The terrestrial P cycle: Ideas and opportunities

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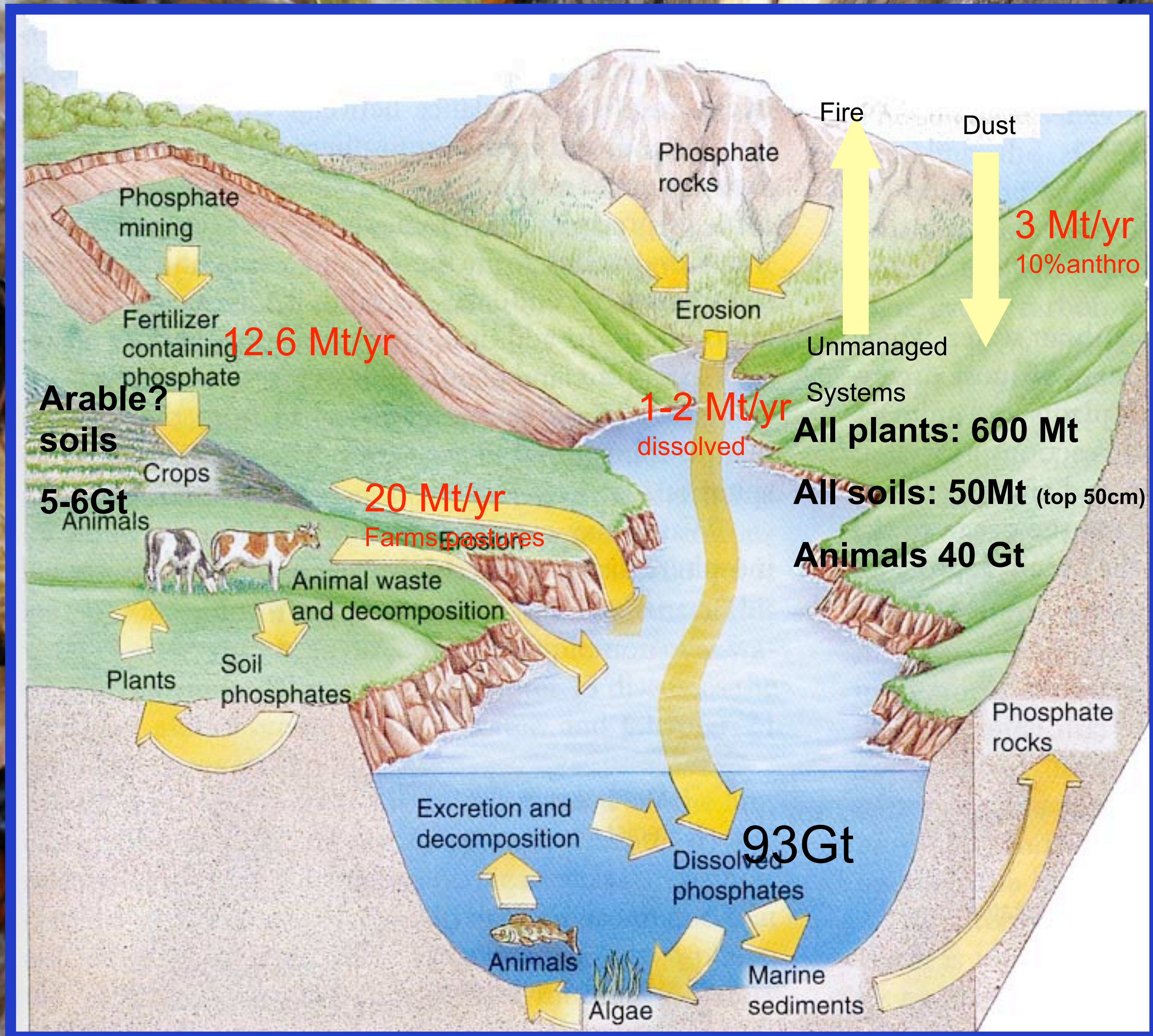

Pools, farm erosion, fertilizer: Smil 2000, Dust: Mahowald et al 2008, Inputs to ocean from Smil 2000 and Paytan and McGlaughlin, 2007

Questions that might be worth exploring

Agriculture:

- How much P do we need for agriculture?
- Where are we going to get it?
- Will we run out?

Limiting nutrient (?):

- How and why does soil P content vary?
- What P forms are biologically available?

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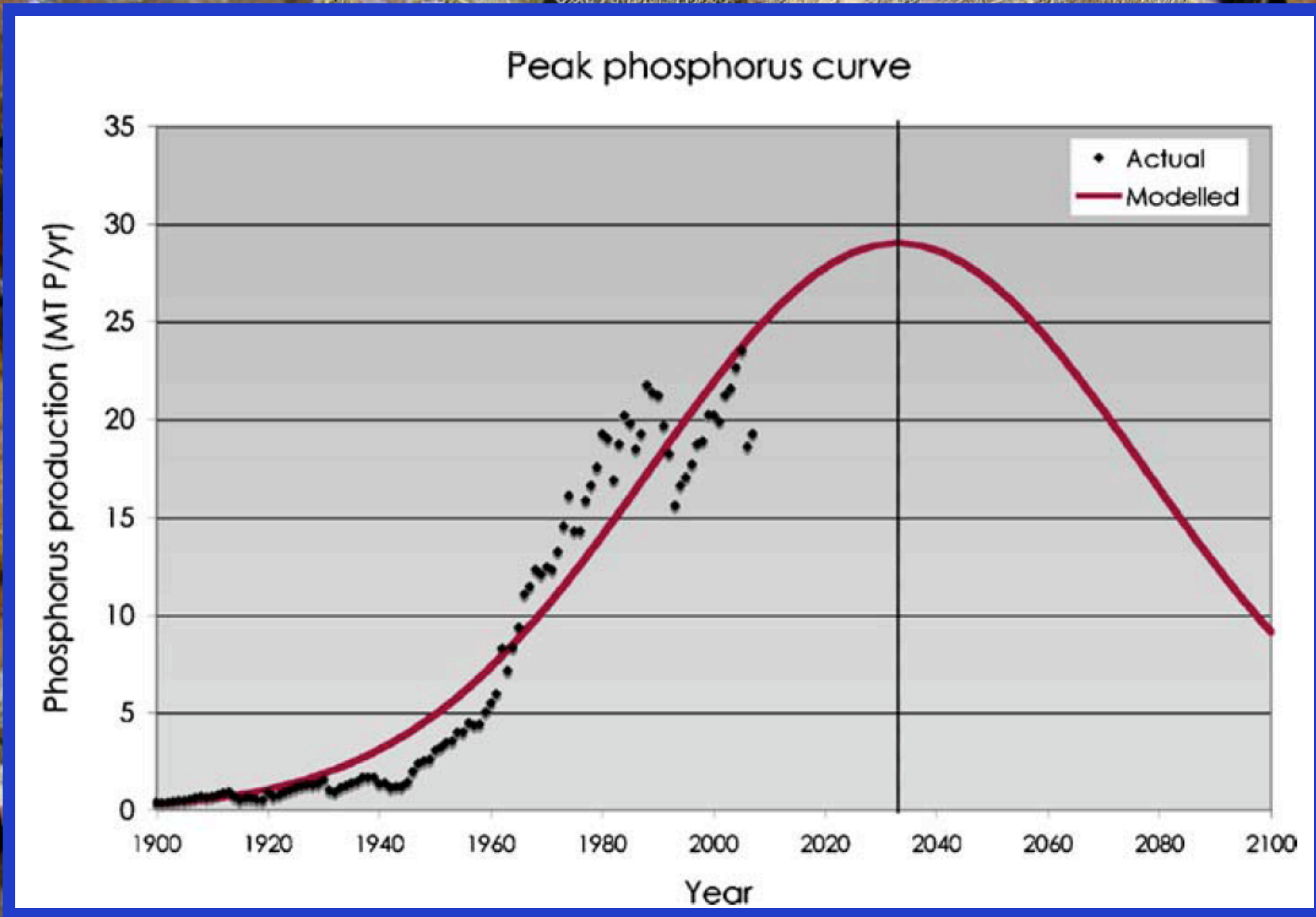
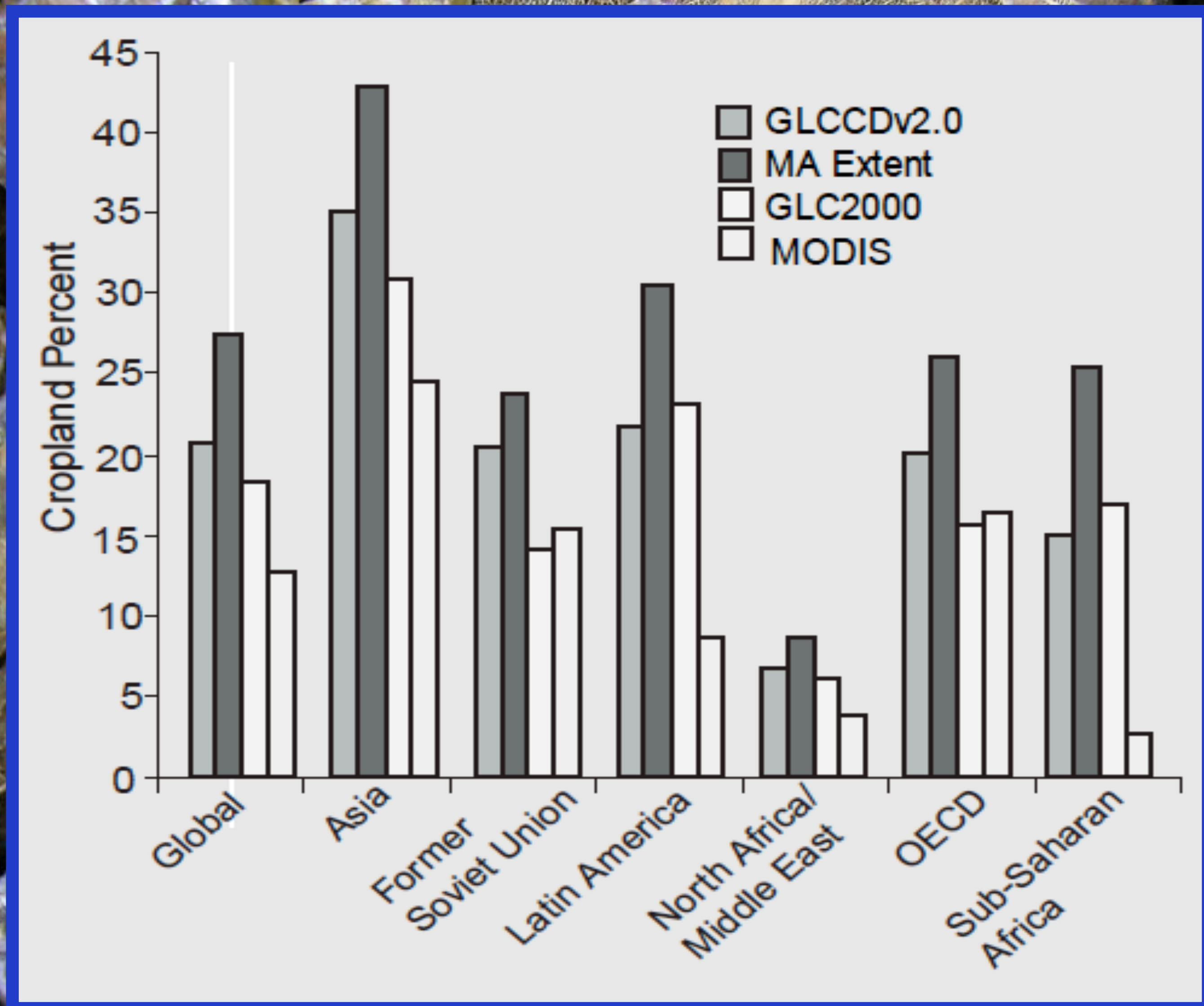
How much P do we need for agriculture?



