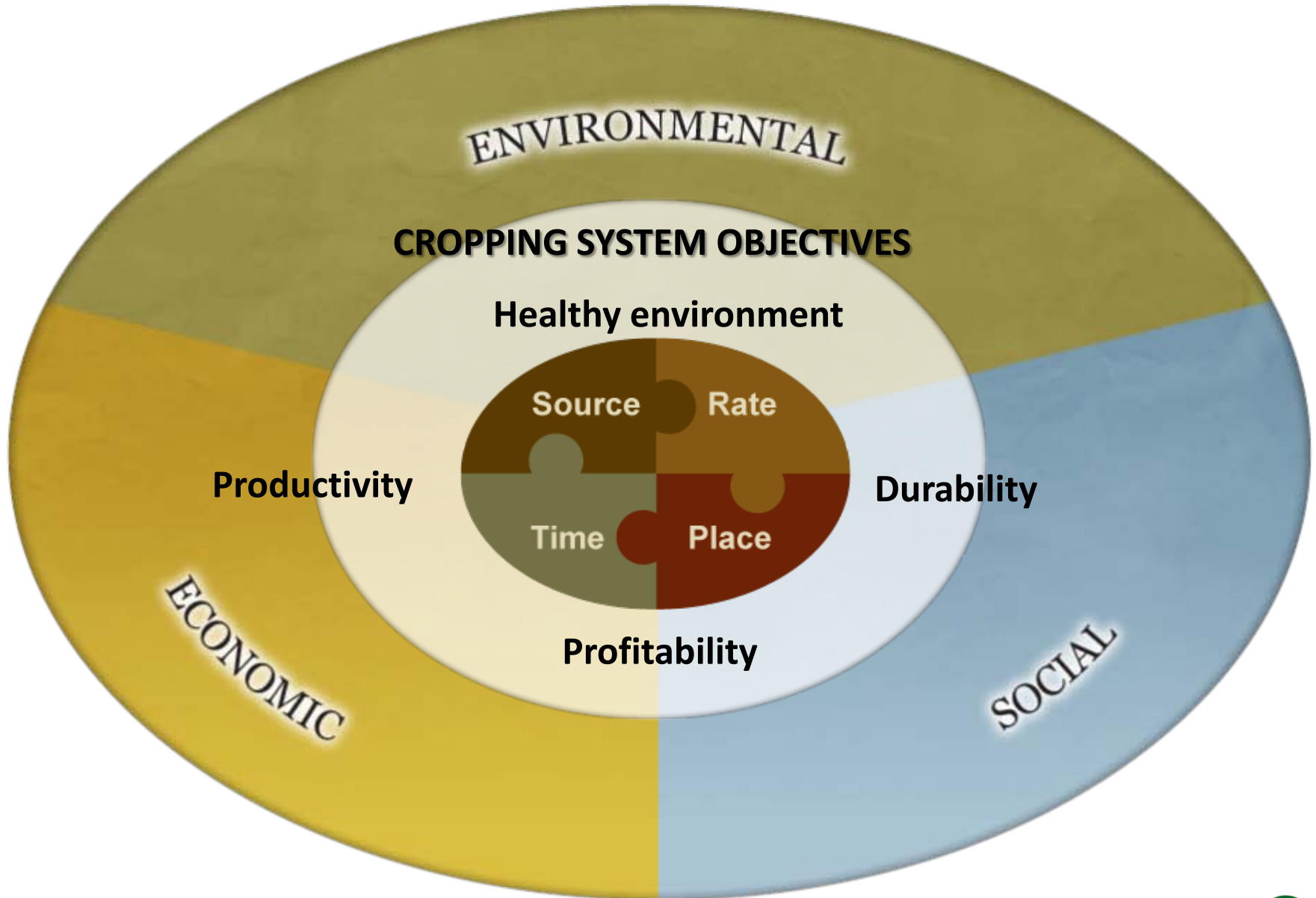Paul E. Fixen
Senior Vice President
pfixen@ipni.net
www.ipni.net

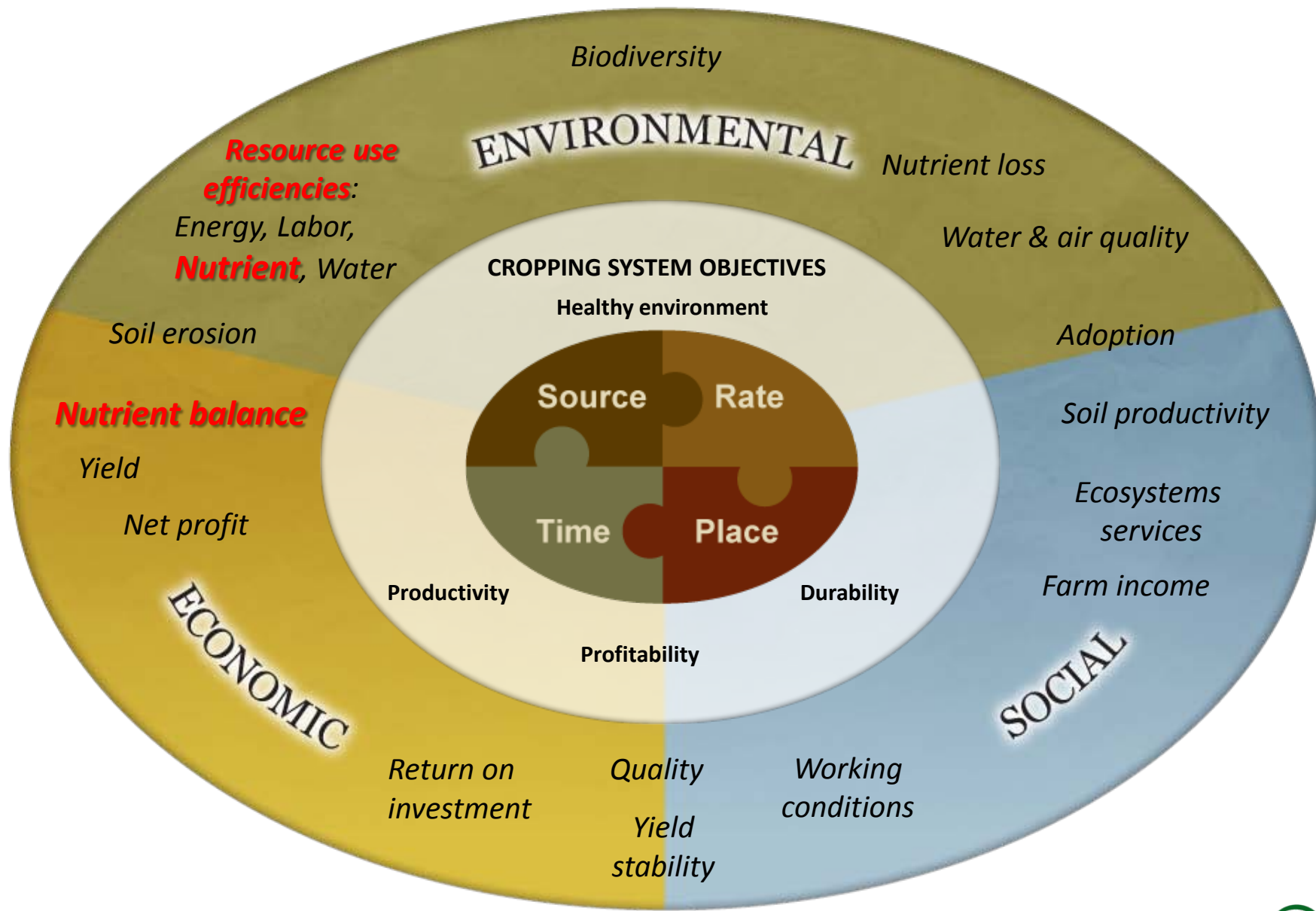# P Efficiency and Effectiveness in Cropping Systems of the U.S.

