IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

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Soil Test Advanced

Tom Bruulsema, PhD, CCA
Director, Northeast Region, North America Program

Agrium Inc.

Arab Potash Company

Belarusian Potash Company

CF Industries Holdings, Inc.

Compass Minerals Specialty Fertilizers

Incitec Pivot

International Raw Materials LTD.

Intrepid Potash, Inc.

K+S KALI GmbH

The Mosaic Company

OCP S.A.

PotashCorp

Qatar Fertiliser Company (QAFCO)

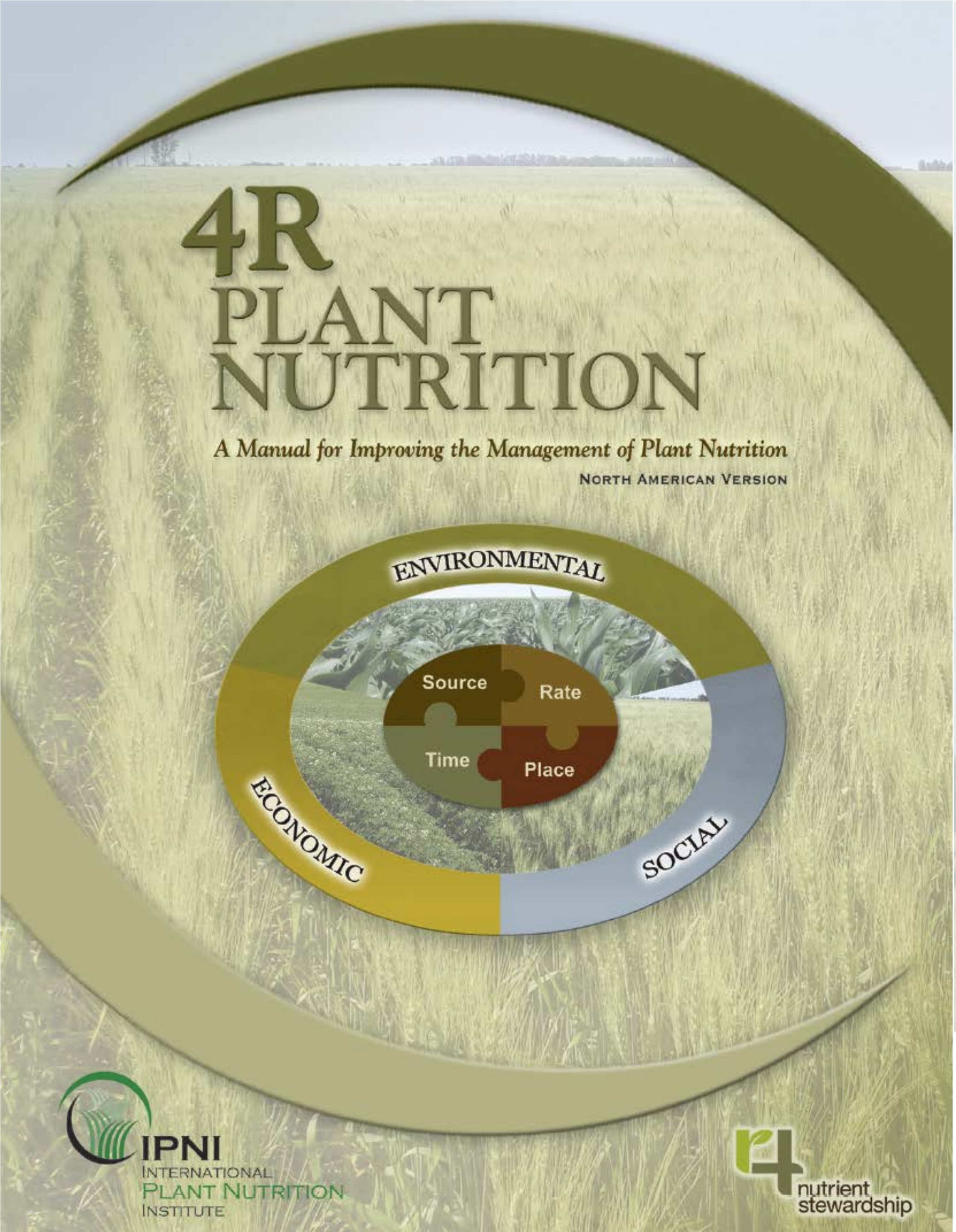
Simplot

Sinofert Holdings Limited

SQM

Uralkali

Formed in 2007 from the Potash & Phosphate Institute, the **International Plant Nutrition Institute** is supported by leading fertilizer manufacturers.



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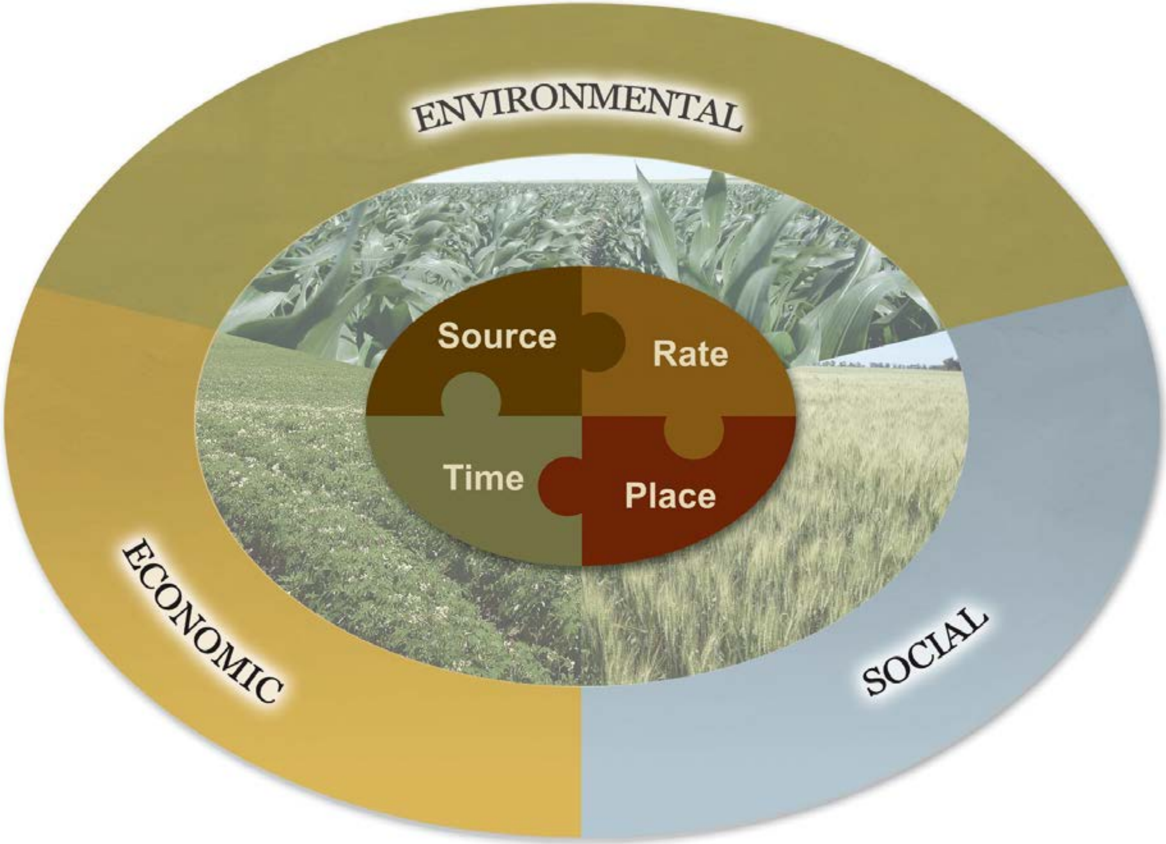
Right means Sustainable

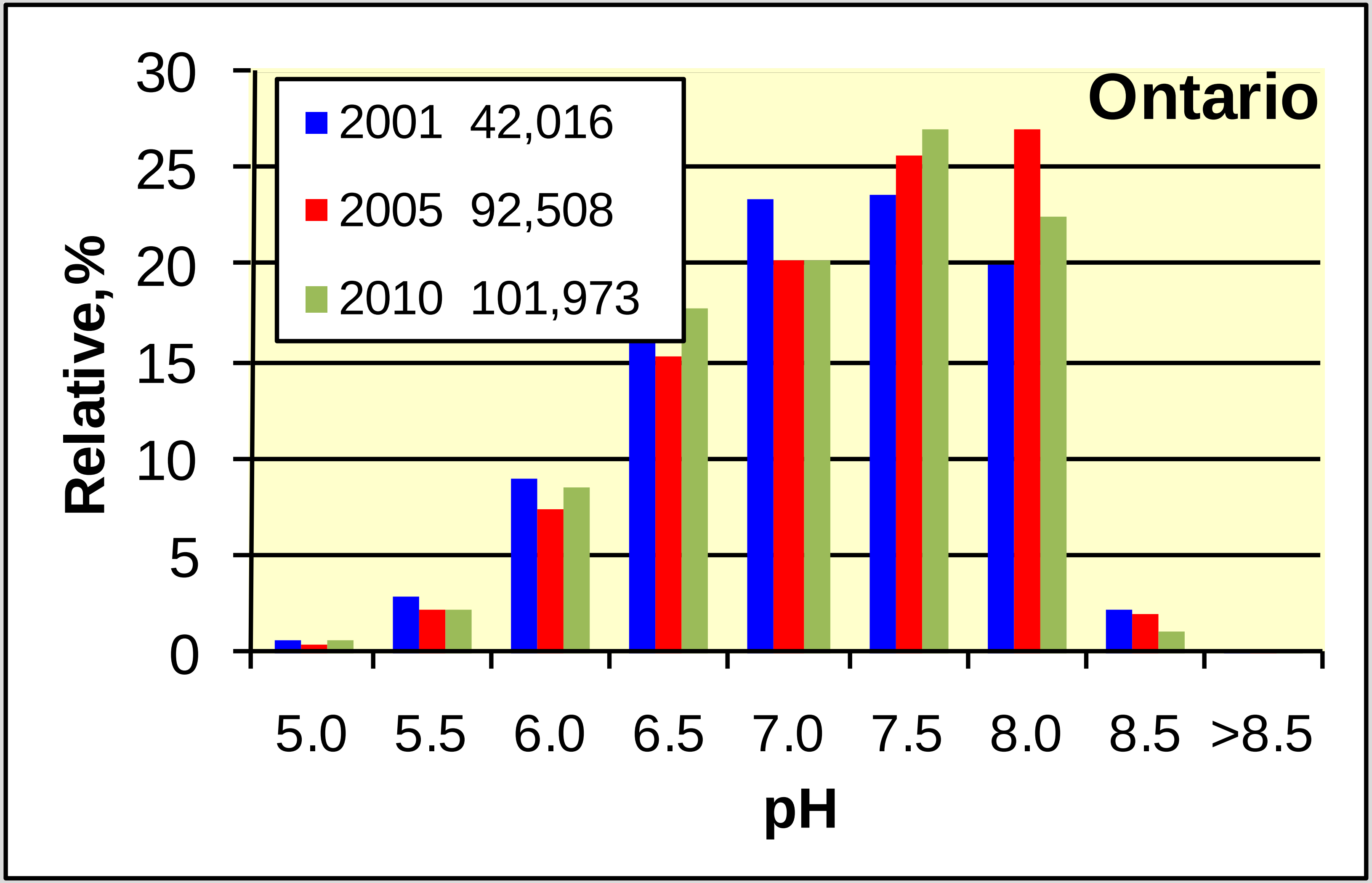
- Right source, rate, time, and place
- Outcomes valued by stakeholders



