



# **Environmental P Management and the Iowa P Index**

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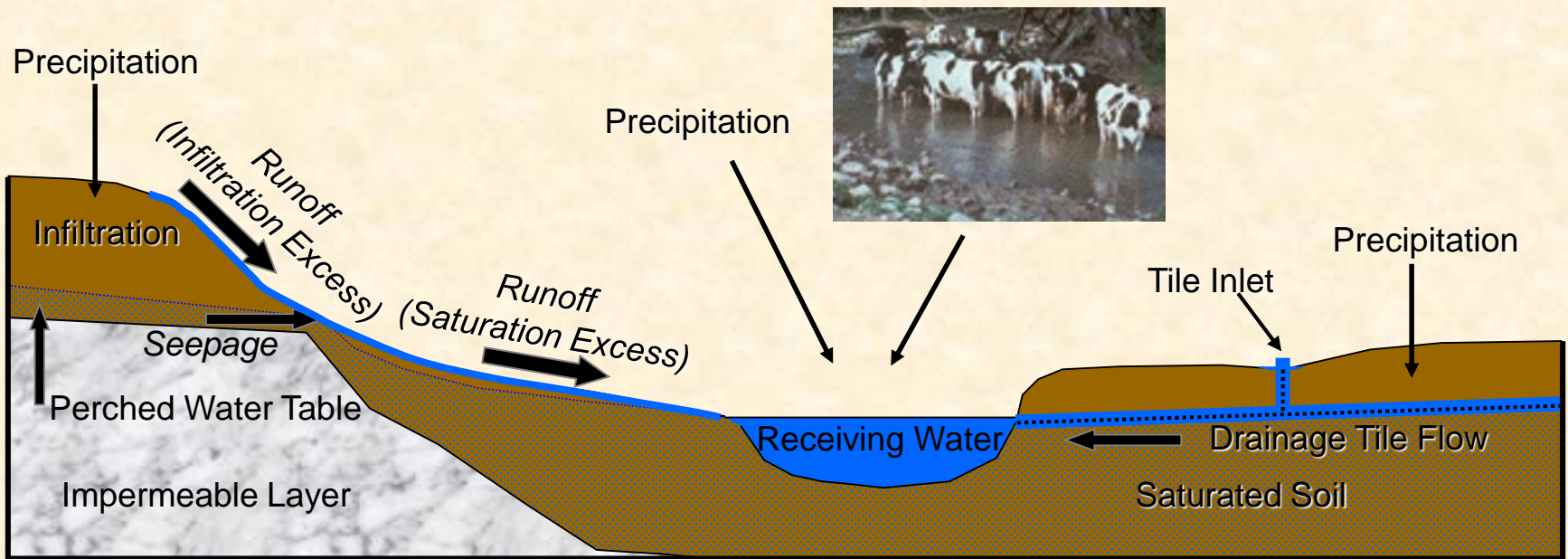


# Impact of P on Water Quality

| Attribute                | Oligotrophic<br>0-20 ppb | Mesotrophic<br>20-70 ppb | Eutrophic<br>70-200 ppb | Hyper Eutrophic<br>200+ ppb |
|--------------------------|--------------------------|--------------------------|-------------------------|-----------------------------|
| Clarity                  | Excellent                | Good                     | Poor                    | Very Poor                   |
| Oxygen                   | Abundant                 | Adequate                 | Hypoxic                 | Anoxic                      |
| Toxic Algae              | Absent                   | Absent                   | Frequent                | Constant                    |
| Bacteria                 | Rare                     | Rare                     | Abundant                | Very Abundant               |
| Silt / Filling           | Very Slow                | Slow                     | Rapid                   | Very Rapid                  |
| NH <sub>3</sub> Toxicity | Improbable               | Infrequent               | Frequent                | Constant                    |
| Biodiversity             | High                     | Good                     | Poor                    | Very Poor                   |
| Fish & Wildlife Habitat  | Good                     | Excellent                | Poor                    | Very Poor                   |
| Sport Fish               | High Quality             | Good Quality             | Poor Quality            | Rough Fish                  |

# Pathways for P Loss

- **Soil erosion:**
  - gully
  - sheet and rill
  - stream bank
- **Surface runoff:**
  - infiltration excess
  - saturation excess
  - seepage
- **Subsurface drainage:**
  - tiles
  - coarse soil/subsoil



# Forms of Soil P Lost

- **Dissolved P in water: immediate but short-term impact on water quality of streams and lakes:**
  - surface water runoff
  - through the soil profile (tiles)
- **P bound to sediment (particulate P): slow but large long-term impacts mainly on lake water**

# The Need for a P Index

- Soil-test P interpretation classes and P recommendations for crops do not apply for environmental purposes
- Factors influencing P transport with soil and water loss (erosion, runoff, drainage) often are more important
- Soil P, P management, and soil & water transport factors should be integrated into a risk rating system

# Advantages of the P Index

- The P index seems a complicated tool, but is the best one
- Use of a simple soil P threshold would not be effective, will be **too low** in some conditions and unnecessarily **restrictive** in others
- The P index is field specific, and gives producers needed flexibility

# P Index, Nutrient Reduction Strategy

|   | Practice                | Comments  | % P Load Reduction <sup>a</sup> | % Corn Yield Change <sup>b</sup> |
|---|-------------------------|---|---------------------------------|----------------------------------|
|   |                         |   | Average (SD) <sup>c</sup>       | Average (SD) <sup>c</sup>        |
| Phosphorus Management Practices             | Phosphorus Application  | Applying P based on crop removal – Assuming optimal STP level and P incorporation   | 0.6 <sup>d</sup>                | 0                                |
|   |                         | Soil-Test P – No P applied until STP drops to optimum or, when manure is applied, to levels indicated by the P Index <sup>f</sup> | 17 <sup>e</sup>                 | 0                                |
|   | Source of Phosphorus    | Liquid swine, dairy, and poultry manure compared to commercial fertilizer – Runoff shortly after application                      | 46 (45)                         | -1 (13)                          |
|   |                         | Beef manure compared to commercial fertilizer – Runoff shortly after application  | 46 (96)                         |                                  |
|   | Placement of Phosphorus | Broadcast incorporated within 1 week compared to no incorporation, same tillage   | 36 (27)                         | 0                                |
|   |                         | With seed or knifed bands compared to surface application, no incorporation   | 24 (46)                         | 0                                |
|   | Cover Crops             | Winter rye  | 29 (37)                         | -6 (7)                           |
|   | Tillage                 | Conservation till – chisel plowing compared to moldboard plowing  | 33 (49)                         | 0 (6)                            |
|   |                         | No till compared to chisel plowing  | 90 (17)                         | -6 (8)                           |
| Land Use Change                             | Perennial Vegetation    | Energy Crops  | 34 (34)                         |                                  |
|   |                         | Land Retirement (CRP)   | 75                              |                                  |
|   |                         | Grazed pastures   | 59 (42)                         |                                  |
| Erosion Control and Edge-of-Field Practices | Terraces                |   | 77 (19)                         |                                  |
|   | Buffers                 |   | 58 (32)                         |                                  |
|   | Control                 | Sedimentation basins or ponds   | 85                              |                                  |

# P Index Three Components

## Soil Erosion (Particulate P)



## Source Factors

- soil P
- application method, timing, and rate

## Water Runoff (Dissolved P)



## Tile Drainage (Dissolved P)

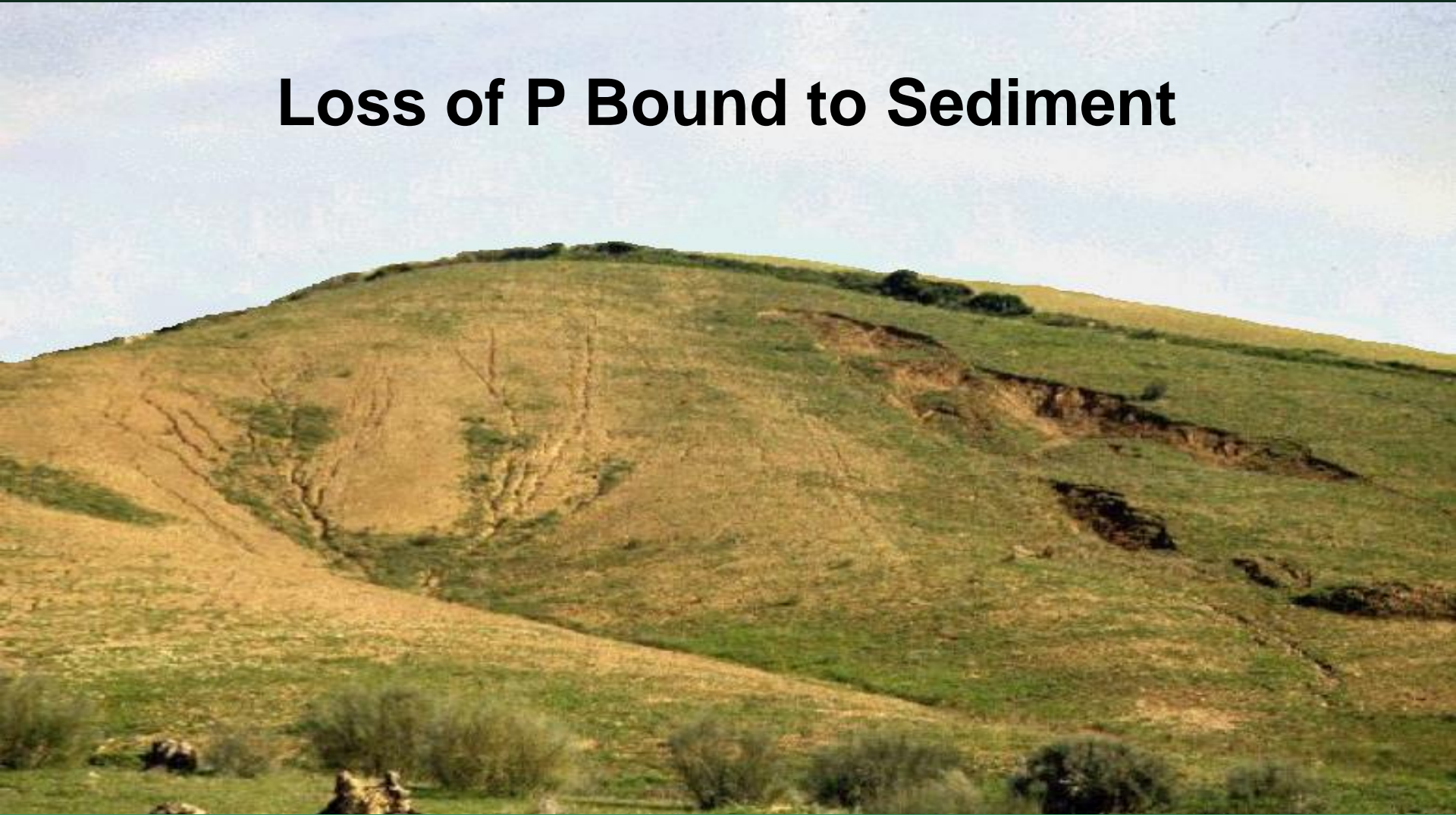


Soil and water  
conservation  
practices



# Soil Erosion Component

## Loss of P Bound to Sediment



# Soil P Loss and Soil Erosion

- Estimates P in sediment that is effectively transported to a stream
- Various factors:
  - Total soil P
  - Soil loss (RUSLE 2 estimate)
  - Sediment traps and delivery, filter strips, sediment enrichment in P
  - Distance to channeled water flow
  - Availability for algae growth

# Estimating Total Soil P

- Can be measured by testing but it is a highly variable and expensive test
- Uses an equation based on data from Iowa and neighboring states
  - Average total P in the 6-inch layer of low-testing soils
  - A recent routing soil P test
  - **Total P = 500 + (3 x Bray-1 Soil P)**



