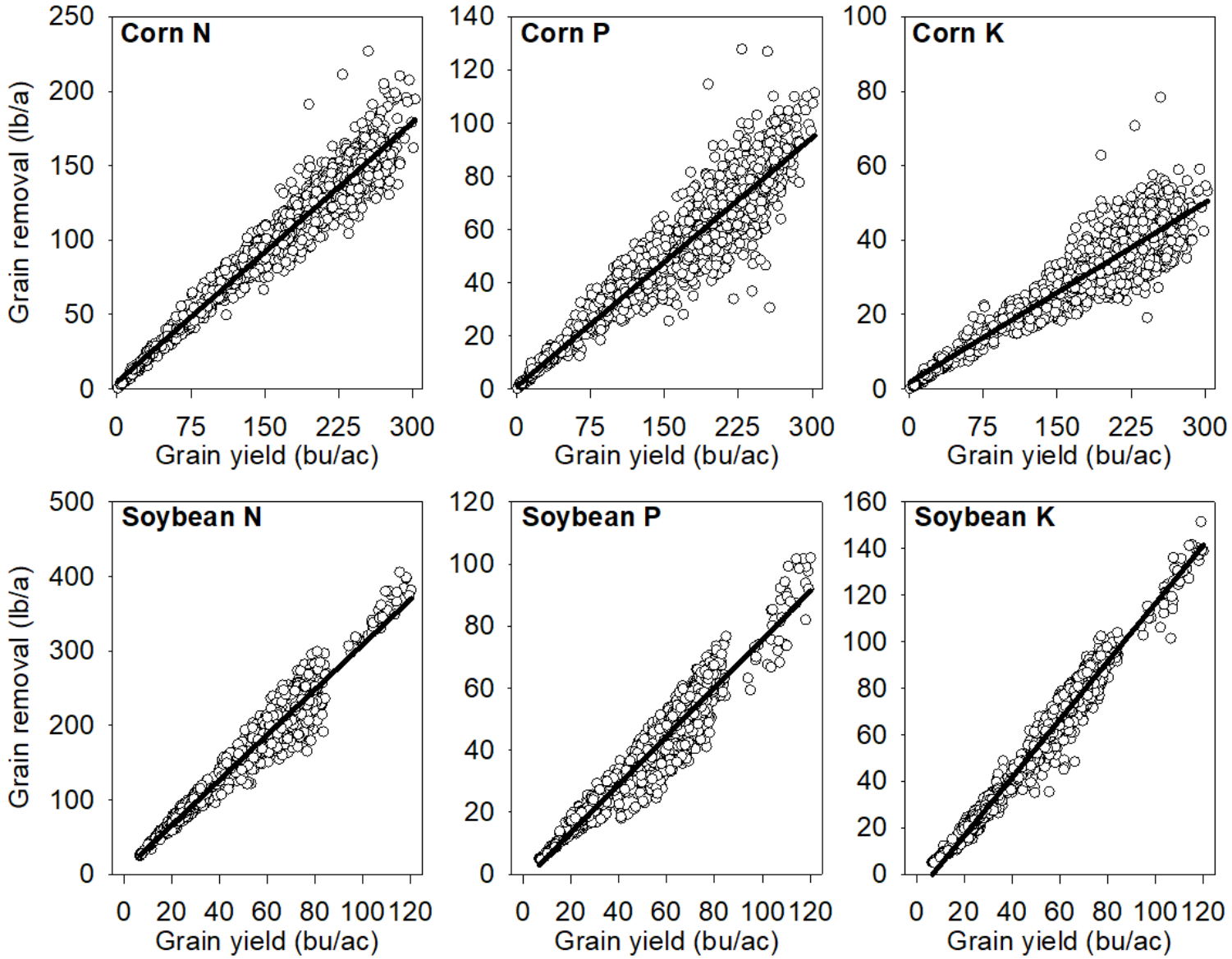
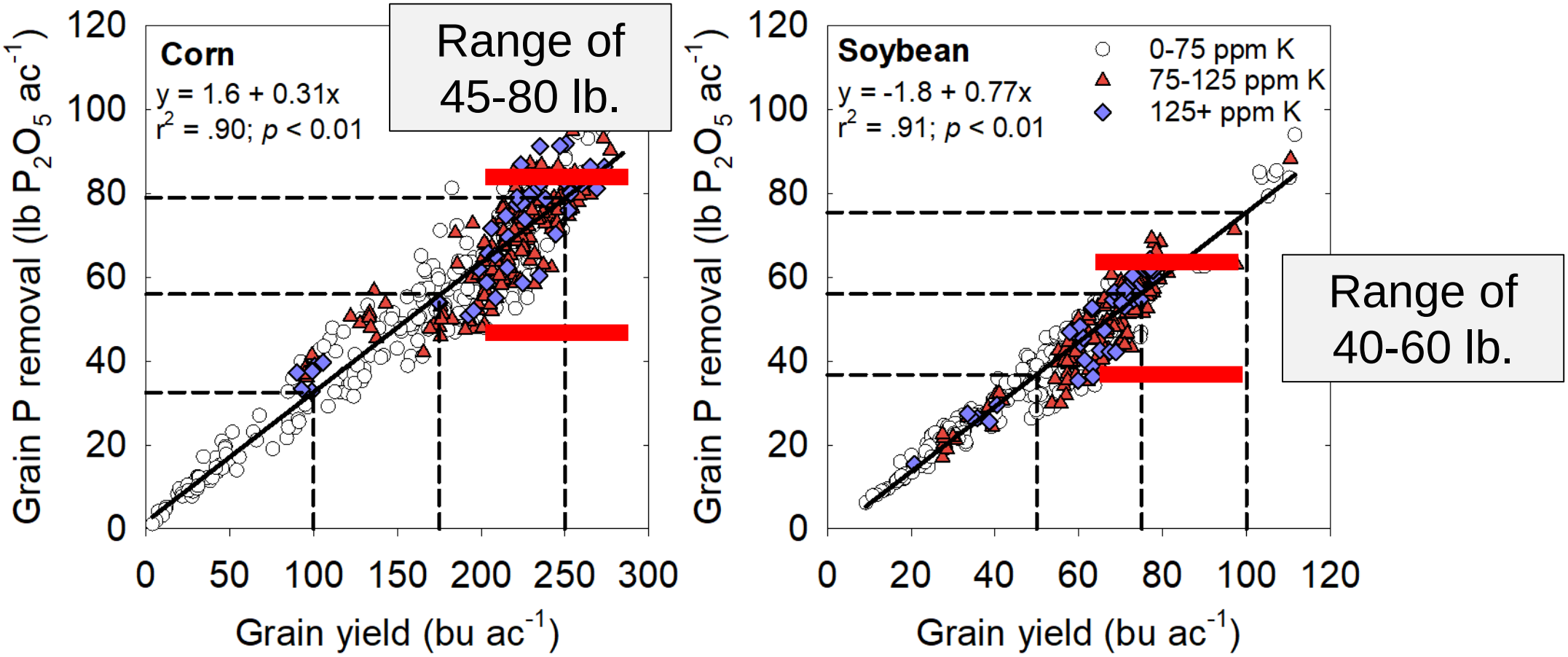
Yield level and nutrient removal



Jones (2023)

