Phosphorus Chemistry and Sequestration in Soil

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Today's Presentation

- Soil Chemical Processes Important to
  P sequestration and solubility / mobility / runoff / leaching

- Soil Testing of "labile P":
  Crop production vs environmental soil testing

- Assessment Tools to predict Risk of P transport (runoff/leaching) in Ohio

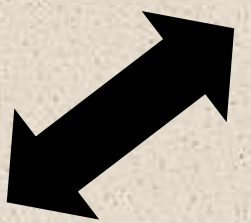
Soil Phosphorus Pools

Sequestered P
very insoluble forms of P
insoluble P minerals
strongly adsorbed P

Intensity

Soil solution P
dissolved P
bioavailable P

“Labile P”
P in Equilibrium with soil solution P
Adsorbed (bound) P
soluble P minerals



Quantity

Q-I is a 2 way street
replaces losses of dissolved P
removes additions of soluble P

Sequestered >> Quantity >> Intensity

Chemical Fate of Introduced Soluble P

Fertilizer / Manure / Biosolids Additions

Soluble $H_2PO_4^-$

Adsorption (Binding) onto soil oxide clays (Fe, Al, Mn oxides)

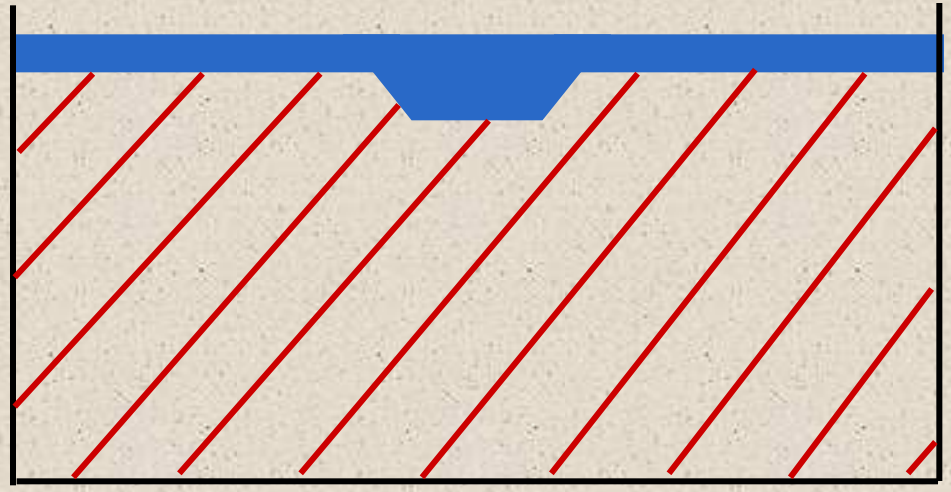
Precipitation (Fe, Ca, Al phosphates) formation and transformation of P minerals

These two mechanisms control labile P in equilibrium with soil solution (QI)