S-4/S-8 Symposium: Optimizing the Efficiency of P Fertilizer Use to Conserve an Essential and Limited Global Resource
November 2, 2010

4R Nutrient Stewardship

Right Source at **Right Rate, Right Time, Right Place**

Performance Indicators

Biodiversity

ENVIRONMENTAL

Nutrient loss

Resource use efficiencies: Energy, Labor, **Nutrient**, Water

Water & air quality

CROPPING SYSTEM OBJECTIVES

Healthy environment

Soil erosion

Adoption

Nutrient balance

Source | Rate

Soil productivity

Yield

Net profit

Time | Place

Ecosystems services

Productivity

Durability

Farm income

Profitability

ECONOMIC

SOCIAL

Return on investment

Quality

Working conditions

Yield stability

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Fertilizer Phosphorus Efficiency

Typical values for 12 T/ha corn in the Midwest

15 recovered/**75** applied = **20%**
VS
75 removed/**75** applied = **100%**

P removed with harvest
75 kg P_2O_5/ha

Fertilizer P
75 kg P_2O_5/ha

P in crop residue
35 kg P_2O_5/ha
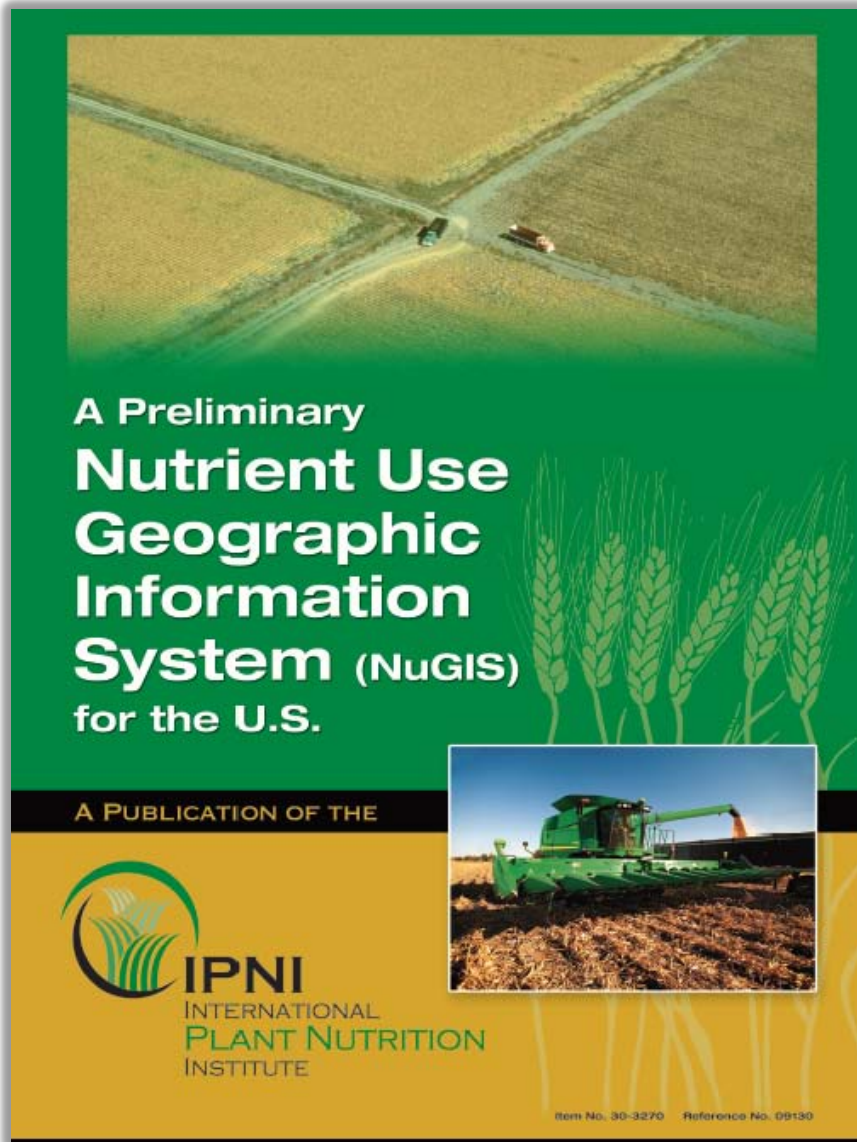
15 kg P_2O_5/ha

95 kg P_2O_5/ha

Soil P

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

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

Focus here will be on long-term efficiency as related to use of global P resources

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Data sources

Fertilizer P consumption in the U.S., 1955-2009
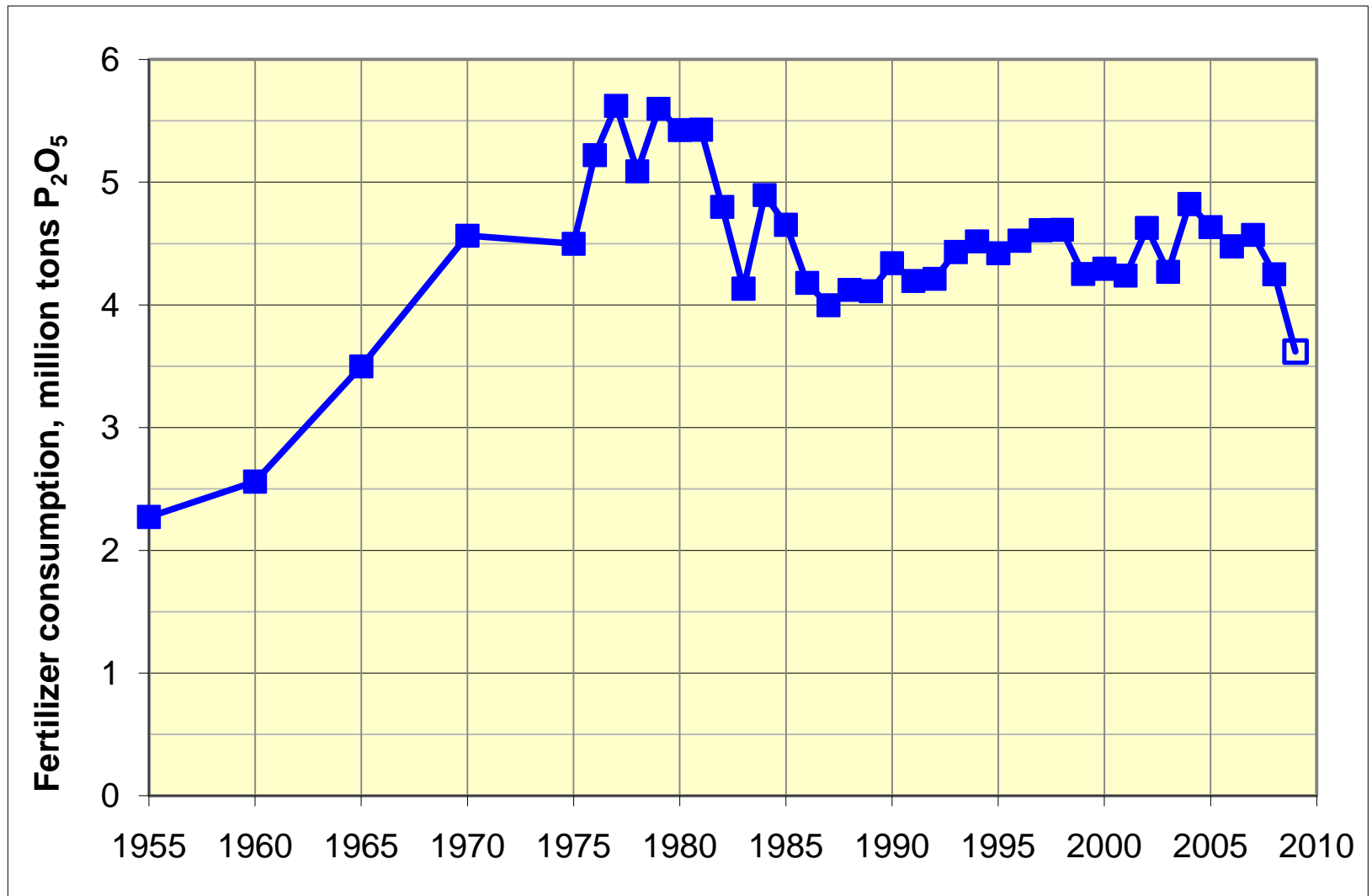
Selected P inputs and crop removal for the contiguous U.S., 1987-2007.
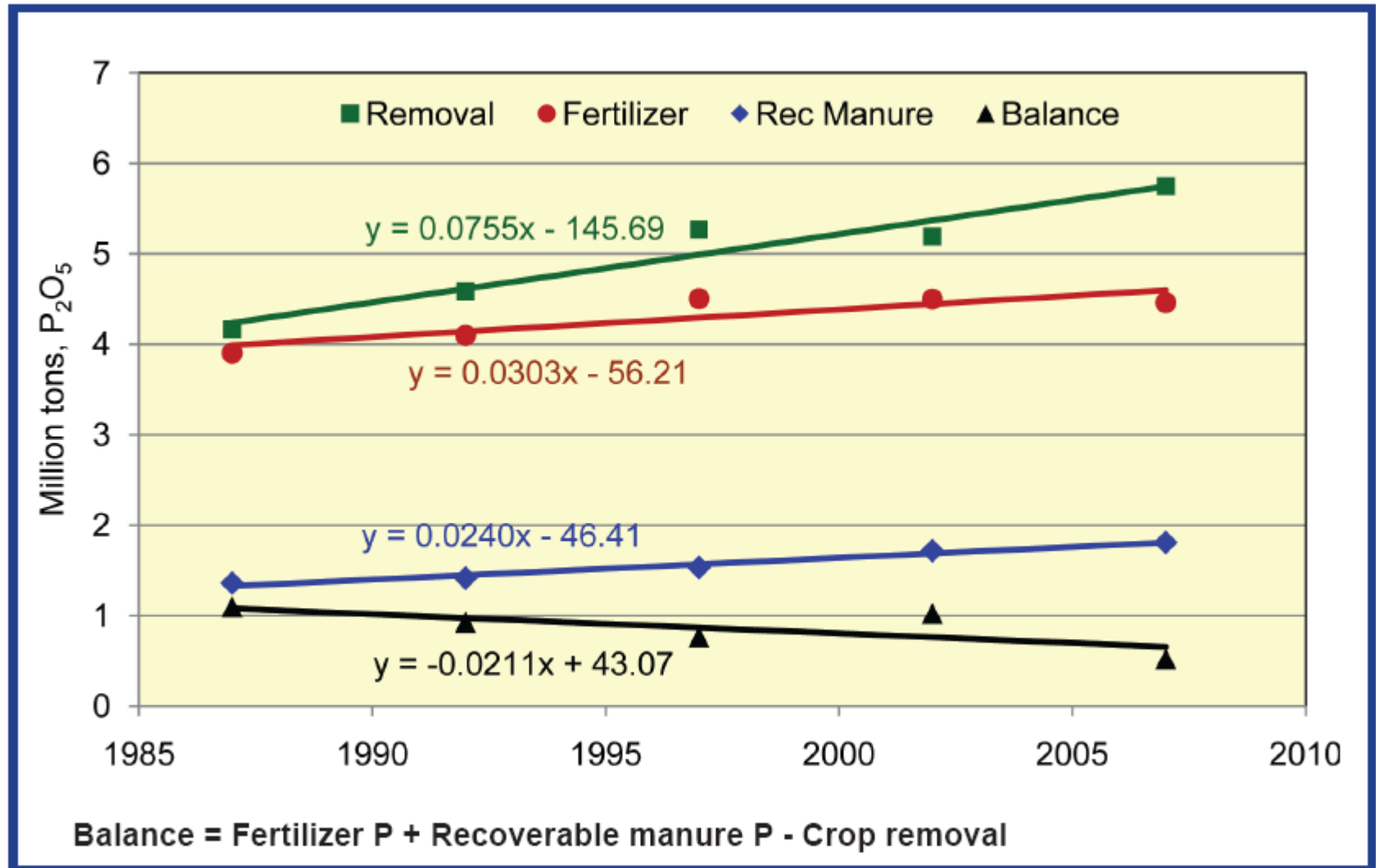
P removal to use ratios for the contiguous U.S., 1987-2007 (P efficiency by balance method).

