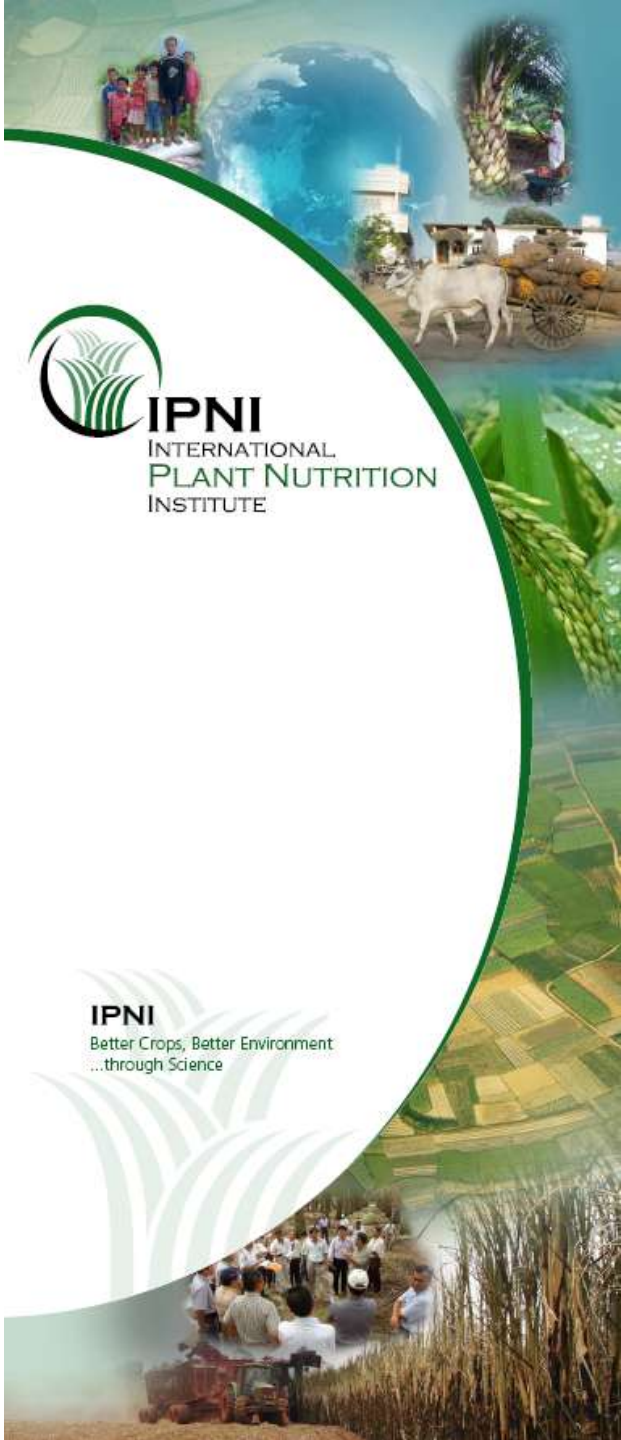
Nutrient Use Efficiency: A Midwest Perspective

T. Scott Murrell
U.S. Northcentral Director

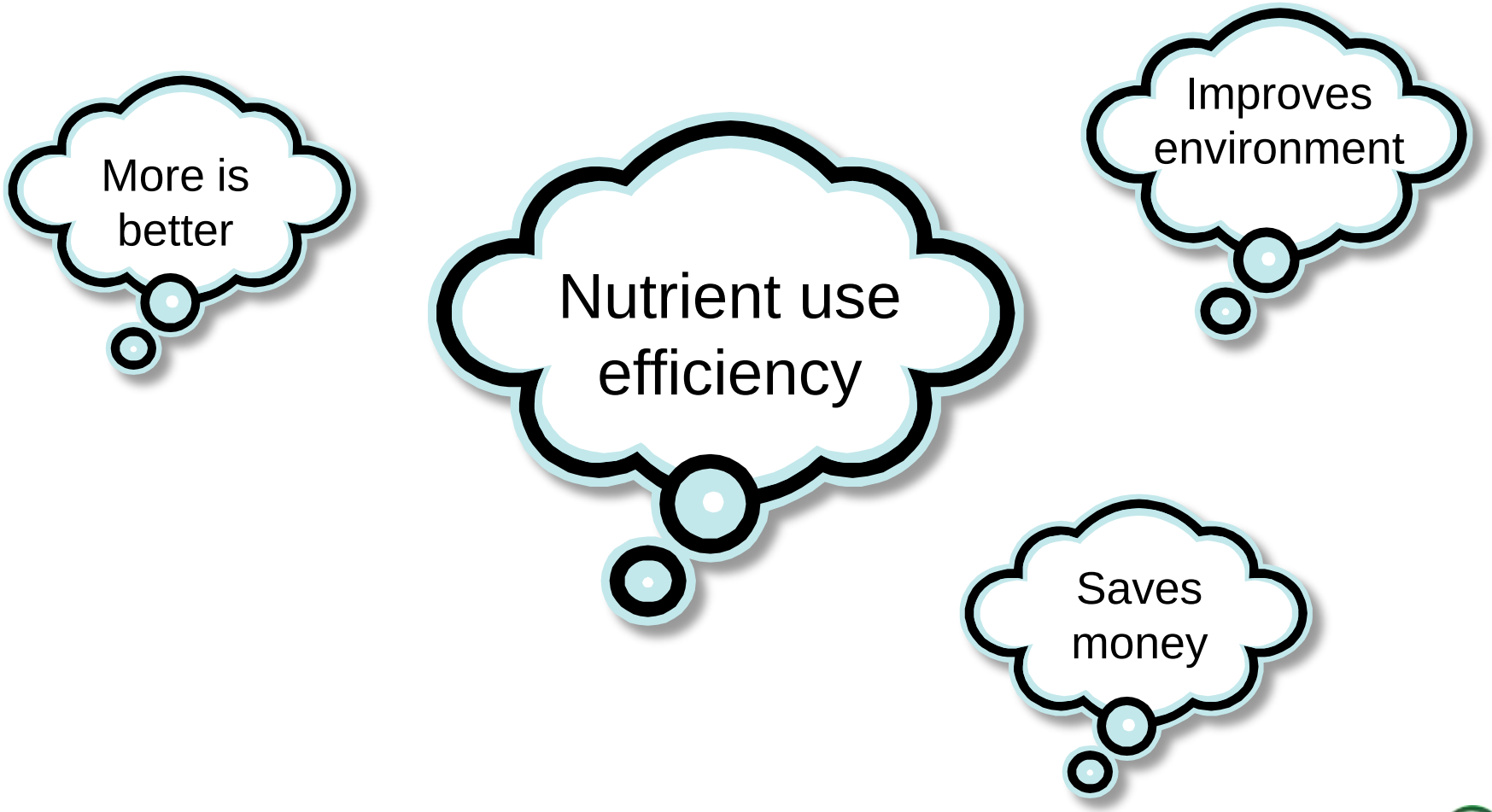
Nutrient Efficiency & Management Conference,
Rochester MN. 15 Feb. 2011



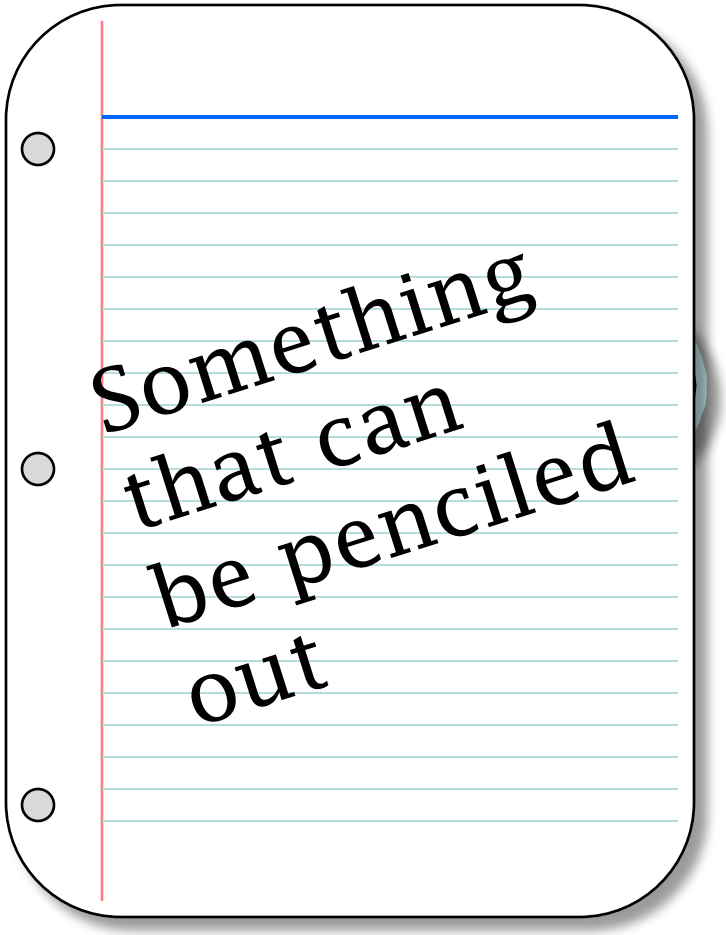
Outline

- The concept of nutrient use efficiency
- Three measures of nutrient use efficiency:
  - Partial factor productivity
  - Agronomic efficiency
  - Partial nutrient balance
- Spatial scale
  - National/state/watershed
    (university/agency scientists)
  - Farm/field/within-field
    (farmers, agency personnel, and consultants/advisers)