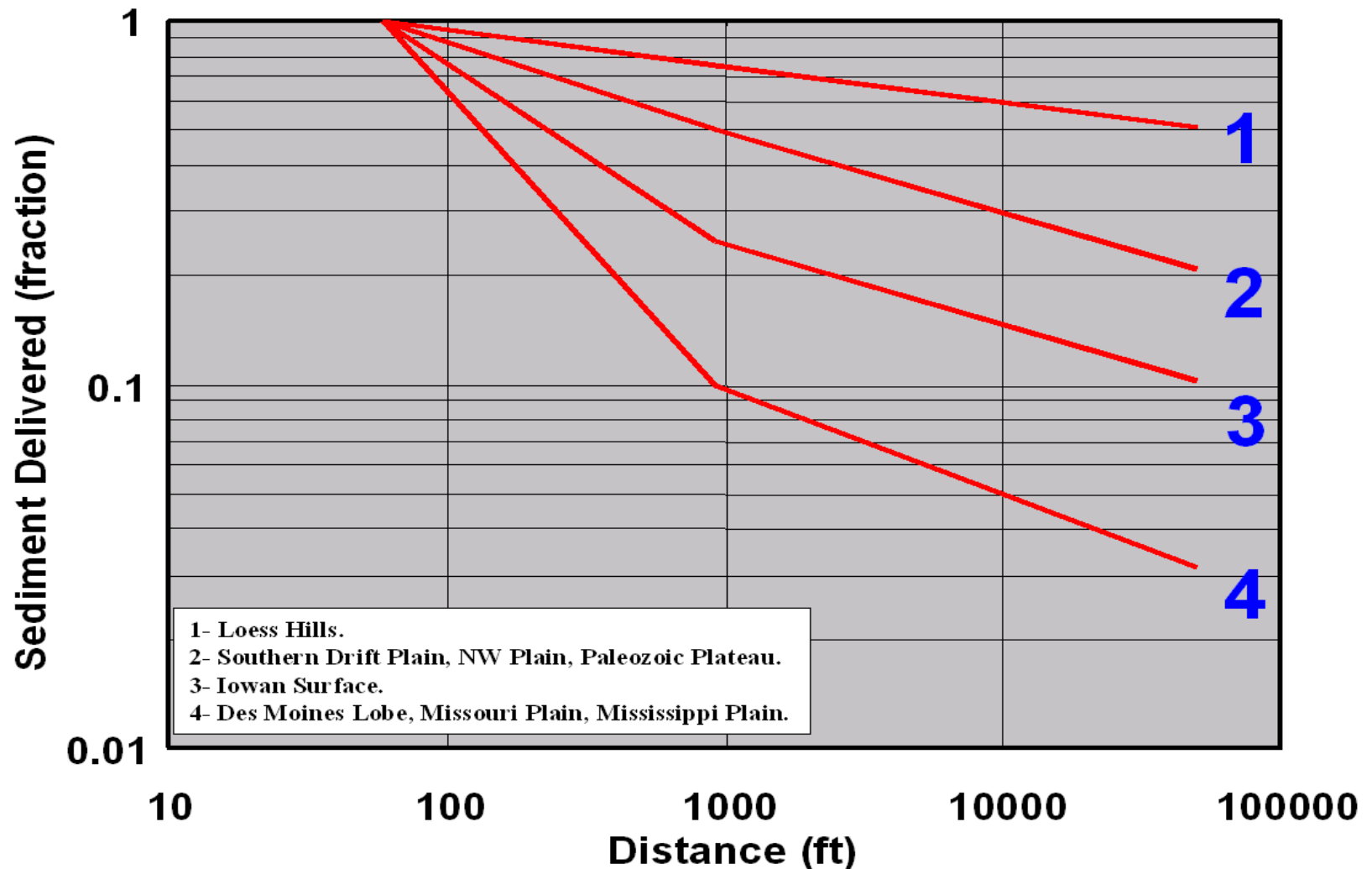
# Sediment Trap Factor

| Conservation Practice  | Factor |
|--|--------|
| Level terrace  | 0.00   |
| Ponds, tile inlet terrace, or<br>grade stabilization impoundment | 0.05   |
| Water & sediment control basin                                   | 0.20   |

# Filter Strip Factor

| Buffer Width      | Factor |
|-------------------|--------|
| Less than 20 feet | 1.0    |
| 20 to 75 feet     | 0.7    |
| More than 75 feet | 0.5    |

# Estimate of Sediment Delivery





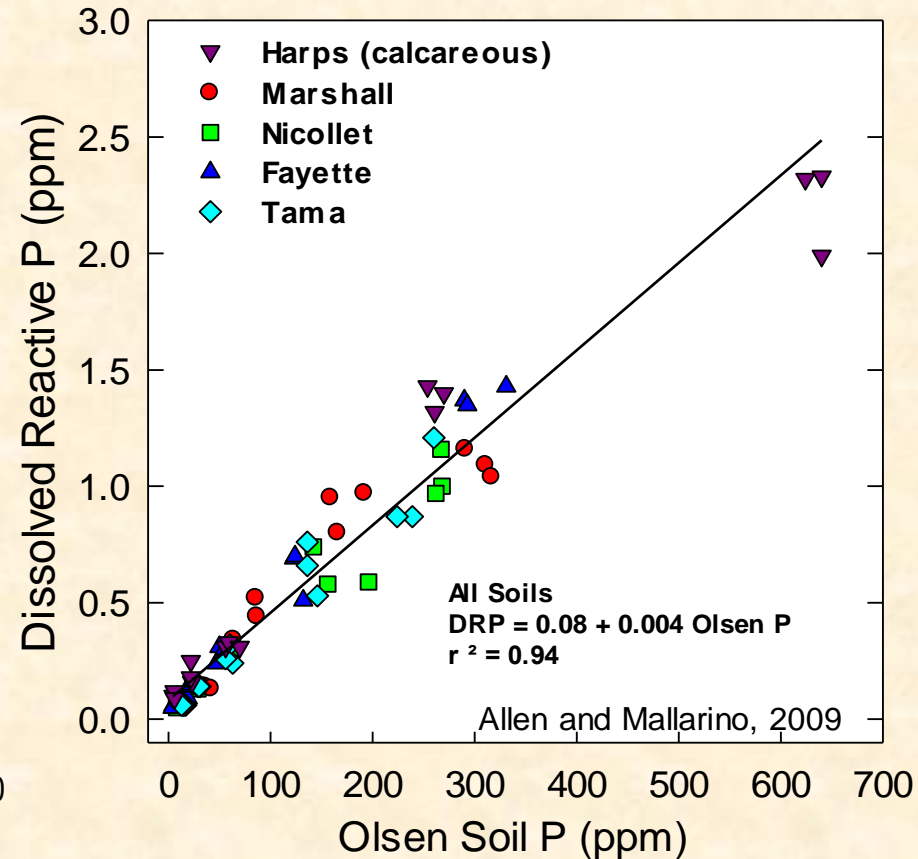
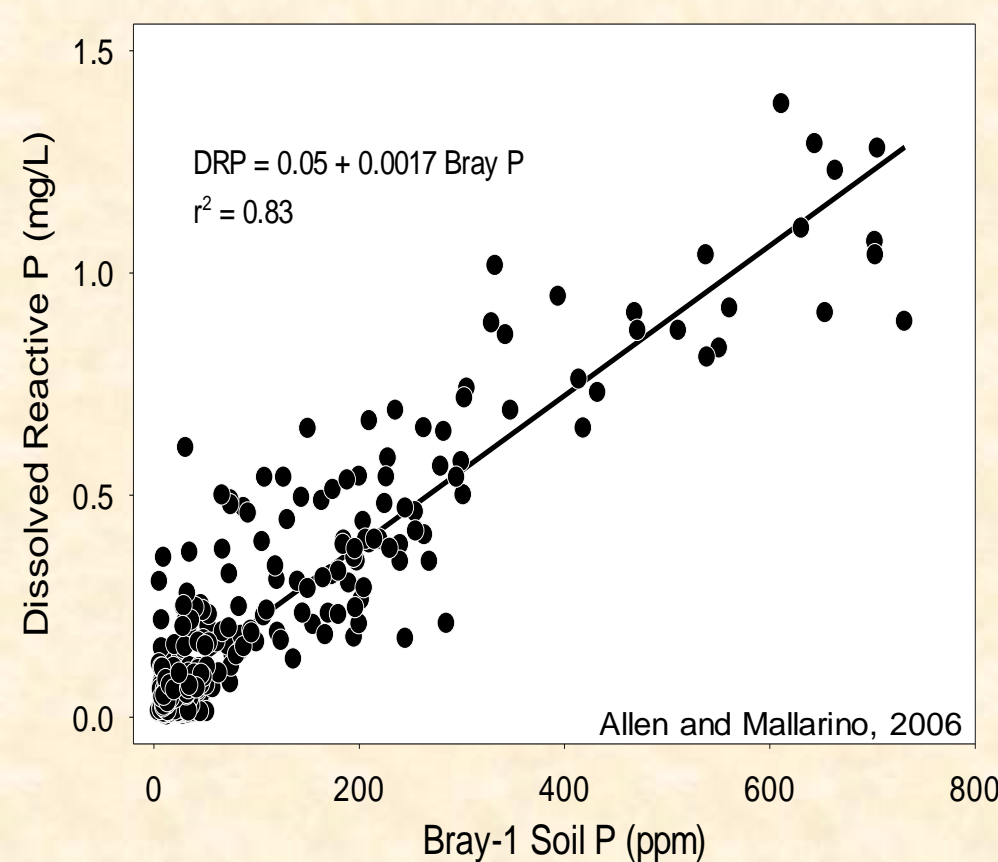
# Surface Runoff Component

Loss of Dissolved P

# Soil P Loss and Surface Runoff

- Estimate of surface runoff volume (NRCS runoff curve numbers)
- Dissolved P concentration in runoff increases with increasing soil-test P, uses average relationships from research in Iowa and other states
- Use agronomic soil-test P methods and sampling depth recommended for crop production in Iowa