Cordell et al., 2009

How much P do we need for agriculture?



MEA, 2005

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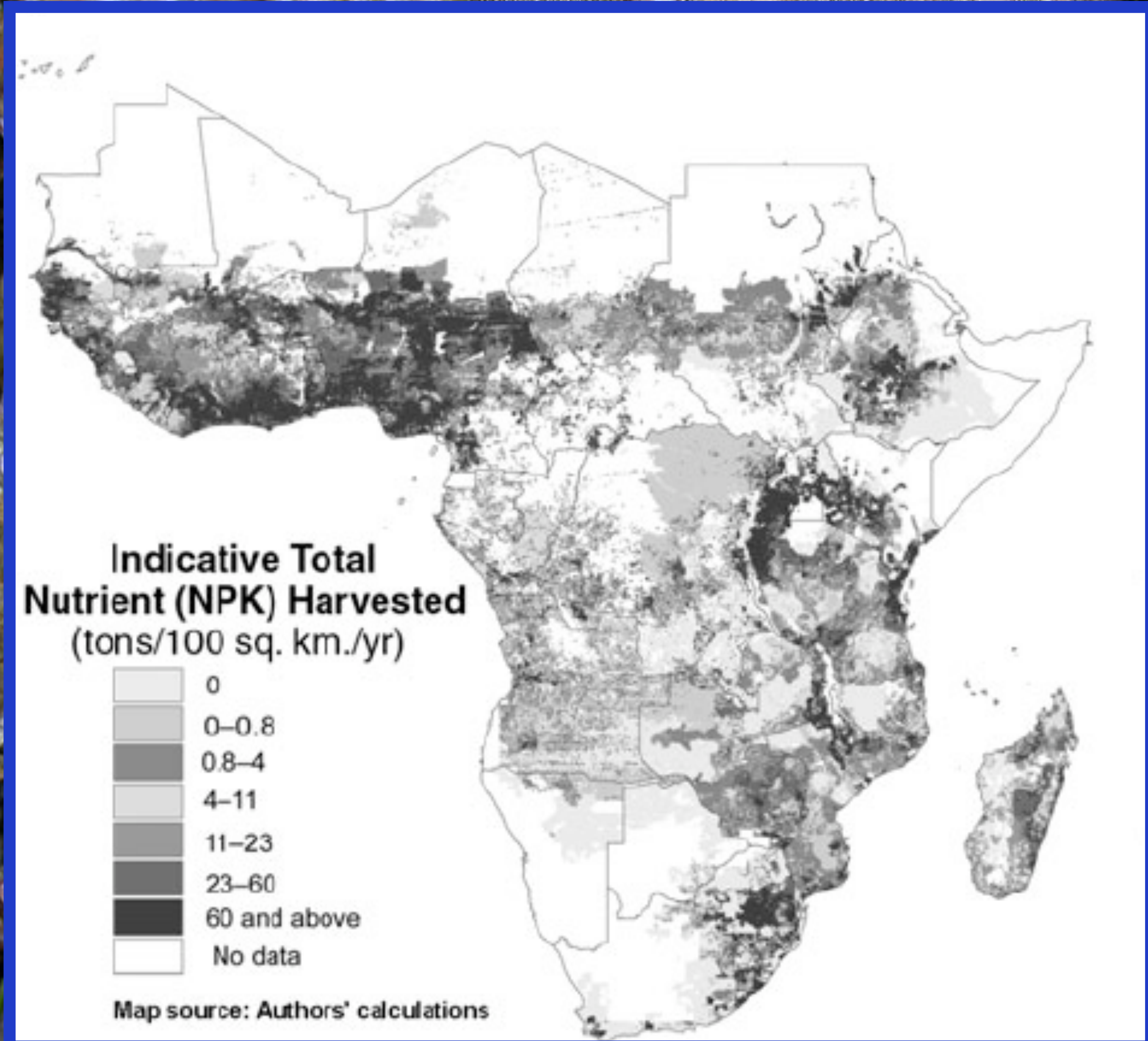
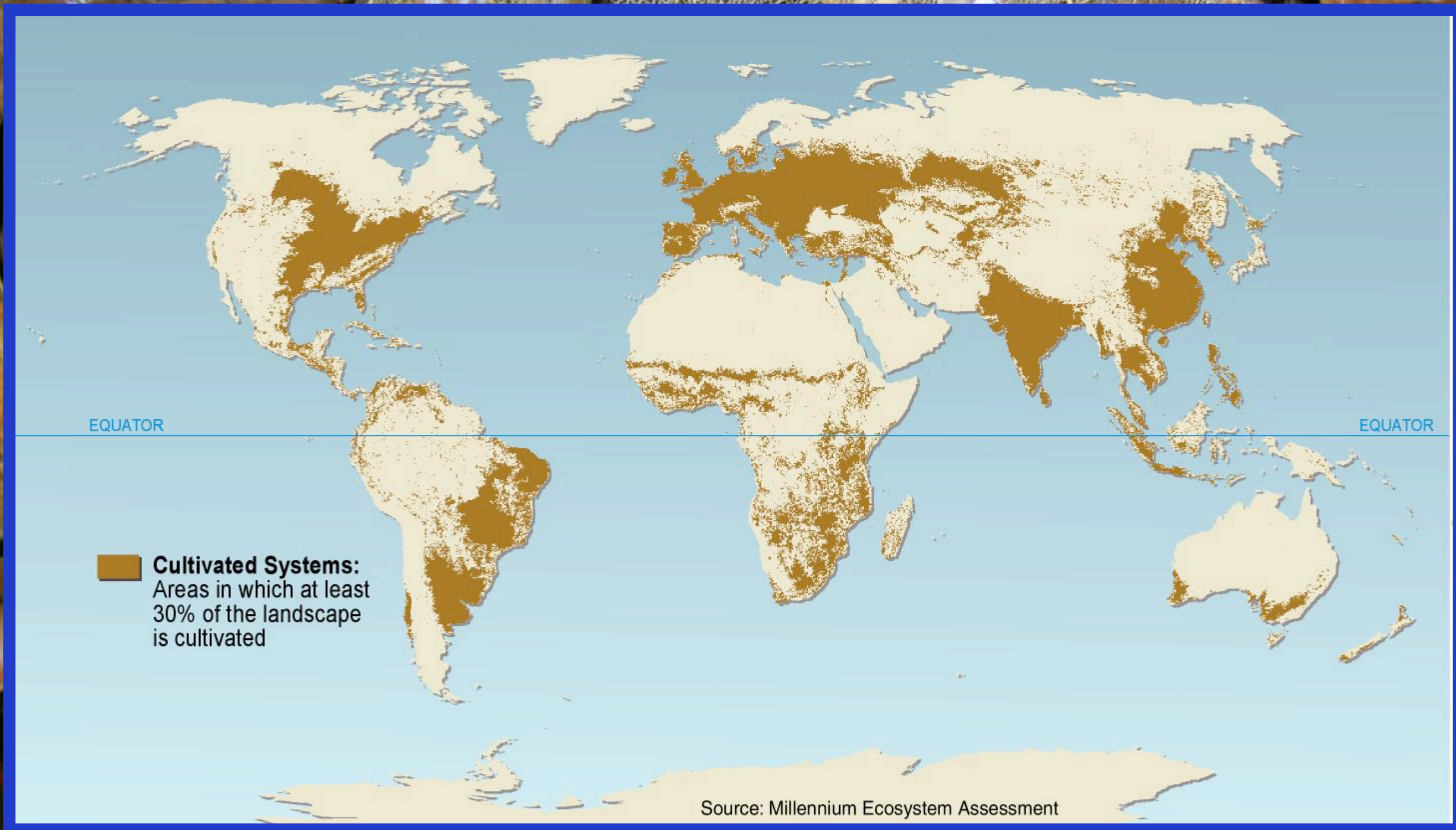


MEA, 2005

How much P do we need for agriculture?

Photos courtesy of Shelby Hayhoe

How much P do we need for agriculture?



