

Do we have soil test recommendations precise enough to support precision agriculture?

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Soil Management

Soil Testing Objectives

- Provide index of nutrient availability or supply
- Predict probability of profitable response to lime and fertilizer
- Guidance on proper amount of lime and fertilizer
- Diagnose nutrient deficiencies or toxicities
- Limits pollution
- Save money
- Optimize plant health
- Evaluate fertility status of soils at many levels; farm, watershed, county, state

Soil Testing

- Four separate activities:
 1. Soil sampling
 2. Soil analysis
 3. Interpretation of results
 4. Recommendations

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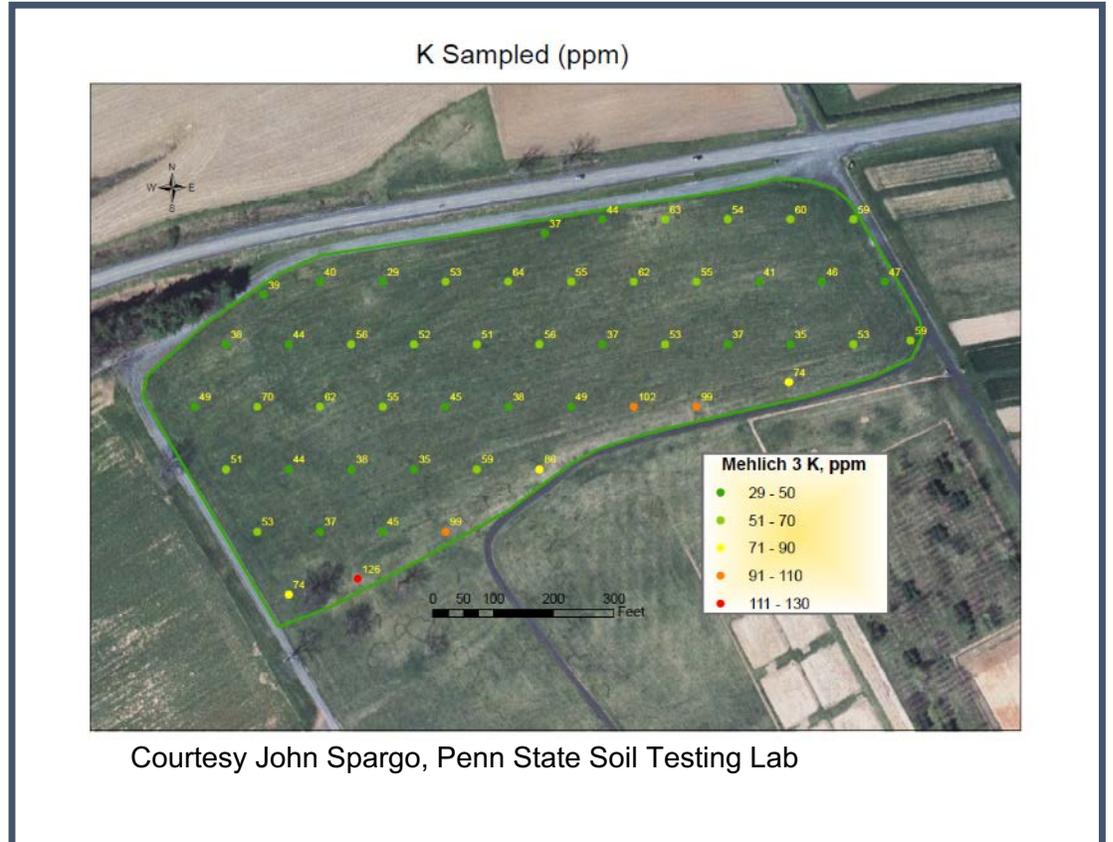
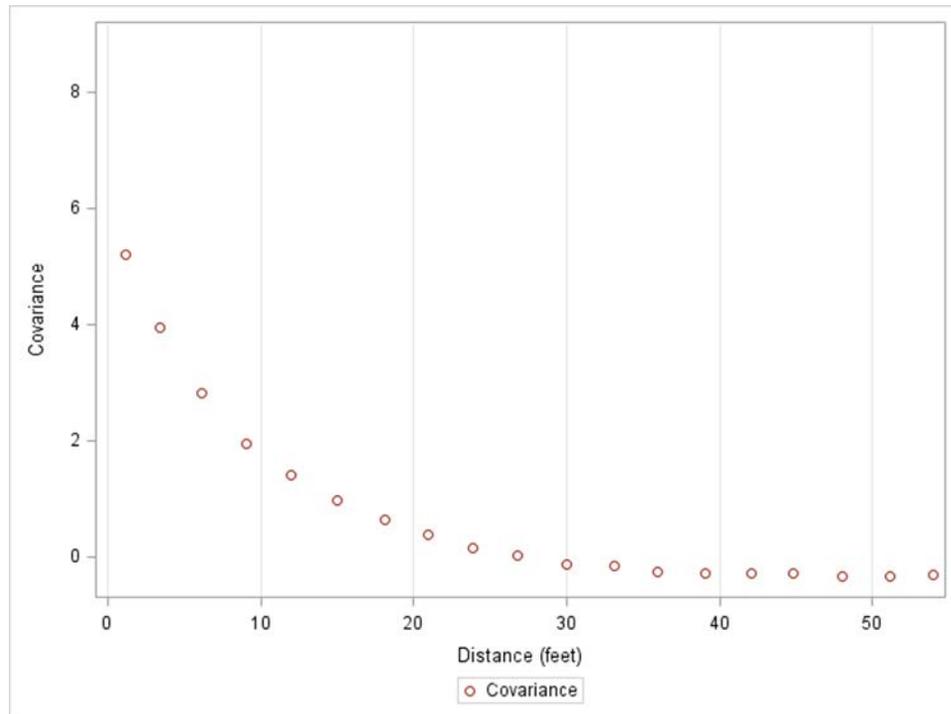
4. Recommendations

- Traditionally viewed as limiting function when managing field average
- When planning VR we often grid sample and interpolate between points

