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Phosphorus Use Efficiency in Production Agriculture

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2007 Fertilizer Outlook and Technology Conference

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A new, not-for-profit organization

Purpose: To help provide a coordinated scientific foundation for fertilizer nutrient use and to scientifically address the associated environmental issues

Better Crops, Better Environment ... through Science

IPNI Founding Members

- Agrium Inc.
- Arab Potash Company
- Belarusian Potash Company
- Bunge Fertilizantes S.A
- CF Industries Holding, Inc.
- Intrepid Mining, LLC.
- K+S KALI GmbH
- Mosaic
- PotashCorp
- Saskferco
- Simplot
- Sinochem Hong Kong Ltd.
- Spur Ventures Inc.
- SQM
- Terra Industries, Inc.
- Uralkali

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A key challenge for agriculture

Parameter		Annual %
Predicted increase in global demand for corn, rice, and wheat from 1995 to 2025*	Kg/ha/yr**	**1.56**
Global rate of yield increase, 1966-2004:	**Corn, 61**	**1.24**
	Rice, 54	**1.36**
	Wheat, 41	**1.42**

** Rosegrant et al. (2002, Food Policy Research Institute) as modified by Cassman (2006) to include 5% of global grain supply in 2025 used for production of biofuel and bio-based industrial feedstocks.*

*** All rates of gain in cereal yields are decidedly linear over the past 40 yrs (Cassman, 2006); proportional rates of gain are based on 2004 yields.*

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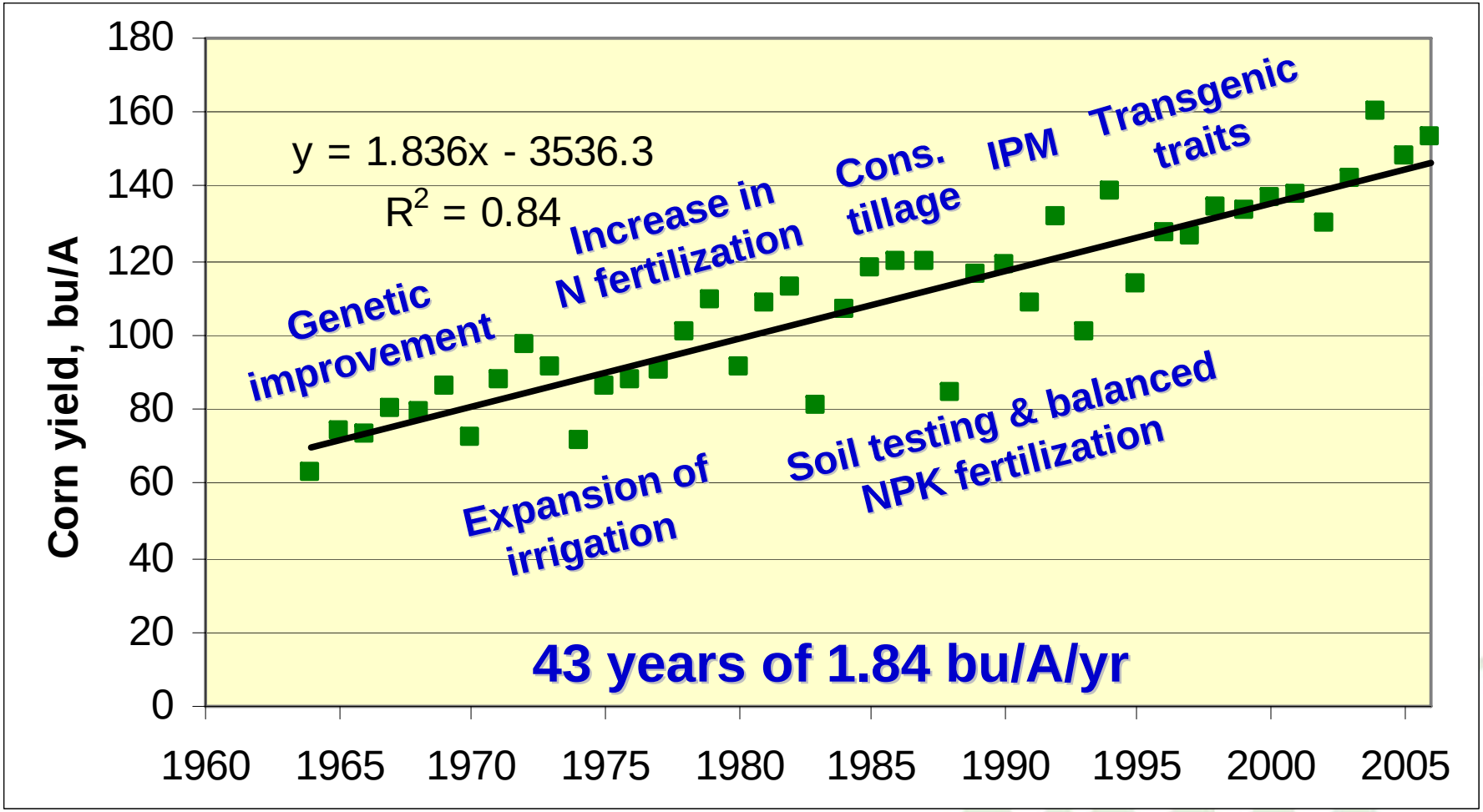
U.S. corn yields, 1964 to 2006



Breaking this line while meeting environmental expectations will be a huge challenge

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Concept by Cassman, 2006

General reasons to be interested in P efficiency

- Recoverable P is a scarce natural resource
  - Manufacturer
  - Grower
  - Consumer
- Potential environmental benefits to keeping P in the field
- Direct economic value to the grower
  - Increased yield
  - Faster return on investment
  - Lower optimum P rates in some situations

Phosphate reserves

	Cost/tonne, Fob mine	
	$40	$100
	Years	
U.S.	25	98
World	90	343

Stewart et al., 2005
(ASA P Monograph)