Thoughts about nutrient use efficiency



Nutrient use efficiency: The role of science



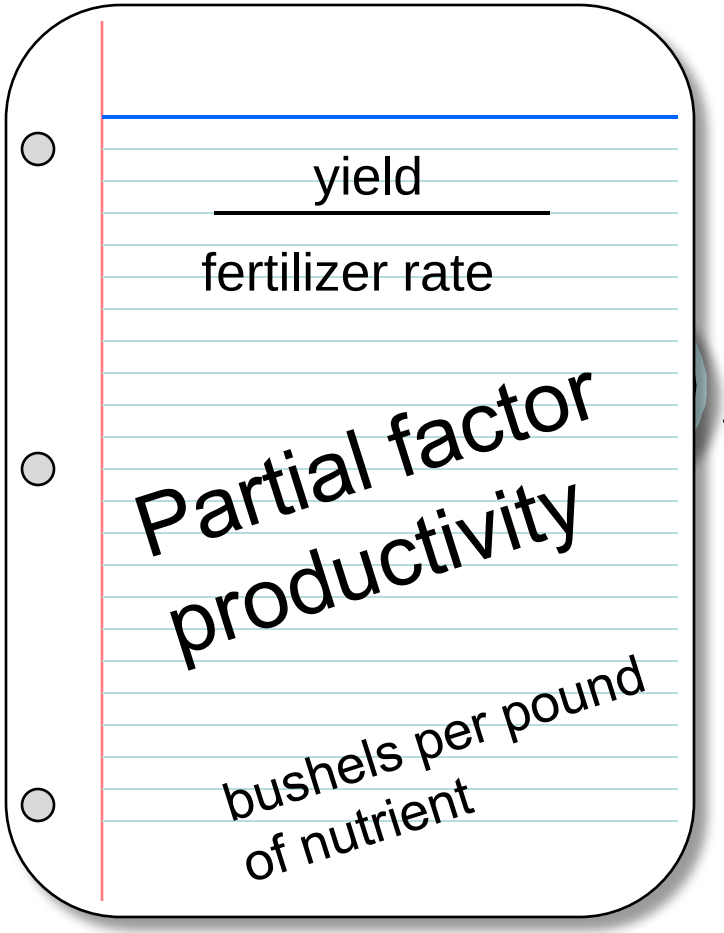
Role of science

- Figure out how to measure it
- Figure out how it relates to the many objectives we have for our feed/fiber/food/fuel supplies (quality, quantity, sustainability, profitability, etc.)
  - What is too little?
  - What is enough?
  - What is too much?

Making nutrient use efficiency something we can measure: Grain crop example

Things we can measure
Grain yield of a fertilized crop
Grain yield of an unfertilized crop
Fertilizer application rate
Nutrient content of the grain

Making nutrient use efficiency something we can measure: Grain crop example



Things we can measure
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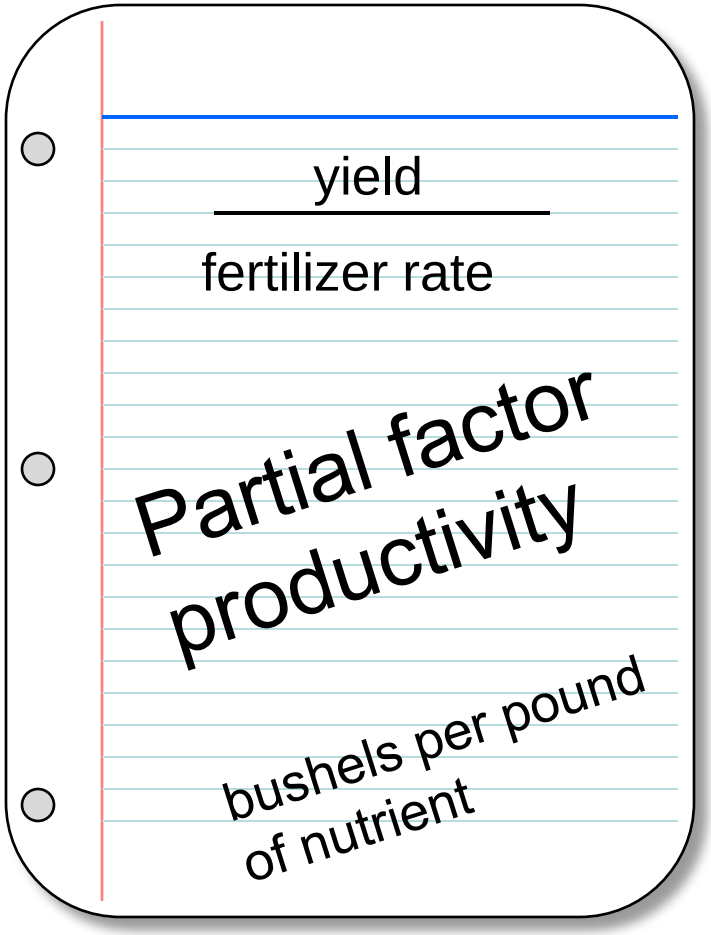
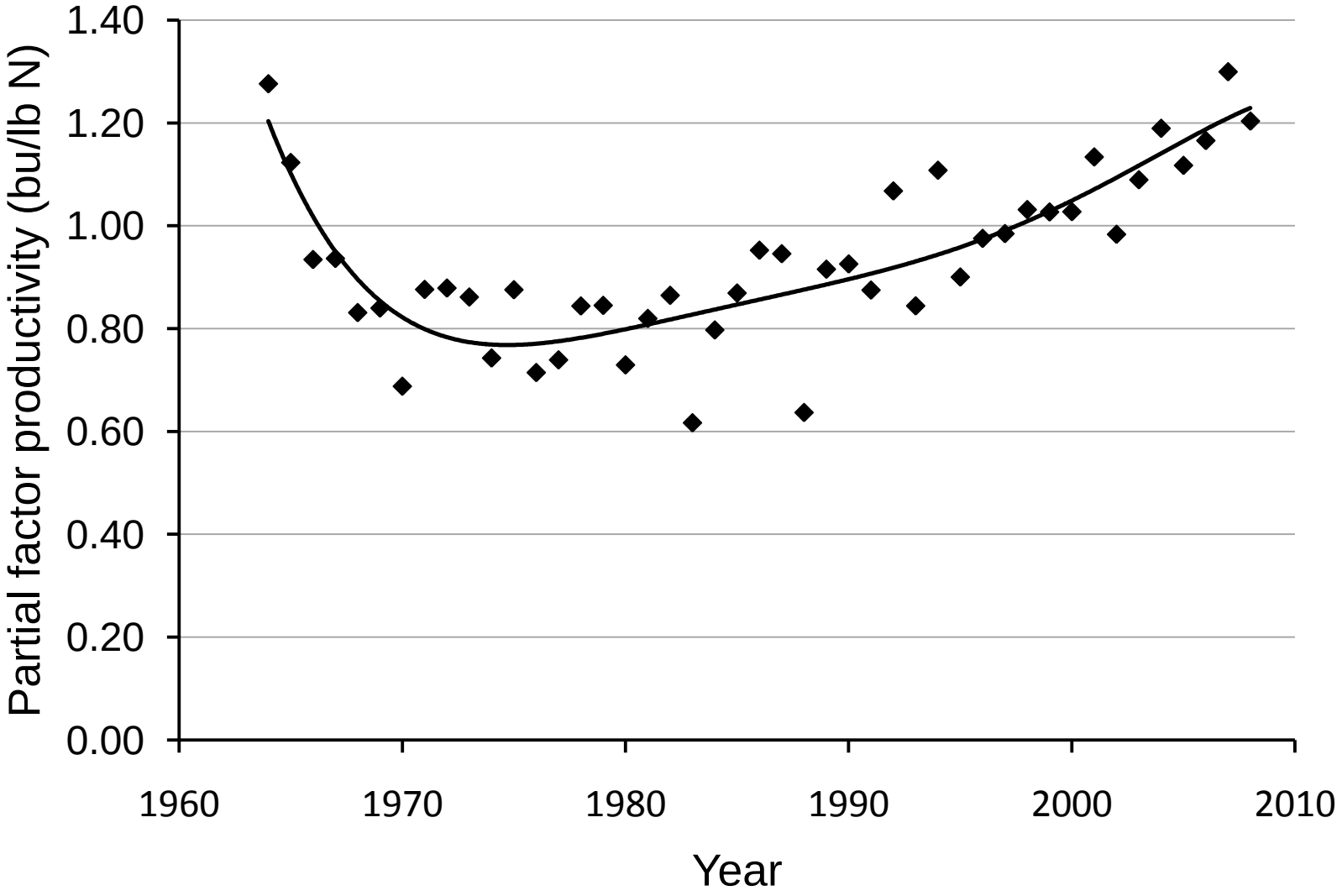
Nutrient use efficiency as measured by: *Partial factor productivity*