Soil Sampling for Precision Ag

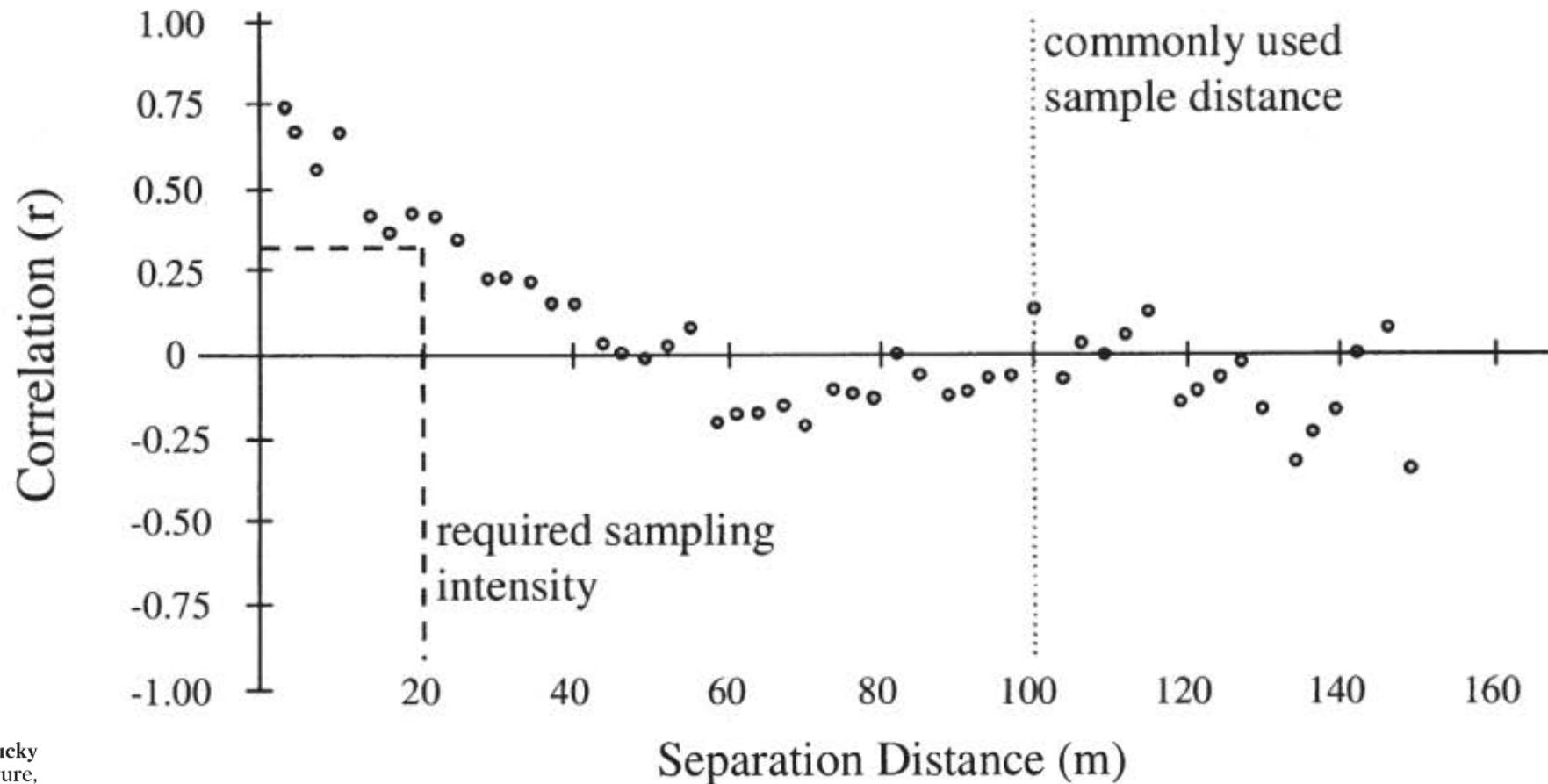
- **Soil sampling traditionally provides average nutrient status and small measure of field variability**
- **Precision ag breaks a field into smaller management zones**
- **Grid Sampling (grid point and grid cell):**
 - Previous management has altered soil nutrient levels
 - Combined small fields into large field
 - A dense nutrient map can be used for several years: 1 acre for variable fields and 2.5 acres for low variability
- **Directed sampling:**
 - Other data available: yield maps, remotely sensed images, or other sources of spatial data
 - Experience with field used to direct management
 - Equipment considerations: Some equipment requires grid-based info
 - Fertility isn't the only source of variability!!

What are we doing when we grid and interpolate?



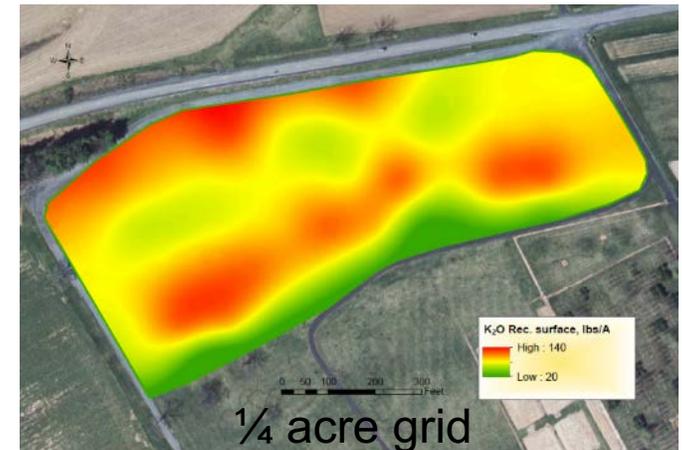
Auto-correlation

LAUZON ET AL.: SPATIAL VARIABILITY OF SOIL TEST LEVELS



How does interpolation perform?

- Often field average is closer to true value than coarse sampling ($>1/4$ acre)
- At small scale soil properties tend to be stochastic
 - Random such that they can be predicted accurately, but not necessarily precisely
- On average the estimated values are right, at each spot they are off further than the field average

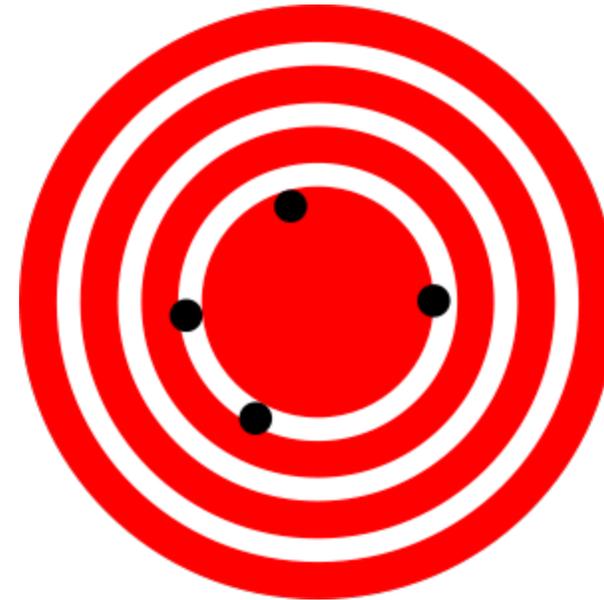


Courtesy John Spargo, Penn State Soil Testing Lab

Reminder: Accuracy v. Precision



**High Precision
Low Accuracy**



**Low Precision
High Accuracy**

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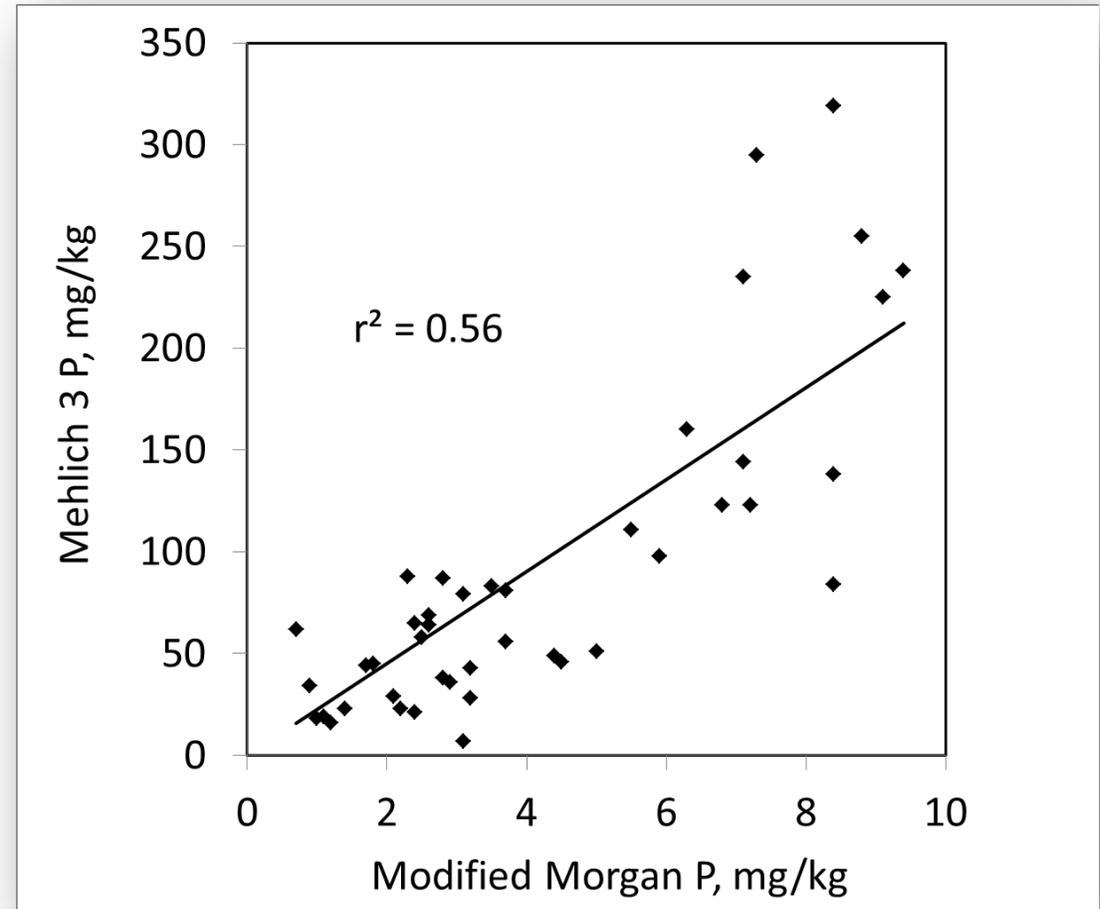
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- We're pretty good at soil analysis