Chart: Removal to use ratio (y-axis, 0.0 to 1.8) vs. year (x-axis, 1985 to 2010).

$y = 0.0051x - 9.31$

0.92

1.00 in 2036!

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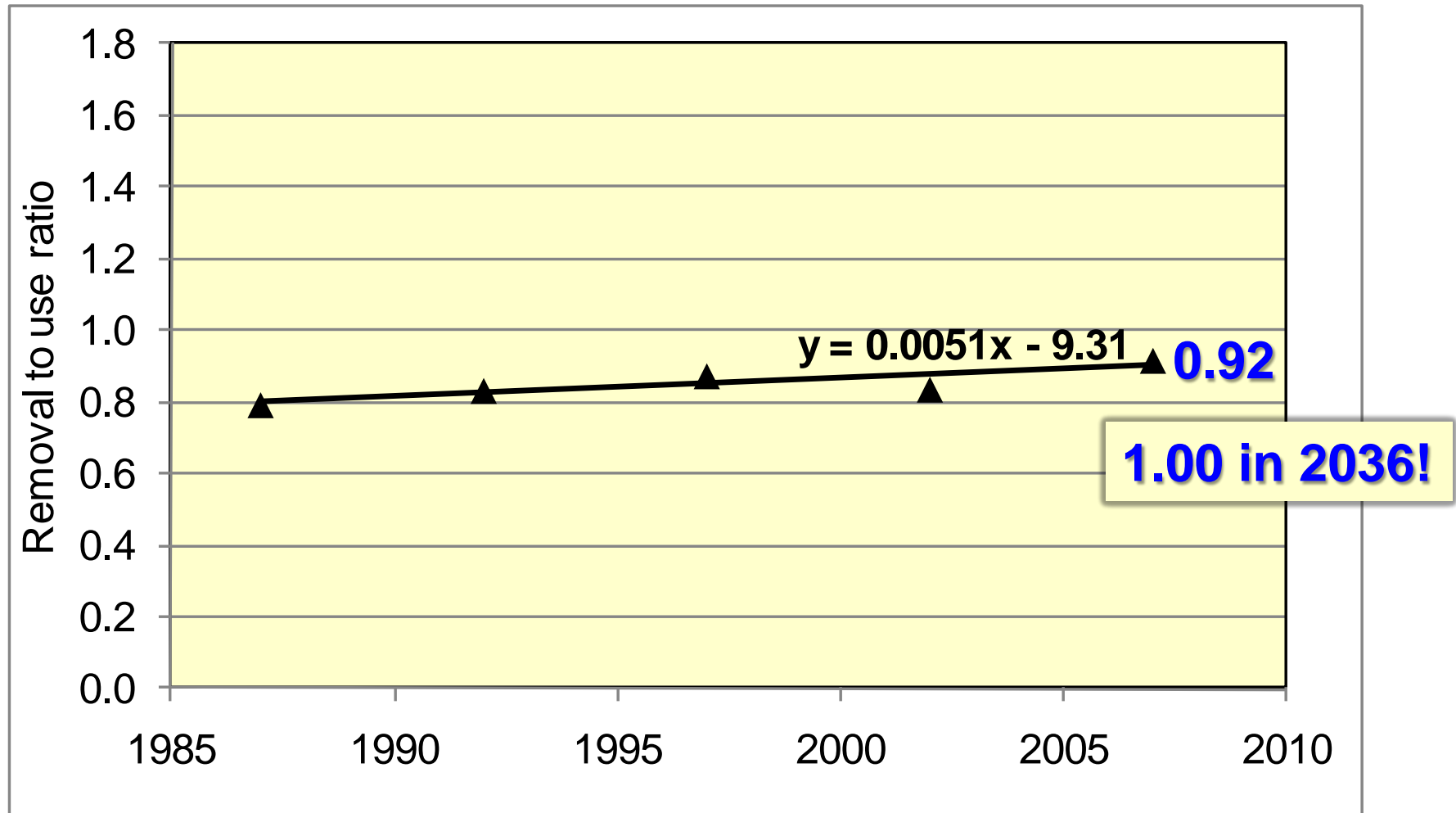
P removal to use ratios for the contiguous U.S. and selected states, 1987-2007.

Estimated P removal to use ratio by watershed, 2007.
(Numbers are state ratios)

IPNI, 2010

Change in typical soil P levels from 2001 to 2005.

