SOIL P-INDEXES: MINIMIZING PHOSPHORUS LOSS

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Penn State & USDA-ARS

Part of a larger national effort to improve the P Index and P Management

Chesapeake Bay Watershed: "Refining and Harmonizing Phosphorus Indices in the Chesapeake Bay Region"

- The Penn State University, University Park, PA.

Heartland Region: "Validate, Improve and Regionalize Phosphorus Indices"

- University of Missouri, Columbia, MO.

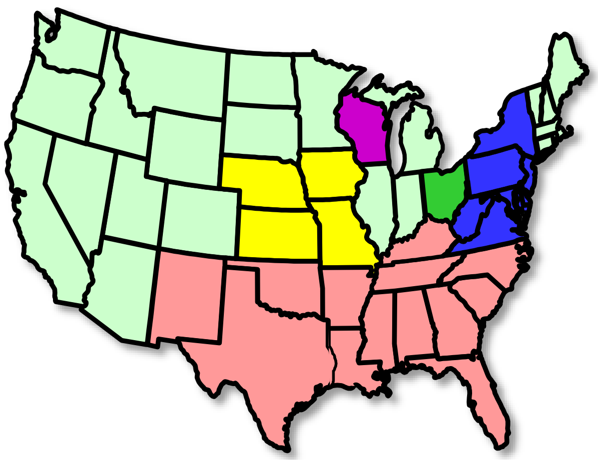
Southern Region: "Refine and Regionalize Southern Phosphorus Assessment Tools"

- North Carolina State University, Raleigh, NC.

National Coordinating Activity: "Synthesize and Extend Lessons and Outcomes from Regional Indexing Efforts"

- University of Arkansas, Fayetteville, AR.

2012 NRCS Conservation Innovation Grants

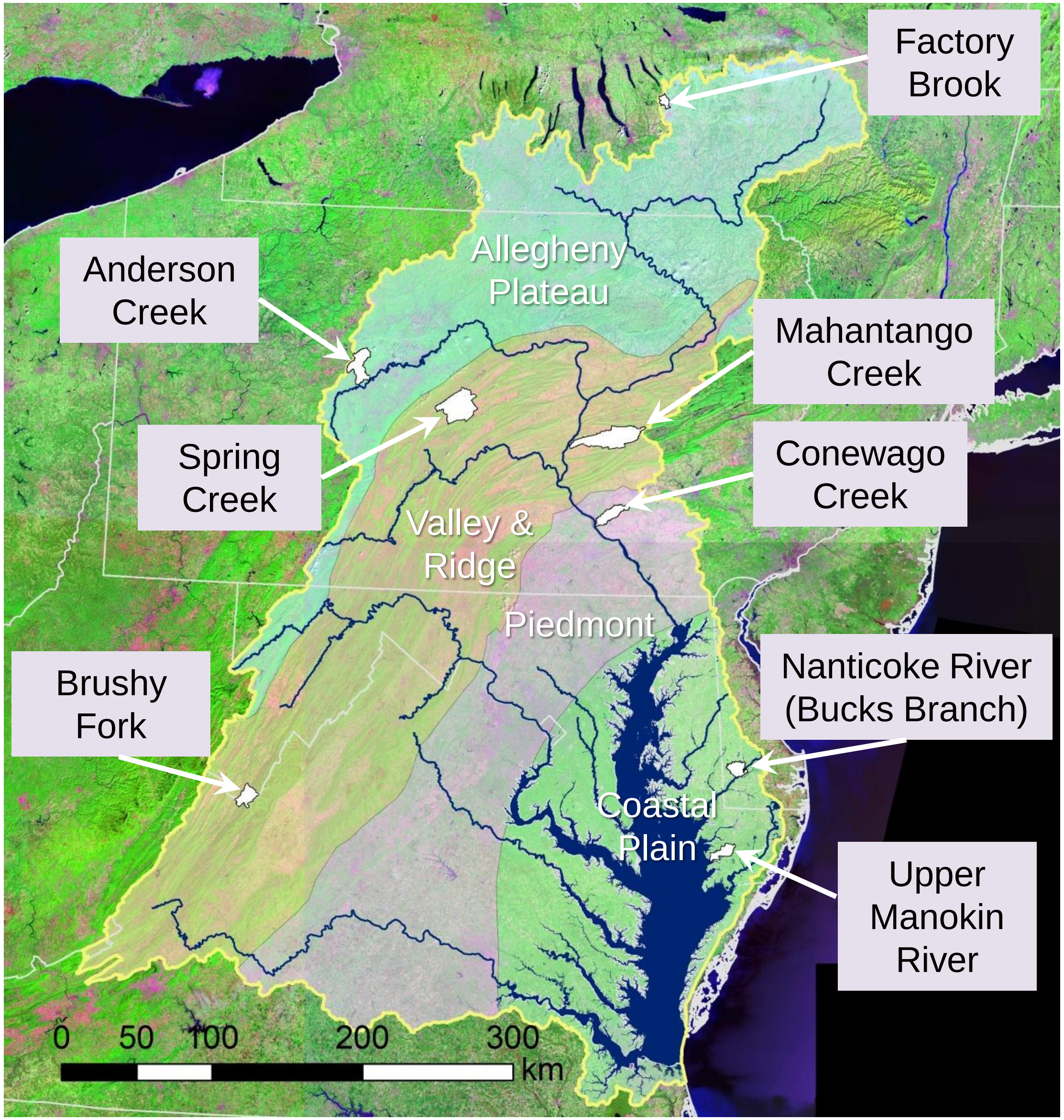


- ***CB Project Collaborators***
  - ***Penn State University***
  - ***USDA-ARS PSWMRU***
  - ***University of Maryland***
  - ***University of Maryland Eastern Shore***
  - ***University of Delaware***
  - ***Cornell University***
  - ***Virginia Tech University***
  - ***West Virginia University***
  - ***USDA-NRCS and USGS***

Objectives:

- Establish a network of nine watersheds within the four major physiographic provinces of the Bay watershed for foundational evaluation of nutrient management site assessment tools.
- For each physiographic province, identify site conditions and practices of priority concern and corresponding remedial practices of greatest efficacy and adaptability.
- Evaluate P site assessment tools by comparing their output with water quality monitoring data and fate-and-transport models.
- Use water quality data (monitored or predicted by model) to refine P Indices, improving their prediction of P loss potential, ensuring consistency across state boundaries and within physiographic provinces.
- Promote practical and effective recommendations for P management.

