Phosphorus Dynamics and Mitigation in Soils

Umass Extension - Managing Phosphorus in Organic Residuals Applied to Soils:
Composts, Biosolids, Manures and Others

November 2, 2016 - Marlborough, MA

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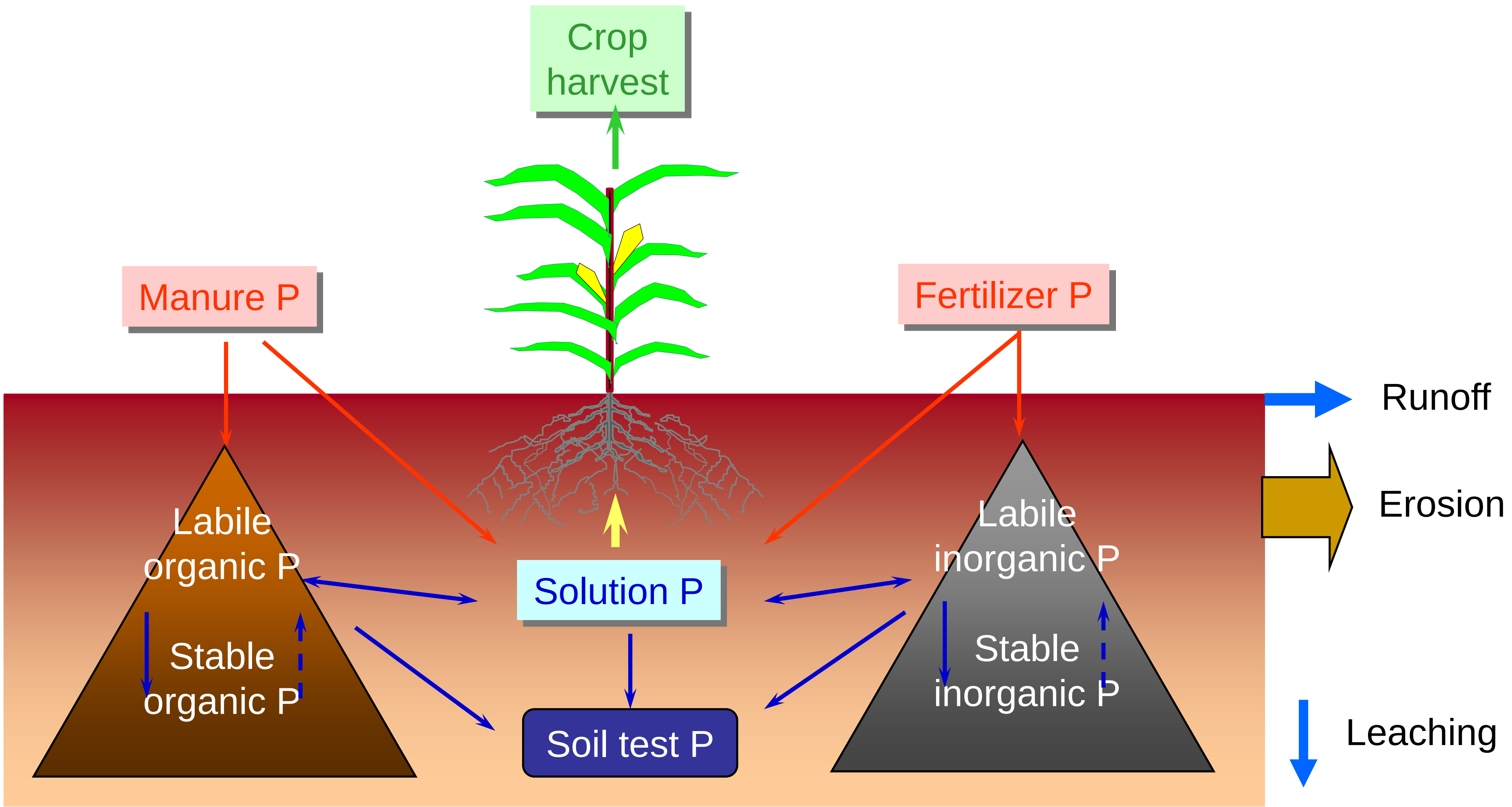
Penn State **Extension**

The Phosphorus Cycle in Soil

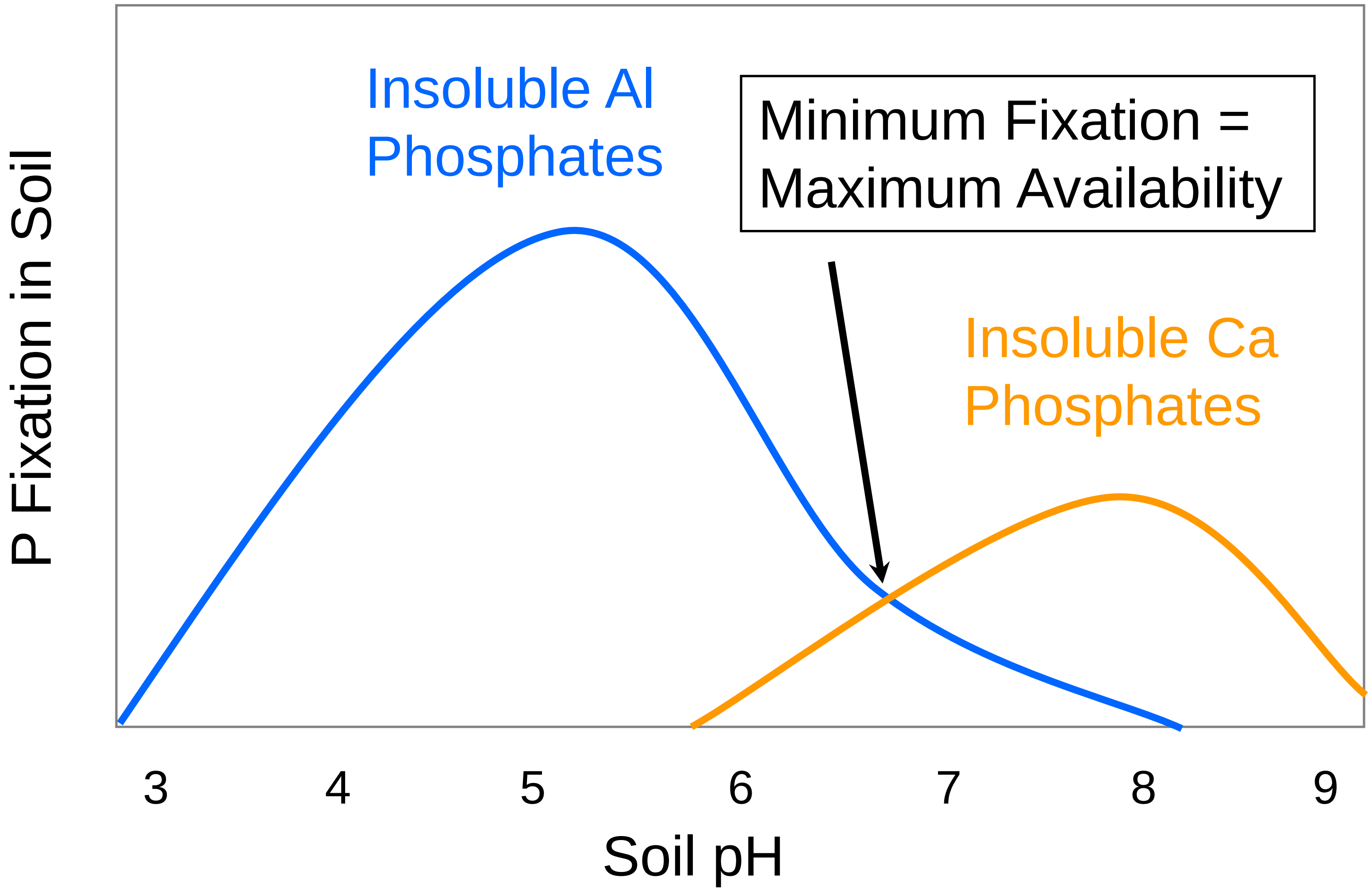


Phosphorus Availability Management

- Replenish dissolved P in soil solution ~ 500 times per year
- P is relatively immobile in the soil
- Optimum pH - 6 to 7
- Ideal soil physical properties
  - Optimum environment for microbes
  - Good root growth
    - P does not move to roots – Roots must grow to the P

Phosphorus Availability Management

Solubility of Soil P Minerals



Soil pH is a key factor in P availability

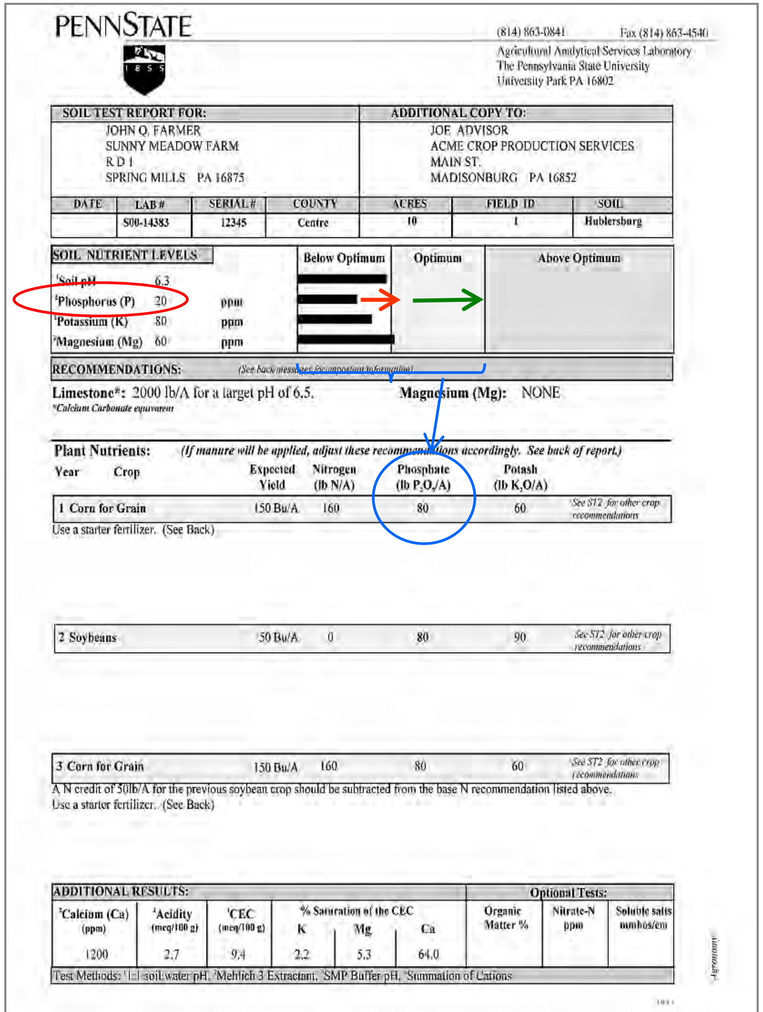
Phosphorus Availability Management

Mineralization of Organic P

- Controlled by rate of organic matter breakdown by microbial population
  - Temperature
  - Moisture
  - Soil fertility
- Average in PA ~ 8 lb P_2O_5/A/yr
- Very dependent on weather and soil physical properties

Phosphorus Availability Management

Soil Testing for Crop Production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(814) 863-0841 Fax (814) 863-4540
Agricultural Analytical Services Laboratory
The Pennsylvania State University
University Park PA 16802

SOIL TEST REPORT FOR:	ADDITIONAL COPY TO:
JOHN Q. FARMER SUNNY MEADOW FARM R D 1 SPRING MILLS PA 16875	JOE ADVISOR ACME CROP PRODUCTION SERVICES MAIN ST. MADISONBURG PA 16852

DATE	LAB #	SERIAL #	COUNTY	ACRES	FIELD ID	SOIL
	S00-14383	12345	Centre	10	1	Hublersburg

SOIL NUTRIENT LEVELS — Below Optimum / Optimum / Above Optimum

Soil pH	6.3	
Phosphorus (P)	20	ppm
Potassium (K)	80	ppm
Magnesium (Mg)	60	ppm

RECOMMENDATIONS: (See back messages for important information)

Limestone*: 2000 lb/A for a target pH of 6.5.
*Calcium Carbonate equivalent

Magnesium (Mg): NONE

Plant Nutrients: (If manure will be applied, adjust these recommendations accordingly. See back of report.)