Precipitation / Dissolution of P Minerals

Solubility of P-minerals limits P dissolution and availability

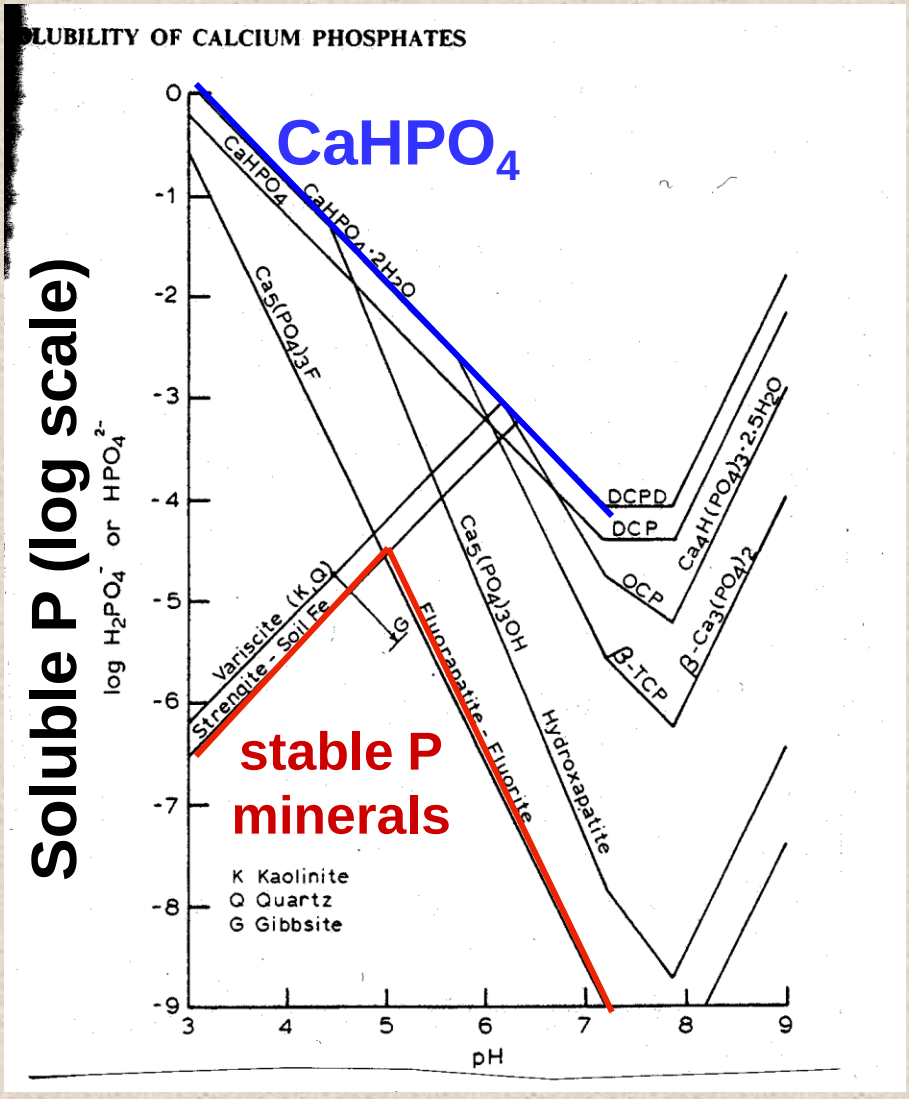
Fe, Al phosphates at low pH (<5)
Ca phosphates at high pH (5 - 8.5)



Very insoluble at most pH
maximum solubility at pH 5 to 7

plant available P can be very low in unfertilized soil
plant growth and crop yield can be limited by P

Does P fertilizer increase P solubility?



