Opportunities with phosphorus and threats with cadmium in fertilizers

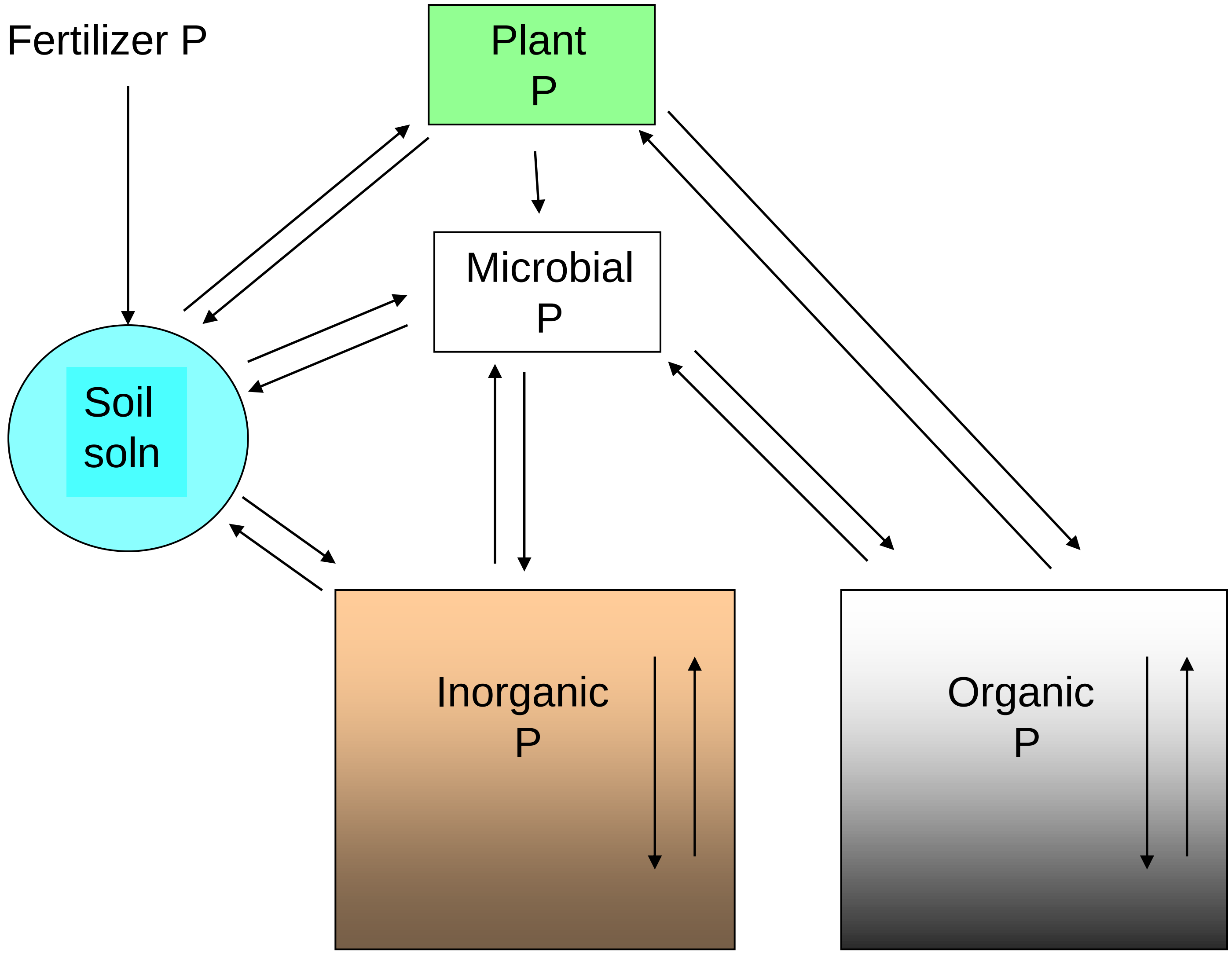
Mike McLaughlin

Overview

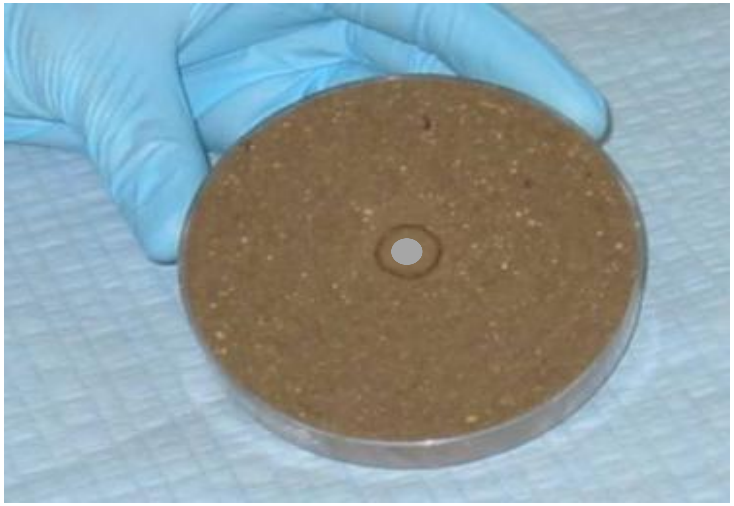
- Reactions of added fertilizer P in soils
- The (partial) myth of P fixation
- Opportunities for P efficiency gains
- The need for science to develop/validate new P efficiency technologies in agriculture
- Reactions of added fertilizer Cd in soils
- Management of fertilizer Cd in agroecosystems
- Are risks due to fertilizer Cd receding?
- Summary

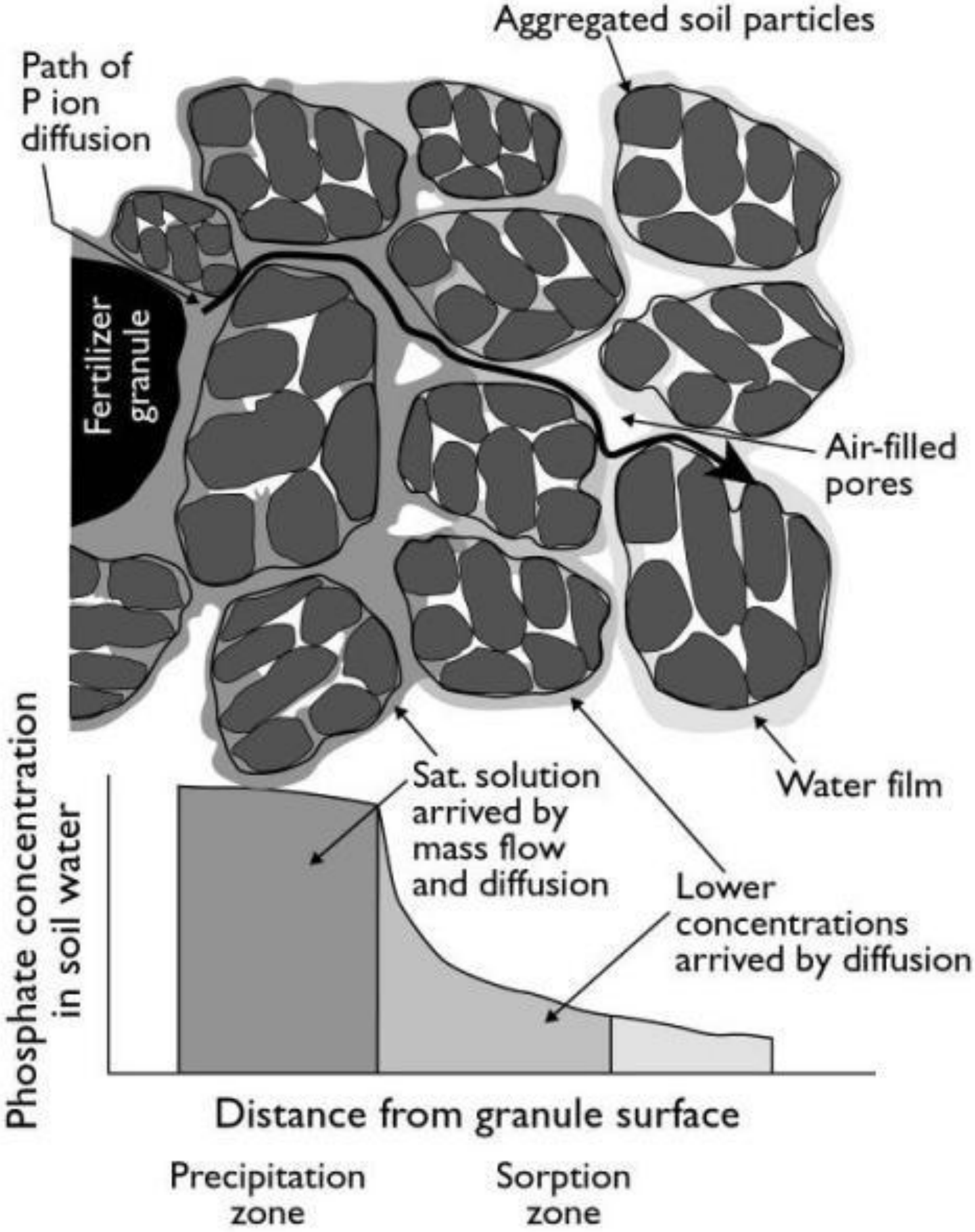
Reactions of added fertilizer P in soils