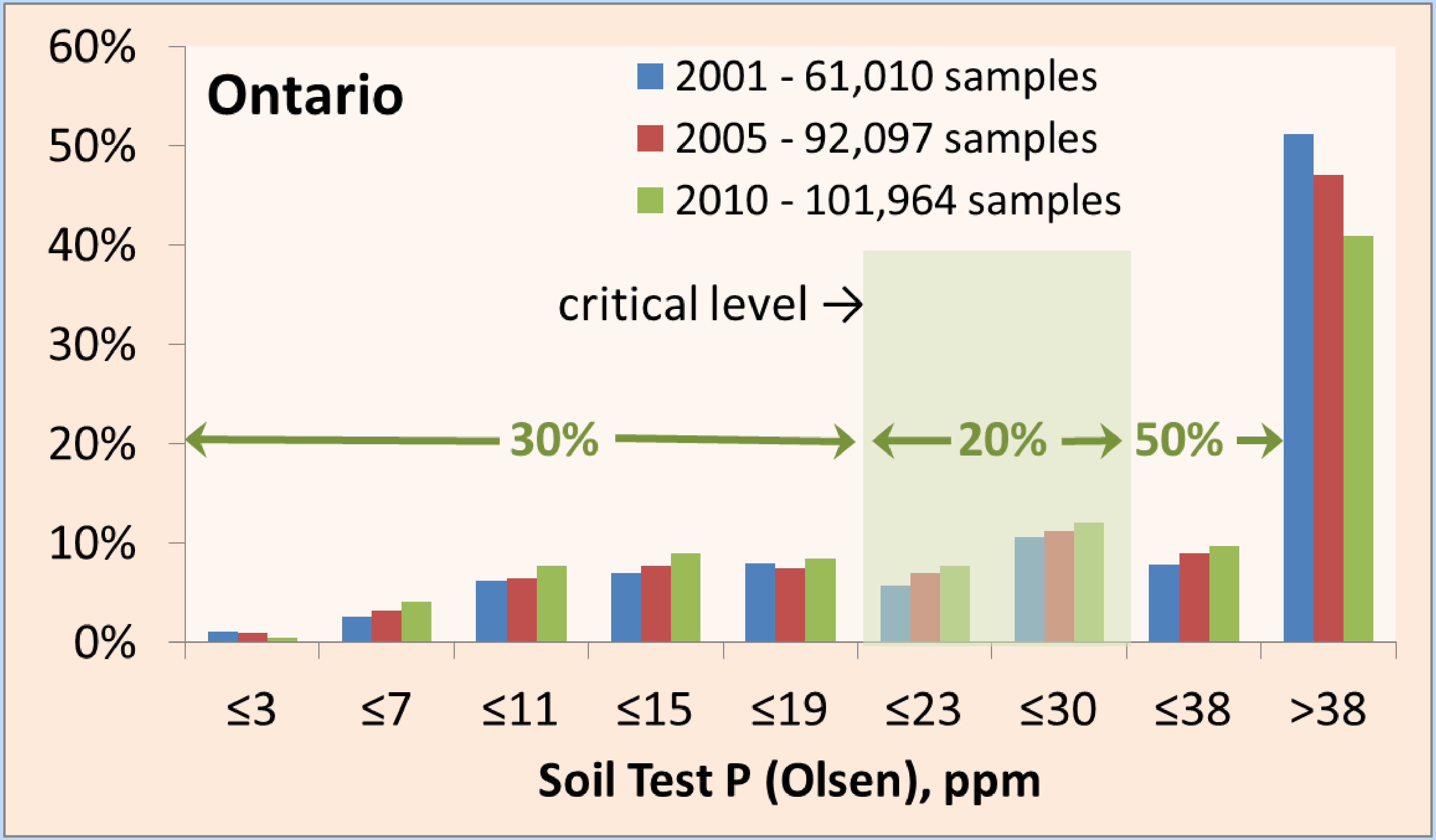
Objectives of Soil Tests

1. Identify yield limiting factors
2. Provide an index of nutrient availability in the soil
3. Predict crop response to a nutrient application
4. Provide basis for a nutrient management plan
5. Monitor soil nutrient status over time
6. To manage risks – economic, environmental