Physiographic Regions & Watershed Network

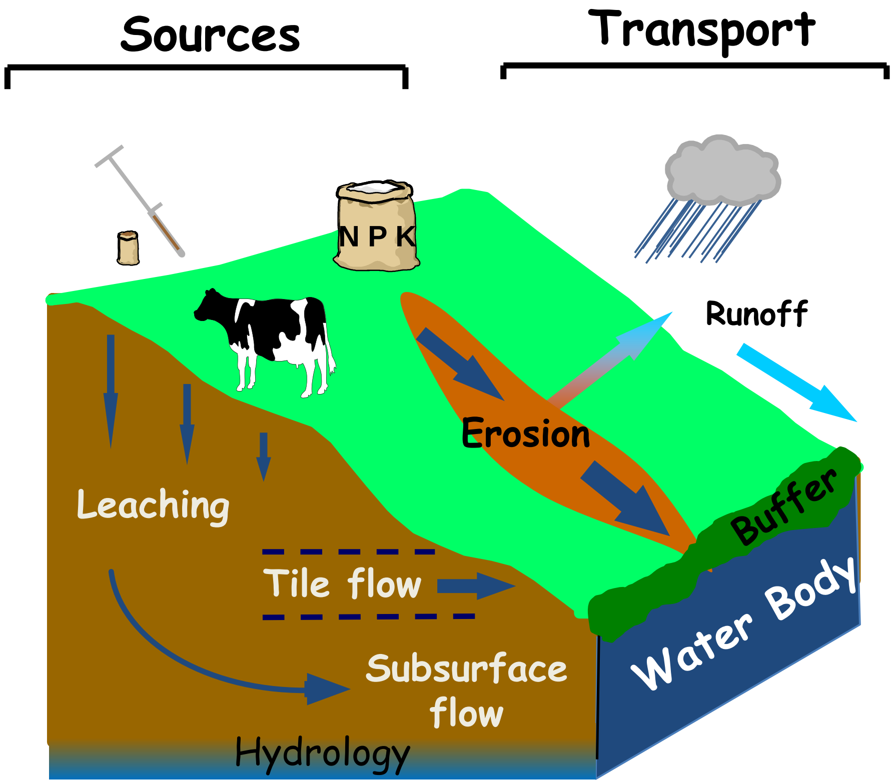


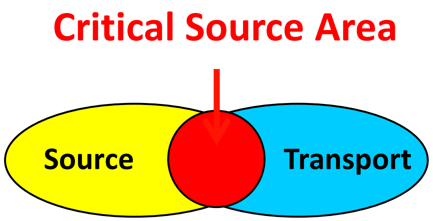
Objectives for the P Index

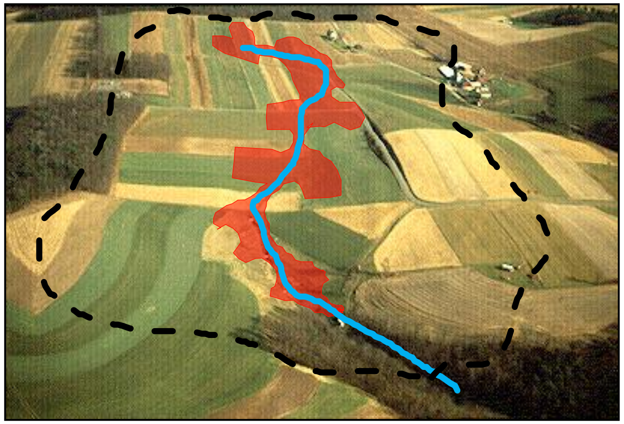
- Reduce the risk of P loss from farm fields by assessing this risk and targeting management changes and best management practices to avoid or mitigate the risk of P loss.
  - Location
  - 4Rs – Source, Rate, Timing, Placement
  - Reduce transport
  - Reduce the source

Phosphorus Loss and the P Index

>> Goal: Reduce the risk of P loss <<







–Ex. 90% of the P comes from 10% of the area

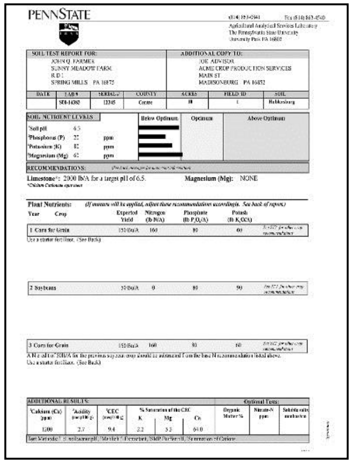
USDA-ARS PSWMRU

Phosphorus Index

Identify and manage critical source areas for environmental protection from P losses

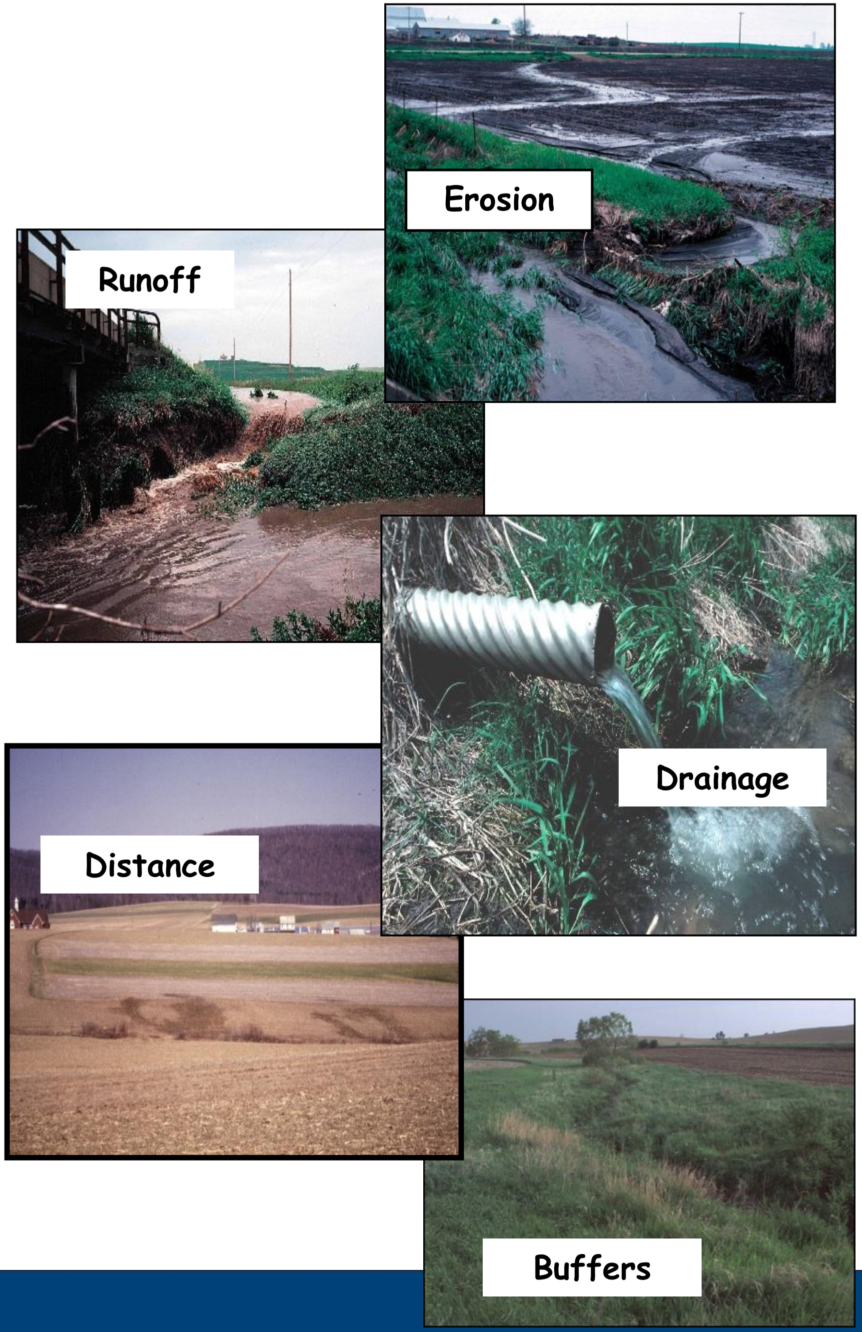
Phosphorus Index

- P Source Site Characteristics
  - Environmental Soil Test P
    - Agronomic soil test P, P Saturation
  - P Fertilizer
    - Rate
    - Application Method
  - Organic P
    - P Source Coefficient
    - Rate
    - Application Method



Phosphorus Index

- P Transport Site Characteristics
  - Soil Erosion
  - Runoff
  - Sub-surface Drainage
  - Contributing Distance
  - Modified Connectivity



PA Phosphorus Index

- Relatively simple to use
- Conceptually clear
- Consistent interpretation

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)					
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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‡ < 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.

Why not just Soil Test P?

Optimum P range

30 – 50 ppm

Median soil test P within upper end of the optimum range. Slight decline in the last 5 years.