The fate of added fertilizer P in soil



Reactions of added fertilizer P

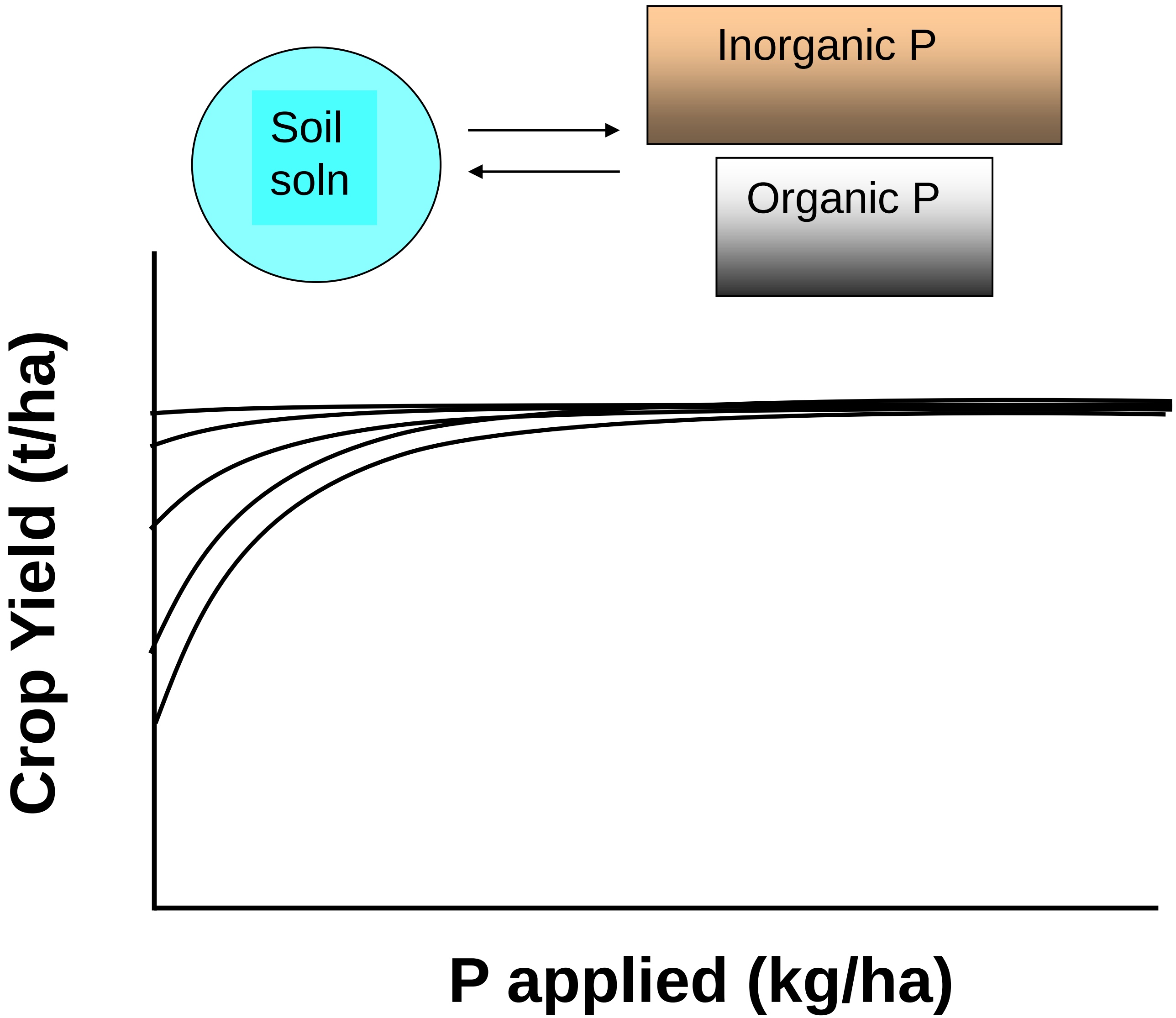




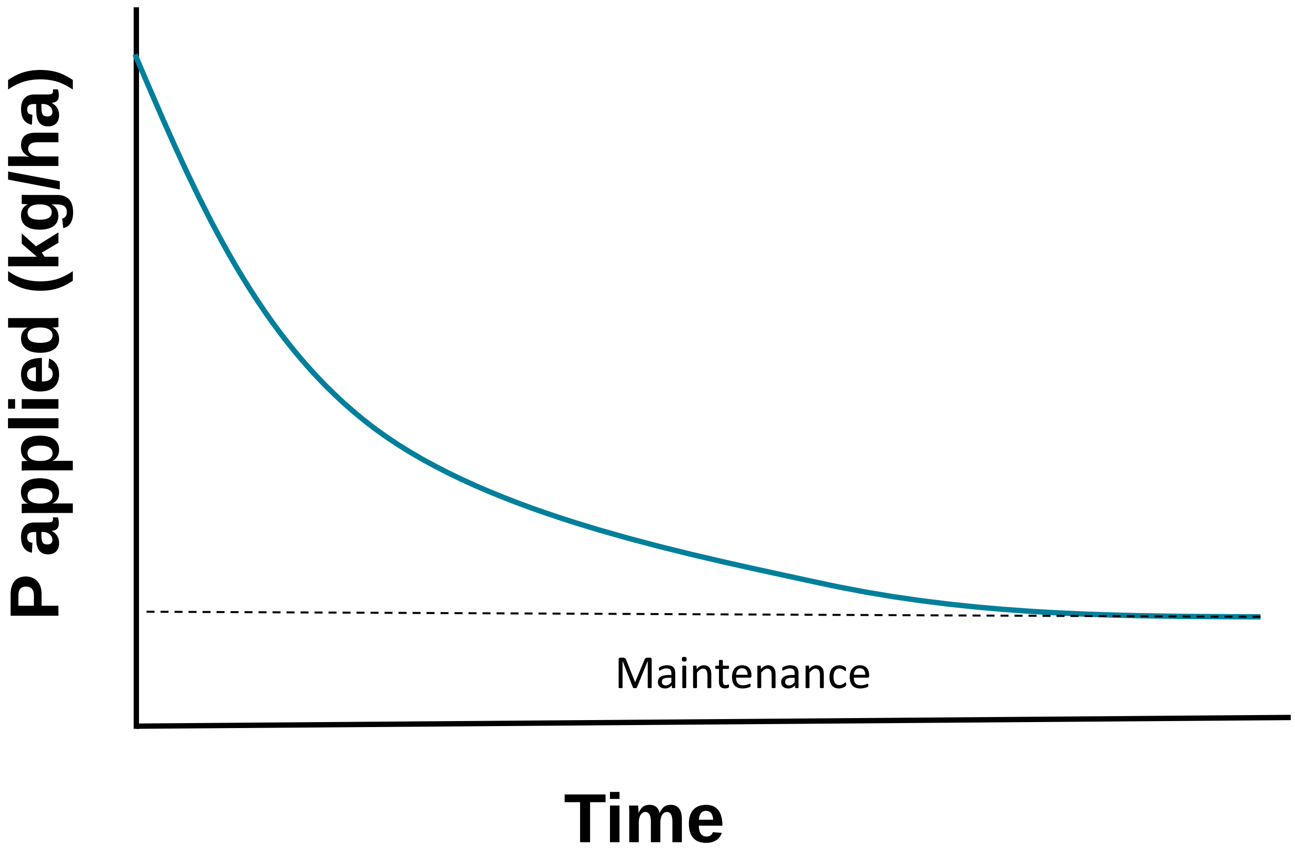
Hedley and McLaughlin (1992)