Fertilizer P becomes $CaHPO_4$ in soil

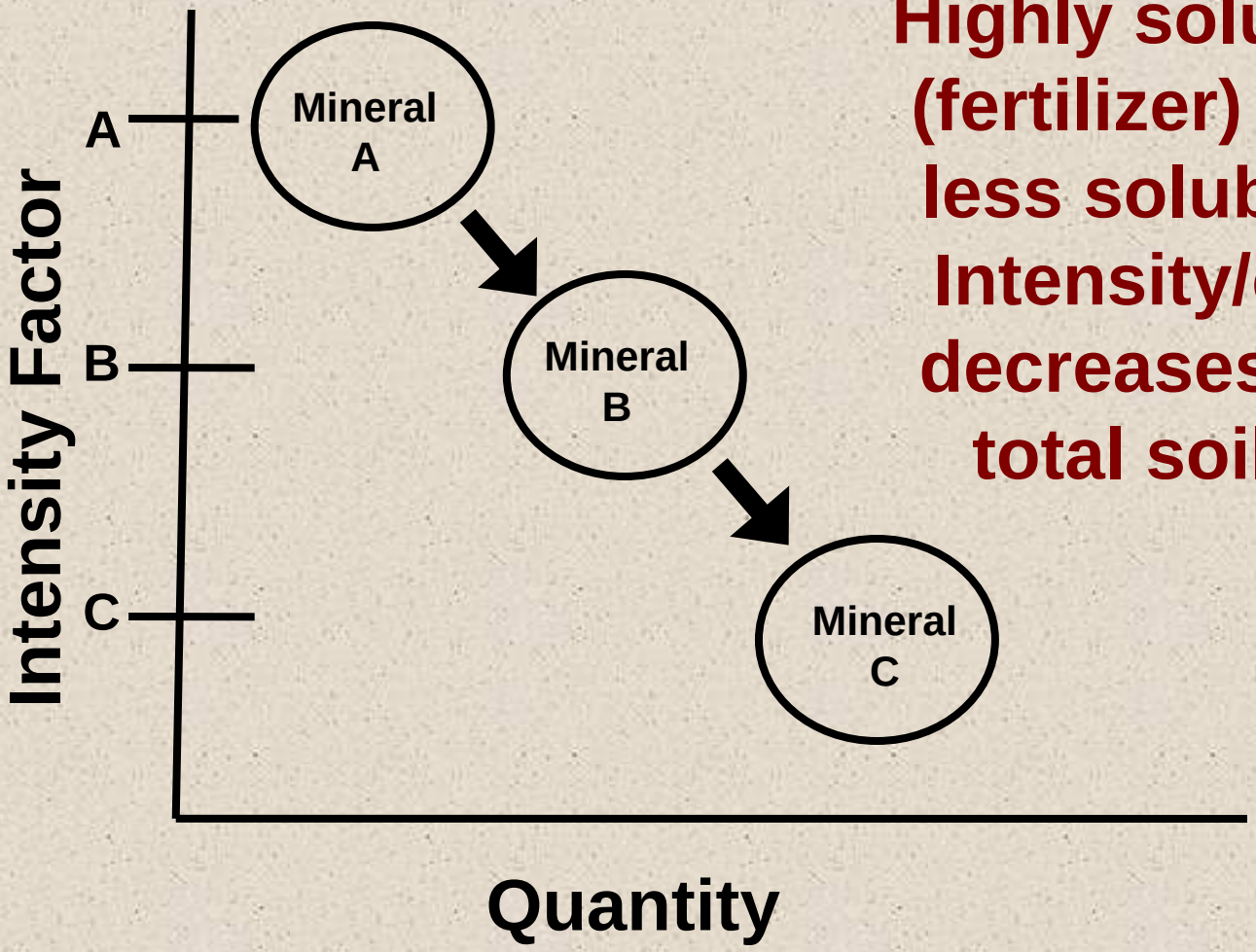
$CaHPO_4$ is metastable

Eventually transforms to $FePO_4$, $AlPO_4$ or a Ca apatite

while $CaHPO_4$ is still around--enjoy a higher soluble P and plants grow well

soluble P fertilizer works

Effect of Q/I on P Availability / Solubility



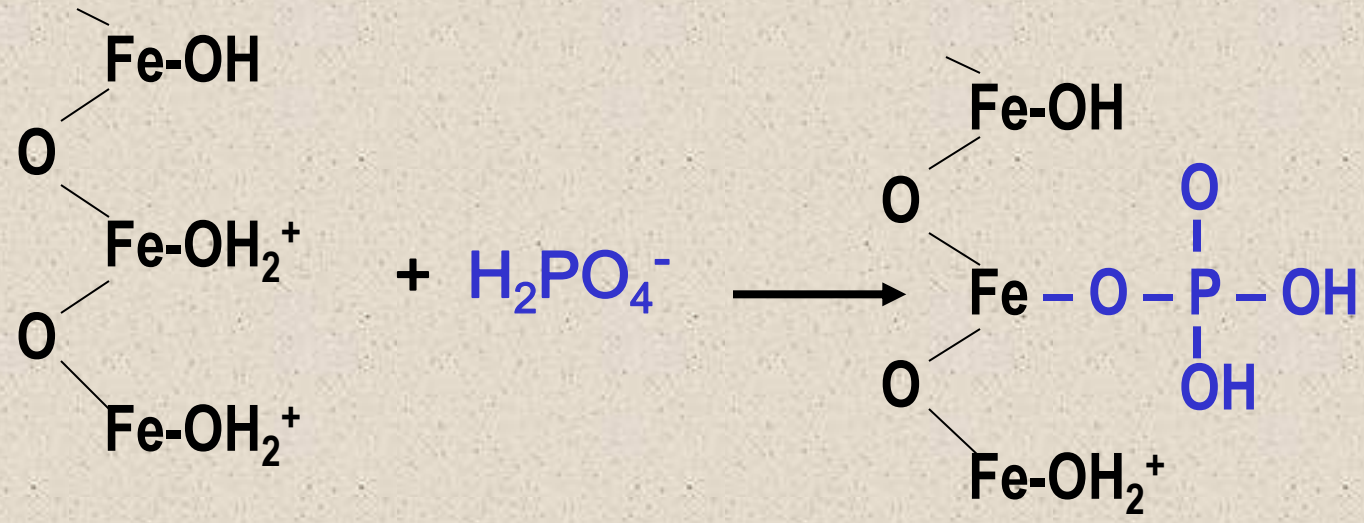
Highly soluble P minerals (fertilizer) transform into less soluble P minerals. Intensity/concentration decreases and quantity/ total soil P increases