# Runoff P Loss and Soil-Test P Level



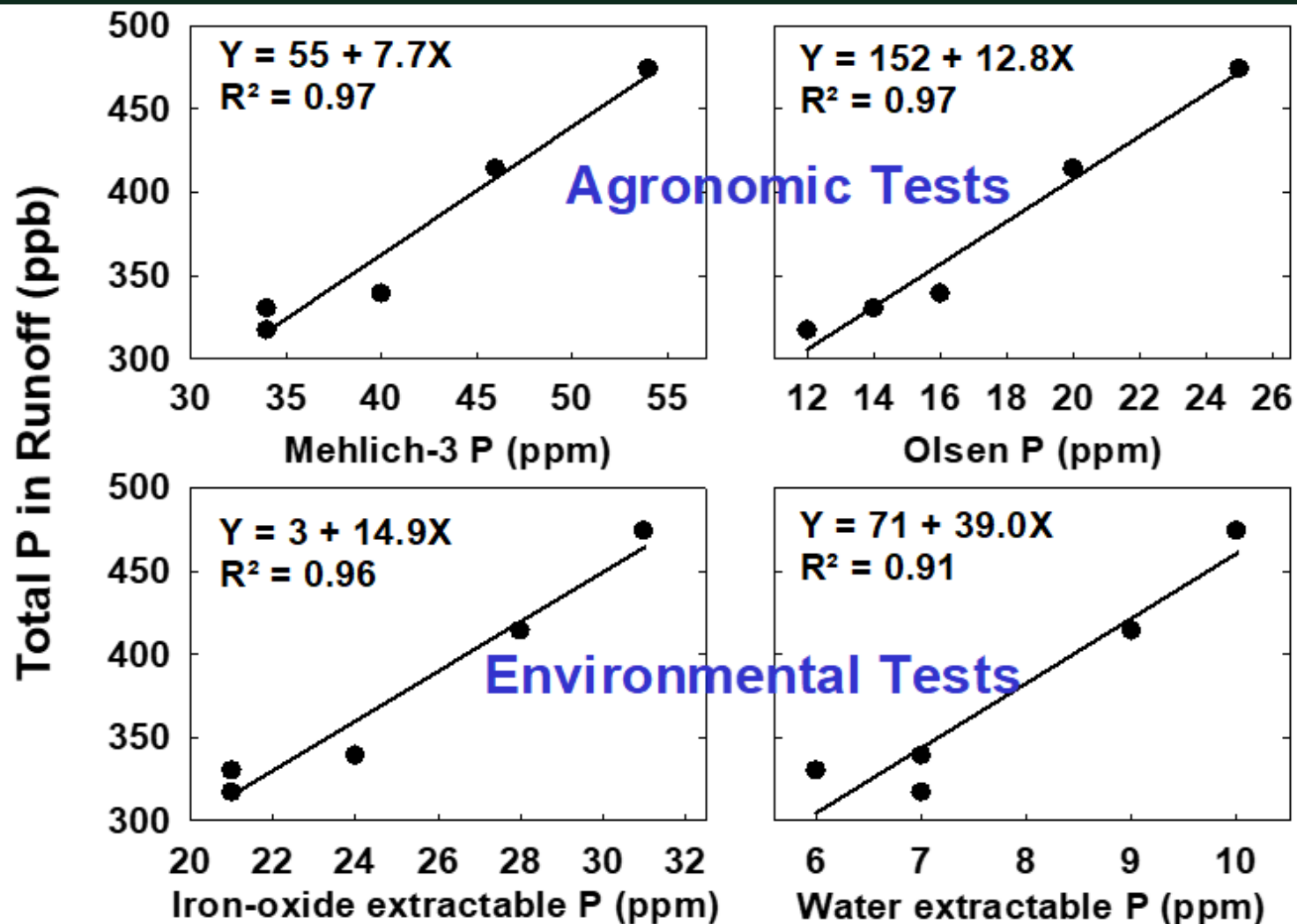
Mallarino, Haq, Allen, Baker; ISU



# P in Surface Runoff and Soil P

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# P in Surface Runoff and Soil P



# P Rate and Application Factors





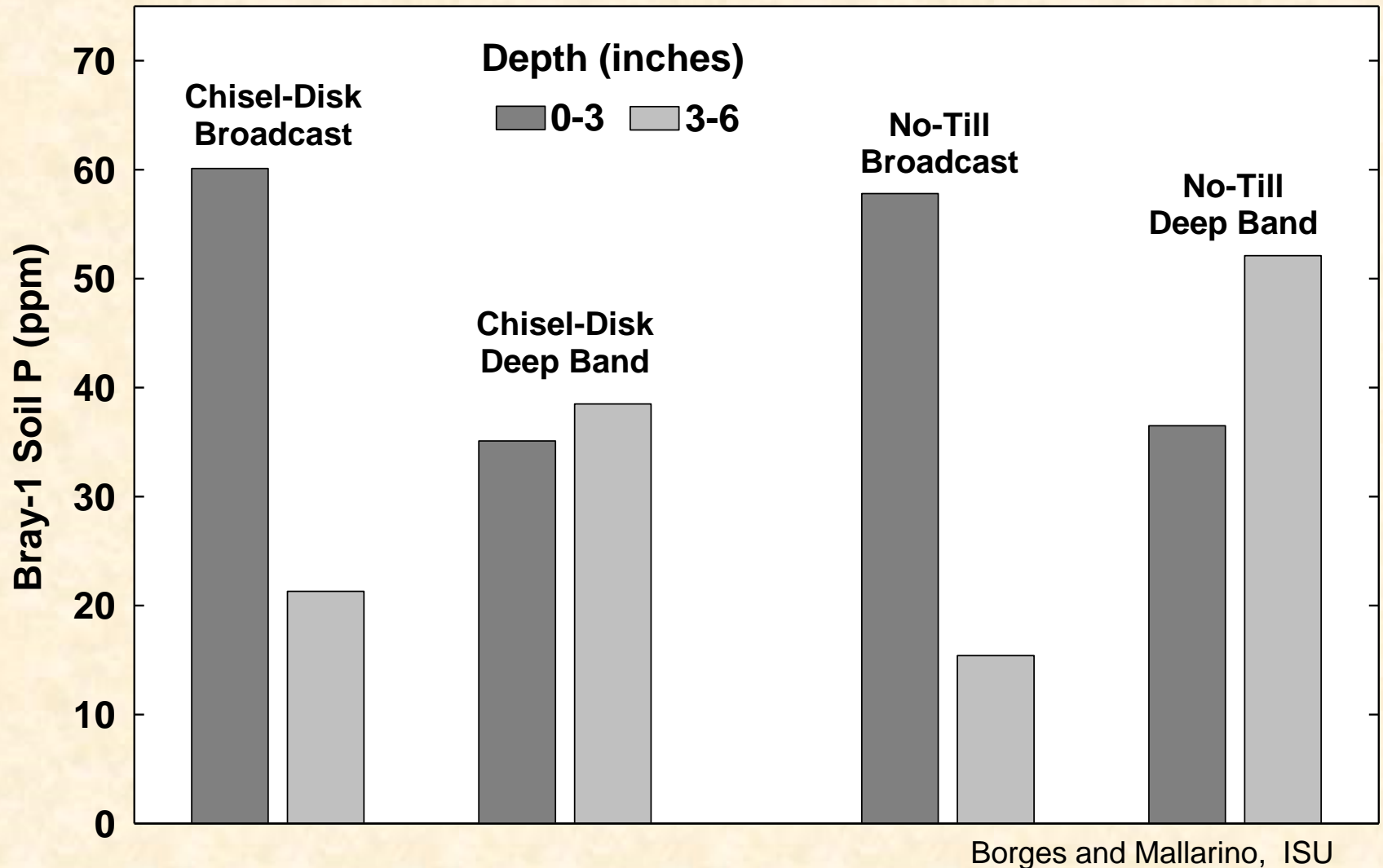
# P Rate and Application Factors

- The main way the Index accounts for P rate is through long-term effects on soil-test P
- This factor applies to recent fertilizer or manure application, since the last soil test
  - Impacts of the P application rate, method, and timing of application on dissolved P loss

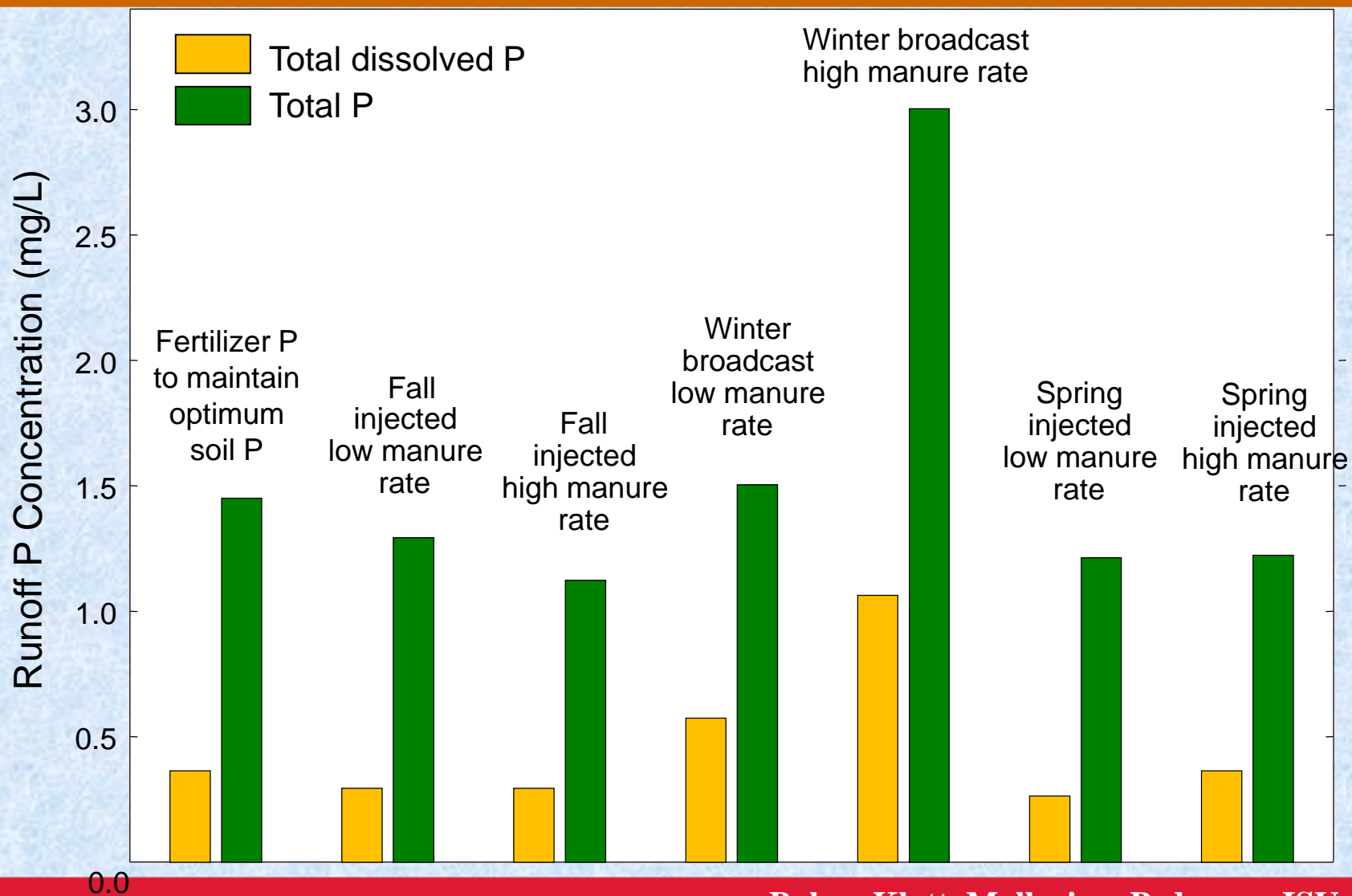
# Method and Time of P Application

| Method/Time of Application            | Coefficient |
|---------------------------------------|-------------|
| Incorporation/injection within 24 hrs | 0.4         |
| Incorporate within one week           | 0.6         |
| Surface applied (good conditions)     | 1.0         |
| Surface app. to frozen/snow ground    | 1.5         |