The (partial) myth of P fixation

Crop P responses to P over time



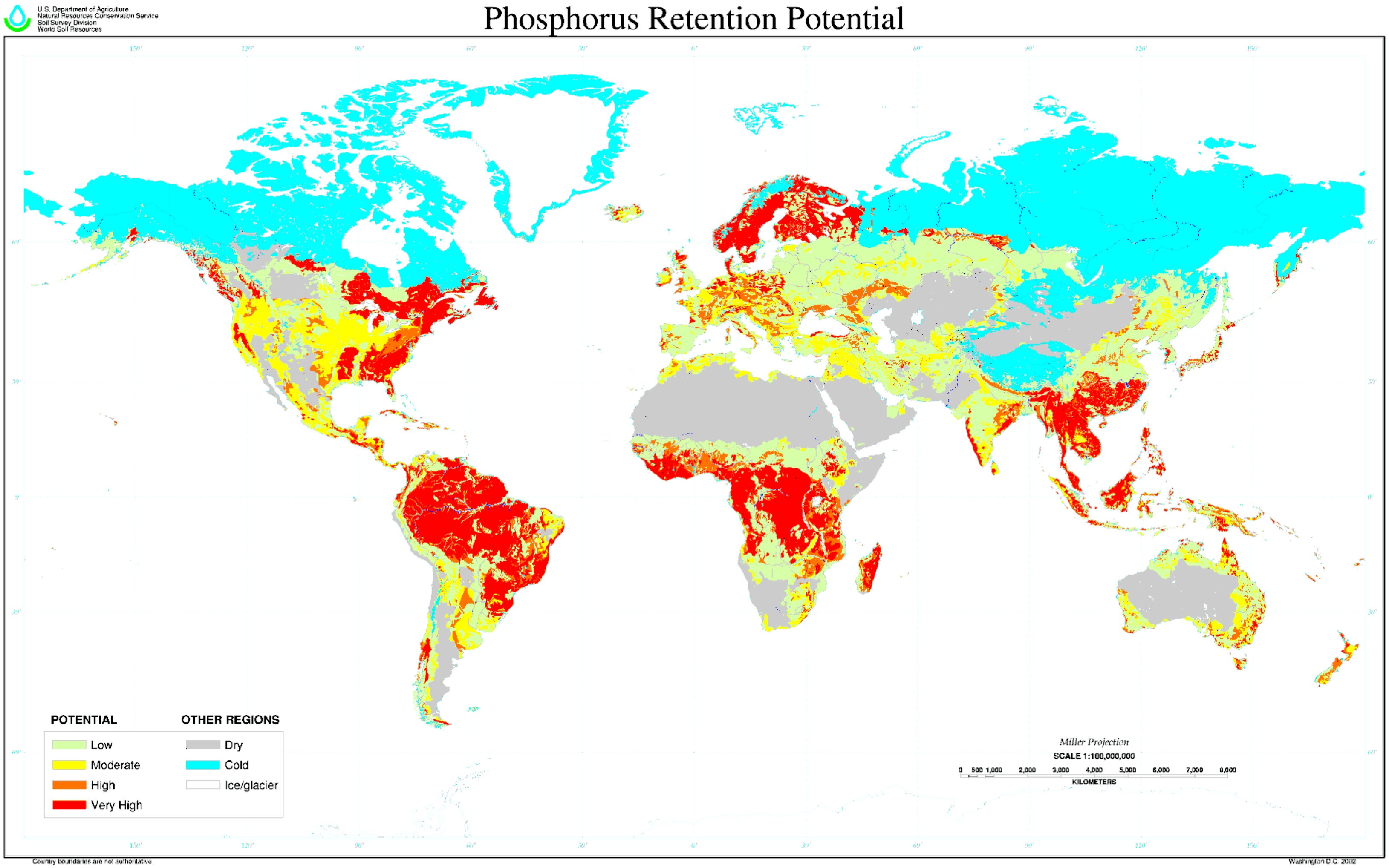
Fertilizer P requirements over time



Soils with strong P adsorption

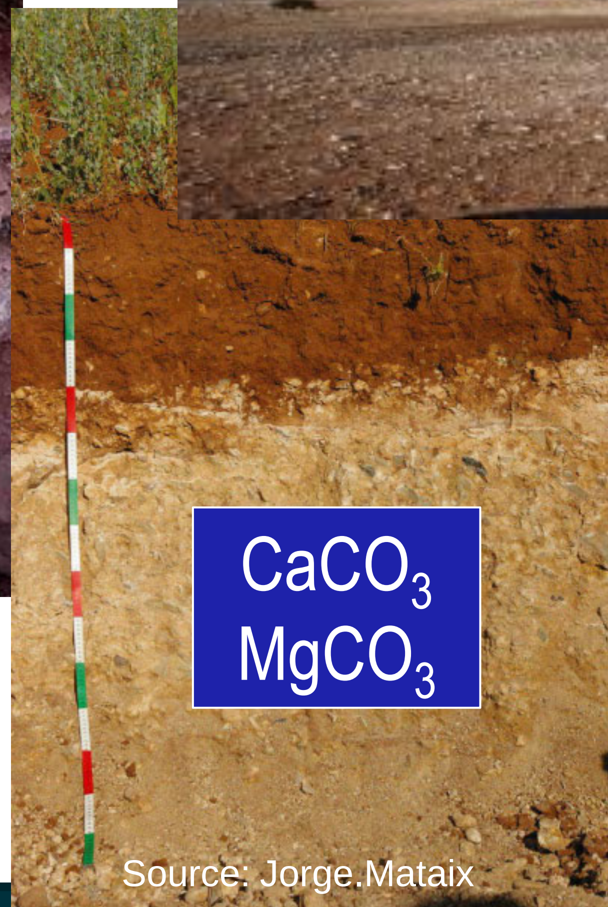
Source: De Sousa, 2011

Global coverage of highly sorbing soils



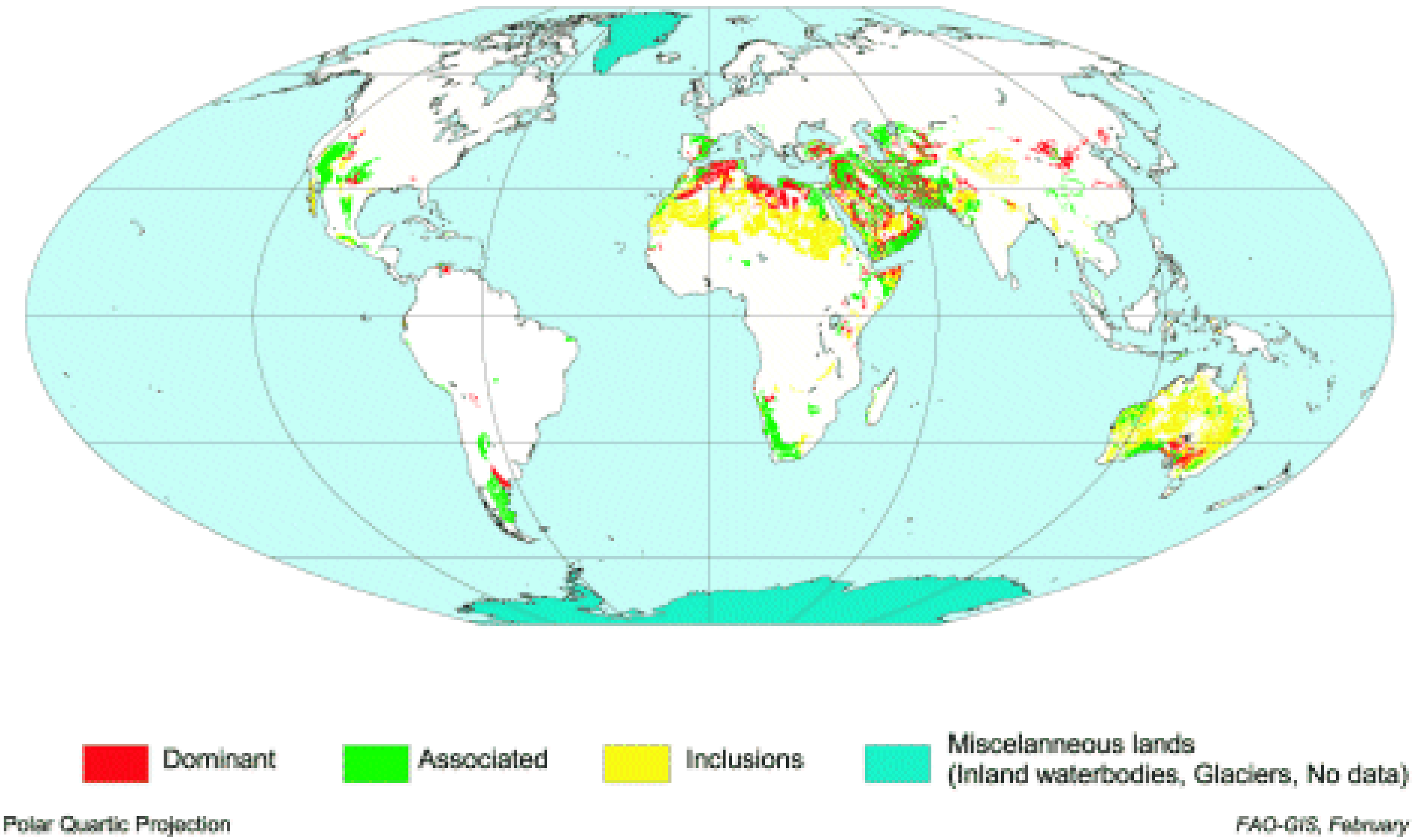
www.nrcs.usda.gov

Soils with strong P precipitation



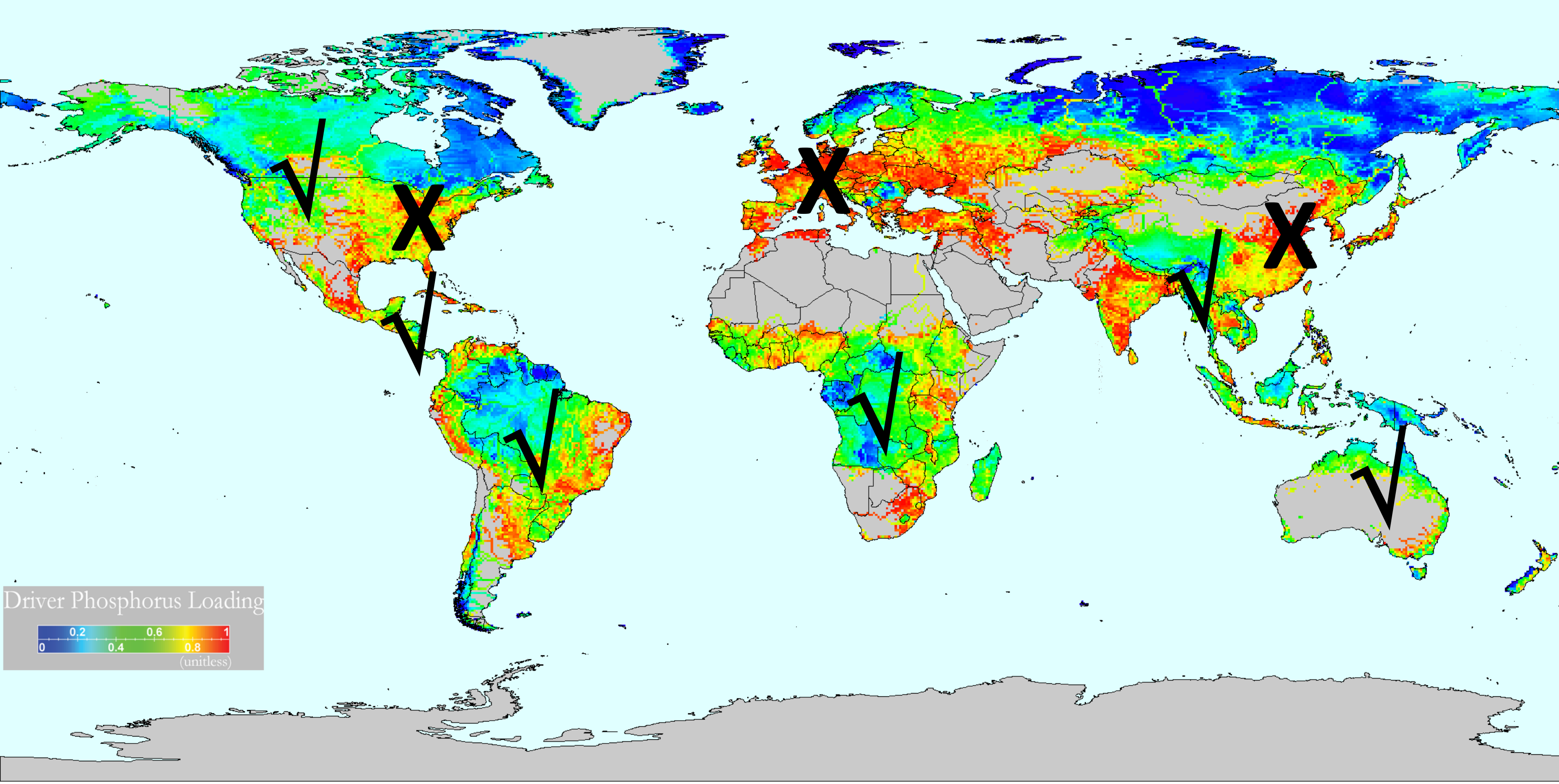
Calcisols
Calcarosols

Global coverage of calcareous soils



Source: FAO

Where is P "fixation" a real problem?



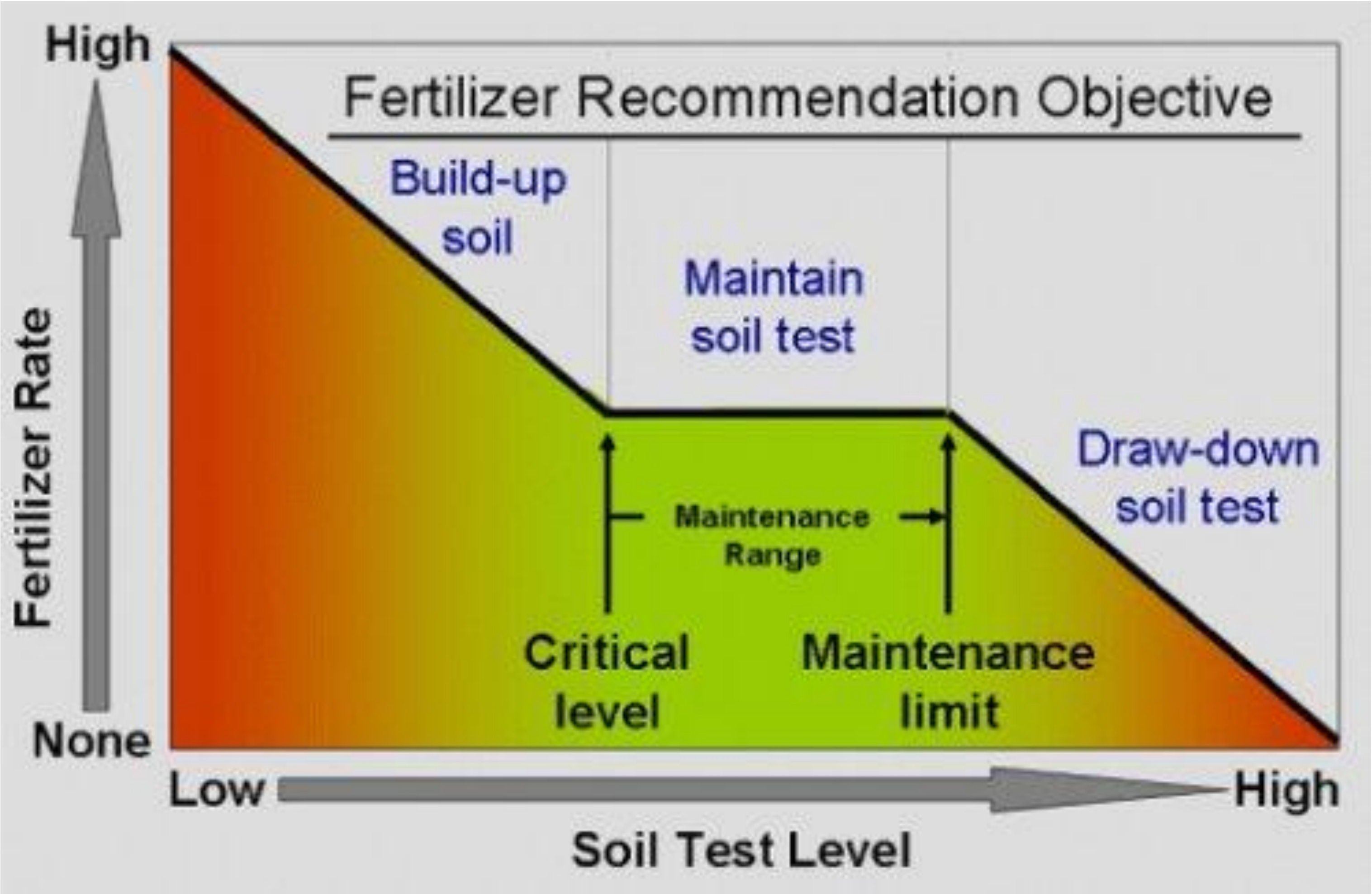
Source: Vorosmarty CJ, McIntyre PB*, et al. (2010) Nature* ***467(7315), 555-561.***

