

9th INTECOL conference, Orlando

Uncertain Supplies, Shifting Demands, and the Sustainability of the Human Phosphorus Cycle

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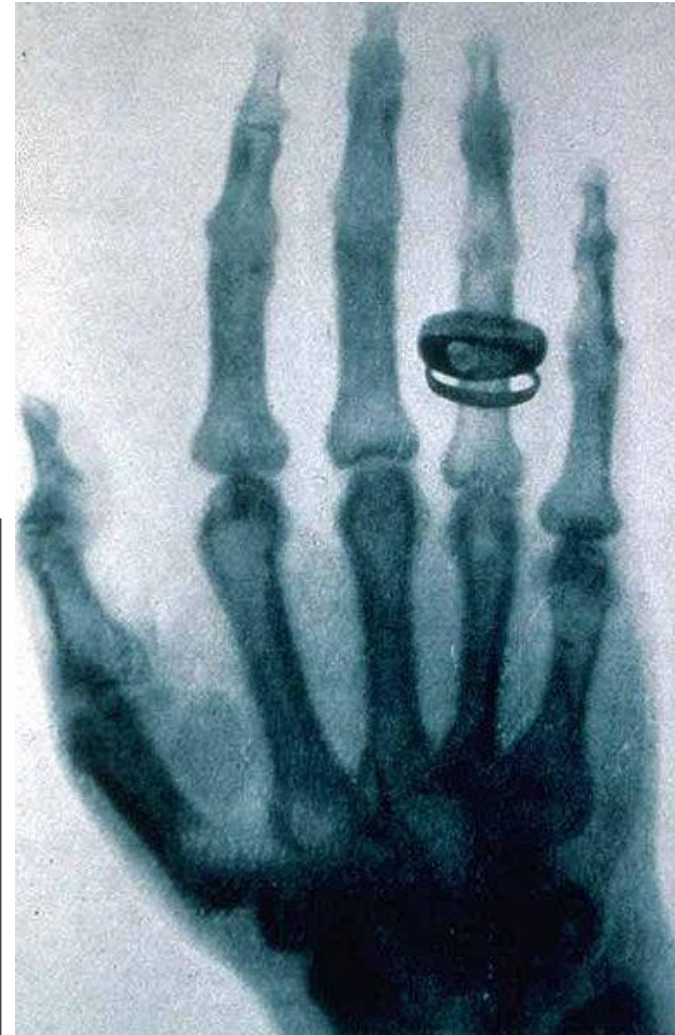
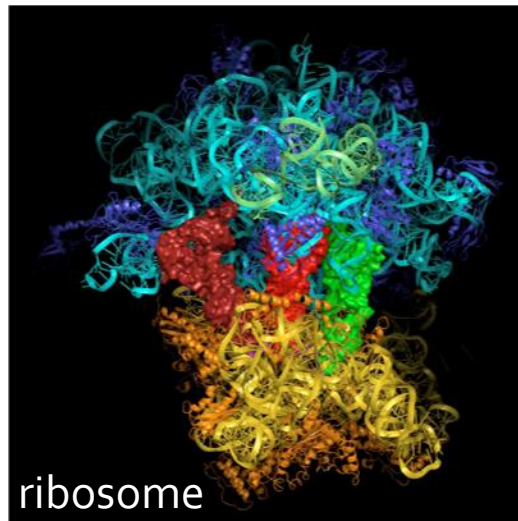
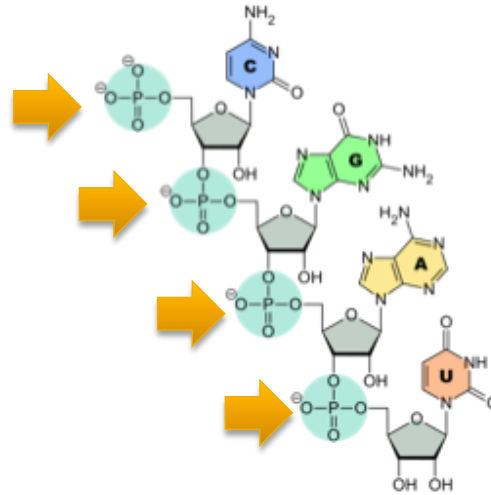
Genevieve Metson