Measurement: Spatial Scales

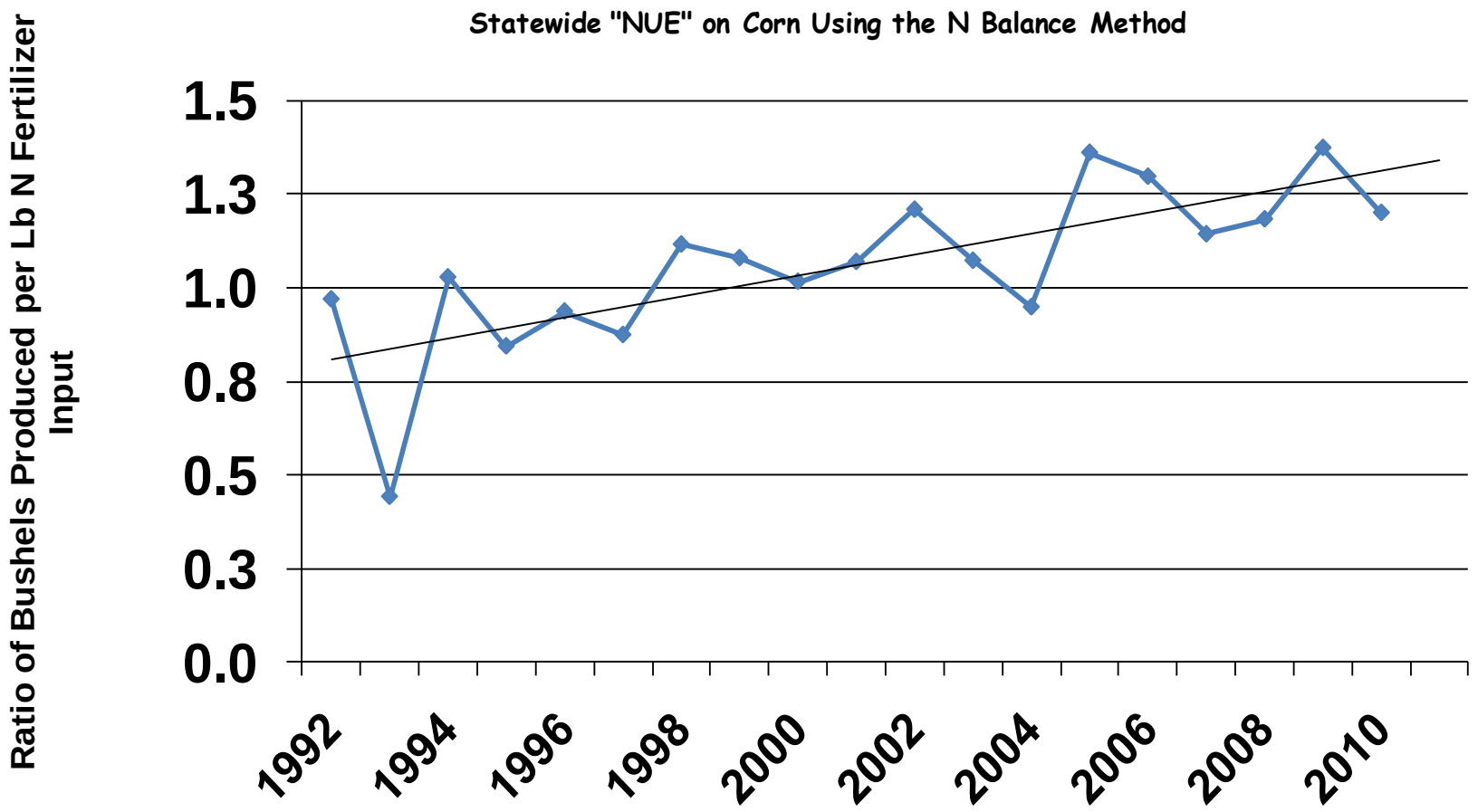
- National/state/county/watershed scale:
  - Crop production statistics
  - Fertilizer use statistics
- Farm/field/within-field scale:
  - Crop yield records/maps
  - Fertilizer application records/maps

Partial factor productivity of nitrogen for corn grain:
Scale: U.S., 1964-2008



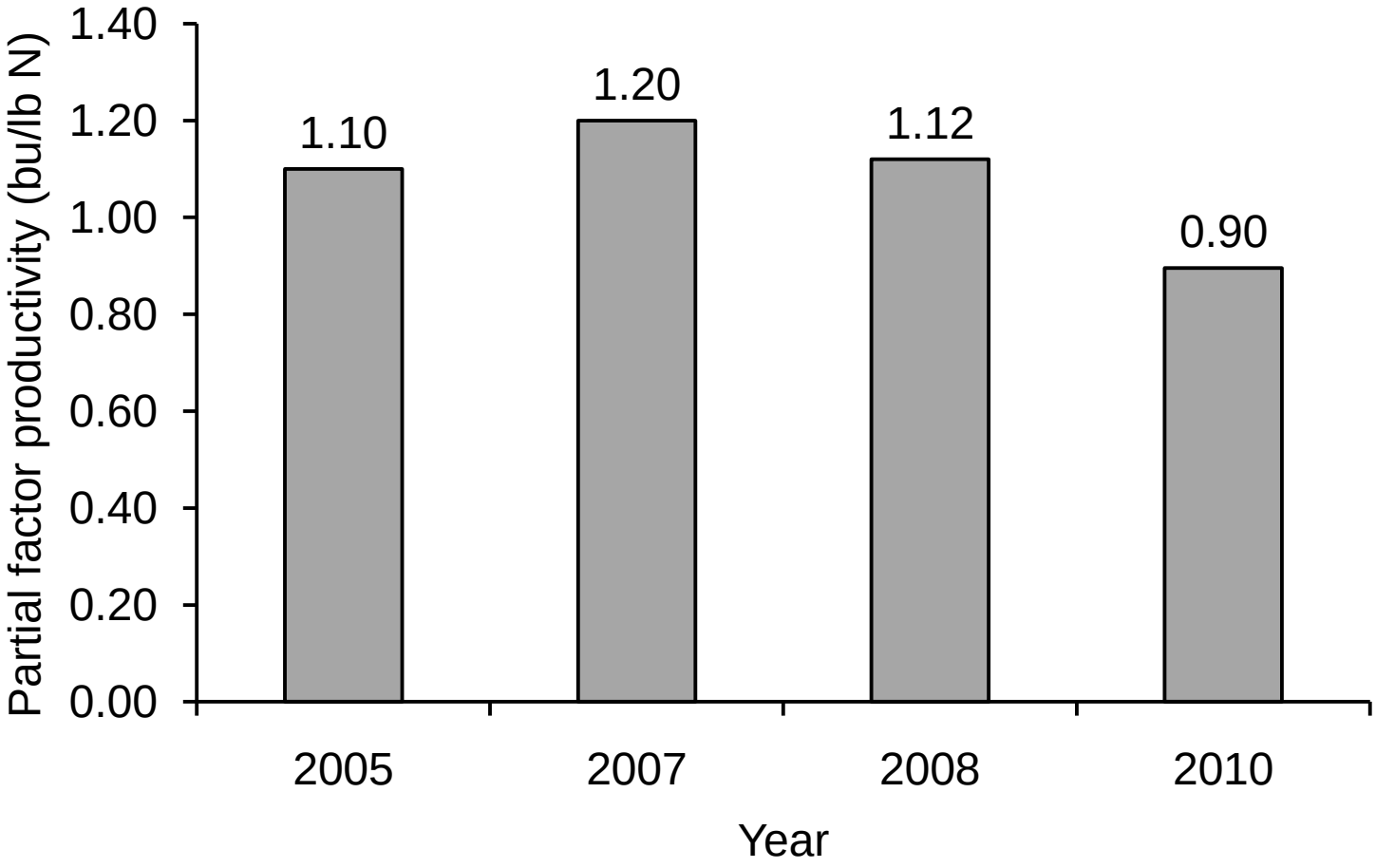
Data: USDA-NASS, USDA-ERS

Partial factor productivity of nitrogen for corn grain:
Scale: Minnesota state, 1992-2010



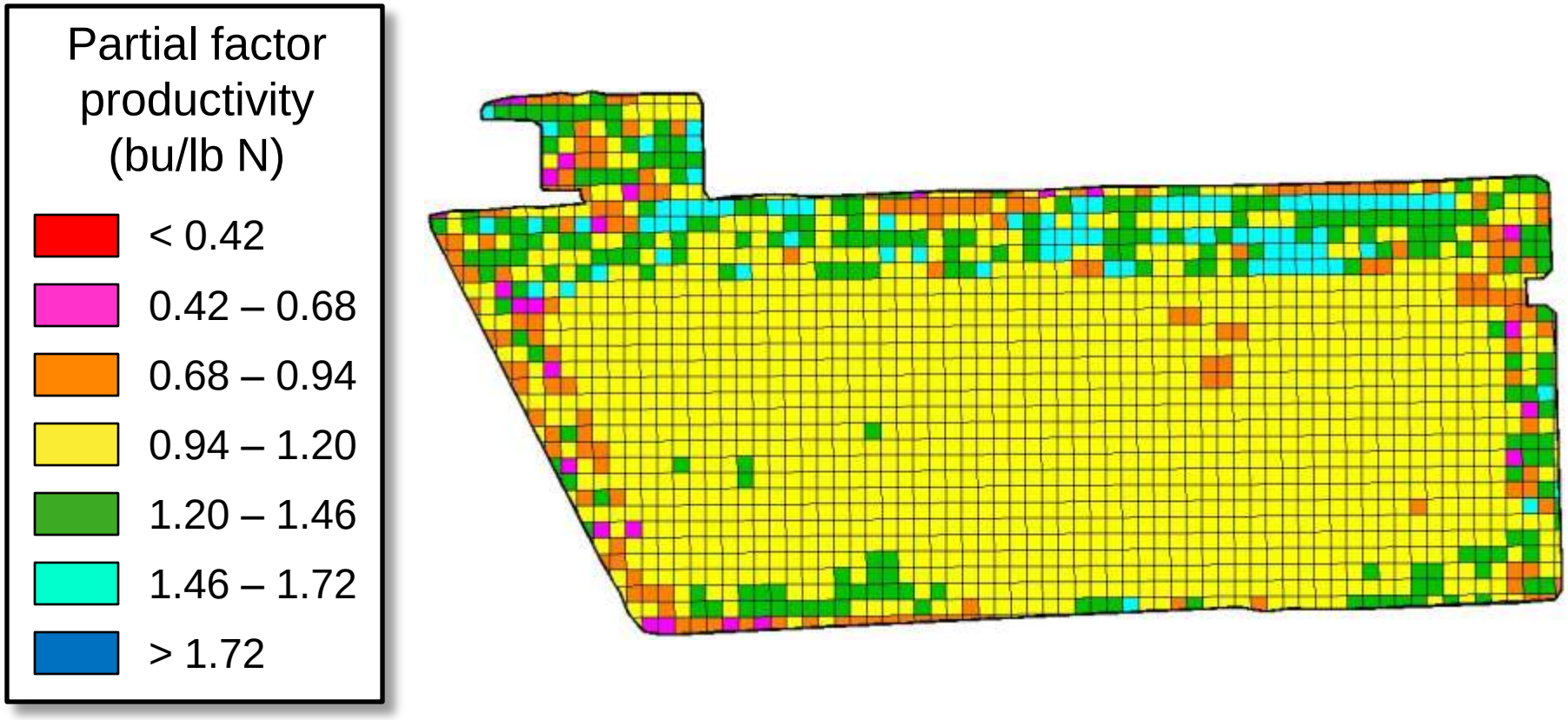
Data: MN Dept. Agric.