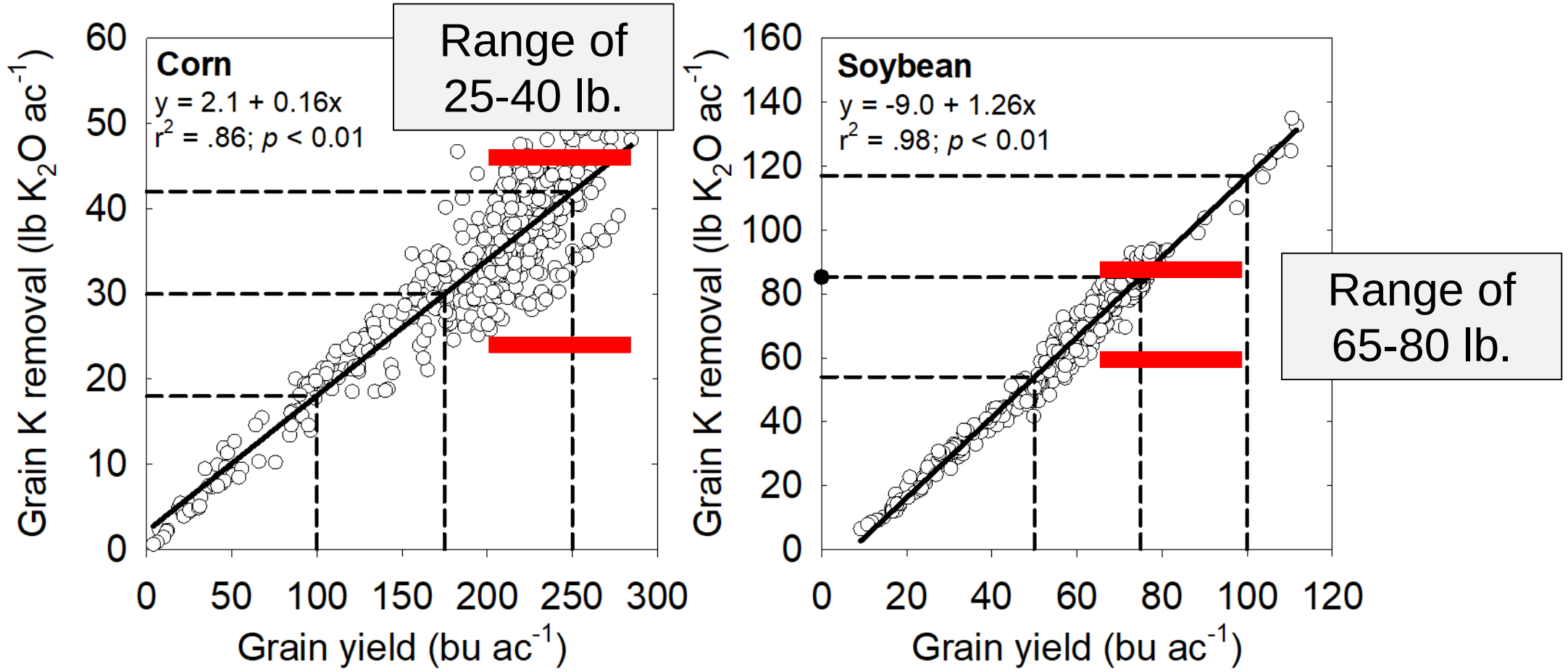
Yield level and phosphorus removal



- Consider the range of removal for a given yield levels (200bu/a and 75 bu/a)

Jones (2023)

Yield level and potassium removal

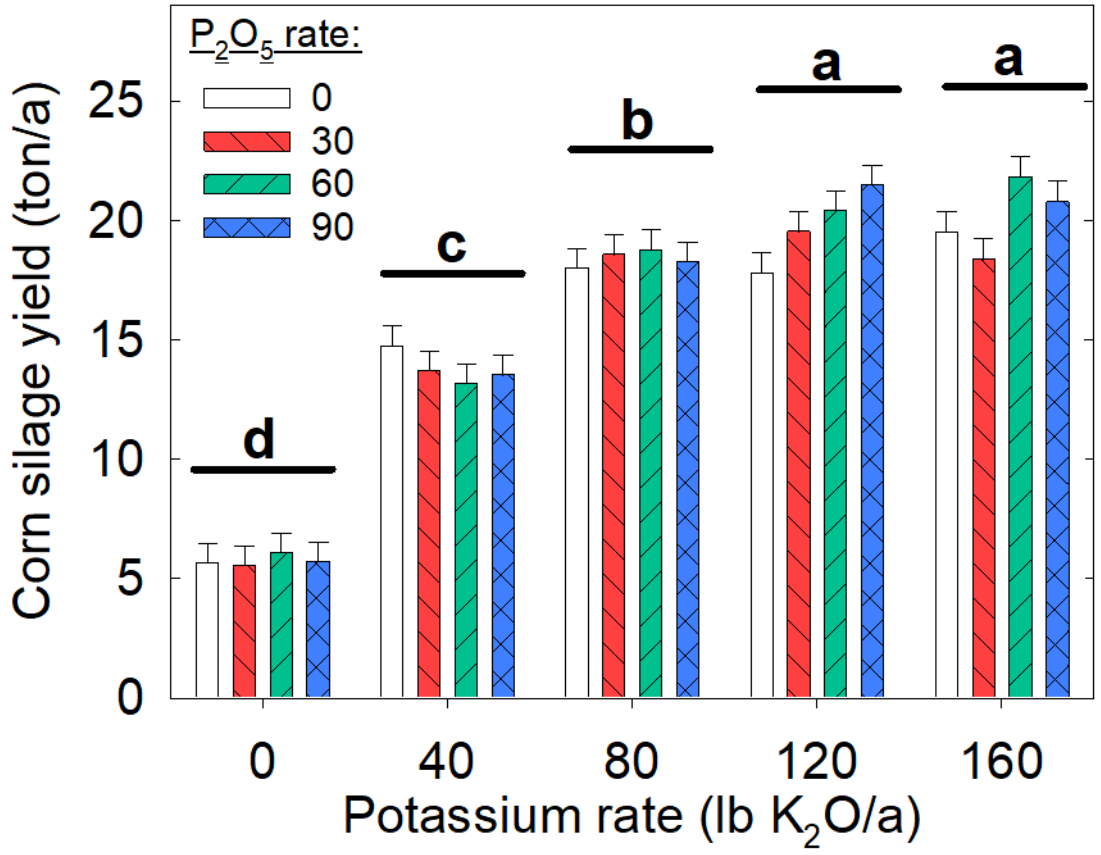


- Consider the range of removal for a given yield levels (200bu/a and 75 bu/a)

Jones (2022)