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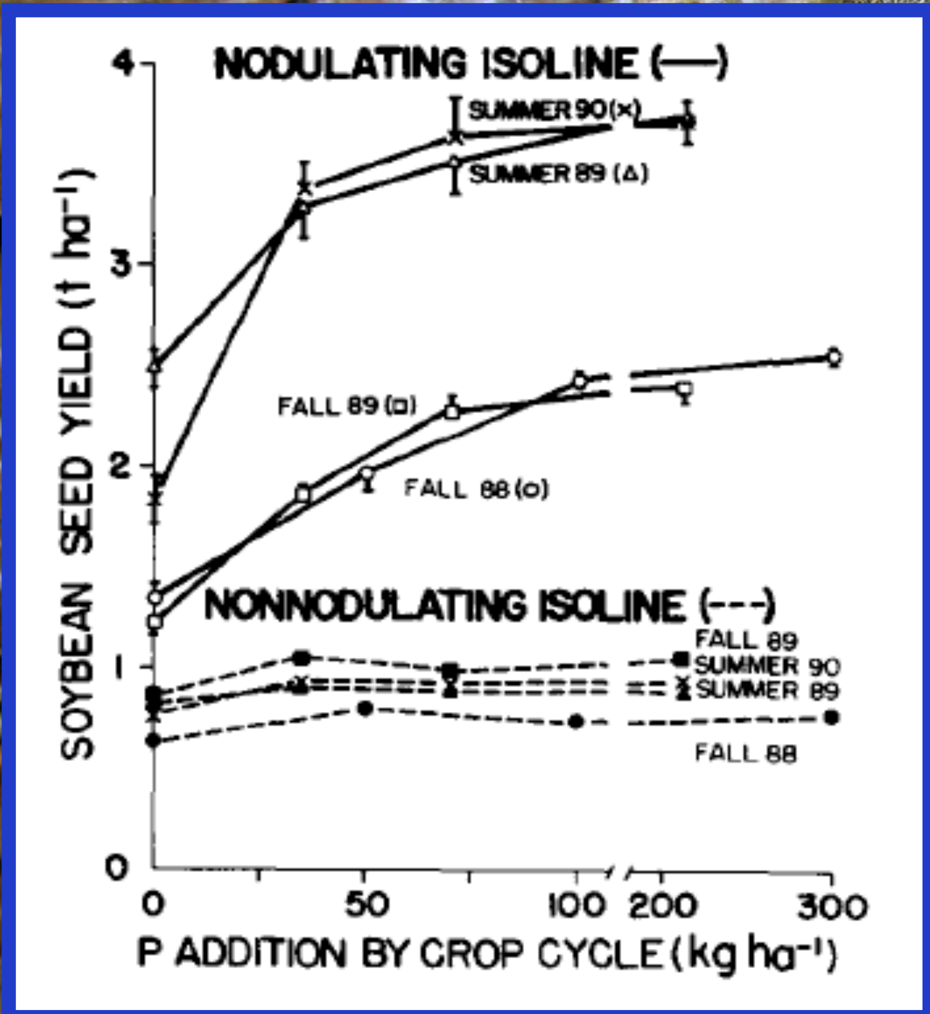
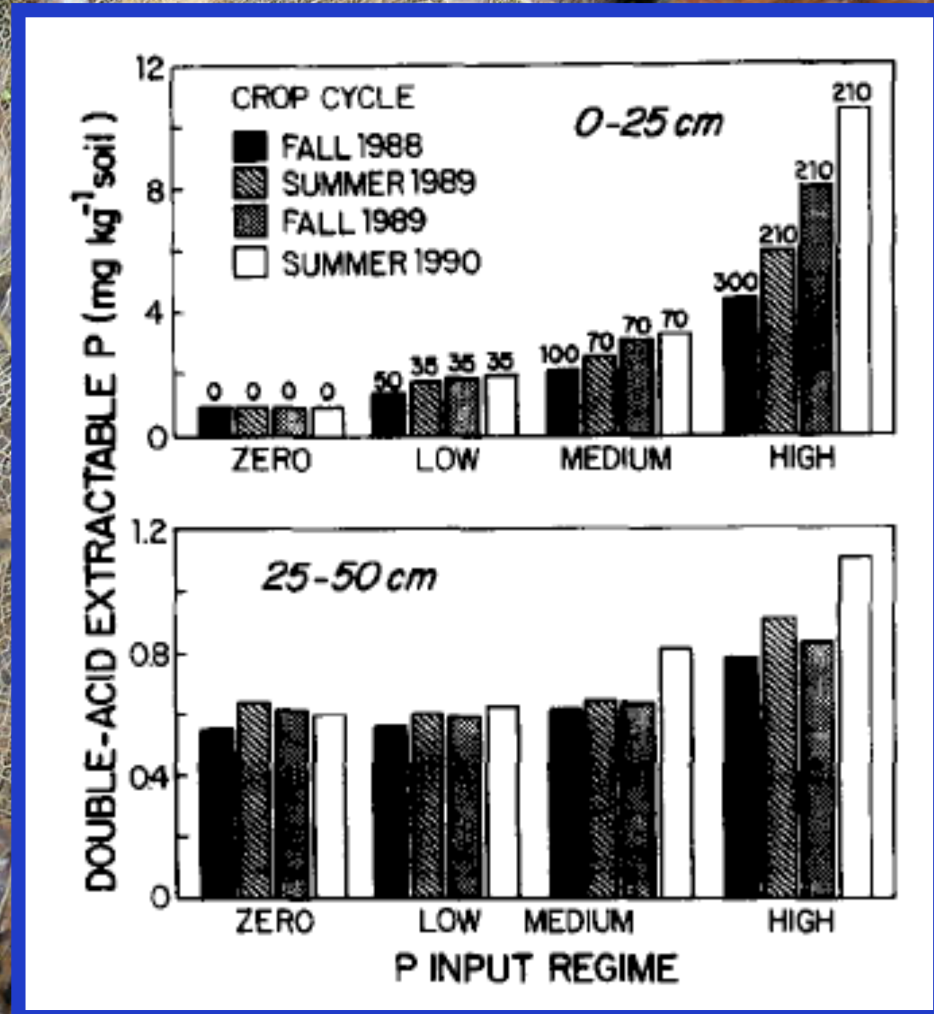
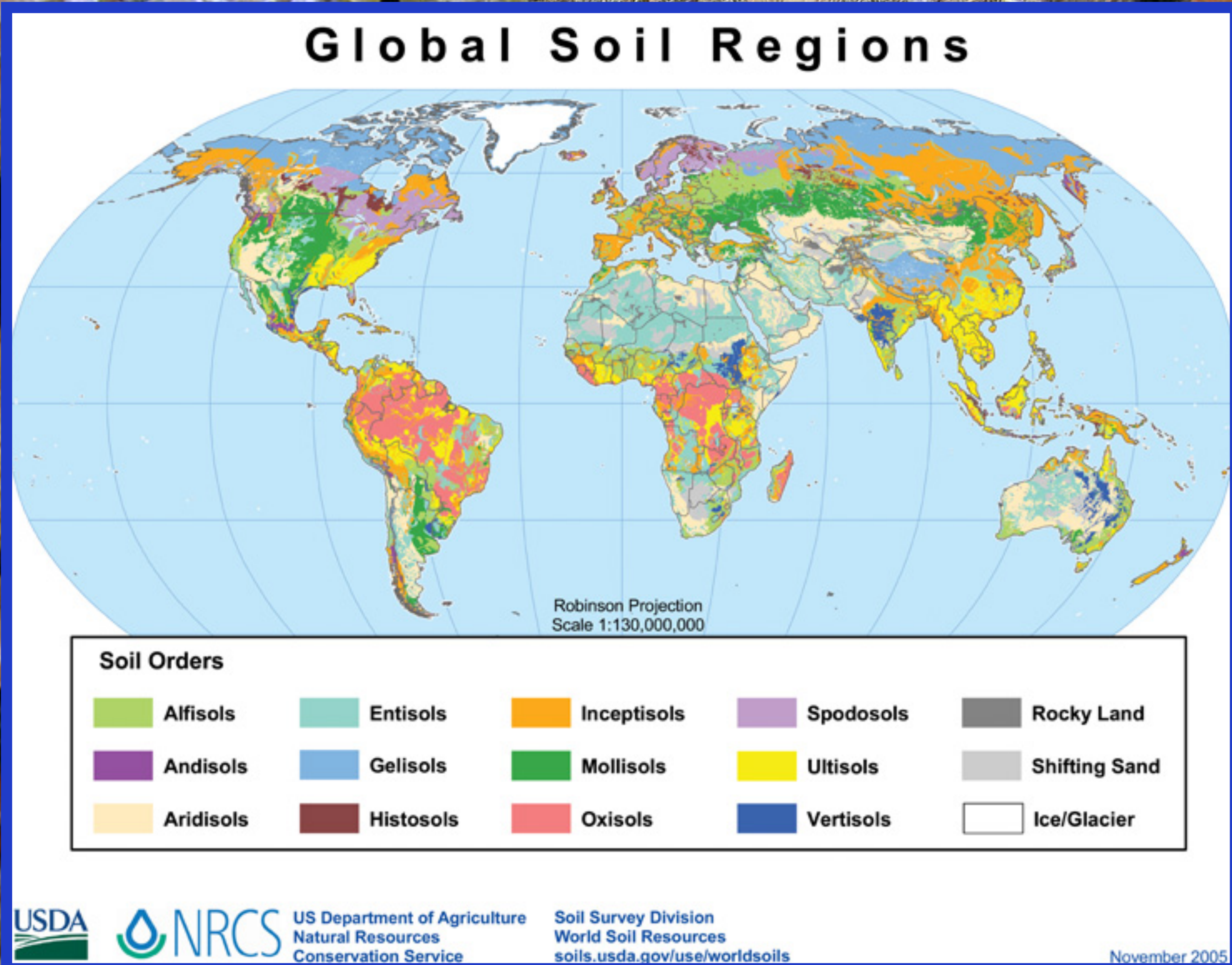




Data from high P Ultisols in Maui

Cassman et al., 1993

How much P do we need for agriculture?



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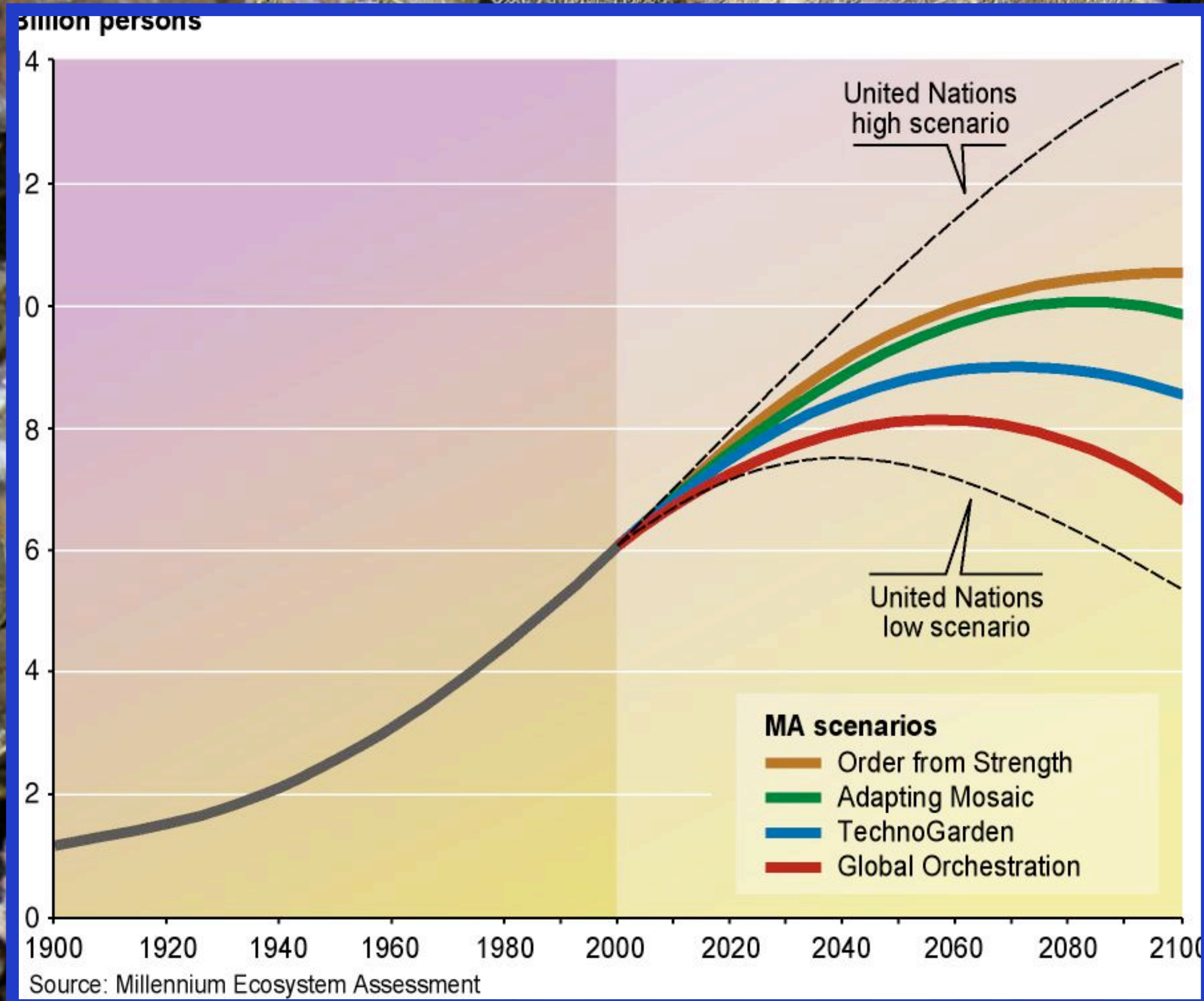

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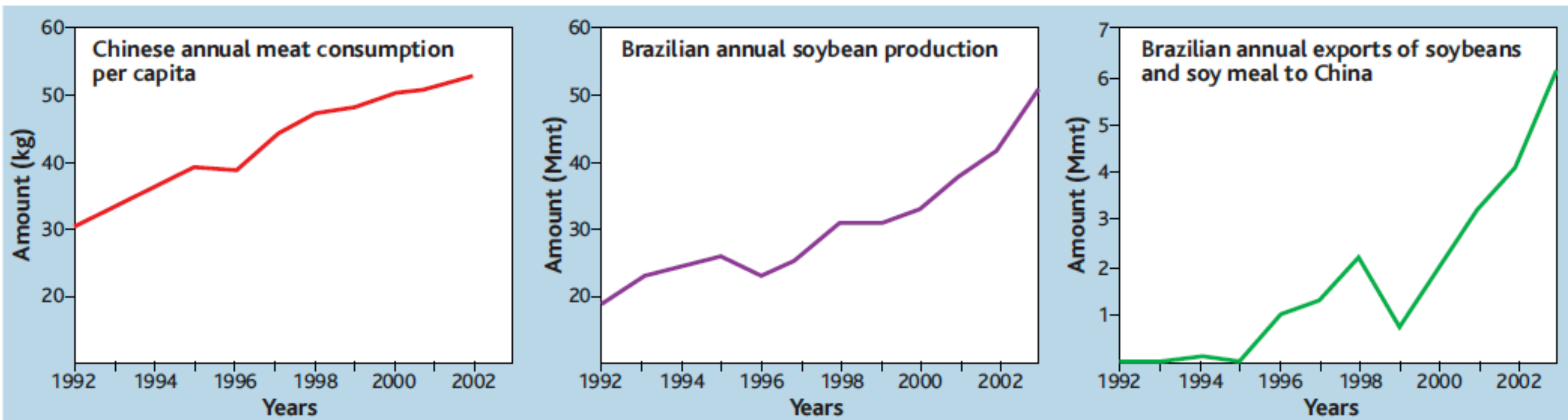

International linkages in supply and demand of livestock products, 1992–2003 (*3*). Mmt, millions of metric tons.