Year	Crop	Expected Yield	Nitrogen (lb N/A)	Phosphate (lb P_2O_5/A)	Potash (lb K_2O/A)	
1	Corn for Grain	150 Bu/A	160	80	60	See ST2 for other crop recommendations
2	Soybeans	50 Bu/A	0	80	90	See ST2 for other crop recommendations
3	Corn for Grain	150 Bu/A	160	80	60	See ST2 for other crop recommendations

Year 1: Use a starter fertilizer. (See Back)

Year 3: A N credit of 50lb/A for the previous soybean crop should be subtracted from the base N recommendation listed above. Use a starter fertilizer. (See Back)

ADDITIONAL RESULTS:

Calcium (Ca) (ppm)	Acidity (meq/100 g)	CEC (meq/100 g)	% Saturation of the CEC: K	Mg	Ca	Optional Tests: Organic Matter %	Nitrate-N ppm	Soluble salts mmhos/cm
1200	2.7	9.4	2.2	5.3	64.0			

Test Methods: 1:1 soil:water pH, Mehlich 3 Extractant, SMP Buffer pH, Summation of Cations

Phosphorus Recommendations

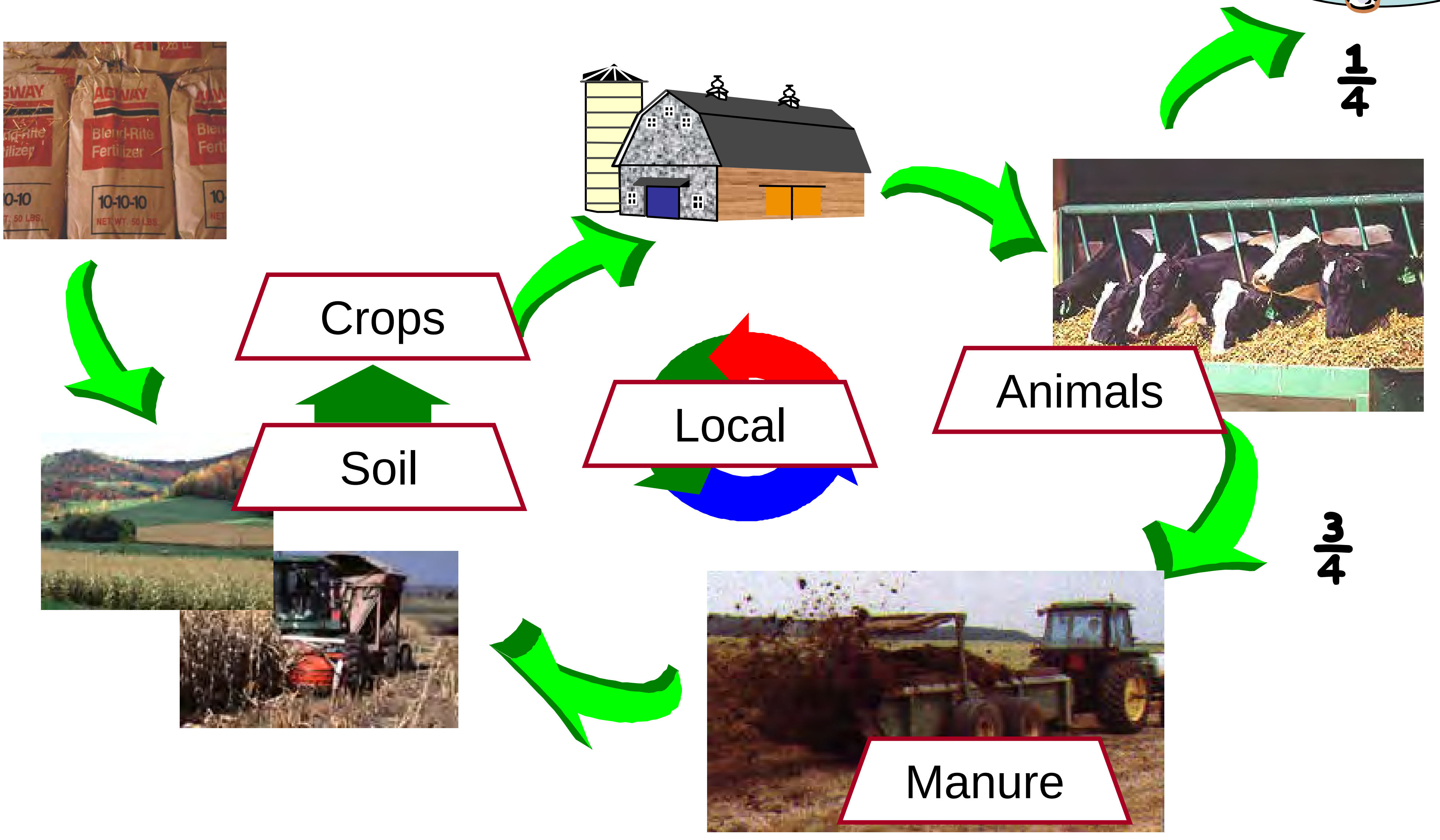
- Below Optimum
  - Buildup into optimum
  - Maintain in optimum by replacing crop removal
- Optimum
  - Maintain in optimum by replacing crop removal
- Above Optimum
  - None recommended

Phosphorus Availability Management

Sources of P for Crops

- Fertilizer P
  - Primary source is fossilized bones
  - Can be rapidly fixed in unavailable forms the soil
    - Fertilizer P only about 15% efficient
- Manure P
  - Mineral and organic
  - Short term lower availability than fertilizer
  - Long term (growing season) similar availability to fertilizer

Traditional Nutrient Cycle



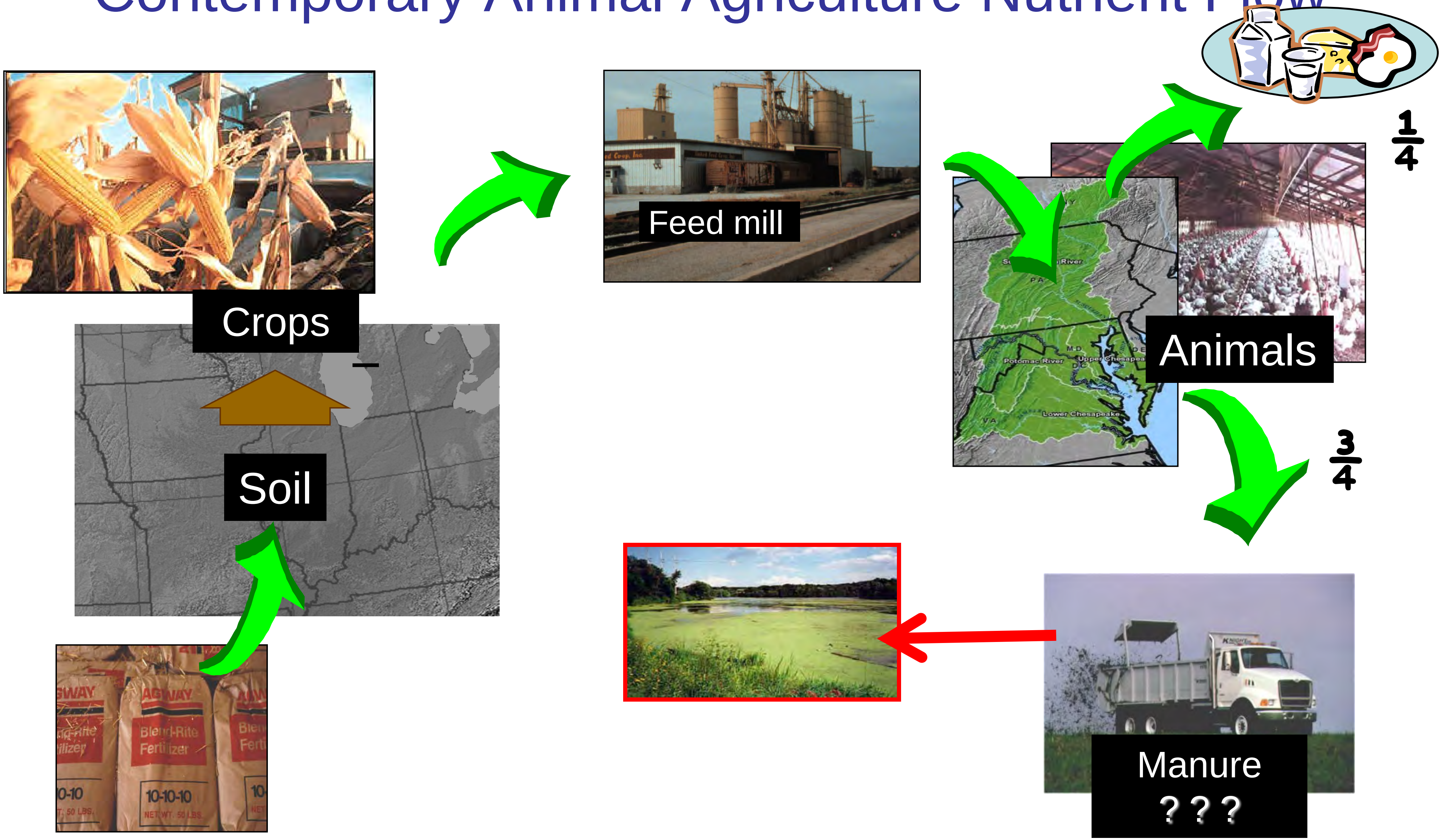
Changes to the Traditional Nutrient Cycle

- Prior to WW II, most farms relatively feed self-sufficient
  - Main source of N was legumes and manure

- Nitrate plants built for explosives in WW II
  - Converted to fertilizer production after the war
  - Enabled grain production on farms without animal manure and legumes to supply N
  - Farms did not have to be self-sufficient any more

- This lead to specialization
  - Specialization
    - Farms in the “corn belt” grew corn
    - Farms in places like PA fed that corn to animals
  - Concentration of ag industries