42% Above Optimum

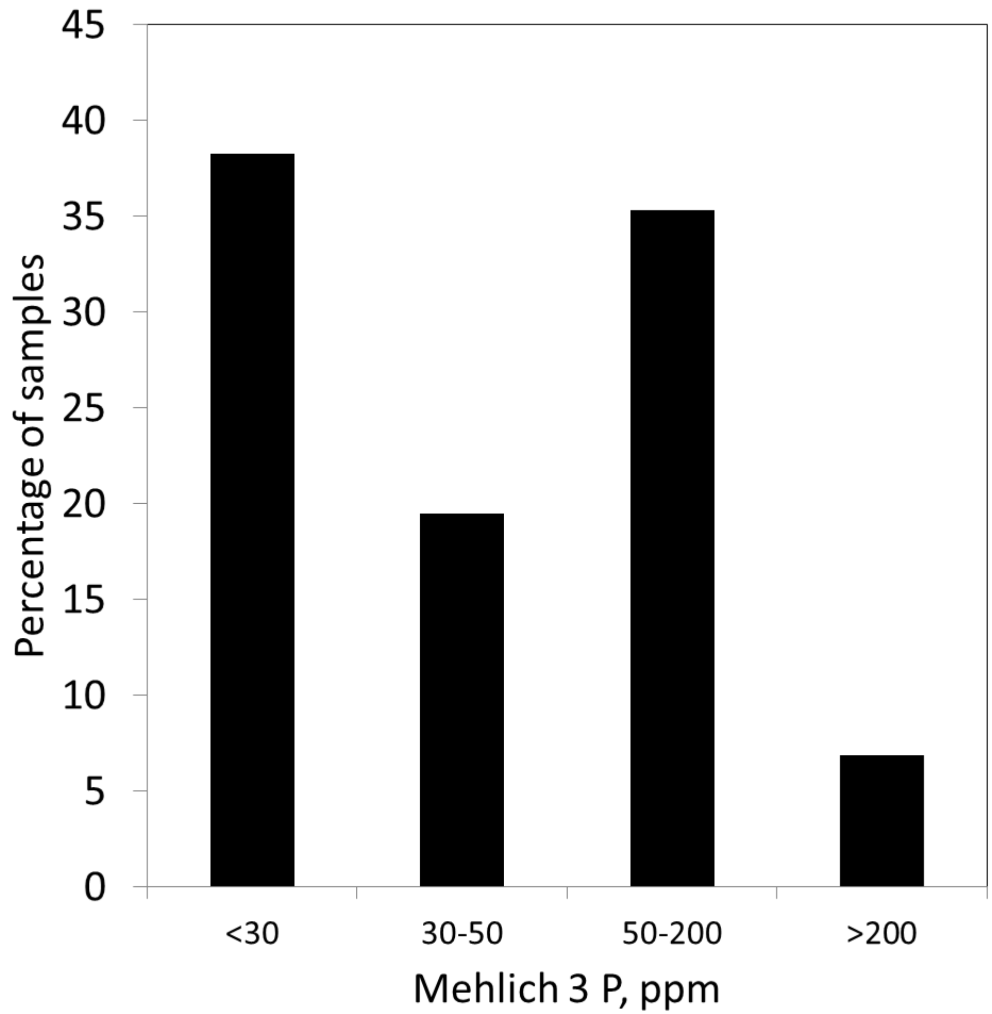
- *No P recommended*

19% Optimum

- *P removal*

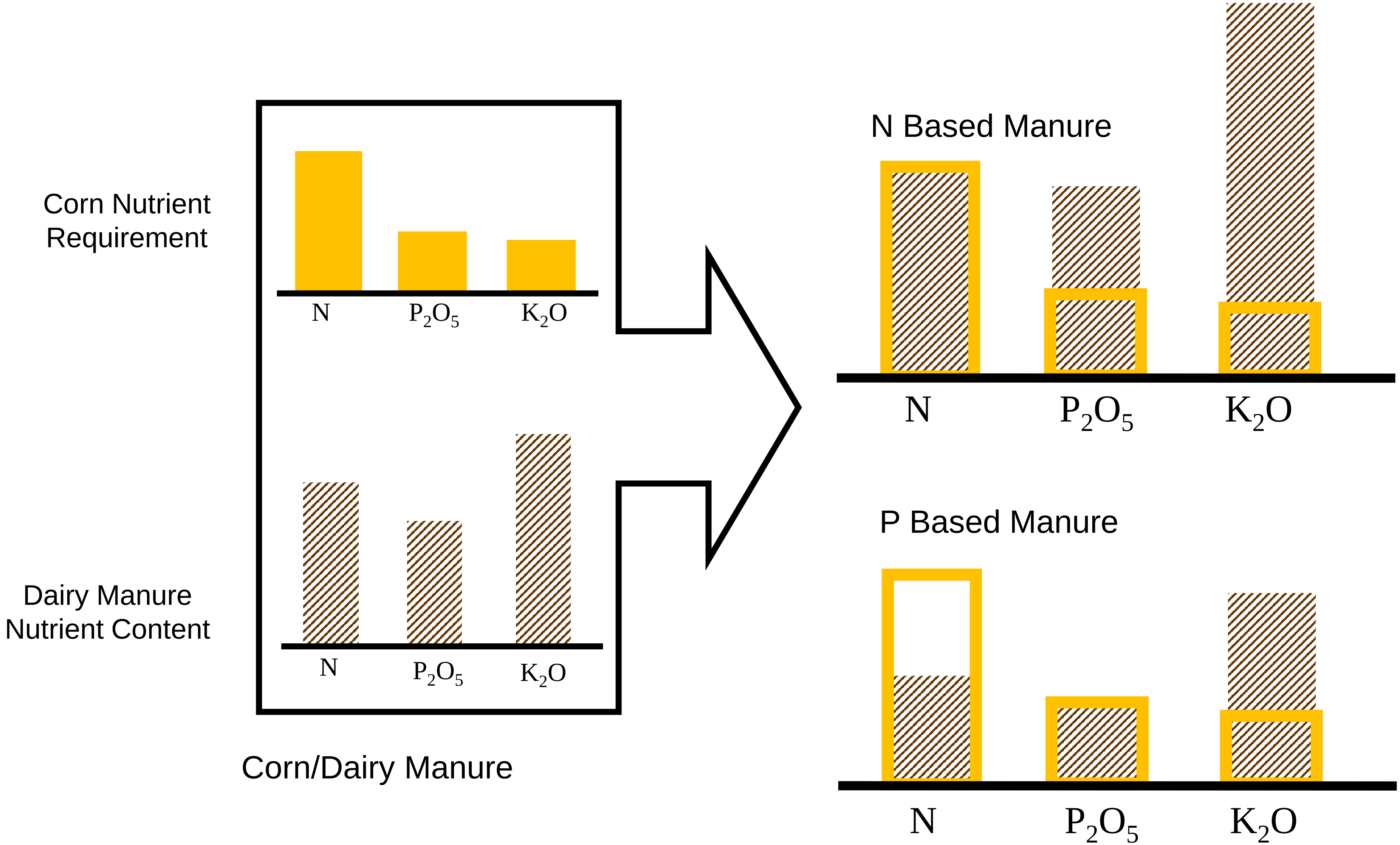
Not uniform

PA Soil test phosphorus distribution, 2015



Source: Penn State Ag Analytical Services Lab (all agronomic crops 2015; ~20,000 obs.)