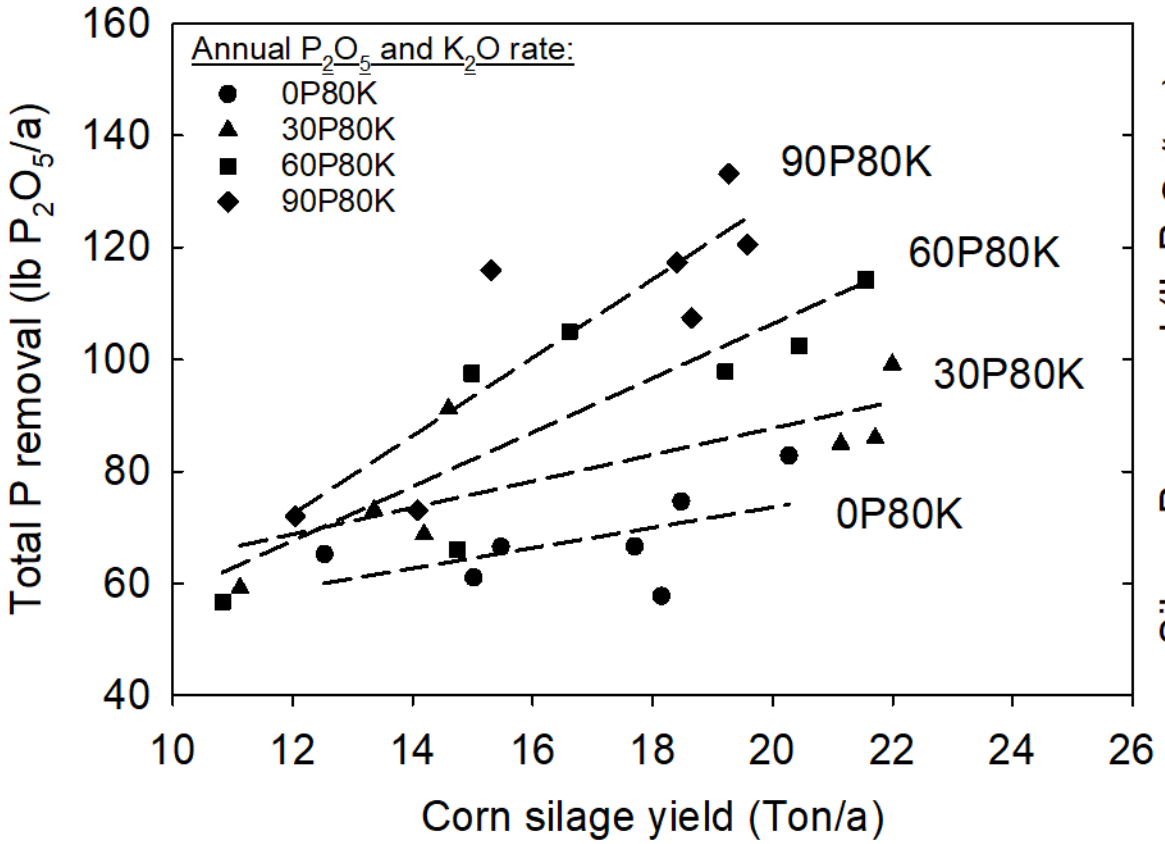
Corn silage yield response to P&K

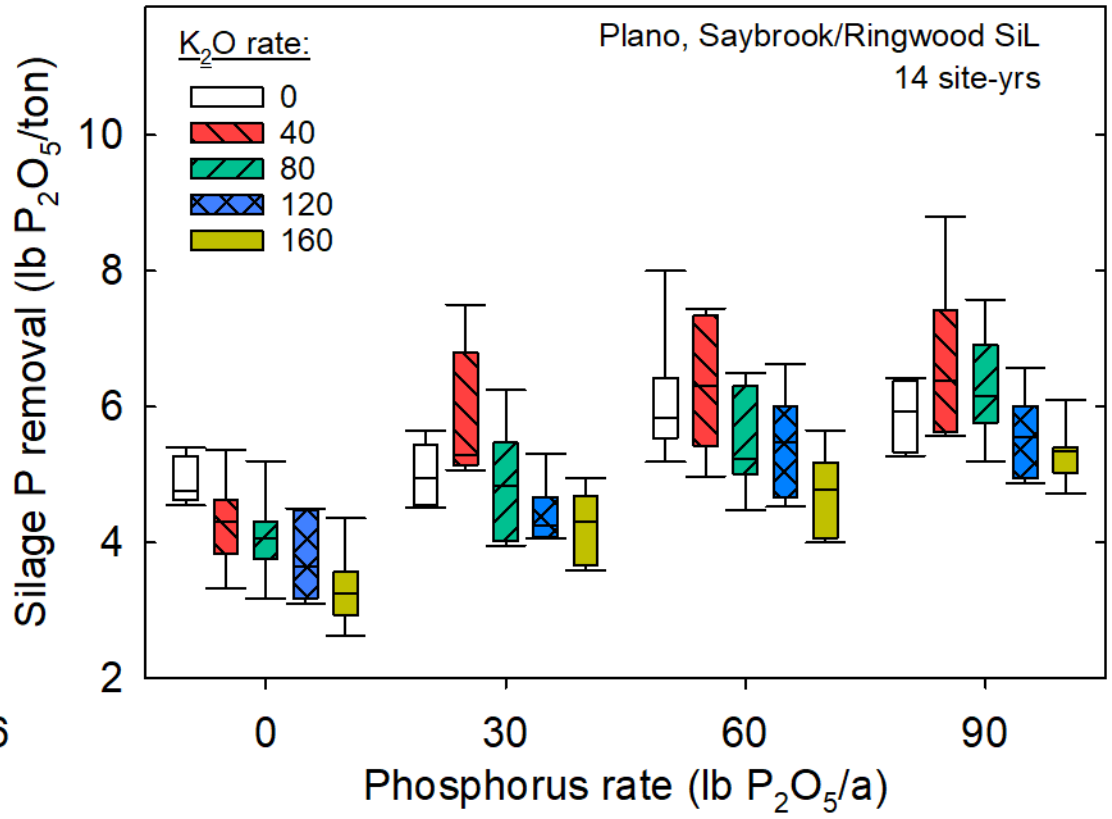
- Grain yield and silage (biomass) respond differently to added K
- Grain P and K responses show clear thresholds
- Biomass will continue to take up K (evidence of this in soybean as well – redistribution of K)



Jones (2022)

Corn silage phosphorus removal

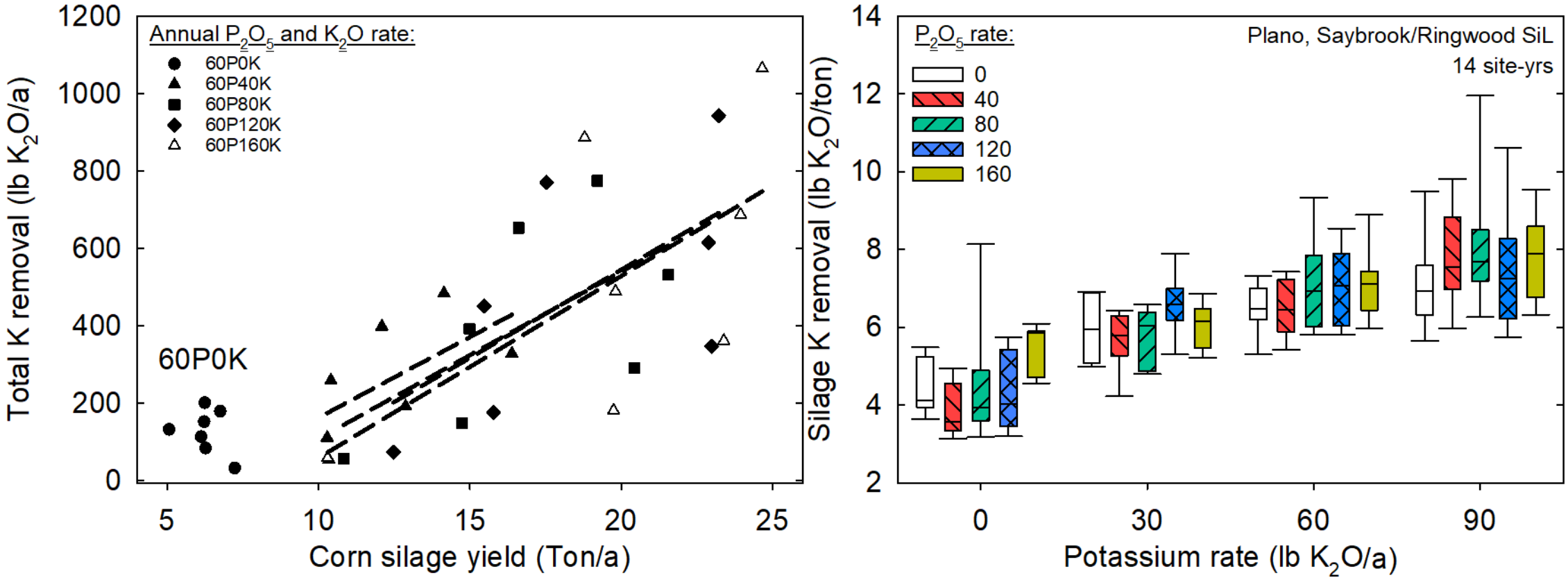




- Phosphorus removal in silage affected by P rate, K rate, and P x K interaction
- Implications for total nutrient uptake in grain corn

Jones (2022)

Corn silage potassium removal

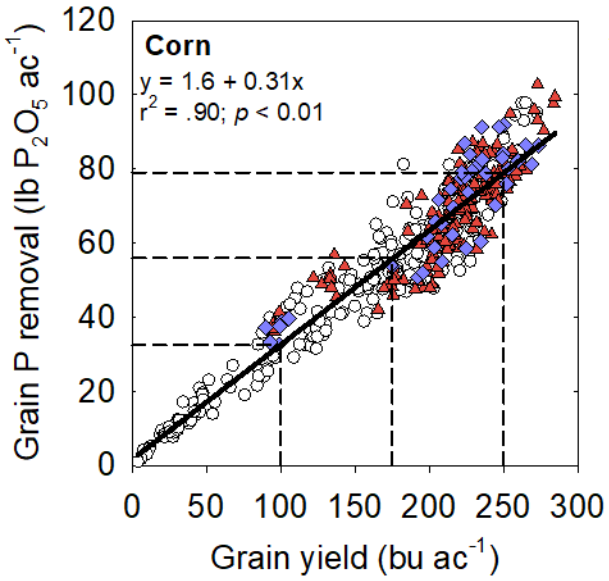


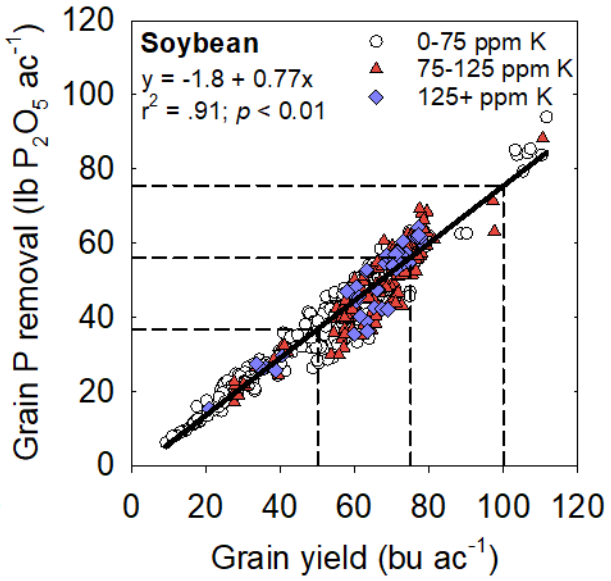
- Potassium removal increases with yield, but not affected by P rate
- Implications for total nutrient uptake in grain corn