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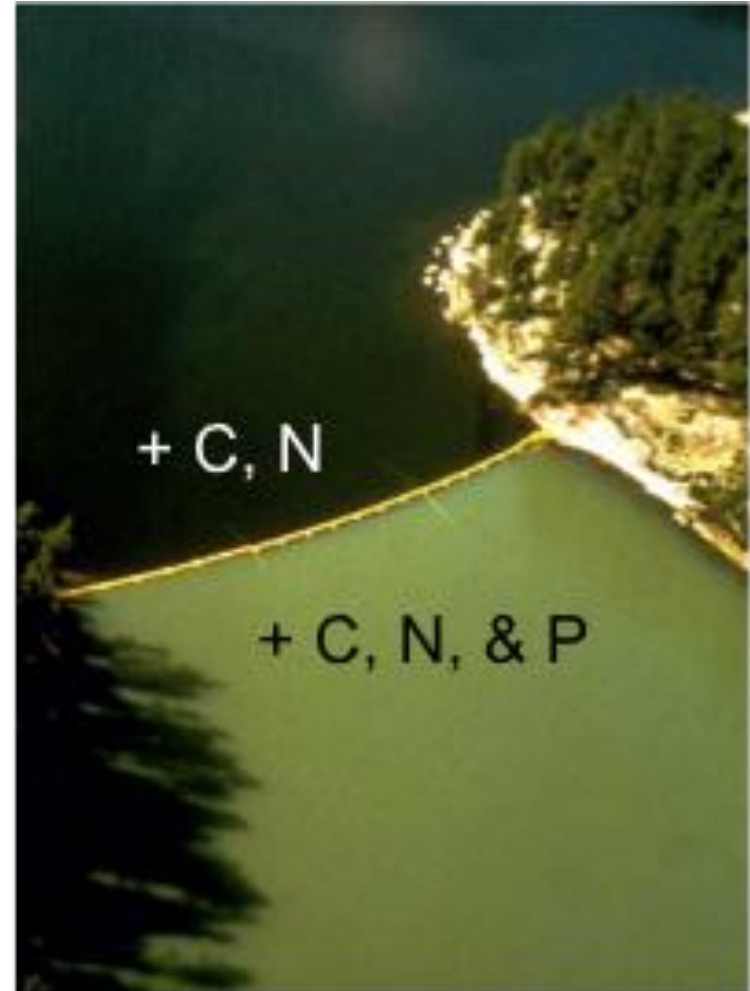
P is essential

- for organisms.



P is limiting

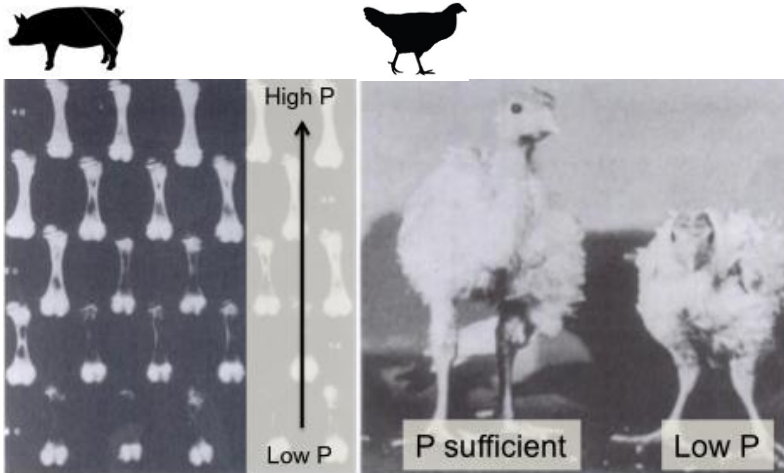
- in ecosystems



Source: E.D. DeBruyn (DFO)