Contemporary Animal Agriculture Nutrient Flow



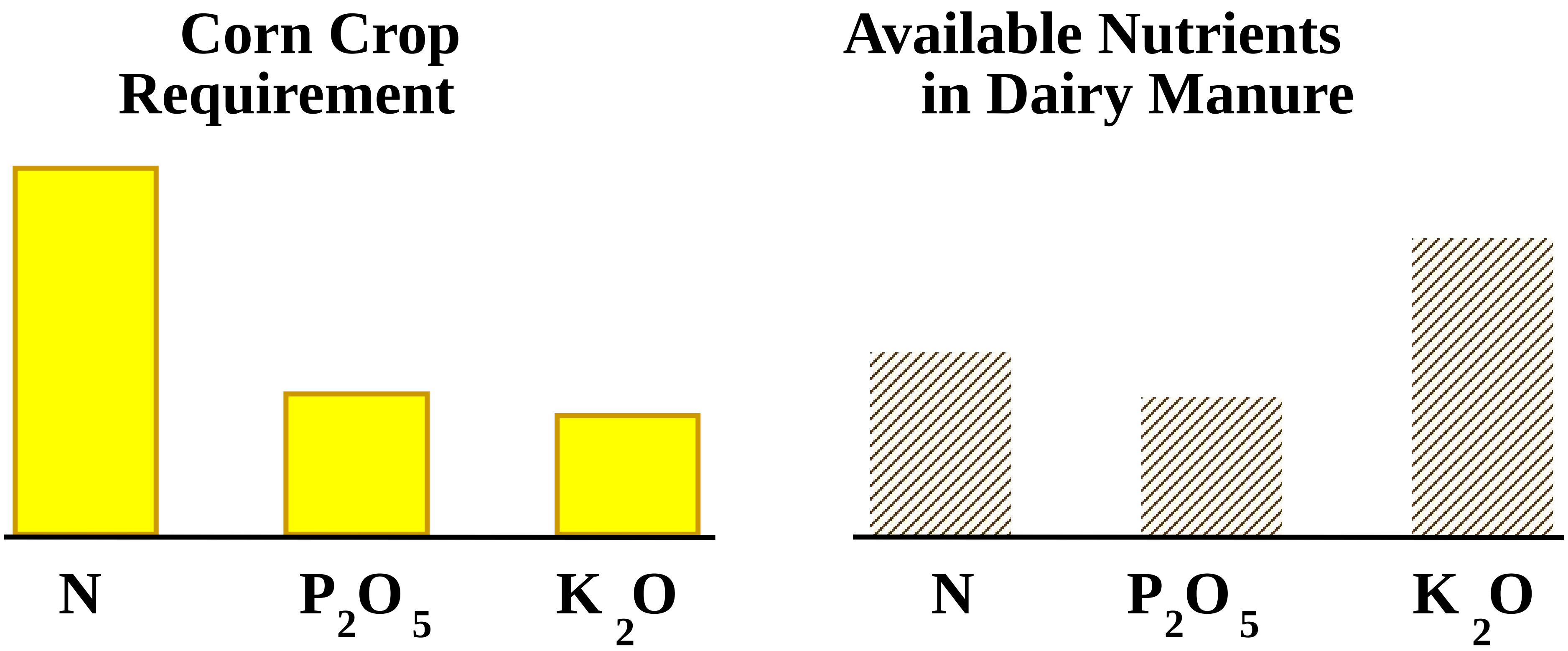
Whole Farm Nutrient Balance

Is there enough land available for manure?

- More than enough land (<1.25 AEU/A)
  - Eliminate fields with restrictions or other issues that might dictate manure applications
  - Nutrient Deficient
  - Maximize efficient utilization of manure nutrients
- Just enough land (1.25-2.25 AEU/A)
  - Nutrient Balance
  - Maximize safe utilization of manure nutrients
  - Probably need most or all of the land for manure
- Not enough (>2.25 AEU/A)
  - Nutrient Excess
  - Determined how you are going to deal with excess manure nutrients
  - Not enough land for manure – Export Manure
  - Approved nutrient management plan required if >2 AEU/A