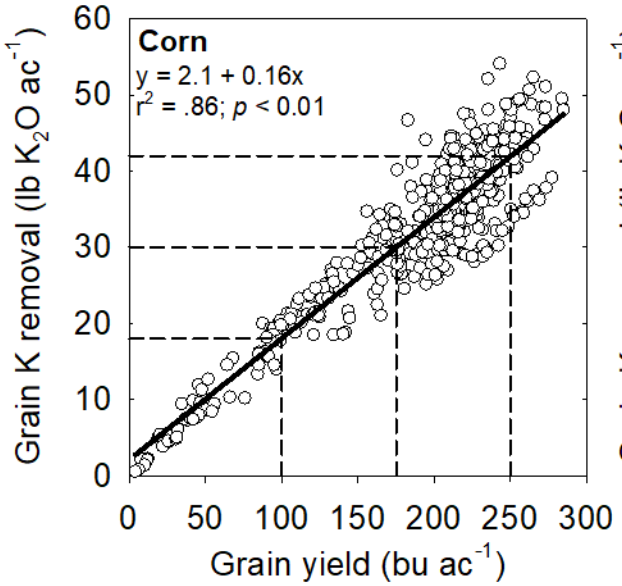
Jones (2022)

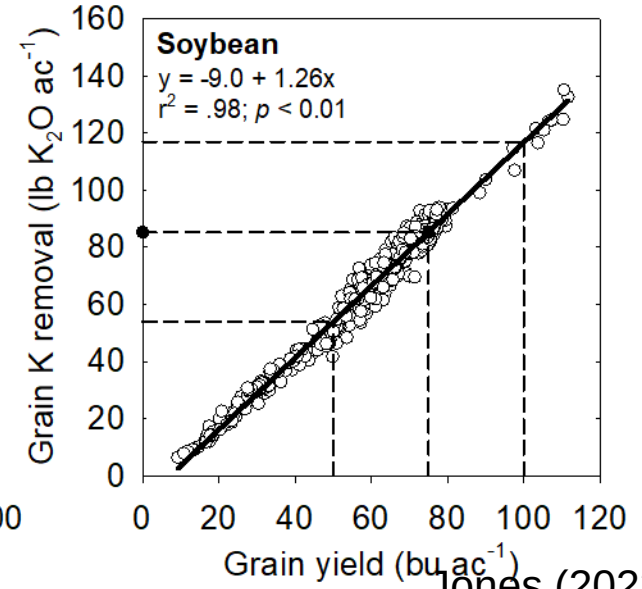
Economics of variable removal

Crop	Nutrient	Yield (bu/a)	Removal range (lb/a)	Replacement cost ($/a)
Corn	P	250	58 to 85	$29 to 43
	K	250	28 to 48	$14 to 24
Soybean	P	75	42 to 65	$25 to 39
	K	75	78 to 93	$47 to 56









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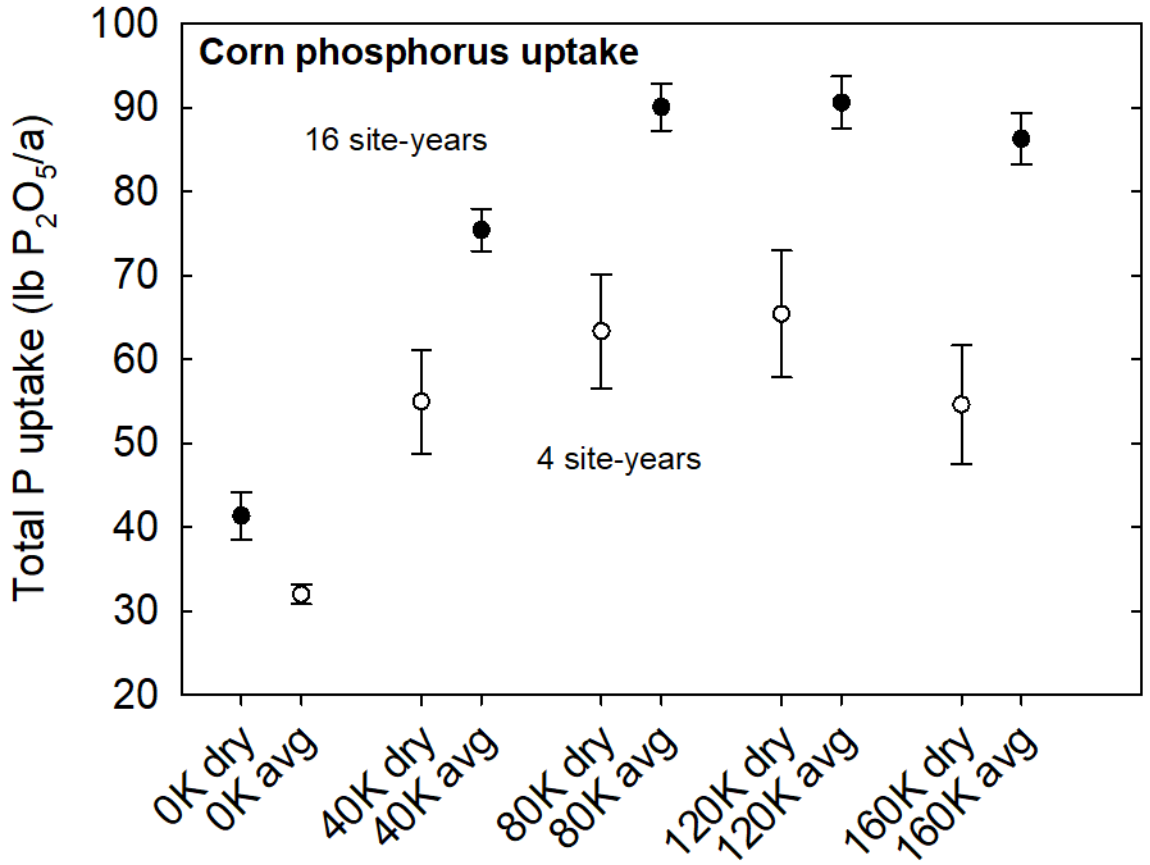
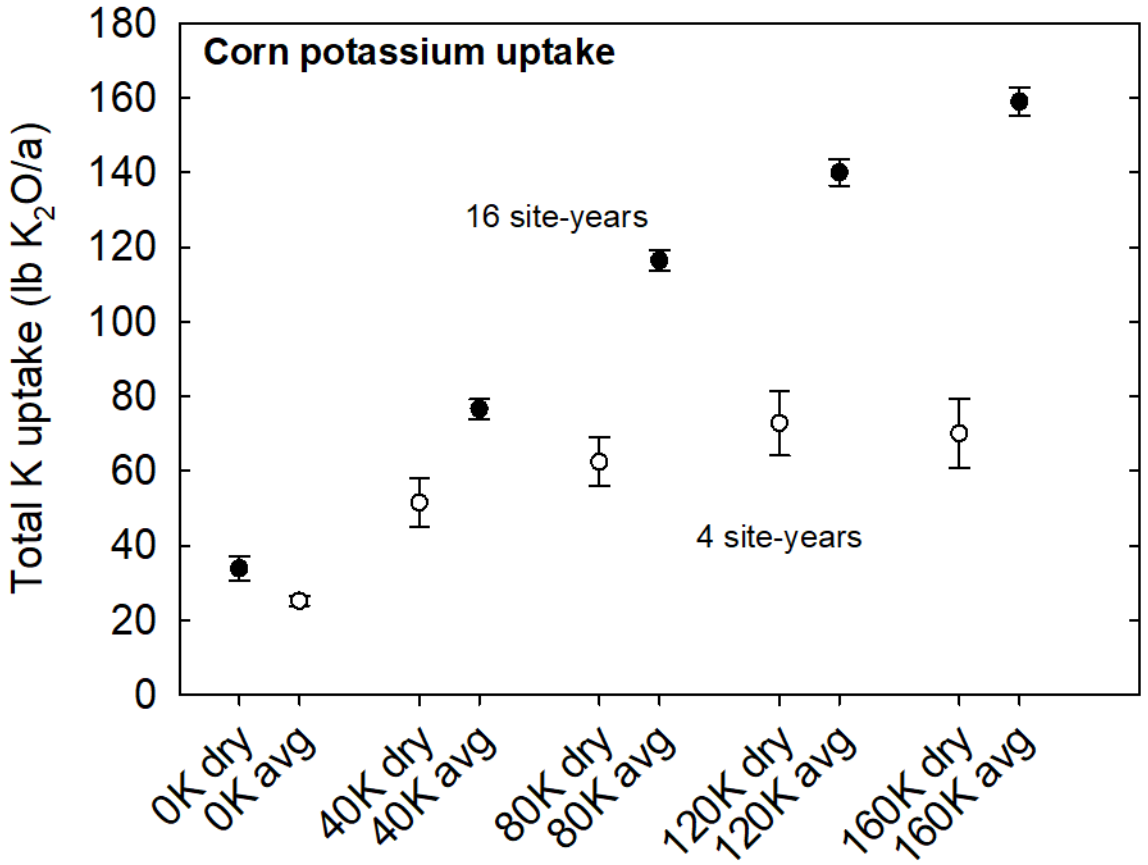
Case study field – soybean removal (south central WI field data)

zones	1	2	3	4	5	6	7
Yield (bu/a)	50	55	38	57	69	71	65
static K removal	60	66	45.6	68.4	82.8	85.2	78
static field average	69						
dynamic K removal	64	71.3	46.48	74.22	91.74	94.66	85.9
dynamic field average	75						