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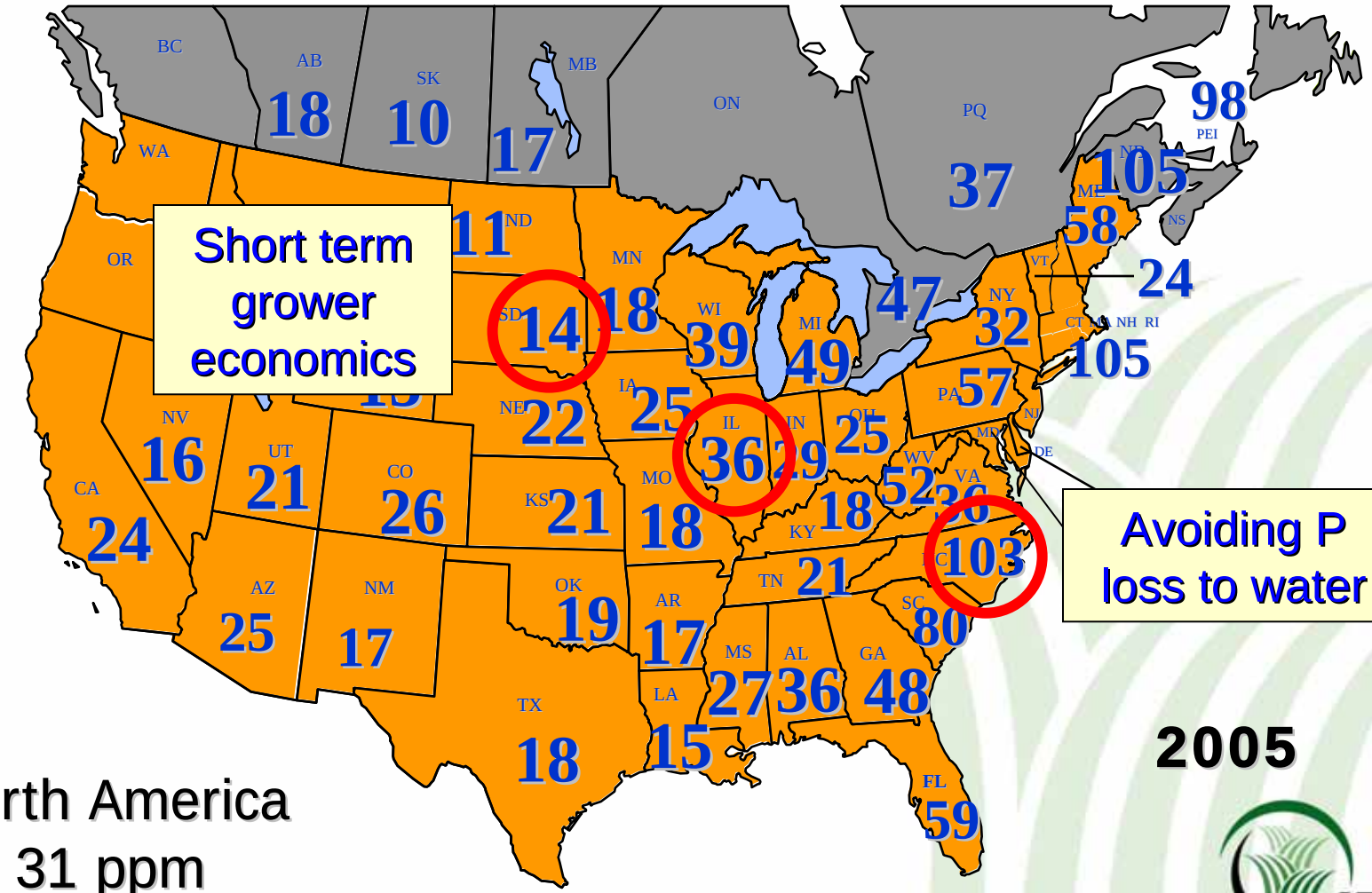
Major reason for interest in efficiency is likely influenced by soil P level

Median Bray P1 equivalent, ppm



The appropriate definition of P efficiency depends on the intended use of the result

$$\frac{\text{Yield increase}}{\text{P applied}}$$ **Agronomic efficiency**

$$\frac{\text{Fertilized uptake – check uptake}}{\text{P applied}}$$ **Recovery efficiency**
(Single yr or long-term)

$$\frac{\text{Removed by crop}}{\text{P applied}}$$ **Removal efficiency**

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One intended use: basis of incentive payments in farm programs

- NRCS: Multiple level nutrient management
- Precursor to 3-tier CSP structure
- Objective: intensify nutrient management beyond the minimums of Form 590
- 2002: Performance-based approach considered
  - Calculating NUE as a basis for incentives?
  - Considered:
    - Recommended/Applied
    - Removed/Applied (removal efficiency)
- Performance-based dropped in favor of practice-based

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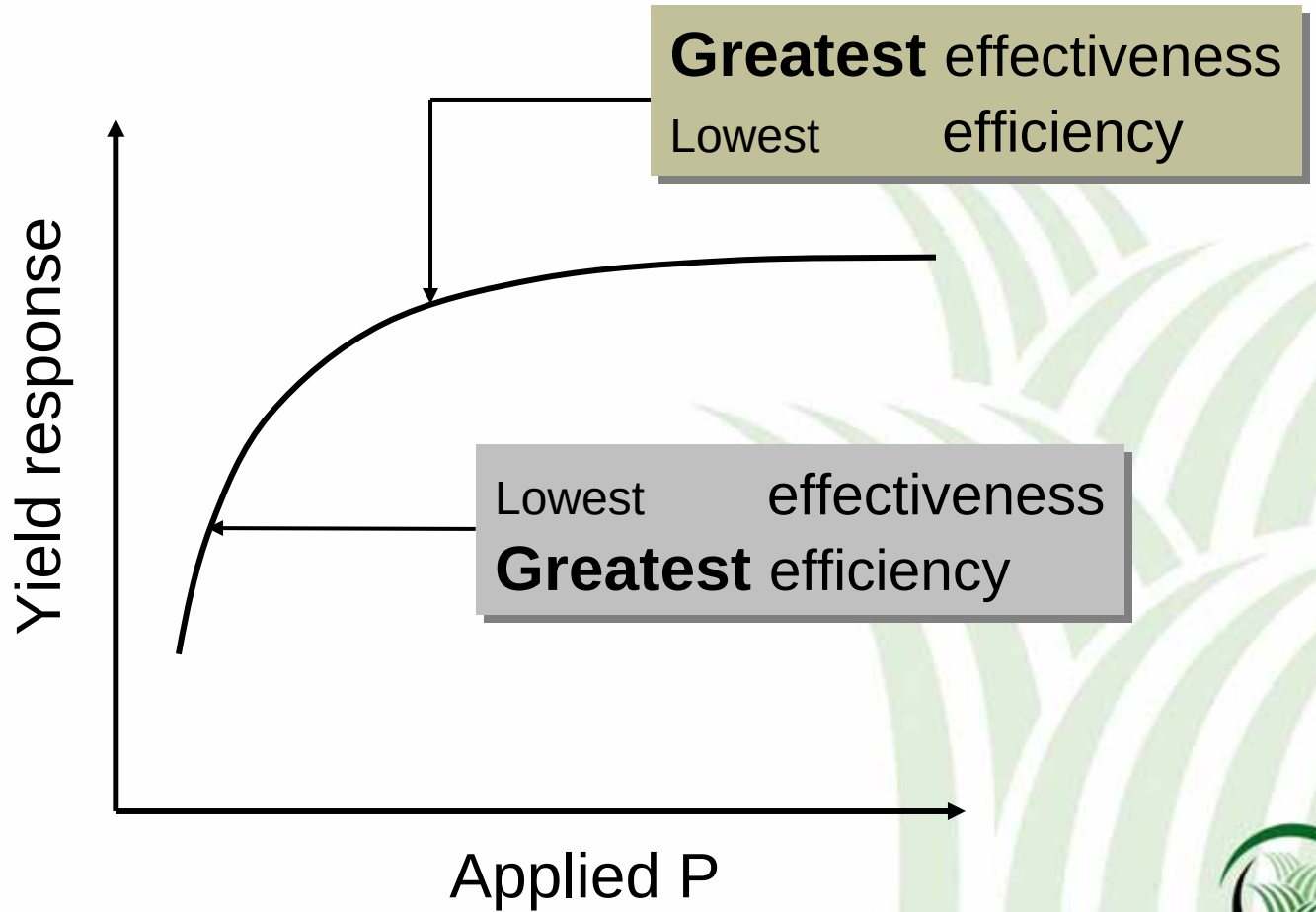
Efficiency vs. effectiveness: a single-season crop response example