P is limiting

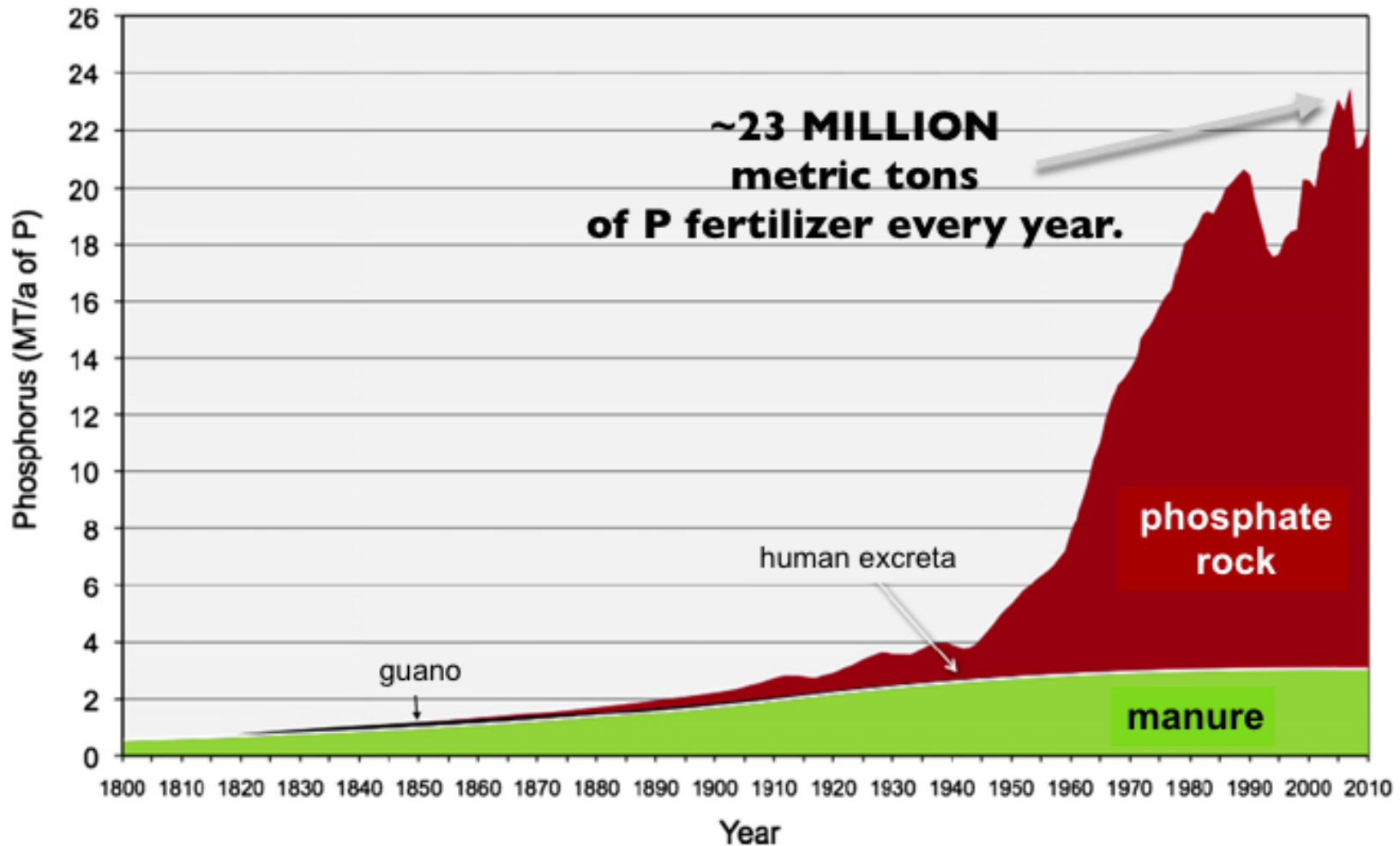
- in ecosystems, including farms.