Partial factor productivity of nitrogen for corn grain:
Scale: Field, north central Indiana



Data: Lance Murrell Consulting and IPNI

Partial Factor Productivity of nitrogen for corn grain:
Scale: Within-field, north central Indiana



Data: Lance Murrell Consulting and IPNI

Nutrient use efficiency as measured by: *Partial factor productivity*

$$\frac{\text{yield}}{\text{fertilizer rate}}$$

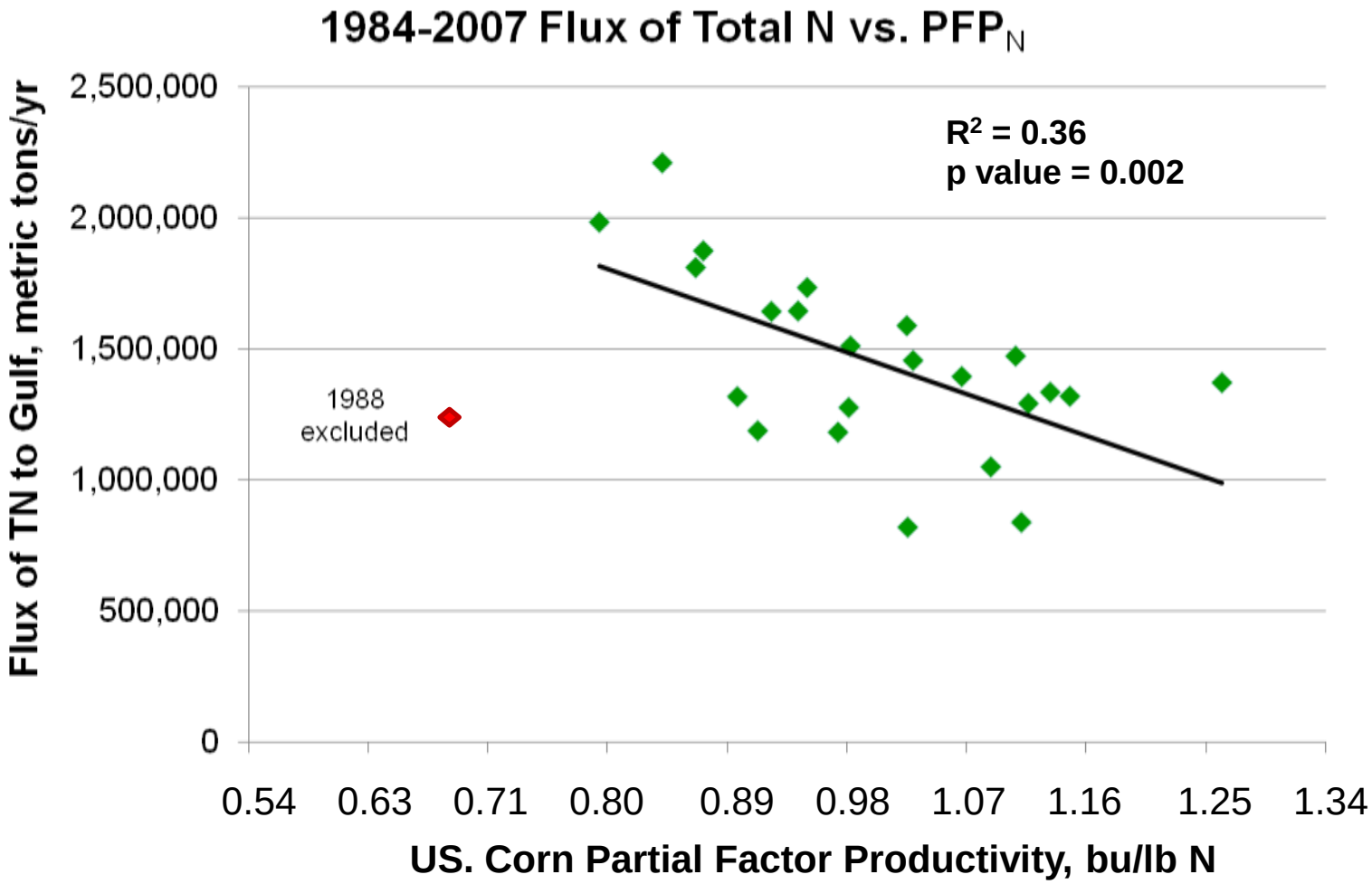
Partial factor productivity

bushels per pound of nutrient

Guidelines

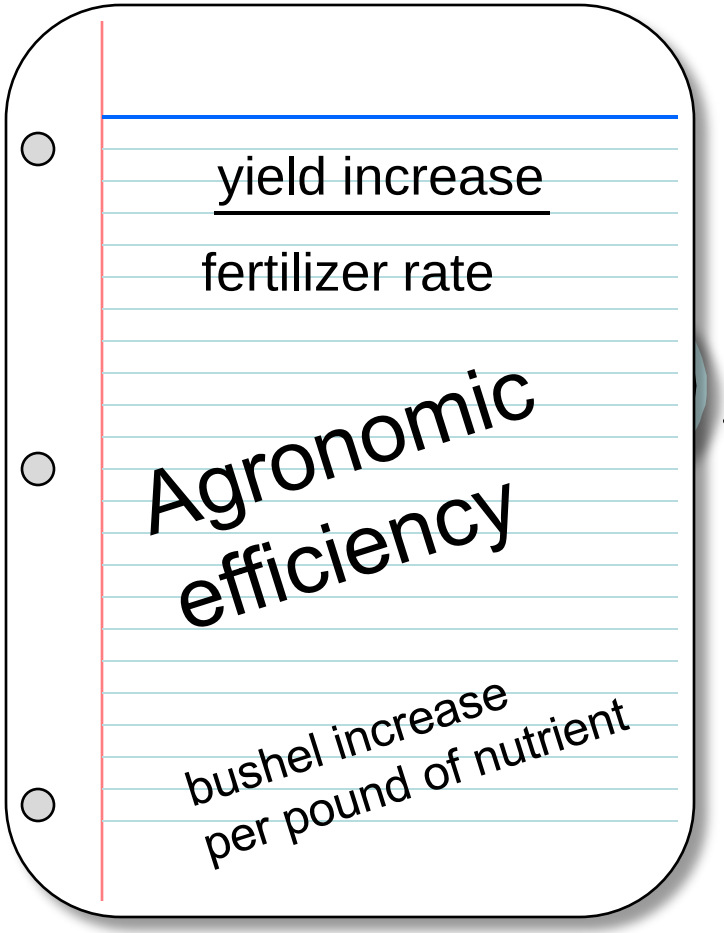
- The trend over time has been toward increasing partial factor productivity, viewed as positive
- What should the target be?

Partial factor productivity of nitrogen (PFP_N) for U.S. corn vs. annual total nitrogen flux to the Gulf of Mexico



Data: C.S. Snyder, IPNI

Making nutrient use efficiency something we can measure: Grain crop example



Things we can measure
Grain yield of a fertilized crop
Grain yield of an unfertilized crop
Fertilizer application rate
Nutrient content of the grain

Nutrient use efficiency as measured by: *Agronomic efficiency*

$$\text{Agronomic efficiency} = \frac{\text{yield increase}}{\text{fertilizer rate}}$$

bushel increase per pound of nutrient

Guidelines
• There is a minimum agronomic efficiency that must be exceeded if the nutrient application is to be profitable in the season for which it is applied • This minimum is equal to the ratio of the nutrient price to the crop price