Phosphorus Availability Management

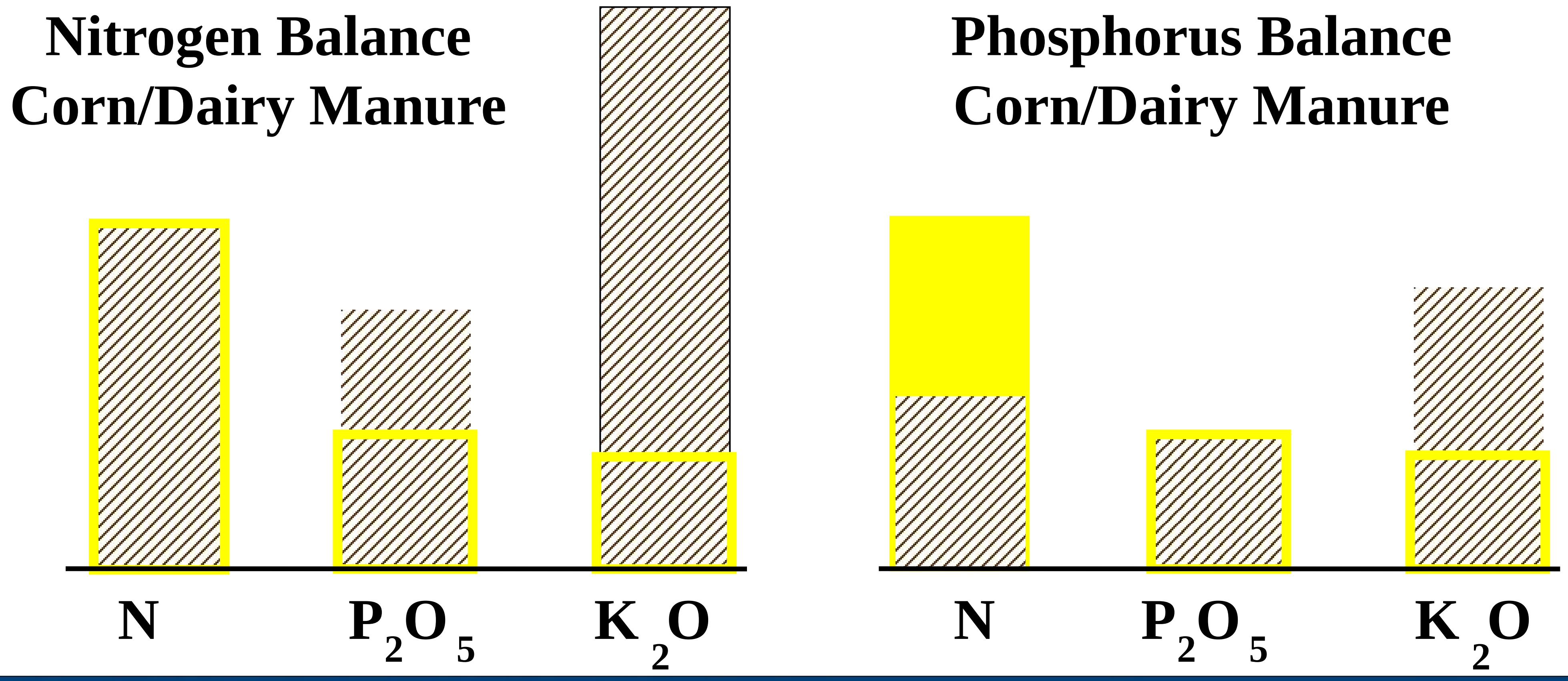
Farm Nutrient Imbalances



Phosphorus Availability Management

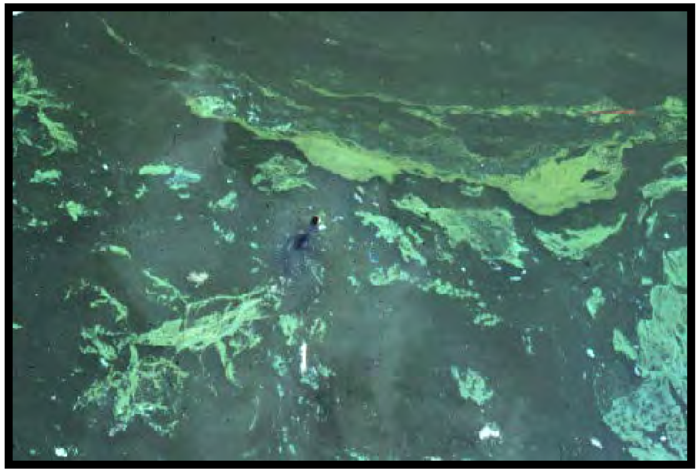
Farm Nutrient Imbalances

Mismatch between manure nutrients and crop requirements

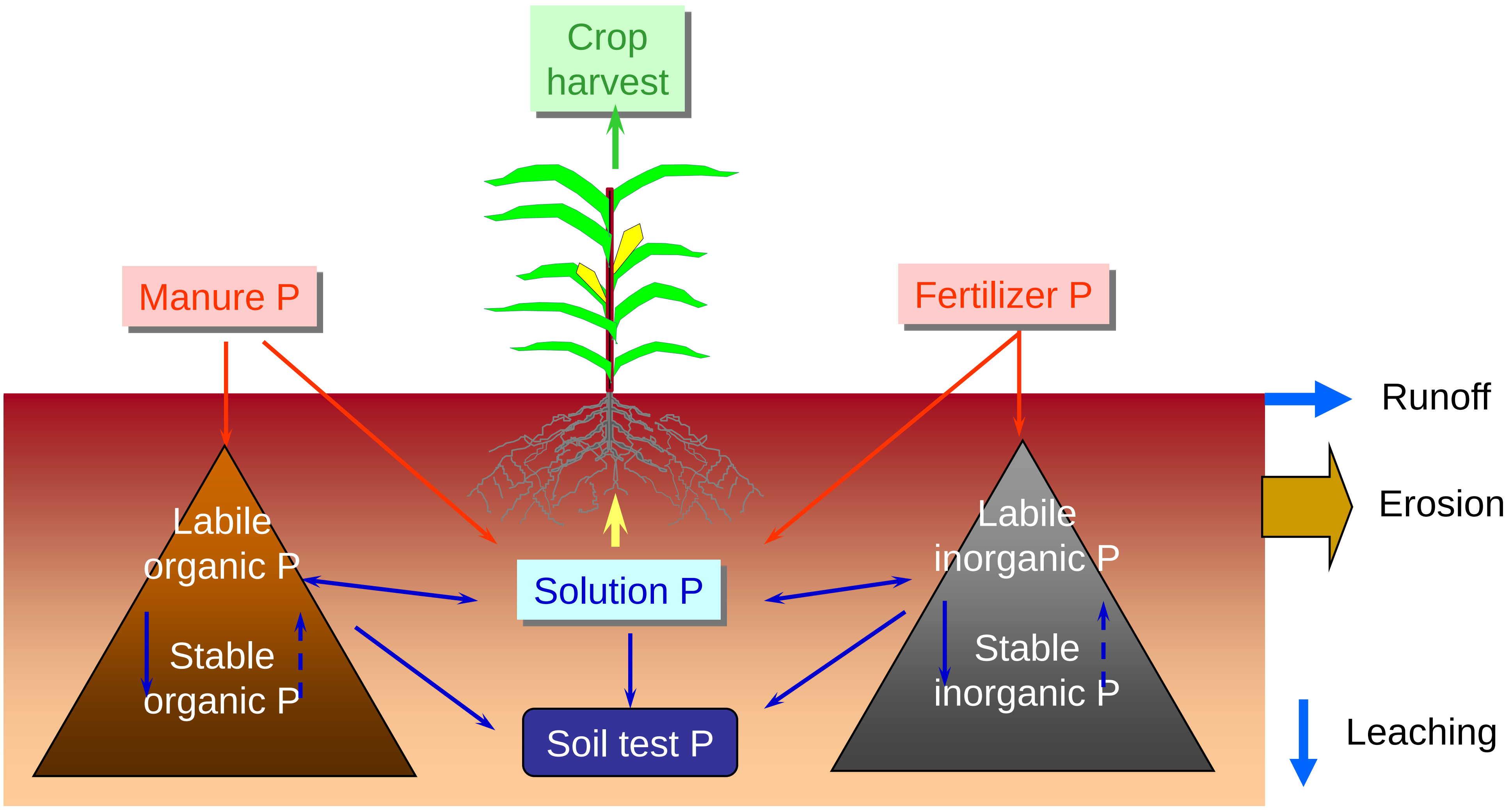


Phosphorus in the Environment

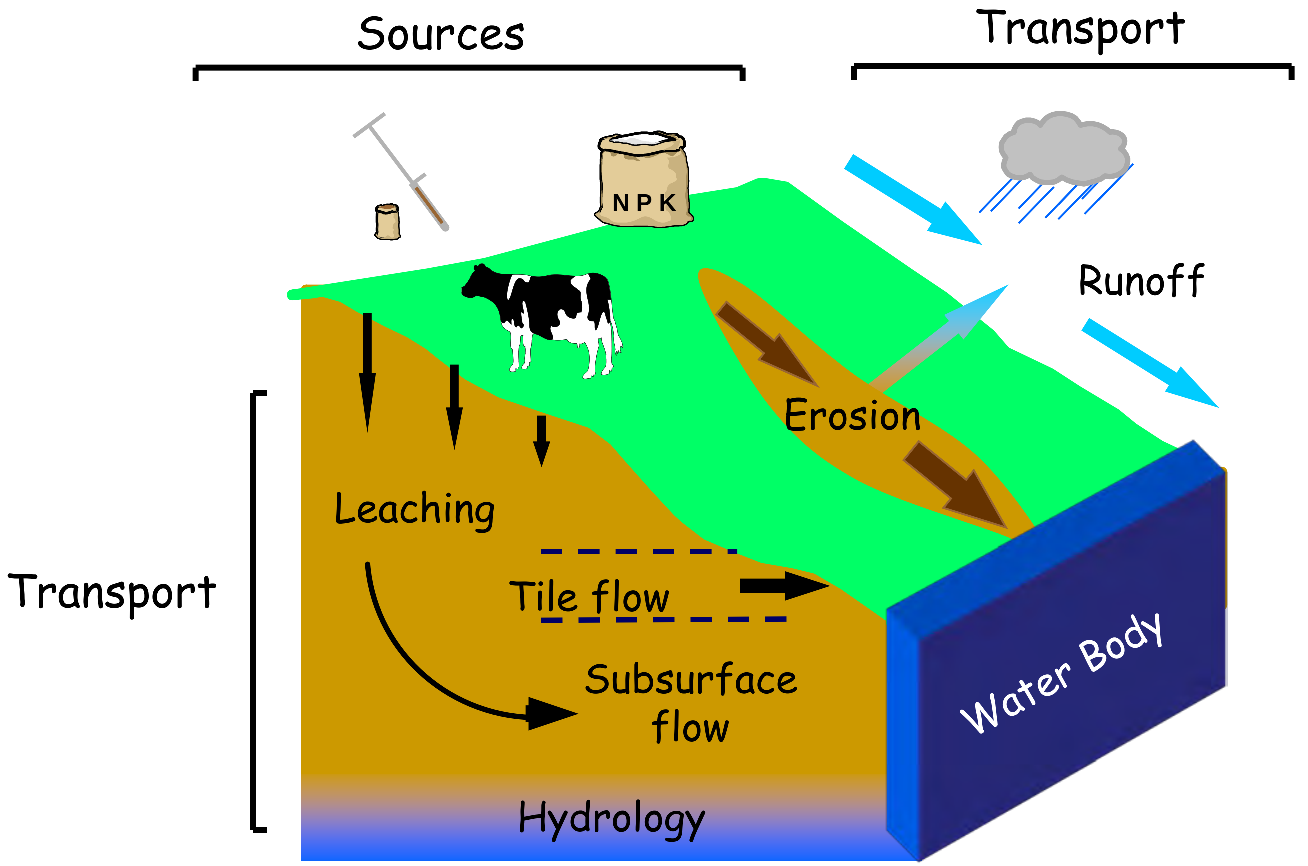
- P is an essential element for plants and animals
- High P is generally non-toxic to plants or animals
- **P causes accelerated eutrophication**
  - **Crop P Requirement = 0.2 mg/L in soil solution**
  - **Common lake eutrophication level = 0.02 mg/L**



The Phosphorus Cycle in Soil



Phosphorus Source and Transport



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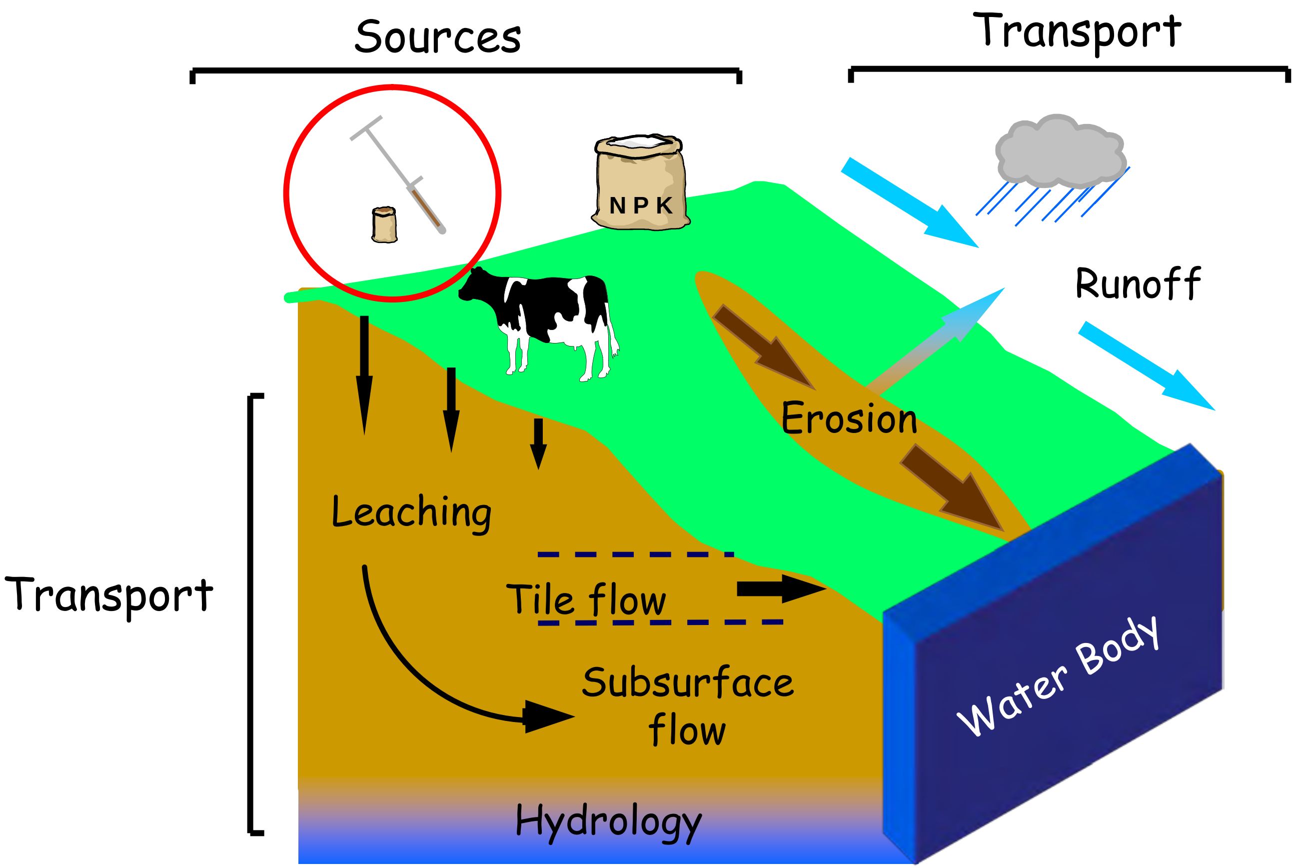
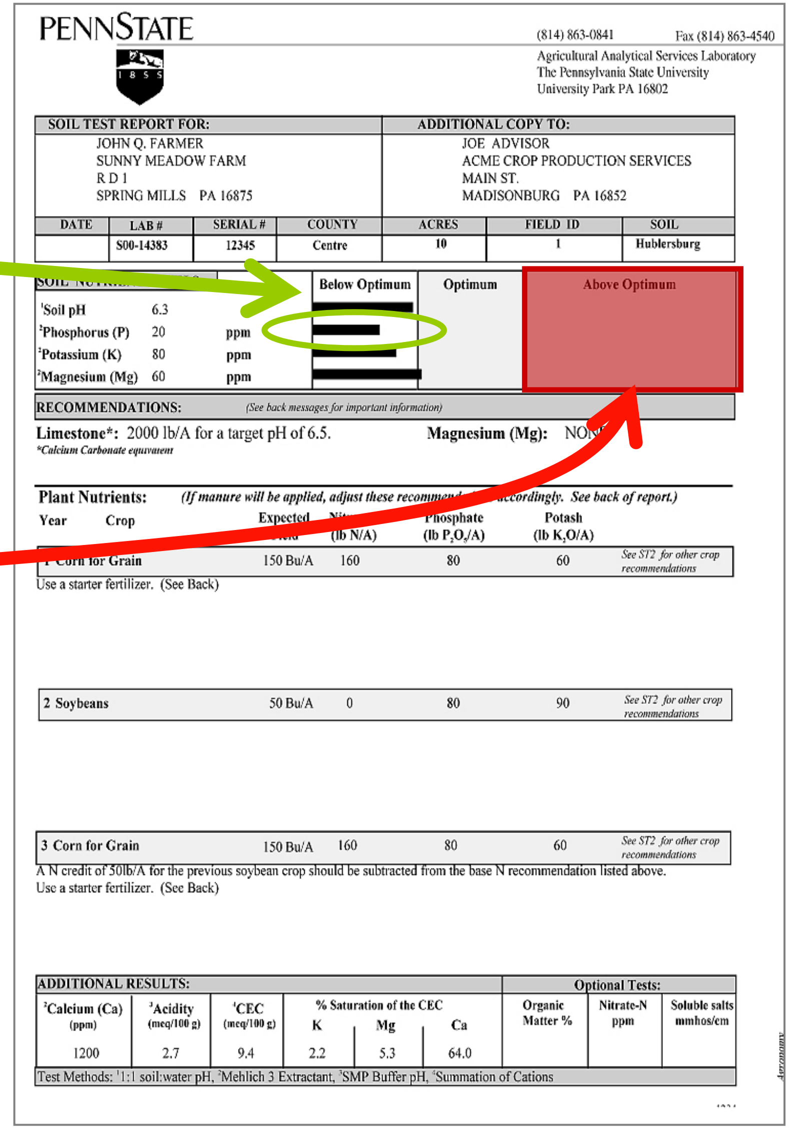


Phosphorus Source and Transport

Soil Test P

- Soil test interpretations are based on crop response
- Does not consider water quality critical levels
- Assumes: “Above Optimum” = “Polluting”
- Not a valid assumption
- What is the actual “polluting” level?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			Below Optimum	Optimum	Above Optimum
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RECOMMENDATIONS: *(See back messages for important information)*

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Calcium Carbonate equivalent

Plant Nutrients: *(If manure will be applied, adjust these recommend... accordingly. See back of report.)*

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Year 1: Use a starter fertilizer. (See Back)