Naylor et al., 2005

Questions that might be worth exploring

Agriculture:

- How much P do we need for agriculture?
- **Where are we going to get it?**
- Will we run out?

Limiting nutrient (?):

- How and why does soil P content vary?
- What P forms are biologically available?

Where will we get our P from?

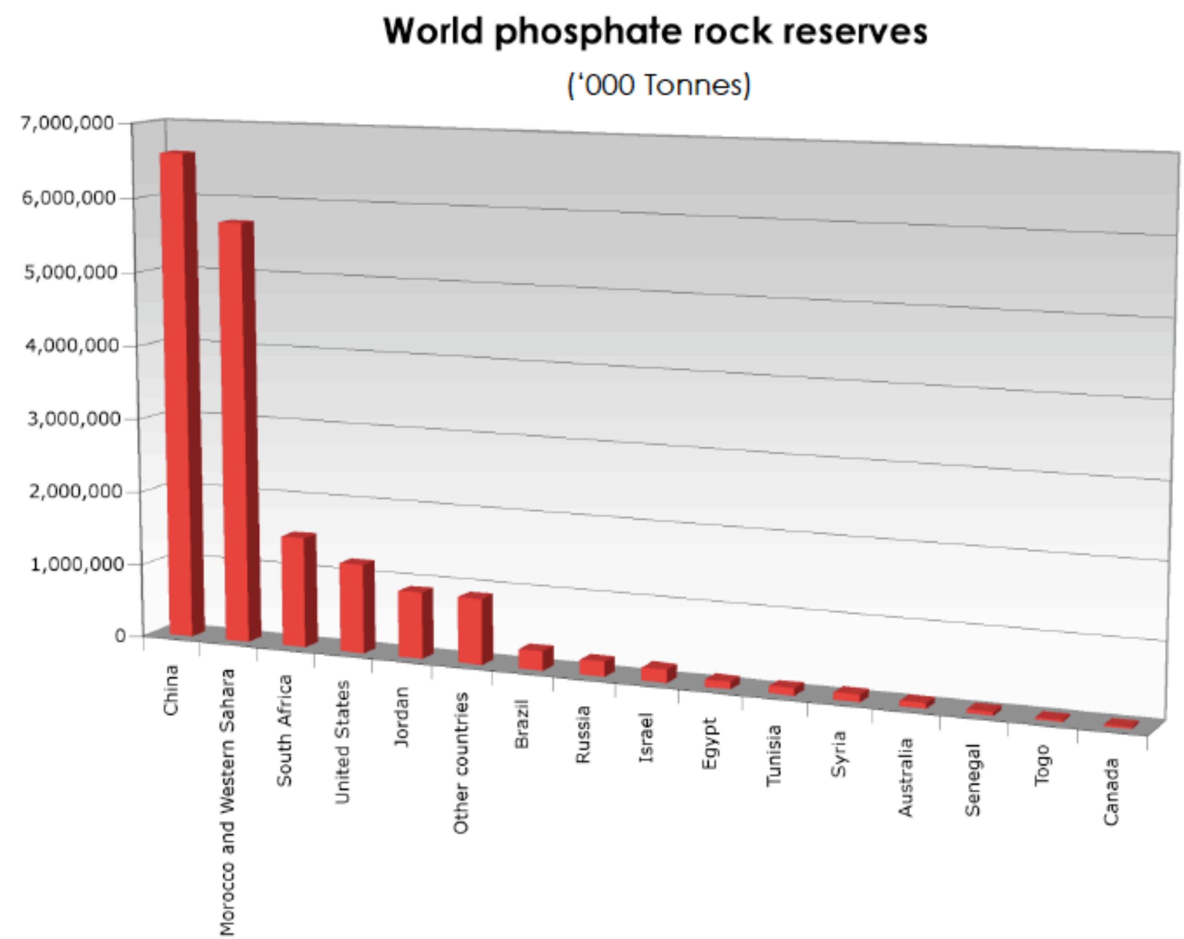

Figure 1: Global phosphorus reserves are highly geographically concentrated and are under the control of only a handful of countries. (data: Jasinski, 2008)

Cordell 2008 unpubl.

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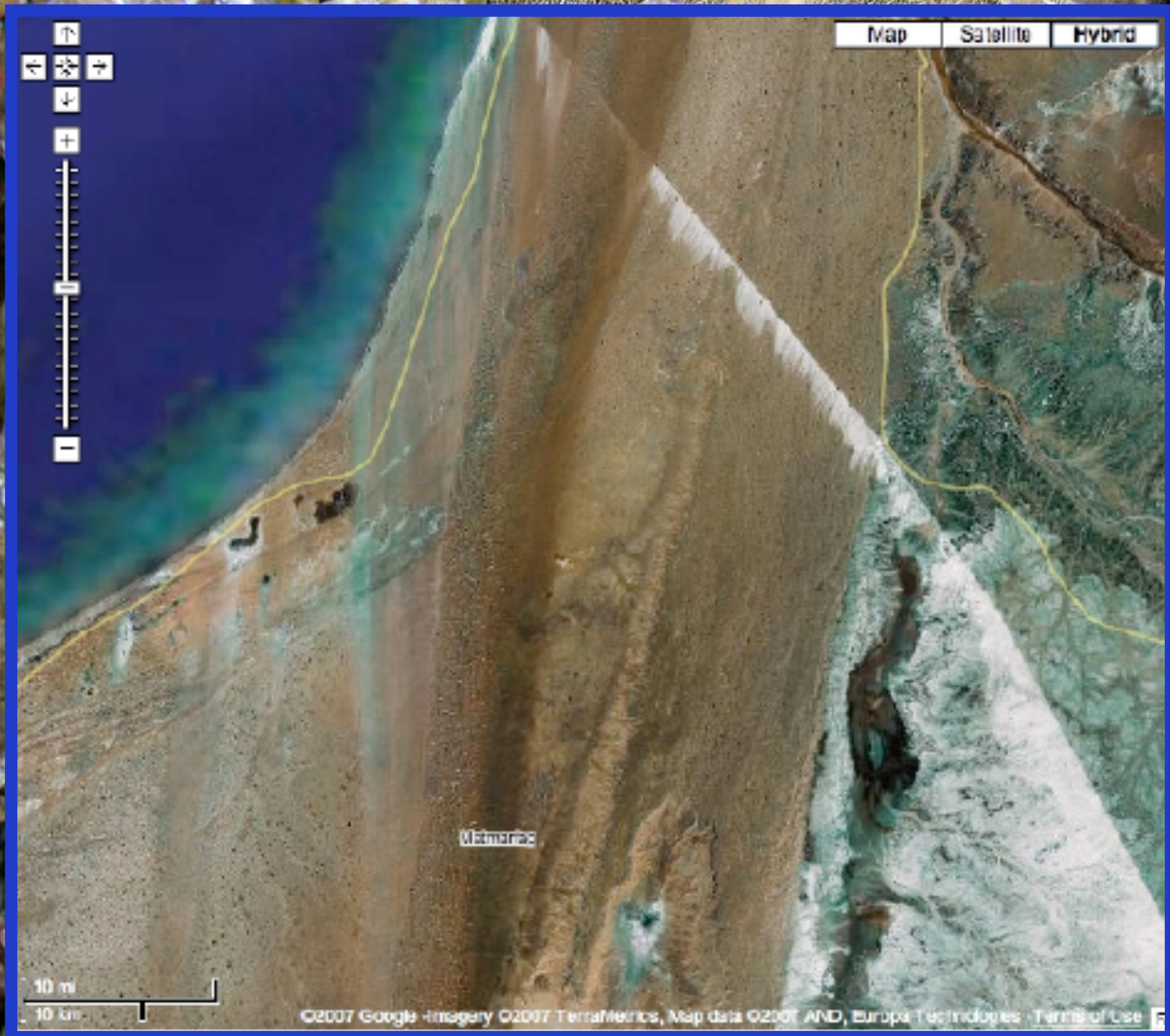

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Questions that might be worth exploring

Agriculture:

- How much P do we need for agriculture?
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Limiting nutrient (?):

- How and why does soil P content vary?
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Will we run out?

- We need to better understand and control P losses from farms.

- We need a global map of Soil P.

- We need to know how much of the P that is in soil is available for plant uptake, and over what timescale.