Typical objectives of nutrient use

- Provide economically optimum nourishment to crop
- Minimize nutrient loss from the field
- Contribute to system sustainability … soil fertility or other soil quality components

Utilization efficiency is not enough … P use must be effective in meeting the objectives of nutrient use

Can be highly efficient … and totally ineffective

(low P rate at a low soil P test)

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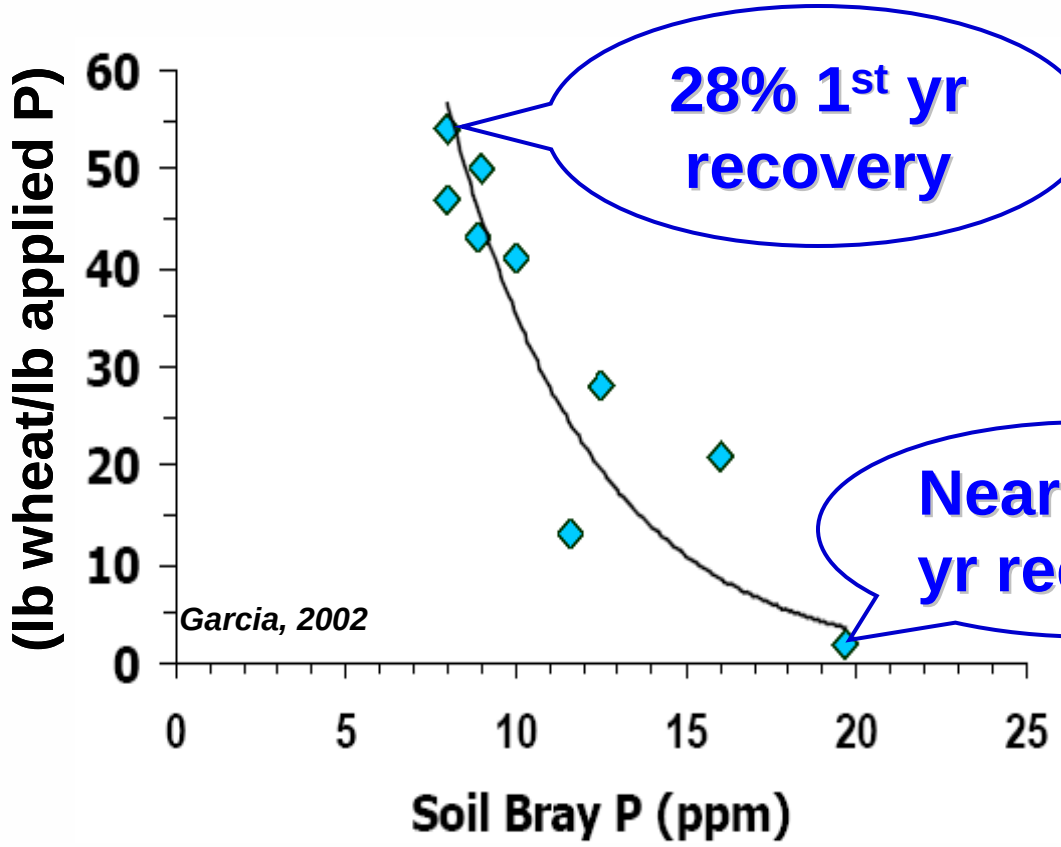
Agronomic and recovery efficiency decline as soil fertility increases



Where do we advise growers to be?