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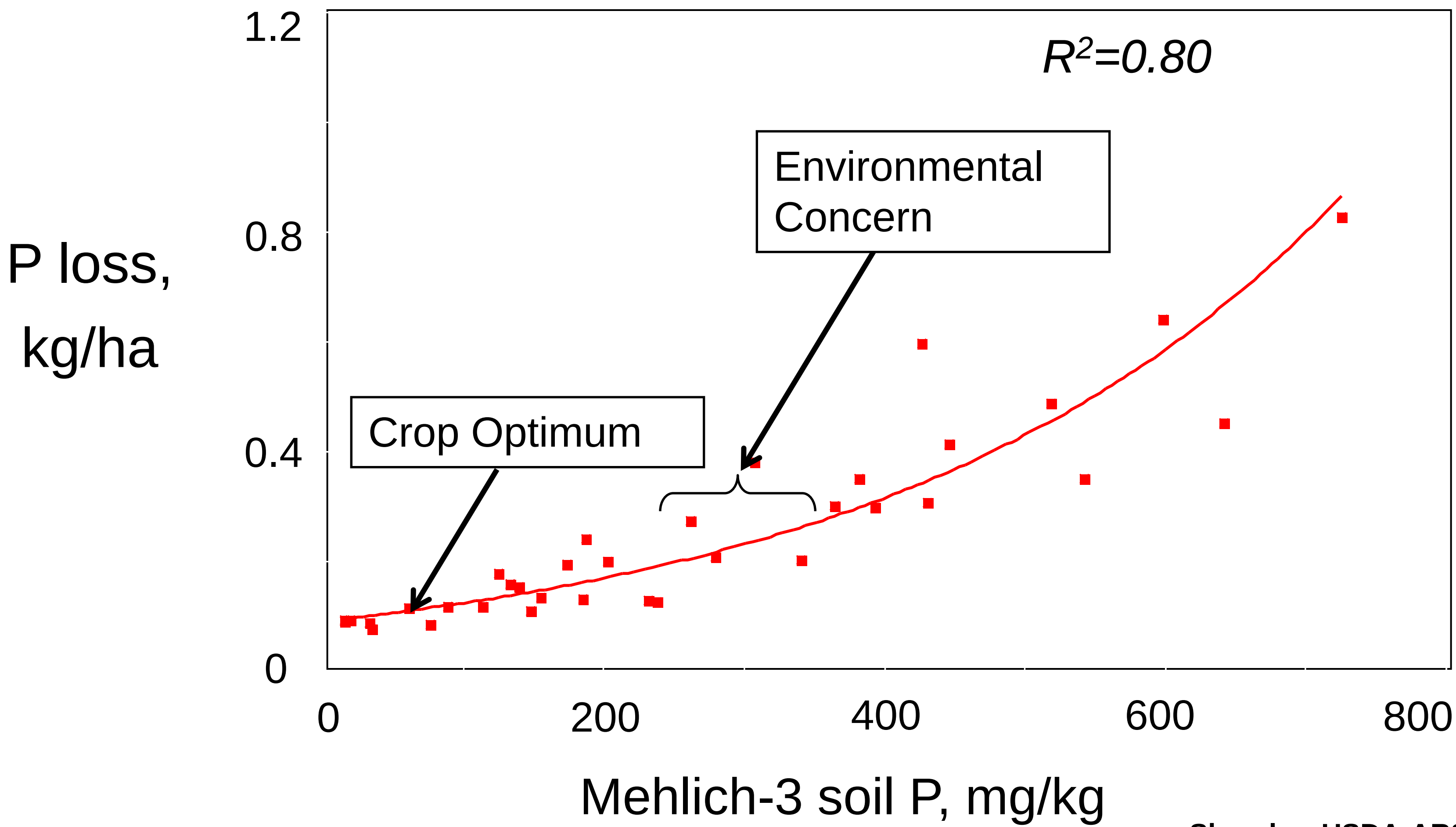
ADDITIONAL RESULTS: / Optional Tests:

[2]Calcium (Ca) (ppm)	[3]Acidity (meq/100 g)	[4]CEC (meq/100 g)	% Saturation of the CEC: K	Mg	Ca	Organic Matter %	Nitrate-N ppm	Soluble salts mmhos/cm
1200	2.7	9.4	2.2	5.3	64.0			

Test Methods: [1]1:1 soil:water pH, [2]Mehlich 3 Extractant, [3]SMP Buffer pH, [4]Summation of Cations