Source: McDowell (2000)

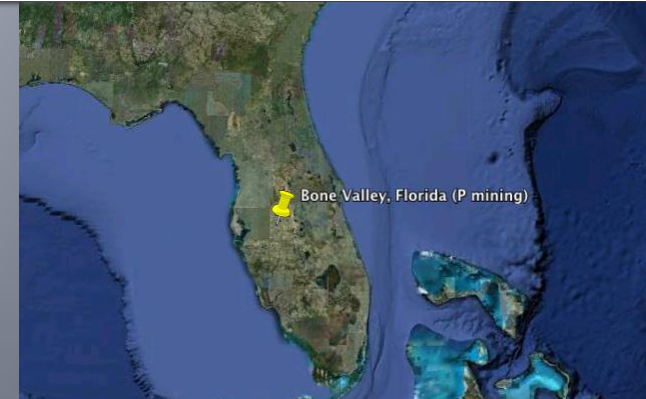
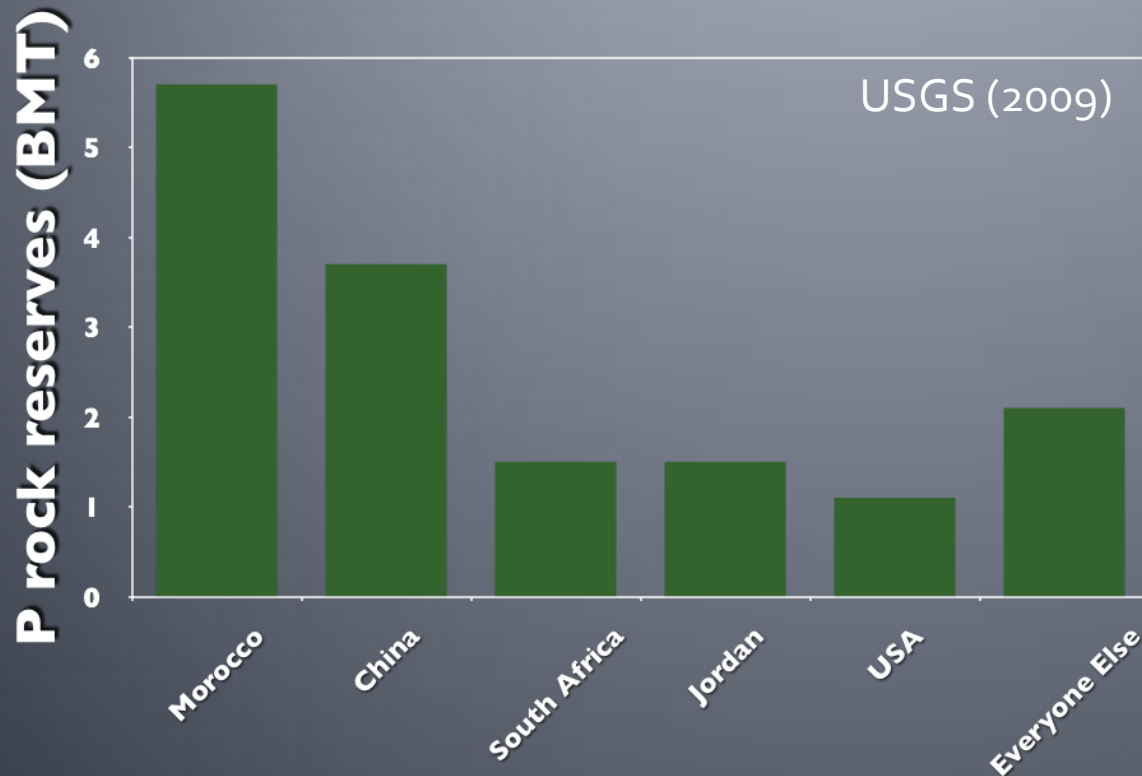