Comparing different extracts

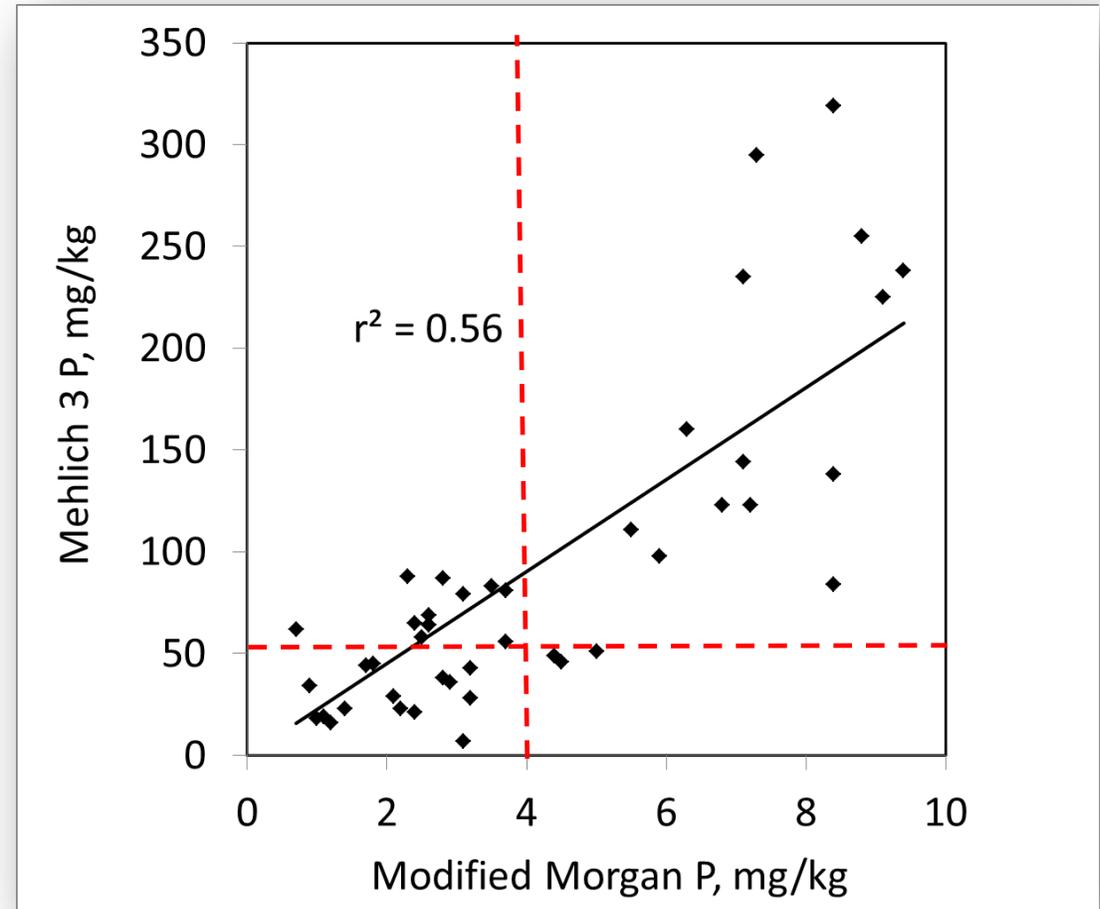
- In this data set of 51 soils collected from the Northeast, Mehlich 3 extracted 2 to 90 times more P than modified- Morgan.
- The two methods are not well correlated
 - they extract P from different pools.



Heckman et al., 2006. Soil Sci. Soc. Am. J. 98:280-288

Comparing different extracts

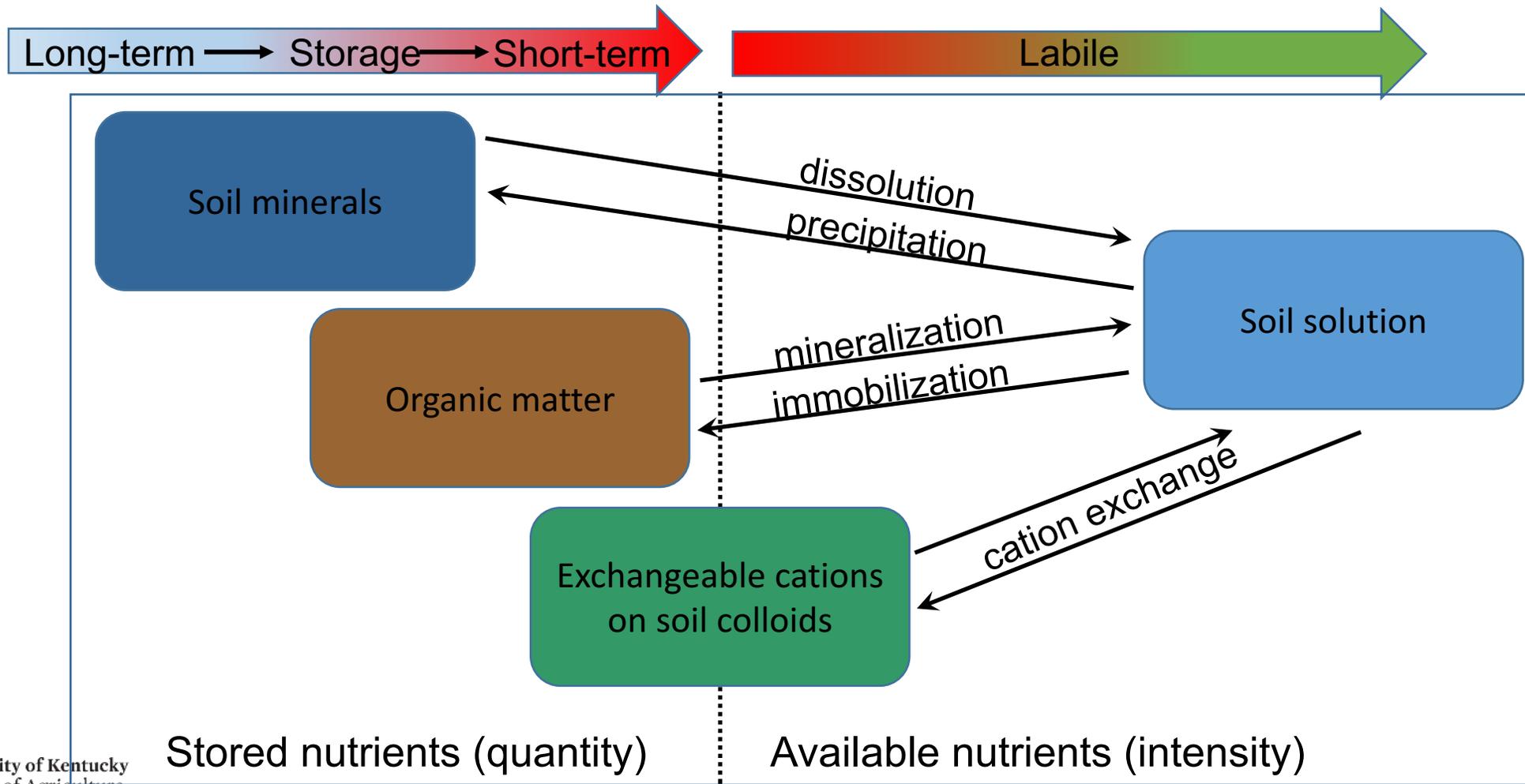
- In this data set of 51 soils collected from the Northeast, Mehlich 3 extracted 2 to 90 times more P than modified- Morgan.
- The two methods are not well correlated
 - they extract P from different pools.
- They do not predict the same fields to be responsive