Increase
No change*
Decrease

White areas had insufficient data to determine a change in median

*Change in median level was less than or equal to 4 ppm
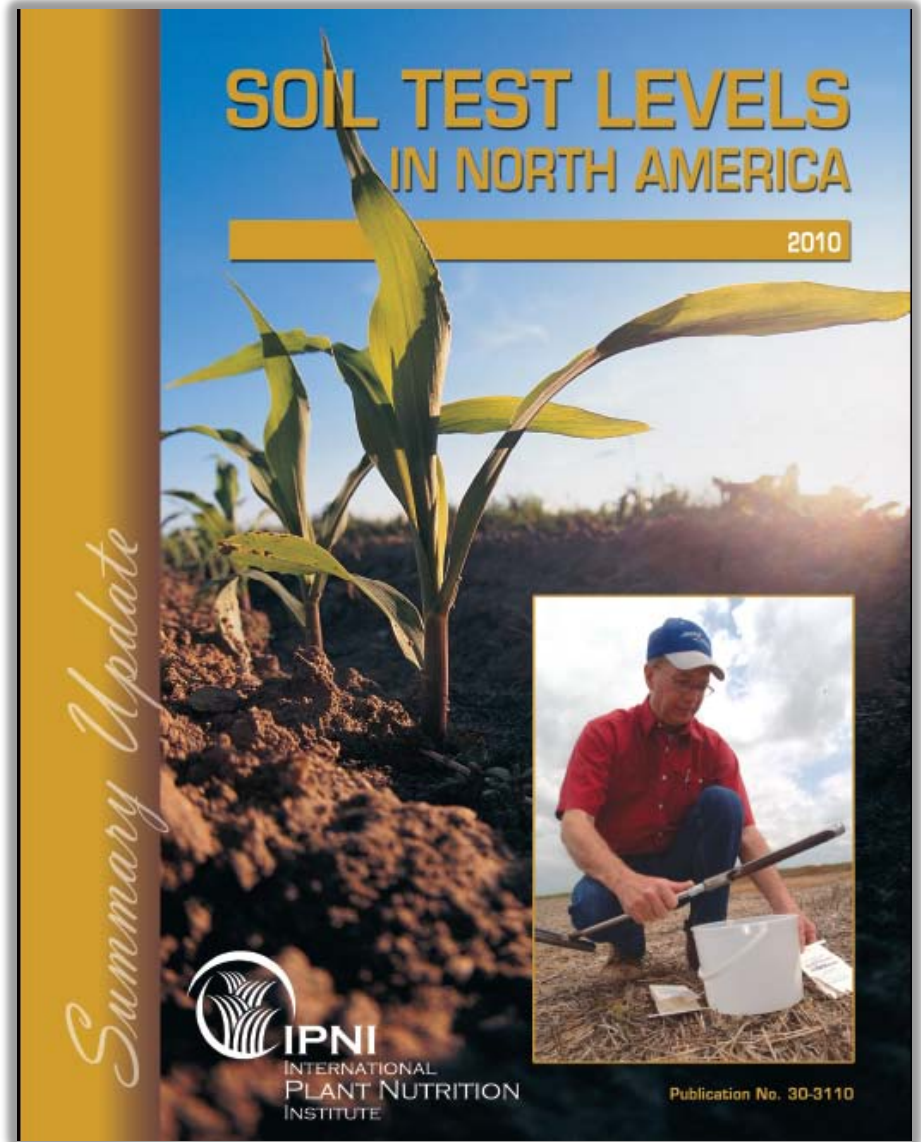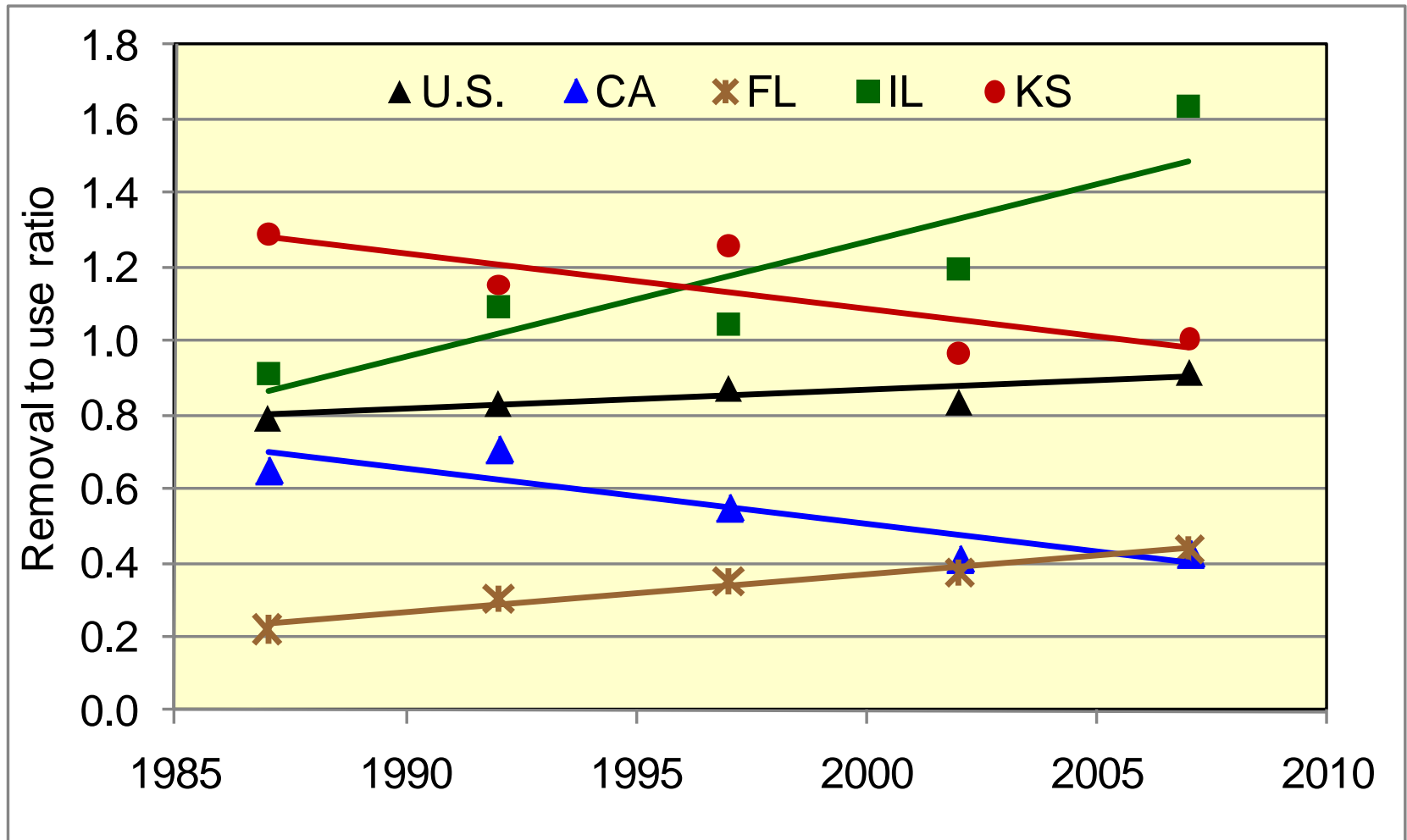
Soil test P levels in North America, 2001-2010.
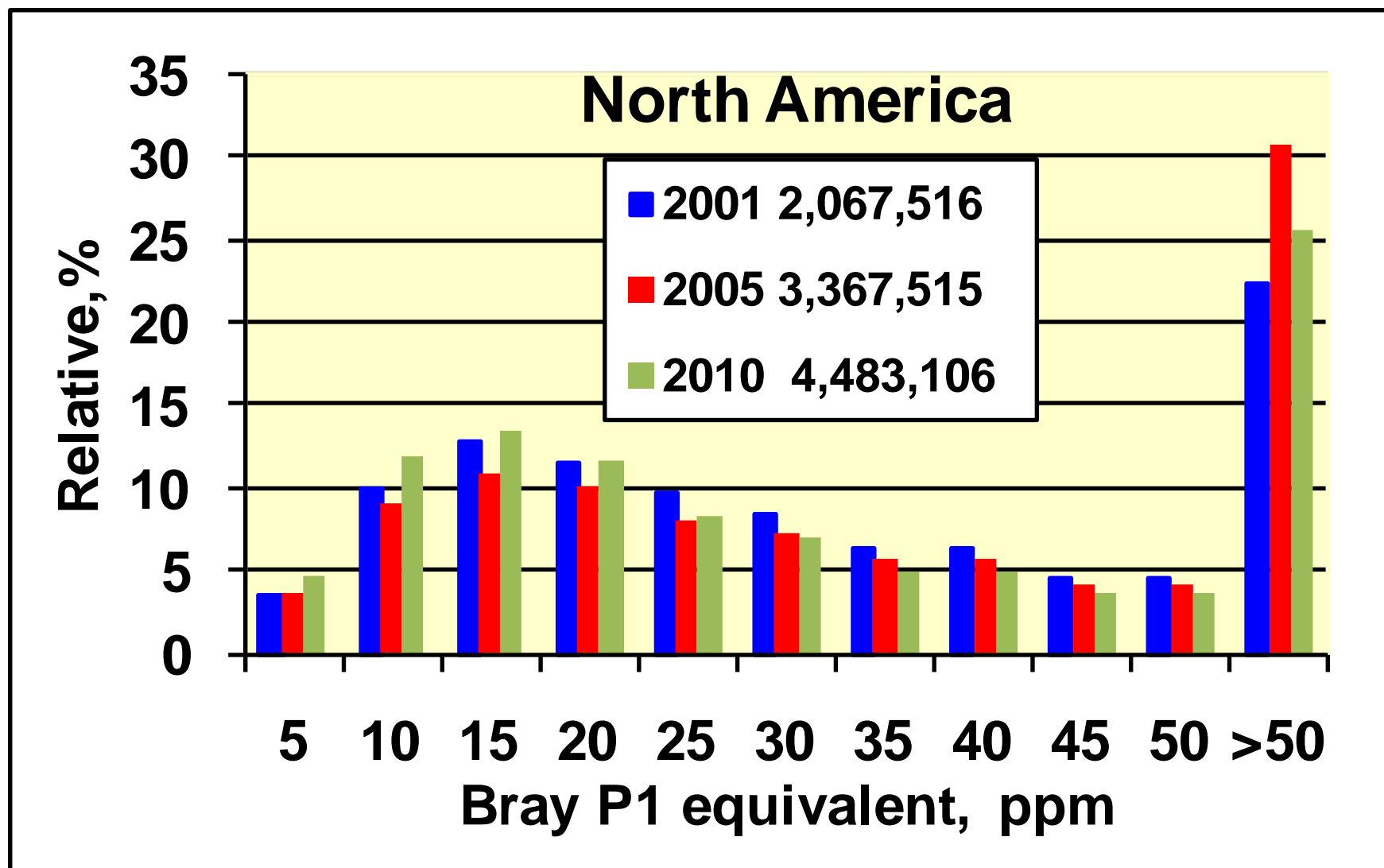
Median Bray P1 equivalent soil test levels in 2010.