Weather conditions & total uptake

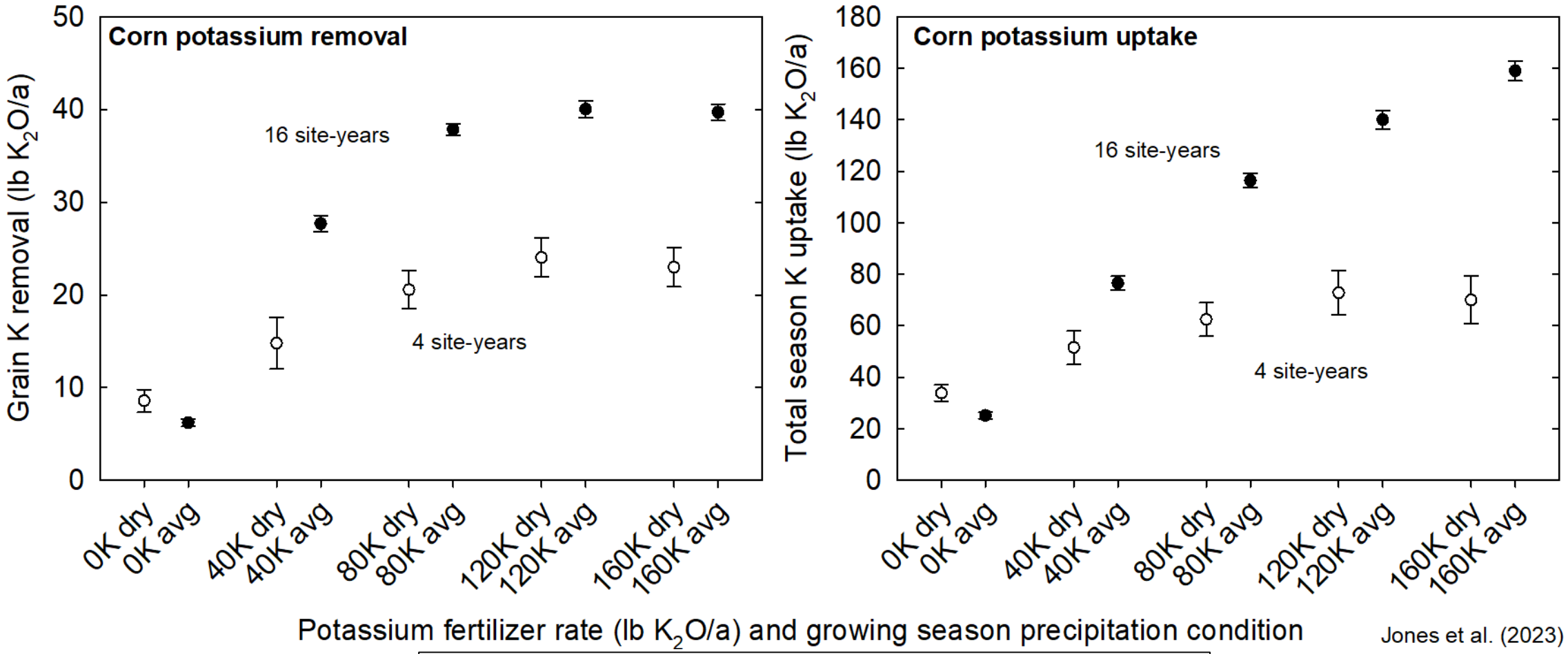




- ● Years within 5" of 30-yr avg growing season rainfall
- ○ Years < 5" of 30-yr avg growing season rainfall

Jones (2023)

Weather conditions & K uptake/removal



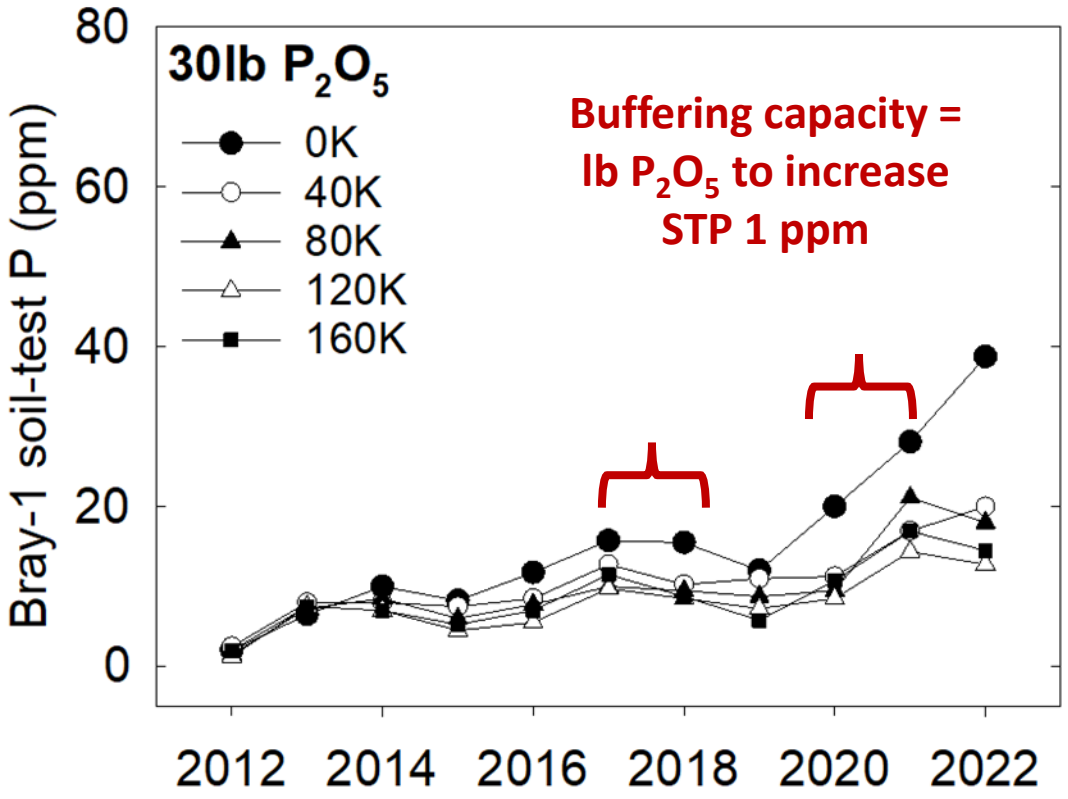
Final topic to cover – removal and soil-test levels

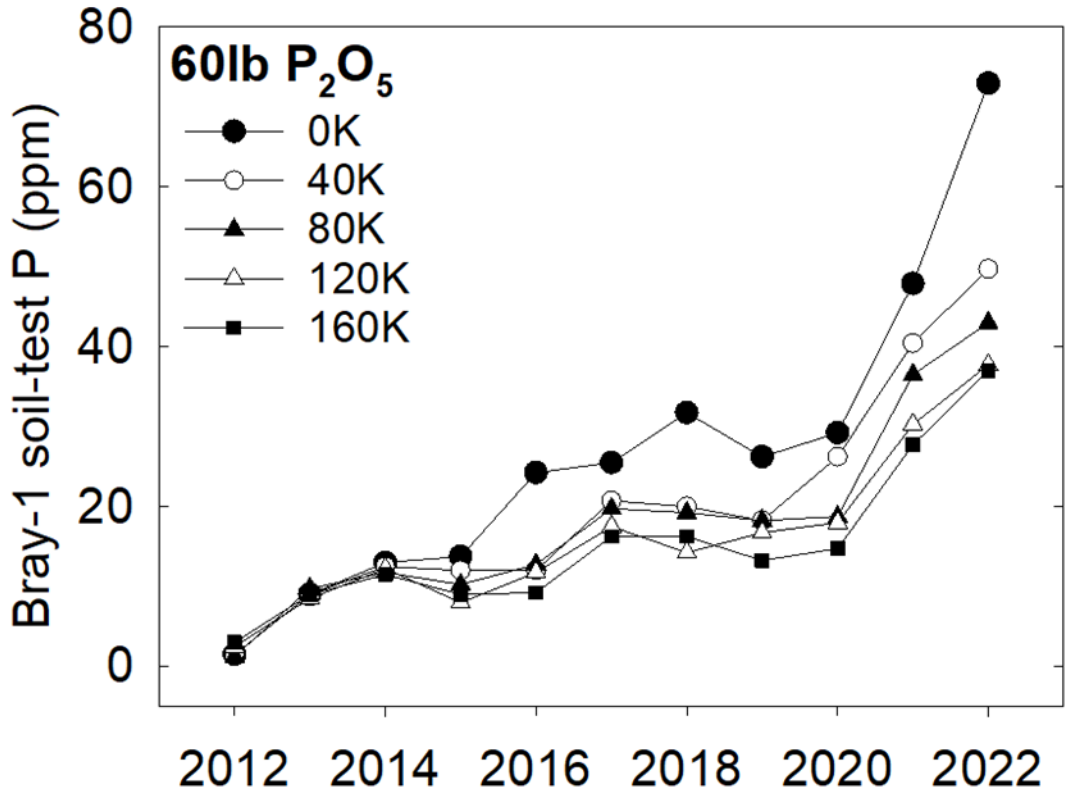
- Some states (WI) define soil nutrient buffer capacity as pound of fertilizer nutrient to increase soil-test 1 part per million.
- This may be applied to drawdown estimates too
  - Assumes that build up and drawdown are equal??
- This definition of buffering capacity is resent in fertilizer rate recommendations (in some form)

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

How fast can I build up soil-tests?