Questions that might be worth exploring

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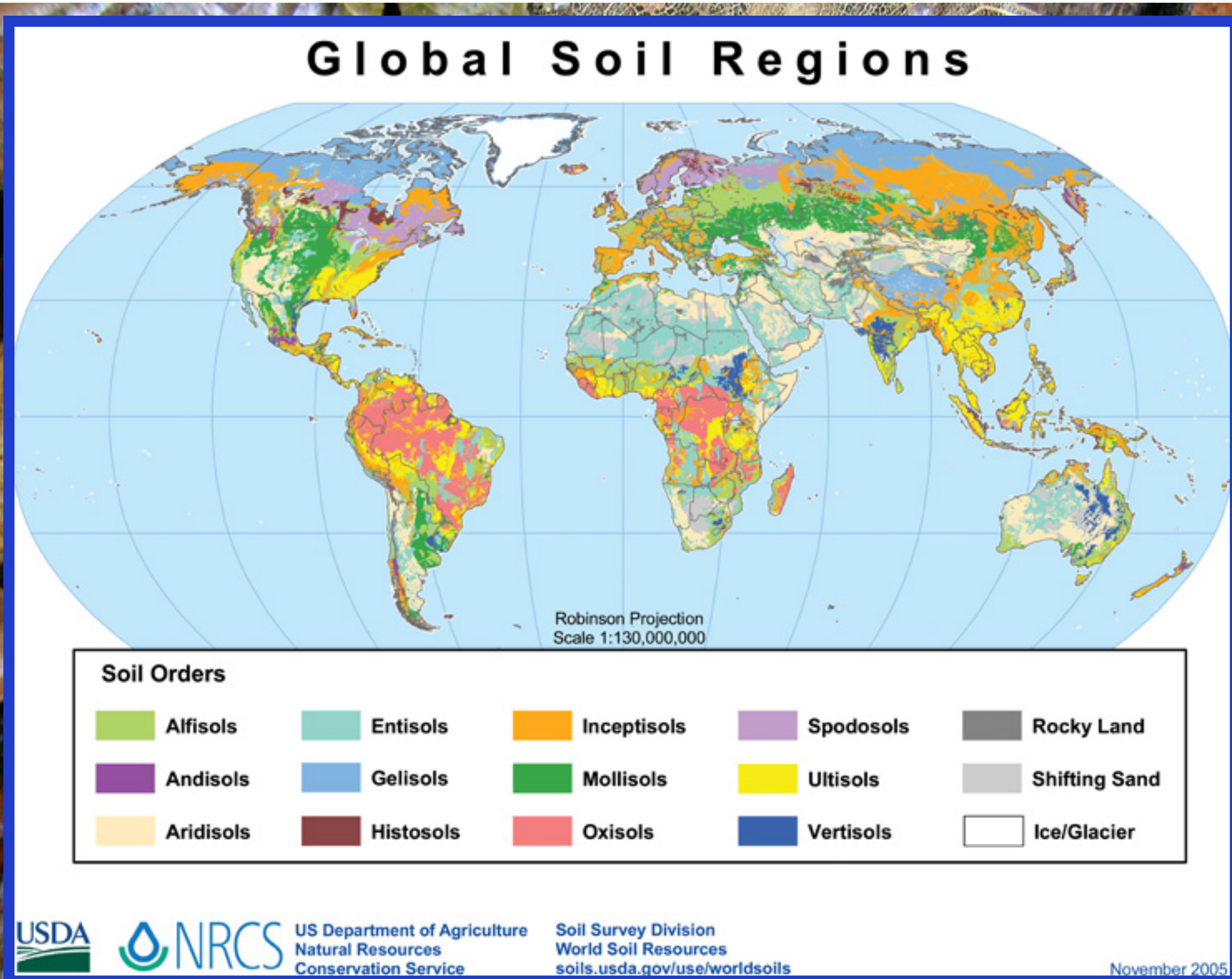
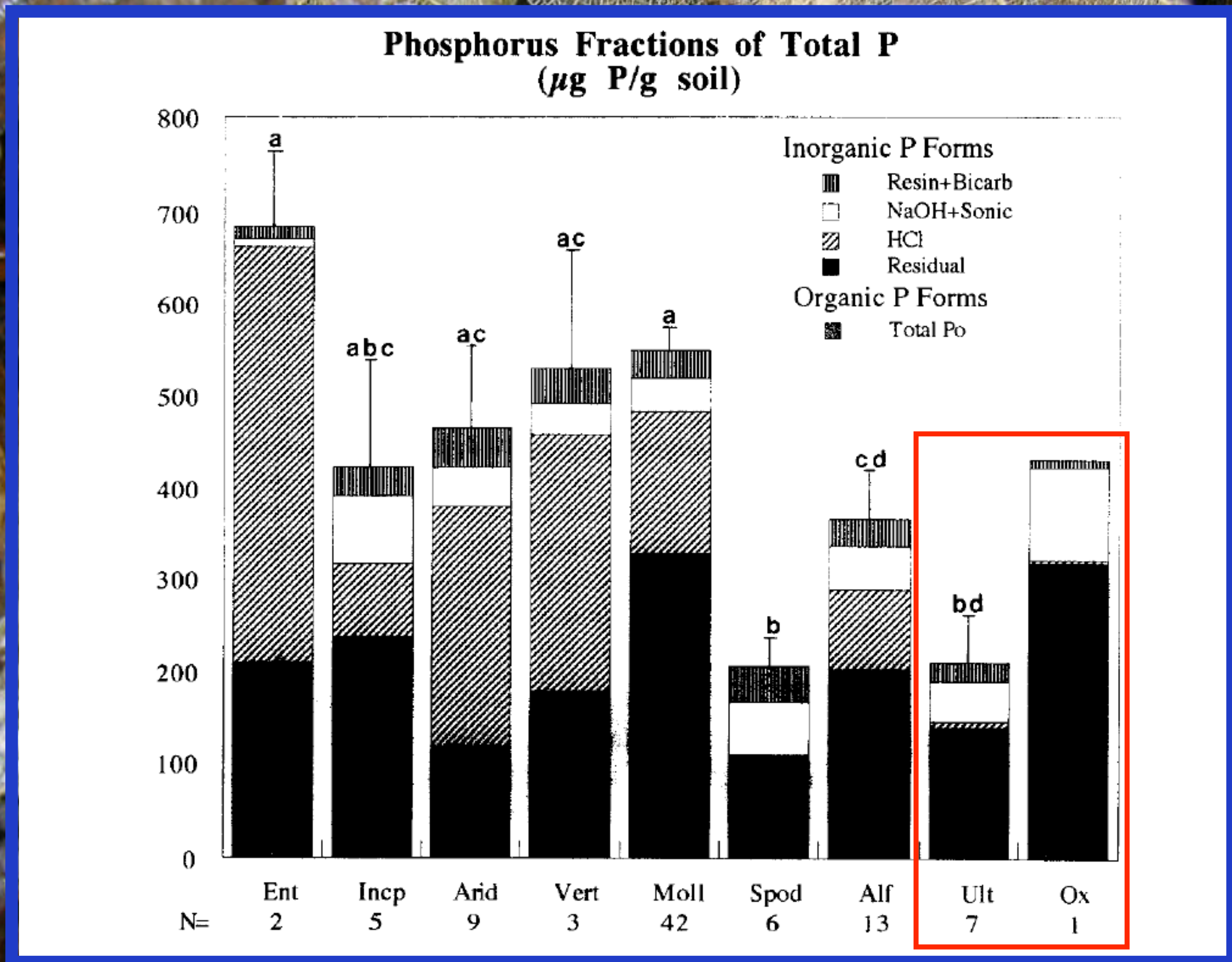
How and why does soil P content vary?



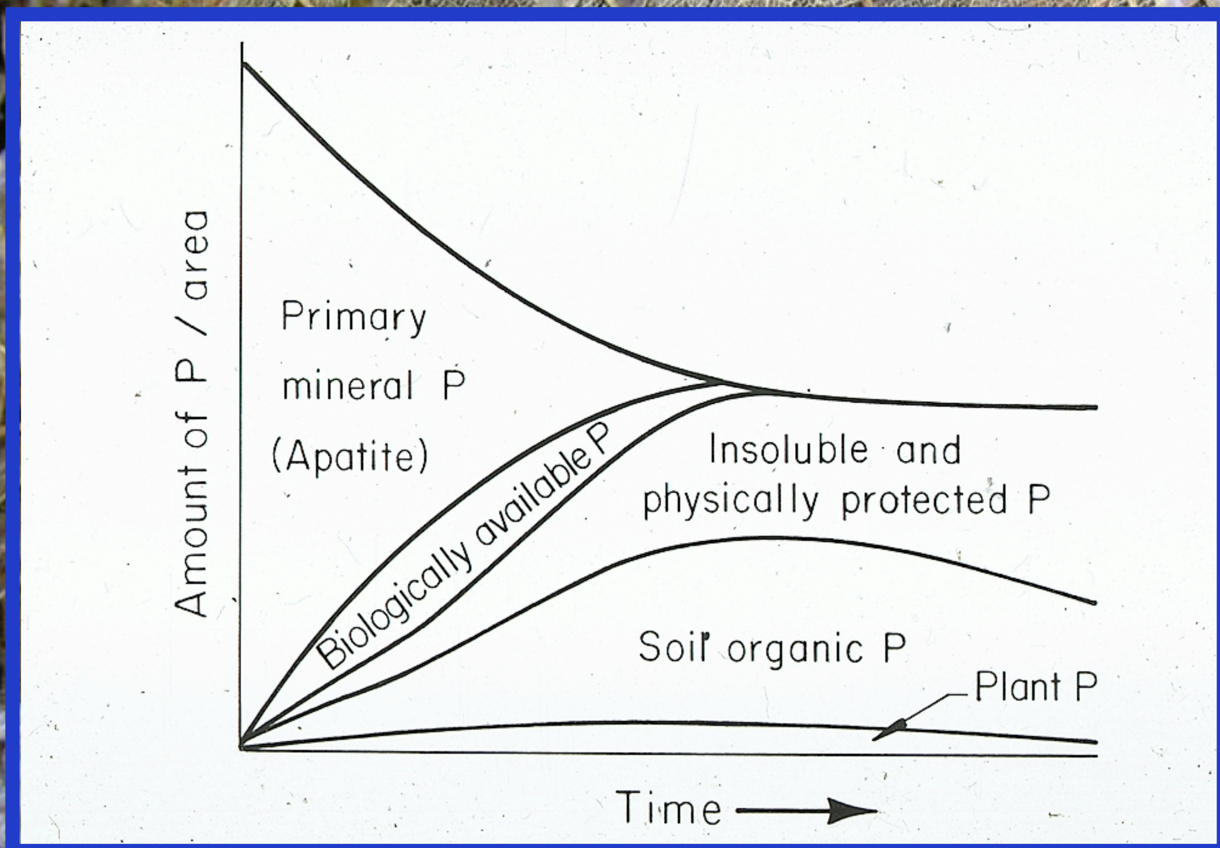
How and why does soil P content vary?



Cross and Schlesinger, 1995

How and why does soil P content vary?

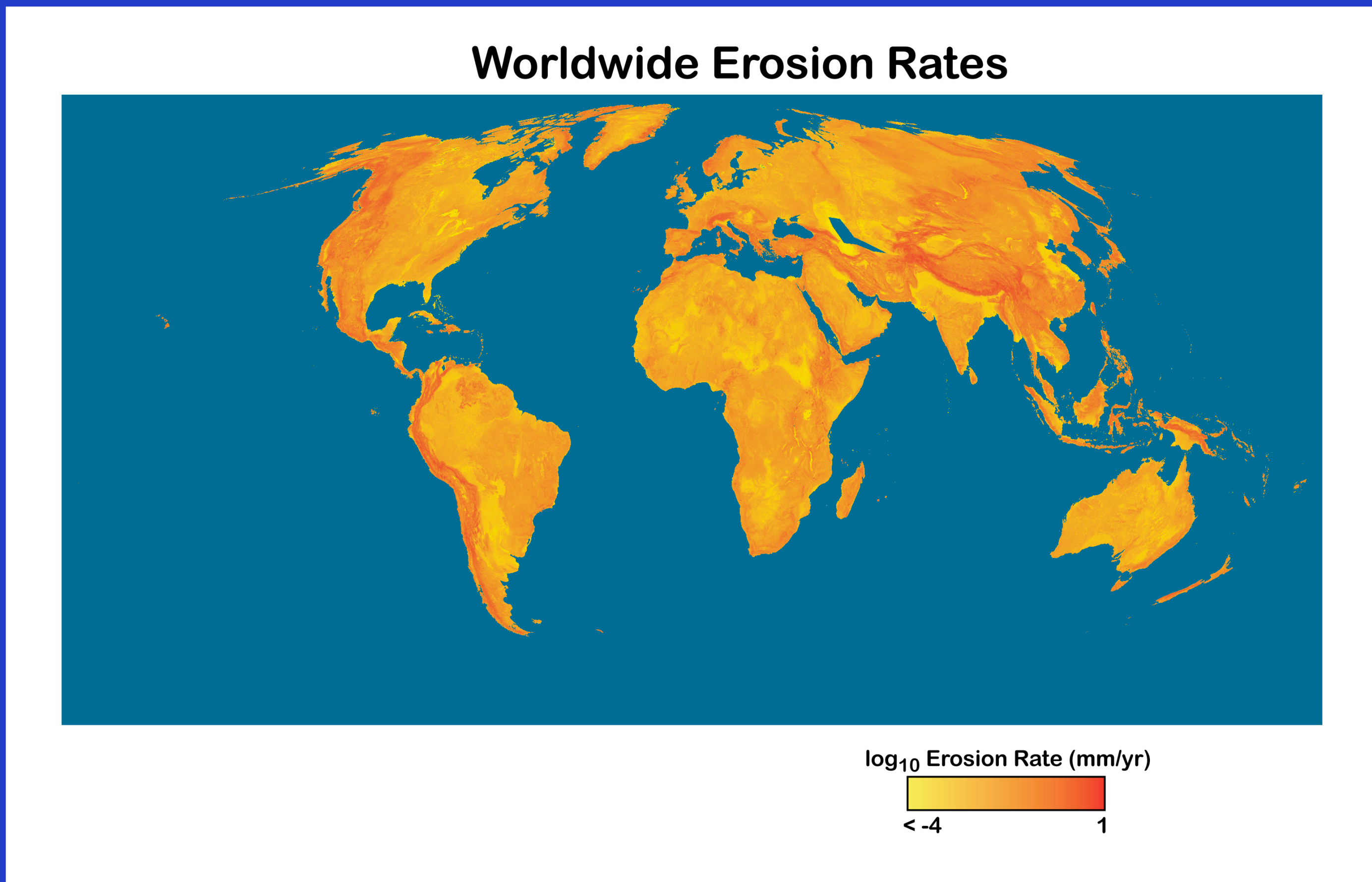
Time plays a big role in determining P status



Walker and Syers, 1976

How and why does soil P content vary?