North America
25 ppm
4.5 million samples

ppm
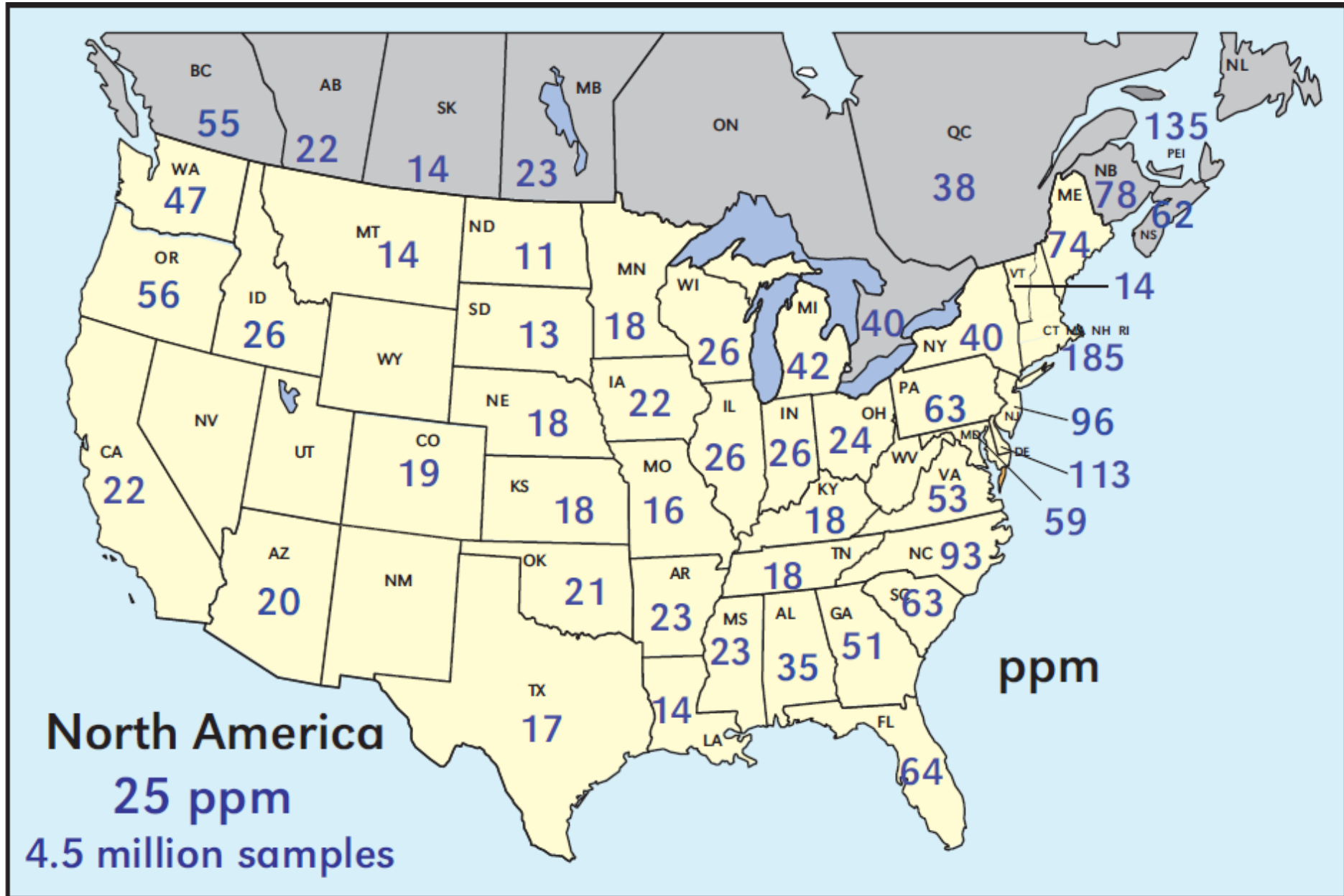
Change in median soil P level from 2005 to 2010.