Perhaps this is why runoff P is often not related to soil test P

P Adsorption (binding) onto Oxide Clay Surfaces

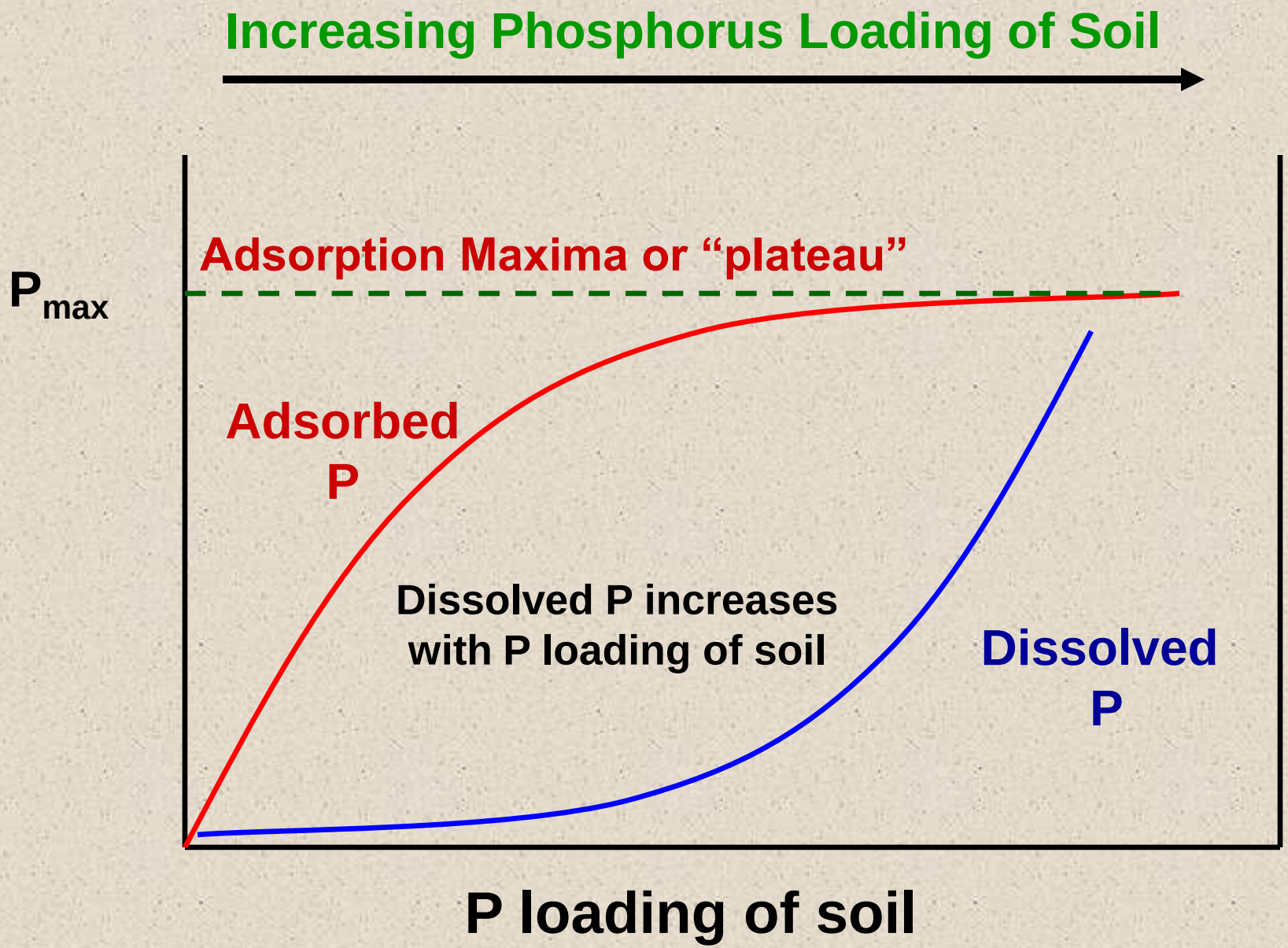
Second mechanism controlling soil P solubility, mobility and availability