How does "time" translate in eroding soils?



After Montgomery, 2002

How and why does soil P content vary?

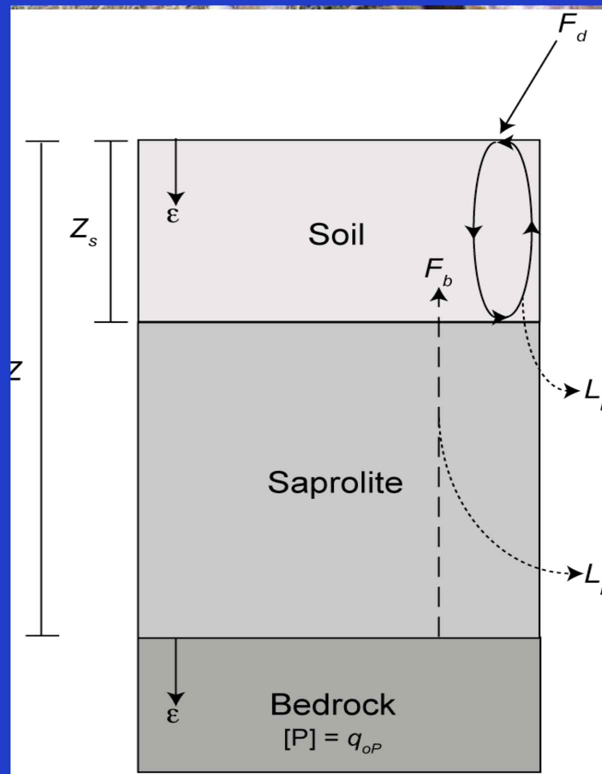
Can we use erosion in place of time to predict soil P?

Modeling Approach

Include:

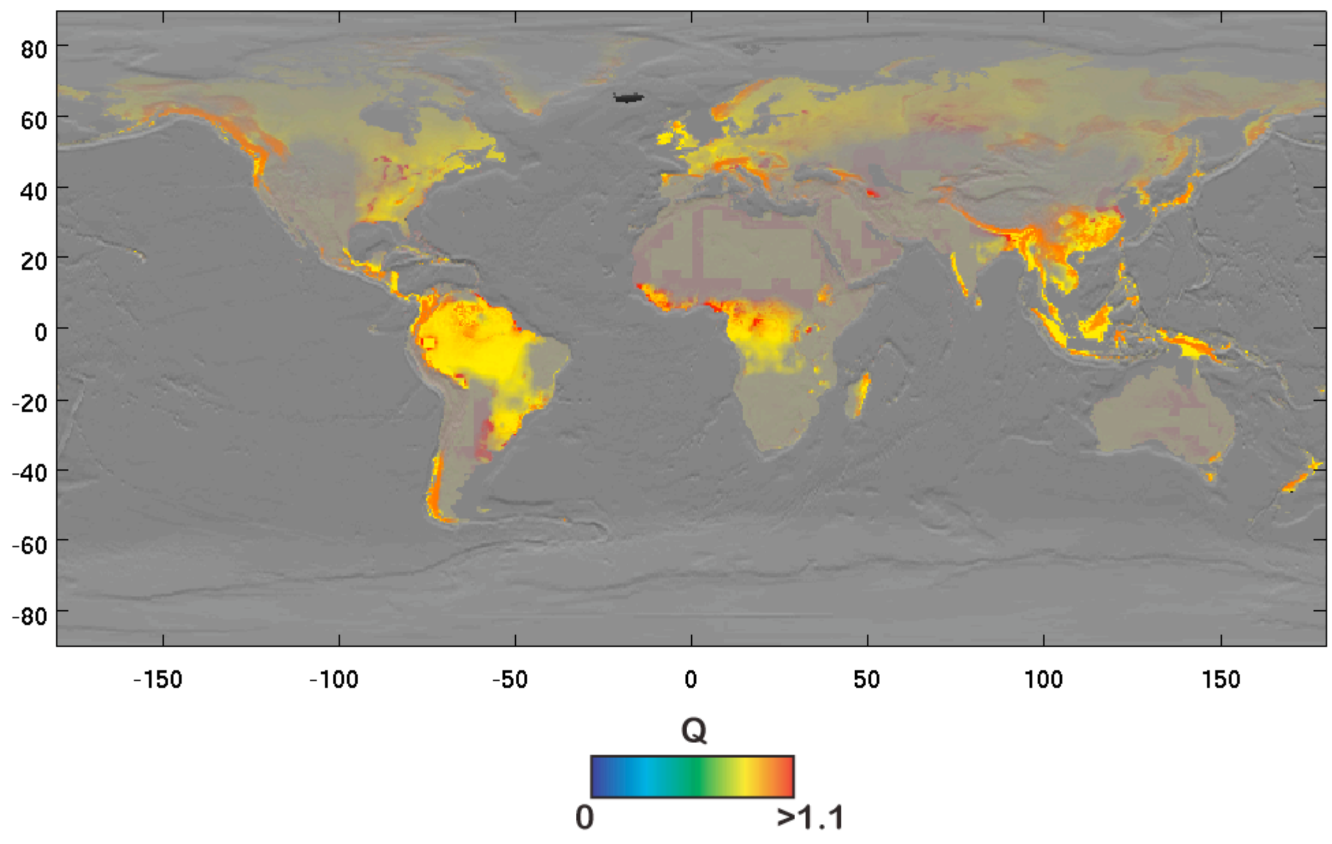
- Erosion rate
- Weathering zone thickness
- P deposition
- P leaching (currently one size fits all)
- Rock P content (currently one size fits all)

Solve for Q - [Soil P]/[Rock P]



Porder and Hilley, submitted

How and why does soil P content vary?

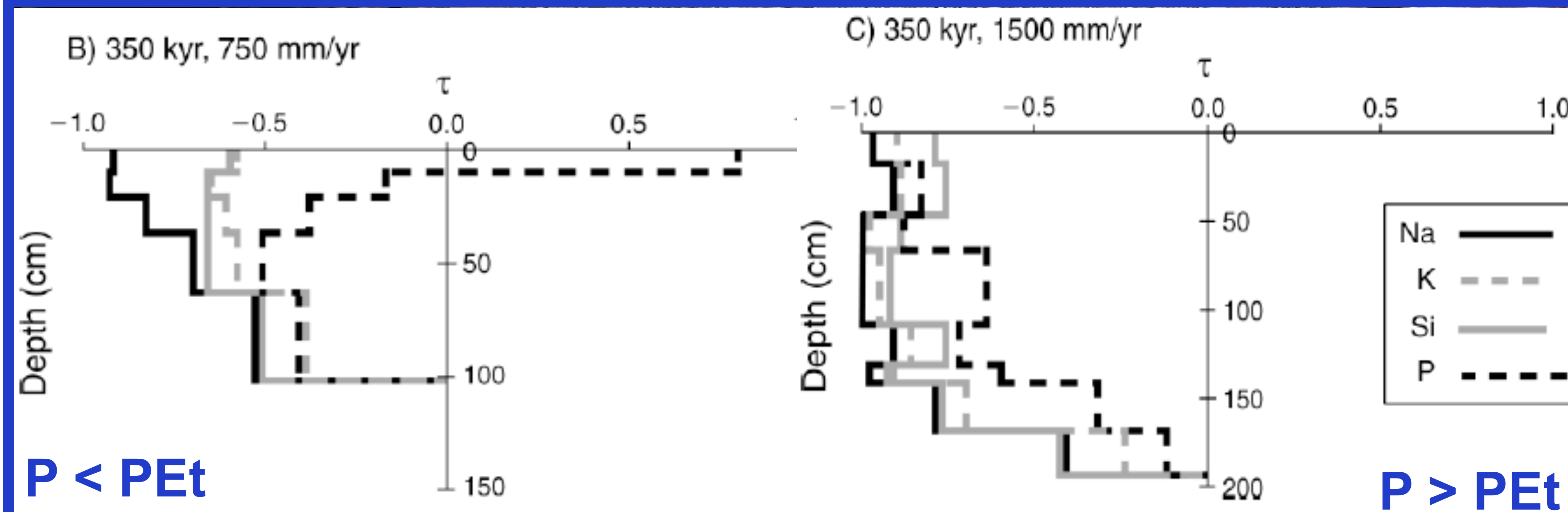


Scenarios vary because of assumptions about weathering zone thickness

Porder and Hilley (submitted)

How and why does soil P content vary?

Missing data: Loss rates



P < PEt

P > PEt

In fact leaching rate is NOT constant.

It may be more important than time in determining P status.

Porder and Chadwick, 2009

How and why does soil P content vary?

Missing data: Rock P content

Table 3.5. Composition of the bulk continental crust (see text for sources).