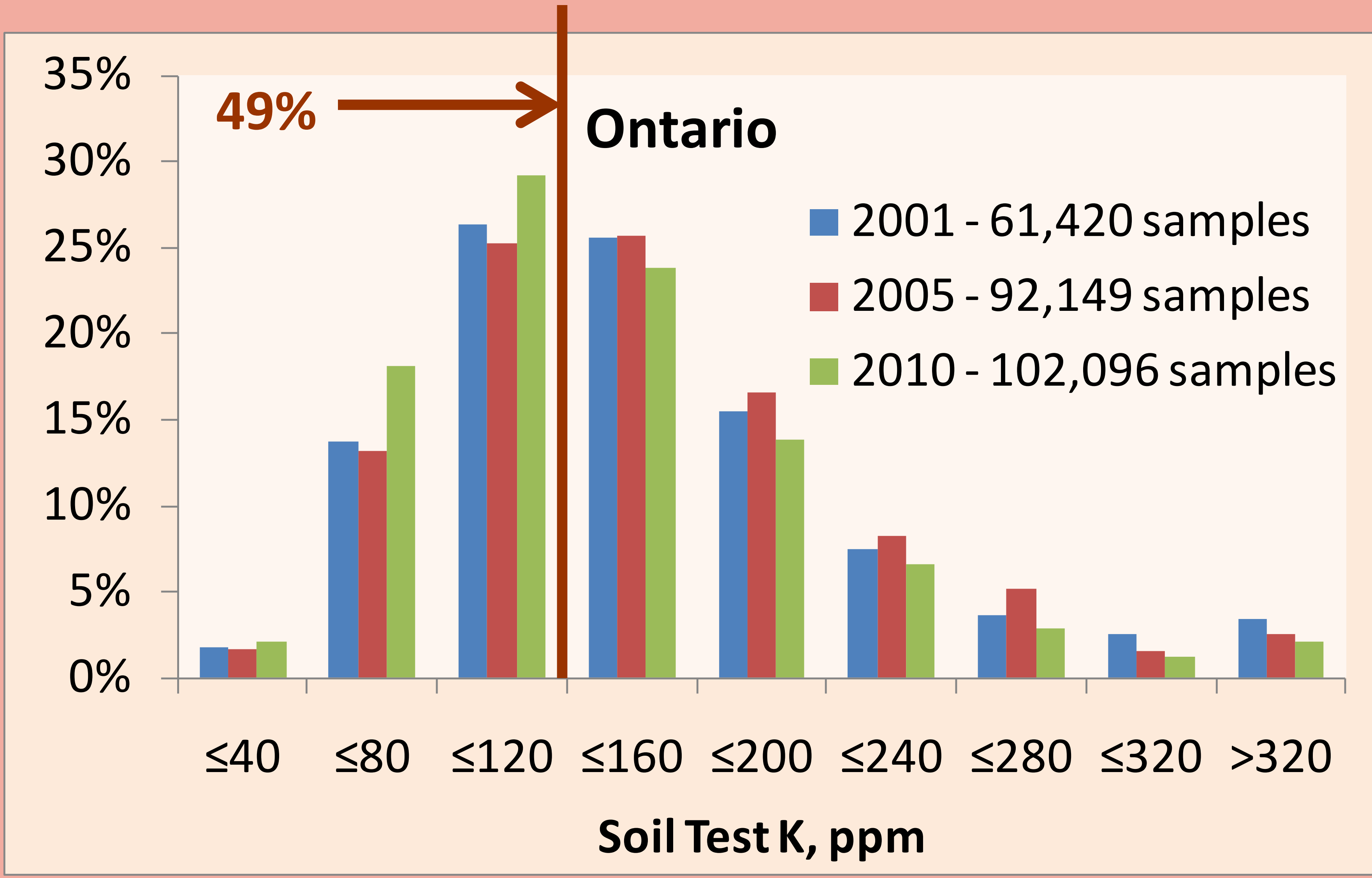
Soil pH in Ontario



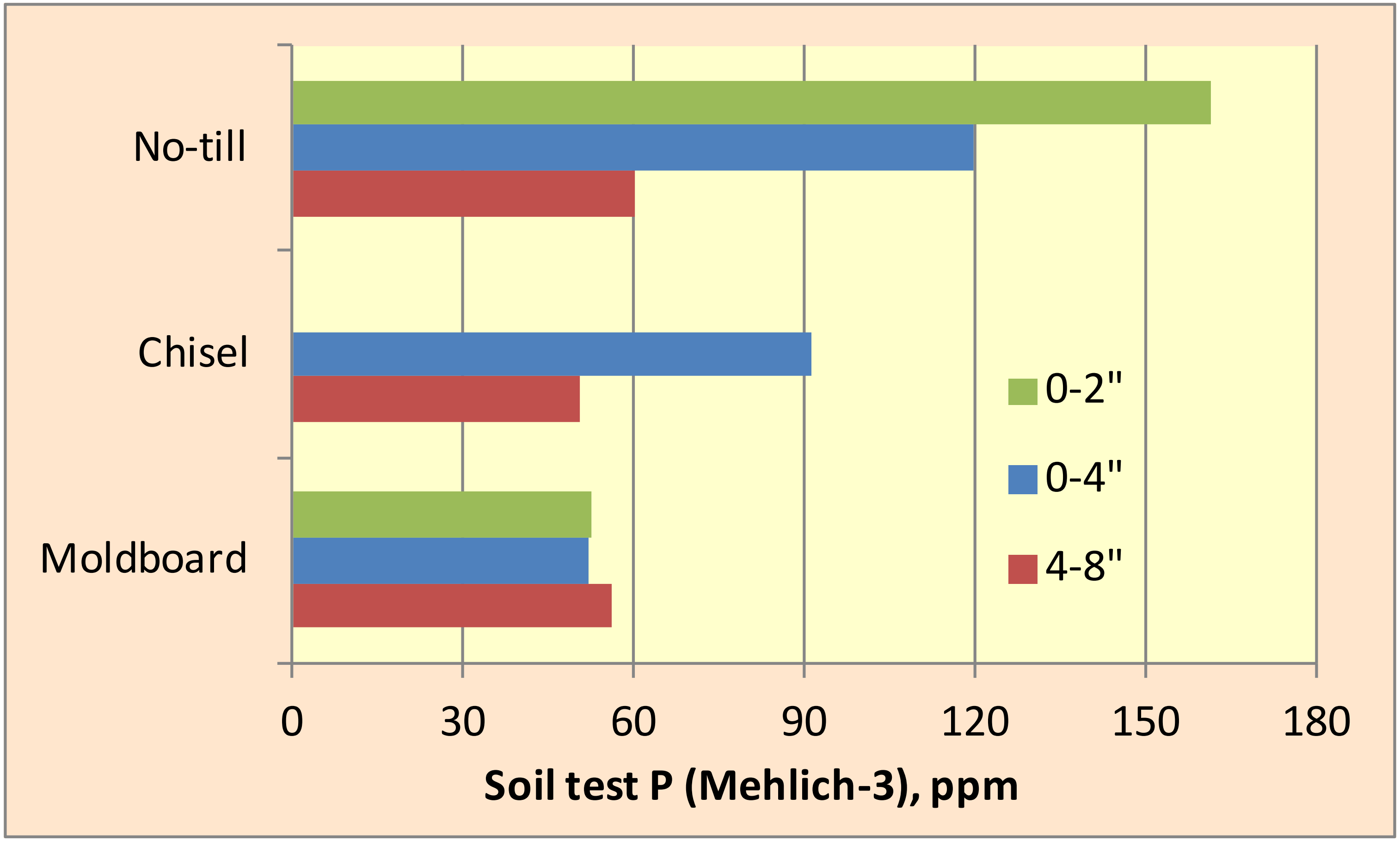
Soil test P distribution, 2001-2010



Soil test K distribution, 2001-2010



Soil test P stratifies when moldboard plowing stops



Soil test P distribution with depth in a long-term tillage experiment on a poorly drained Chalmers silty clay loam soil near West Lafayette, Indiana. Moldboard and chisel plots were plowed annually to a depth of 8”. Data from Gál (2005) and Vyn (2000). Fertilizer P applied broadcast.

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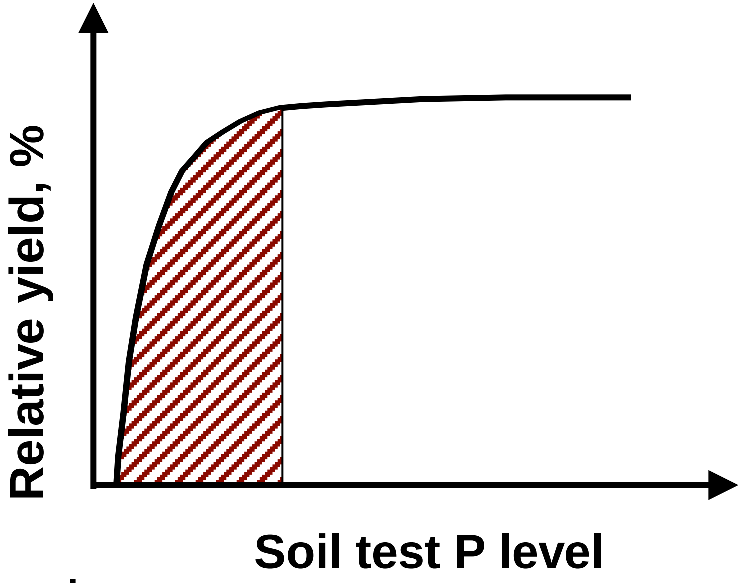
Soil Test Interpretation Approaches

- **Sufficiency**
  - Add necessary rates of deficient nutrients so yields are not limited in present crop
- **Build-Maintenance**
  - Add enough of needed nutrient/s to supply present crop need, and gradually increase soil supply to non-limiting level
  - Replace crop harvest removed nutrients to keep plant nutrient levels at non-limiting levels

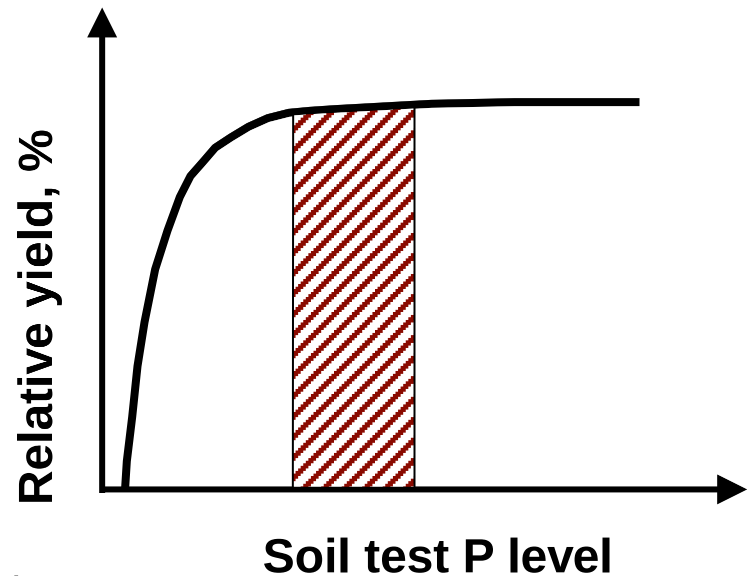
Approaches to P Fertilization

- **<u>Sufficiency approach</u>**: Apply P to maximize net returns to fertilization in the year of application
  - Strategy: fertilize only when there is a good chance that a profitable yield response will be realized
  - Soil test levels kept in lower, responsive ranges
  - Normally adopted on land leased for short periods of time or when cash flow is limited

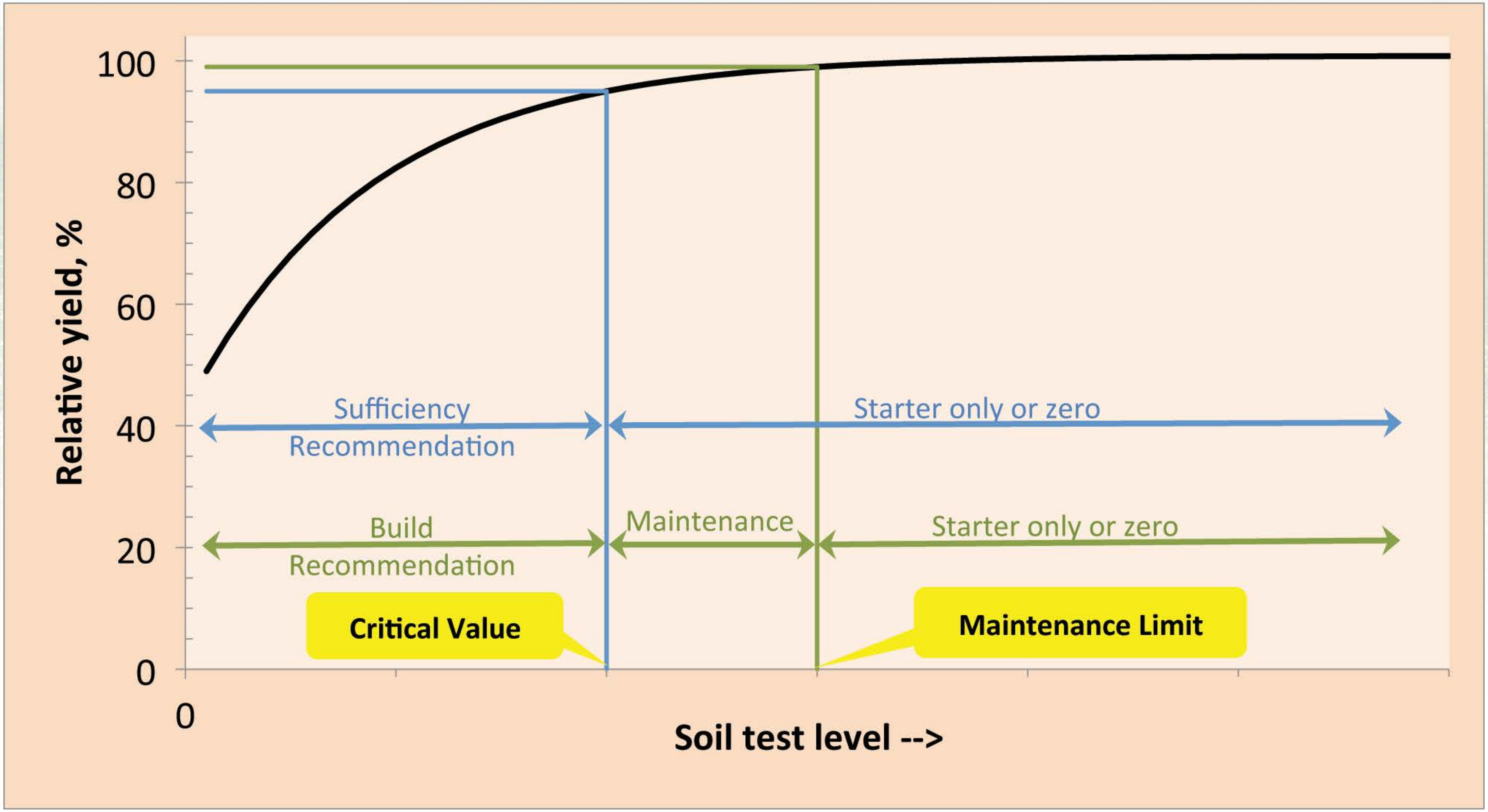


Approaches to Fertilization

- **<u>Build and maintenance approach</u>:**
  Remove P as a yield-limiting variable
  - Strategy: apply extra P (more than crop removal) to build soil tests to levels that are not yield-limiting
  - Soil test levels kept in higher, non-responsive ranges
  - Normally adopted on owned land or land leased for longer periods of time



Soil Test Levels and Management Approaches



(Adapted from Leikam et al., 2003)