P adsorbs strongly to Al, Fe, Mn oxide soil surfaces



- **Dependent on reactive oxide surface availability**
- **Not concentration dependent like mineral precipitation/dissolution reactions**

Dissolved vs Adsorbed P



Risk of P Transport in Ohio

In Ohio, the risk of agricultural phosphorus (P) runoff transport into surface water is assessed by either the Ohio USDA-NRCS

Phosphorus Index (P Index) Assessment Procedure
or the
Soil Test Risk Assessment Procedure (STRAP)

within the
Nitrogen and Phosphorus Risk Assessment Procedures

http://efotg.nrcs.usda.gov/references/public/OH/Nitrogen_and_Phosphorous_Risk_Assessment_Procedures.pdf

Both are currently being reviewed

Predicting P solubility and risk
Ohio NRCS P Index

P Source Factors	+	Transport Factors	= P Index
Soil Test P		Runoff Potential (slope)	
Soluble P In Manure/biosolids		Distance To Stream Erosion Class, etc.	

The Ohio P Index combines well established factors that influence the transport of P from agricultural fields to surface waters. Each factor is evaluated based on site specific data and weighted, or modified, according to its overall effect on P transport. Each of the site sub-values are added together to establish an overall site rating, or score, of Low, Moderate, High or Very High risk

Phosphorus source terms / weighting factors in current Ohio P Index

4	Soil Test P mg/kg	Bray-Kurtz-P1 mg/kg X 0.07				
5	Fertilizer Application Rate	Planned Fertilizer P_2O_5 Application (lbs/A) X 0.05				
6	Fertilizer P_2O_5 Application Method	0 Applied Value = 0	Immediate Incorporation OR Applied on 80% Cover Value = 0.75	Incorporation < 1 Week OR Applied on 50-80% Cover Value = 1.5	Incorporation > 1week and < 3 months OR Applied on 30-49% Cover Value = 3.0	No Incorporation or Incorporation > 3 months OR Applied on < 30% Cover Value = 6.0
7	Organic P Application Rate	Planned Manure/Biosolids P_2O_5 Application (lbs/A) X 0.06				
8	Organic P_2O_5 Application Method	0 Applied Value = 0	Immediate Incorporation OR Applied on 80% Cover Value = 0.5	Incorporation < 1 Week OR Applied on 50-80% Cover Value = 1.0	Incorporation > 1week and < 3 months OR Applied on 30-49% Cover Value = 2.0	No Incorporation or Incorporation > 3 months OR Applied on < 30% Cover Value = 4.0

The Soil Test Risk Assessment Procedure (STRAP)

Simpler than P Index
Often used as a screening tool

Used to predict risk of P transport based on the Bray-P1 extractable STP level. As STP levels increase above 150 mg/kg Bray-P1 it is presumed that their will be an increase in P transport and no additional phosphorus application is recommended.

Once field STP levels exceed 150 mg/kg Bray-P, the P Index can be used to evaluate risk of P transport and it is possible that the use of the P Index may allow for additional P application.