# Deep P Placement



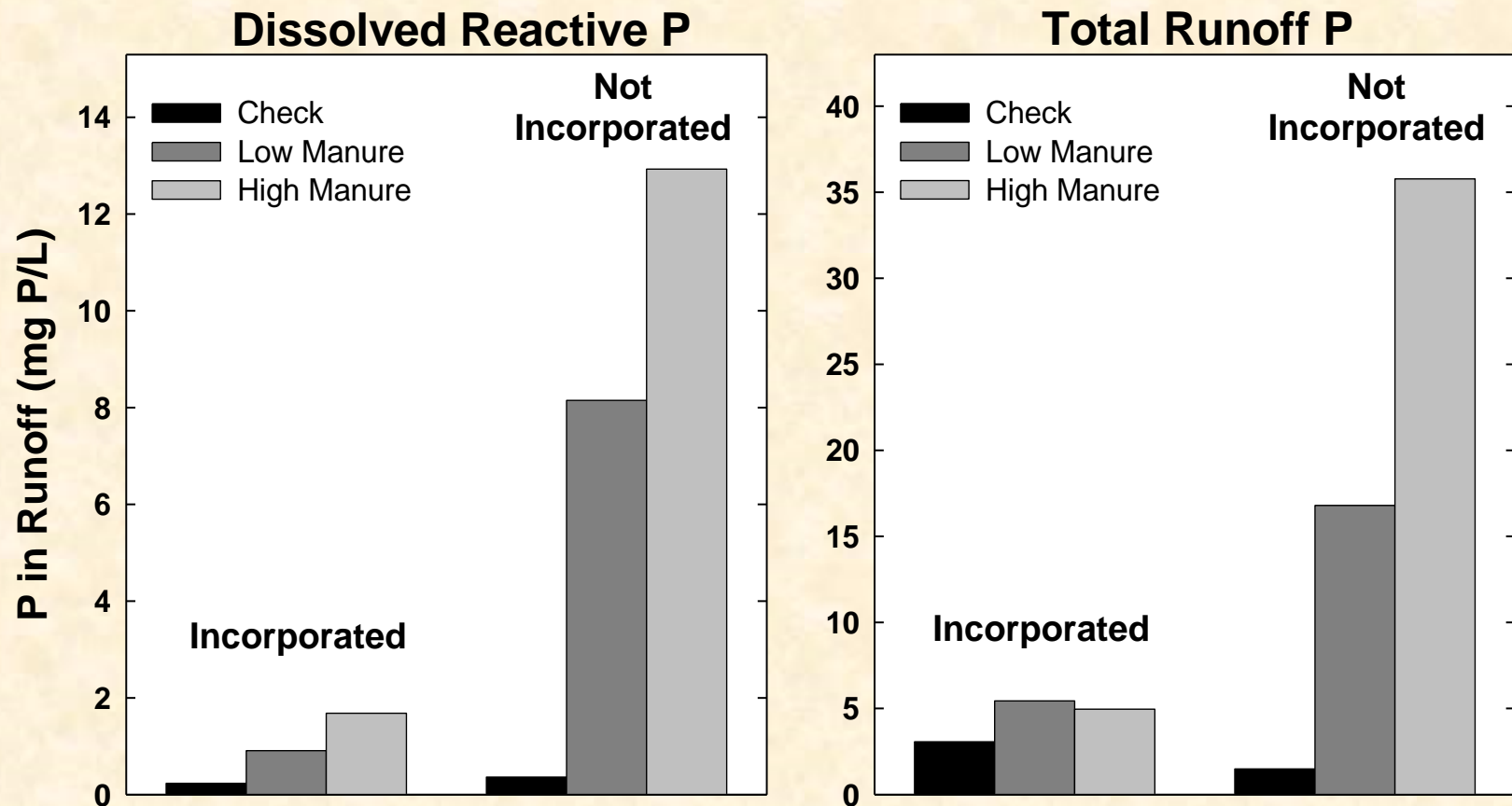
# Swine Manure Placement and Runoff P





# Manure Incorporation and Runoff P Loss

Poultry Manure at 0, 150, and 300 lb N/acre, Shortly After Application  
Averages Across Six Years, One Site



Haq, Mallarino, Allen, Kanwar, & Pederson; ISU

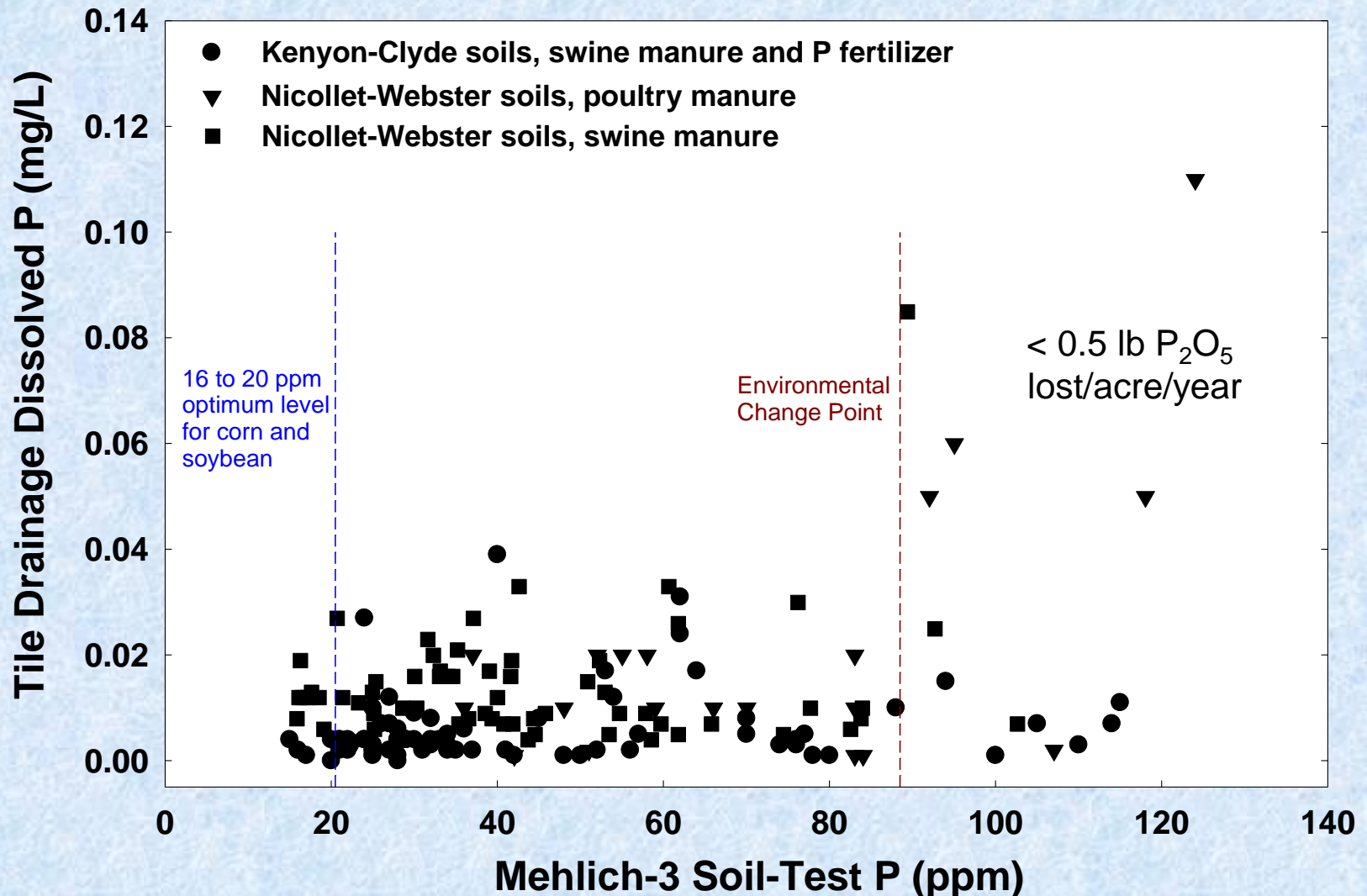
# Subsurface Drainage Component



# Soil P Loss and Subsurface Drainage

- Assumes water flow as 10% of annual precipitation
- Are tiles or sandy subsoil present?
- Assume no P loss if answer is no
- Soil-test P drainage factor:
  - 0.1 if Bray P is less than 100 ppm
  - 0.2 if Bray P is 100 ppm or higher

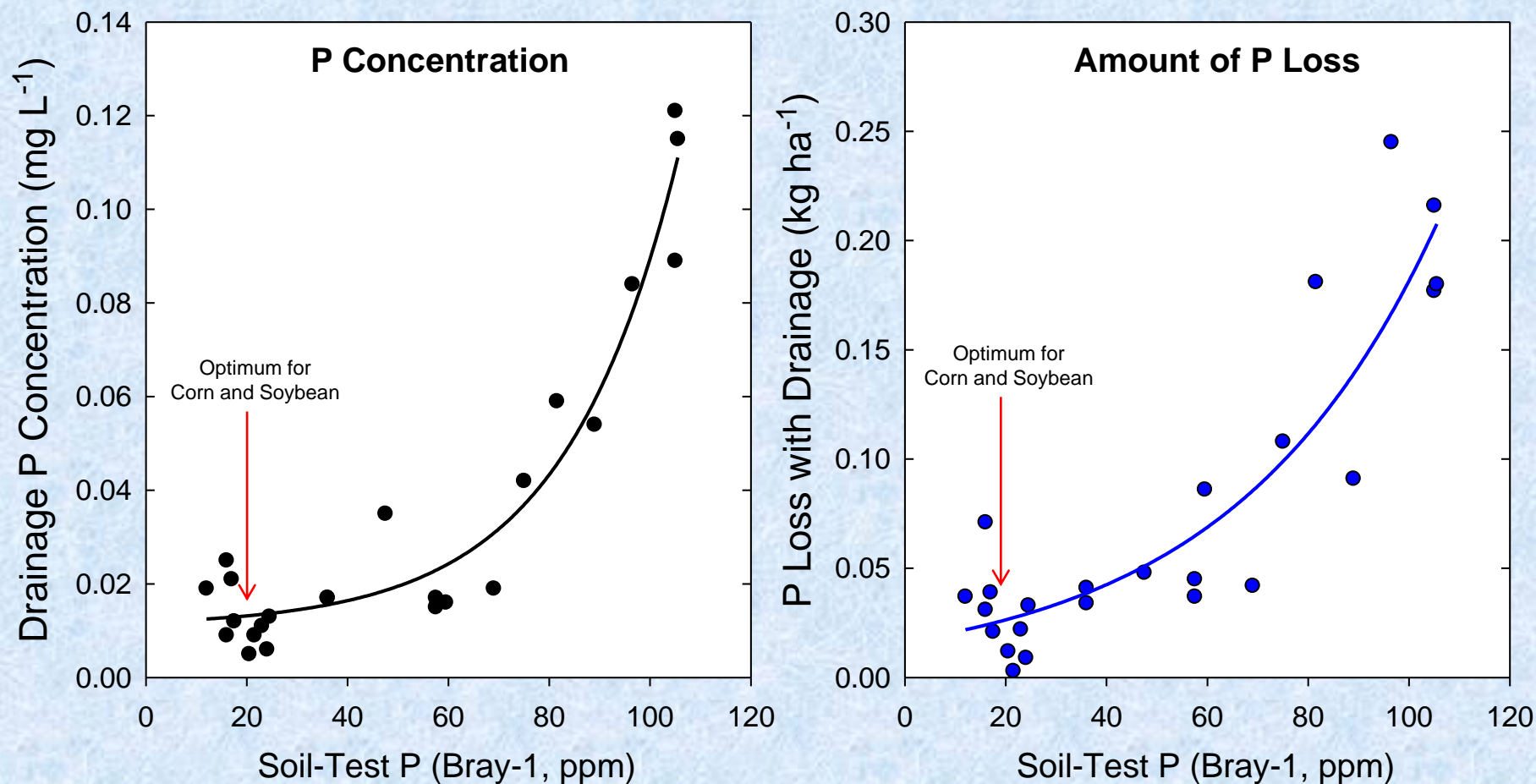
# Soil-Test P and Tile Drainage P Loss





# Tile Drainage P and STP

## Northeast Research Farm, Water Quality Project



Haq, Mallarino, Baker, Helmers, Pederson; 2011

# The P Index Calculator

File Edit View Insert Format Tools Data Window Help Acrobat

100% Arial 10 B U

138

B C D E F G H I J K L M N O P Q R S T U V W X Y

1 INSTRUCTIONS: Enter data in yellow cells. Enter all Erosion Data first,  
2 all Runoff Data next, and all Drainage Data last. v. 7/1/2004

3

4 Erosion Component Value 0.00

5

6 **Gross Erosion (tons/acre)**

7 Sheet & Rill (RUSLE2) Area (ac) Tons

8 Ephemeral 0.0

9 Gully 0.0

10

11 Factor 0.0

12

13 **Sediment Trap Factor (Conservation Practices)**

14 Note: Area to be credited with reduction is the area  
15 affected by the practice and should be broken out into  
16 separate Conservation Planning Units for P-Index  
17 calculation purposes.

18 None

19

20 Factor 1.00

21

22 **Sediment Delivery Ratio** View Map and Choose

23 Select Landform Region

24

25

26

27 Enter the distance from the center of the field  
28 to the perennial or intermittent stream (ft)

29

30 Factor 1.00

31

32 **Filter Factor** Click here for information... 393 Standard

33 Select the width of filter

34

35 Factor 1.0

36

37 **Enrichment Factor (Residue Management Effect)**

38 Select the enrichment factor

39

40 Factor 1.0

41

42 **P Test Factor**

43 Select the type of P Test

44

45 Enter the test result (ppm)

46

47 Factor 1.00 Next >

48

49

50

51

52

53

54

55

Clear Inputs Highlight Land Management Inputs Only Highlight All Inputs

Runoff Component Value 0.00

RCN Factor

Select the County Precipitation Factor

Landform region not selected!