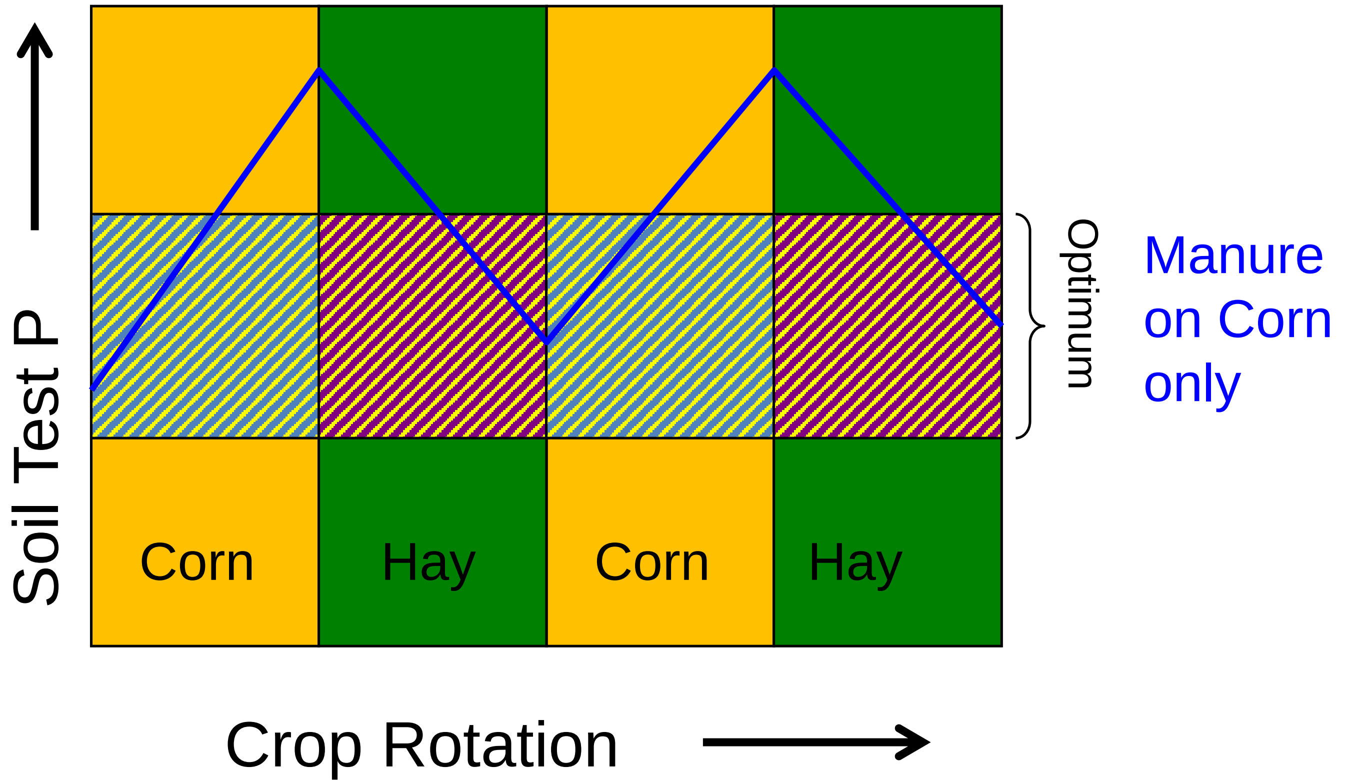
Imbalance between Crop and Manure Nutrients



Field Nutrient Balance with Manure

Manure in rotation

- Apply manure to corn on an N basis
- Build up soil P & K
- Draw down P and K in hay




4620
78
8
144
92
1
177
44
<1
Buda et al. JEQ, 2009
Soil P – mg kg-1
Runoff – liters
P loss – kg P ha-1 yr-1