1st yr recovery is a poor indicator of long-term profitability

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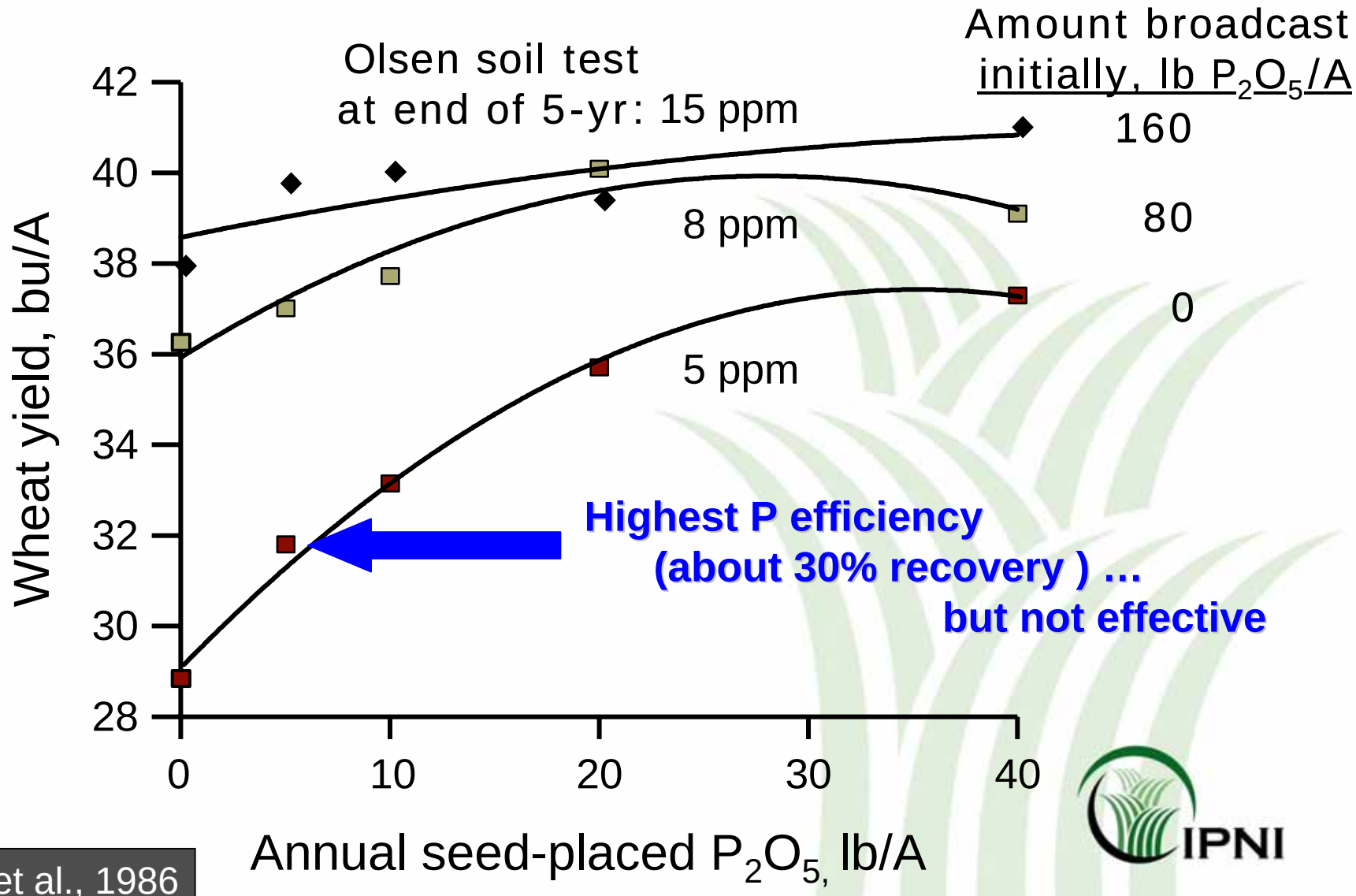
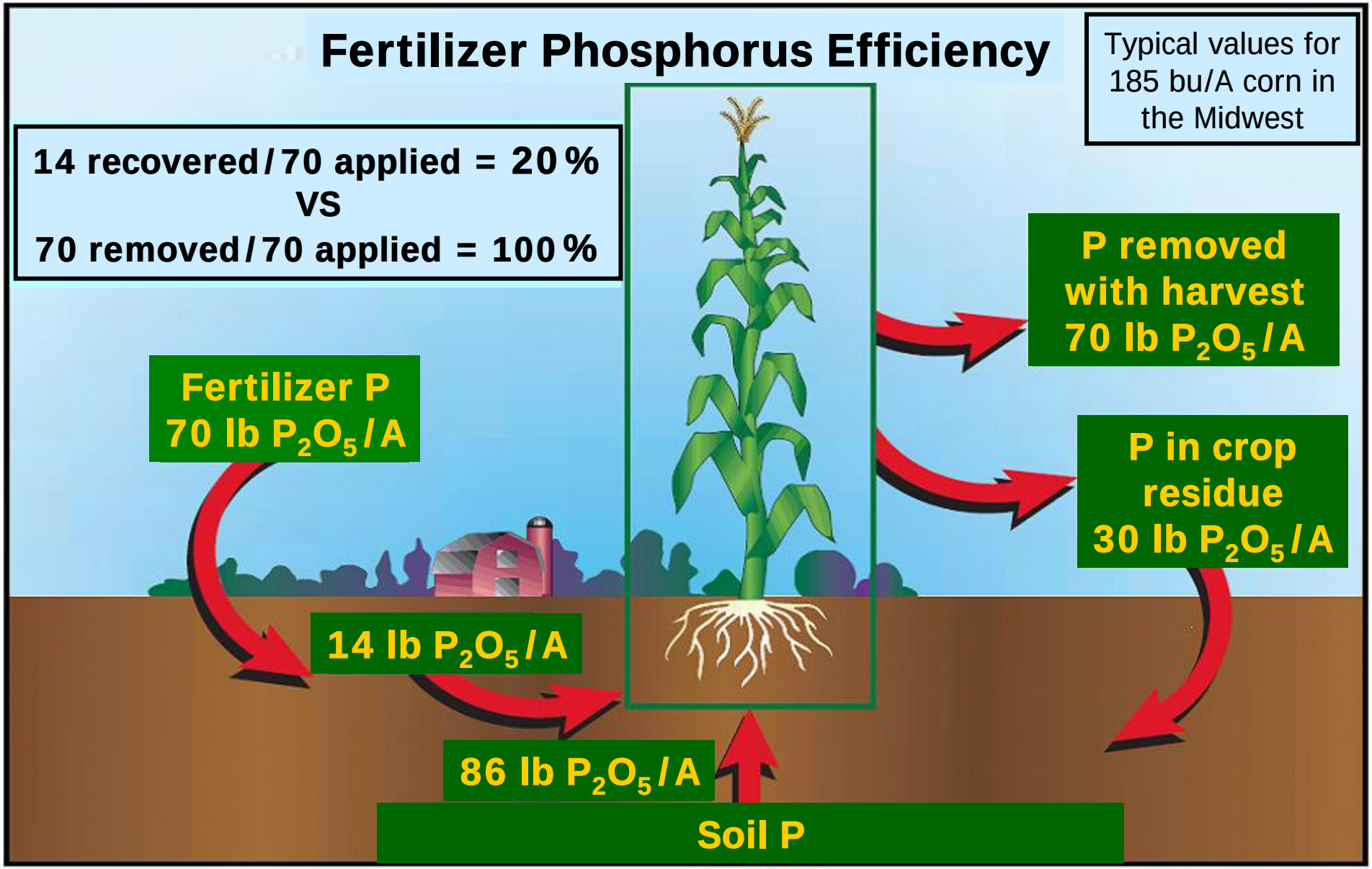
High efficiency is not enough