0.0

Select the land use

Select the dominant soil type

Runoff Curve Number  
RCN Fraction

Factor 0.00

P Test Factor

Select the type of P Test

Test result (ppm) 0.0

Factor 0.00

Rate Factor Click here for information...

Enter the Rate of P Application  
From All Sources (lb P<sub>2</sub>O<sub>5</sub>/acre)

Elemental P (lbs) Convert

Select the application method

Factor 0.00 Next >

Subsurface Drainage Component Value 0.00

Flow Factor

Tile

Is Tile Present?

Factor 0.0

STP Factor

Assumes 10% of annual rainfall flows through tile or leaches  
through coarse textured subsoil/substratum.

Factor 0.000

P-INDEX 0.00

Two reports are available for storing P-Index data.

1. Summary report stores data for 3 fields, and up to  
10 runs per field.

2. Detailed report does not separate runs and fields,  
but keeps track of all variables in the P-Index.

Choose output location for summary report:

Enter field name:

Enter run name:

Use the Copy button to copy data from this worksheet  
to the reports.

Summary Detailed Copy to

Calculator Summary Report Detailed Report Lookups SoilsThatArePoorlyDrained SoilsThatArePermeable SDR Hydrologic Soils RCN Landform

# P Index Risk Ratings

Current P **and** soil conservation practices result in:

- **Very Low** or **Low** impacts
  - Excellent from an ecological water quality perspective
- **Medium** impact
  - Acceptable P loss, but future practices should not increase the risk of P loss

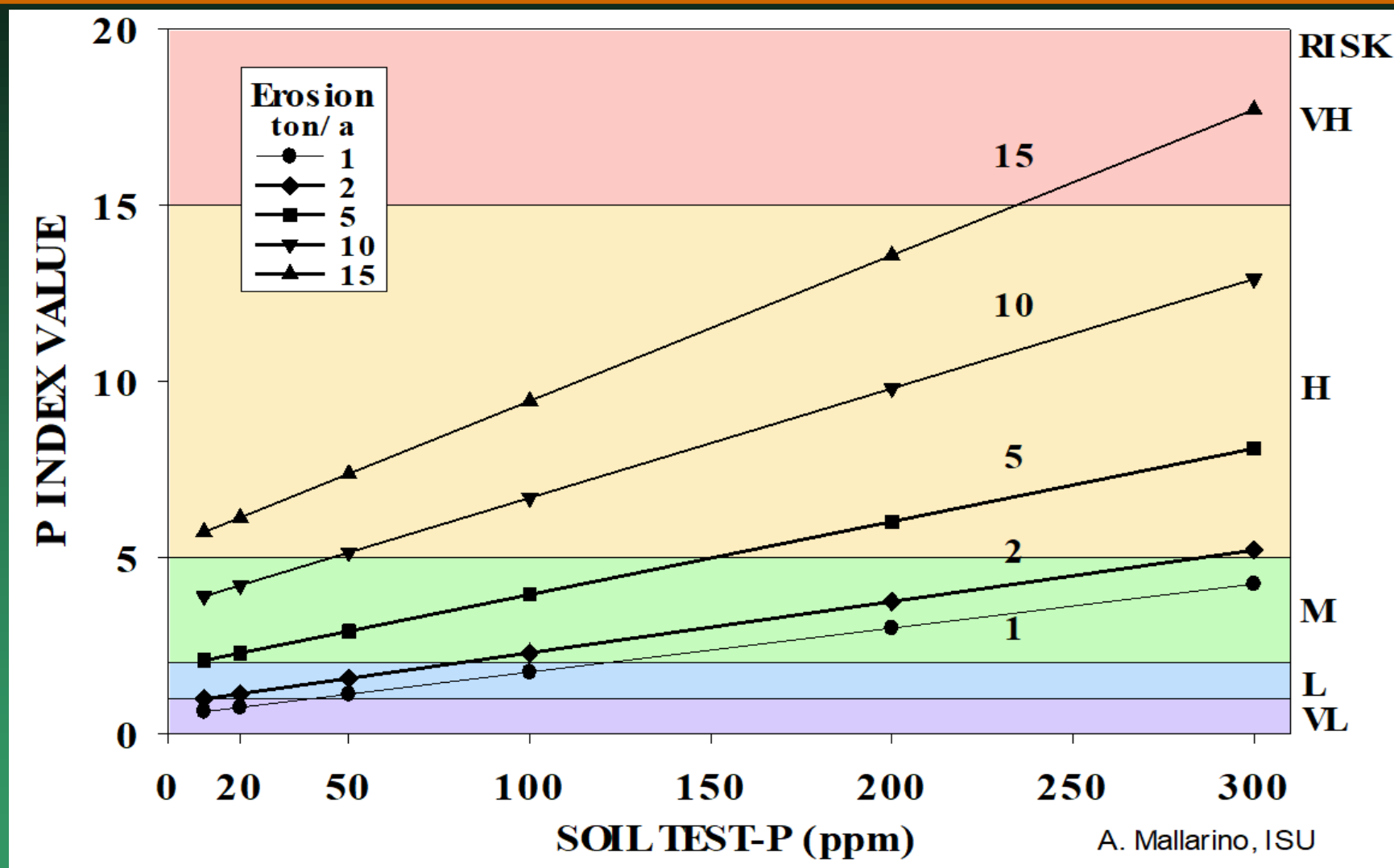
# Site Vulnerability Ratings

- **High** impact
  - Obvious problem, new soil conservation **and/or** P management practices should be implemented
- **Very High** impact
  - Extreme problem, new soil conservation **and** P management practices that **may** require no P application are needed