Soil Test vs P Loss

P loss,

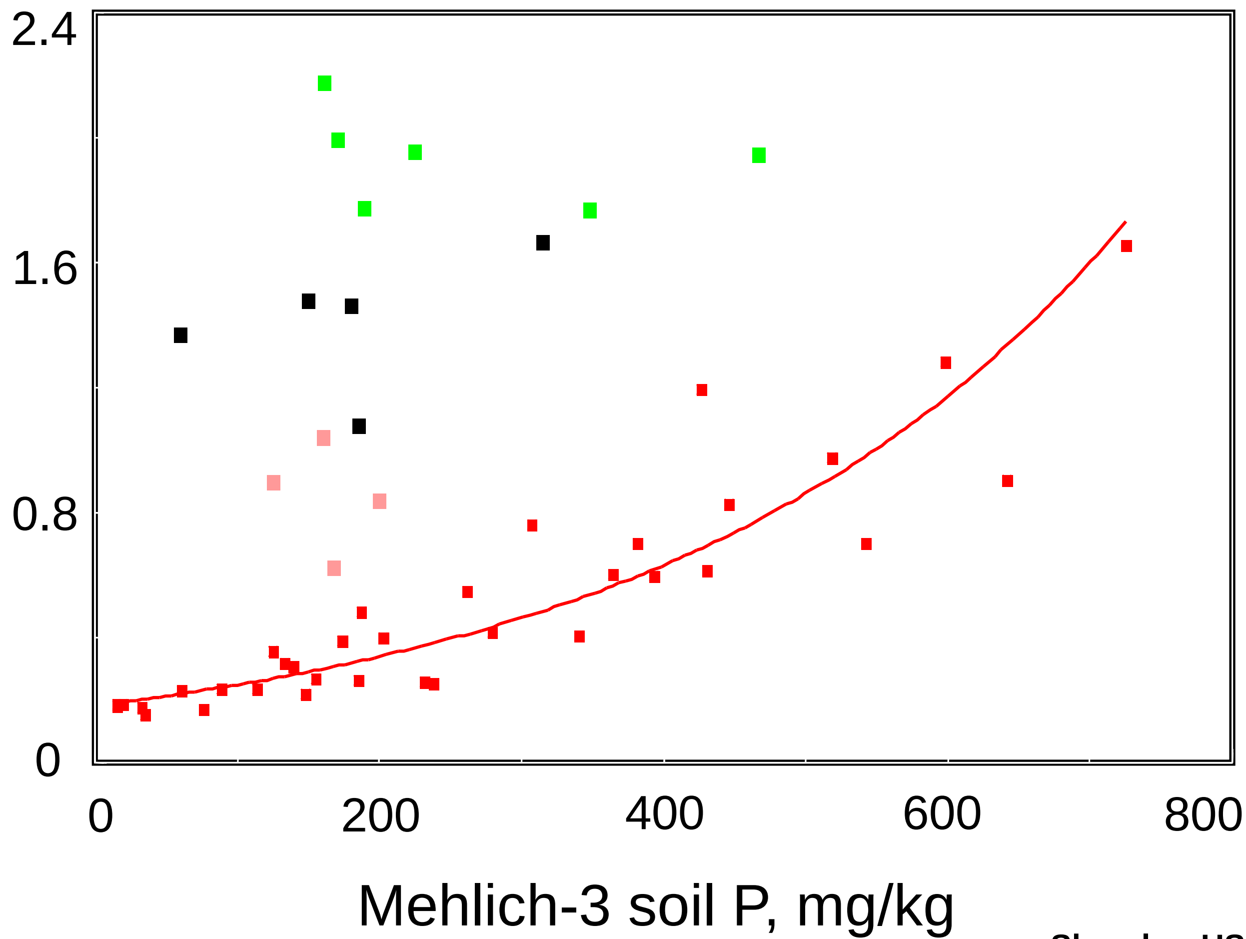
lb P_2O_5/A

75 kg P/ha TSP

112 kg P/ha swine slurry

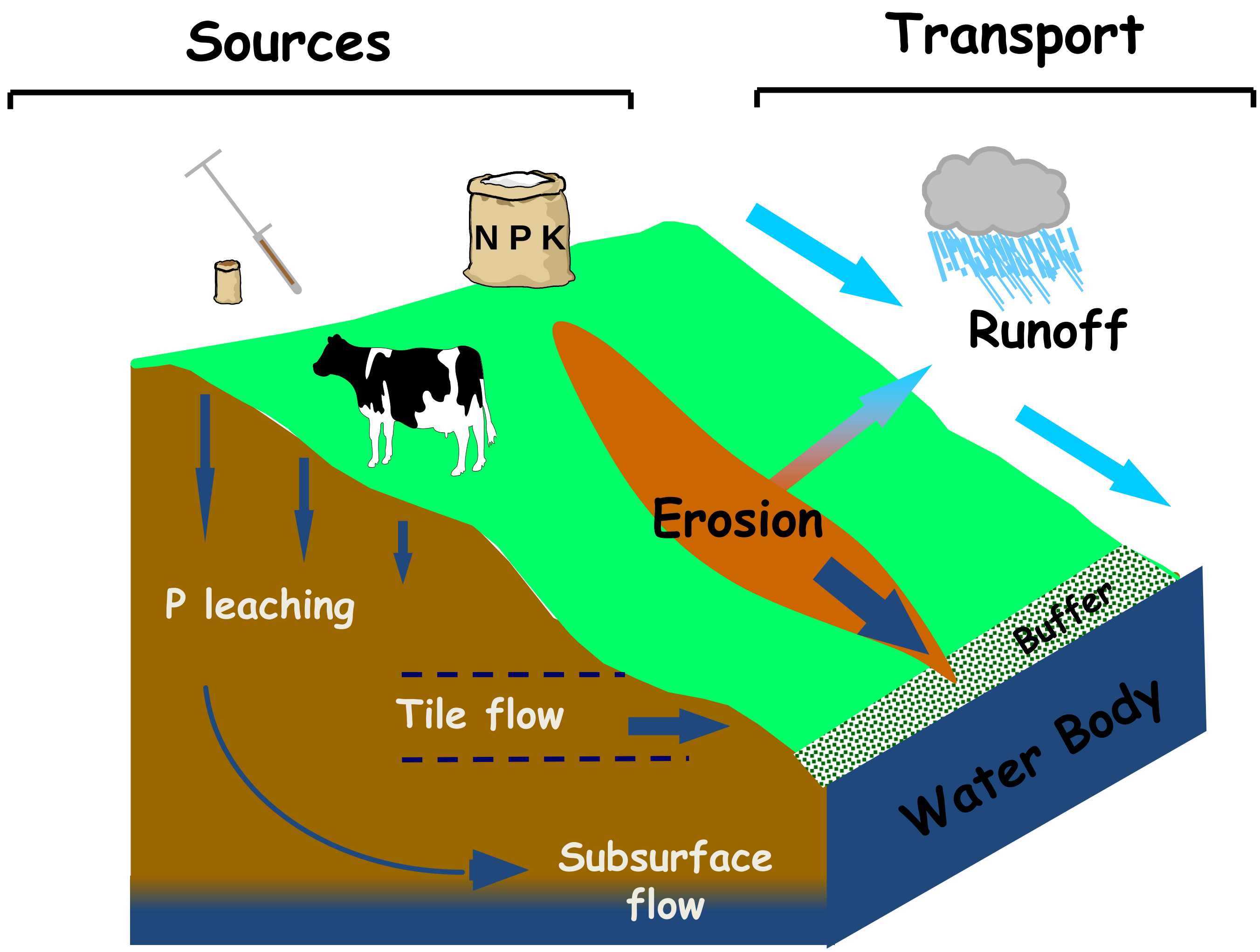
150 kg P/ha poultry manure

- Forced Runoff
- No applied P



Sharpley, USDA-ARS

Critical Source Area Management



PA Phosphorus Index

- Scientifically sound
- Not a direct measure of P loss
  - INDEX: Magnitudinally and directionally correct
- Minimum required critical inputs
- Simple to use
- Conceptually clear
- Consistent interpretation

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Phosphorus Index

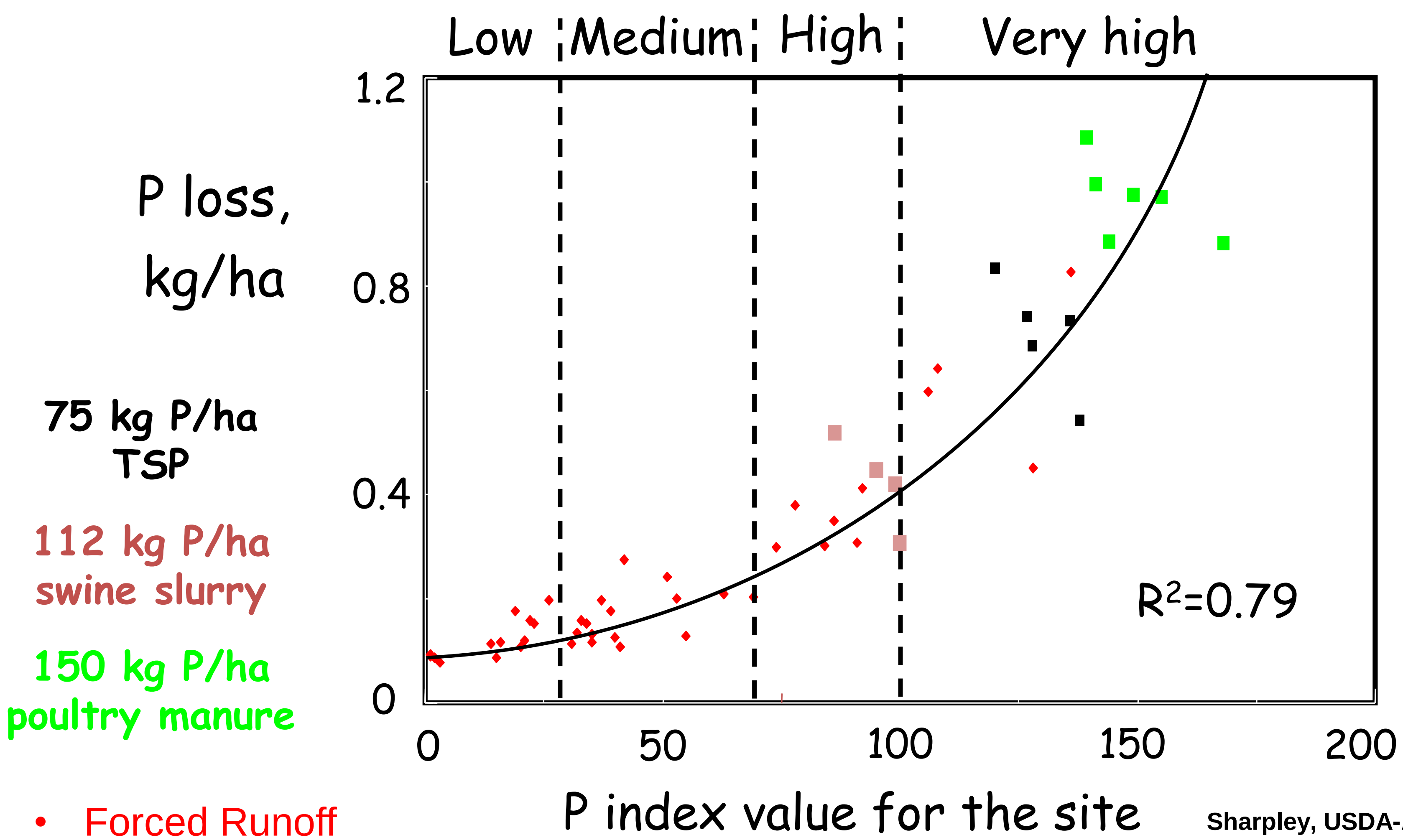
- Low P Index
  - N Based Management
- Medium P Index
  - N Based Management
- High P Index*
  - P Based: Crop removal
- Very High P Index*
  - No P: Manure or Fertilizer

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

- Modify Management based on P
  - No or reduced manure
  - Change time or method of application
  - Conservation practices
  - Buffers
  - Etc.