Soil Test Extractants

- Procedure must be rapid, accurate and reliable
- May consist of:
  - water, alkali, weak or strong acids, chelates
- Ontario
  - P - sodium bicarbonate (Olsen)
  - K - ammonium acetate
- Others
  - P - Mehlich III, Bray P1, Kelowna, Morgan
  - K - Mehlich III, Kelowna

Soil Test Extractants for P

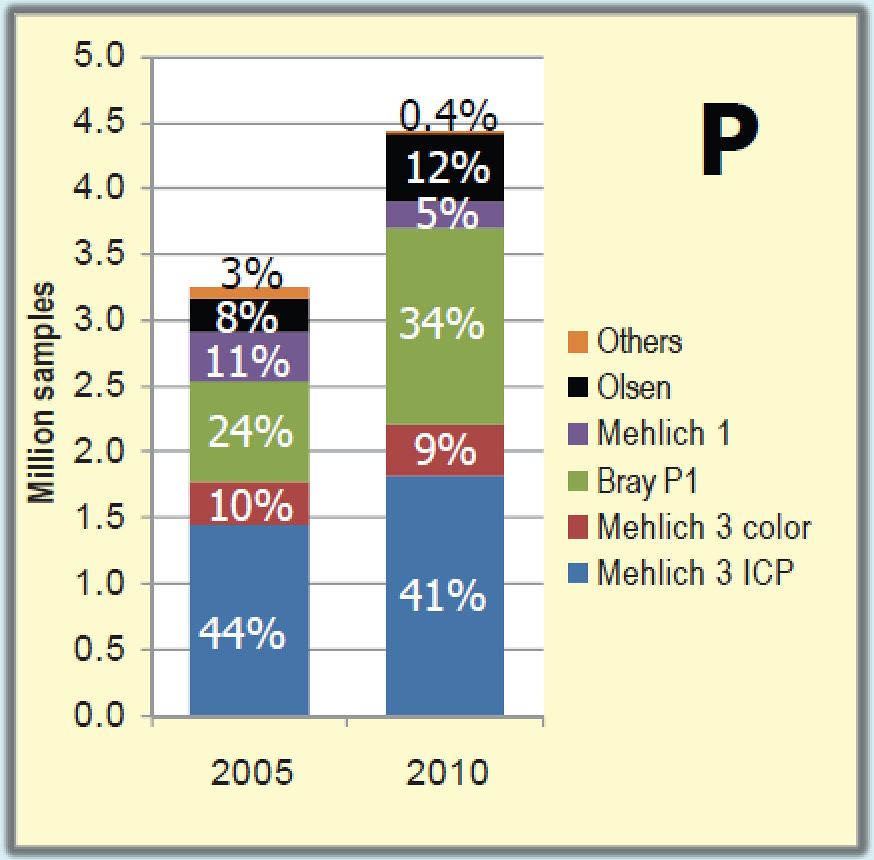
Test	Extractants	pH	Ratio, solution:soil	Extraction time, min
Olsen P	0.5M sodium bicarbonate	8.5	20	30
Bray P1	0.03M ammonium fluoride + 0.025M hydrochloric acid	2.5	7	1
Mehlich-3 P	0.2M acetic acid, 0.25M ammonium nitrate, 0.015M ammonium fluoride, 0.13M nitric acid, 0.001M EDTA	2.5	10	5
Colwell P	0.5M sodium bicarbonate	8.5	100	960
Morgan	0.54 M acetic acid + 0.72 M sodium acetate	4.8	5	15
Exchange resins	Mixture of anionic and cationic resins			

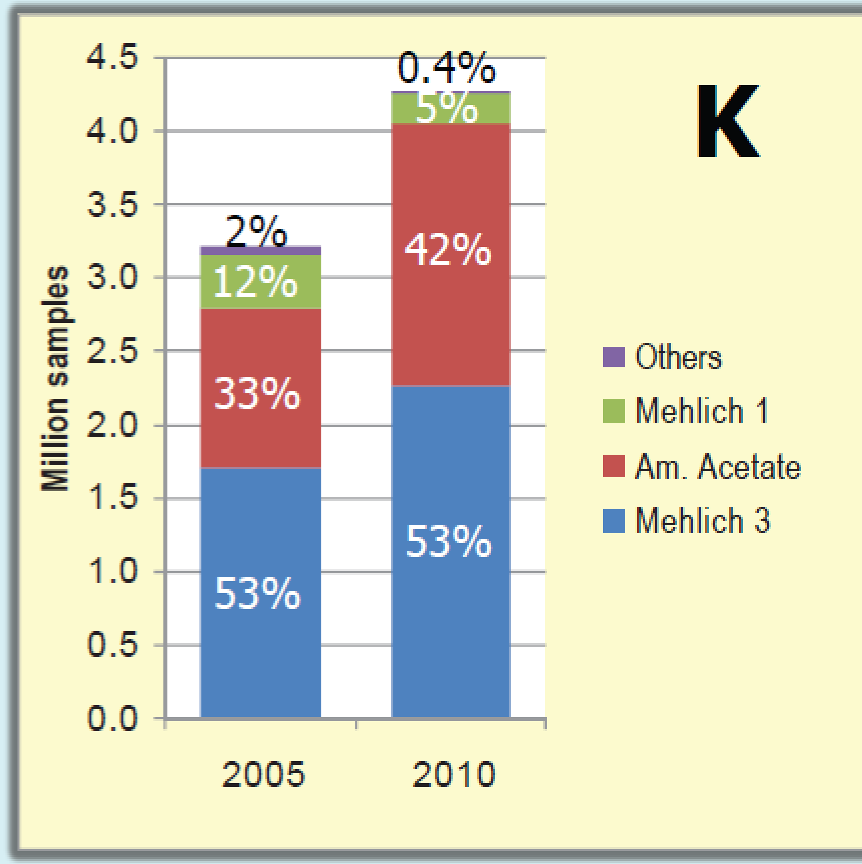
Different P soil tests give widely different #s

Phosphorus							
Ammonum Bicarbonate-DTPA	0-1	2-3	4-5	6-7	8-9	10-11	12-15
Bray and Kurtz P1	0-5	6-10	11-15	16-20	21-25	26-30	31-40
Bray and Kurtz P2	0-9	10-18	19-27	28-35	36-40	41-45	46-55
Kelowna, Modified	0-5	6-10	11-15	16-20	21-25	26-30	31-40
Lancaster P	0-5	6-10	11-15	16-20	21-25	26-30	31-40
Mehlich 1 P	0-3	4-6	7-9	10-12	13-15	16-18	19-24
Mehlich 2 P	0-5	6-10	11-15	16-20	21-25	26-30	31-40
Mehlich 3 P (colorimetric)	0-5	6-10	11-15	16-20	21-25	26-30	31-40
Mehlich 3 P (ICP)	0-9	10-18	19-27	28-35	36-40	41-45	46-55
Morgan, Cornell		0-0.9	1.0-2.3	2.4-3.6	3.7-4.4	4.5-5.3	5.4-6.9
Morgan, Modified	0-2.5	2.6-3.4	3.5-4.9	5.0-6.3	6.4-7.1	7.2-8.0	8.1-9.7
Olsen P (sodium bicarbonate)	0-3	4-7	8-11	12-15	16-19	20-23	24-30

Note: *These equivalencies are not recommended for the purpose of determining appropriate rates to apply.*