Heckman et al., 2006. Soil Sci. Soc. Am. J. 98:280-288

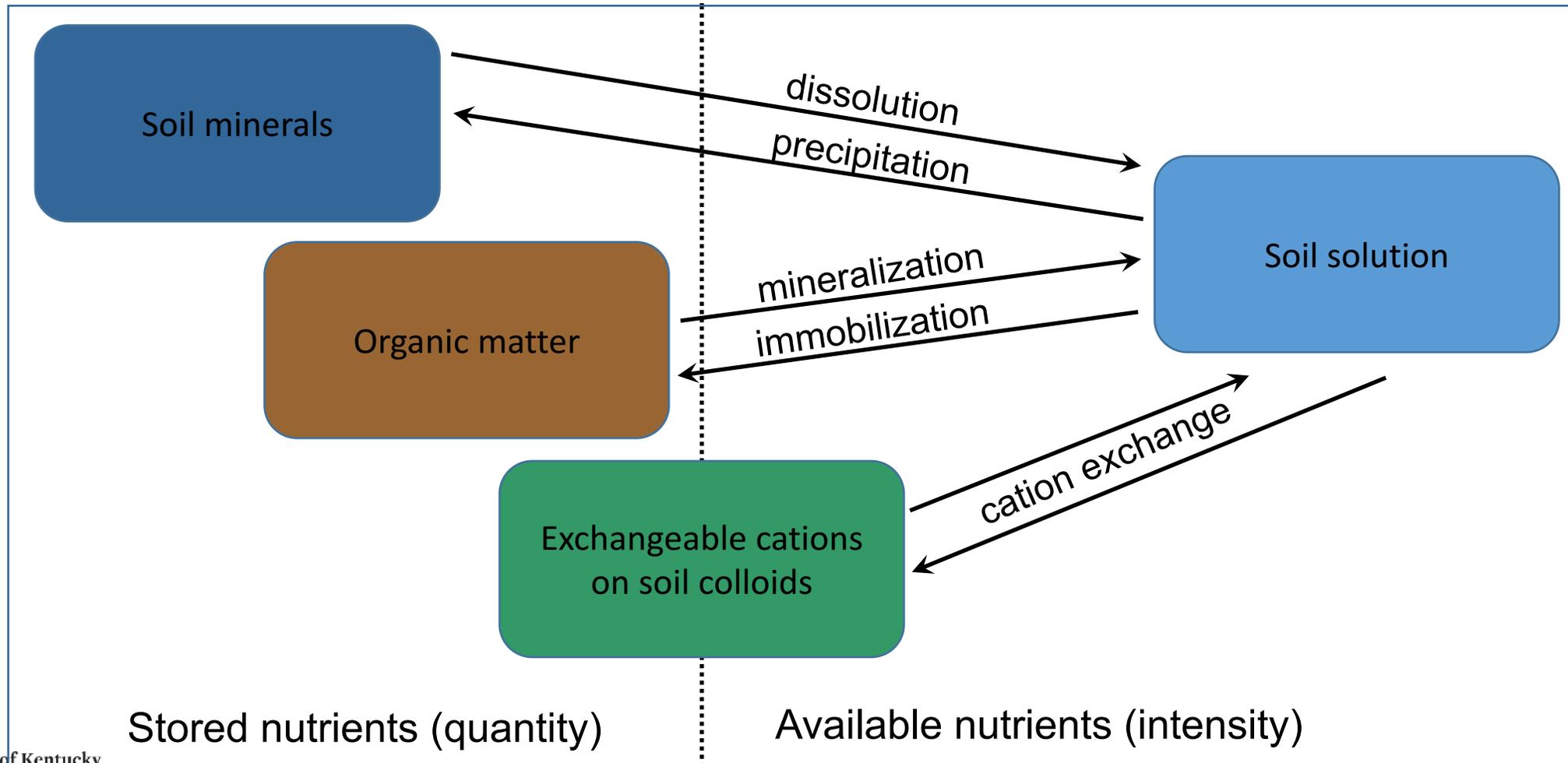
Soil analysis

Extract portions of stored nutrient pools and most labile nutrient



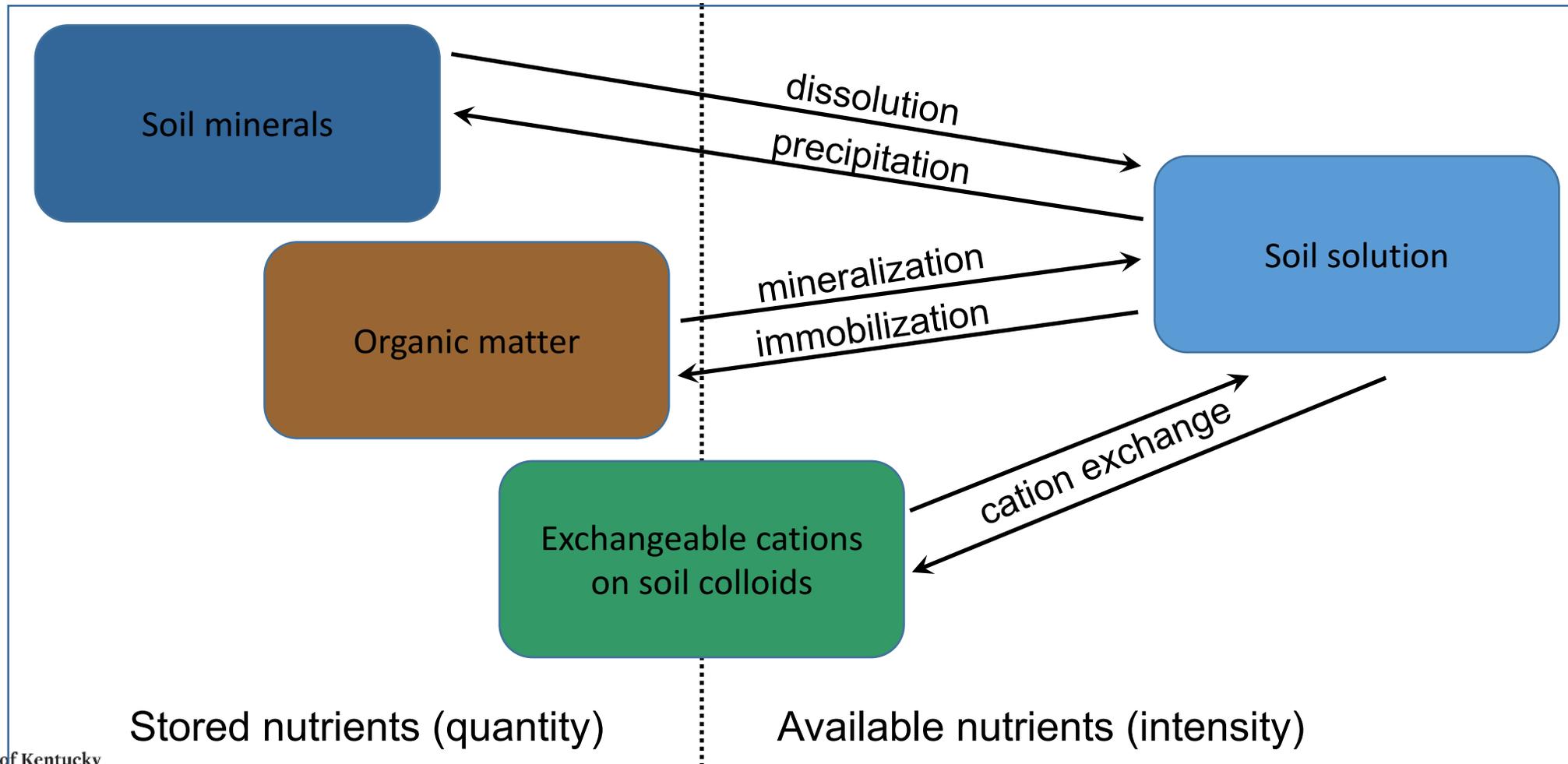
Soil analysis

Soil testing should provide a measure of nutrients in soil solution (intensity), in stored pools (quantity), and buffering capacity (change in quantity with respect to intensity).