Area of emphasis in next generation P Index development

P Index describes P loss potential

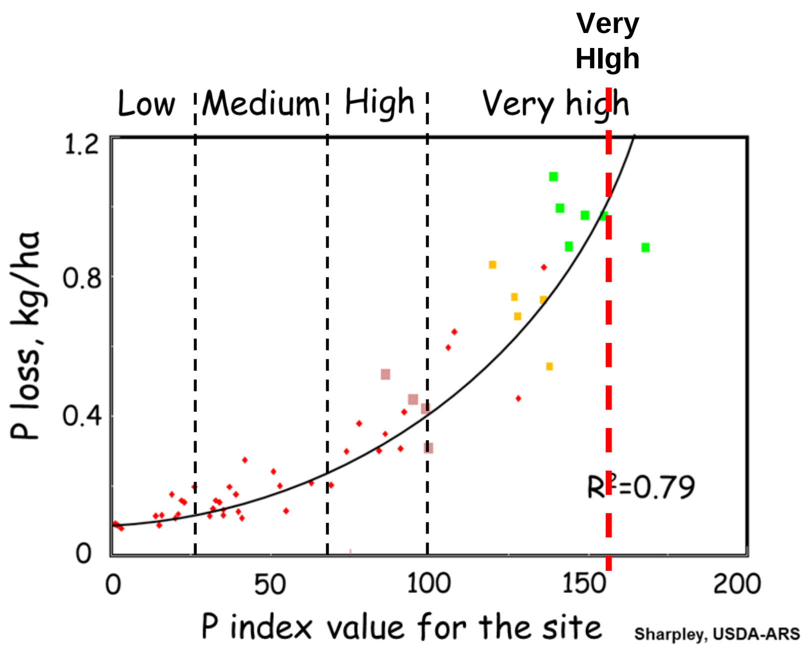


- Forced Runoff

Sharpley, USDA-ARS

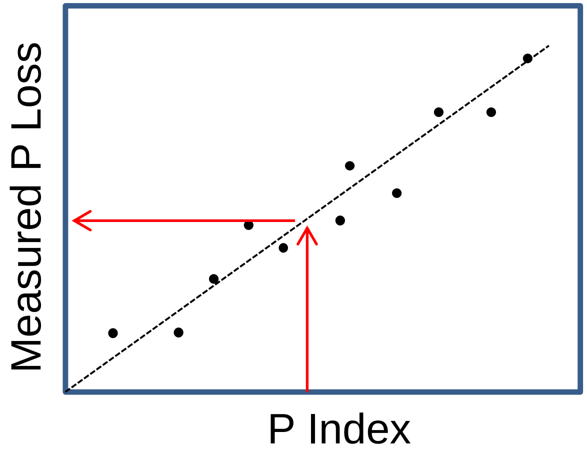
Challenges to the P Index

- Objective: Keep P out of water
  - Not necessarily P restriction
- P Index allows excess P to be applied in low risk situations
- Targets management for maximum effectiveness and return on limited resources
- Does not solve the regional nutrient imbalance issues
- Limited direct calibration of the P Index
  - Setting interpretation categories?
  - Science and Values



P Index Moving Forward

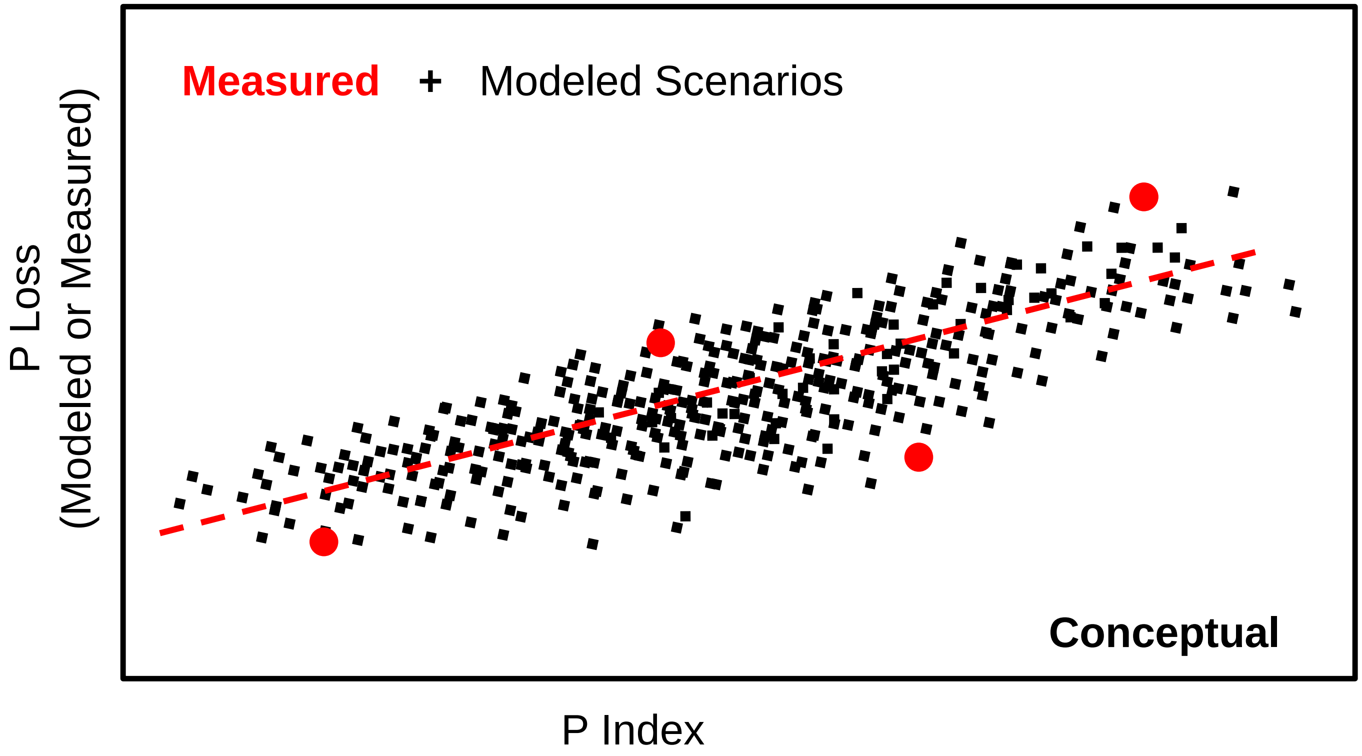
- Science keeps advancing our understanding of P behavior and the effects of BMPs
- P Indices can be improved
  - Keep it simple and practical for planners and farmers
  - Make sure it directs effective management
- ***Challenge in calibrating the P Index***
  - Calibration: Quantitative relationship between P Index and P loss



P Index Evaluation and Improvement: Experimental vs Modeling

- Not feasible to have enough experimental sites to completely calibrate a P Index
- Process based models can be used to simulate fate and transport of P over a much wider range of conditions to calibrate the P Index
  - SWAT, APEX, DRAINMOD, APLE
- *Why not just use the models?*
- Monitoring network will be used to validate the models
- Models will be used to suggest improvements to the P Index and evaluate effectiveness of revised P Indices

Integrating Modeling and Monitoring to Calibrate the P Index - Approach



Measured

Modeled Scenario

Example: PA Phosphorus Index

Current

SOURCE Factor
- Soil Test
- Fertilizer
  - Rate
  - Method
- Manure
  - Rate
  - Method
  - PSC

Each Source Factor weighted

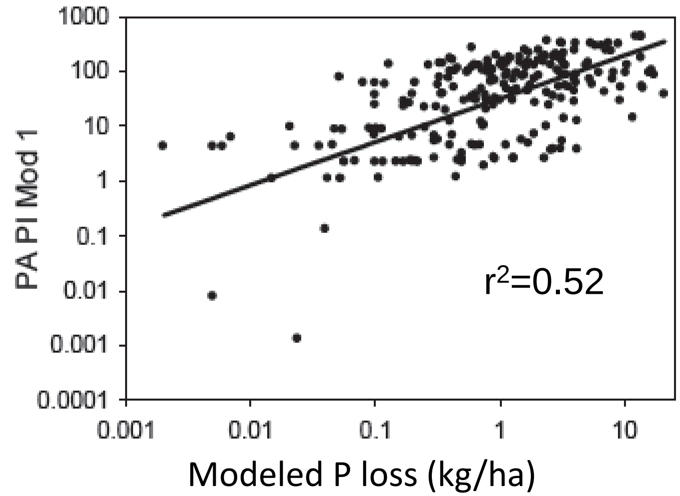
X

Transport Factor
- Erosion
- Runoff
- Leaching
- Distance
- Modified Connectivity