	%	NORM	
SiO_2	57.3	Q	6.6
TiO_2	0.9	Or	6.5
Al_2O_3	15.9	Ab	26.2
FeO	9.1	An	26.2
MgO	5.3	Di	8.7
CaO	7.4	Hy	24.1
Na_2O	3.1	Il	1.7
K_2O	1.1		
Σ	100.1		

Li	13 ppm	Ni	105 ppm	In	50 ppb	Er	2.2 ppm
Be	1.5 ppm	Cu	75 ppm	Sn	2.5 ppm	Tm	0.32 ppm
B	10 ppm	Zn	80 ppm	Sb	0.2 ppm	Yb	2.2 ppm
Na	2.30%	Ga	18 ppm	Cs	1.0 ppm	Lu	0.30 ppm
Mg	3.20%	Ge	1.6 ppm	Ba	250 ppm	Hf	3.0 ppm
Al	8.41%	As	1.0 ppm	La	16 ppm	Ta	1.0 ppm
Si	26.77%	Se	0.05 ppm	Ce	33 ppm	W	1.0 ppm
K	0.91%	Rb	32 ppm	Pr	3.9 ppm	Re	0.5 ppb
Ca	5.29%	Sr	260 ppm	Nd	16 ppm	Ir	0.1 ppb
Sc	30 ppm	Y	20 ppm	Sm	3.5 ppm	Au	3.0 ppb
Ti	5400 ppm	Zr	100 ppm	Eu	1.1 ppm	Tl	360 ppb
V	230 ppm	Nb	11 ppm	Gd	3.3 ppm	Pb	8.0 ppm
Cr	185 ppm	Mo	1.0 ppm	Tb	0.60 ppm	Bi	60 ppb
Mn	1400 ppm	Pd	1.0 ppb	Dy	3.7 ppm	Th	3.5 ppm
Fe	7.07%	Ag	80 ppb	Ho	0.78 ppm	U	0.91 ppm
Co	29 ppm	Cd	98 ppb				

Taylor and McClenan, 1985

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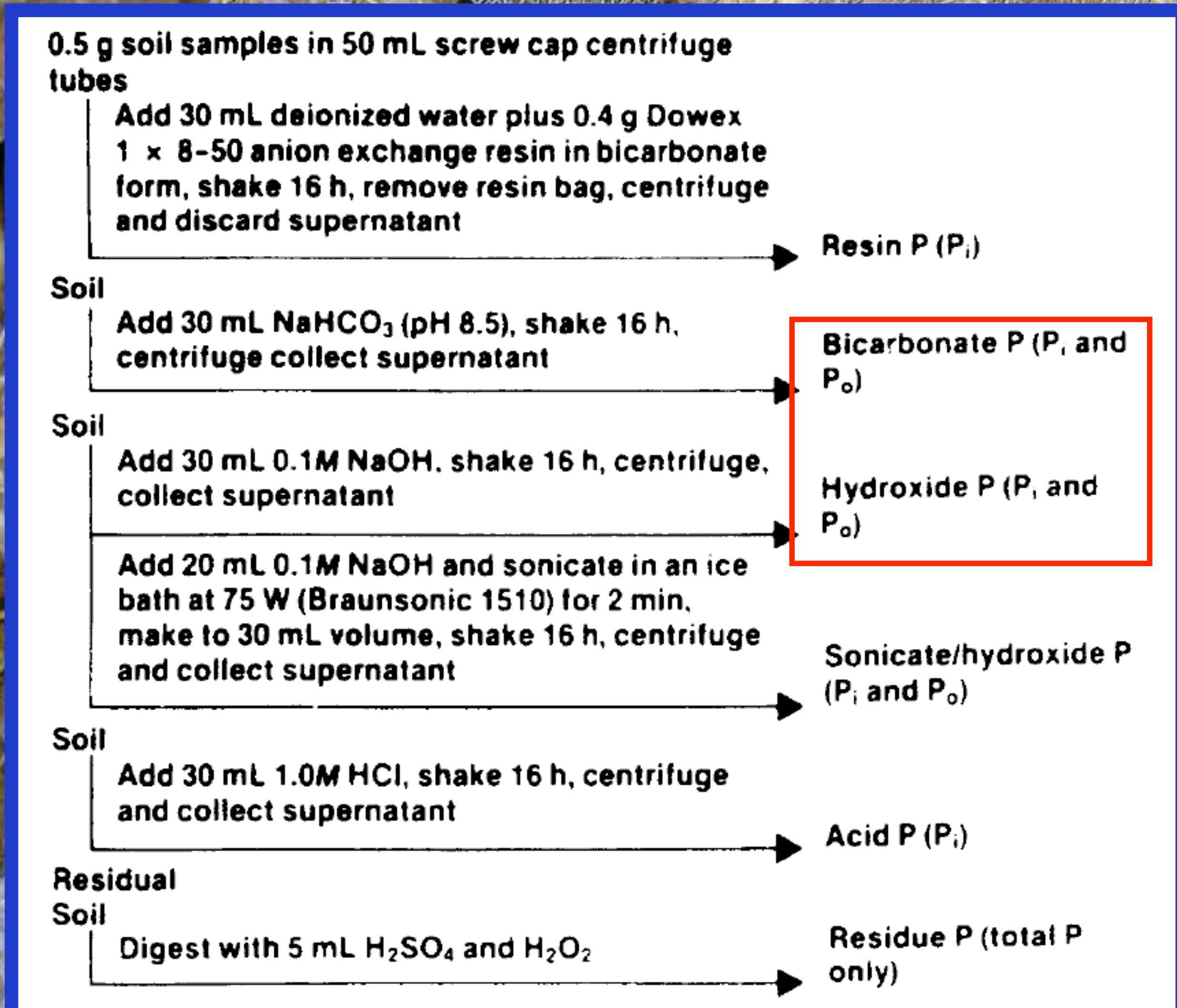
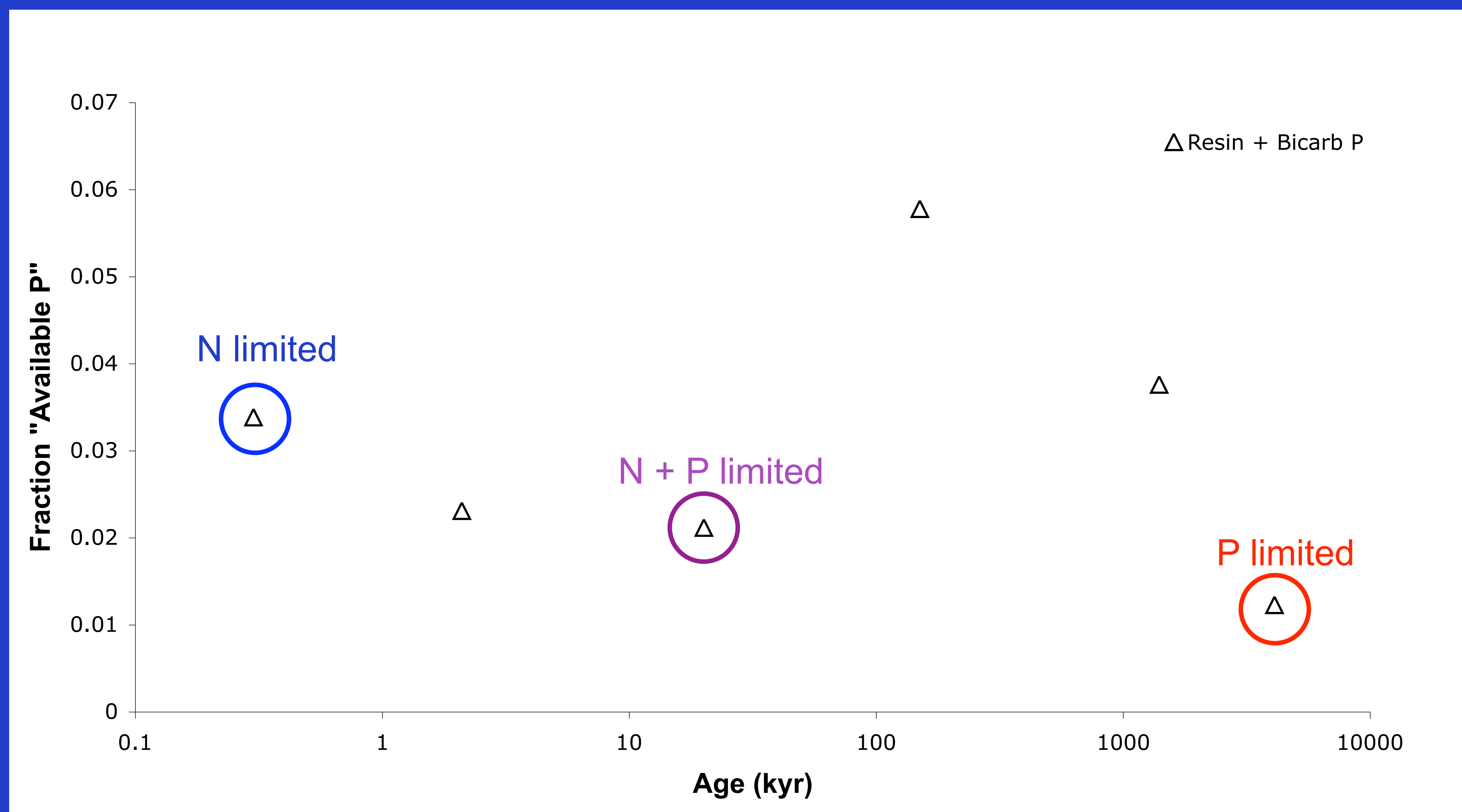


Fig. 1. Hedley sequential phosphorus fractionation method for soils (after Tiessen et al., 1984).

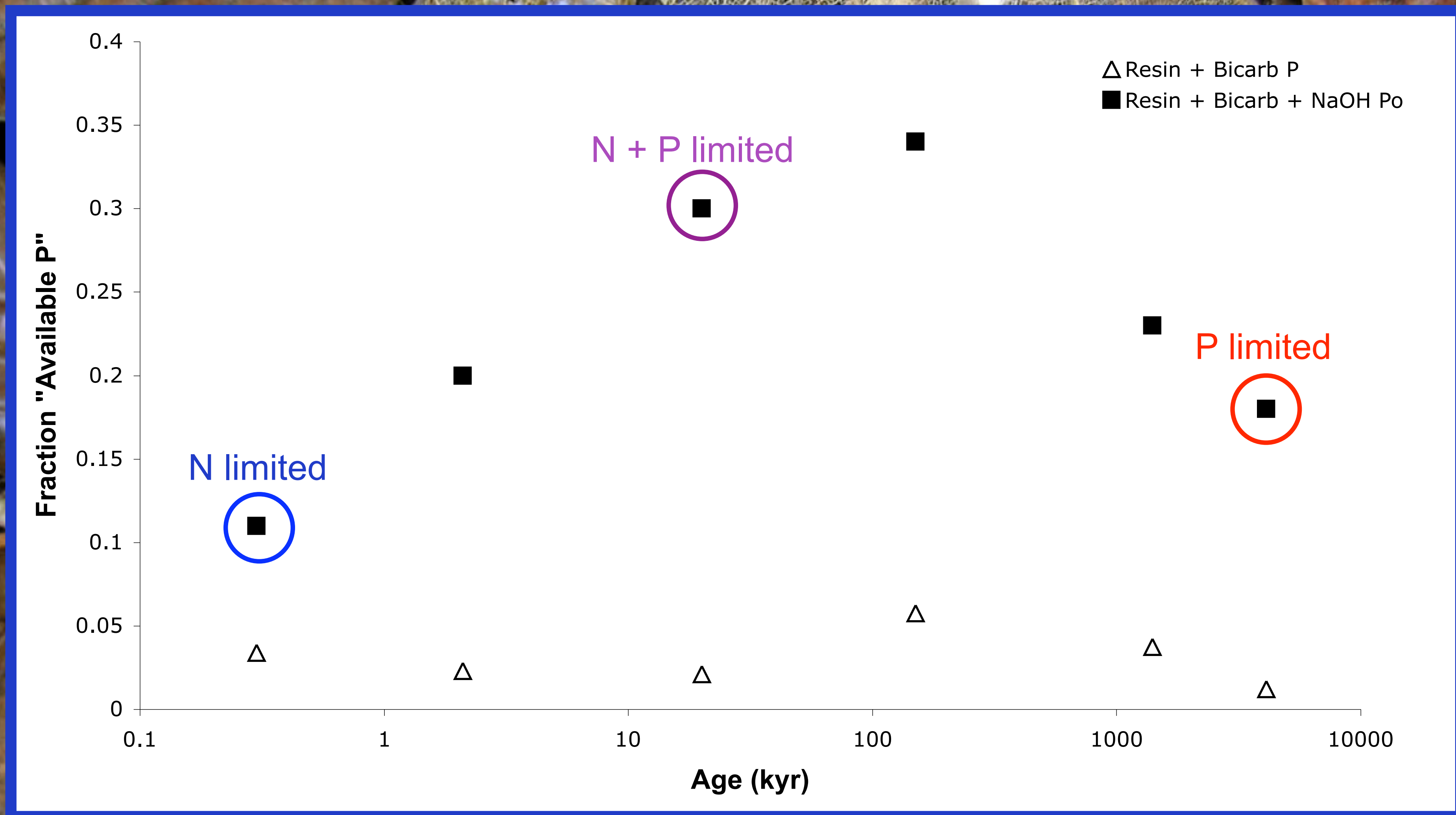
Cross and Schlesinger, 1995

What P forms are biologically available?