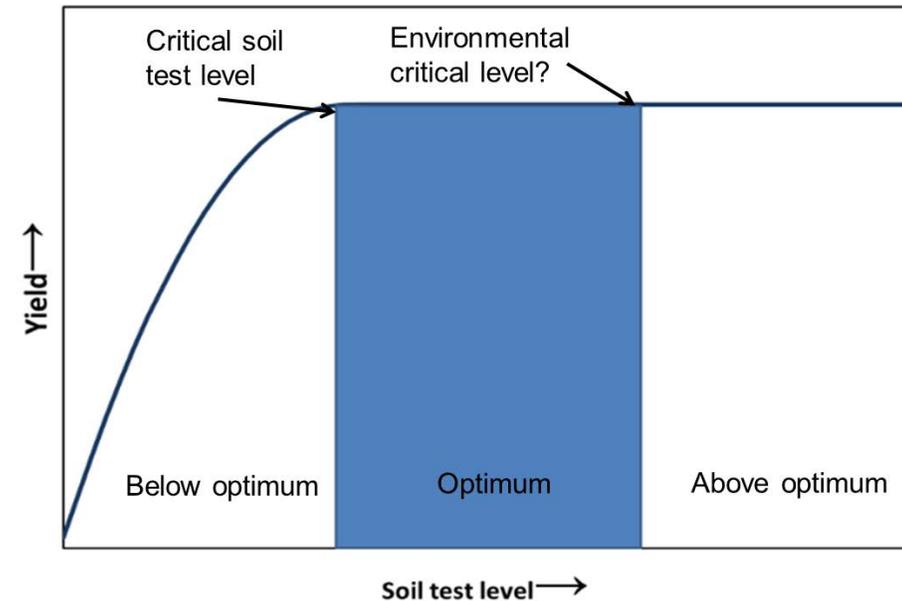
Soil analysis

Because so many factors influence quantity-intensity relationship, soil testing can only provide an *index* of nutrient supplying capacity of a soil.



Soil test interpretation

- Extractable nutrient values have little meaning unless they have been shown to be related to:
 1. the soil concentration at which response occurs (correlation)
 2. plant response to application of that element at specific soil concentration (calibration)
- Research, under regional conditions, with representative soils ranging from deficient to adequate for given nutrient is necessary to obtain useful soil test correlation and calibration.



General concept of soil test interpretation

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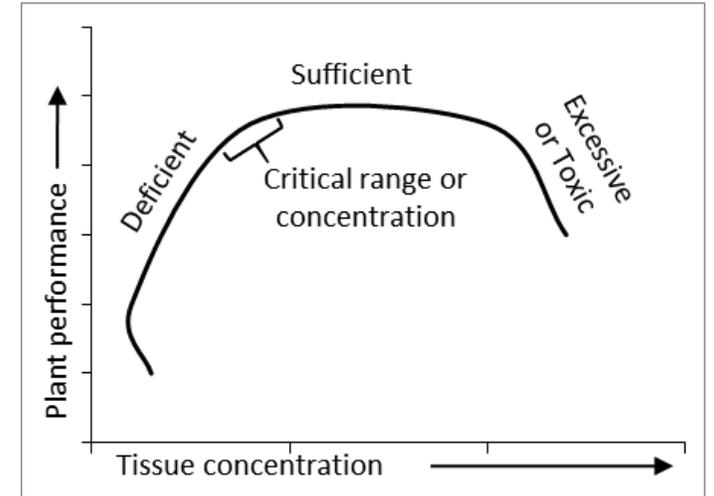
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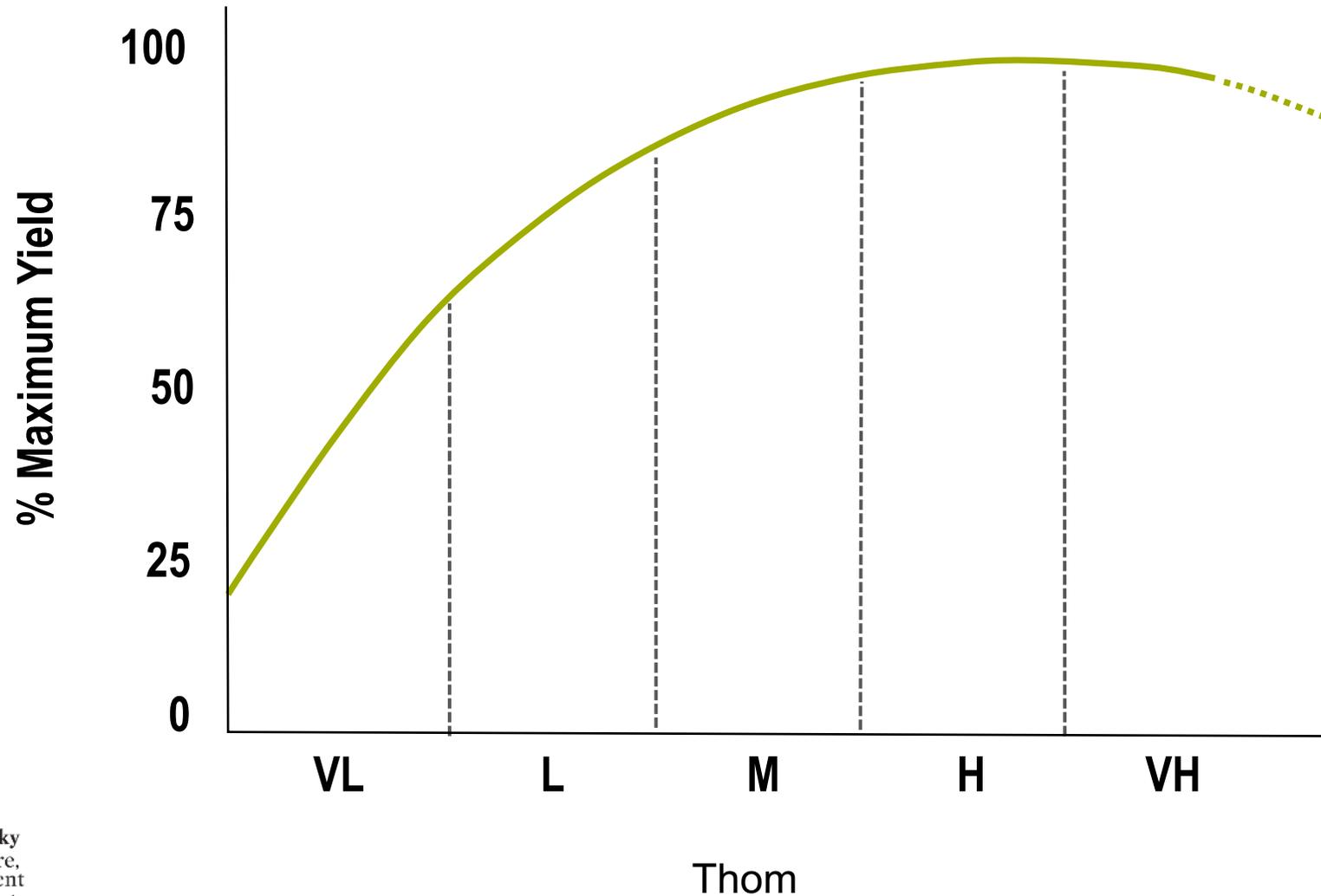
- We have a long way to go here