Nutrient use efficiency as measured by: *Agronomic efficiency*

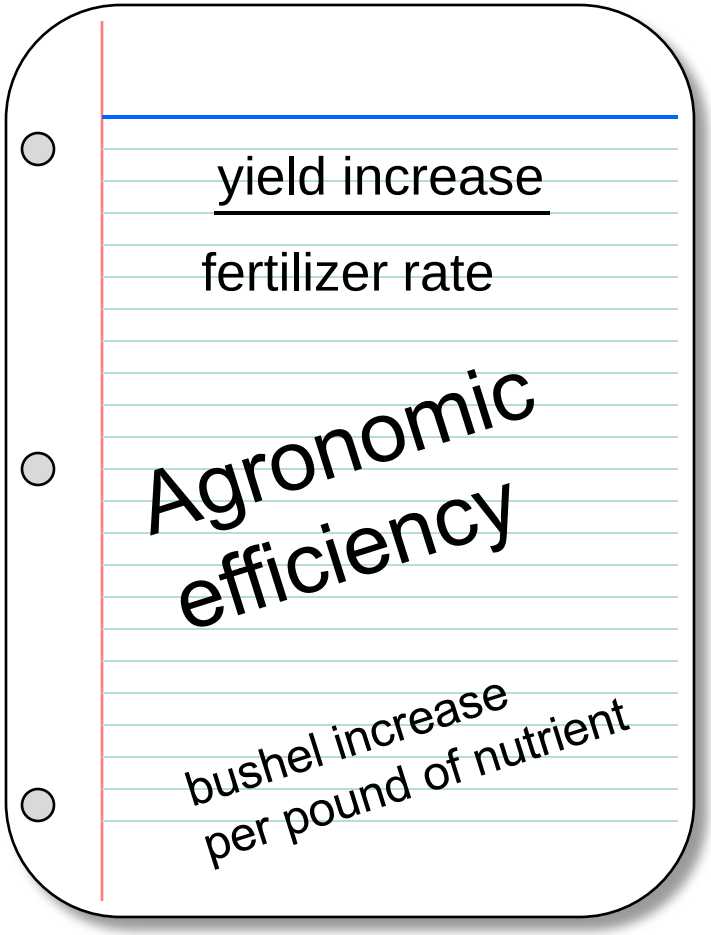
$$\text{Agronomic efficiency} = \frac{\text{yield increase}}{\text{fertilizer rate}}$$

bushel increase per pound of nutrient

Guidelines

- Example:
  - Nitrogen price = $0.45
  - Crop price = $4.50
  - Nitrogen:crop price ratio = 0.1
- So agronomic efficiency must be more than 0.1 to be profitable

Nutrient use efficiency as measured by: *Agronomic efficiency*



Measurement: Spatial Scales

- National/state/county/watershed scale:
  - Databases of fertilizer rate studies
  - Crop production statistics
- Farm/field/within-field scales:
  - Omission plots

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Agronomic efficiency of nitrogen for corn grain
Scale: State

http://extension.agron.iastate.edu/soilfertility/nrate.aspx

IOWA STATE UNIVERSITY
Agronomy Extension

Iowa State University
ISU College of Agriculture
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Corn Nitrogen Rate Calculator

Finding the Maximum Return To N and Most Profitable N Rate

A Regional (Corn Belt) Approach to Nitrogen Rate Guidelines

This web site provides a process to calculate economic return to N application with different r
and corn prices and to find profitable N rates directly from recent N rate research data. The r
used follows a newly developed regional approach for determining corn N rate guidelines tha
implemented in several Corn Belt states.

Regional Corn N Rate Publication

Single Price Ratio | Multiple Price Ratios

V. 1.4

Choose state

Iowa
Illinois - North
Illinois - Central
Illinois - South
Indiana
Michigan
Minnesota
Ohio
Wisconsin - VH/HYP Soils
Wisconsin - M/LYP Soils
Wisconsin - Irr. Sands
Wisconsin - Non-Irr. Sands

Choose rotation pattern(s)

- Corn following soybean
- Corn following corn

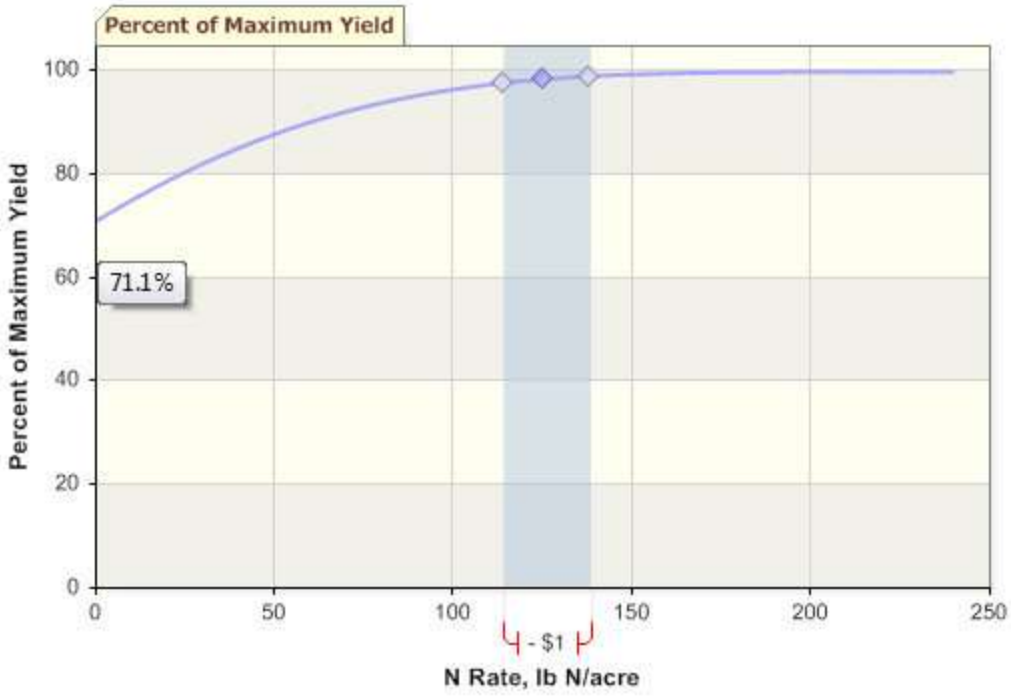
Include non-responsive sites

Set corn and nitrogen prices

Anhydrous Ammonia (82% N) 738 ($/Ton)
Nitrogen price 0.45 ($/lb N)
Corn price 4.50 ($/bu)

Calculate | Reset

Illinois Map | How to Use | More Info



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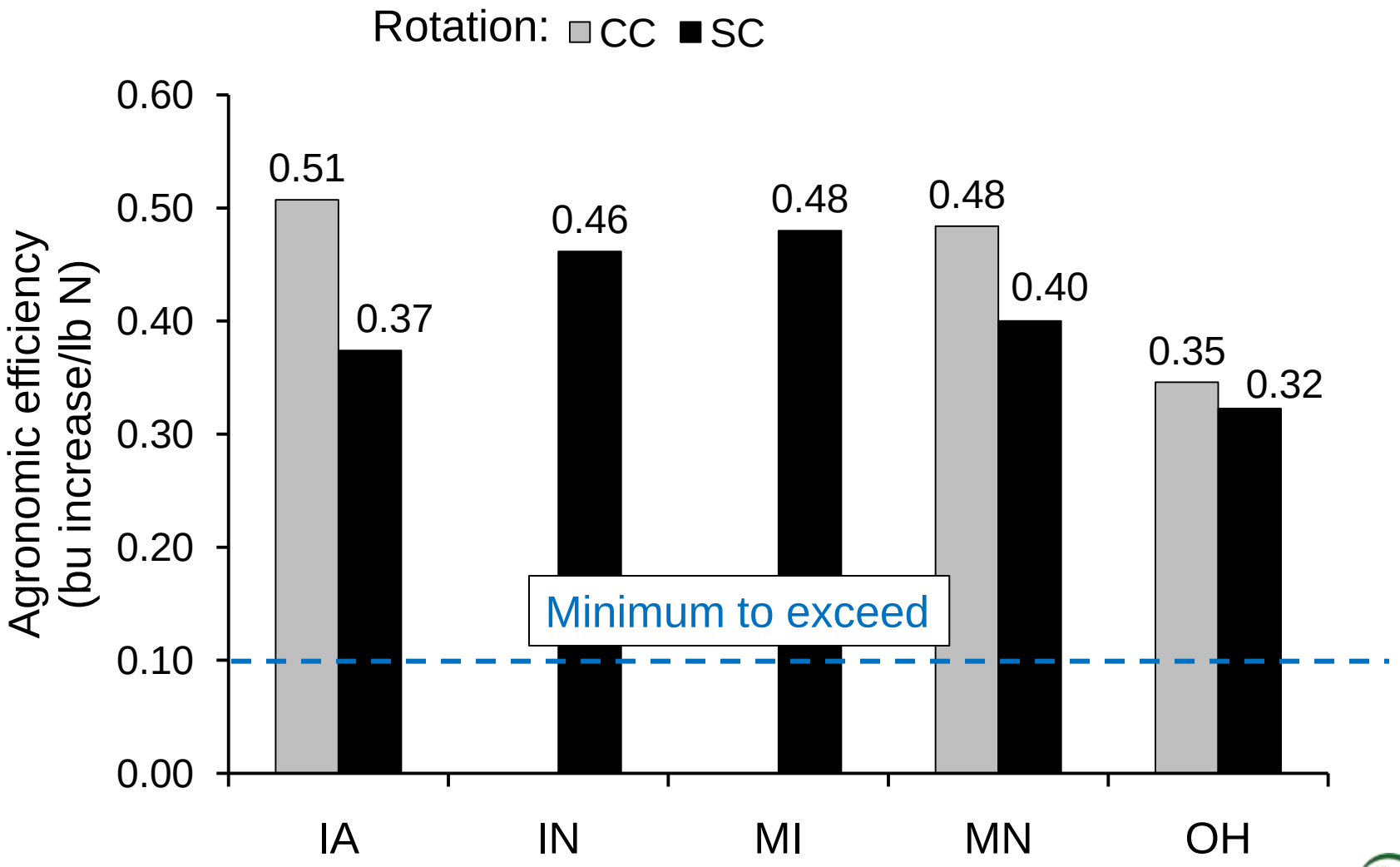
Estimated agronomic efficiency of nitrogen for corn grain:
Scale: State, 2001-2010 averages



Data: USDA-NASS, IA State Univ. Corn Nitrogen Rate Calculator

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Agronomic efficiency of nitrogen for corn grain:
Scale: Field