Phosphorus Source and Transport

Soil Test P – Environmental Thresholds

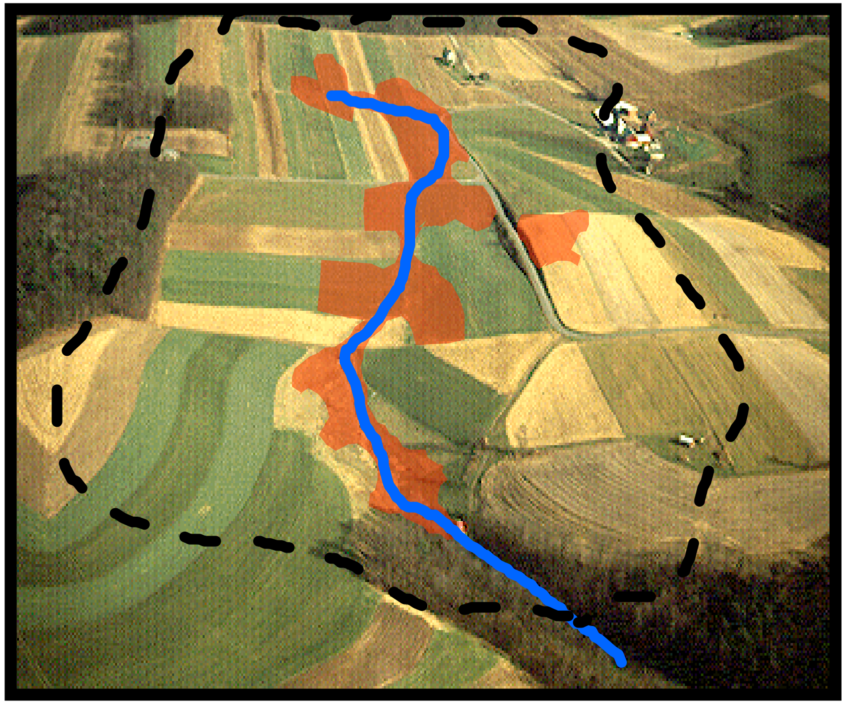


Sharpley, USDA-ARS

Phosphorus Source and Transport

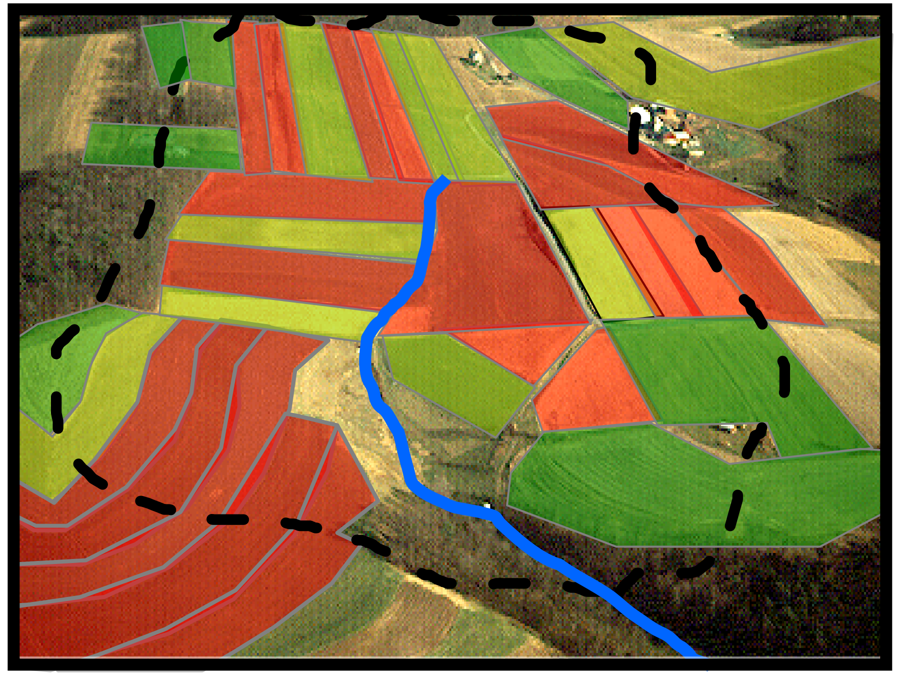
Soil Test P and Areas of P Loss

Areas of P Loss



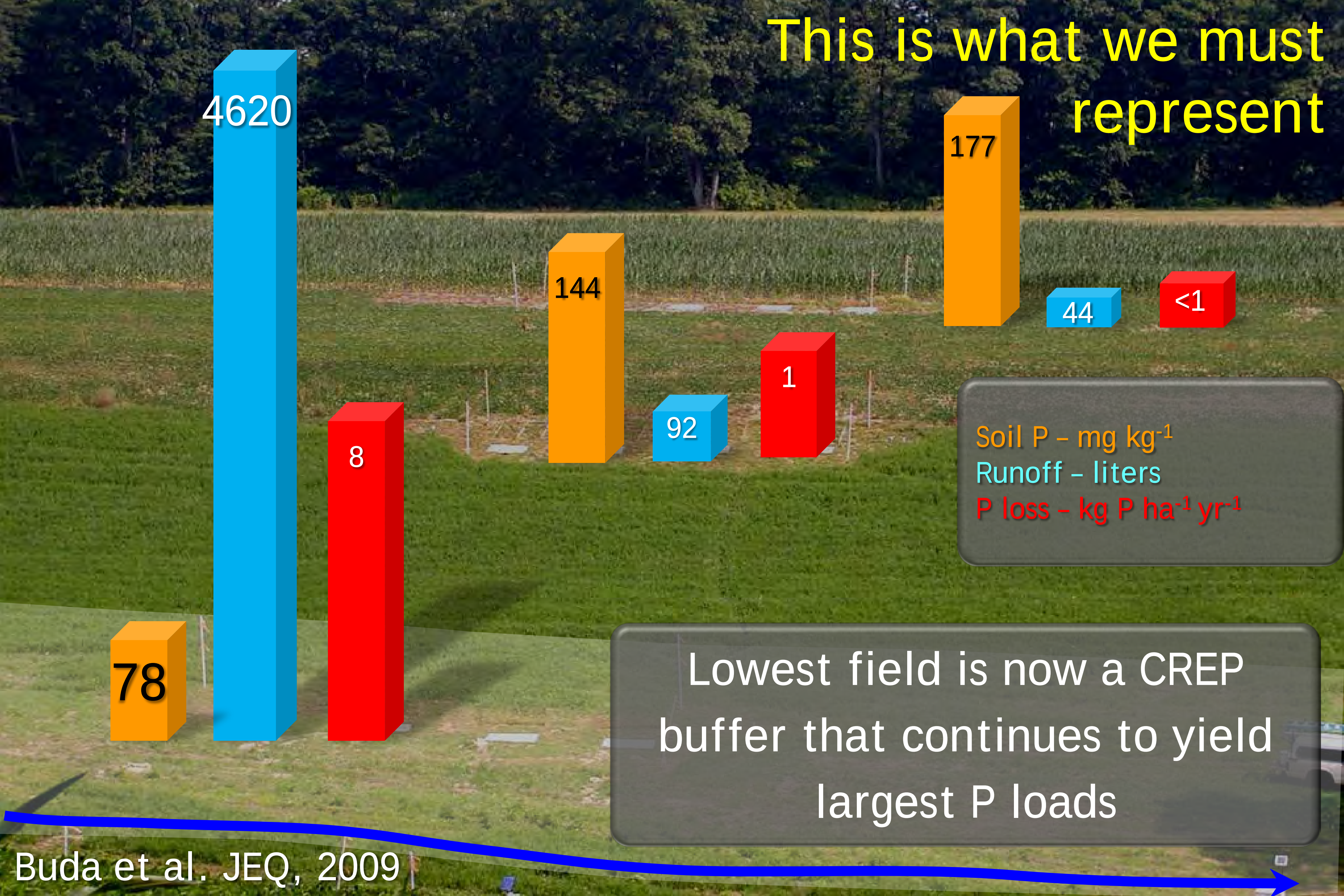
High P loss

P Soil Test



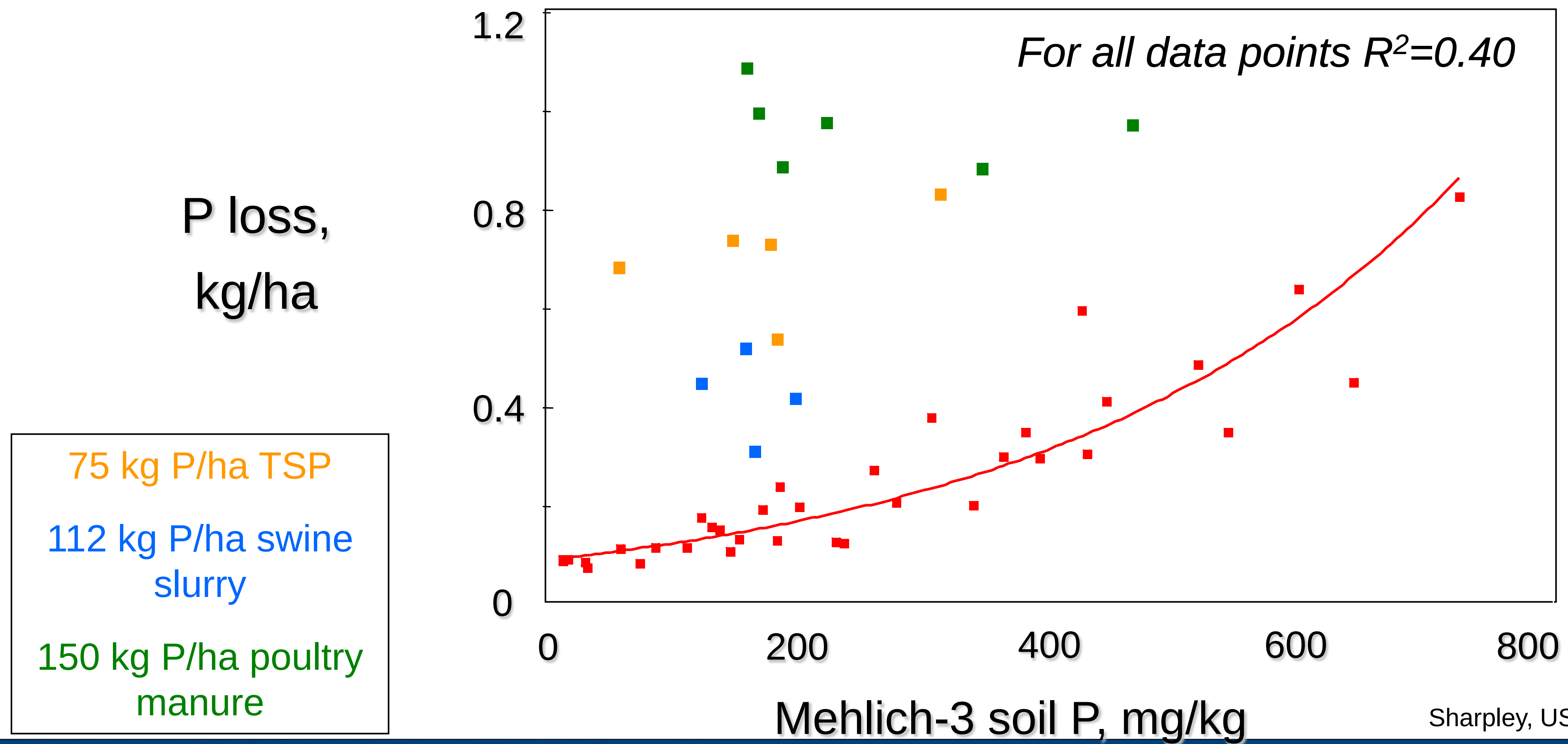
Low Med High

Adapted from Sharpley, USDA-ARS


This is what we must represent
78
4620
8
144
92
1
177
44
<1
Soil P – mg kg-1
Runoff – liters
P loss – kg P ha-1 yr-1
Lowest field is now a CREP buffer that continues to yield largest P loads
Buda et al. JEQ, 2009

Phosphorus Source and Transport

Soil Test P vs P Loss – with applied P

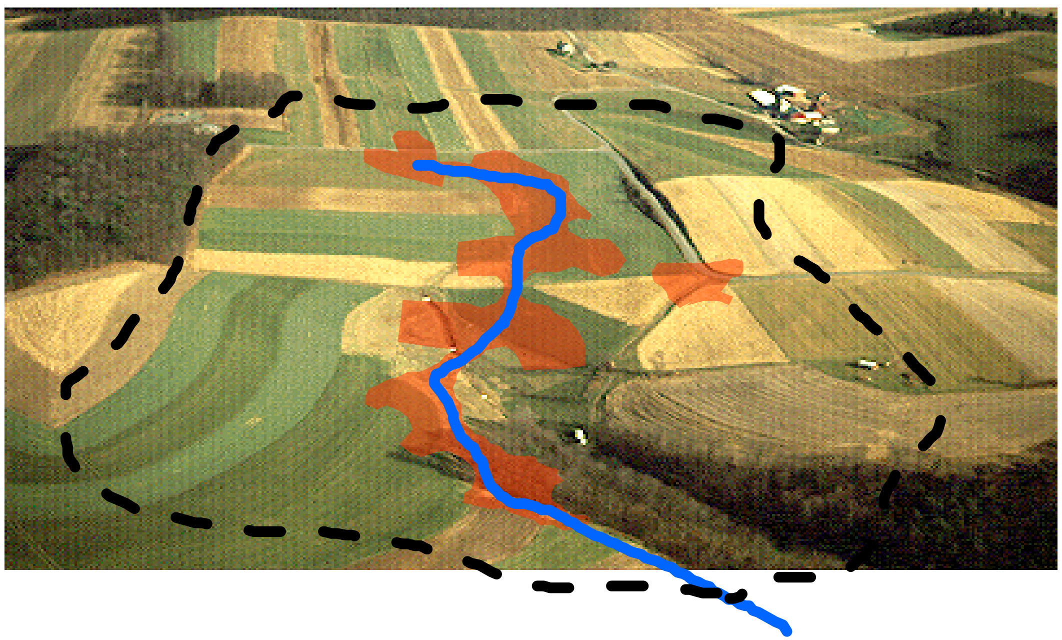


Sharpley, USDA-ARS

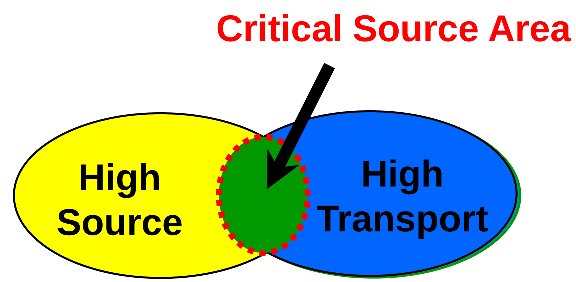
Phosphorus Source and Transport

Critical Source Area Management

- Overlap of high source and high transport
- Identify and manage those critical areas based on P
- Integrates all sources and all modes of transport
- Phosphorus Index - Tool that evaluates source and transport to estimate P loss risk



90% of the P comes from about 10% of the area



Pennsylvania P source factors - management based

- Soil P content
- Fertilizer P – rate, method, timing
- Organic P – rate, method, timing, availability coefficient

Pennsylvania P transport factors – landscape based

- Erosion potential
- Runoff potential
- Sub-surface drainage
- Connectivity to stream channel

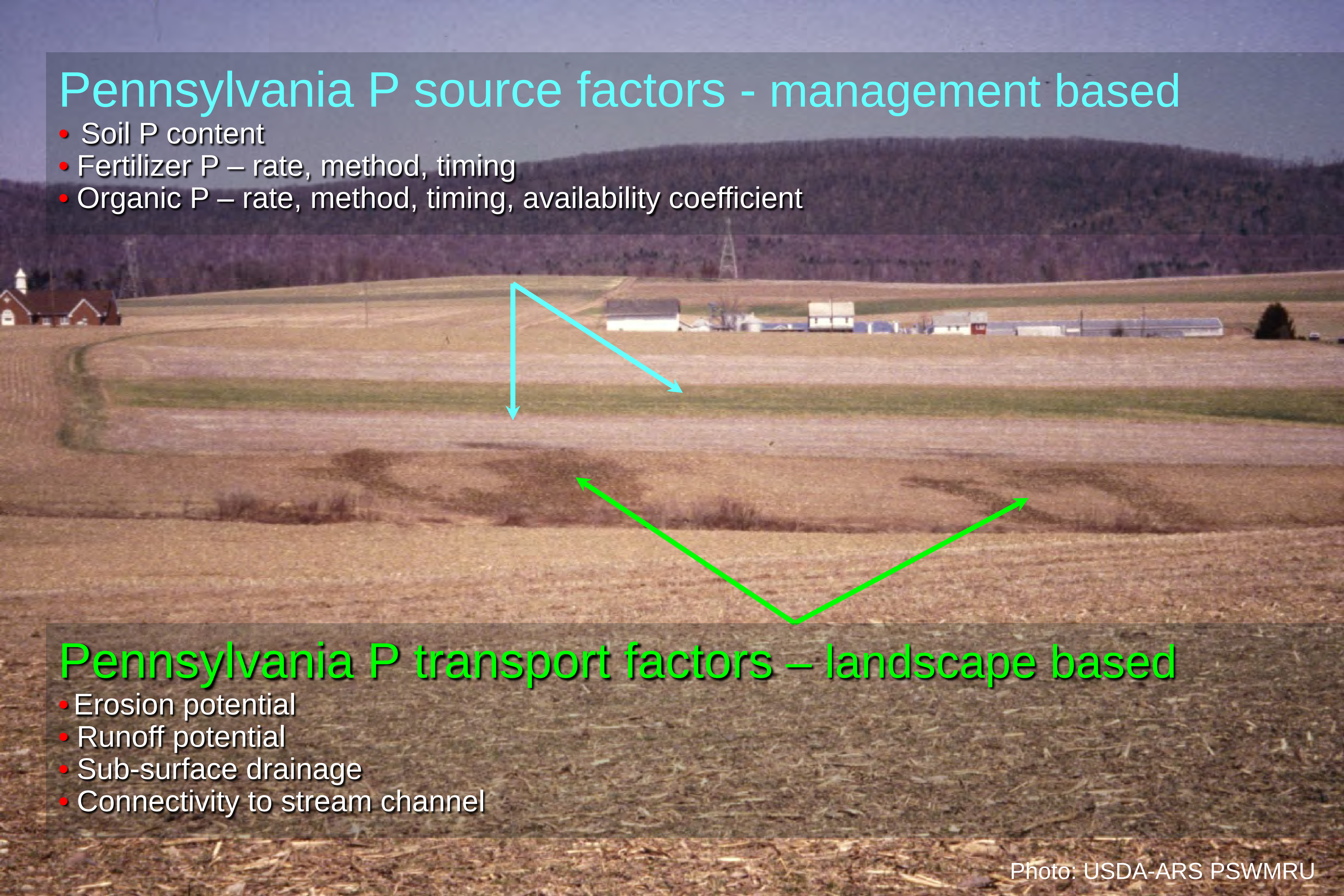


Photo: USDA-ARS PSWMRU

PA Phosphorus Index

Version 2

Low P Index
N Based Management

Medium P Index
N Based Management

High P Index
P Based: Crop removal

Very High P Index
No P: Manure or Fertilizer

PART A: SCREENING TOOL

		Field ID
Is the CMU in a Special Protection Watershed?	If the answer is yes to any of these questions Part B must be used.	
Is there a significant farm management change as defined by Act 38?		
Is the Soil Test Mehlich-3 P greater than 200 ppm P?		
Is the contributing distance from this CMU to water less than 150 ft.?		