Wager et al., 1986



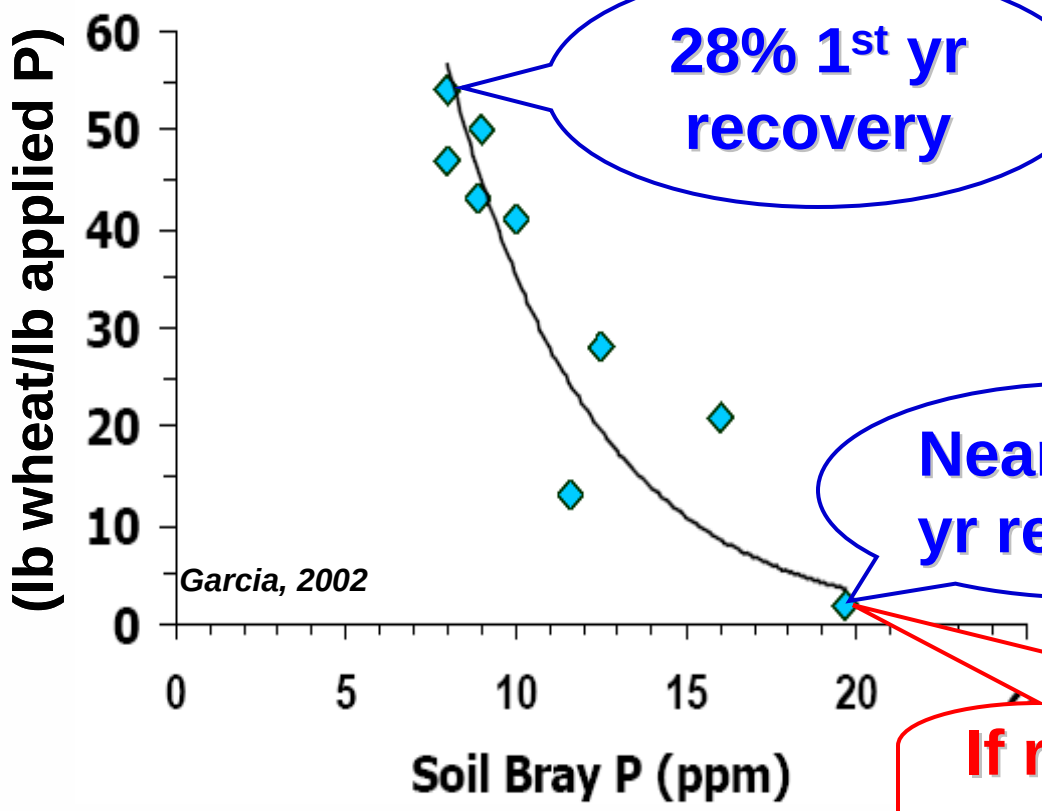
Recovery efficiency:useful in short-term; Removal efficiency: useful in long-term when combined with soil P change

System level efficiency

Nutrients recovered in the crop plus the net change in available soil nutrients

Dobermann et al, 2005

Agronomic and recovery efficiency decline as soil fertility increases



28% 1st yr recovery

Near 0% 1st yr recovery

If replacing removed P maintains soil P, system efficiency is 100%

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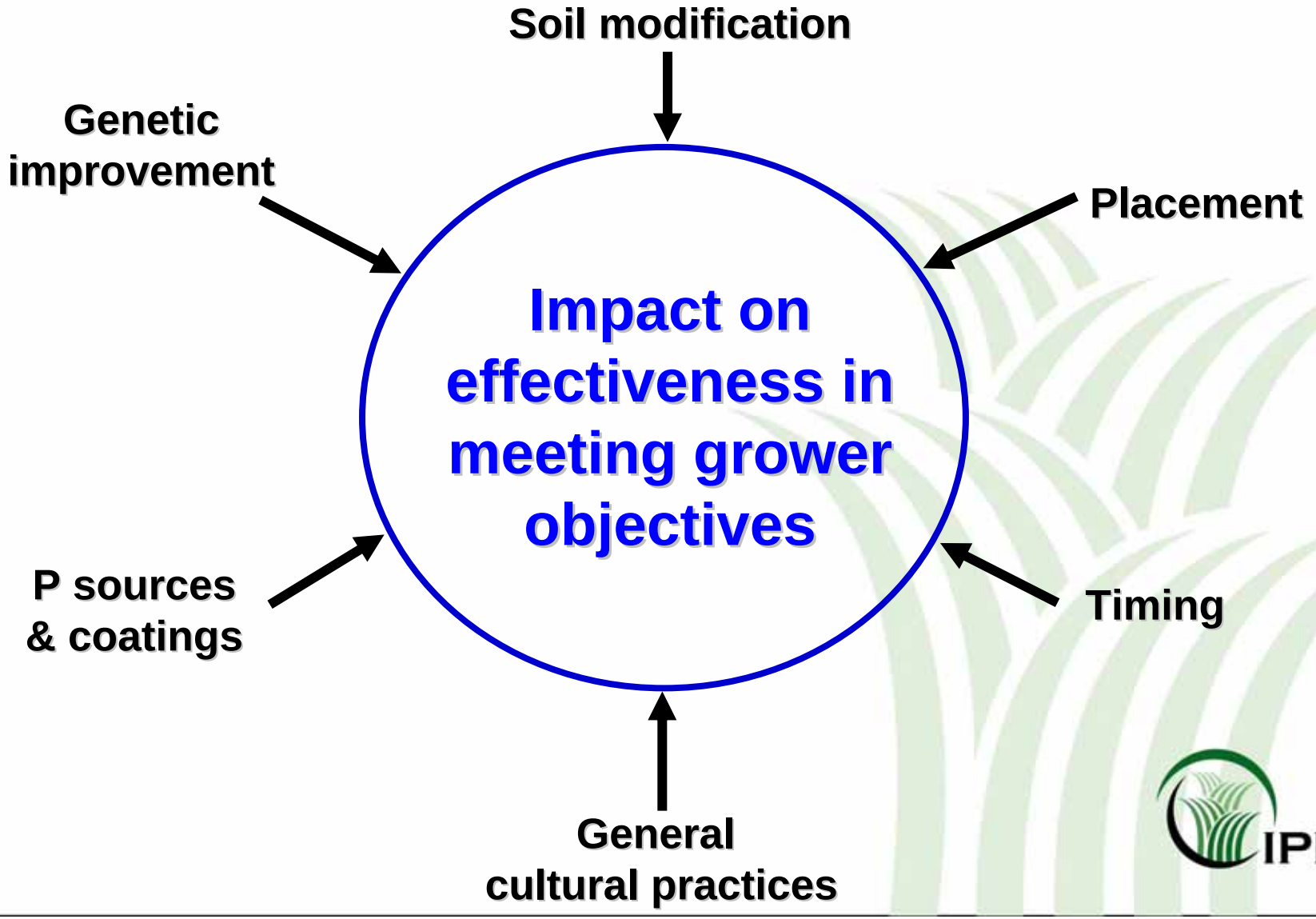
The value to the grower of practices that improve P efficiency