Data from Tim Crews

What P forms are biologically available?



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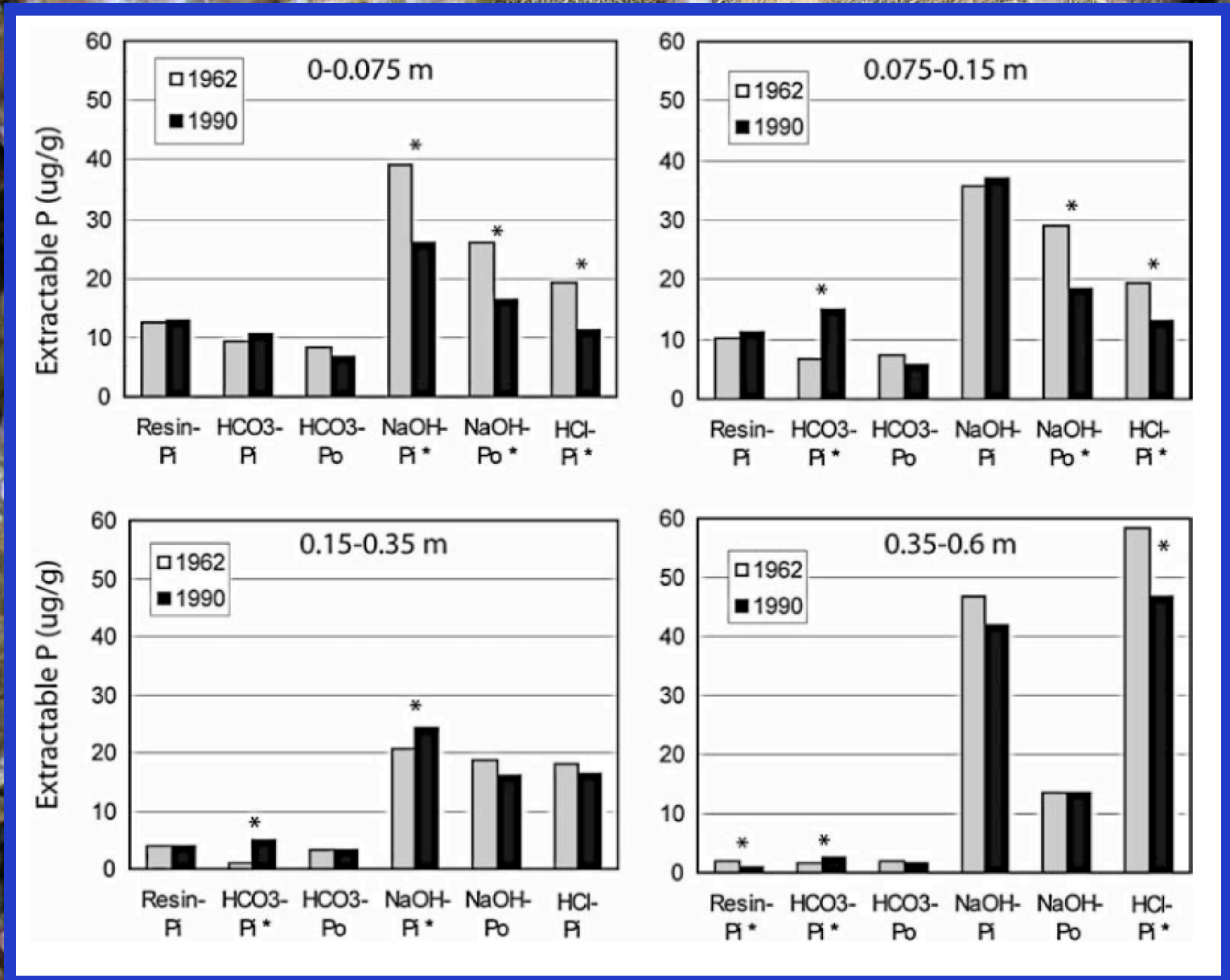

Calhoun experimental forest planted w/seedlings in 1962

Richter et al, 2006

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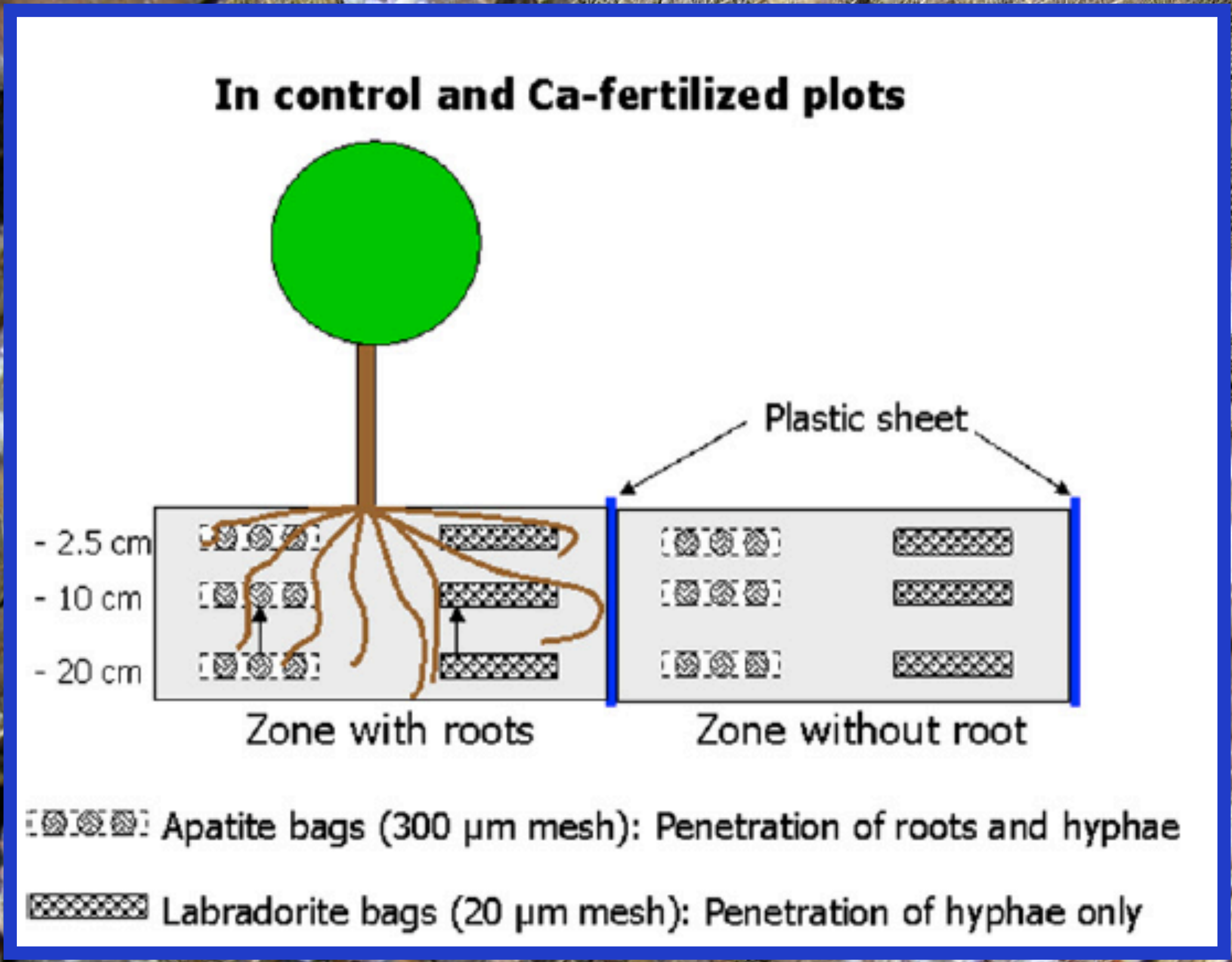
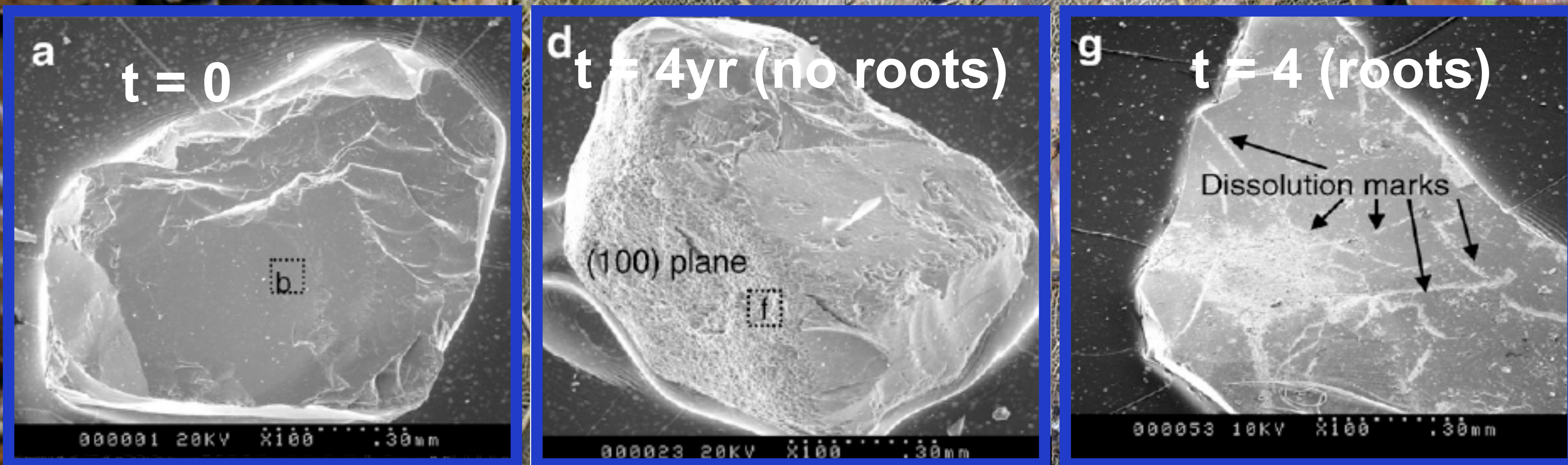


Marie-Pierre et al., 2009

What P forms are biologically available?



- Is fungal mining the P equivalent of N fixation?
- What determines how long apatite stays around?

Marie-Pierre et al., 2009

Potential Directions

Agriculture:

- A review of P binding capacities of Oxisols and Ultisols, coupled with assessments of likely farm expansion and readily available P deposits.

Limiting nutrient (?):

- Revisiting (gathering new) chronosequence data to get a handle on P depletion rates in different climate zones.

- Experiments that get at availability/turnover times for P.

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