Soil analysis methods across North America





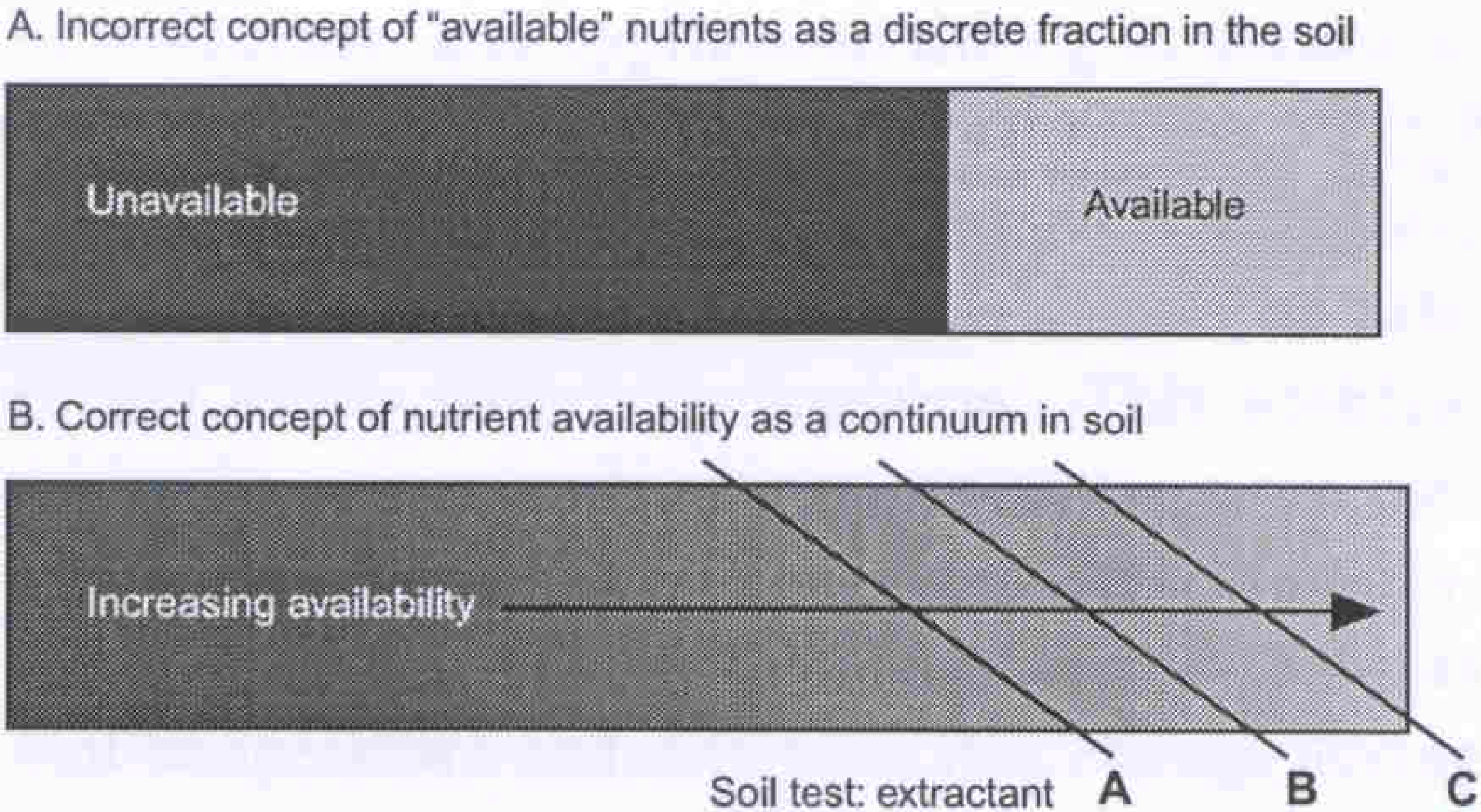


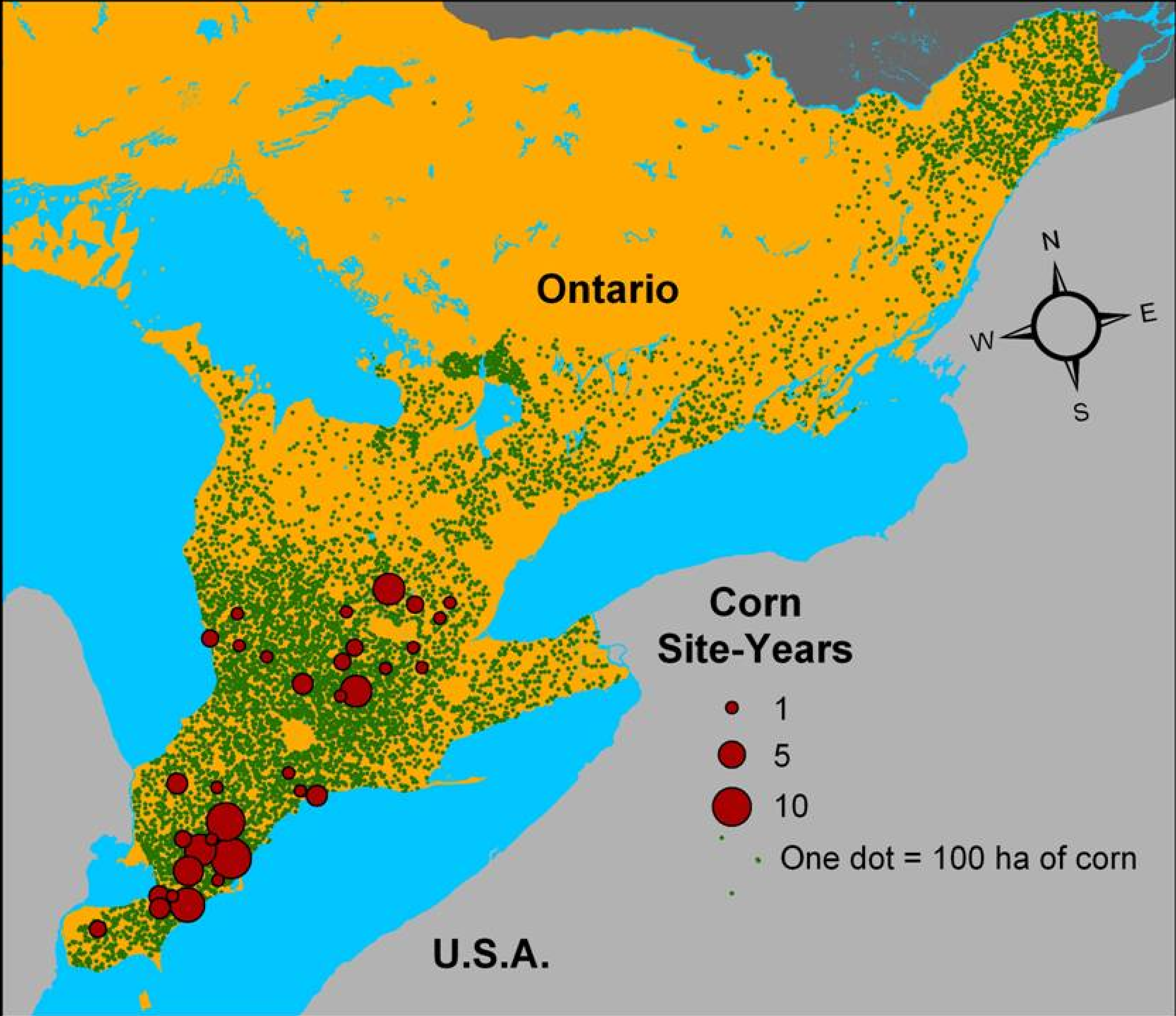
Figure 1. Concepts and relationships between available nutrients and soil test extractions.

P and Aluminum

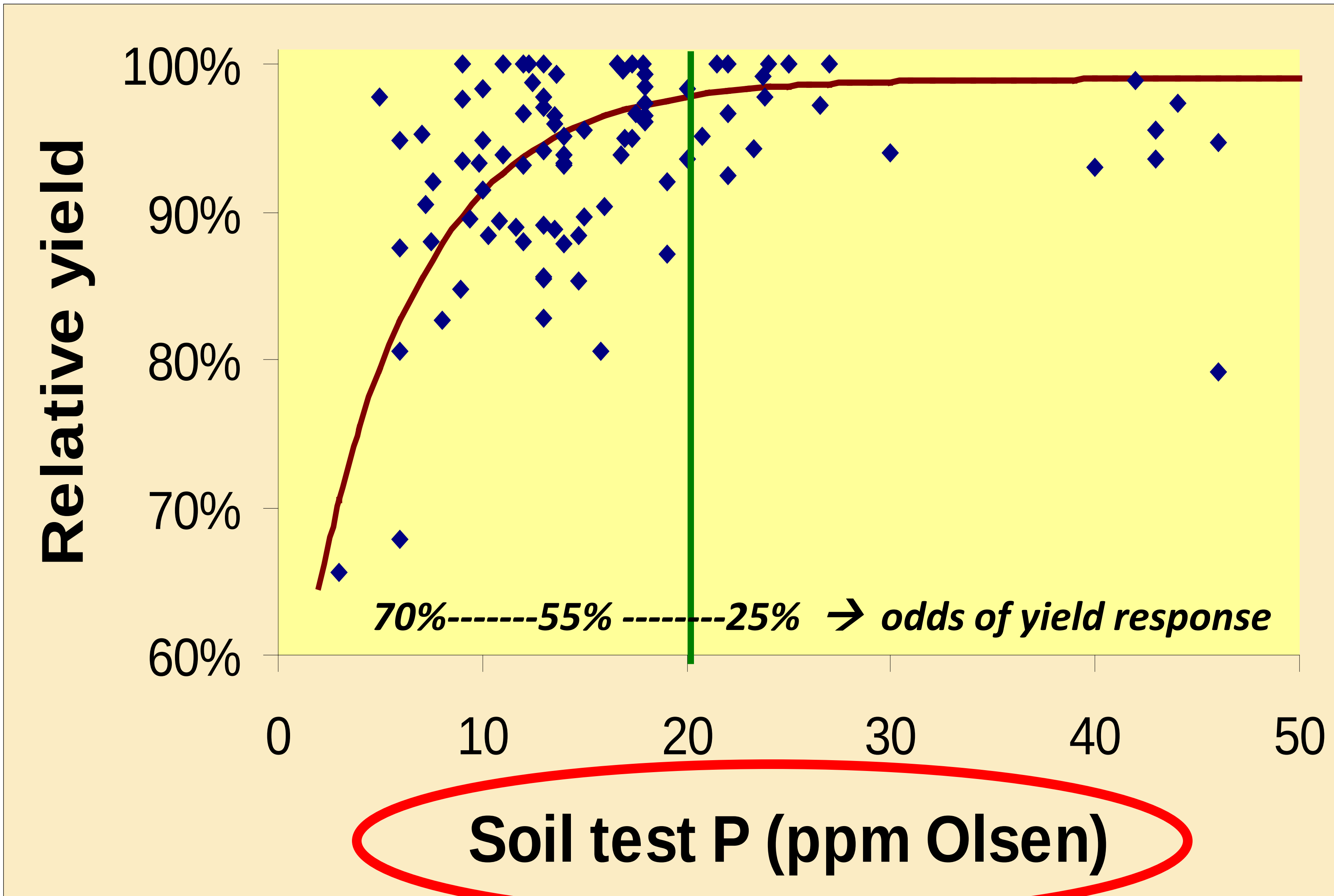
- Ratio of P and Al sometimes used as an index of degree of P sorption saturation (DPSS)
- Oxalate extractable: $P_{ox}/(Fe_{ox}+Al_{ox})$
- Mehlich-III: P/Al
- Used for
  - corn & potatoes in Quebec
  - limits on manure application in the Netherlands