Soil test interpretation & Fertilizer recommendations

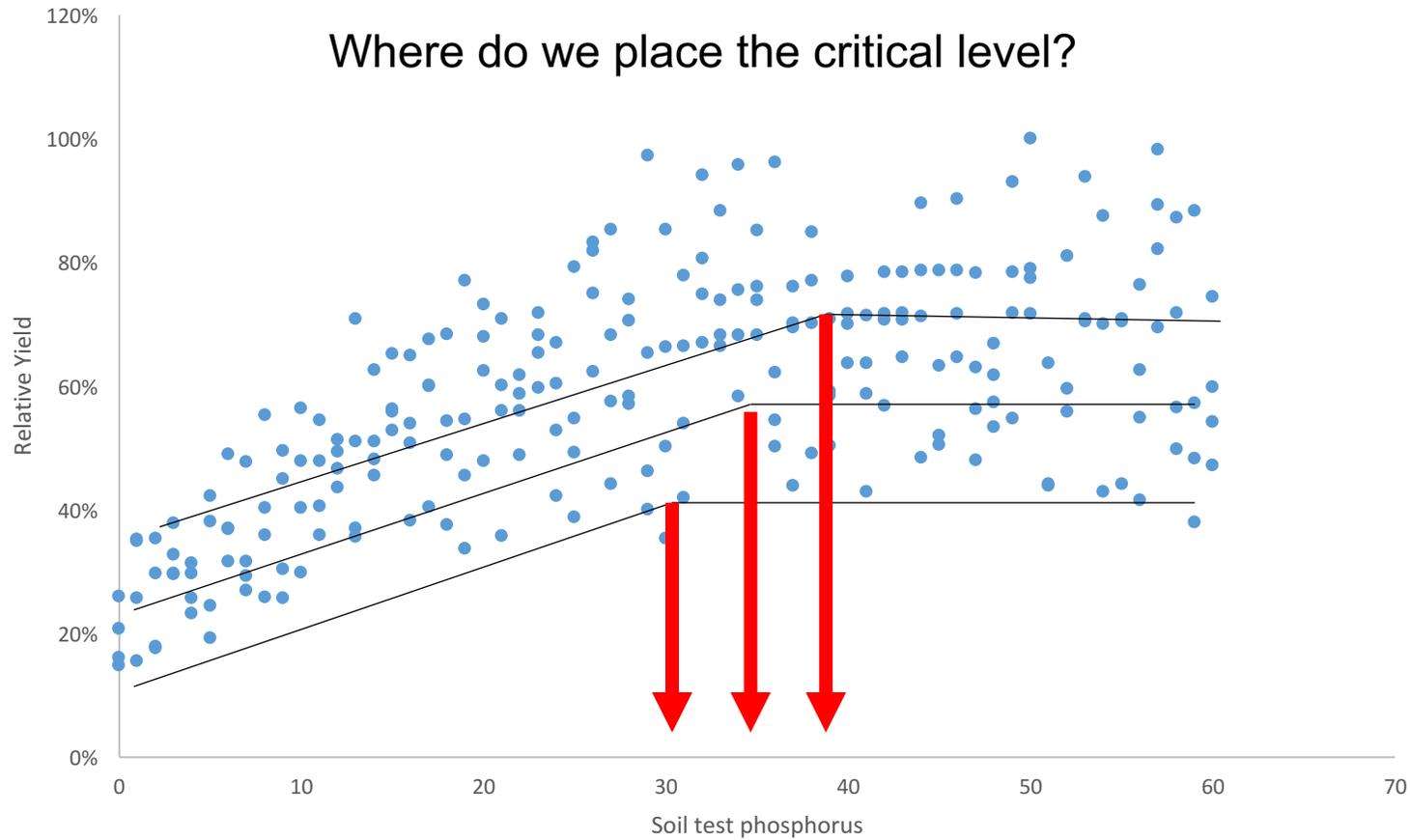
- Correlation
 - Relative yield versus soil test value
 - Plant response to application of element
 - Requires check plot and sufficient plot
 - Conduct experiment at multiple sites (multiple soil concentrations)
- Calibration
 - Amount of applied nutrient versus soil test value
 - Multiple fertilizer rates at one site (one soil test value)
 - Conduct at multiple sites
 - Build fertilizer recommendations for different soil test values



Correlation: Yield = f(soil test)



Soil Test Correlation: What's the critical level?



Soil Test Calibration: How much fertilizer?

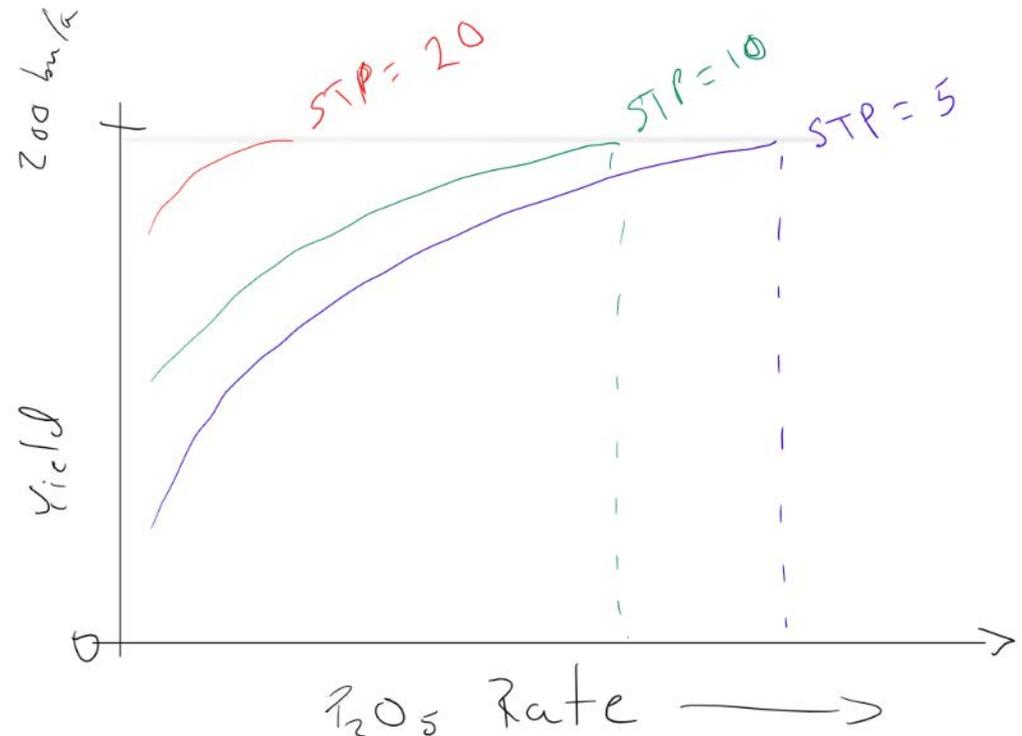
1. Sufficiency approach

- When soil test level is below optimum, apply only enough nutrients to meet crop needs

2. Buildup and maintenance approach

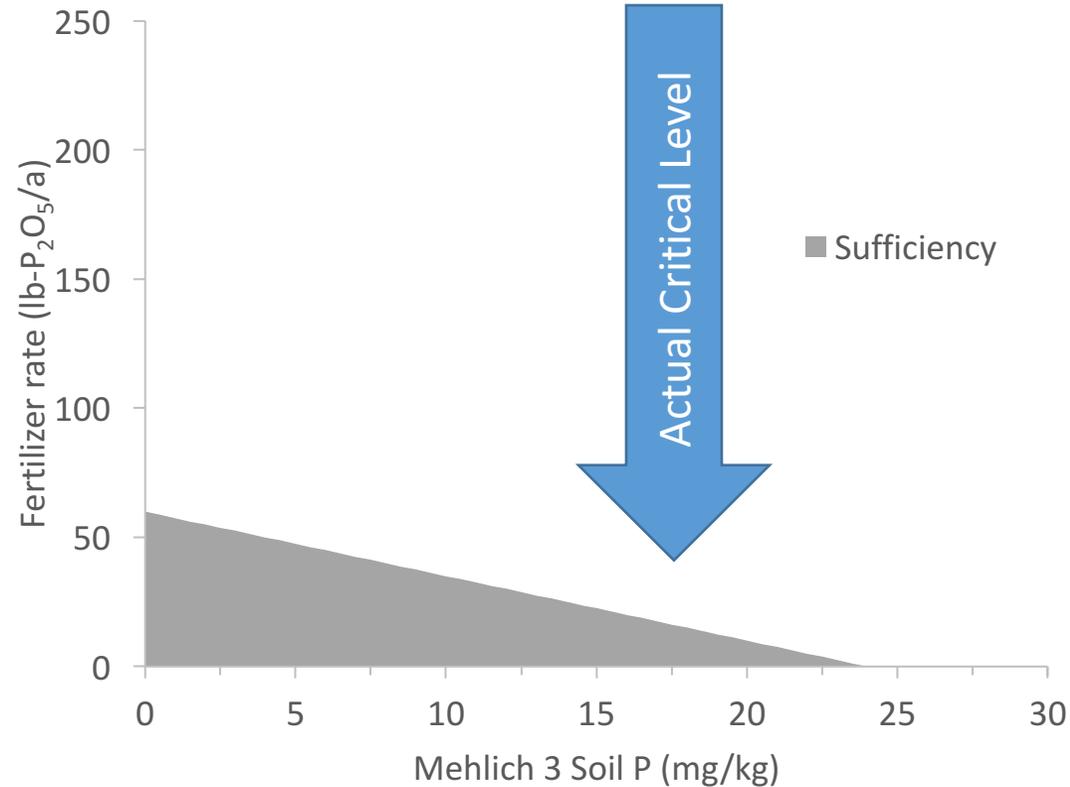
- Rapidly build low soil test concentrations to optimum level
- Replace nutrients removed by crop at higher soil test levels where response is not expected