Reduced N rate
(40 lb N = 113 bu/acre)

Normal N rate
(215 lb N = 200 bu/acre)

Data: Lance Murrell Consulting and IPNI

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North America - North Central

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- Tool Box

Rate Reduction Calculator v2.0

Printable Version

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An example of the output:

Estimated Economic Consequences of a Rate Reduction

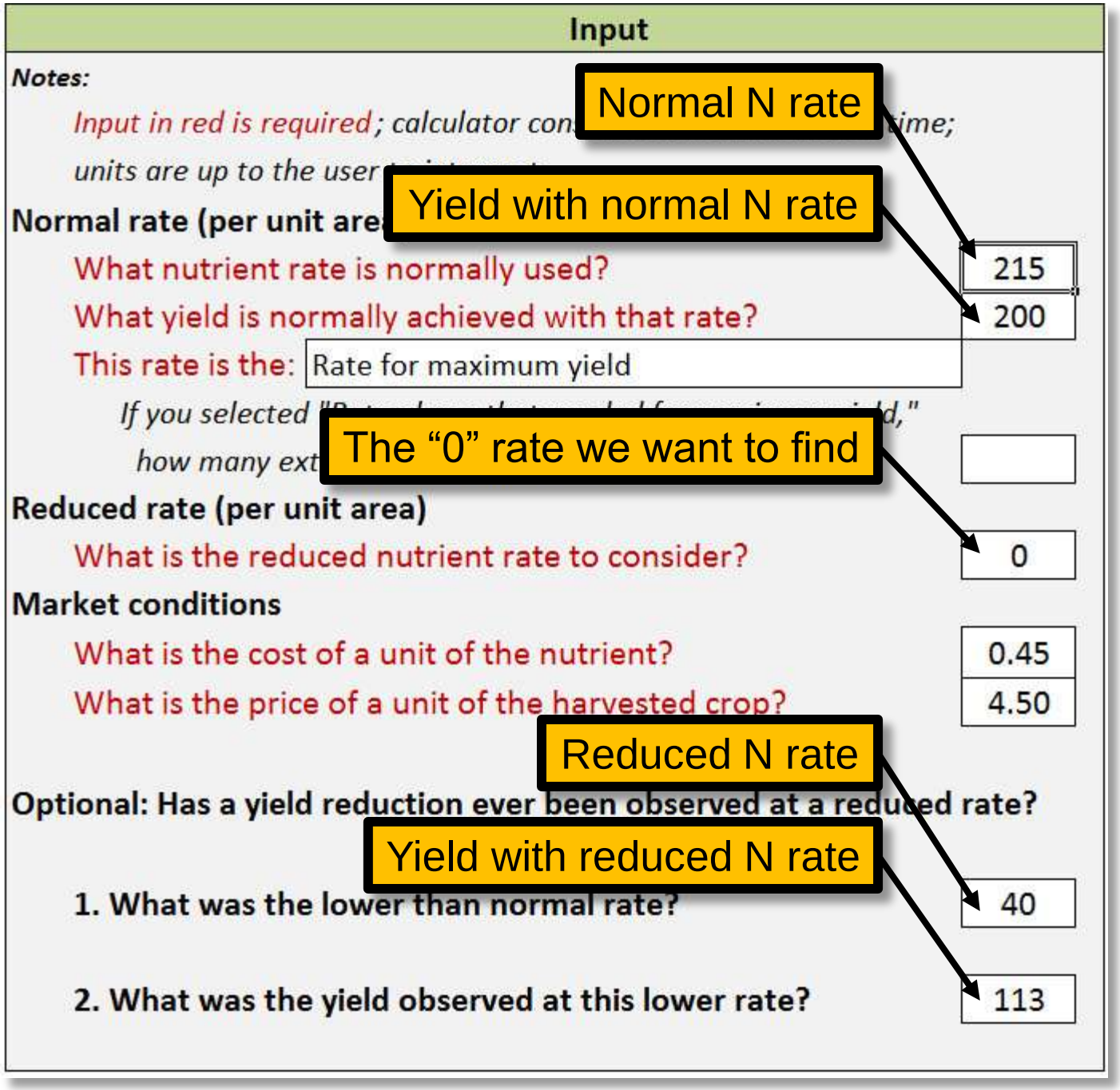
Scenario results:

The following estimates were made by the model or were entered by the user:

Estimated yield at reduced rate:	173
Estimated yield loss (yield units):	6.61
Estimated yield loss (% of normal yield):	3.67%
Estimated economically optimum nutrient rate:	134
Estimated nutrient rate for maximum yield:	150

	Monetary savings from fertilizer reduction:	16.00
-	Monetary loss from yield reduction:	19.83
=	**Net monetary gain (+) or loss (-) per unit area**	**-3.83**

http://nanc.ipni.net/

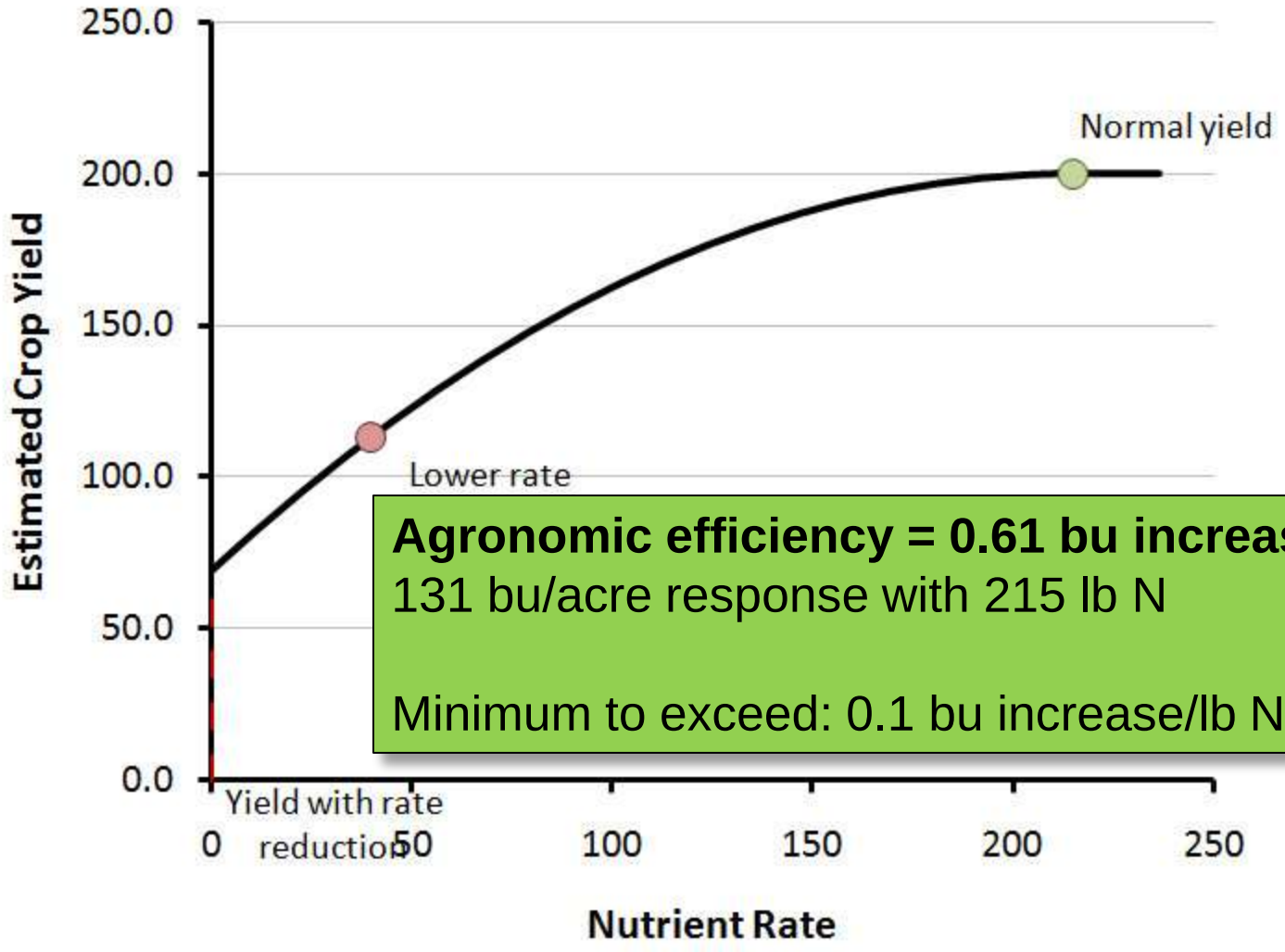

Input
Notes:
Input in red is required; calculator cons
time;
units are up to the user
Normal rate (per unit are
What nutrient rate is normally used?
215
What yield is normally achieved with that rate?
200
This rate is the:
Rate for maximum yield
If you selected
how many ext
Reduced rate (per unit area)
What is the reduced nutrient rate to consider?
0
Market conditions
What is the cost of a unit of the nutrient?
0.45
What is the price of a unit of the harvested crop?
4.50
Optional: Has a yield reduction ever been observed at a reduced rate?
1. What was the lower than normal rate?
40
2. What was the yield observed at this lower rate?
113
Normal N rate
Yield with normal N rate
The “0” rate we want to find
Reduced N rate
Yield with reduced N rate

Scenario Results

Estimated yield loss (yield units): 131.32

Estimated yield loss (% of normal yield): 65.66%

Yield response (bu/acre)