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Right rate, right time, right place
does not always result in the highest "efficiency", but should offer the greatest effectiveness in accomplishing grower objectives

- **Optimizing profitability**
- **Minimizing nutrient loss**
- **Providing system sustainability**

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Recovery and removal efficiencies for P

Area	Term (years)	P NUE (%)	Source & method
World	1	**15-25** (**recovery** efficiency)	Smil, 2000; survey
World	Many	**50-90** (**recovery** efficiency)	Smil, 2000; survey*
US	Annual	**87** (**removal** efficiency)	PPI, 2002**; partial budget

* A global literature review is underway by Syers, Johnston and Curtin; funded by FAO, IFA, IMPHOS, PPI/PPIC, and TFI that will offer more detailed information.

** 0.35 lb P_2O_5/bu used for removal by corn.

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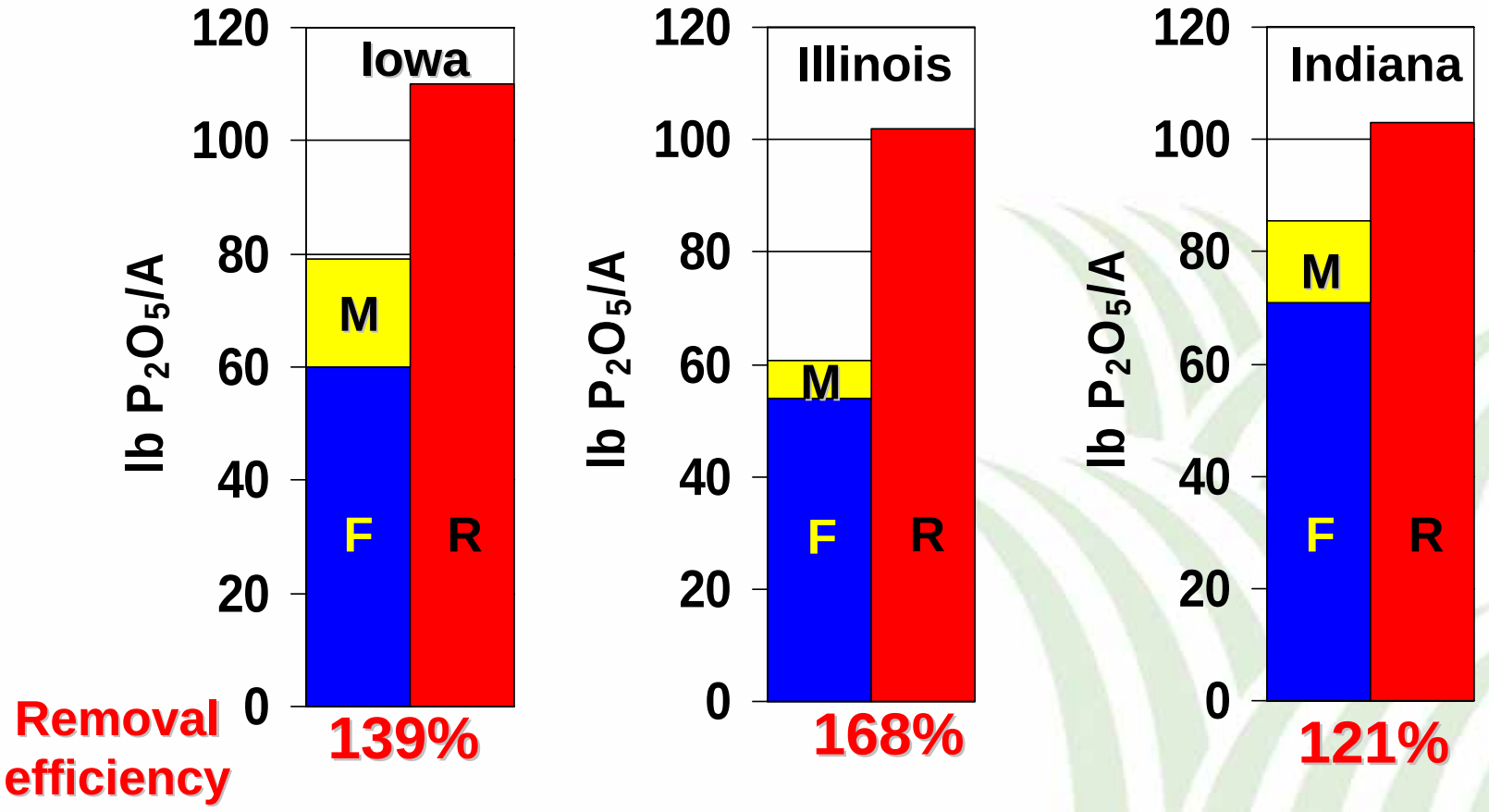
Phosphorus use compared to crop removal for a corn-soybean rotation (2 yrs)

(avg of 2004 & 2005)