P is mined at increasing rates.



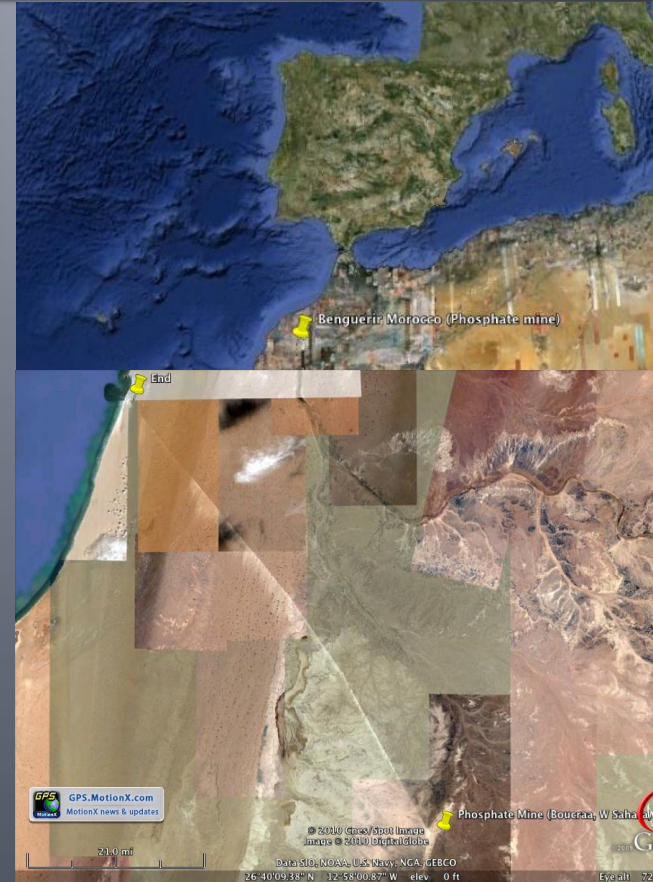
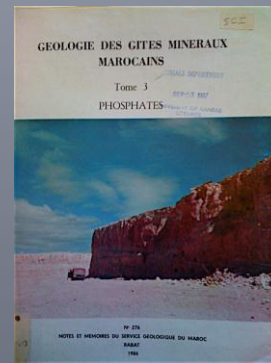
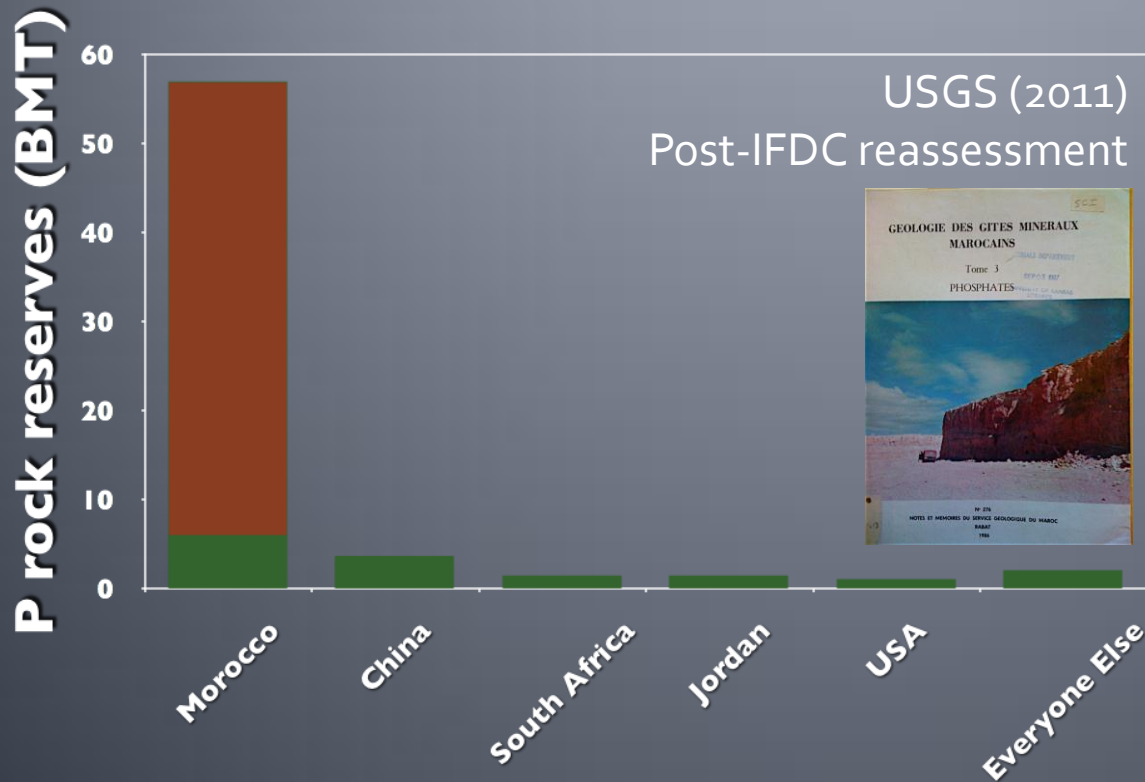
How much P do we have?