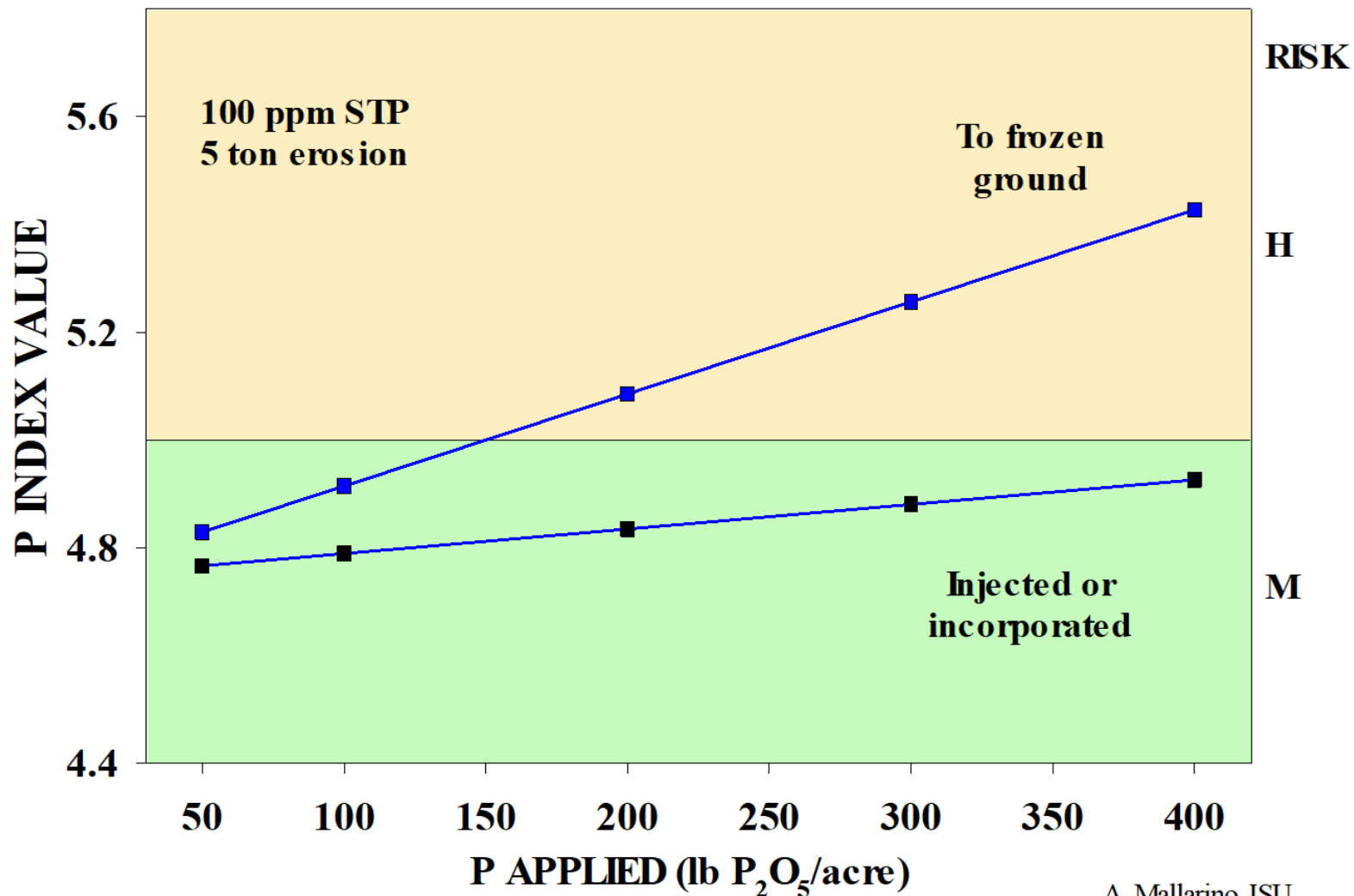




# Combined Effects: Erosion and Soil P



# Combined Effects: Application Method and Soil P



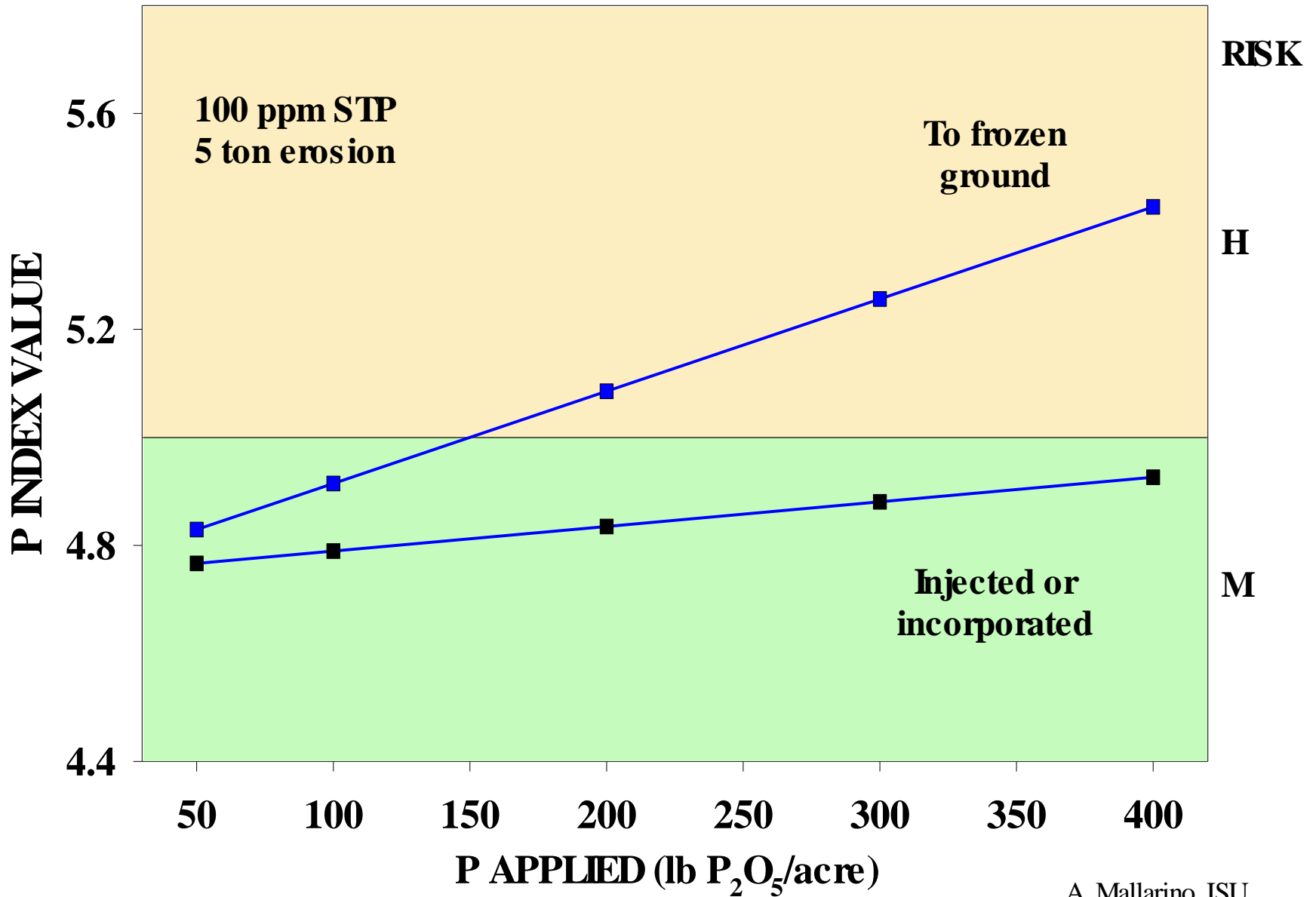
A. Mallarino, ISU

# Study Individual Components

| Index Component      | Very High Soil Test, High Erosion |  |
|----------------------|-----------------------------------|--|
| Gross Erosion        | 10                                | RUSLE erosion: 10 ton                                      |
| Sediment Trap/SDR    | 0.49                              | SIDP: 1,000 feet   |
| Buffer Factor        | 1                                 | Buffer: None   |
| Enrichment Factor    | 1.1                               | Tillage without Buffer                                     |
| STP Erosion Factor   | 1.54                              | Bray 1-P: 200 ppm  |
| → Erosion            | 8.30                              |  |
| Runoff Factor        | 0.21                              | RCN: 78  |
| Precipitation Factor | 7.9                               | Adams County   |
| STP Runoff Factor    | 1.05                              | Bray 1-P: 200 ppm  |
| P Application Factor | 0.02                              | 100 lb P <sub>2</sub> O <sub>5</sub> /acre; 24 hr. incorp. |
| → Runoff             | 1.78                              |  |
| Flow Factor          | 0.1                               | Tile/Coarse Subsurface: Yes                                |
| Precipitation Factor | 7.9                               | Adams County   |
| STP Drainage Factor  | 0.2                               | Bray 1-P: 200 ppm  |
| → Subsurface         | 0.16                              |  |
| → P- Index           | 10.2                              | High Risk Rating   |



# IMPACT OF P RATE AND APPLICATION METHOD



# Meaning of Partial P Index Values

- The index provide partial ratings for Erosion, Runoff and Subsurface Drainage components
- The partial ratings are very useful:
  - identify reasons of high loss risk
  - suggests what P management or soil conservation practices will be more effective

| Index Component      | Very High Soil Test, High Erosion |  |
|----------------------|-----------------------------------|--|
| Gross Erosion        | 10                                | RUSLE erosion: 10 ton                                      |
| Sediment Trap/SDR    | 0.49                              | SIDP: 1,000 feet   |
| Buffer Factor        | 1                                 | Buffer: None   |
| Enrichment Factor    | 1.1                               | Tillage without Buffer                                     |
| STP Erosion Factor   | 1.54                              | Bray 1-P: 200 ppm  |
| → Erosion            | 8.30                              |  |
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| → Subsurface         | 0.16                              |  |
| → P- Index           | 10.2                              | High Risk Rating   |

**Zoning fields for  
P Index calculation  
and P management**

**M**

++

**VL**

**L-M**

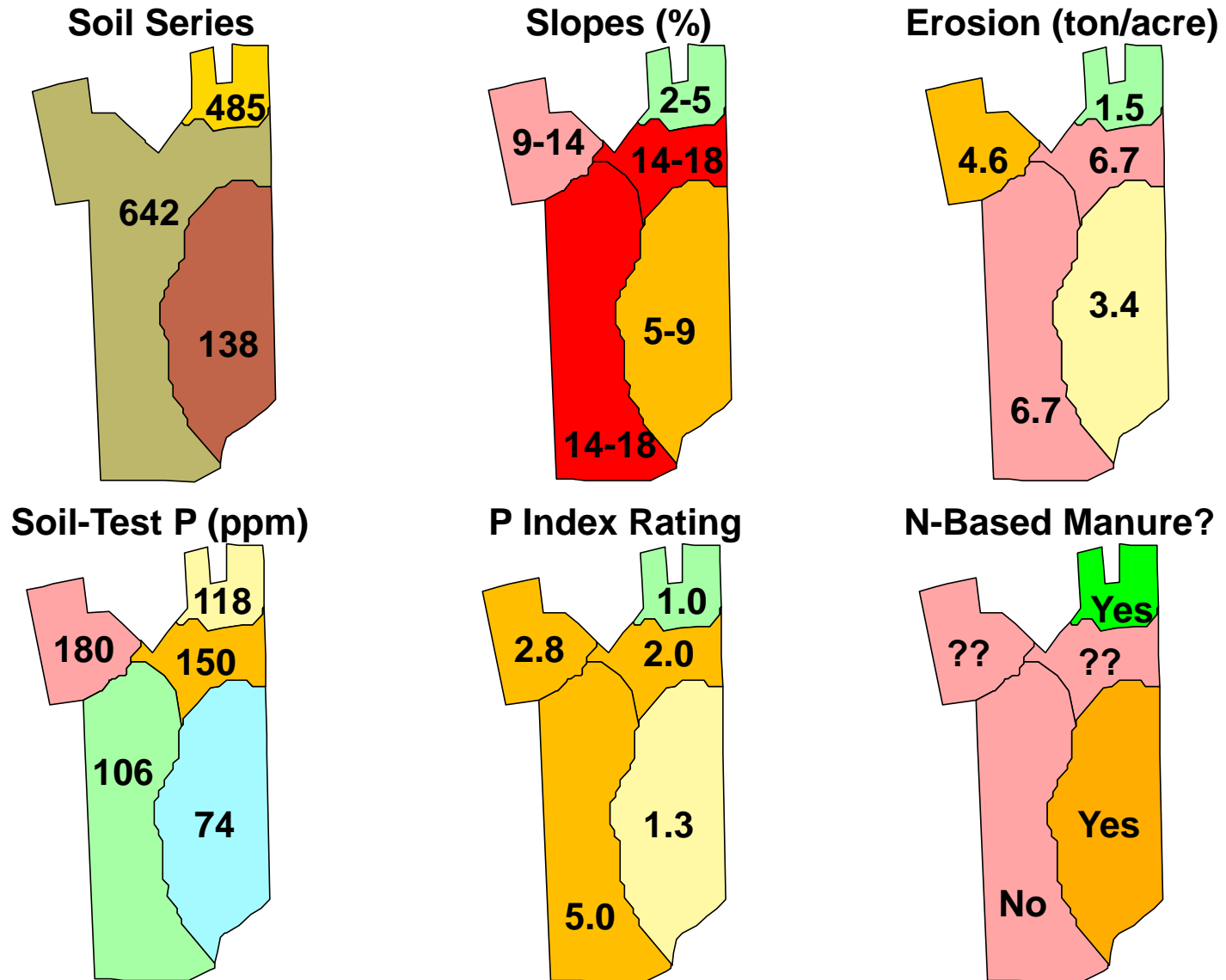
**L**

**H**

**Soil-test P was  
74 to 180 ppm  
(Very High)**

**But the P Index  
ratings were  
Very Low to High**

# Delineate Field Zones for P Index Calculation



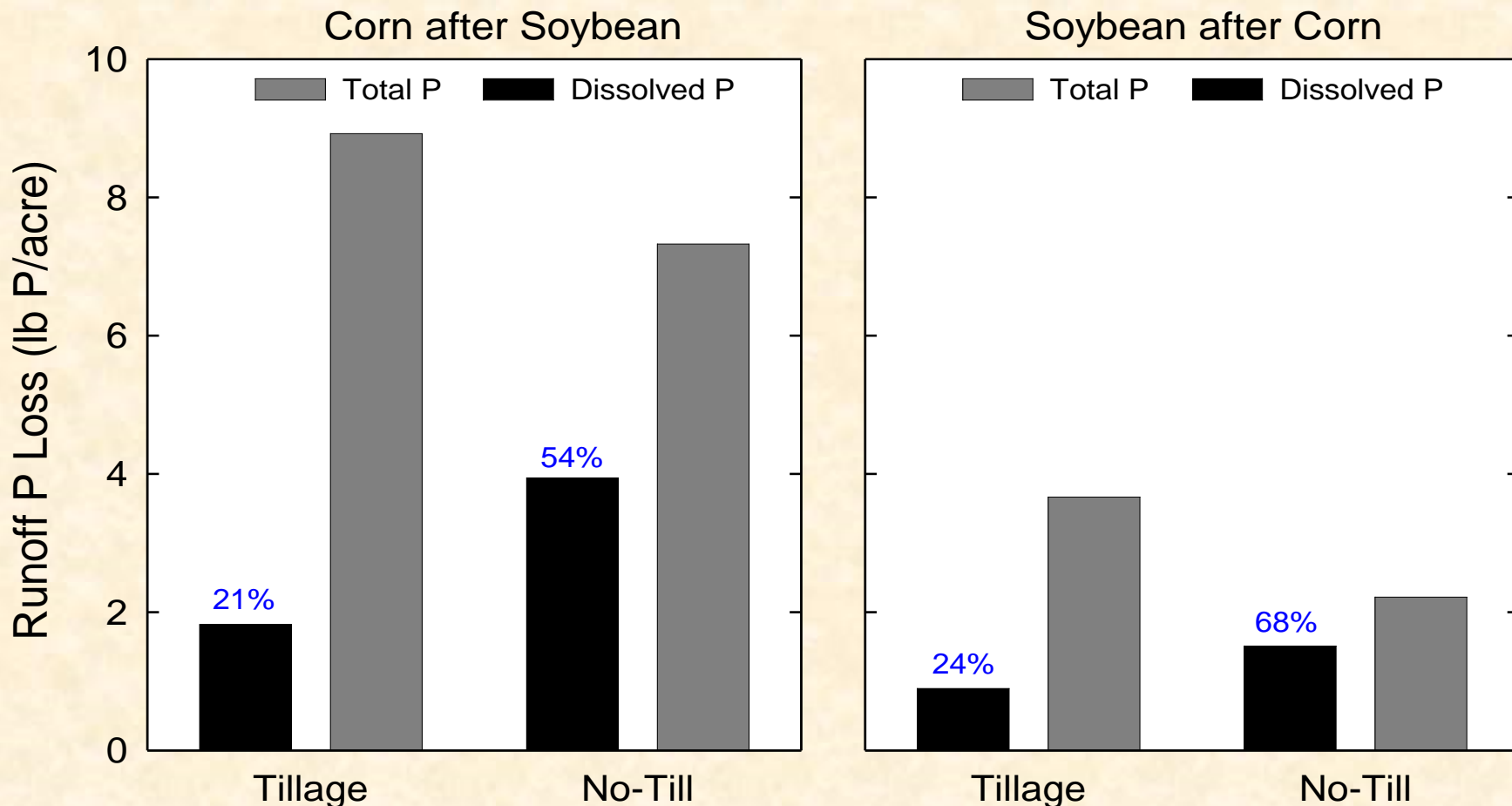


# P Index and P Management

- The index is a P assessment tool
- Identifies reasons for high P loss, but **has no built-in limits** for soil-test P or P application rates
- Suggests alternative **field-specific** management **and** soil & and water conservation practices to reduce risk of P loss