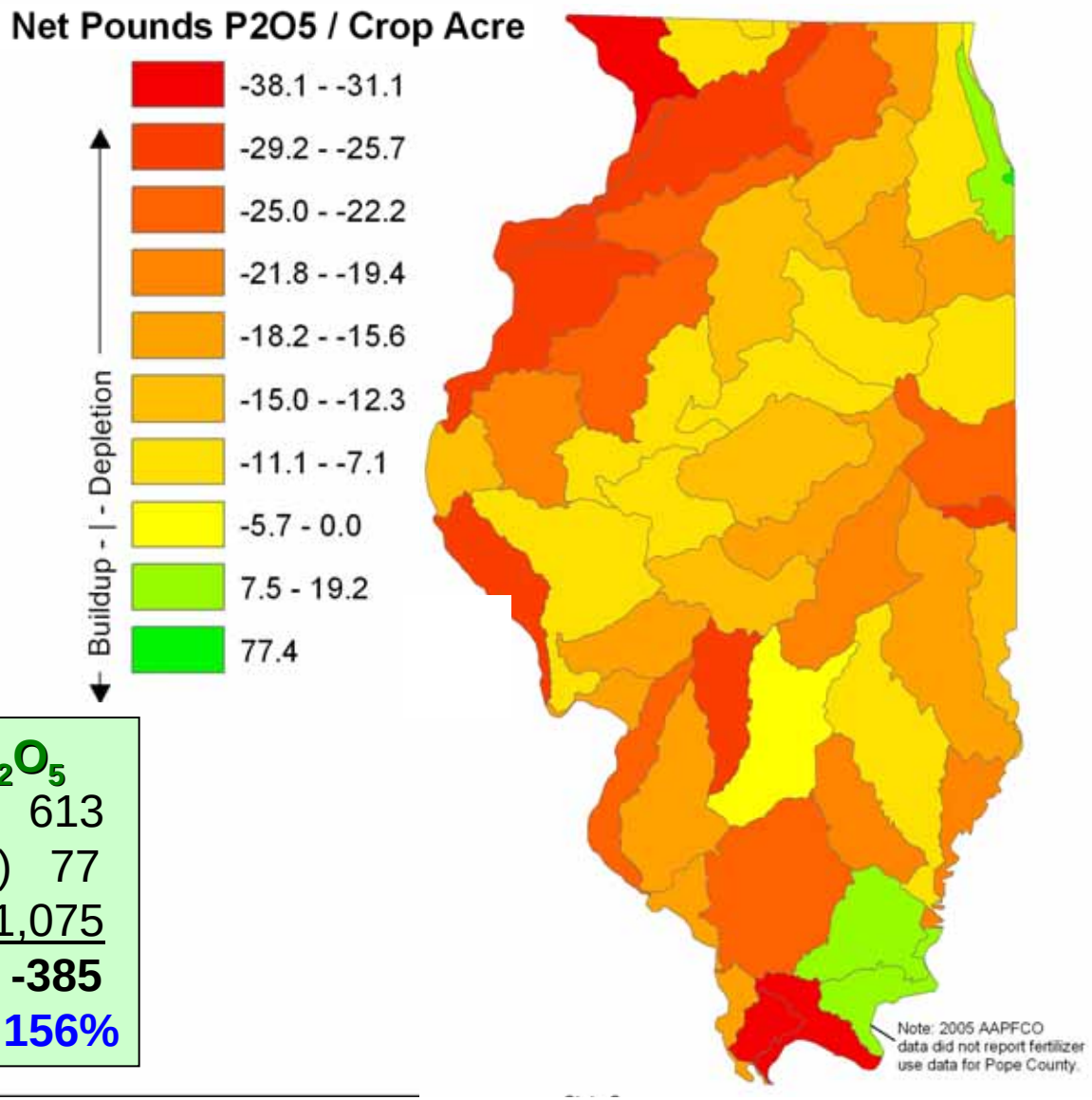
F Fertilizer P consumption/A planted to principle crops in 2004 + 2005.

M Annual recoverable manure P for 1997 x 2 (NRCS, 2000).

R Crop removal for 2004 and 2005 corn and soybean yields.

P budget for the state of Illinois by watershed

Median Bray P-1 level for 2005 crop = 36 ppm



State total, million lbs P_2O_5	
+ Applied fertilizer (2005)	613
+ Recoverable manure (1997)	77
- Crop removal (2005)	1,075
Net budget	**-385**
Removal efficiency	**156%**