BC **-33**

AB **+4**

SK **+4**

MB **+6**

ON **+1**

QC

NL

PEI **+9**

NB **-27**

NS

ME **+16**

WA **-5**

OR **+1**

ID **+1**

MT **0**

ND **0**

SD **-1**

MN **0**

WI **-13**

MI **-7**

VT **-10**

NY **+8**

CT MA NH RI **+25**

NV

UT

WY

CO **-7**

NE **-4**

IA **-3**

IL **-10**

IN **-3**

OH **-1**

PA **+6**

NJ **+12**

MD

DE **+3**

CA **-2**

AZ **-5**

NM

KS **-3**

MO **-2**

KY **0**

WV

VA **+17**

+1

OK **+2**

AR **+6**

TN **-3**

NC **-10**

SC **-17**

TX **-1**

MS **-4**

AL **-1**

GA **+3**

LA **-1**

FL **+5**

ppm

North America
-6
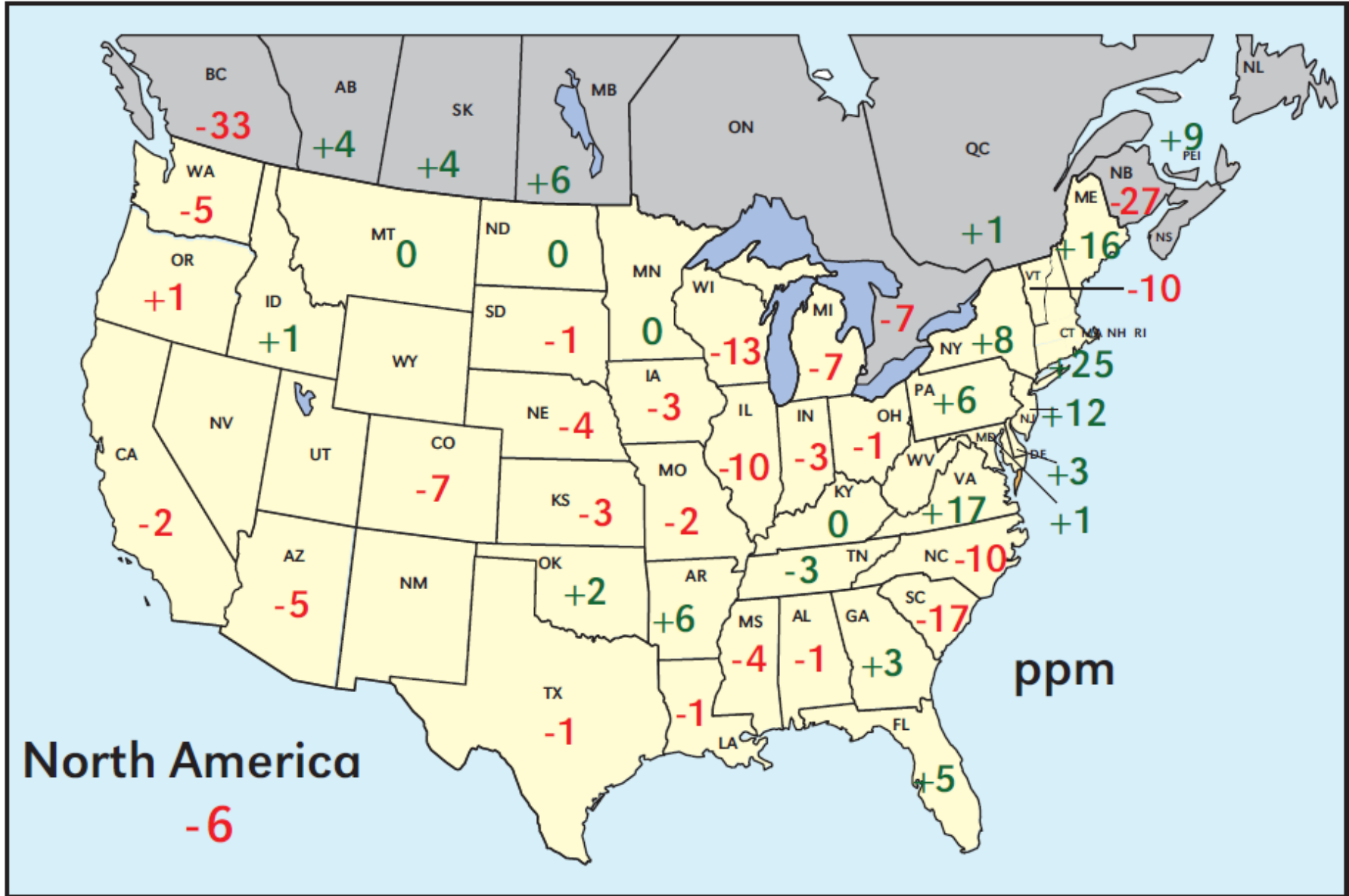
Recovery efficiency by balance method in MT, ND, and SD (NuGIS, IPNI).

	Median Bray P, ppm			P removal/use* ratio		
State	**2001**	**2005**	**2010**	**2002**	**2007**	**Average**
MT	12	14	14	0.91	1.04	**0.98**
ND	10	11	11	1.07	1.01	**1.04**
SD	11	14	13	1.06	1.00	**1.03**

* Use = Fertilizer P applied plus recoverable manure P.

Replacing the P removed in the harvested portions of crops appears to be maintaining soil P as indicated by soil tests = **Recovery efficiency by balance is near 100%.**

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2010 median soil P levels* and change from 2005
(Soil samples, millions: 2005=2.0; 2010=3.0)

MN
18
0

SD **13**
-1

WI
26
-13

MI
42
-7

ON
40
-7

IA **22**
-3

NE **18**
-4

IL
26
-10

IN
26
-3

OH
24
-1

KS **18**
-3

MO
16
-2

KY
18
0
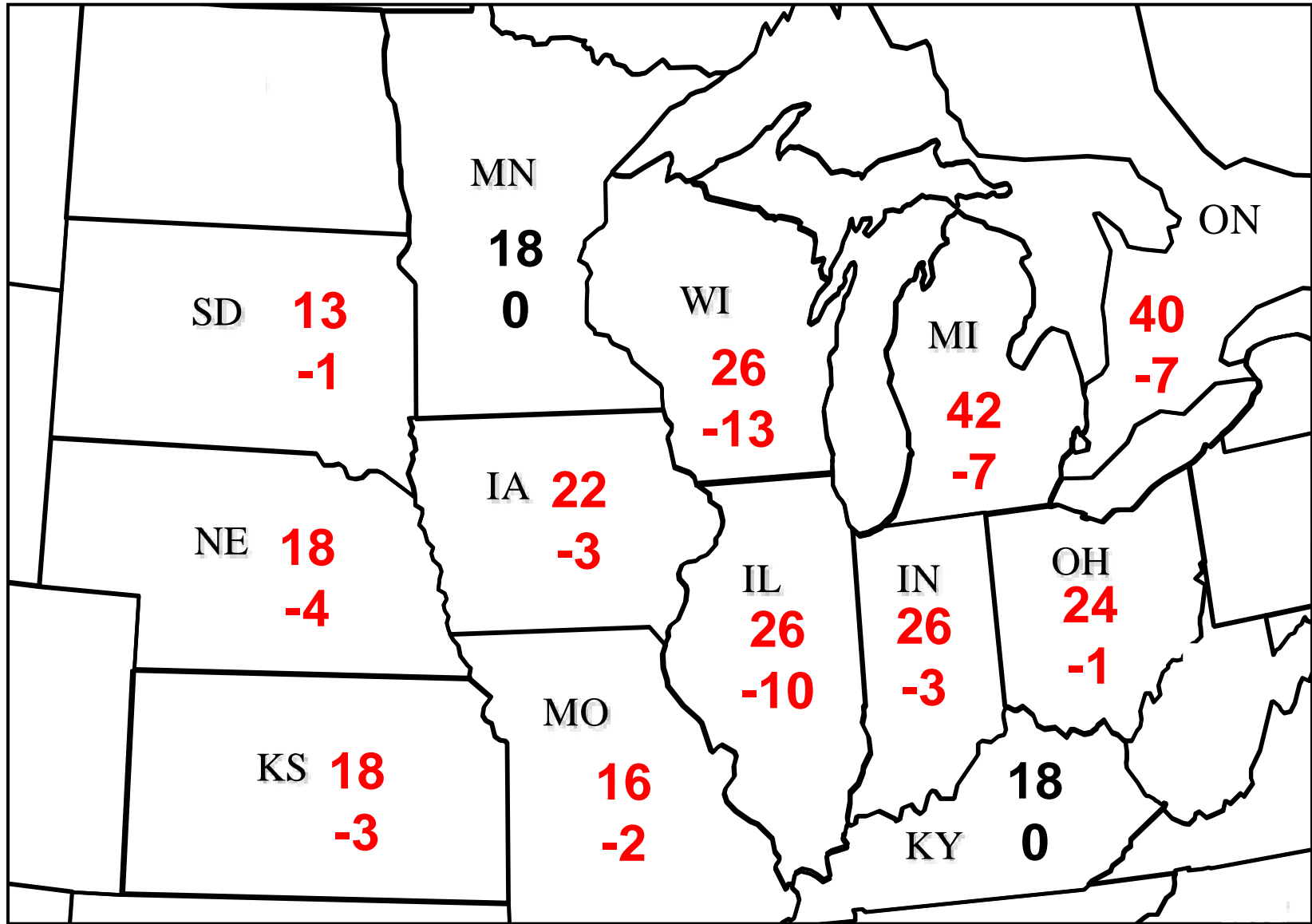
*Median Bray P1 equivalent, ppm

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Annual change in median soil P level for 12 Corn Belt states as related to state P balance, 2005-2009.