Opportunities to improve efficiency

Opportunities to improve P efficiency

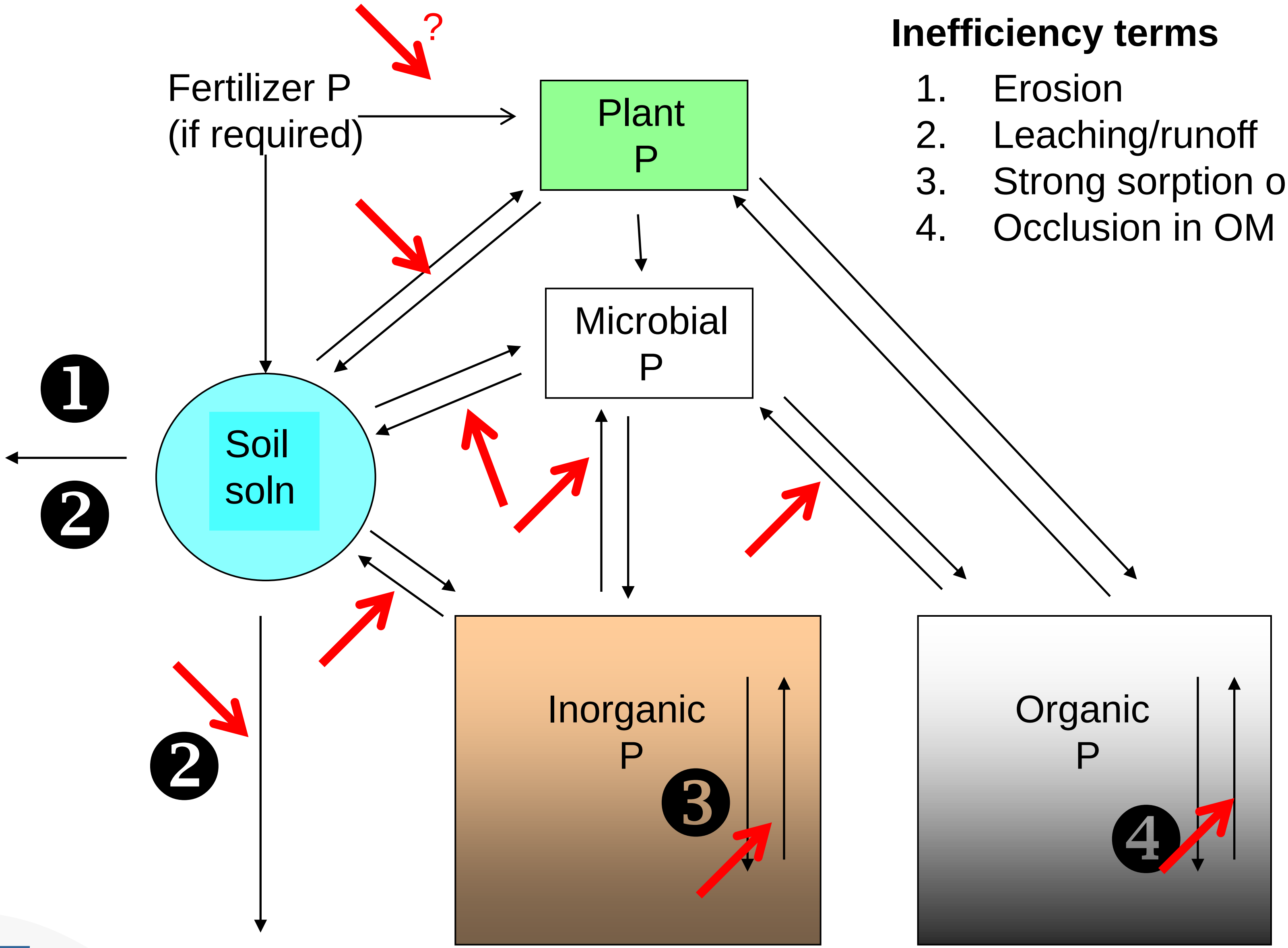
- The largest and biggest gains in P efficiency in agriculture are achieved by modifying the application rate
- If the crop/animal system does not need P to attain the desired production, add less (or no) P (until economic responses to P are predicted)

Fertilizer P recommendations



Source: http://msue.anr.msu.edu

The fate of added fertilizer P in soil



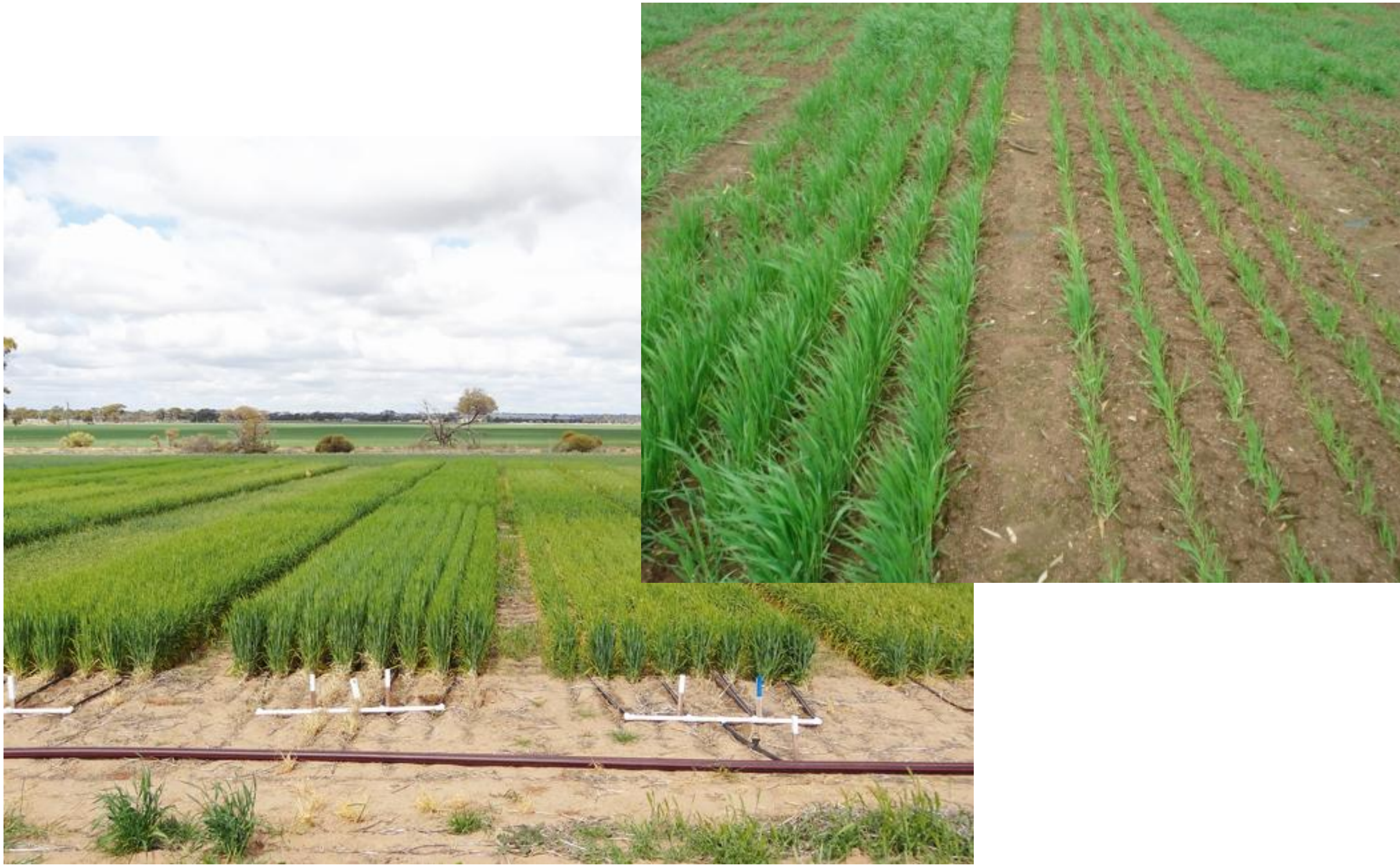
Inefficiency terms

1. Erosion
2. Leaching/runoff
3. Strong sorption or ppt
4. Occlusion in OM

Field evidence of efficiency of slow release P

Source: Water Corporation of Western Australia

Field evidence of cultivar P efficiency



Source: Glenn Macdonald and GRDC

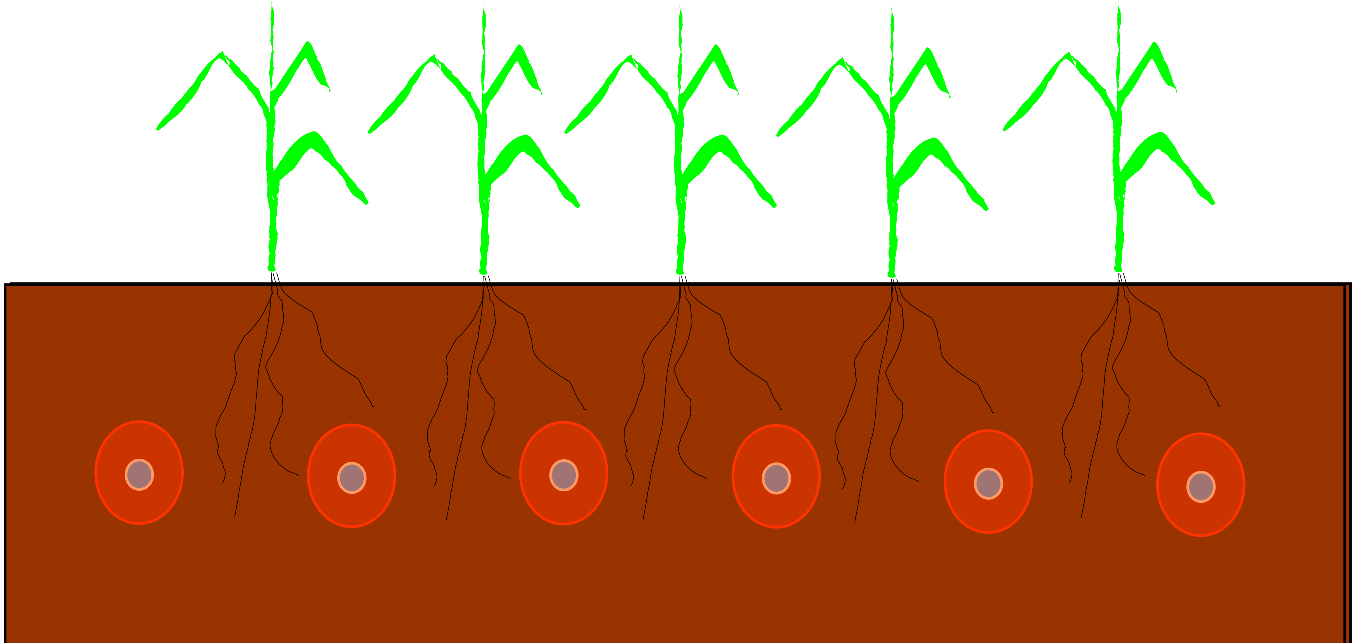
Field evidence of efficiency of formulations