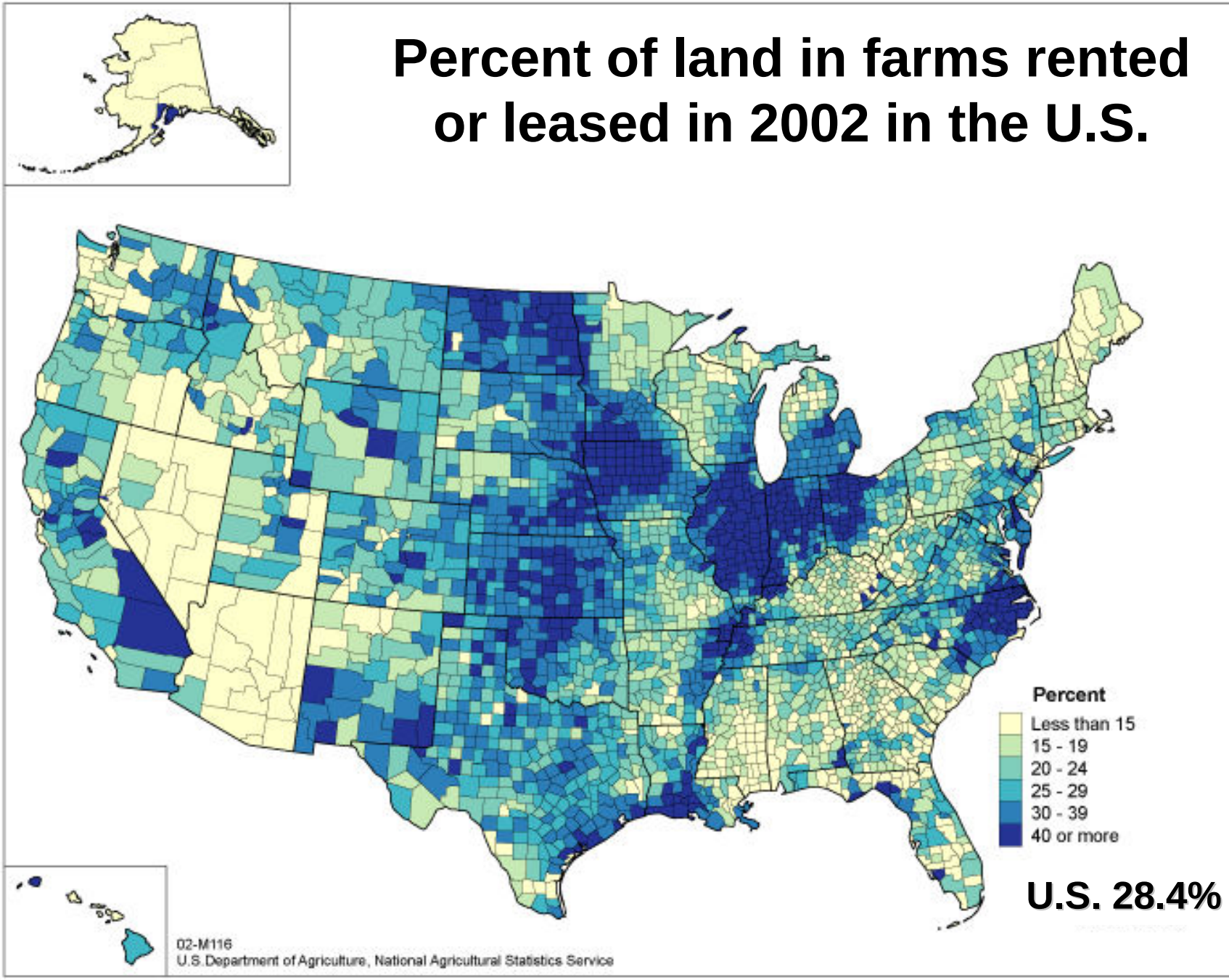
Short-term vs long-term P efficiency

- **Long-term P efficiency**
  - Generally high in North America
  - Removal efficiency of 85-90%
  - Long-term recovery efficiency in research of 40-90%
- **Short-term P efficiency**
  - Much lower than long-term efficiency
  - Single-year recovery seldom higher than 20%; often less than 10%

Where short term recovery is important

- Time value of money … always has some importance
- Short land tenure

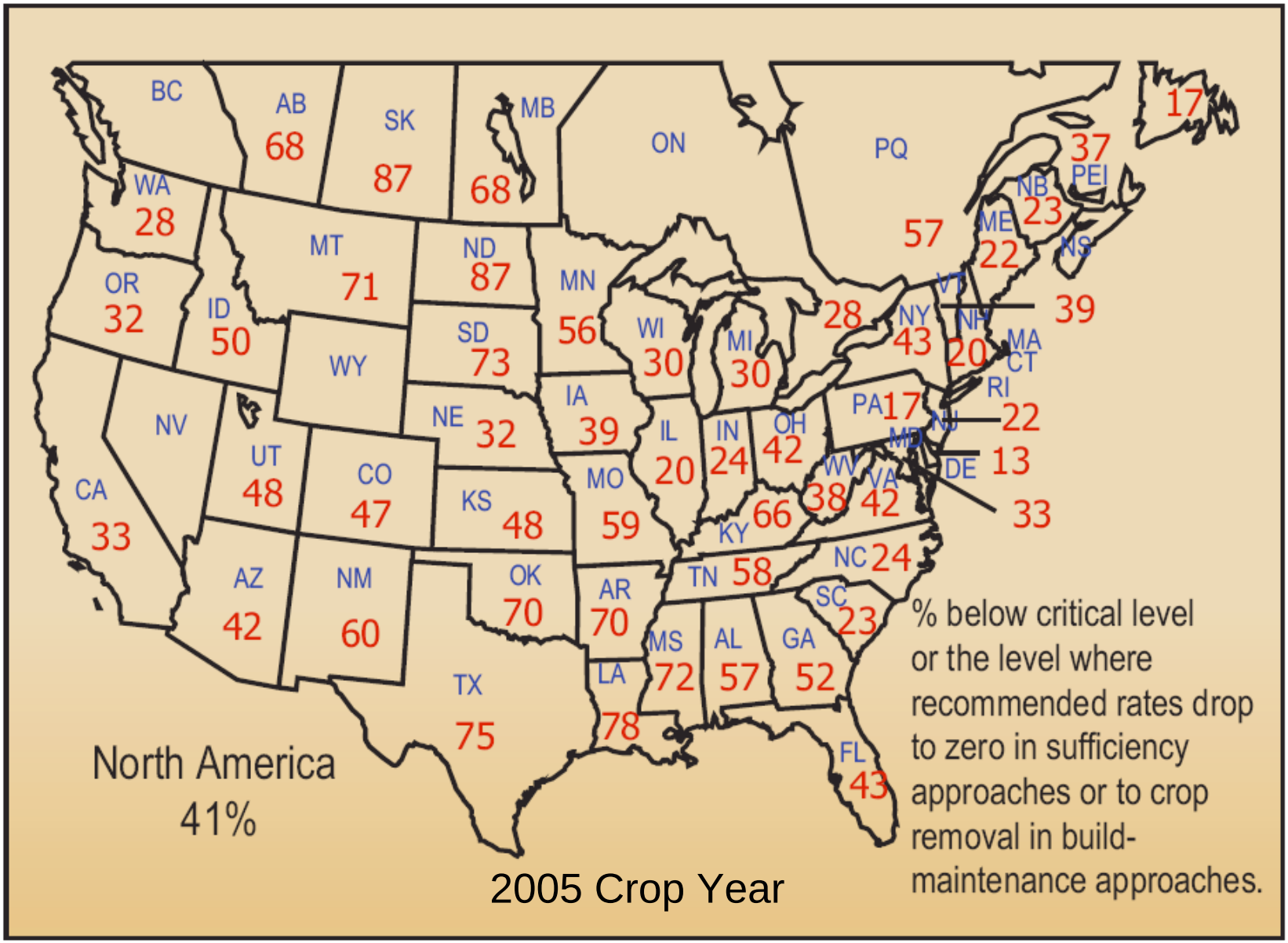
Percent of land in farms rented or leased in 2002 in the U.S.



Where short term recovery is important

- Time value of money … always has some importance
- Short land tenure
- Limited operating capital and sub-optimal soil test levels

Percent of soil samples requiring annual P fertilization to avoid profit loss in most major crops



Where short term recovery is important

- Time value of money … always has some importance
- Short land tenure
- Limited operating capital and sub-optimal soil test levels
- Soils with severe P fixing potential
- Threat to water quality

Summary

- **The value of practices that improve P efficiency is dependent on impact on effectiveness in meeting grower objectives**
  - **Optimizing profitability**
  - **Minimizing nutrient loss**
  - **Providing system sustainability**
- **Long-term fertilizer P efficiency in North America is usually high but short-term efficiency can be quite low**
- **Short-term efficiency is most important when:**
  - **Land tenure is short or uncertain**
  - **Operating capital is limited and soil test levels are below optimum**
  - **Soils have high P fixing potential**
  - **Fields or field areas pose a threat to water quality**

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