PART B: SOURCE FACTORS

						Field ID
SOIL TEST	Mehlich-3 Soil Test P (ppm P)					
	Soil Test Rating = 0.20* Mehlich-3 Soil Test P (ppm P)					
FERTILIZER P RATE	Fertilizer P (lb P_2O_5/acre)					
FERTILIZER APPLICATION METHOD	0.2 Placed or injected 2" or more deep	0.4 Incorporated <1 week following application	0.6 Incorporated > 1 week or not incorporated following application in April - October	0.8 Incorporated >1 week or not incorporated following application in Nov. - March	1.0 Surface applied to frozen or snow covered soil	
	Fertilizer Rating = Fertilizer Rate x Fertilizer Application Method					
MANURE P RATE	Manure P (lb P_2O_5/acre)					
MANURE APPLICATION METHOD	0.2 Placed or injected 2" or more deep	0.4 Incorporated <1 week following application	0.6 Incorporated > 1 week or not incorporated following application in April - October	0.8 Incorporated >1 week or not incorporated following application in Nov. - March	1.0 Surface applied to frozen or snow covered soil	
MANURE P AVAILABILITY	Refer to: Test results for P Source Coefficient OR Book values from P Index Fact Sheet Table 1					
	Manure Rating = Manure Rate x Manure Application Method x Manure P Availability					
				Source Factor Sum		

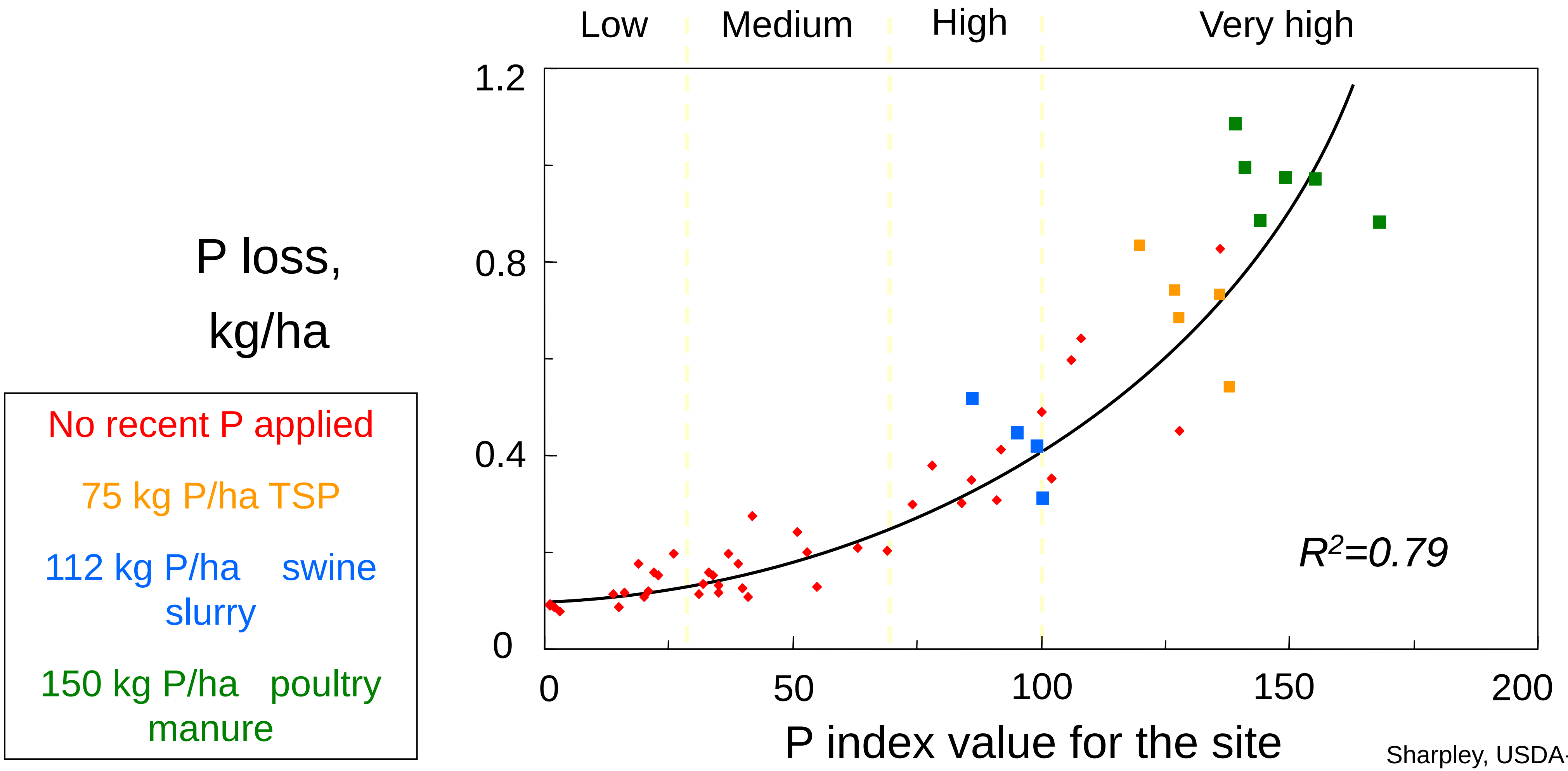
PART B: TRANSPORT FACTORS

						Field ID
EROSION	Soil Loss (ton/A/yr)					
RUNOFF POTENTIAL	0 Excessively	2 Somewhat Excessively	4 Well/Moderately Well	6 Somewhat Poorly	8 Poorly/Very Poorly	
SUBSURFACE DRAINAGE	0 None		1 Random		2* Patterened	
CONTRIBUTING DISTANCE	0 > 500 ft.	2 350 to 500 ft.	4 200 to 349 ft.	6 100 to 199 ft. OR <100 ft. with 35 ft. buffer	$9^{\ddagger}$ < 100 ft.	
	Transport Sum = Erosion+ Runoff Potential + Subsurface Drainage + Contributing Distance					
MODIFIED CONNECTIVITY	0.85 50 ft. Riparian Buffer APPLIES TO DIST < 100 FT		1.0 Grassed Waterway or None		1.1 Direct Connection APPLIES TO DIST > 100 FT	
			Transport Sum x Modified Connectivity/24			
			P Index Value = 2 x Source x Transport			

* OR rapid permeability soil near a stream
‡ "9" factor does not apply to fields with a 35 ft. buffer receiving manure.

Phosphorus Source and Transport

P Index describes P loss potential



Sharpley, USDA-ARS

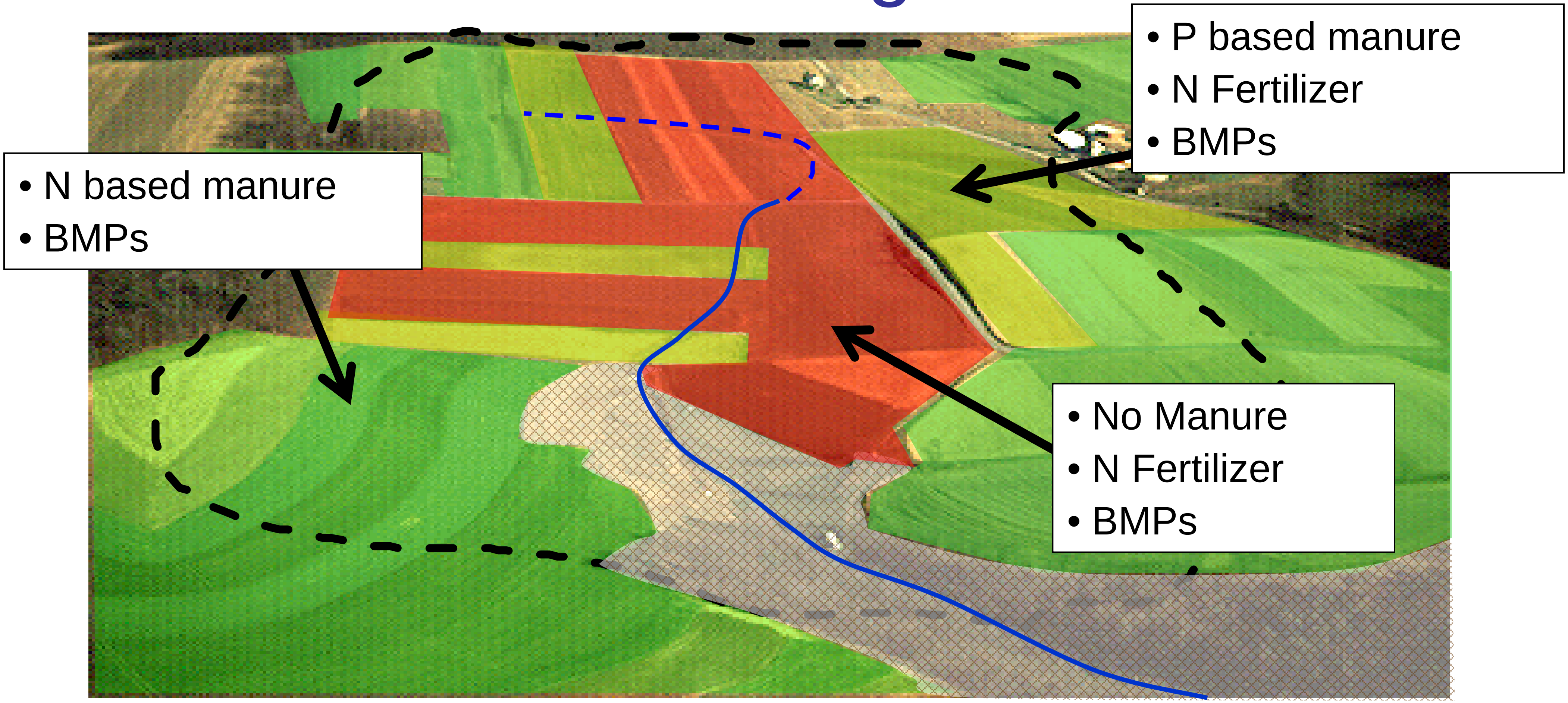
Phosphorus Index

- Low P Index
  - N Based Management
- Medium P Index
  - N Based Management
- High P Index*
  - P Based: Crop removal
- Very High P Index*
  - No P: Manure or Fertilizer

<u>High and Very High</u>*

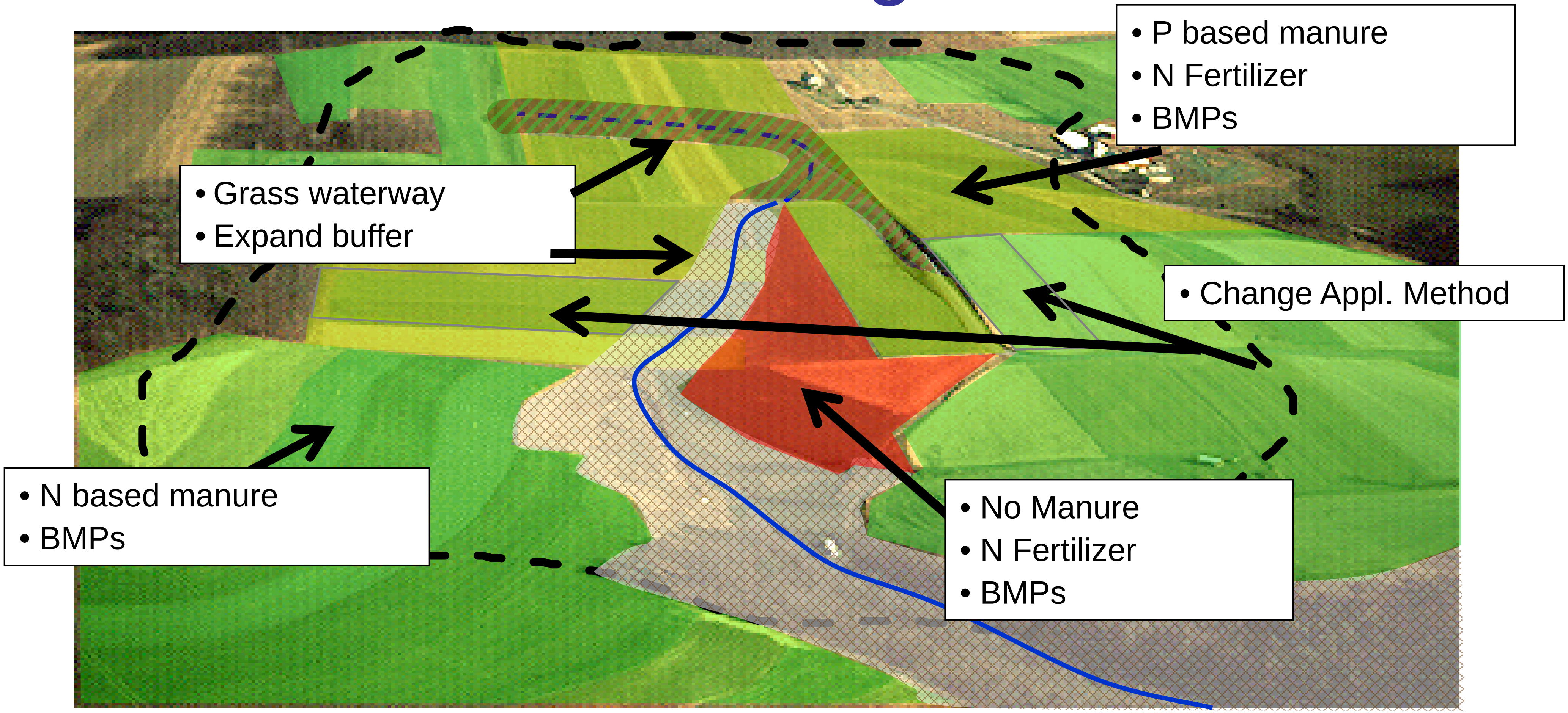
- Management Options
- Modify Management based on P
  - No or reduced manure
  - Change time or method of application
  - Conservation practices
  - etc