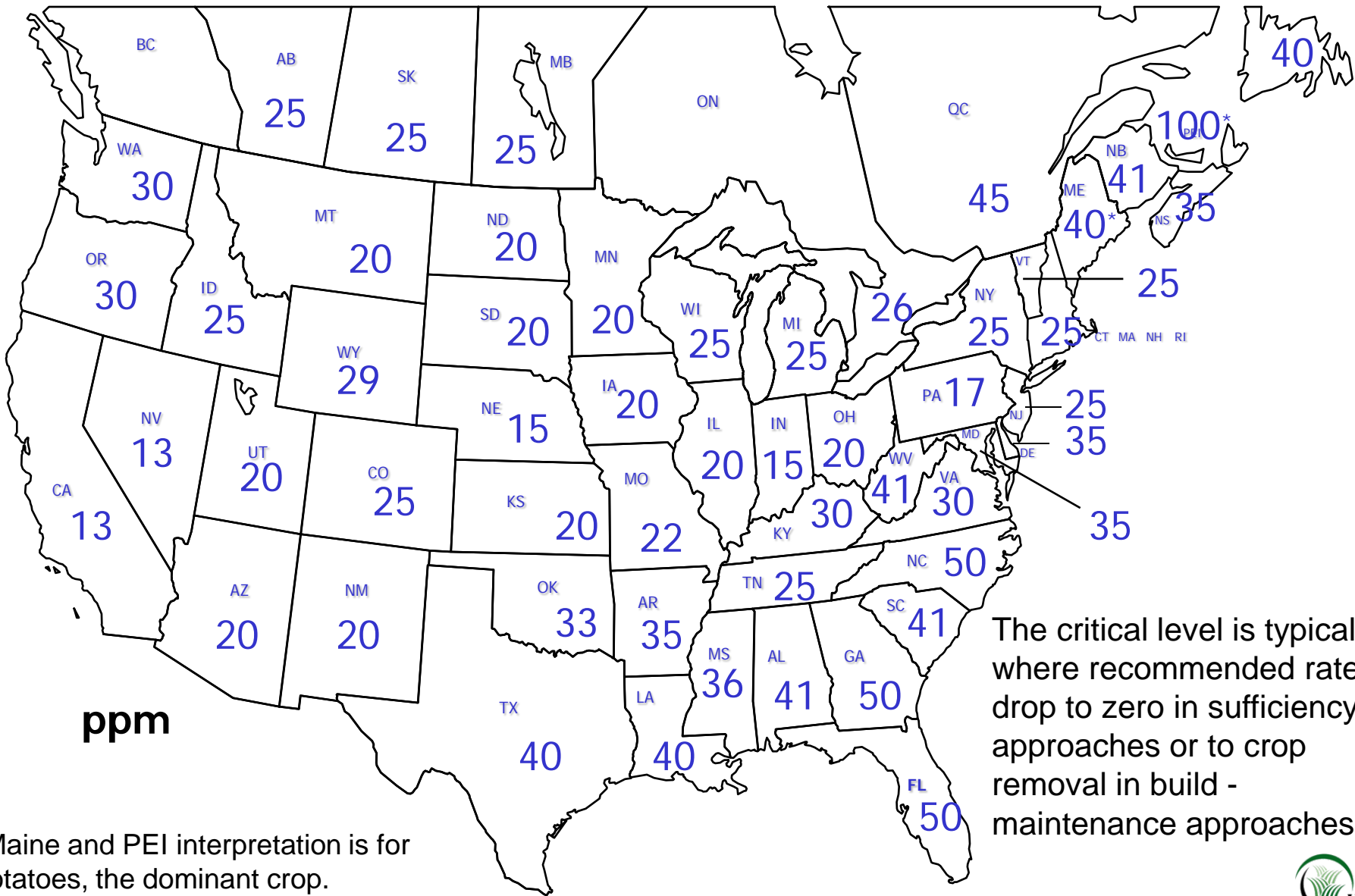$y = 0.0897x - 0.063$

$r^2 = 0.62$

A balanced budget gives no net change in soil P

Annual change in median P, ppm

NuGIS balance*, lb P_2O_5/A/yr
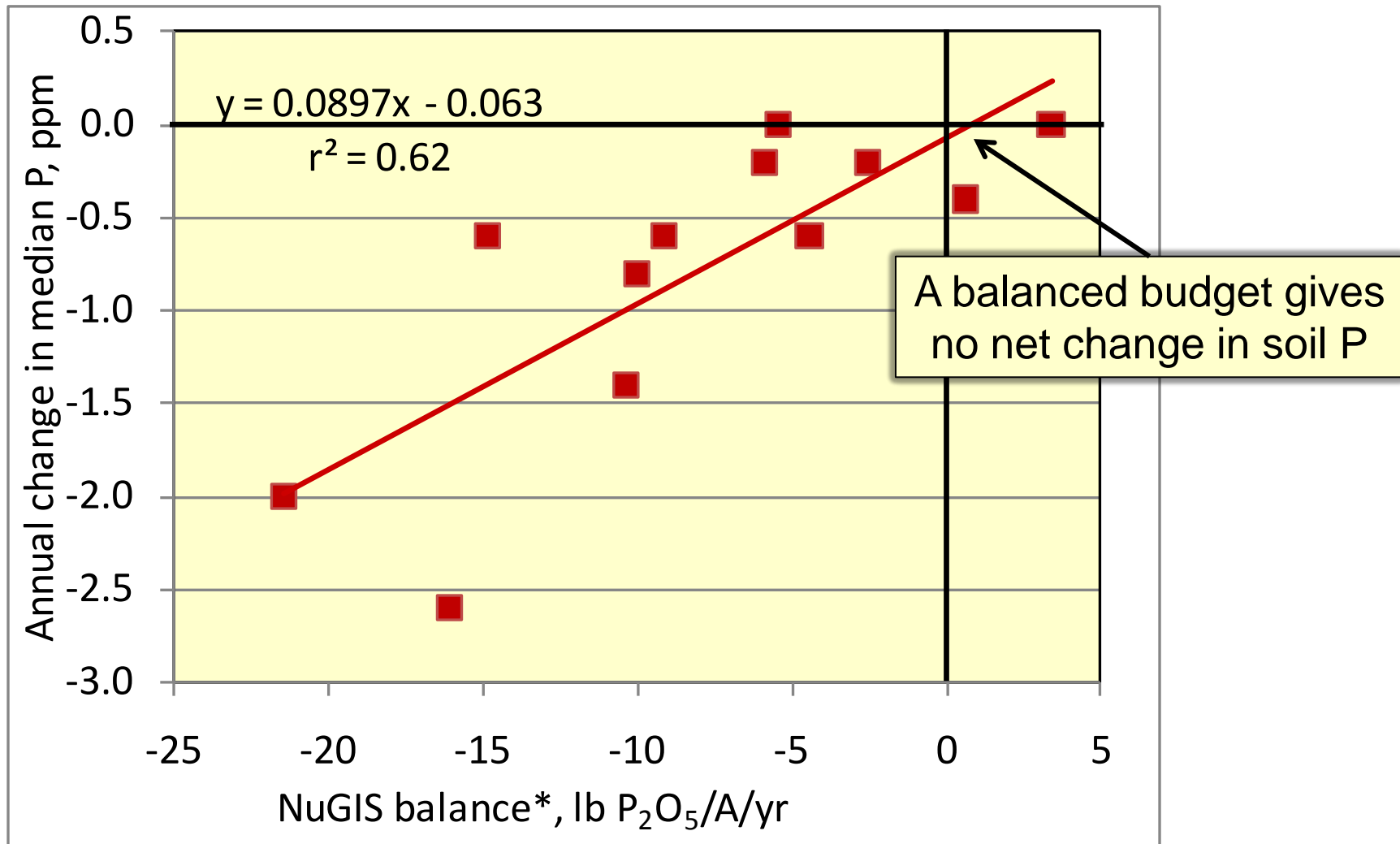
*NuGIS is a GIS nutrient balance model (IPNI, 2010).

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Figure 1. Critical Bray P1 equivalent soil test levels, 2010.