Each Transport Factor weighted

=

P Index



Revised "Component" PI

Sediment P SOURCE
- **Soil Test**

X

Sediment Transport
- **Erosion**

= **Sediment P Factor**

Soluble P SOURCE
- **Manure P**
- **Fertilizer P**
- **Soil P_{sat}**

X

Runoff Transport
- **Runoff**

= **Runoff Soluble P Factor**

Soluble P SOURCE
- **Manure P**
- **Fertilizer P**
- **Soil P_{sat}**

X

Leaching Transport
- **Leaching**

= **Leaching Soluble P Factor**

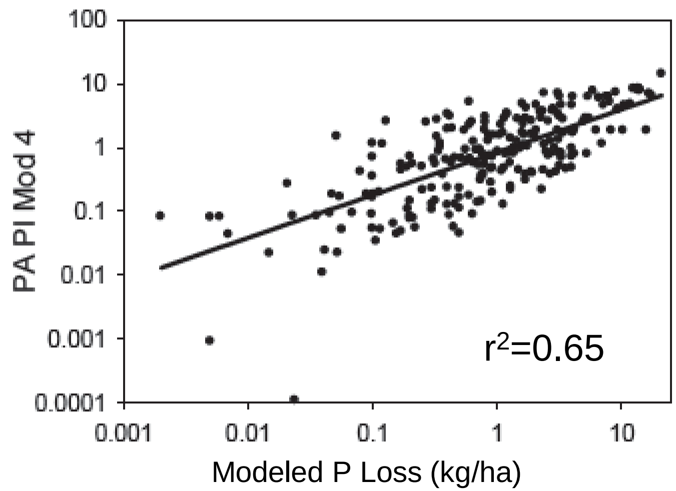
Each Source Factor weighted

Each Transport Factor weighted

Distance

Connectivity

P Index

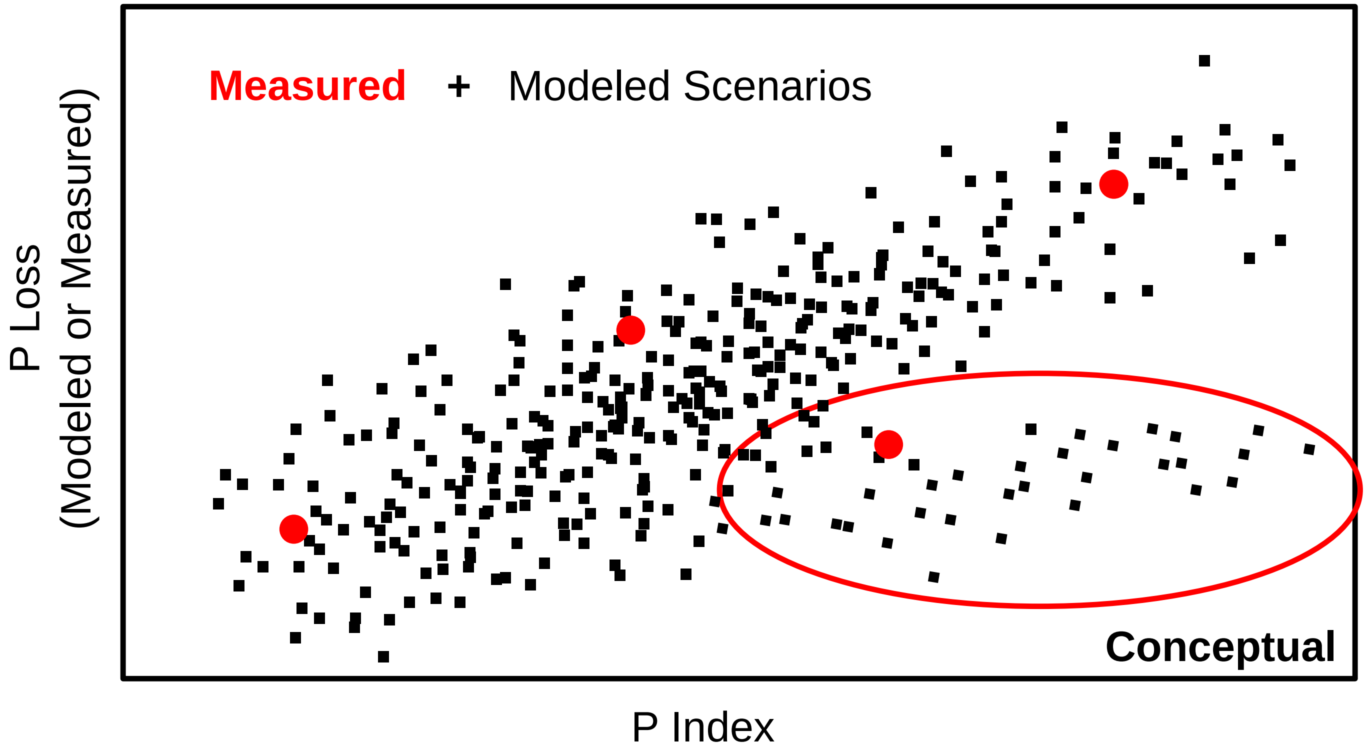


(Bolster et al. 2012)

Developing Model Scenarios

- Site selection represent state-wide soil and landscape characteristics
  - Soil properties
  - Topography
  - Distance and connectivity to water
- Representative cropping and nutrient management
  - Management
    - P Application source, method, and timing