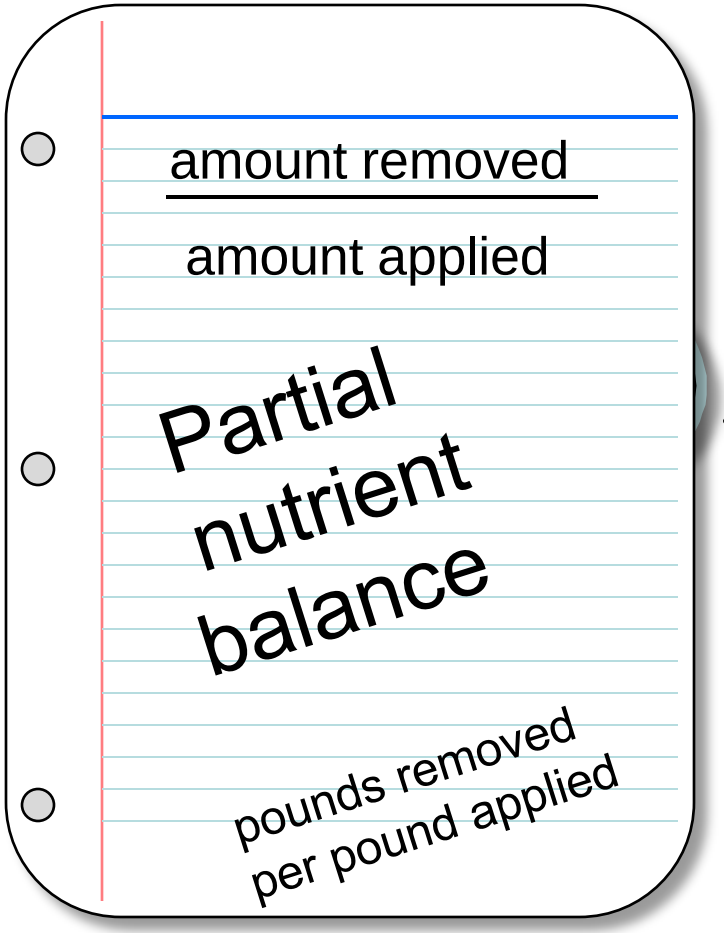


Agronomic efficiency = 0.61 bu increase/lb N

131 bu/acre response with 215 lb N

Minimum to exceed: 0.1 bu increase/lb N

Making nutrient use efficiency something we can measure: Grain crop example



Things we can measure
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Grain yield of an unfertilized crop
Fertilizer application rate
Nutrient content of the grain

The “partial” of partial nutrient balance

Amount applied	Amount removed
☑ Fertilizer application	☑ Crop harvest
☑ Manure application	☐ Leaching losses
☑ Nutrients in irrigation water	☐ Runoff losses
☑ Nitrogen fixation	☐ Erosion losses
☐ Atmospheric deposition	☐ Gaseous losses
☐ Deposition from other landscape areas	

Nutrient use efficiency as measured by: *Partial nutrient balance*

$$\frac{\text{amount removed}}{\text{amount applied}}$$

Partial nutrient balance

pounds removed per pound applied

Guidelines

- Partial nutrient balance values:
  - approx. 1.0
    removal = application
    (some sense of sustainability)
  - less than 1.0
    removal is less than application
    (soil nutrient levels are increasing)
  - greater than 1.0
    removal is more than application
    (soil nutrient levels are decreasing)

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Nutrient use efficiency as measured by: *Partial nutrient balance*

$$\frac{\text{amount removed}}{\text{amount applied}}$$

Partial nutrient balance

pounds removed per pound applied

Measurement: Spatial Scales

- National/state/county/watershed scale:
  - Fertilizer use statistics
  - Crop production statistics
  - Nutrient removal estimates
- Farm/field/within-field scales:
  - Fertilizer application rates
  - Crop yield
  - Nutrient concentration (from soil and plant analysis lab)