Granular MAP   Fluid MAP

Source : Bob Holloway

Holloway et al. 2001 *Plant and Soil* ***236, 209-219.***

Field evidence of placement effects



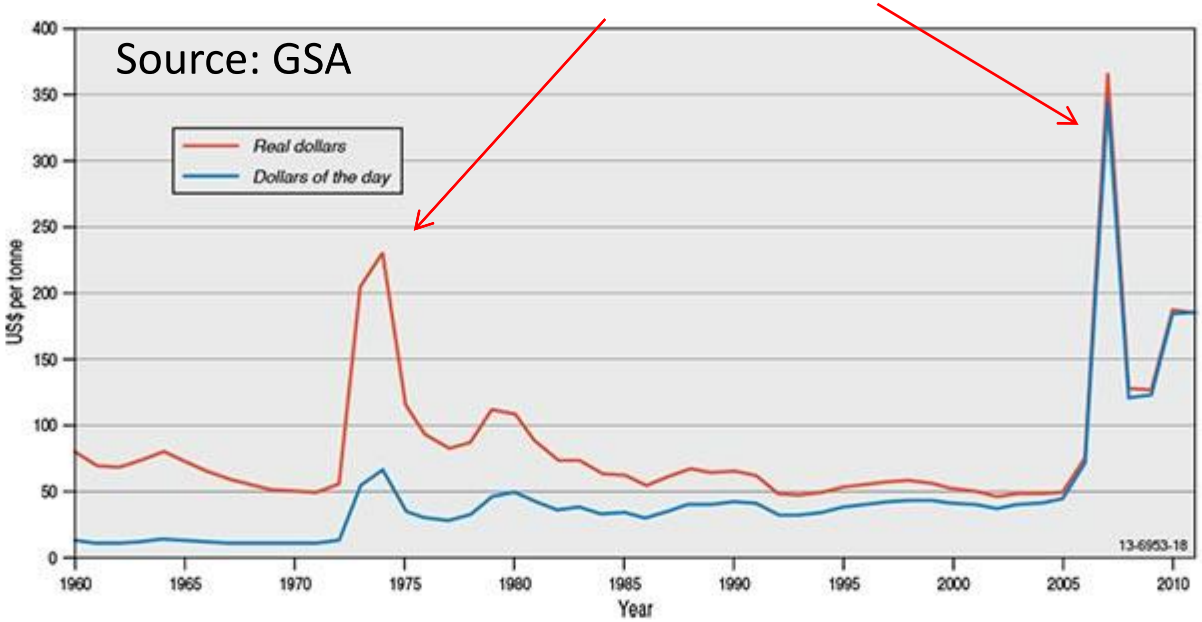
Improving P efficiency by releasing "fixed" P/reducing sorption

The scorecard

- Placement of P e.g. banding √
- Cultivation to mineralise organic P √
- Changing fertilizer formulation - fluids √
- Changing fertilizer formulation – slow release (for leaching) √
- New fertilizer formulations - chelates, slow release (to reduce sorption) ?
- Inoculants/biostimulants to release "fixed" P ?
- Inoculants/biostimulants to release stable organic P ?

The need for science to validate new P efficiency technologies

Peak "technology" release times



New P efficiency technologies

P2O5 MAX™
Phosphate Fertilizer Additive

TOP-PHOS®
A REVOLUÇÃO DOS FOSFATADOS

JumpStart®
Enhancing Phosphate Fertility

THE UNIVERSITY OF ADELAIDE AUSTRALIA

CSIRO

Data compilation of response to the polymer in trials

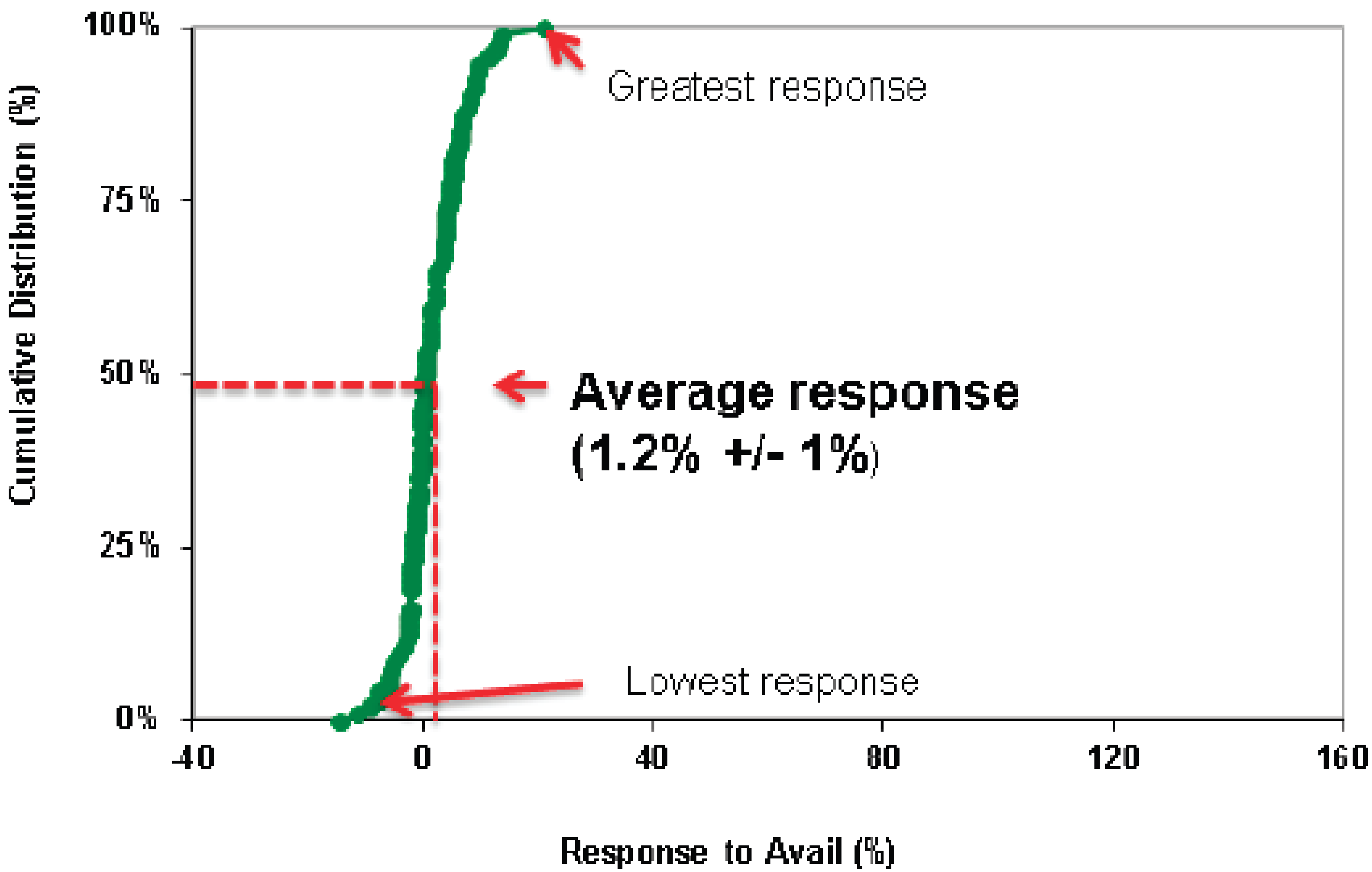
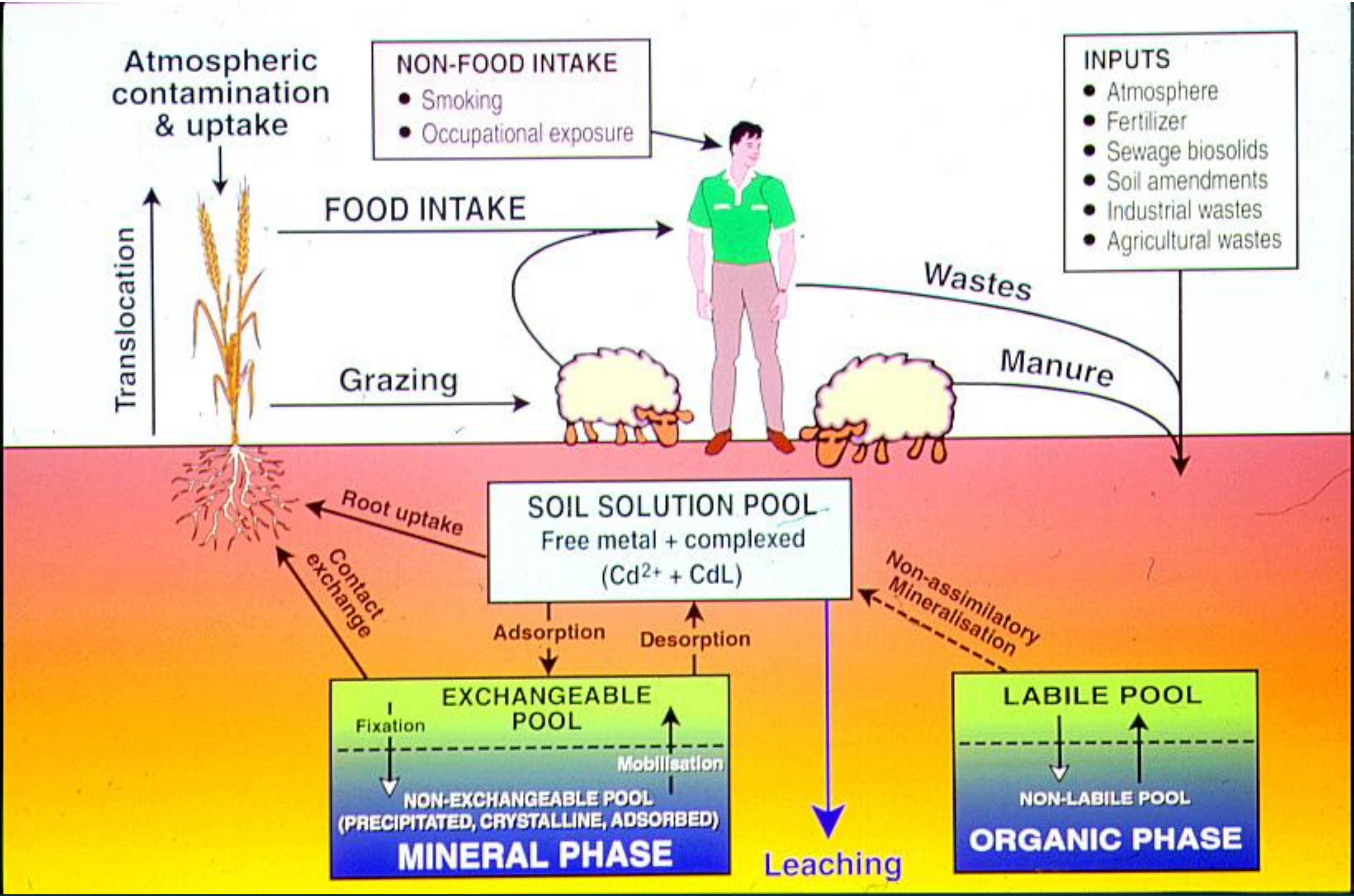