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

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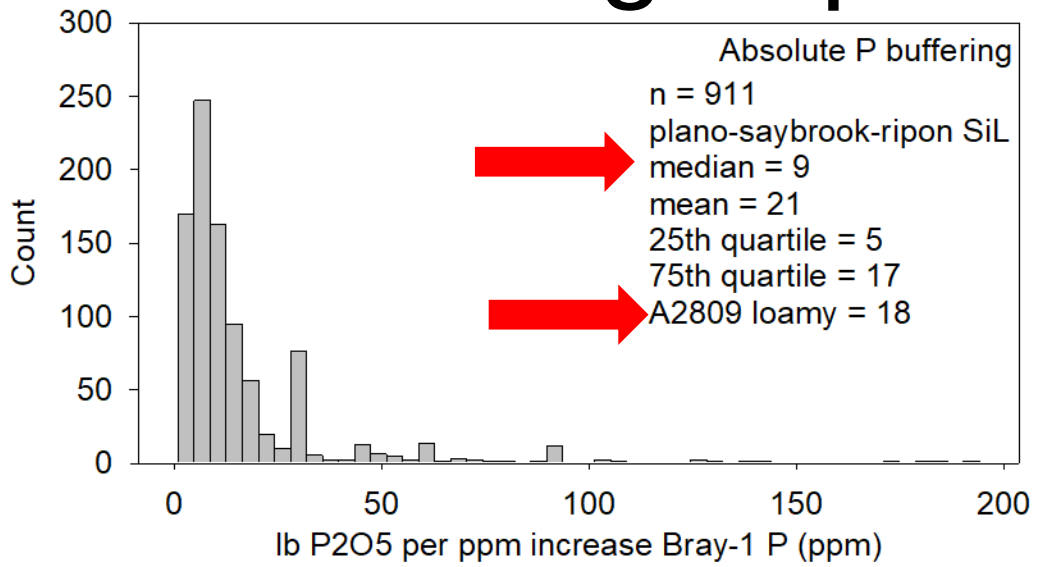
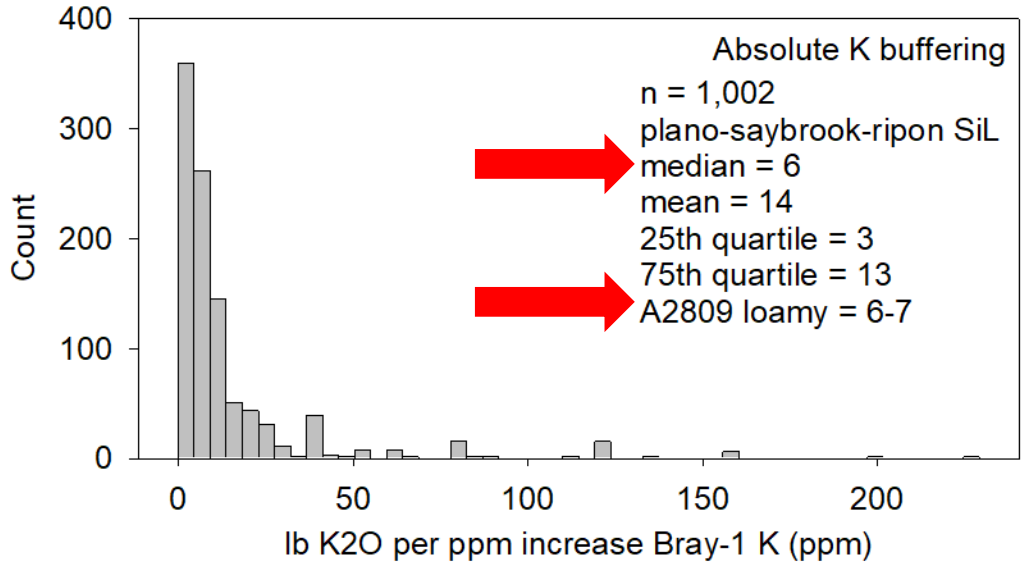
Soil buffering capacities – highly variable





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Loamy	18	6–7
Sandy	12	6
Organic	18	5

UW A2809

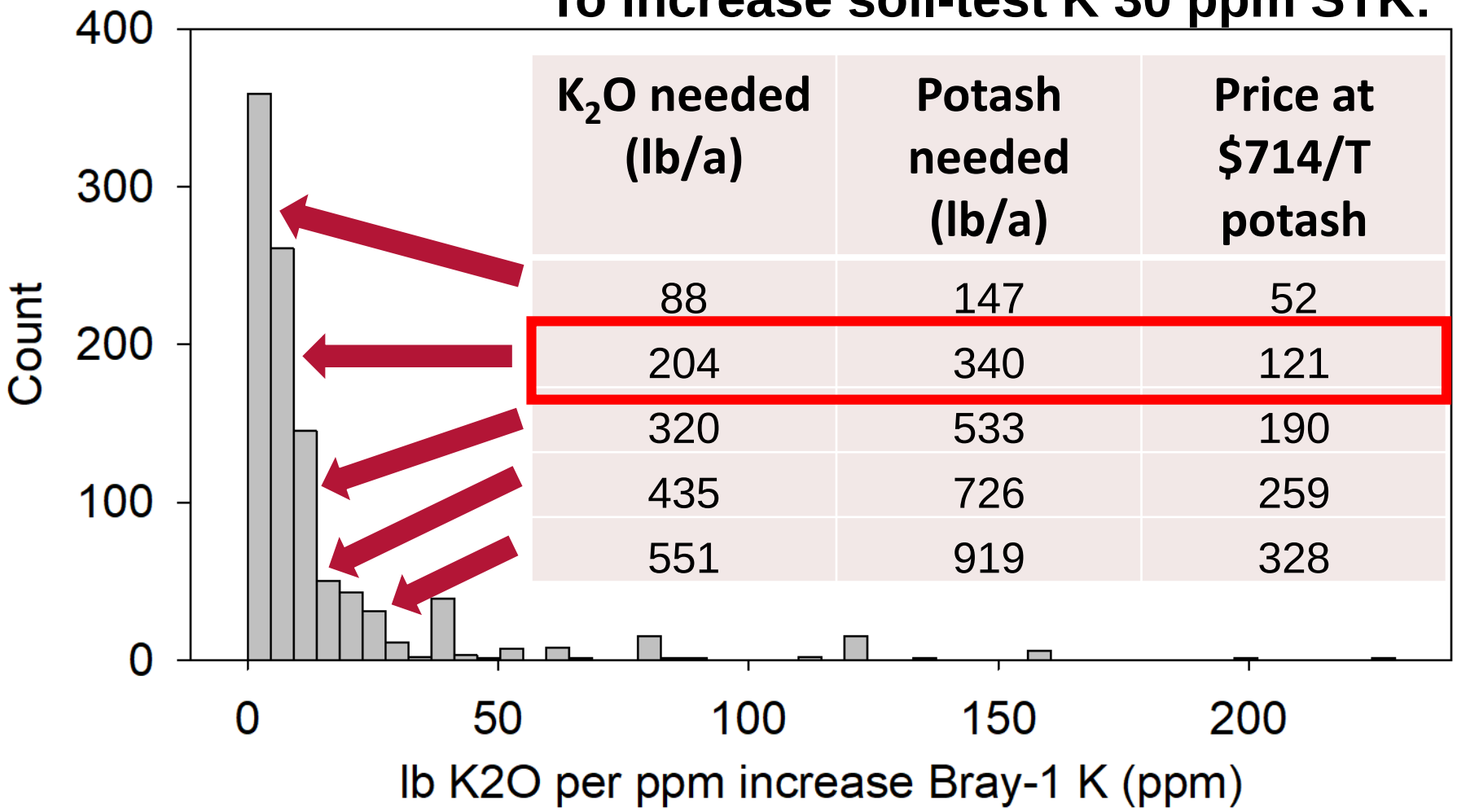
- Single field near Arlington, WI
- Well represented in recommendation dataset

Jones (2022)

Why are buffering capacities important?