3. Hybrid Approach

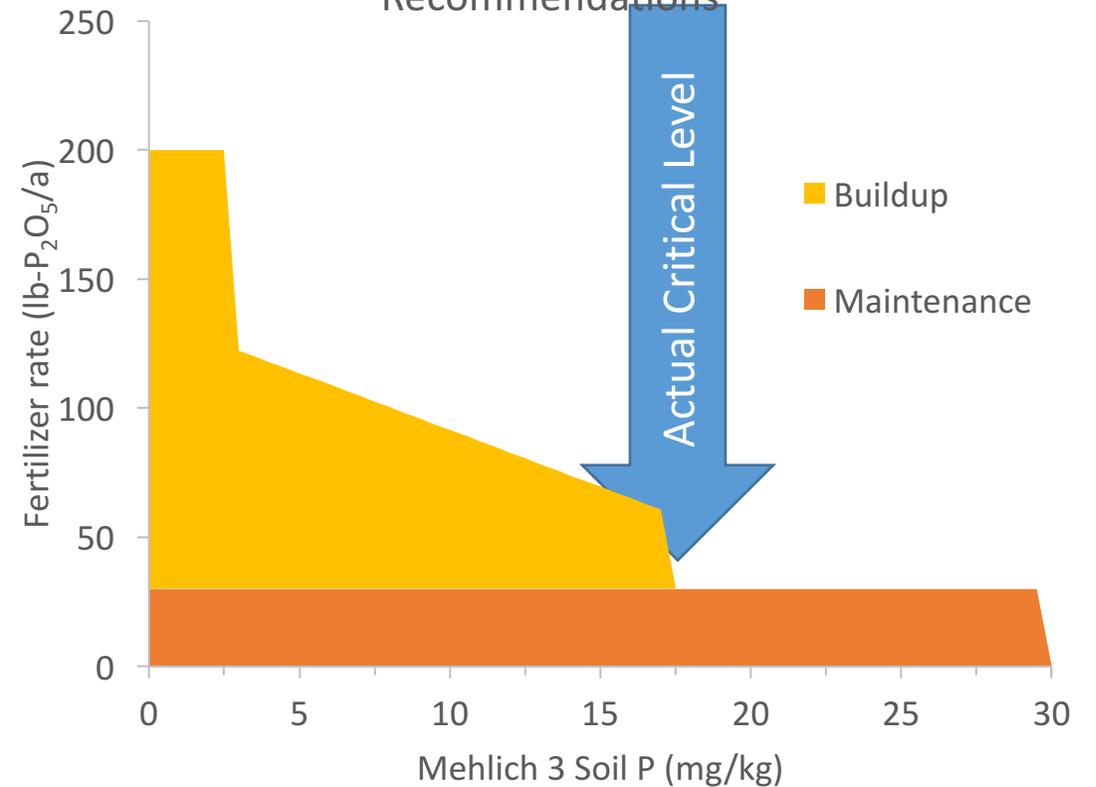


Calibration: Fertilizer Recommendation Systems

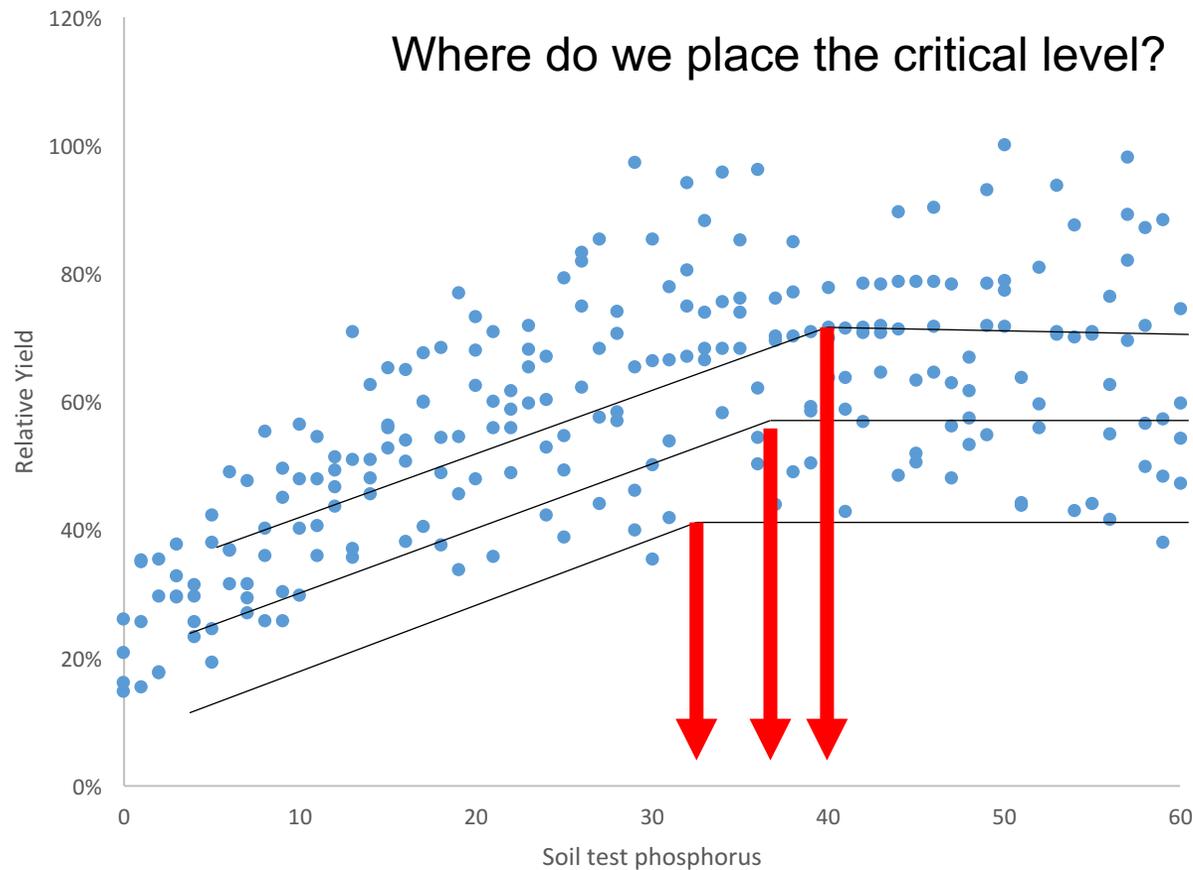
Sufficiency only recommendations



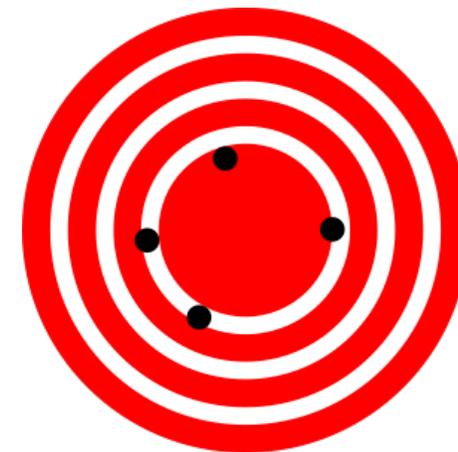
Example of Build and Maintain Recommendations