Soil Test P (STP)

Important Component for BOTH Ohio Indices

Crop Sufficiency vs Environmental Risk

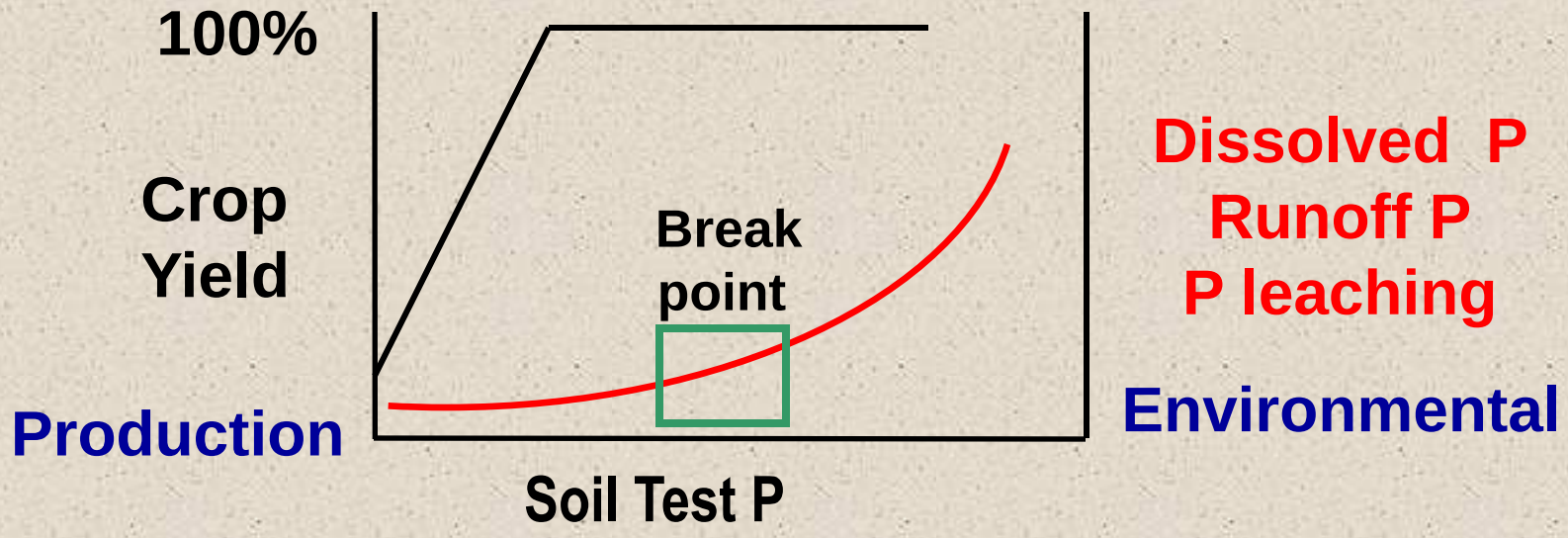
Crop production soil tests: Measure the "labile" nutrient pool that will be available to the crop during some / all of the growing season

Professor Bray's Requirement for a "good soil test" (1948)

1. Extract a proportionate part of plant available forms of nutrient from different soils
2. Extracted nutrients should correlate with uptake of nutrient and crop yield

Is it appropriate to extrapolate soil fertility test data to predict risk of P transport to surface water (runoff/leaching)?