To increase soil-test K 30 ppm STK:

K_2O needed (lb/a)	Potash needed (lb/a)	Price at $714/T potash
88	147	52
204	340	121
320	533	190
435	726	259
551	919	328



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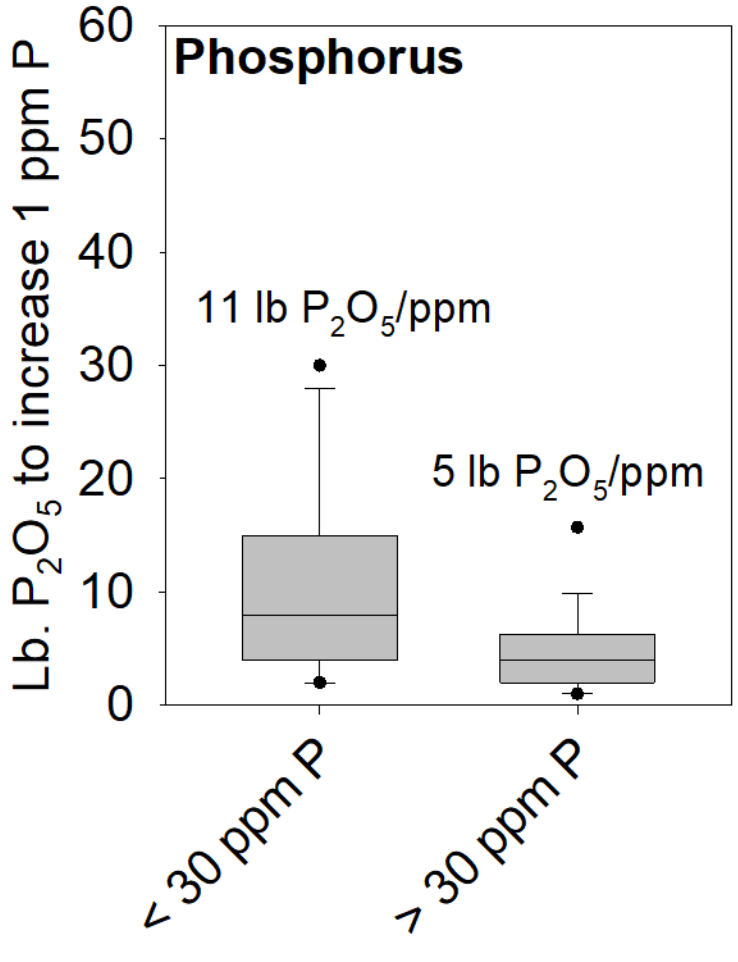
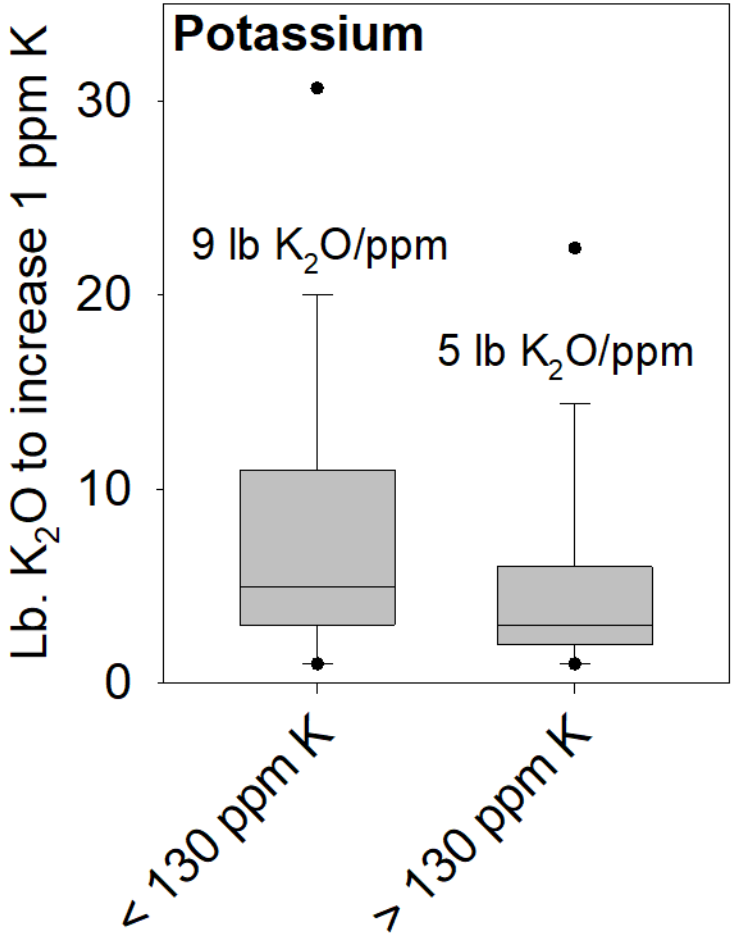
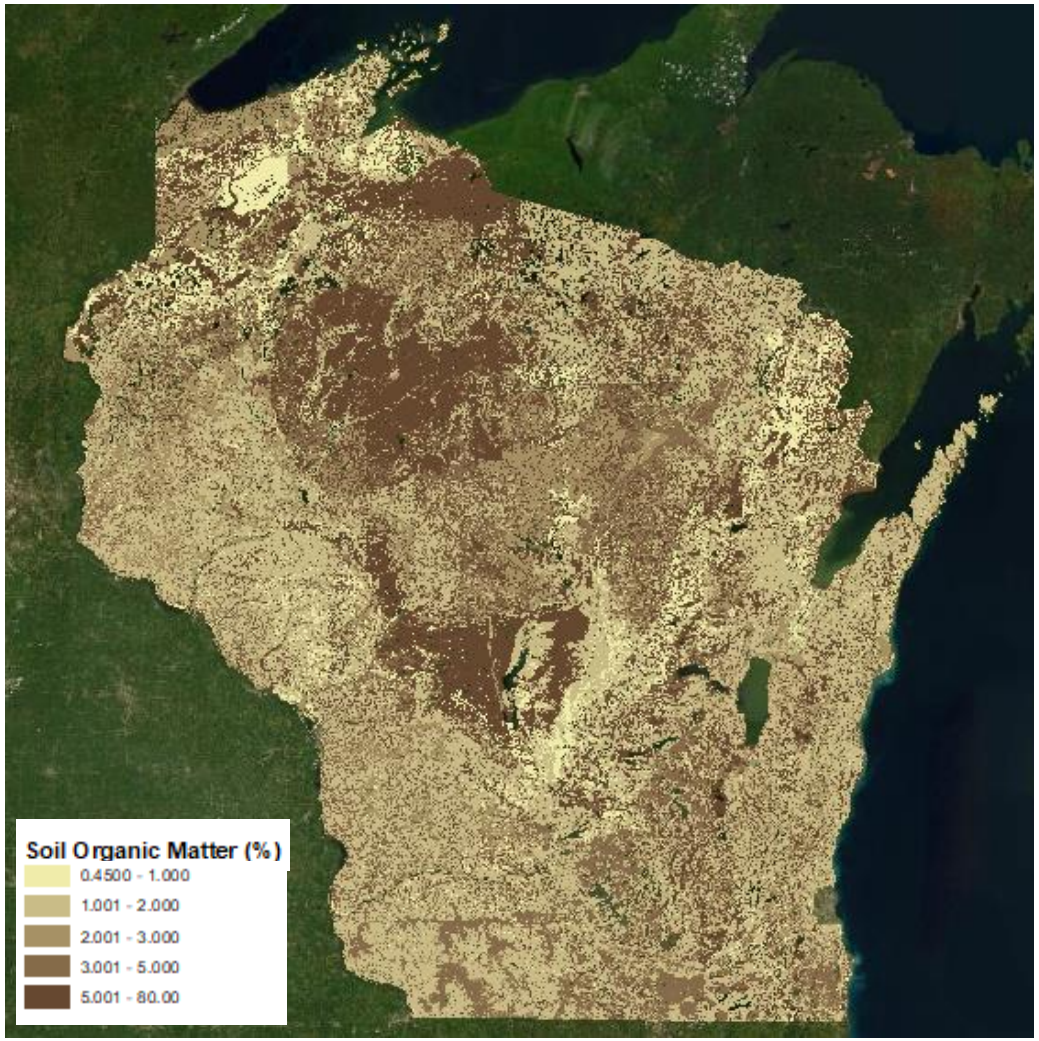
Soil buffering capacities vary by initial soil-test level