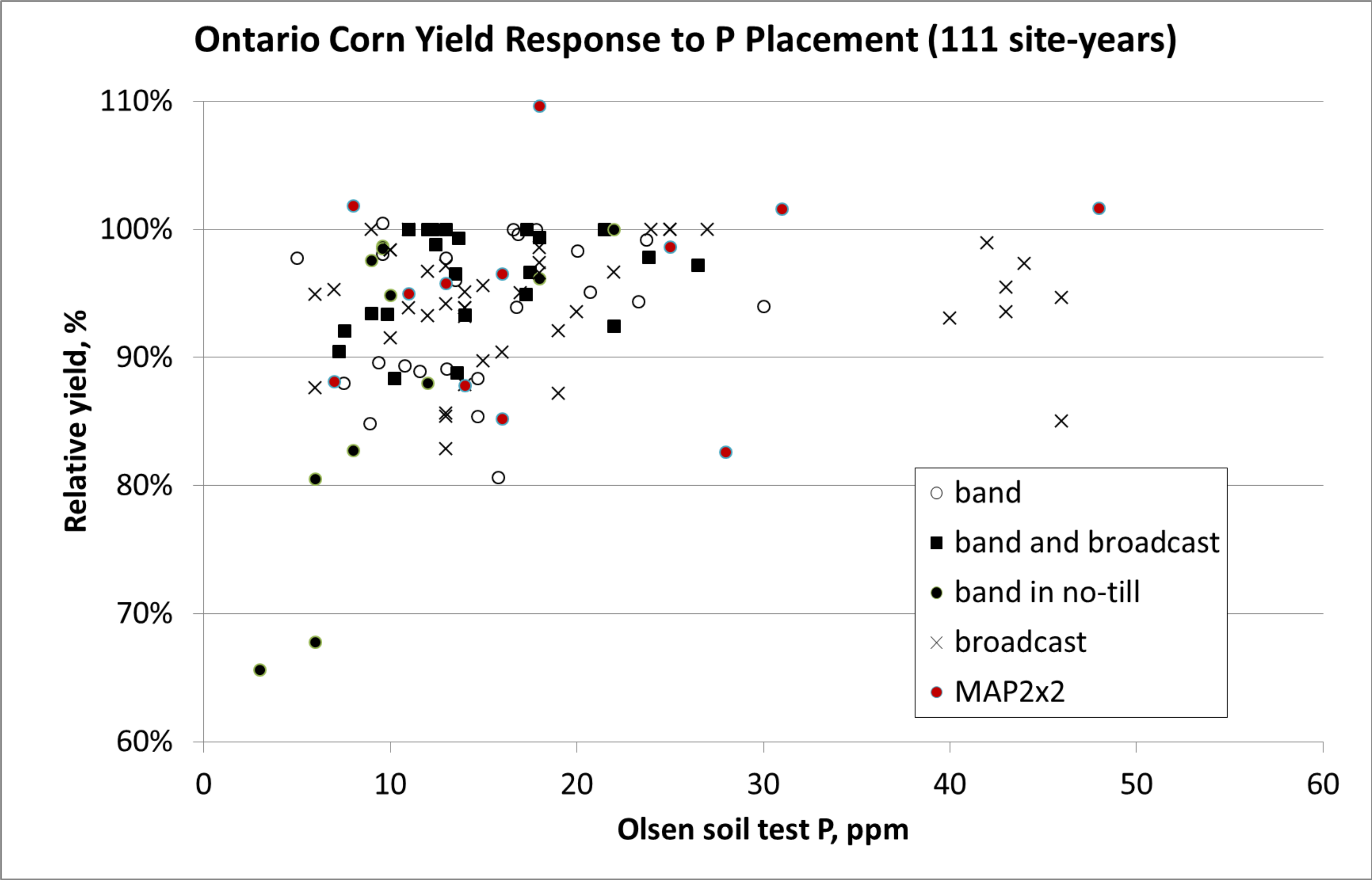
Soil Test Calibration

- Determines the relationship between soil test level and the rate to apply
- Depends on the nature of crop response to the nutrient, as a function of soil test level
- Crop responses are smaller and less frequent at higher soil test levels

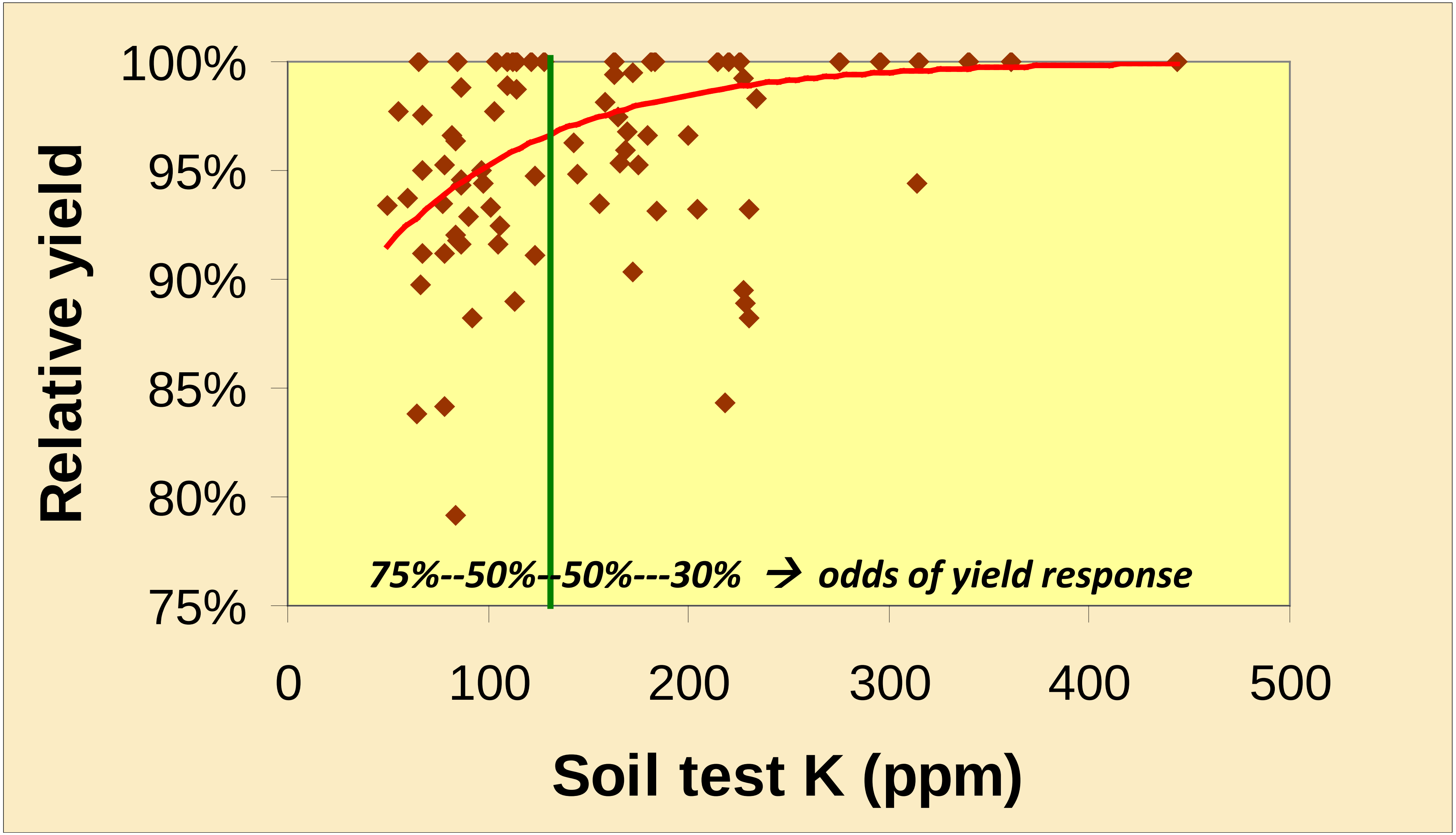

Ontario
N
E
W
S
Corn
Site-Years
1
5
10
One dot = 100 ha of corn
U.S.A.

Ontario Soil Test P Calibration

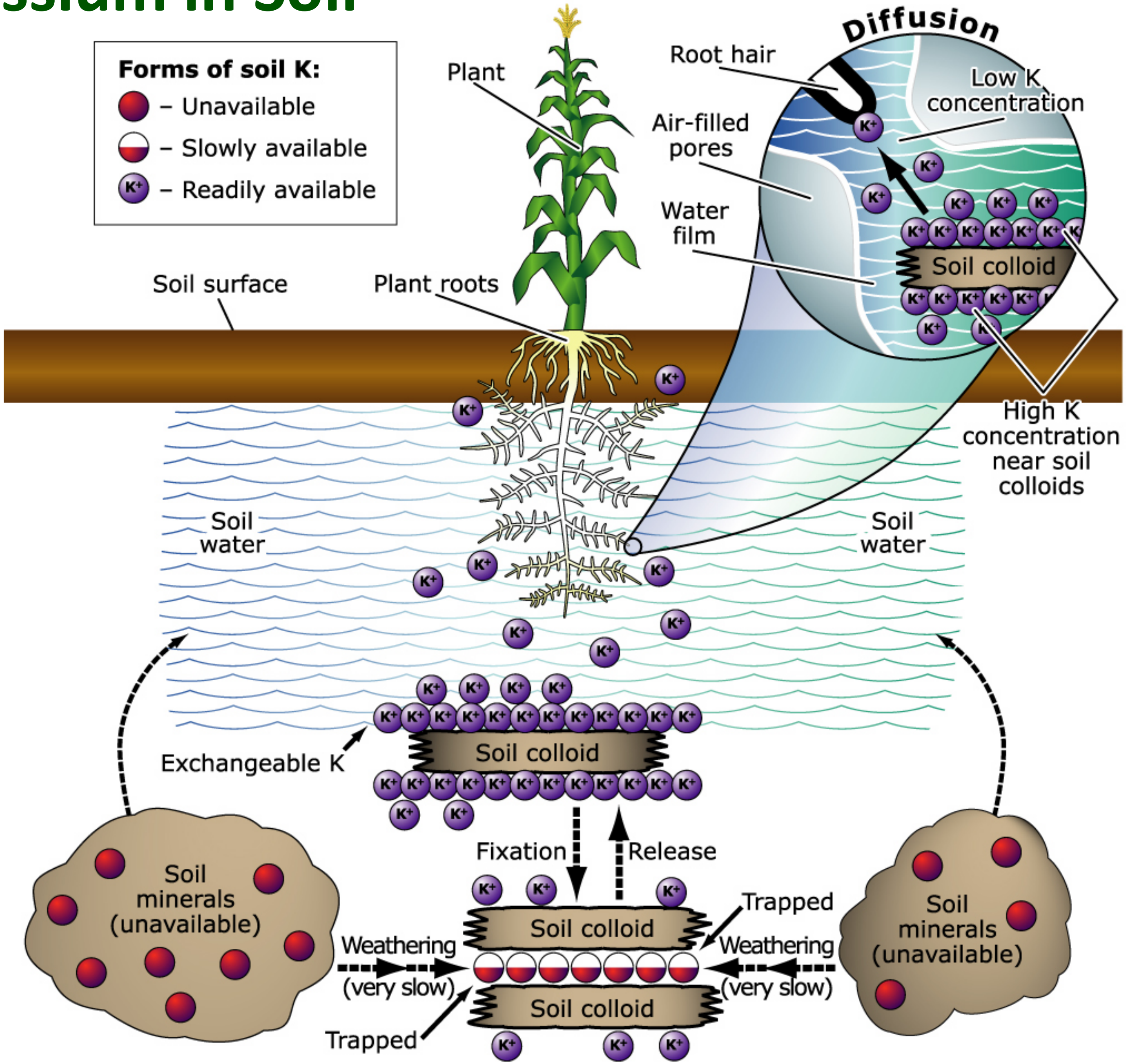



Ontario Corn Yield Response to P Placement (111 site-years)
Relative yield, %
110%
100%
90%
80%
70%
60%
0
10
20
30
40
50
60
Olsen soil test P, ppm
band
band and broadcast
band in no-till
broadcast
MAP2x2
IPNI

Ontario Soil Test K Calibration



Potassium in Soil



Base cation extractants

- K, Ca, Mg, Na
- ammonium acetate or Mehlich III displace cations with NH_4^+
- complicated by the presence of free lime in calcareous soils
  - $CaCO_3$ dissolves to release large amounts of Ca^{++}
- used to calculate CEC, base saturation

Calculating CEC
(Soil Fertility Handbook, page 35)

- bCEC = Ca/200 + K/390 + Mg/120

  (CEC in meq/100g; Ca, K, Mg in mg/kg)