It's surprisingly uncertain!



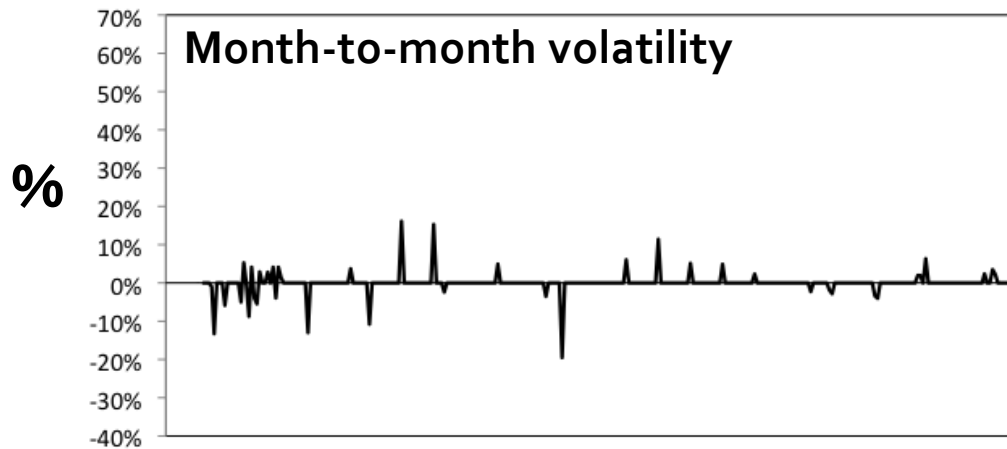
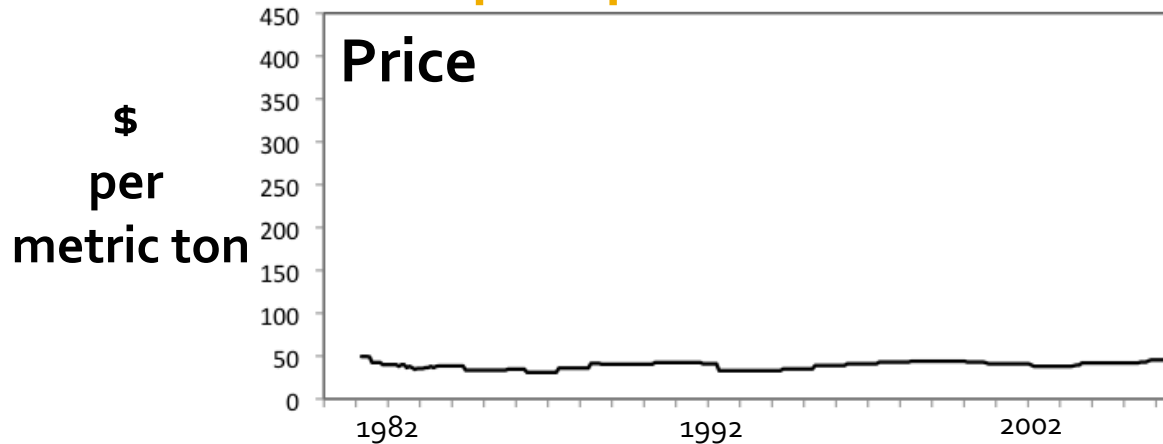
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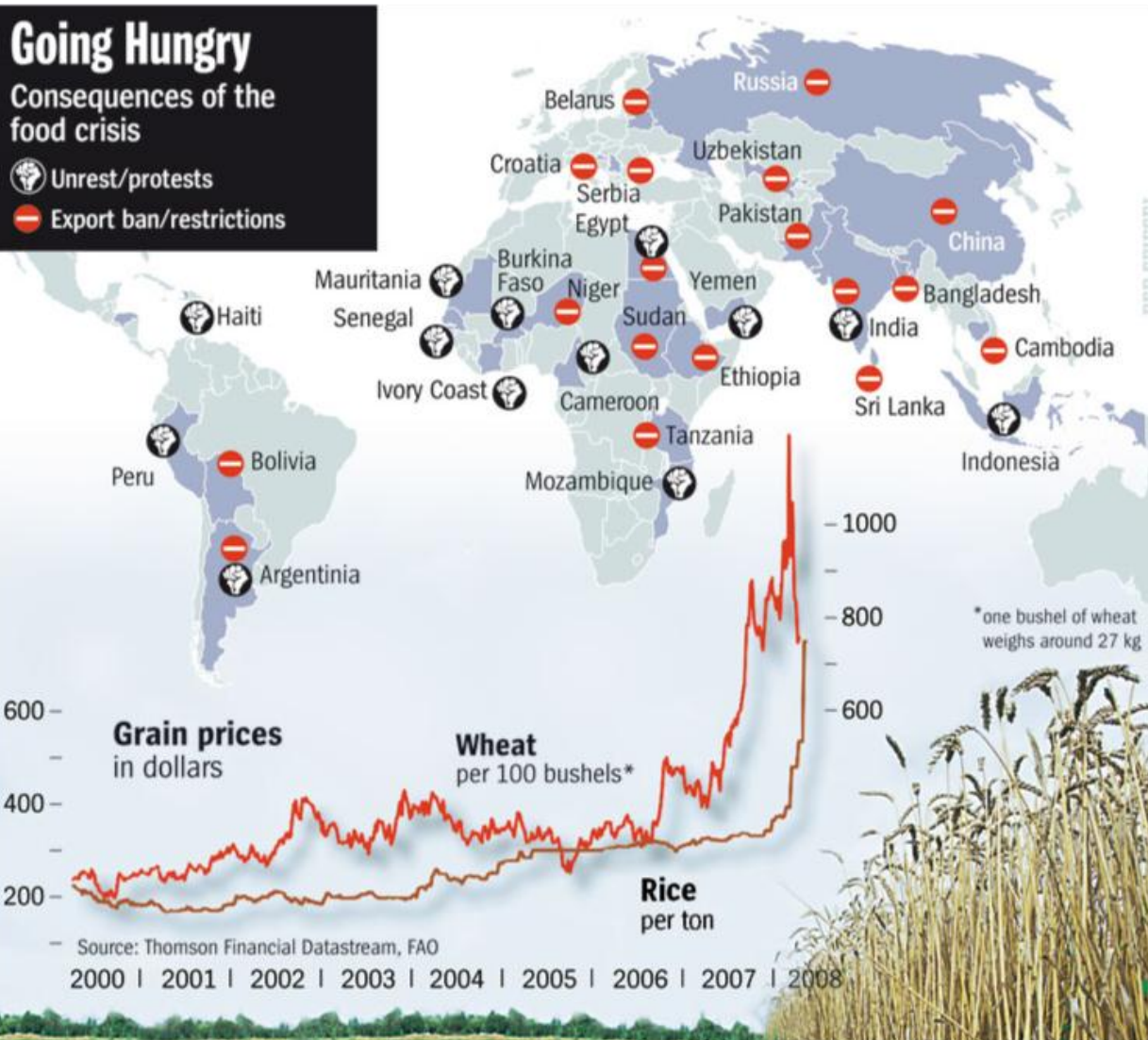


P is getting costly and unpredictable.

Rock phosphate



This might be a problem.



Der Spiegel (2008)

What about the future?