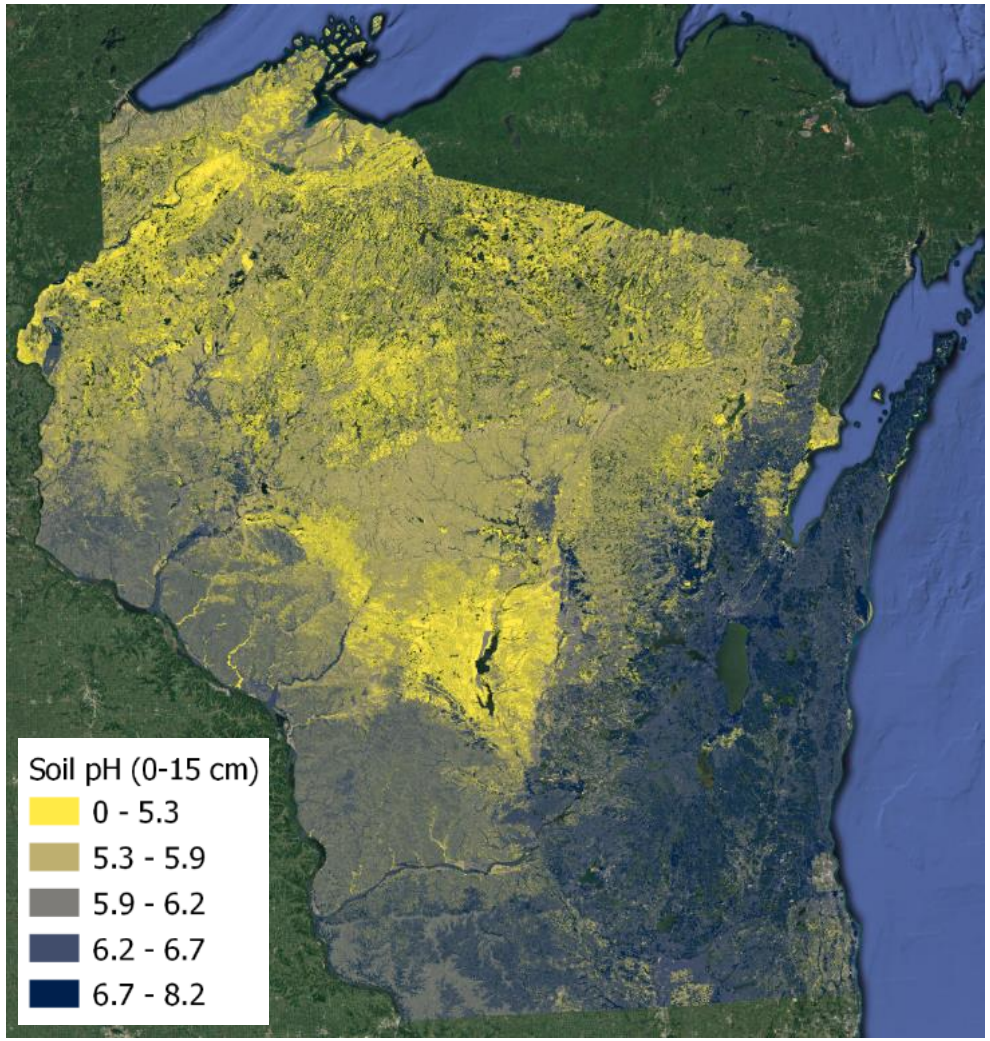
- More fertilizer is required to increase soil-test levels if the initial level is low
- Remember: this is based on extractable nutrient amounts
- Finding true fate of applied nutrients at higher levels needs other tactics (lab methods)



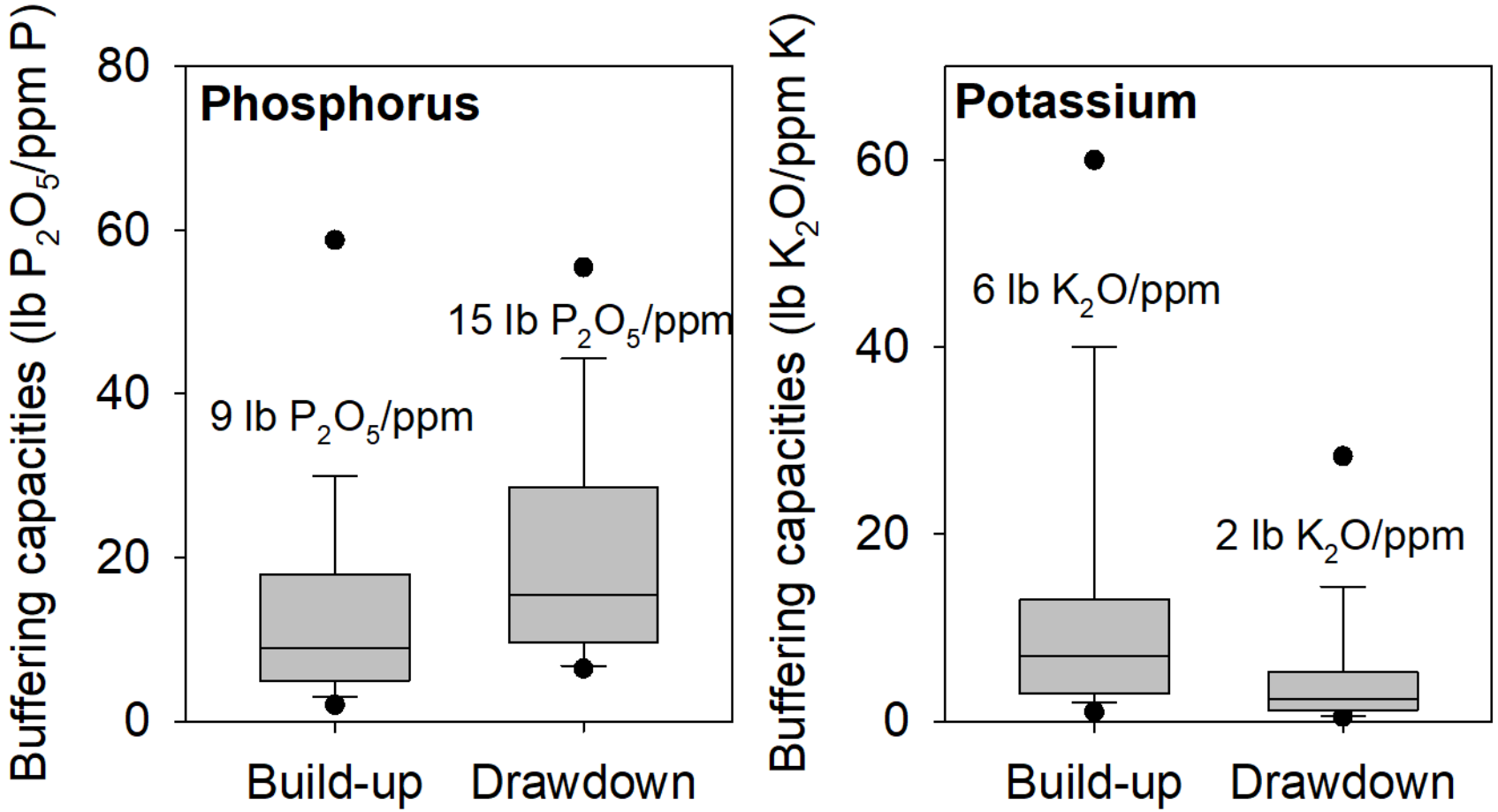


Challenge in Wisconsin: >750 soil series





Are build-up and drawdown equivalent?



- Suggests that they are not. Fertilization and nutrient uptake kinetics very different

Wrapping up – removal varies & affects many system components

- While nutrient concentrations vary, yield will be main driver of spatial and temporal trends in removal
- So, accurate yield estimates or calibrated monitors/data are best to save over-applying removal fertilization
- Can we collect representative field-level grain samples to make precision removal estimates? Does it matter?
- Field-specific “yield” maps of removal and NUE to driving site-specific decisions
- Finally, soil sampling will tell the real “truth” for fertilizer rate decisions, but in-between accurate removal (yield) is second best

Thank you!

John D. Jones, PhD, CCA

jjones58@wisc.edu,
@JDjonesPKL

Research team & collaborators: Andrew Larson, Daniela Orjuela Diaz, Francisco Arriaga, Carrie Laboski
Funding provided by: Wisconsin Fertilizer Research Program, Fertilizer Recommendation Support Tool