# Northwest Iowa Runoff P Study

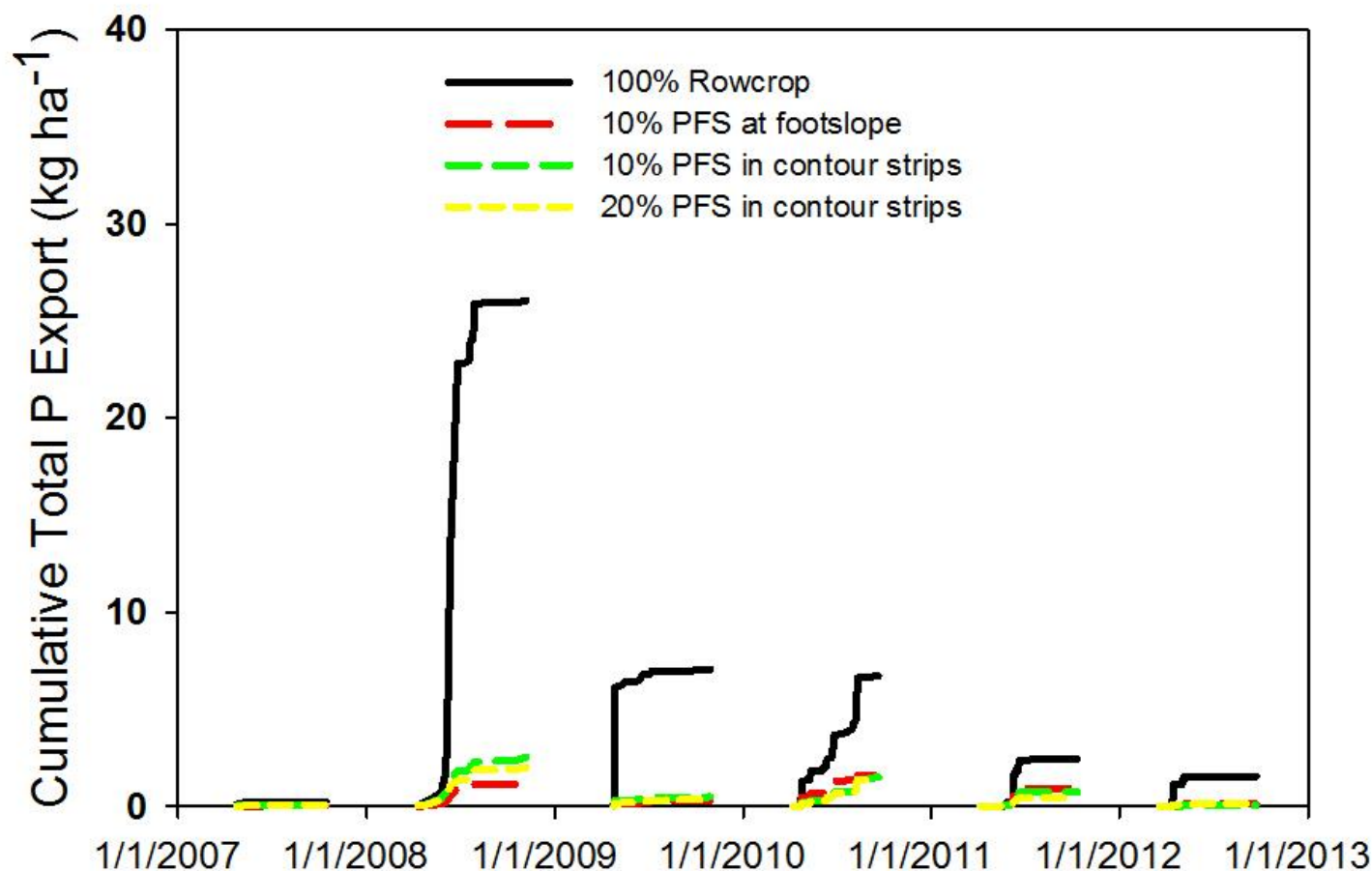
Natural Rainfall, 100 lb  $P_2O_5$ /acre to Corn for the C-S Rotation (6 Years Avgs.)



Mallarino, Haq, et al., 2012

# Grass Filter Strips

Zhou et al., 2014

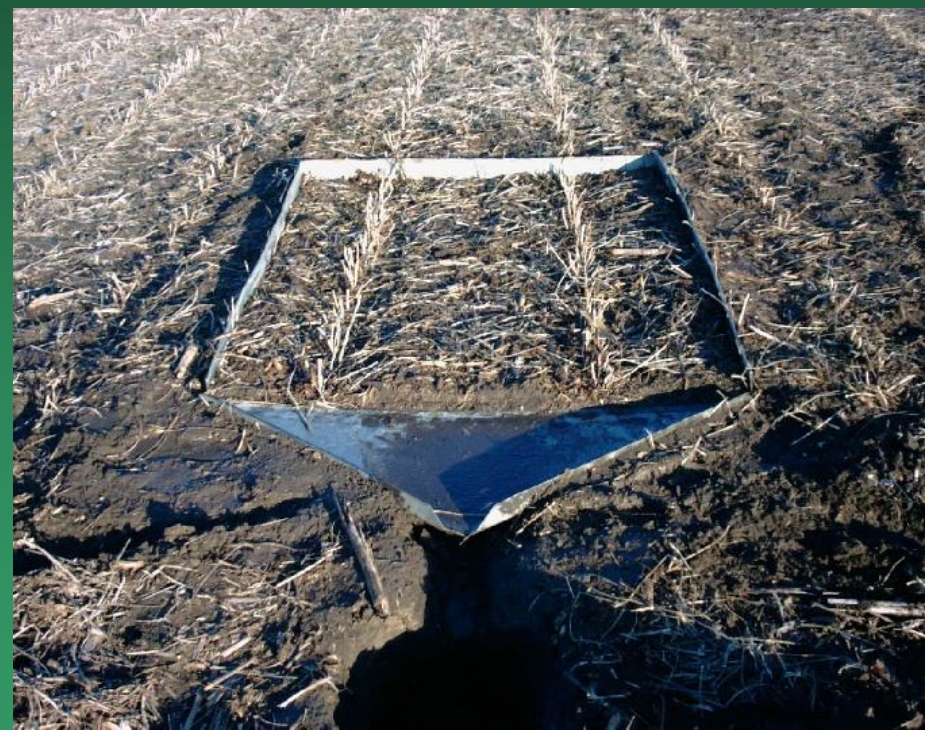


**>90%  
Reduction  
in P export  
from  
watersheds  
with prairie  
filter strips.**

**But recent  
research  
shows can  
increase  
dissolved P  
loss**

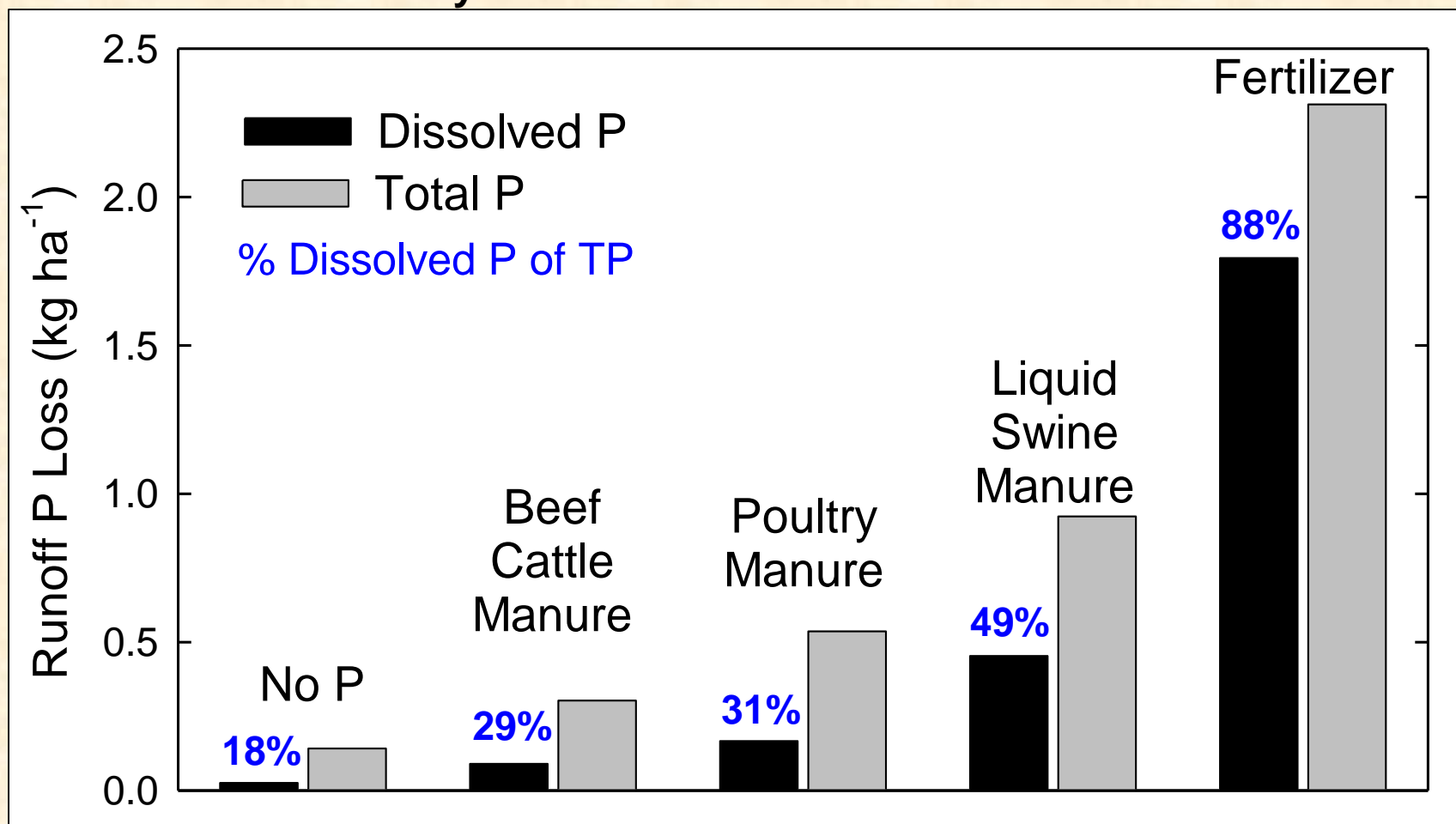
# Field Rainfall Simulations

Differences between fertilizer and manure P sources and of time to a runoff event on P loss with surface runoff after applying P with or without incorporation