P Index Based Management



P Index: Low/Medium High Very High

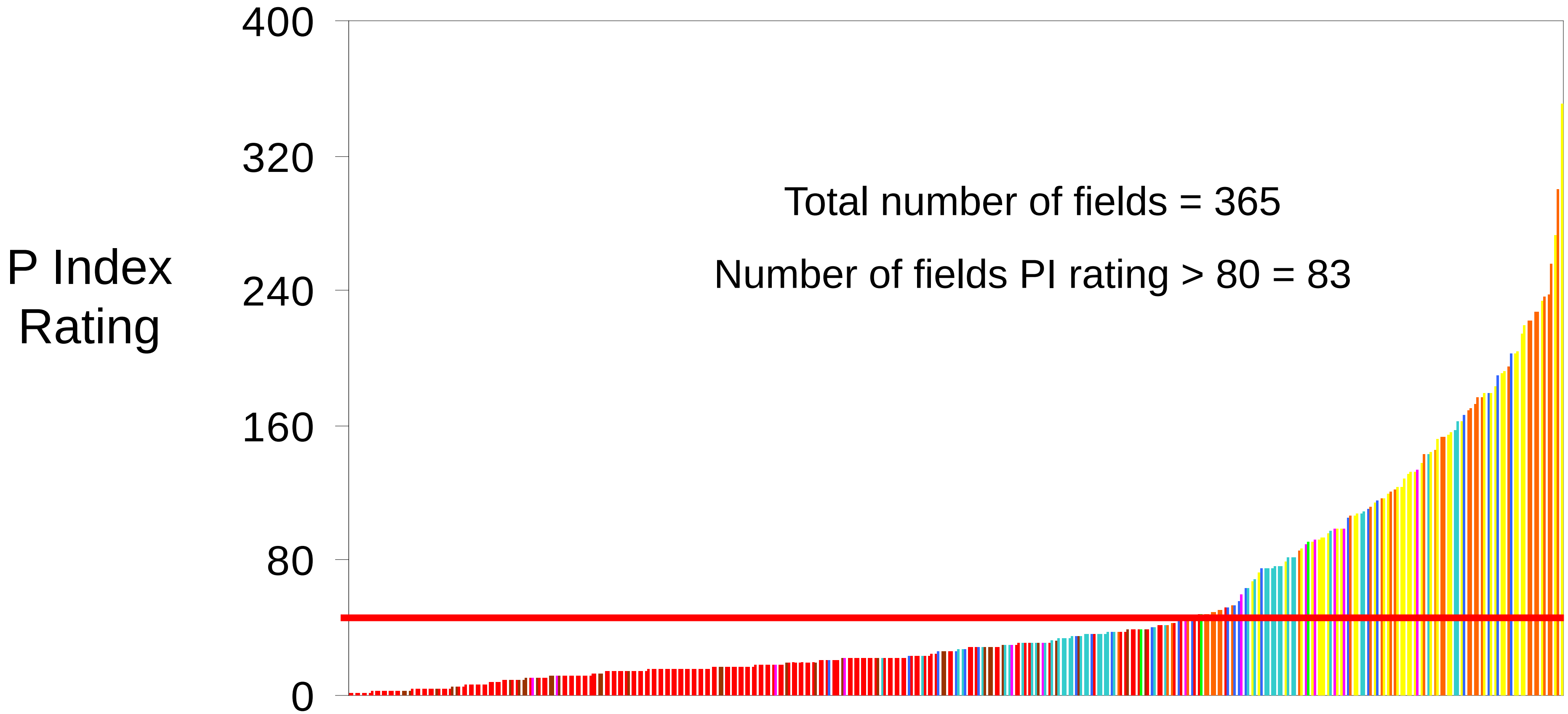
P Index Based Management



P Index: Low/Medium High Very High

P Index Rating Distribution

Based on results from 11 Farms of different types across PA



Weld et al., 2002

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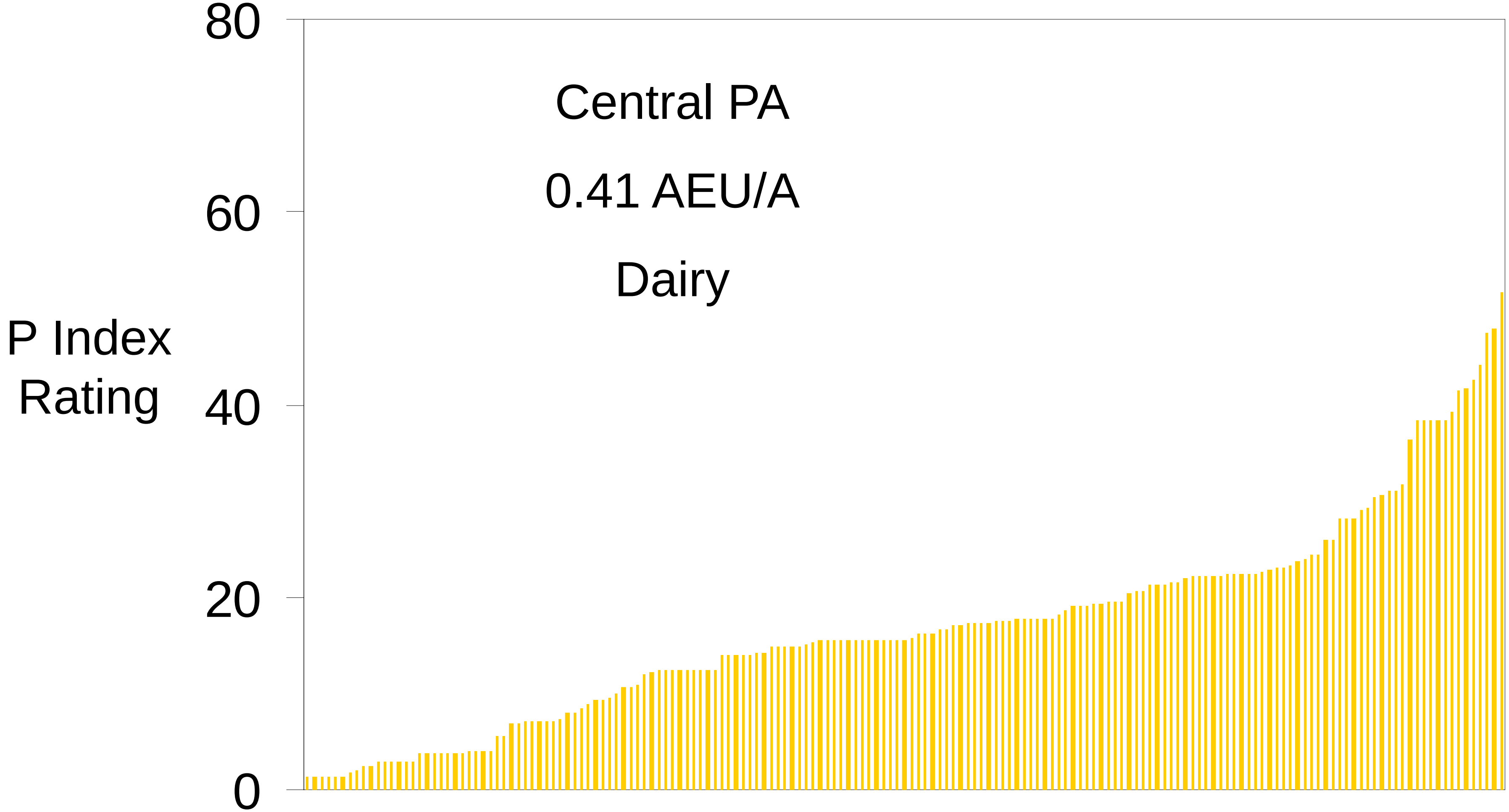

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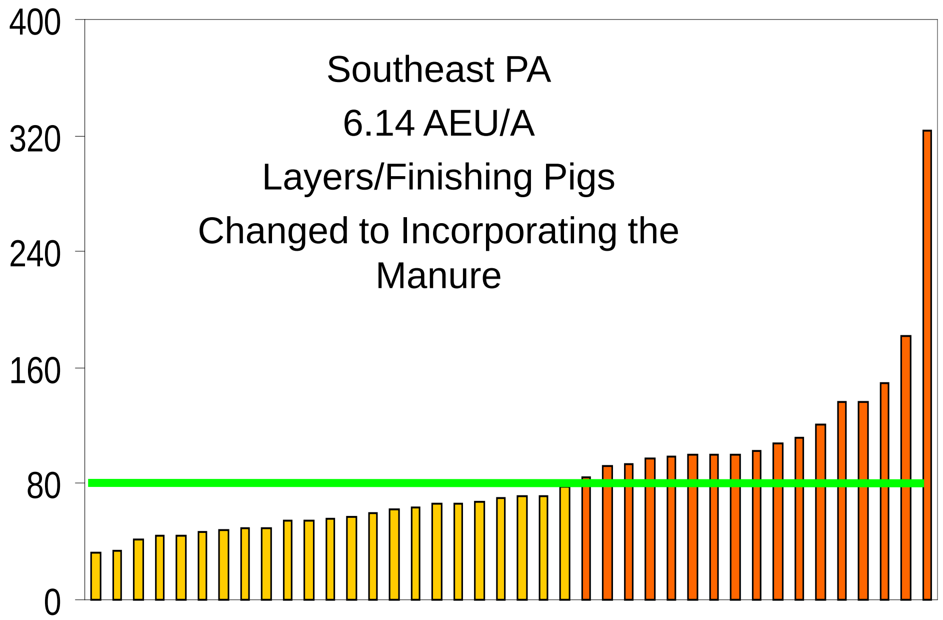

Weld et al., 2002

Phosphorus Index

- Relatively simple indication of the relative risk of P loss
  - Targets management resources
- Applied to farm field or management unit
- Assesses P implications of the N based plan
- Not just a yes or no answer
  - Indicates relative impact of risk factors
  - Provides guidance for management action
- Provides management flexibility
- Does not solve the nutrient problem just helps avoid immediate problems

Summary

- Environmental problems with P from Ag have become a major national issue
- Balancing P cycles is critical for long term
- Short term - Critical Source Area Management
  - P Index emphasizes combining source and transport
- P Based planning implementation
  - State regulations using P Index based planning
  - EPA - AFO/CAFO using P Index
  - NRCS requires P Index based planning – 590 Std.
  - Very active area of research


USDA-ARS PSWMRU