Using Crop Production Soil Tests as Environmental Soil Tests



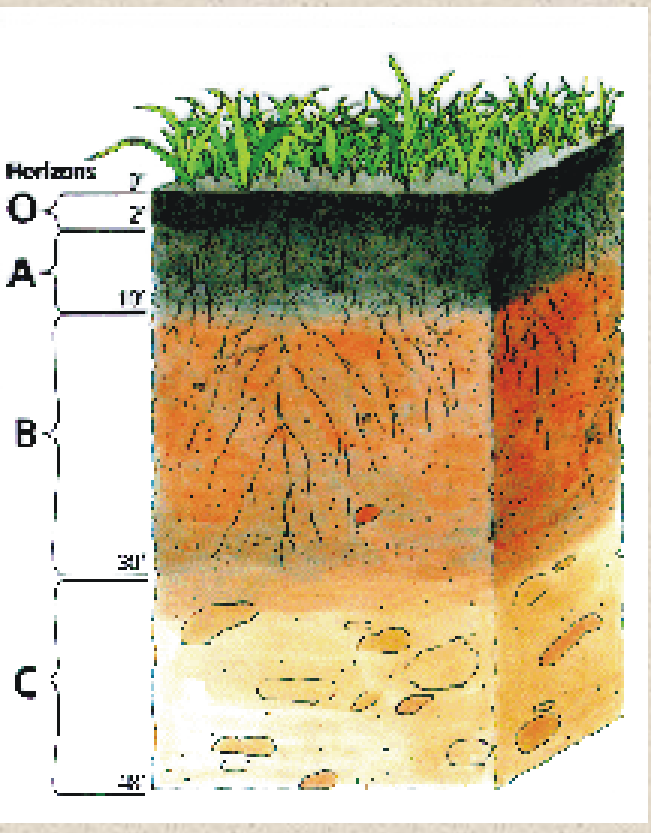
Identify soil test level "break point" where P solubility begins to increase rapidly if there is one

Set STP limit at break point to minimize soluble P

Problems: Are we confident where the break point is? What depth is the soil sampled to?

Soil Depth and P Sorption

Typical Soil Profile



A Horizon

zone of organic matter accumulation
Typically less clay than B horizon
lower P sorption than B horizon

B Horizon

zone of clay (oxide) accumulation
increase in P adsorption
decrease in soluble P

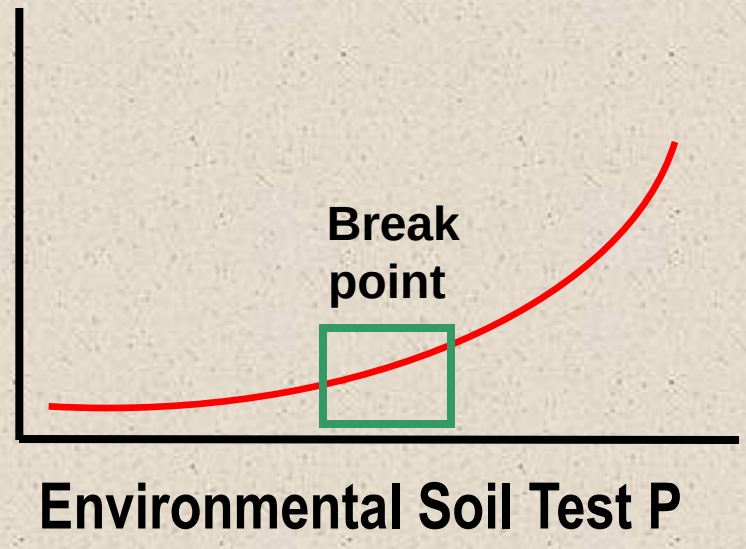
Non conservation tillage:
P incorporation 6 to 8 inch depth

Surface fertilizer application or Conservation tillage: incorporation of P (< 2 inch) more P in A horizon which has lower sorption capacity.

Potential for increased soluble P at the surface

Environmental P Soil Tests

Dissolved P
Runoff P
P leaching



Similar approach – evaluate other test methods not necessarily correlated to crop yield.

Evaluate surface (0-2 in) soil sampling vs agronomic soil sampling (0-8 in) to determine which (if either) best predicts risk of P transport (runoff / leaching)

Current and Future Research Goals

Evaluate (validate) and if necessary revise

- **P Index P source terms [Soil test P (STP), P application rate, and P application methods]**
- **Weighting/modifying factors to make P Risk Index more quantitative**
- **The threshold STP level of 150mg P/kg used in STRAP to predict P transport risk.**

Results could be directly applied toward revising Ohio P assessment tools as necessary.

Long-term experiment at:
Waterman Research Farm
Columbus, OH
no-till, silt loam

CIG: Grand Lake St Mary's:
Mercer County
Celina, OH
no-till, silt loam

GLNPO-R4 Sandusky Watershed
mixed tillage
silt loam and silty clay loam

GLNPO-R5, Robert Mullen
Maumee watershed
mixed tillage, silty clay loam

Questions??

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