Fig. 8. The distribution frequency of plant yield responses to copolymer + P fertilizer expressed as a decrease or increase (%) relative to control for a subset of trials that are defined as very reliable trials (Edmeades and McBride, personal communication, 2012).

Reactions of added fertilizer Cd in soils

The fate of added Cd in soil



Food regulations drive Cd management

13.5.2014 EN Official Journal of the European Union L 138/75

COMMISSION REGULATION (EU) No 488/2014

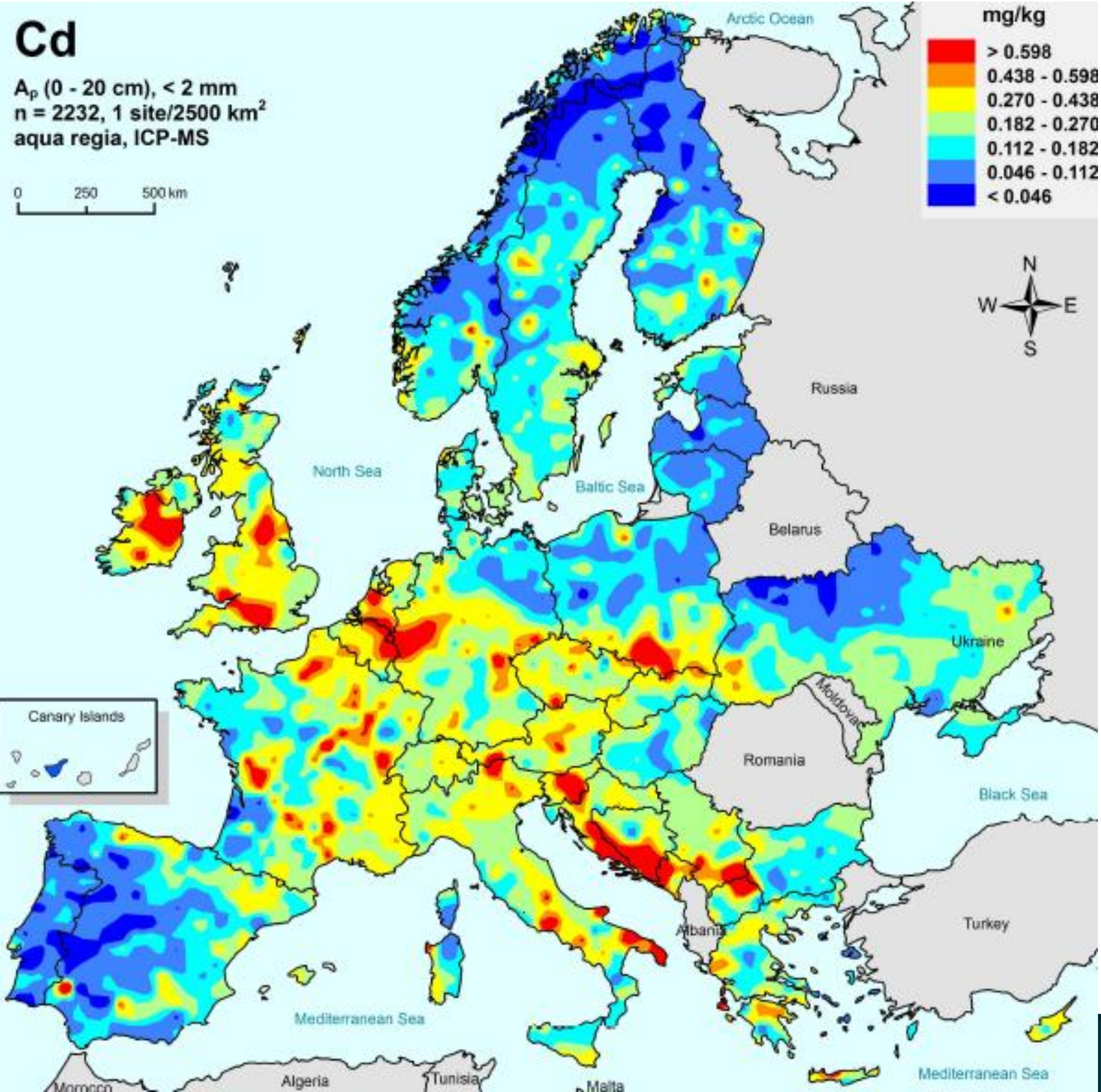
of 12 May 2014

amending Regulation (EC) No 1881/2006 as regards maximum levels of cadmium in foodstuffs

(2) The Scientific Panel on Contaminants in the Food Chain (CONTAM Panel) of the European Food Safety Authority (EFSA) adopted an opinion on cadmium in food on 30 January 2009 [3]. In that opinion, EFSA established a tolerable weekly intake (TWI) of 2,5 μg/kg body weight for cadmium. In its 'Statement on tolerable weekly intake for cadmium' [4], EFSA took into account the recent risk assessment carried out by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) [5] and confirmed the TWI of 2,5 μg/kg body weight.

(3) In the scientific opinion on cadmium in food, the CONTAM Panel concluded that the mean dietary exposures to cadmium in European countries are close to or slightly exceeding the TWI of 2,5 μg/kg body weight. Certain subgroups of the population may exceed the TWI by about 2 fold. The CONTAM Panel further concluded that, although adverse effects on kidney function are unlikely to occur for an individual exposed at this level, exposure to cadmium at the population level should be reduced.

(4) According to the scientific opinion on cadmium in food of the CONTAM Panel, the food groups that contribute to the major part of the dietary cadmium exposure, primarily because of the high consumption, are cereals and cereals products, vegetables, nuts and pulses, starchy roots or potatoes and meat and meat products. Highest cadmium concentrations were detected in the food commodities seaweed, fish and seafood, chocolate and foods for special dietary uses as well as in fungi, oilseeds and edible offal.



Soil Cd in Europe

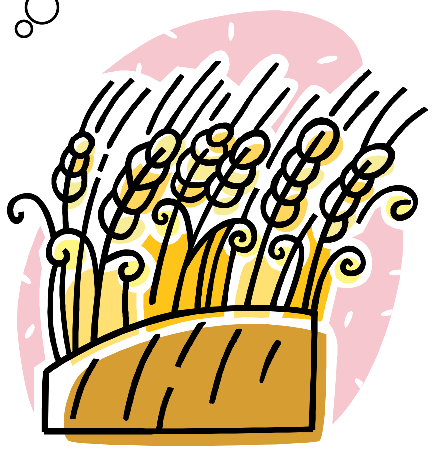
Management of fertilizer Cd in soils

Factors affecting Cd concentration of crops

Soil characteristics

Crop Genetics

Soil Cd concentration



Tillage and agronomic management

Irrigation and water management

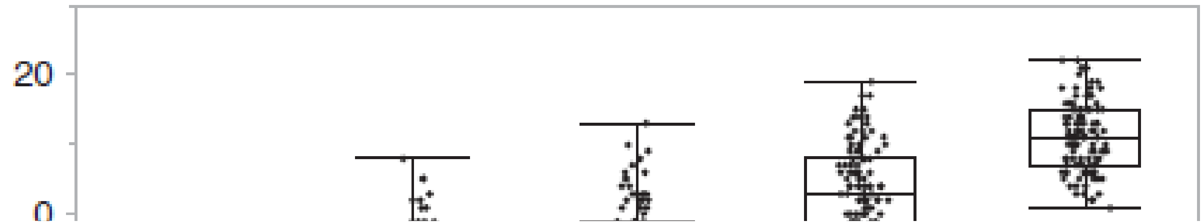
Crop Rotation

Fertilizer management

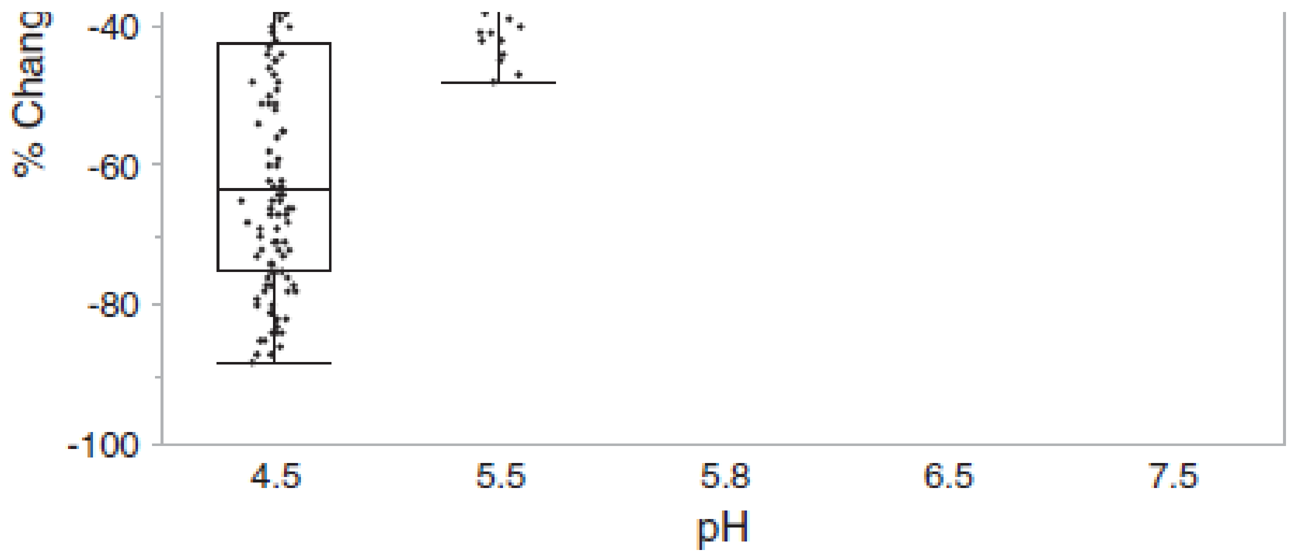
Are fertilizer Cd risks receding?