- CEC = bCEC + [1.2*(70-BpH*10)]

or…

- 0.5 * % clay + 2 * SOM

Basic cation saturation ratios

- 65% Ca, 10% Mg, 5% K and 20% H - ideal?
- Many studies indicate that when each are sufficient, ratio does not matter
  - Ca:Mg from 267:1 to 1:1 for alfalfa & trefoil in NY
- Useful when one or more of K, Mg, or Ca approaches deficiency
- CEC effect on K recommended:
  - increase in MI-OH-IN
  - decrease in NY

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Nitrate extractants

- concentrated KCl extractant
- neutral pH
- requires special sample handling - avoid mineralizing N after sampling
- sampling depth unique (12” rather than 6”)
- importance of timing

Sulfur soil test

- Not well correlated to crop response, except in sandy soils
- Can measure both the inorganic sulfate-S and the labile organic S in a calcium phosphate extract
- Account for atmospheric deposition, manure applied, soil texture and soil OM

Sulfur				
Calcium phosphate S	0-3	4-6	7-9	>9
Mehlich 3 S	0-6	7-12	13-18	>18

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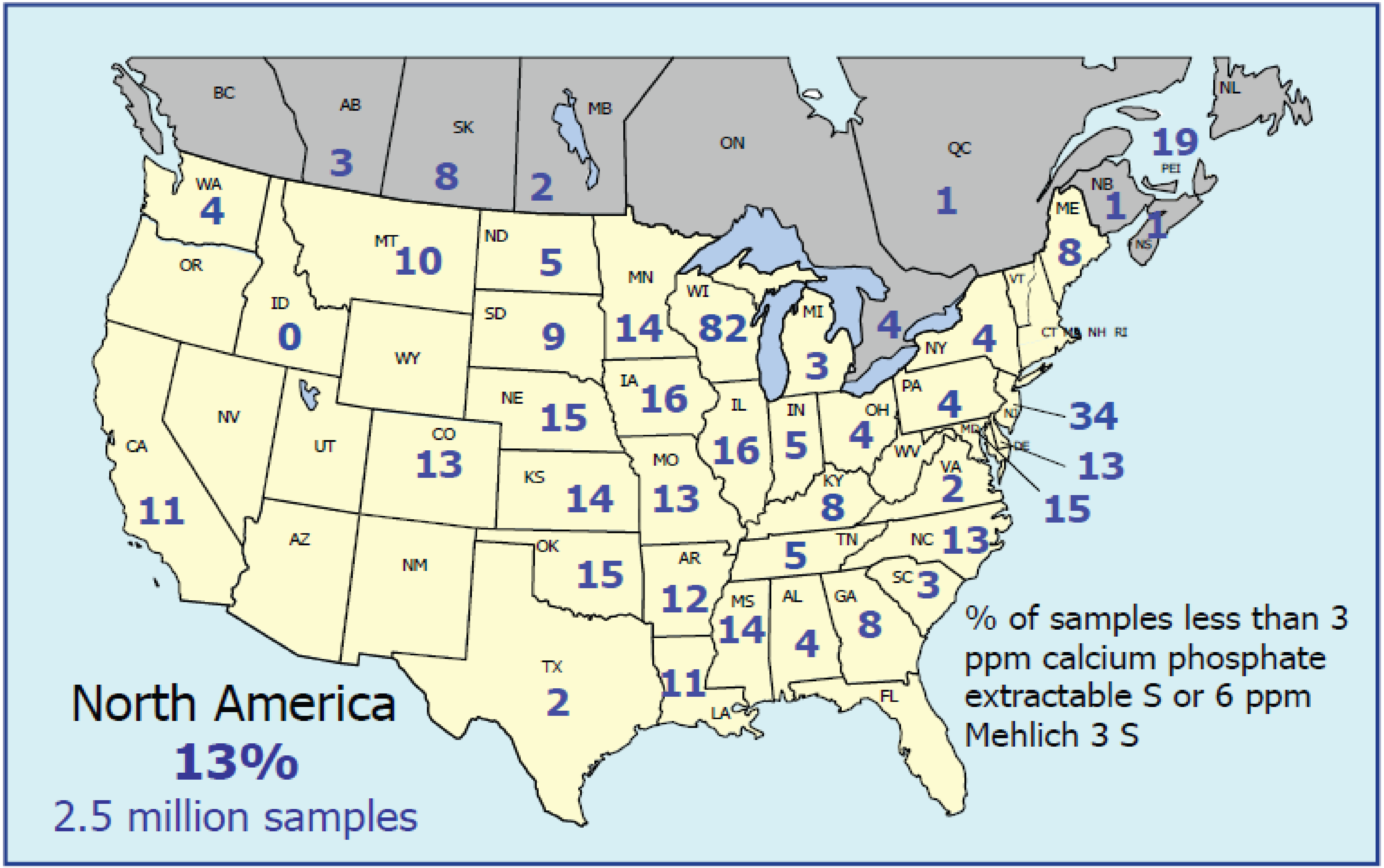


Figure 16. Percent of soils testing less than 3 ppm S in 2010 (for states and provinces with at least 2,000 S tests).

Zinc soil test

- 0.005 M DTPA extraction, 2:1 solution:soil, 1 hour
  - chelator
  - Zn availability
  - Index = 203 + 4.5(DTPA-Zn) - 50.7(pH) + 3.33$(pH)^2$
- Mehlich-III uses EDTA as chelator

	Zn index	DTPA-Zn, ppm	M-3 EDTA-Zn, ppm
Deficient	<15	<0.5	0.6 – 2.6[1]
Borderline	15 to 25	0.6 to 1.0	
Adequate	25 to 200	>1.0	1 to 80[2]

[1]University of Kentucky, depending on soil pH and soil test P
[2]Penn State University, normal range

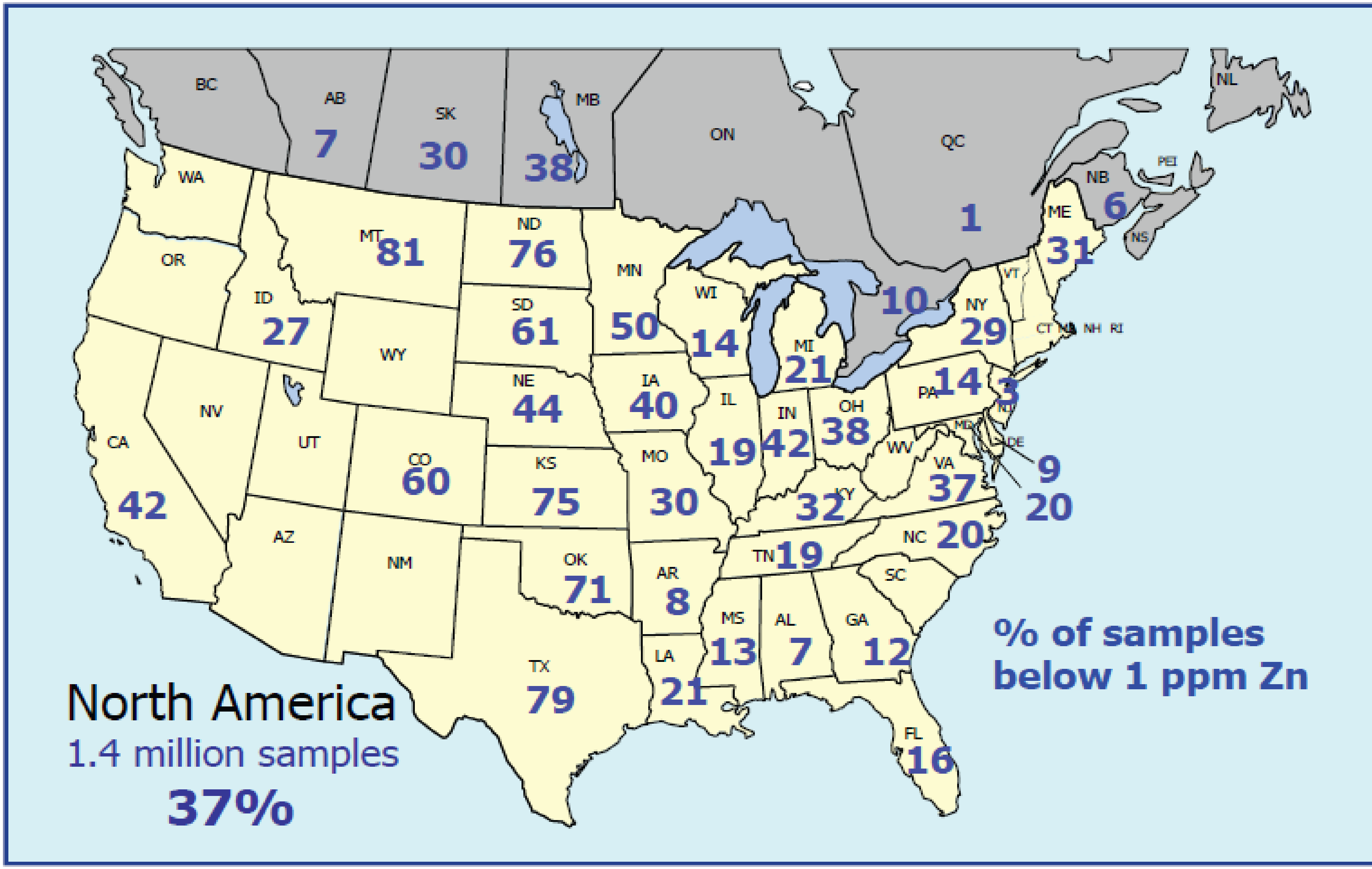


Figure 17. Soil samples testing less than 1.0 ppm DTPA equivalent Zn in 2010 (for states and provinces with at least 2,000 Zn tests).