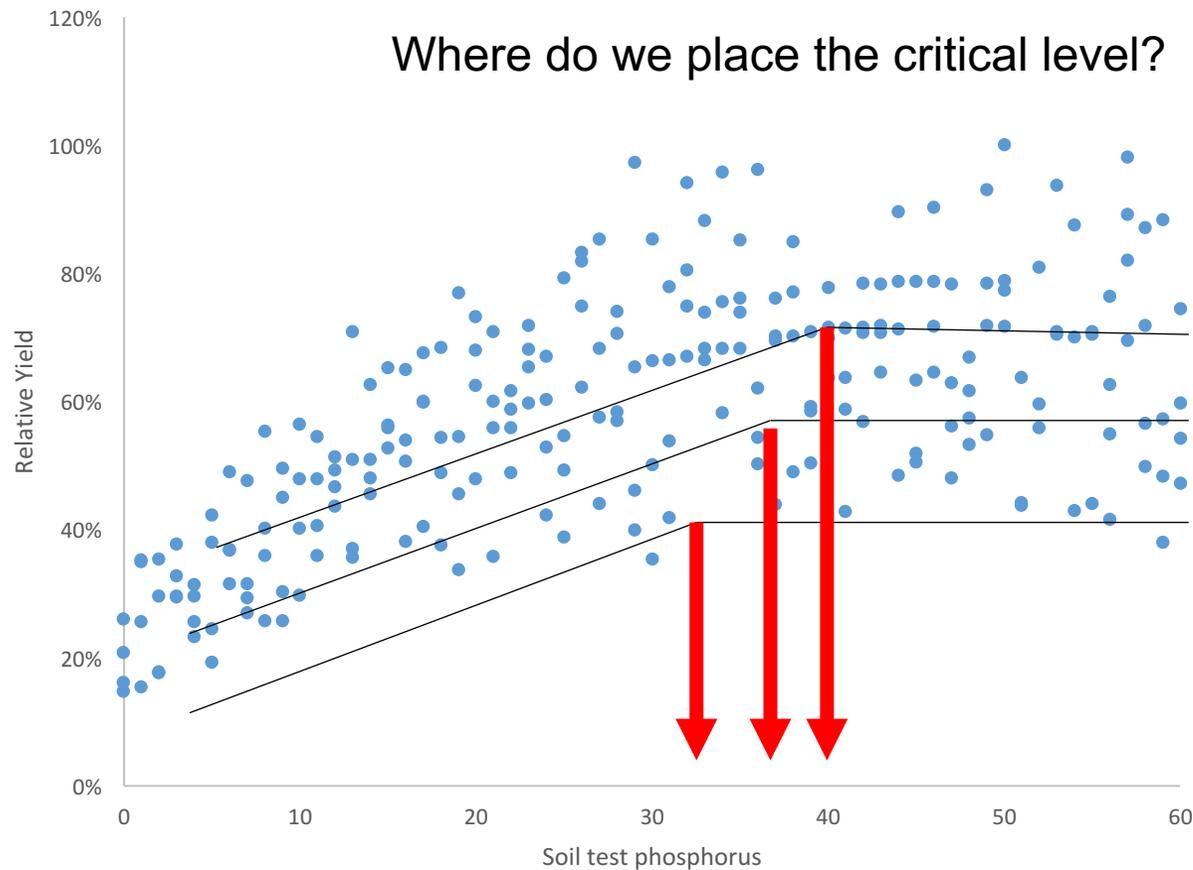
Soil testing for SSM: New challenges



- We have focused on mapping soil P status spatially
- Correlation and calibration were designed to make accurate recommendations

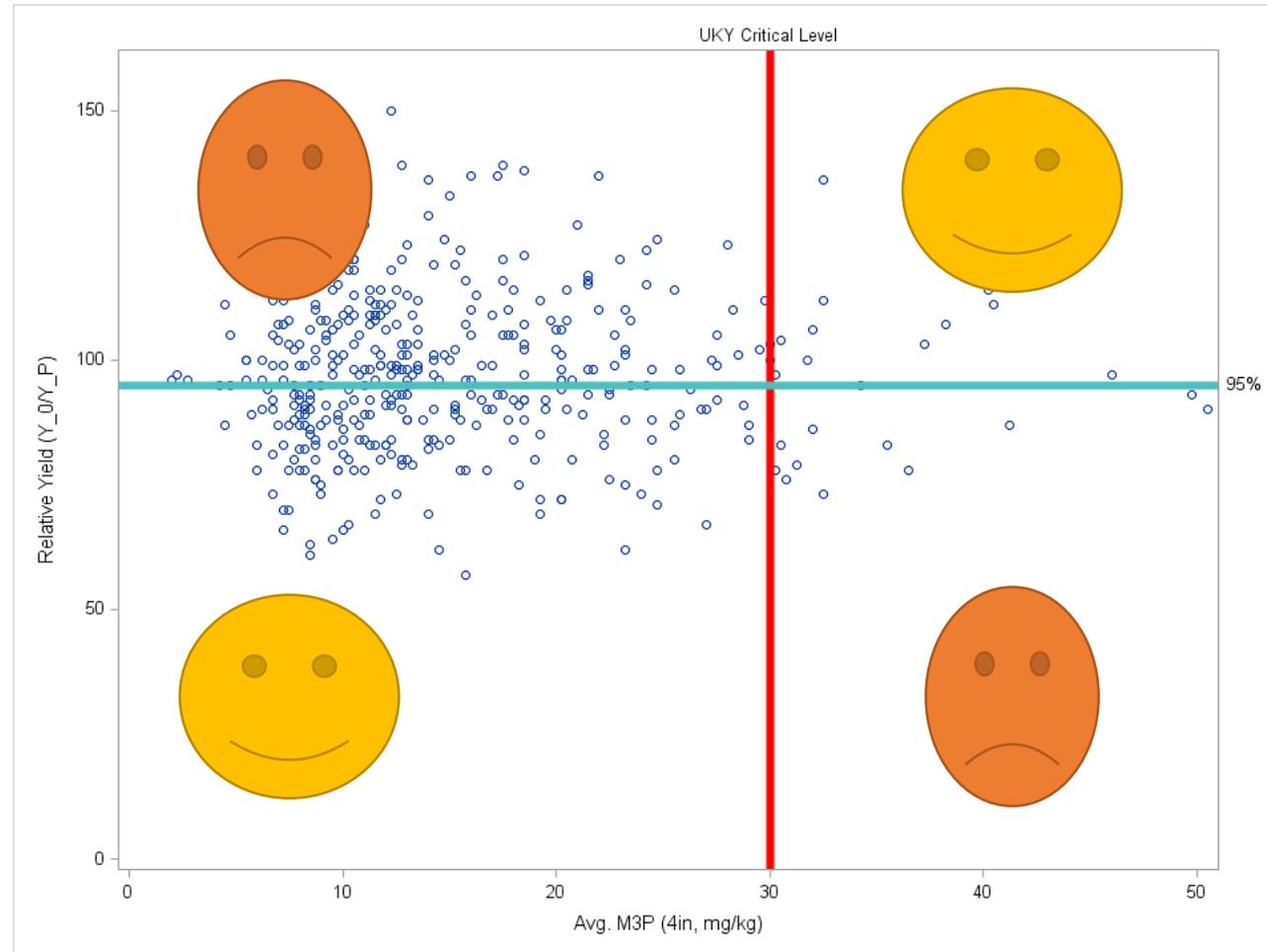


Soil testing for SSM: New challenges



- We have focused on mapping soil P status spatially
- Correlation and calibration were designed to make accurate recommendations
- What if in addition to soil P concentration varying, the critical level varies?
 - spatially and temporally?

High resolution response study in one field



Where do we go from here?

- Historically soil testing has focused on accuracy and not precision
 - Stochastic nature of soil properties -- imprecision amplified when managing at higher spatial resolution
 - Perhaps we should sacrifice some accuracy for greater spatial precision?
- We need to examine soil test interpretation and recommendations in context of SSM
 - Probability of response?
 - Quantity versus intensity?
 - Temporal resolution?
- Soil test recommendations are really an model – leaning towards empirical
 - Based on correlations
 - Interpretation limited to scale of inference
 - Bias from extrapolation beyond scope of calibration data
- Move towards process oriented approaches? – **DATA INTENSIVE**
 - Can be extrapolated beyond calibration data
 - Larger uncertainty due to error from parameterization
 - More complex

What can you do now?

- Interpolated soil sample maps (>1/4 acre grid) are unreliable **AT BEST**.
 - Use the money you're spending on grid sampling to sample more frequently (sample every year and shift your grid)
- Intensively sampled zones might work
 - The best thing about grid sampling is the number of individual cores – the problem is we should put them in the same bucket
 - How do we determine the zones?
 - Data quality and interpretation?
- Even with a decent soil test map (grid or zone) our recommendations are very coarse and were intended to be an average
 - Use your technology to insert check plots (High P, Low P, No-P) within your prescription and evaluate recommendations yourself
- Can you interpret your on-farm research?

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