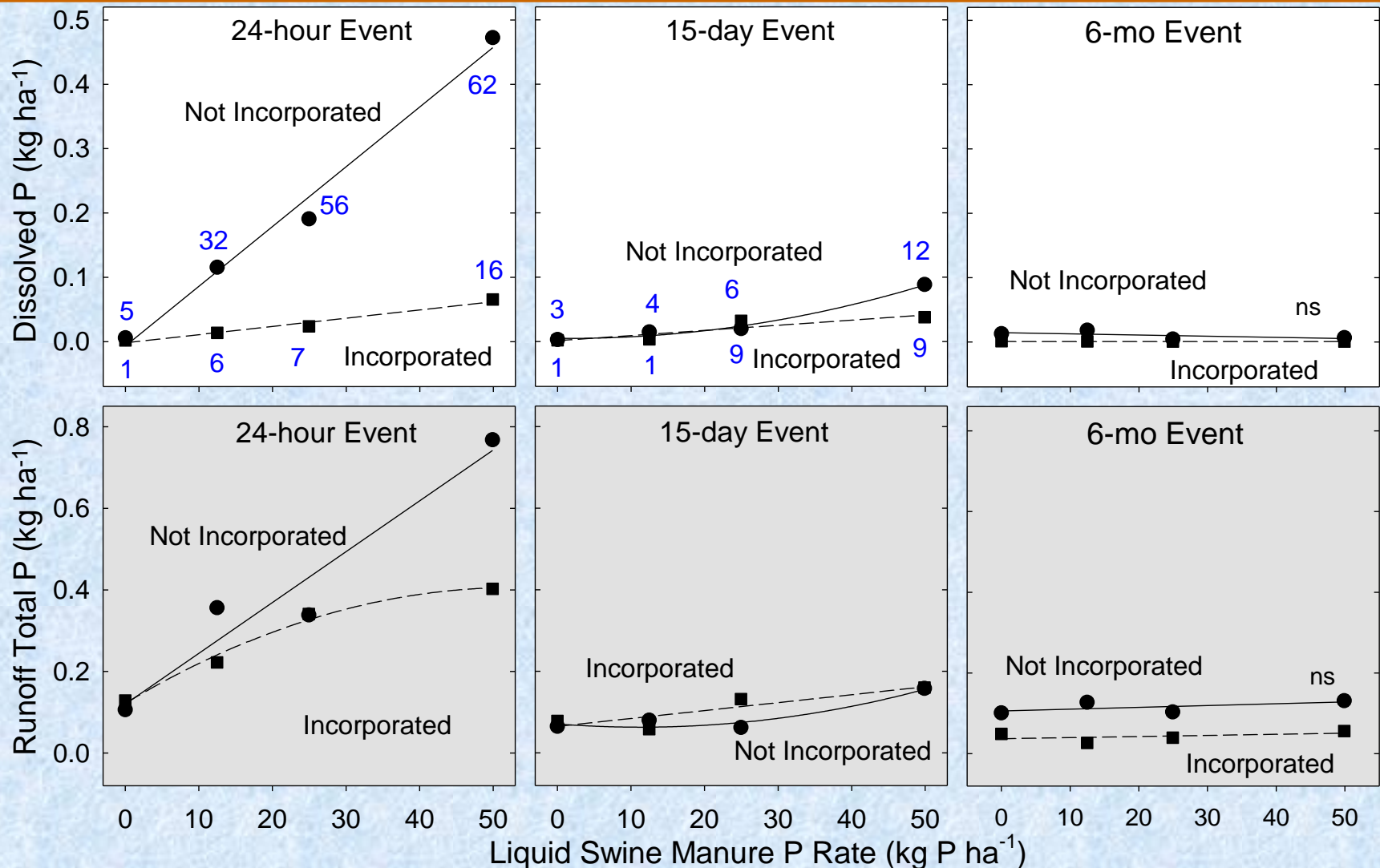
# P Source Effects: Immediate Runoff Event

Runoff within 24 hours, No Incorporation, Broadcast 100 lb  $P_2O_5/a$  to Soybean Residue - Means of 21 Fields





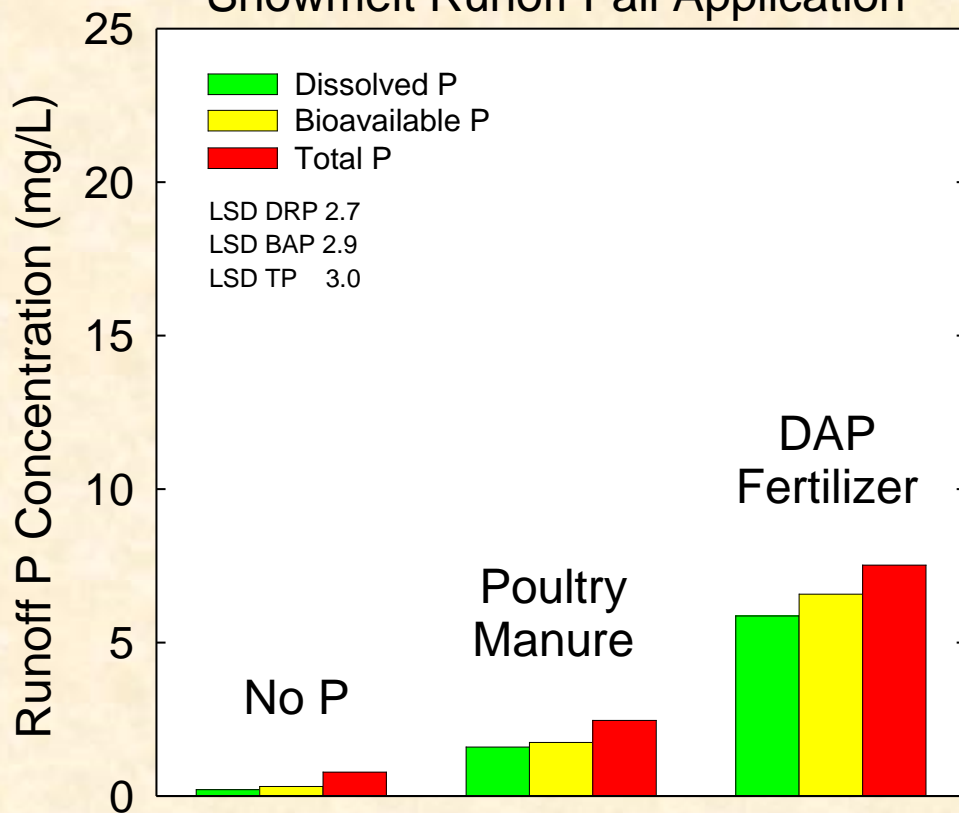
# P Rate, Incorporation, Time to Runoff



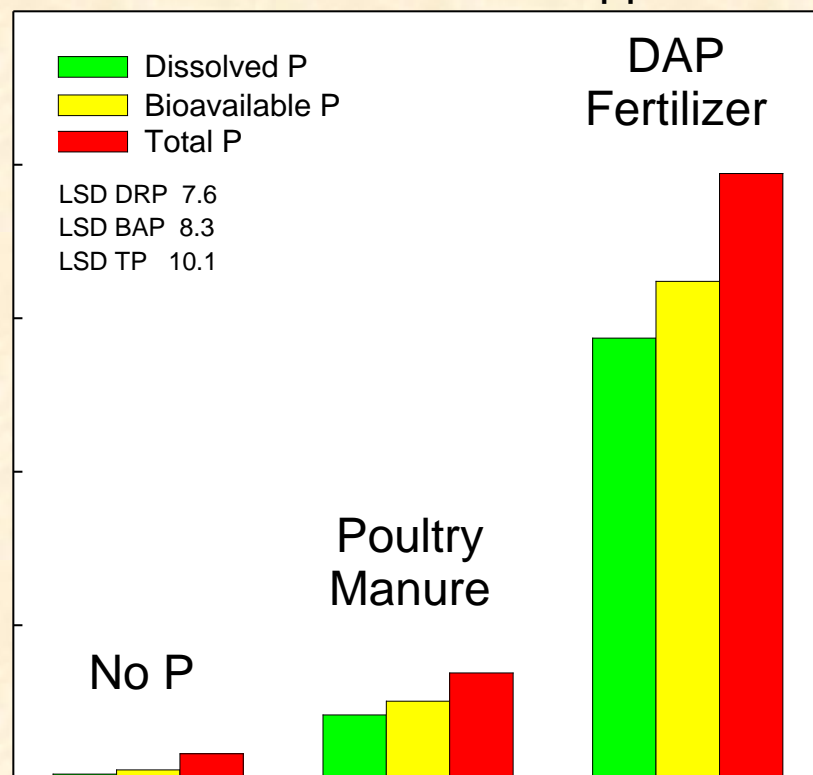
# P Sources Applied in Fall or Winter

100 lb  $P_2O_5$ /acre to Soybean Residue, No Incorporation  
Averages of 3 Fields

Snowmelt Runoff Fall Application



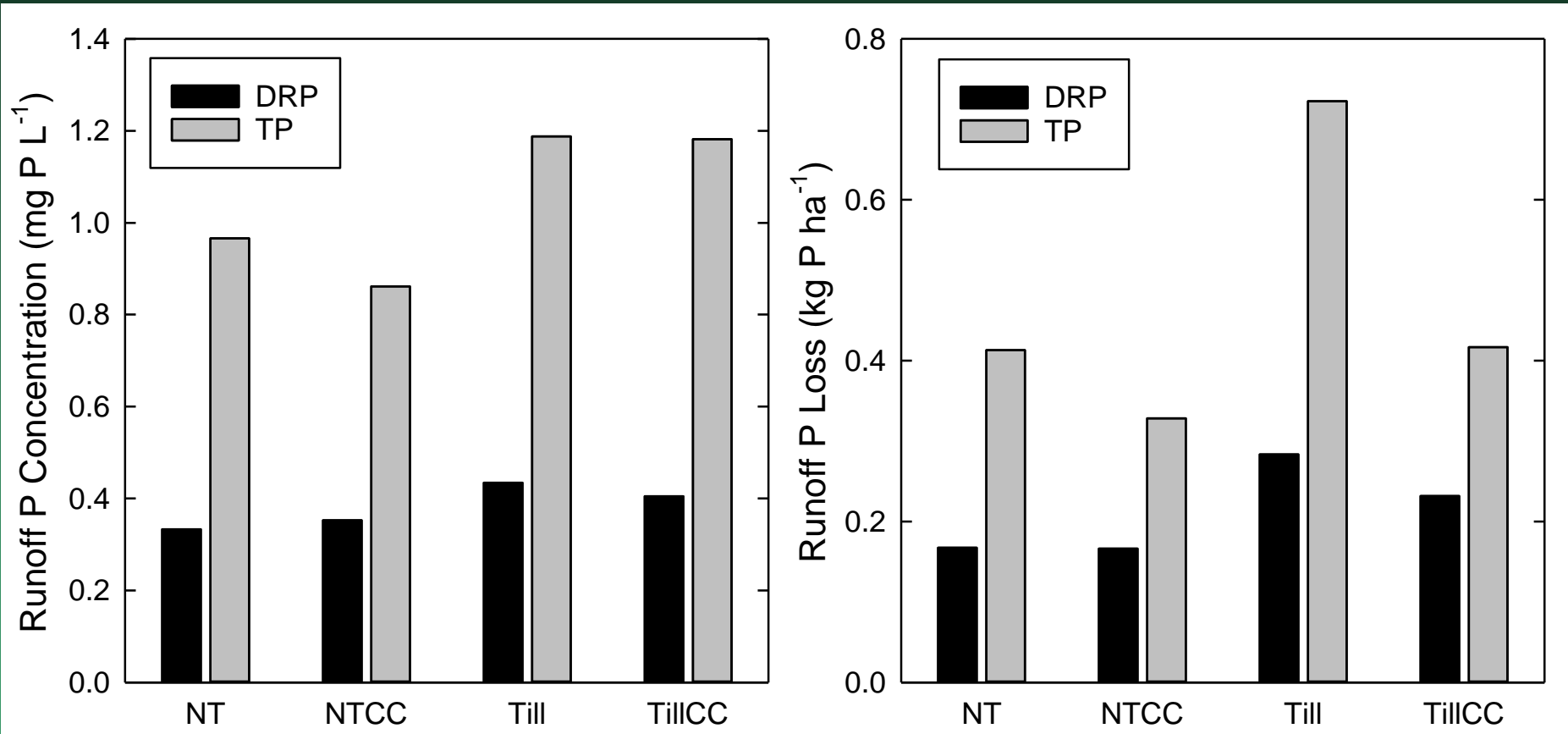
Snowmelt Runoff Winter Application



Haq and Mallarino, 2012

# Cover Crops and P Loss with Runoff

## Averages of Four Years



# When do P losses occur?

- When there is soil erosion or water runoff!
- **Late February to late June:**
  - Snow melt and high-rainfall period
  - Little or no crop canopy
  - Saturated soils (moisture, floods)
  - Reduced conditions (soluble  $\text{Fe}^{+2}$ )
  - Soils tilled and with little cover

# Sound Phosphorus Management

- Use conservation practices!
- Apply manure based on crop nutrient needs and P index ratings.
- Reduce P of manure: feed phytase enzyme, low phytate grain, reduce P supplements as much as possible.
- Dedicate time to careful manure application. Incorporate or inject it without increasing soil erosion.



**Soil Fertility Web Site**  
**<http://www.agronext.iastate.edu/soilfertility/>**

**[apmallar@iastate.edu](mailto:apmallar@iastate.edu)**  
**515-294-6200**

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