Manganese extractants

- Phosphoric acid extraction
- other areas use DTPA or EDTA
  - Mn index = 498 + 0.248 (PA-Mn) - 137 (pH) + 9.64 $(pH)^2$

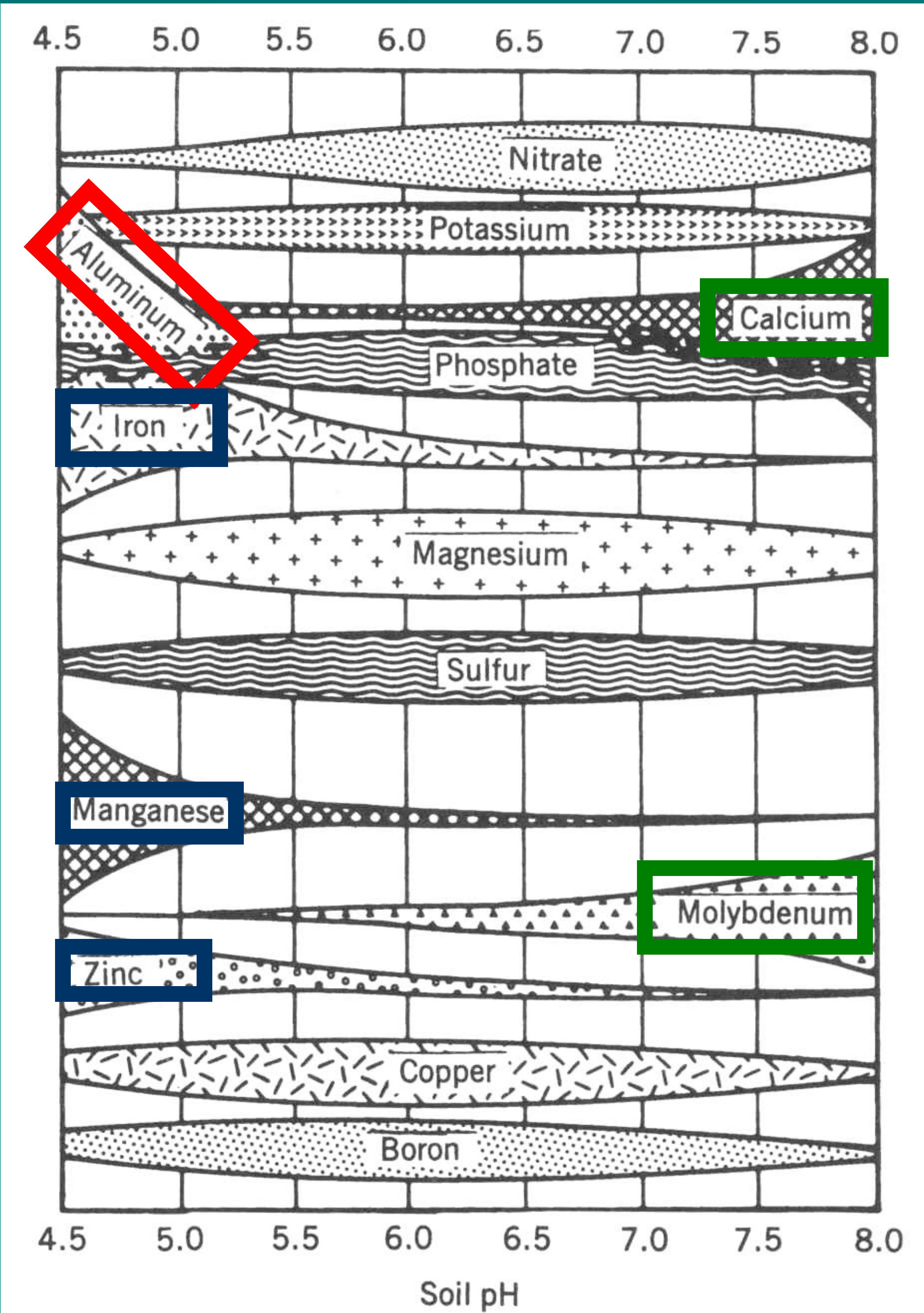
	Mn index	DTPA-Mn, ppm
Deficient	<15	<1.0
Borderline	15 to 30	
Adequate	>30	>1.0

Reserve vs. Active Acidity

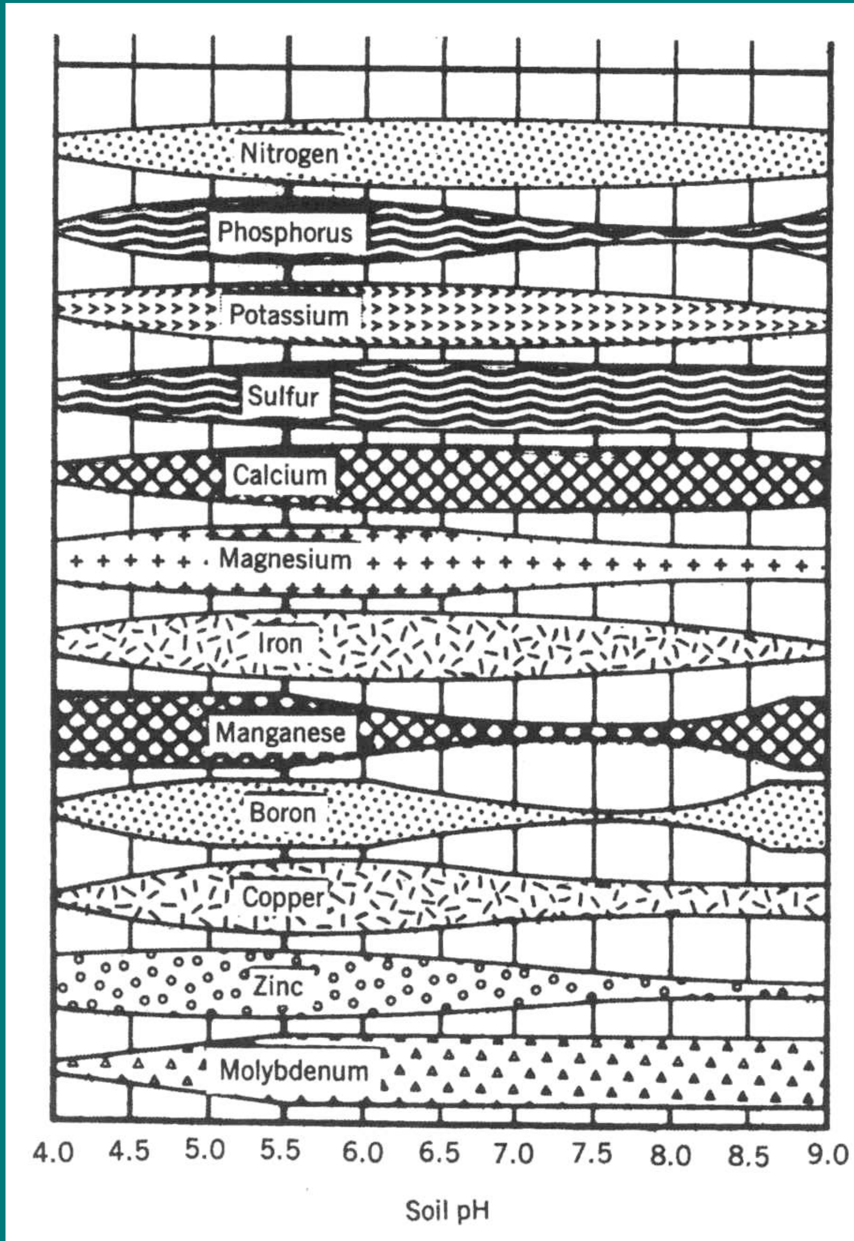
$$\underset{\textit{reserve}}{HA} \rightleftharpoons \underset{\textit{active}}{A^- + H^+}$$

- pH: whether to lime
- buffer pH: amount of lime

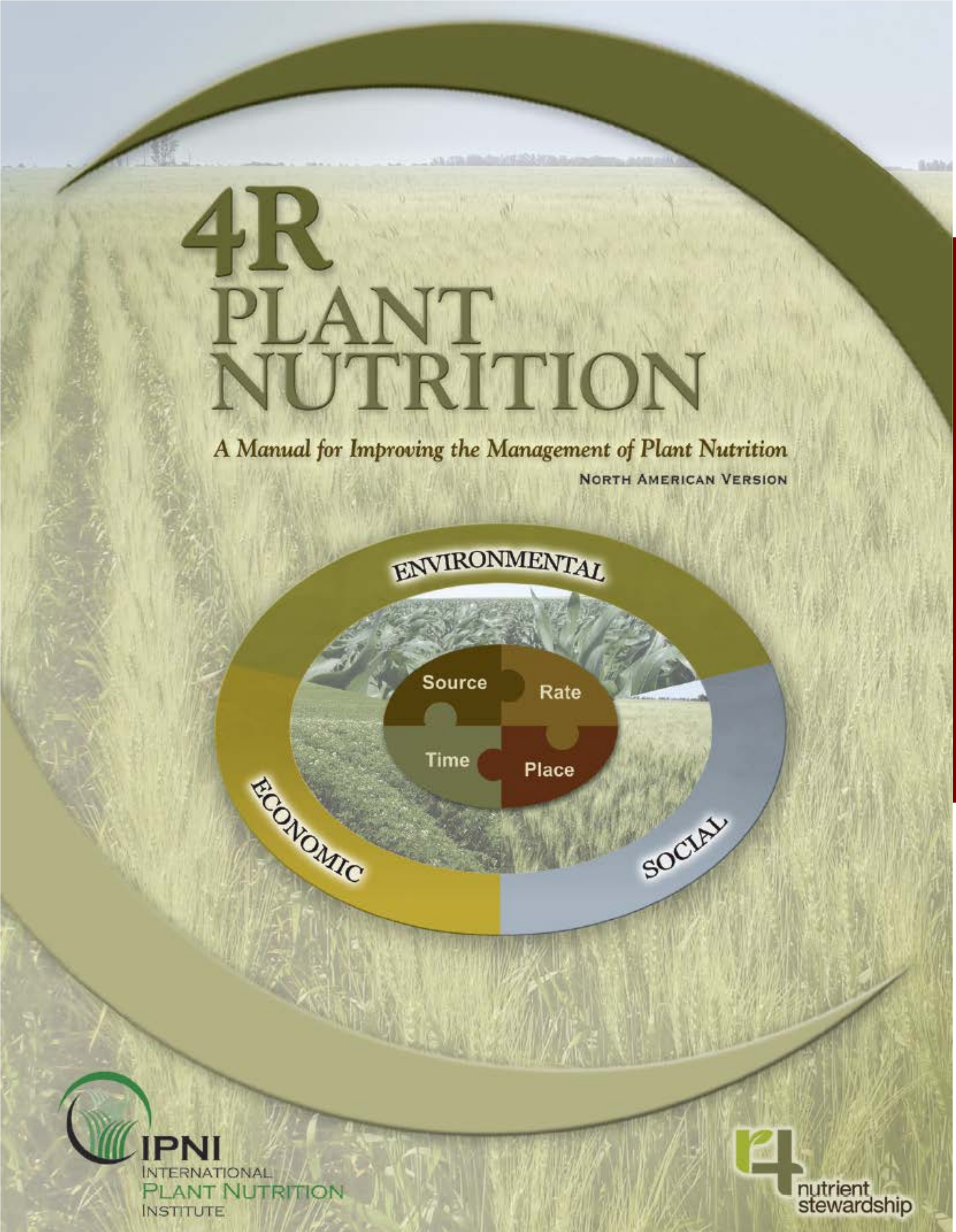
Mineral soils



Organic soils



Foth & Ellis, 1997, p. 83



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