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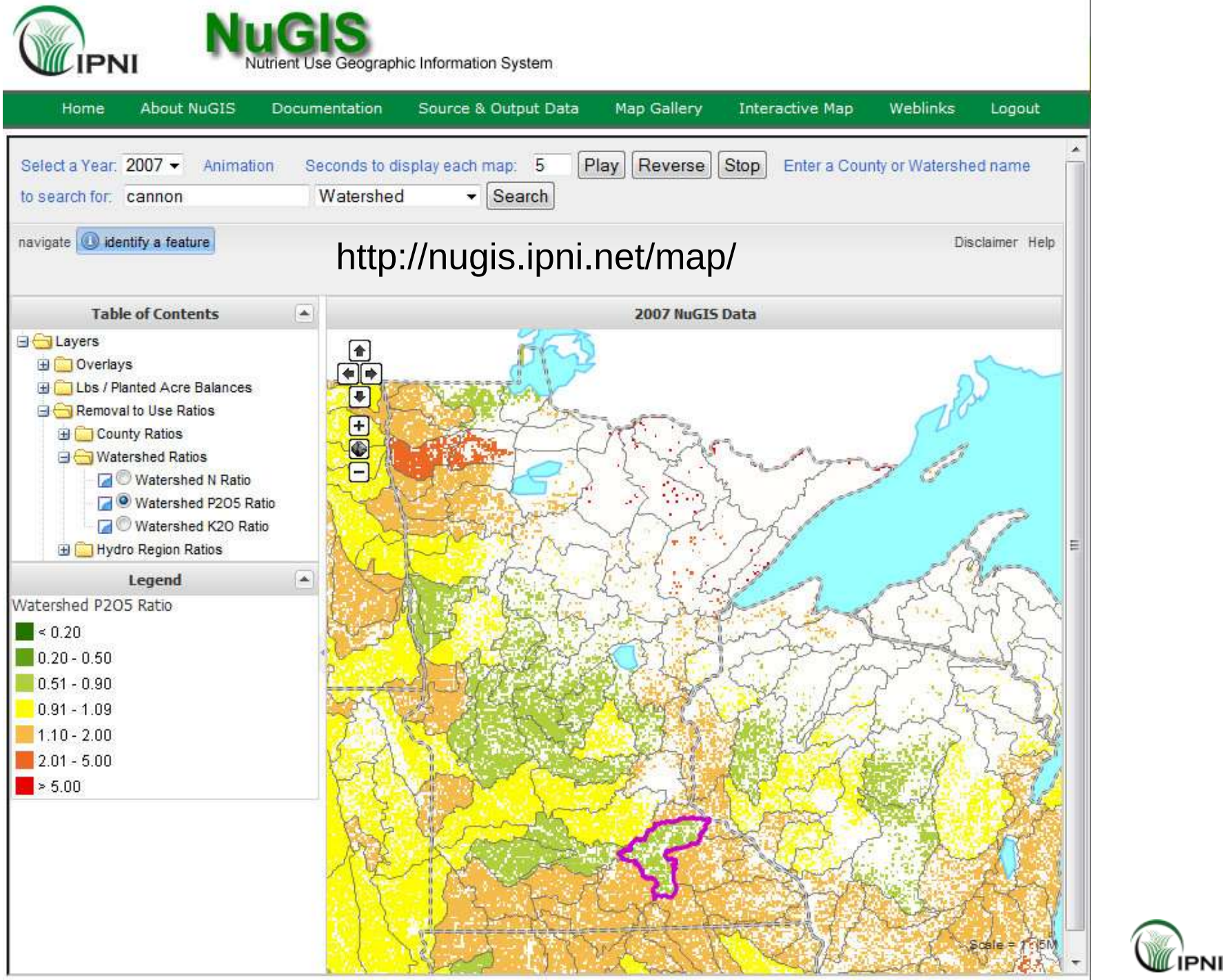
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Nutrient Use Geographic Information System
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Weblinks
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Select a Year: 2007
Animation
Seconds to display each map: 5
Play
Reverse
Stop
Enter a County or Watershed name
to search for: cannon
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identify a feature
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http://nugis.ipni.net/map/
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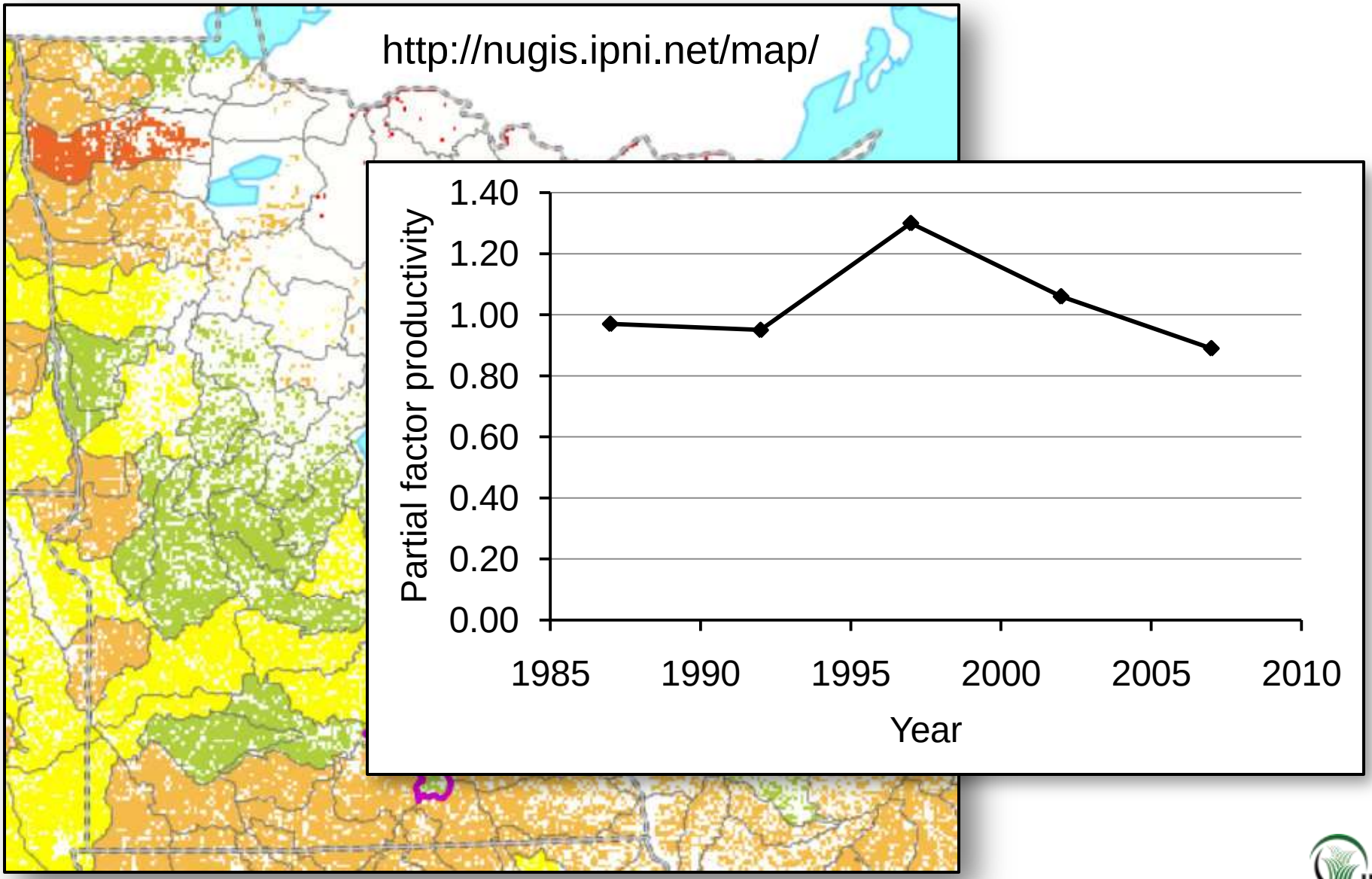
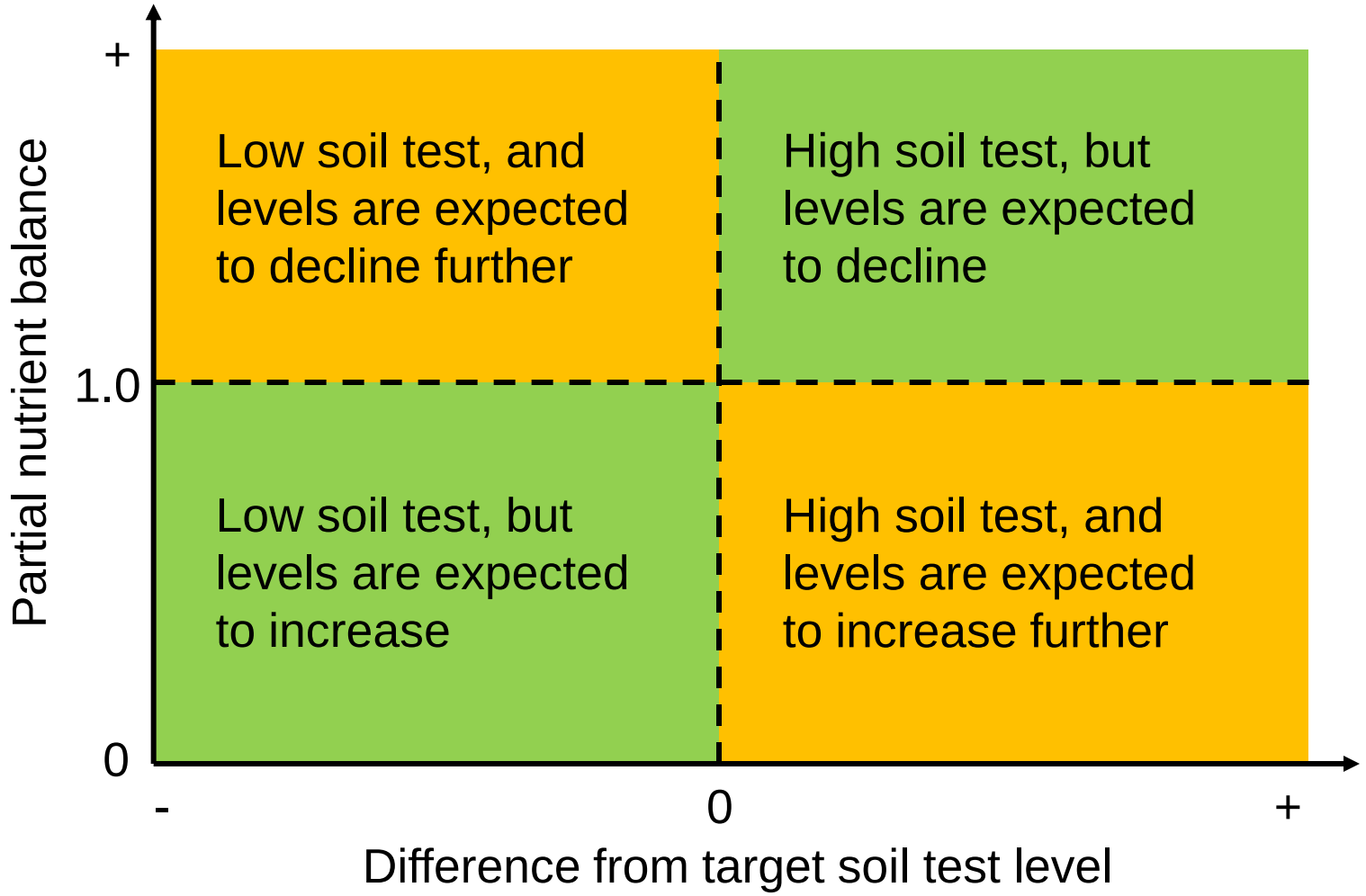
< 0.20
0.20 - 0.50
0.51 - 0.90
0.91 - 1.09
1.10 - 2.00
2.01 - 5.00
> 5.00
2007 NuGIS Data
Scale = 1 : 5M

Partial nutrient balance of phosphorus:
Scale: Watershed, Cannon 1987-2007



Combining partial nutrient budgets with soil test information

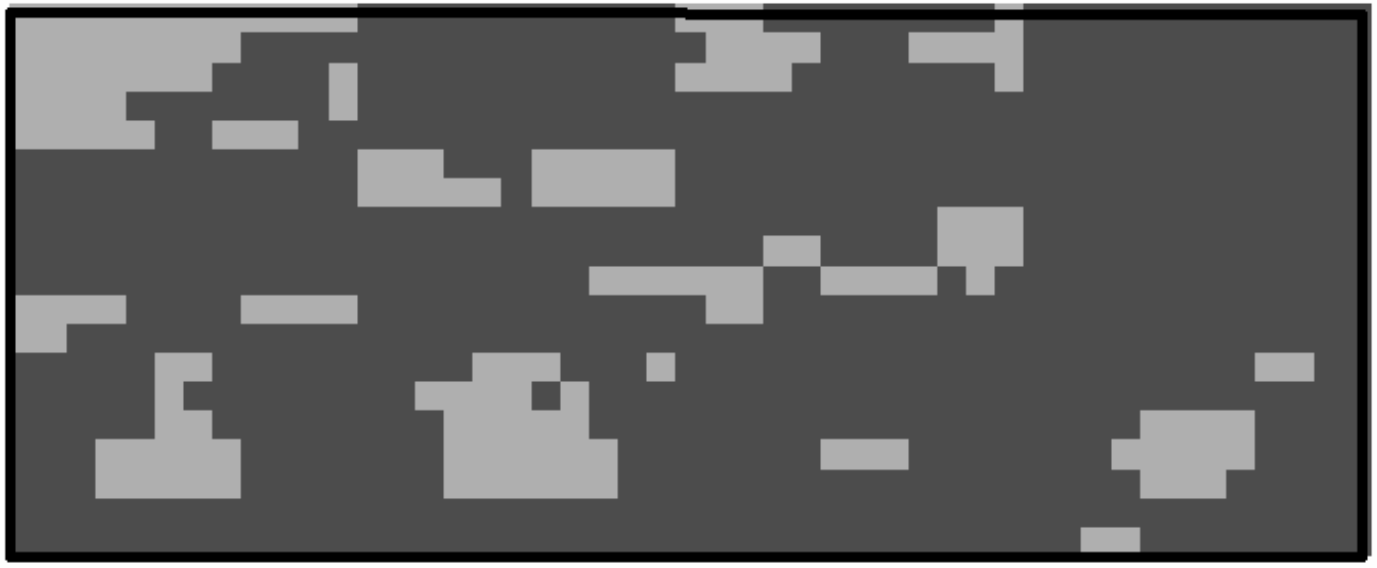


(Actual soil test level – target soil test level)

Partial nutrient balance of phosphorus:
Scale: Within-field

Agronomically sound partial nutrient budget

Inappropriate partial nutrient budget



Summary

- Nutrient use efficiency is a general concept that must be translated into something measurable
- Partial factor productivity (bu/lb nutrient)
  - U.S. is increasing, on average toward 1.2 to 1.3
  - Minnesota is increasing toward 1.4
- Agronomic efficiency (bu increase/lb nutrient)
  - Several states have 3 to 5 times the minimum efficiency needed to be profitable with nitrogen applications
- Partial nutrient balance (lb removed/lb applied)
  - A balance of 1.0 is a guidepost
  - Combining this information with soil tests provides agronomic interpretations

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A Future Goal of Nutrient Use Efficiency Research

The “Holy Grail” of nutrient use efficiency