Predicted change in soil Cd over 100 years in 540 potential European scenarios: soil pH is the main driver

Average scenario: 15% depletion

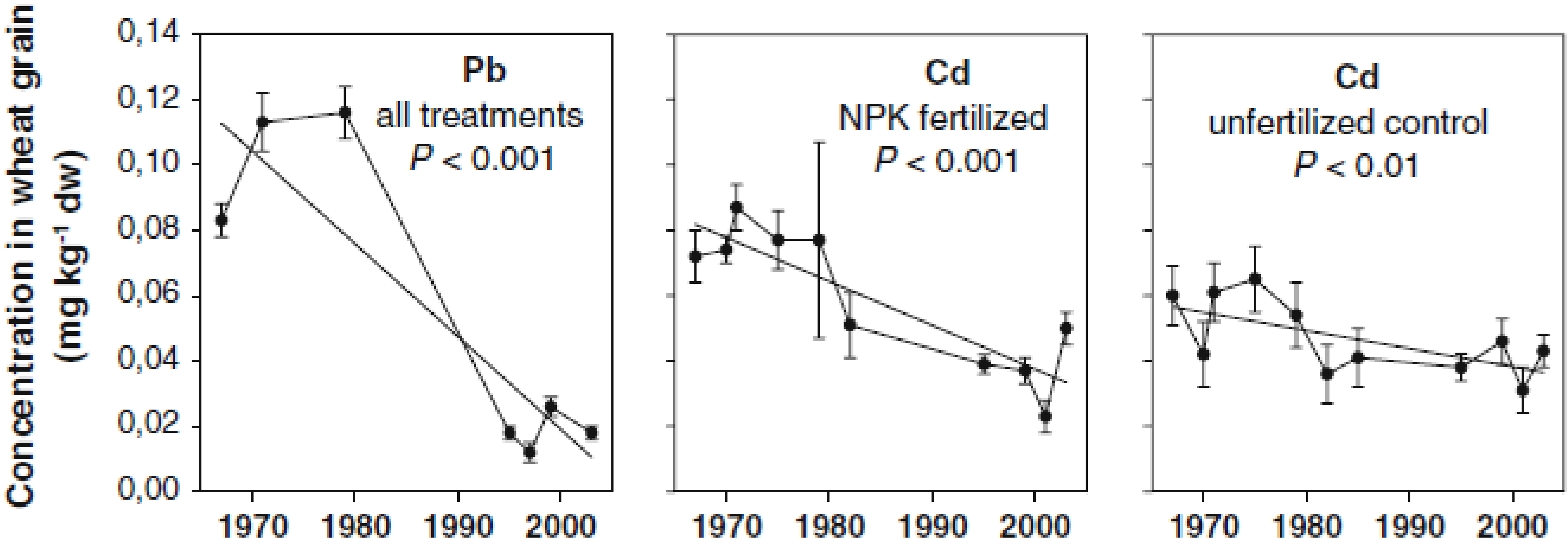


- **Reduced atmospheric deposition of Cd**
- **Large reductions in use of P fertilizers in EU**



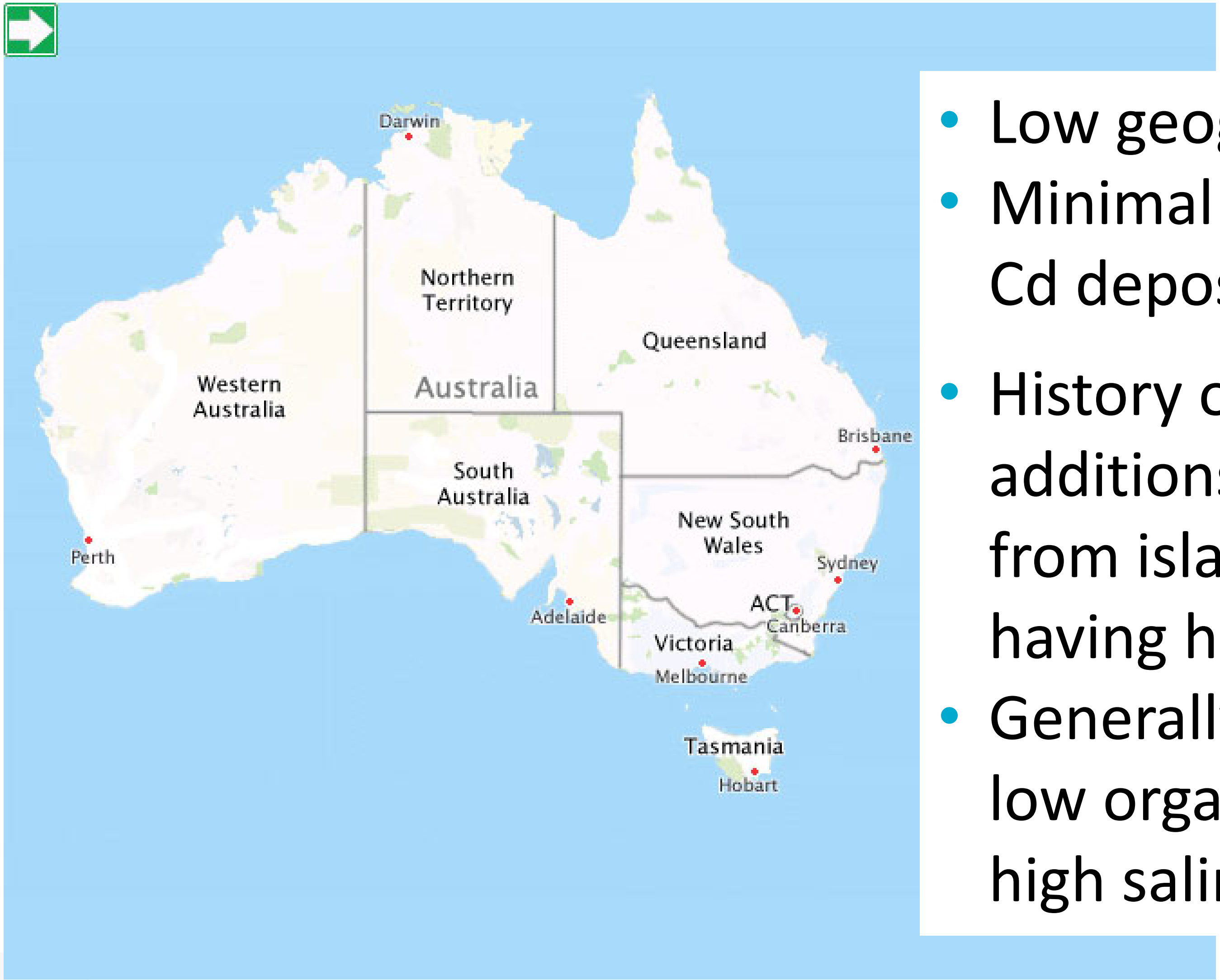
Six L, Smolders E (2014) Future trends in soil cadmium concentration under current cadmium fluxes to European agricultural soils. *Science of the Total Environment* ***485, 319-328.***

Cadmium in European crops now declining



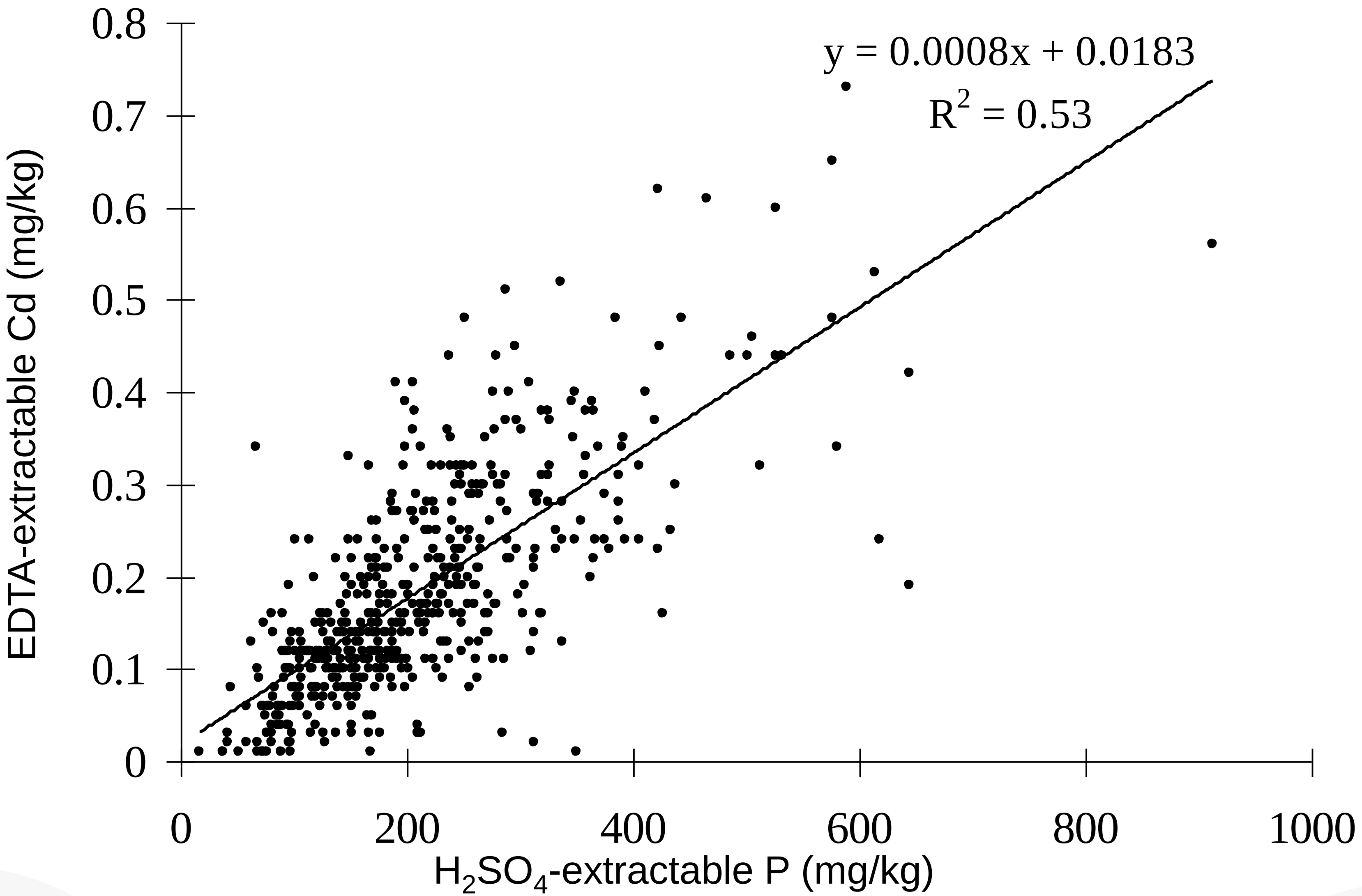
Kirchmann H, Mattsson L, Eriksson J (2009) Trace element concentration in wheat grain: results from the Swedish long-term soil fertility experiments and national monitoring program. *Environmental Geochemistry and Health* ***31(5), 561-571.***