BC

AB 25

SK 25

MB 25

ON

QC 45

40

100 *
PEI

NB 41

NS 35

WA 30

MT 20

ND 20

MN 20

ME 40 *

VT 25

OR 30

ID 25

SD 20

WI 25

MI 25

26

NY 25

25

CT MA NH RI

WY 29

NE 15

IA 20

IL 20

IN 15

OH 20

PA 17

NJ 25

MD 35

DE

35

NV 13

UT 20

CO 25

KS 20

MO 22

WV 41

VA 30

CA 13

KY 30

NC 50

AZ 20

NM 20

OK 33

AR 35

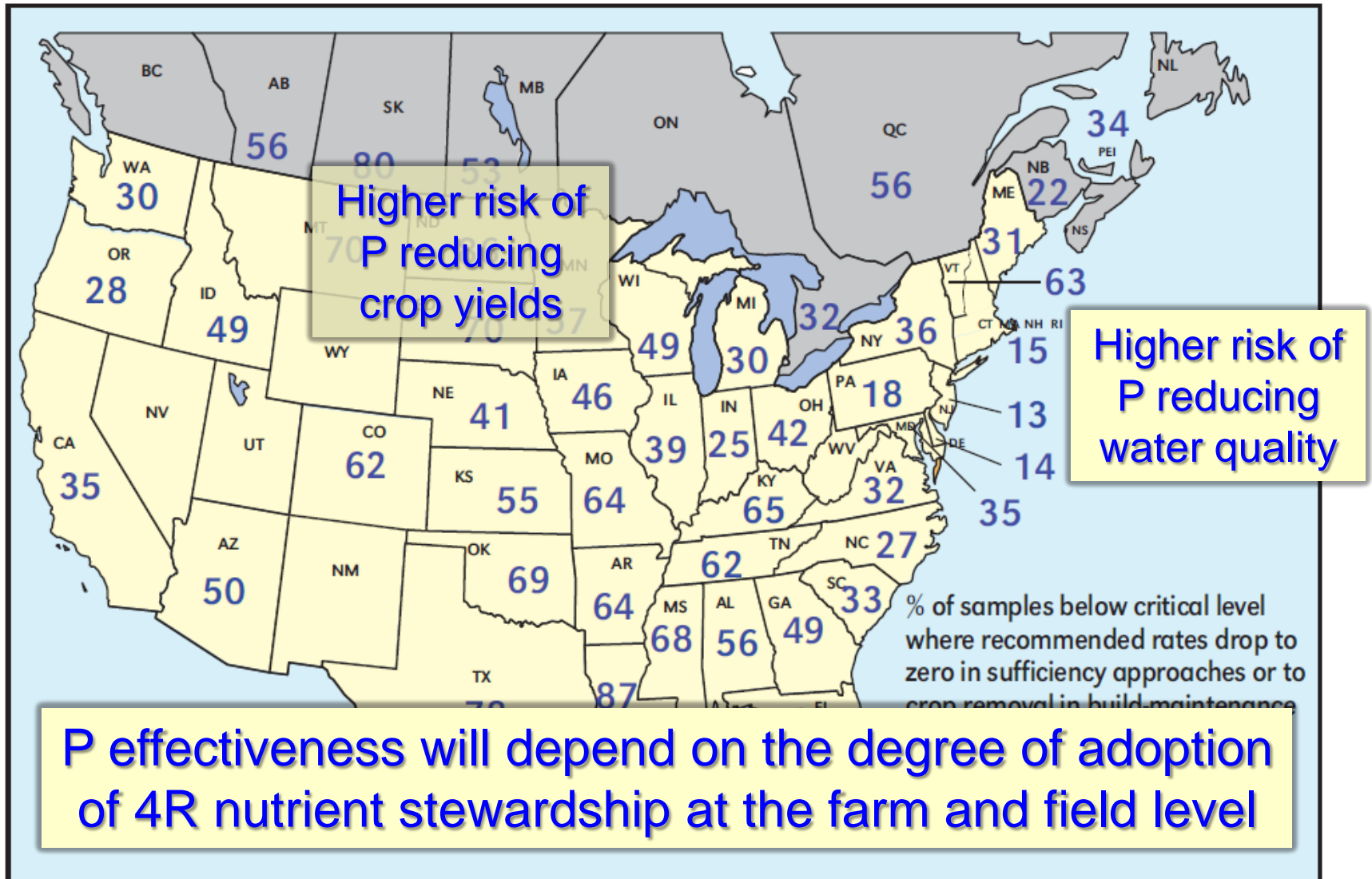TN 25

SC 41

TX 40

LA 40

MS 36

AL 41

GA 50

ppm

FL 50

The critical level is typically where recommended rates drop to zero in sufficiency approaches or to crop removal in build - maintenance approaches.
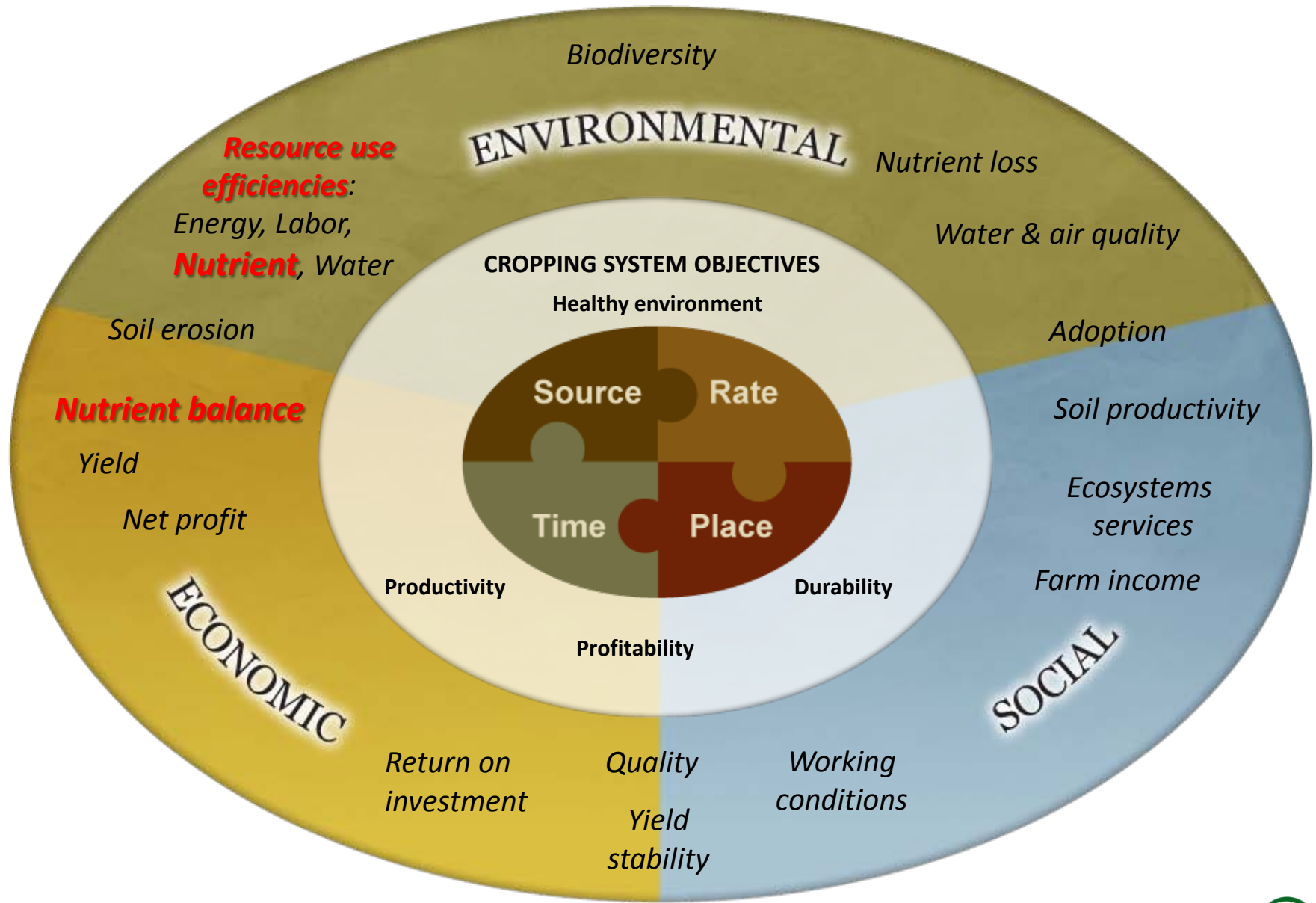
*Maine and PEI interpretation is for potatoes, the dominant crop.

IPNI

Percent of soil samples testing below critical levels for P for major local crops in 2010.

Higher risk of P reducing crop yields

Higher risk of P reducing water quality

% of samples below critical level where recommended rates drop to zero in sufficiency approaches or to crop removal in build-maintenance

P effectiveness will depend on the degree of adoption of 4R nutrient stewardship at the farm and field level

Performance Indicators

What does this aggregate data analysis indicate about long-term P efficiency in the U.S.?

- Varies among regions of the country.

- Regions with apparent P efficiency approaching 100%
  - Northern Great Plains, Corn Belt, possibly others.

- Regions with apparent efficiency <50%
  - Atlantic Coastal Plains States and CA
  - Low apparent efficiencies often associated with high livestock inventory per cropland area and areas of intensive vegetable or fruit production.

IPNI