On the decrease side:

Soil P saturation Many developed world soils are now P-saturated and can probably lower P application w/o reduced yield.

Overapplication Rates of P application in some regions, e.g. China, can probably be scaled back w/o reducing yield.

On the increase side:

Population Estimates indicate that, to achieve global food security in 2050, food production will need to *double*.

Growing affluence Meat consumption is increasing as developing countries become more affluent. Meat is P intensive.

Bioenergy In 2009, ~10% of all USA P fertilizer use was for corn grown for ethanol production.

Non-agricultural use The lithium-iron-phosphate batteries in an electric car contain 60 kg P.

How does diet affect P demand?

GOAL: Assess the contribution of **shifting dietary composition**, especially changing consumption of meat, to increasing human P use at global, regional, and national scales.

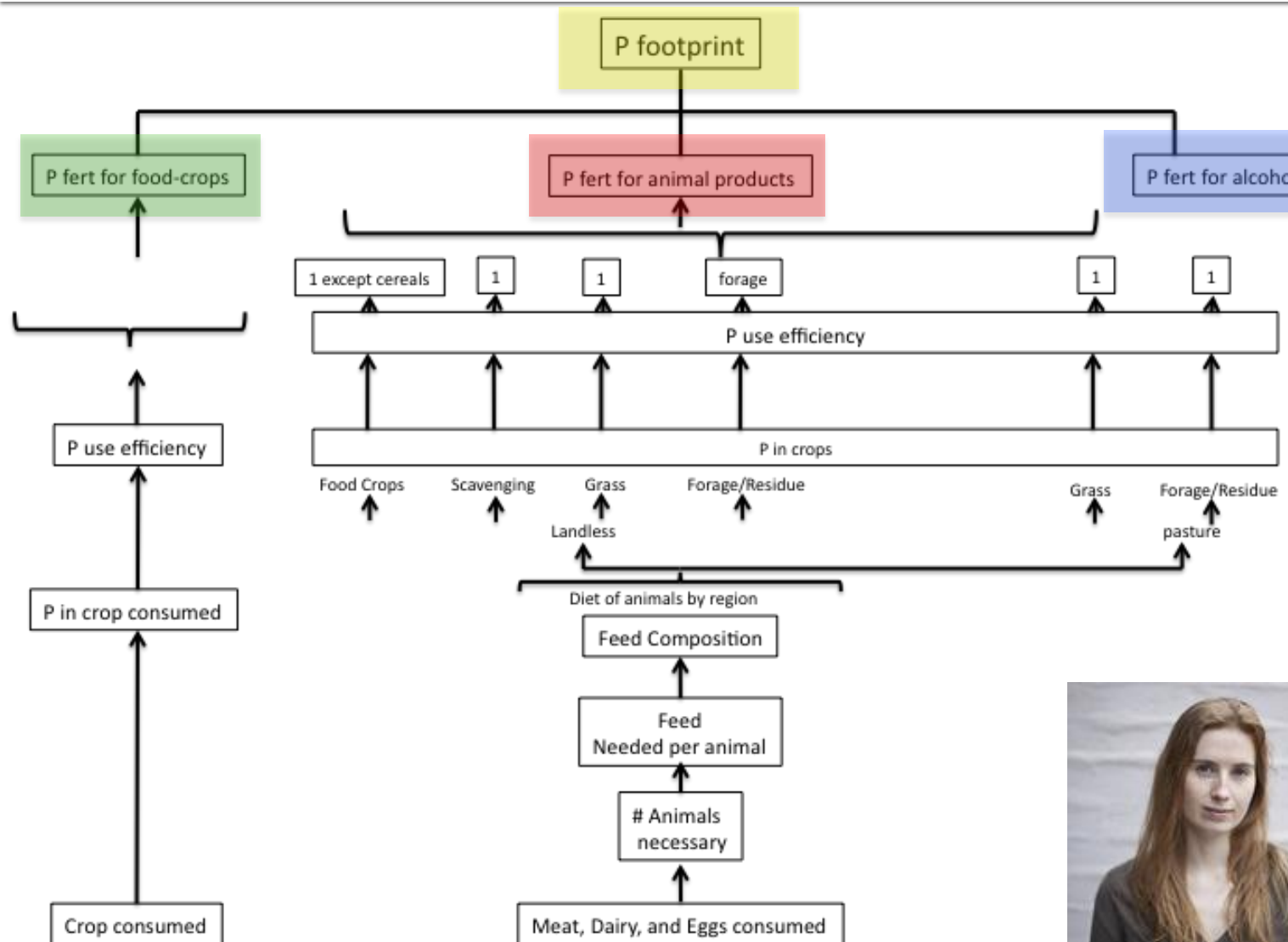
WHAT:

- Quantified changes in diet, population, and **P footprint** (equation coming) for a globally distributed set of countries (~165) 1961 vs. 2007.
- Also for 19 countries for each year between 1961 and 2007.