Cadmium in Australian agroecosystems



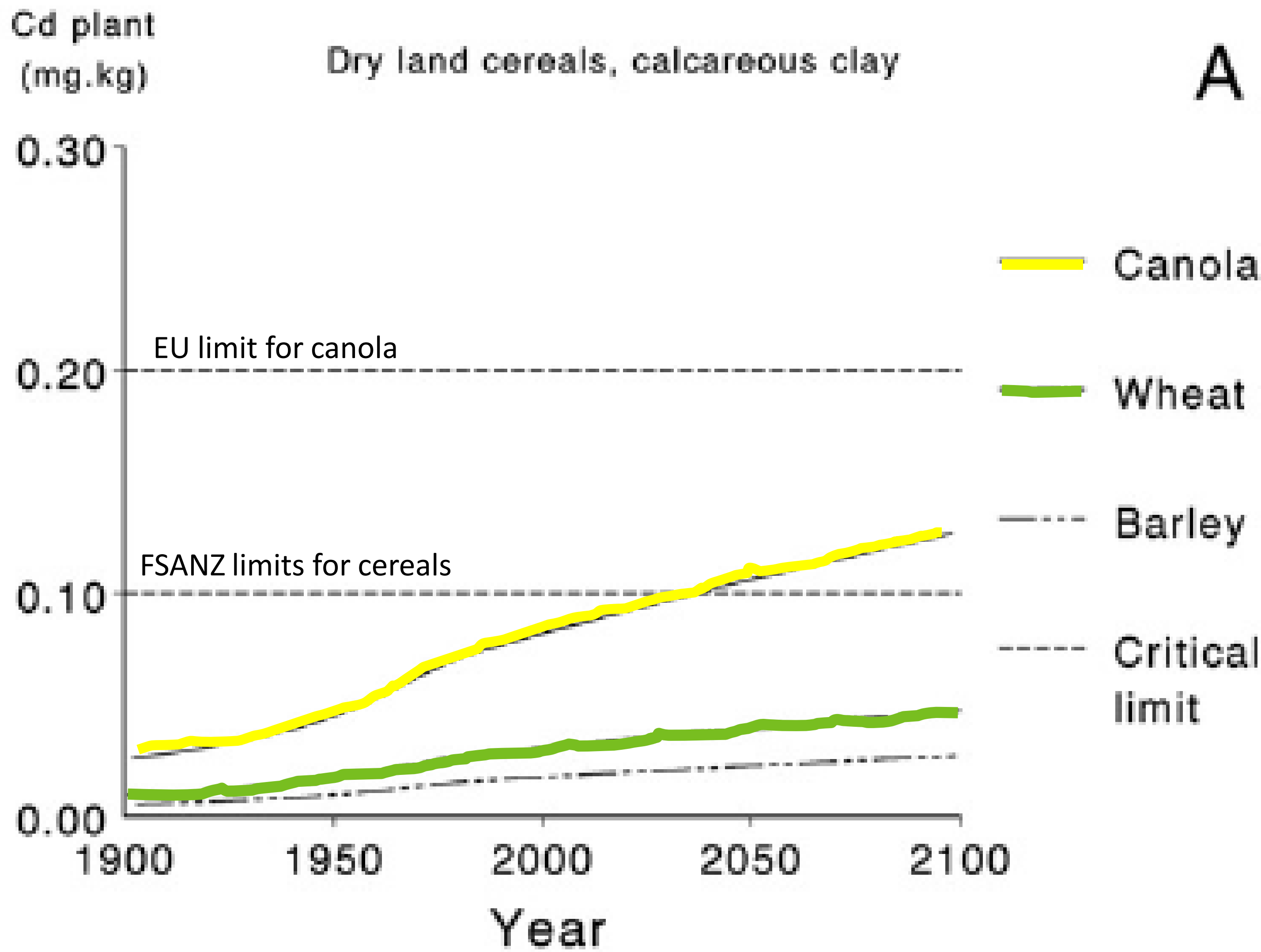
- Low geogenic soil Cd
- Minimal atmospheric Cd deposition
- History of low P additions in fertilizer from island rocks having higher Cd
- Generally sandy soils, low organic matter, high salinity

Soil Cd closely linked to fertilizer addition



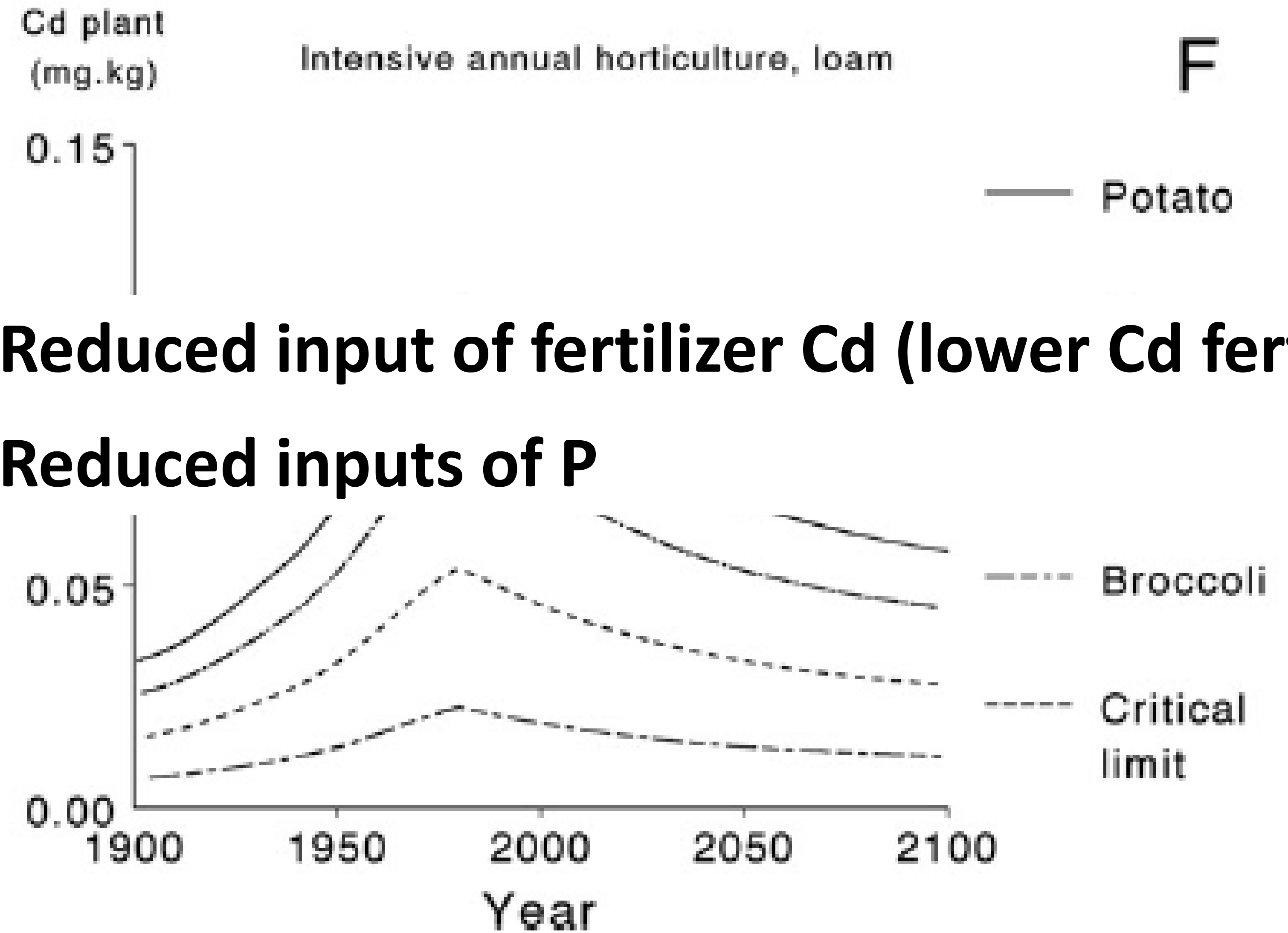
Merry, R. H., (1992) *CSIRO Report to MRC/FIFA, Australia.*

Predicting crop Cd concentrations over time



Vries W de, McLaughlin MJ (2013). *Sci. Tot. Environ.* ***461-462,*** *240-257.*

Predicting crop Cd concentrations over time



- **Reduced input of fertilizer Cd (lower Cd ferts)**
- **Reduced inputs of P**

"Critical" Cd concentrations in fertilizers

Calculated critical loads for Cd in soil and related critical Cd/P ratios in P fertilizers

Land use	Soil type	CLO_{Cd} g ha^{-1} yr^{-1}	P input kg ha^{-1} yr^{-1}	Cd/P_{crit} mg Cd kg P^{-1}
Dry land cereals	Calcareous clay	0.38	20	19
	Sand	2.85	20	143
Sugarcane rotation	Heavy clay	5.91	50	118
	Loam	18.13	50	363
Dairy production	Organic heavy clay	1.37	40	34
	Loam	2.96	40	74
Intensive annual horticulture	Heavy clay	7.16	100	72
	Loam	21.20	100	212

Current average fertilizer quality used in Australia = ~60 mg Cd/kg P

Vries W de, McLaughlin MJ (2013). *Sci. Tot. Environ.* ***461-462,*** *240-257.*

Summary

- Efficiency of P fertilizer use may not be as low as you think – over-application is often the key cause
- Some soils do not need novel P "enhancers"
- Work on improving P efficiency is most critical for developing countries with high-sorption soils having had poor P fertilizer inputs
- A combination of plant, fertilizer formulation/ management and soil factors can be used to improve P efficiency
- New "P efficiency" technologies need proper mechanistic and field evaluation

Summary

- Cadmium is of concern in fertilizers, but is not as big as hazard for P use as previously thought
- Cadmium build-up in soils is much lower than previously predicted due to
  - Lower atmospheric Cd inputs (in Europe)
  - Lower fertilizer P (Cd) inputs (as soils become “P fertile”)
  - Greater control of Cd quality of other soil amendments
- In the short term, agronomic management can effectively control food chain Cd contamination
- More data and modelling needed for developing countries

Acknowledgements

Mosaic
CSBP
GRDC Grains Research & Development Corporation
SA Grain Industry Trust Fund — Targeting Research
Fluid Fertilizer Foundation
SARDI — South Australian Research and Development Institute
agrichem plant nutrition solutions
Australian Synchrotron Research Program
IPNI International Plant Nutrition Institute
State Government Victoria
Australian Government — Australian Research Council

Thank you