Integrating Modeling and Monitoring to Improve the P Index - Approach

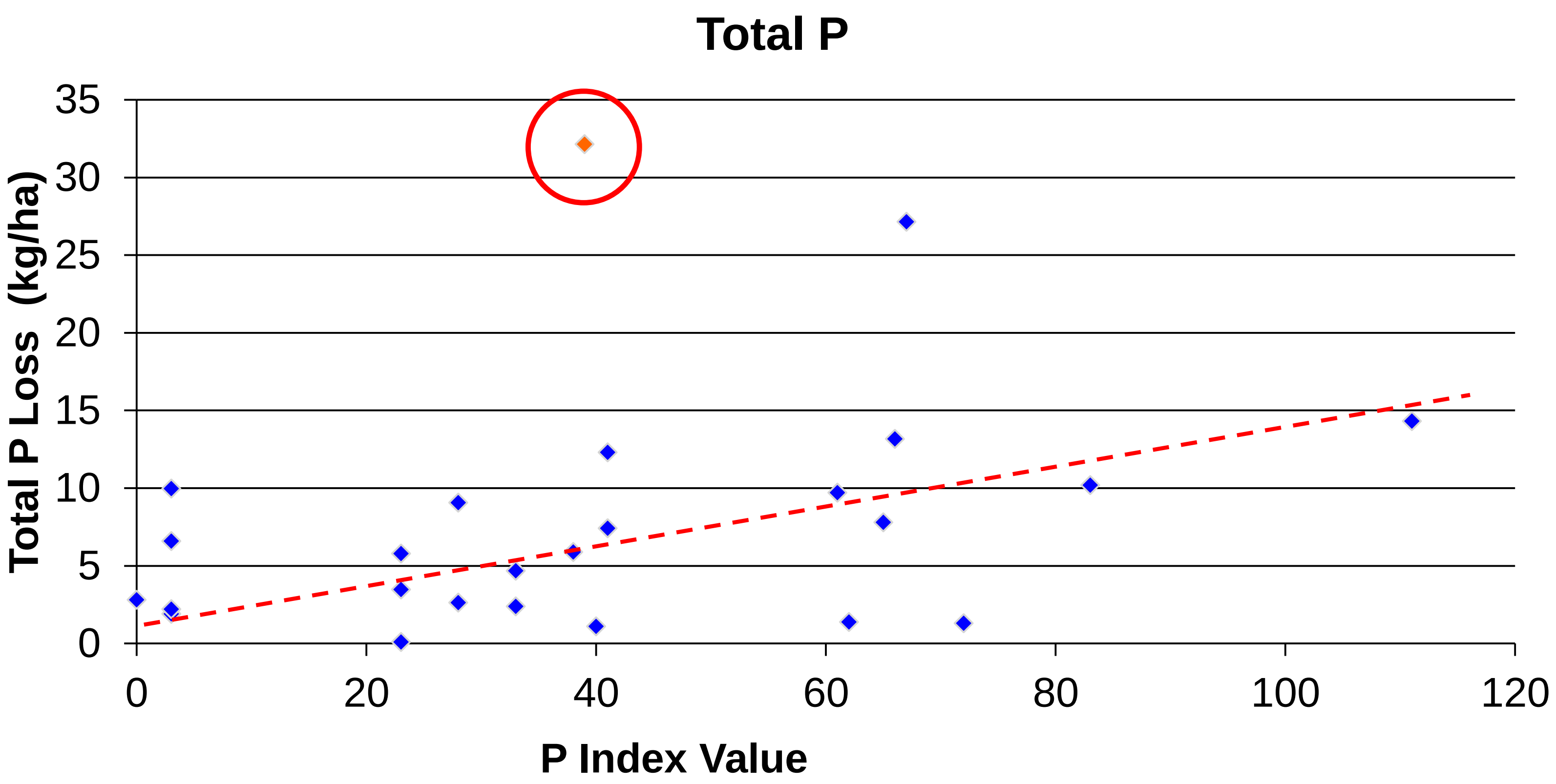


● Monitored Scenario

▪ Modeled Scenario

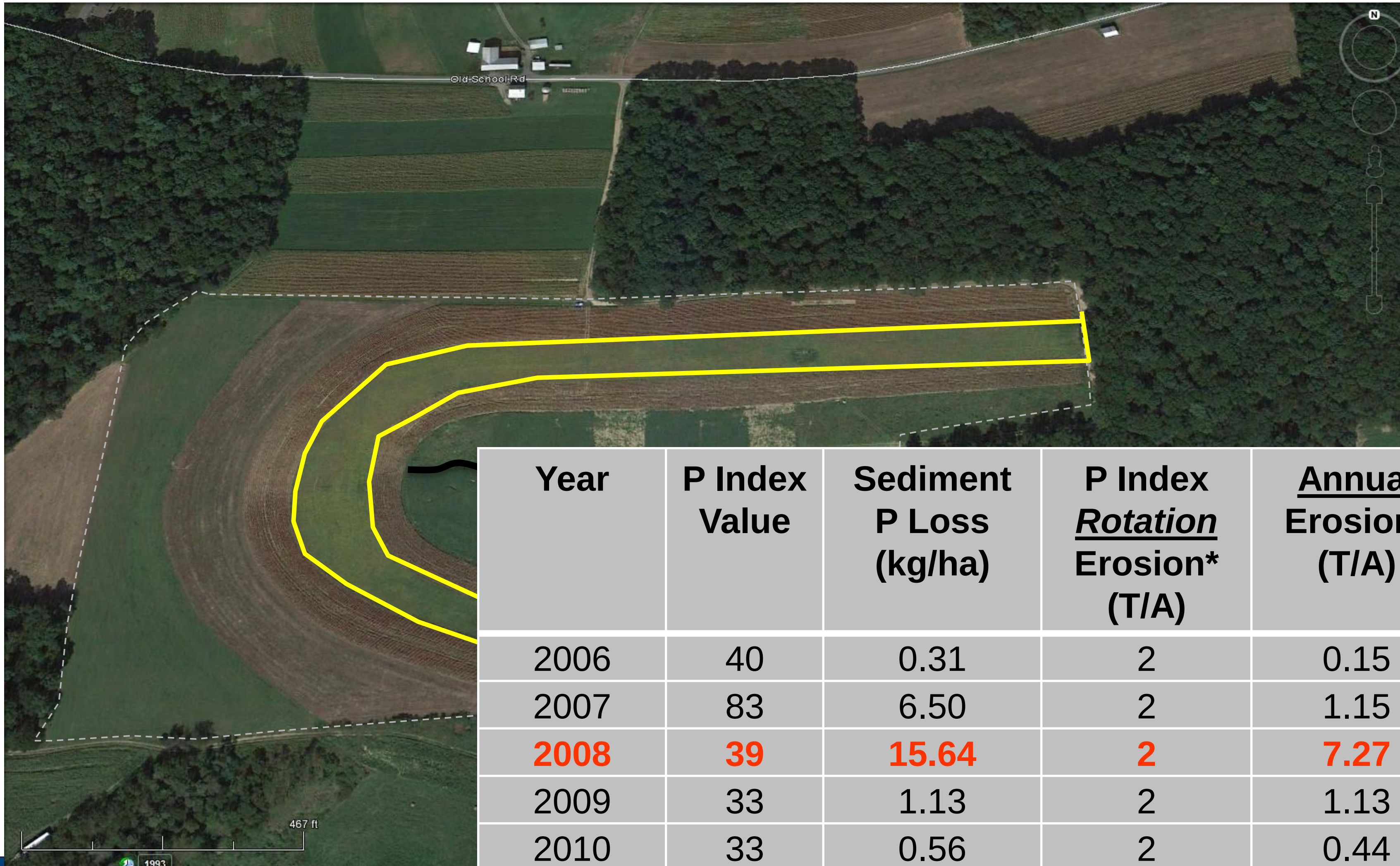
P Index does a poor job of predicting the risk of P loss

P Index and TopoSWAT Comparison



Mattern Watershed
5 years of management and
P loss data

Study site: Mattern Watershed



Year	P Index Value	Sediment P Loss (kg/ha)	P Index *Rotation* Erosion* (T/A)	Annual Erosion* (T/A)
2006	40	0.31	2	0.15
2007	83	6.50	2	1.15
2008	**39**	**15.64**	**2**	**7.27**
2009	33	1.13	2	1.13
2010	33	0.56	2	0.44

*RUSLE

Final P Index Revision

- PA SCC consider adopting next generation P Index
  - Next year
- Scientifically sound
  - Component P Index
  - P Saturation for soluble P
  - Annual erosion
  - Reevaluate runoff component
  - Refined distance factors
  - Better relative weighting for the factors
- Practical for planners
  - Straight forward calculations and interpretations
  - Minimum dataset of readily available inputs
    - Automatic GIS inputs? *PAOneStop*

MAPS OF TRANPORT POTENTIAL – edge of field transport (runoff prone, erosion prone, artificially drained) modified by degree of hydrologic connectivity

<u>Away from stream/waterway</u>
1. Erosion control practices
3. Winter restrictions

<u>Near stream or waterway</u>
1. Field buffer options or employ setback
2. Inject nutrients
3. Timing/ site condition restrictions

General good Management

P Site Index

	Low	Med	High
Application Rate:	N	P	None

MAPS OF TRANPORT POTENTIAL – edge of field transport (runoff prone, erosion prone, artificially drained) modified by degree of hydrologic connectivity

General good Management

P Site Index

Application Rate:	Low	Med	High
	N	P	None

Final P Index Revision

- More direct connection between P Index results and recommended BMPs
  - Most effective BMPs
  - Practical BMPs
  - Penn State Center for Nutrient Solutions
- Summary of planner's feedback (survey and meeting)
  - Manure application BMPs:
    - timing
    - fields close to stream
    - saturated ground
    - without incorporation
  - Other BMPs:
    - Buffers/Setbacks
    - Cover Crops
    - Crop residues