HOW:

- Starting with the *per capita* availability of a food crop or animal product, we created conversion factors to determine the relationship between the amount of P in the product consumed and the P needed to grow the inputs for that crop or product.
- To isolate the role diet plays in aggregate P demand, we used a global phosphorus use efficiency (PUE, expressed as P in plant/P applied to plant) average by crop (or group of crops) and kept this PUE constant through time.

How to calculate P footprint?



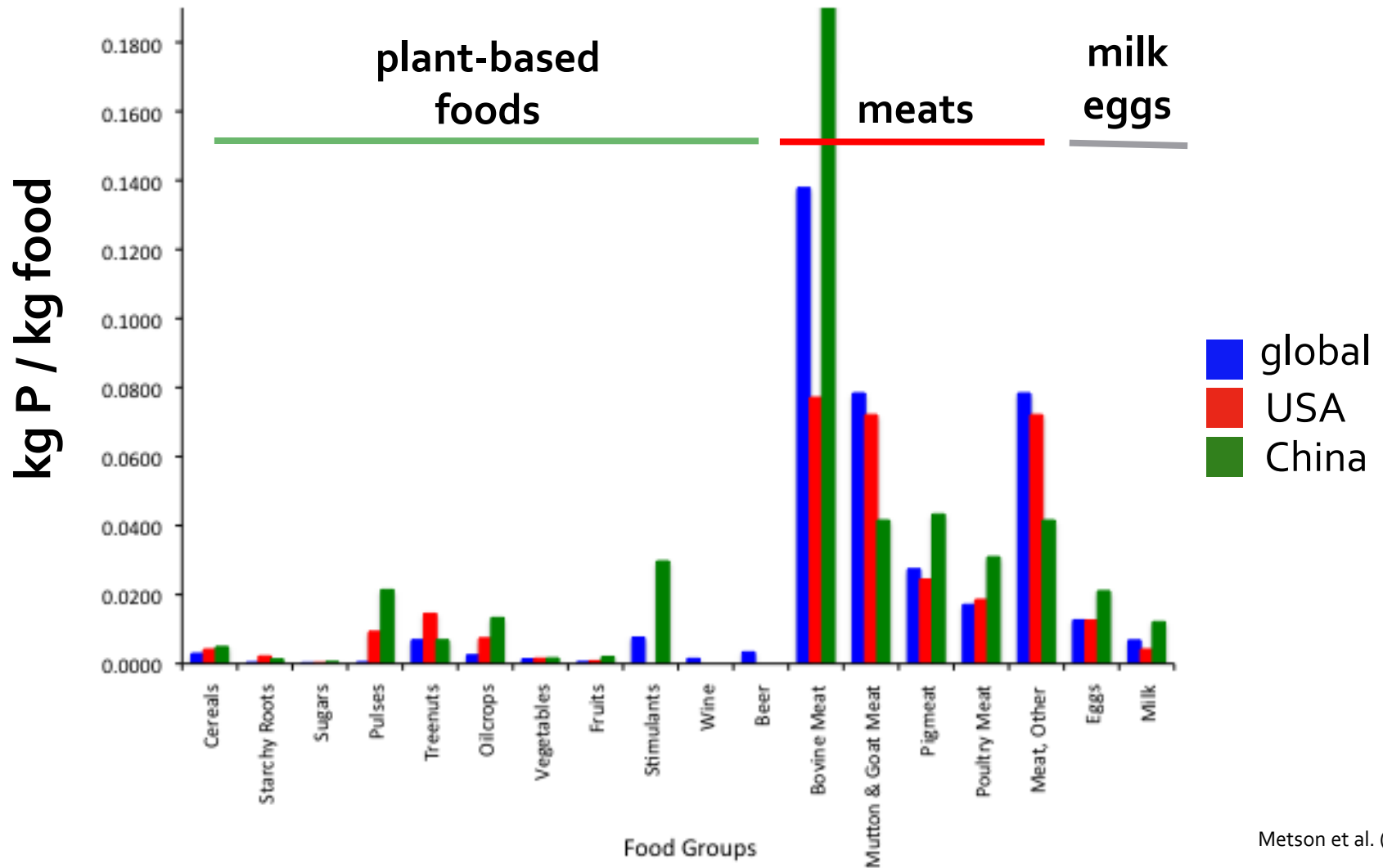
$$\begin{aligned}
 & \text{sum}P_p \\
 & + \\
 & \text{sum}P_m \\
 & + \\
 & \text{sum}P_a \\
 & = \\
 & \text{P-consumed}
 \end{aligned}$$

Then express as *per capita*.



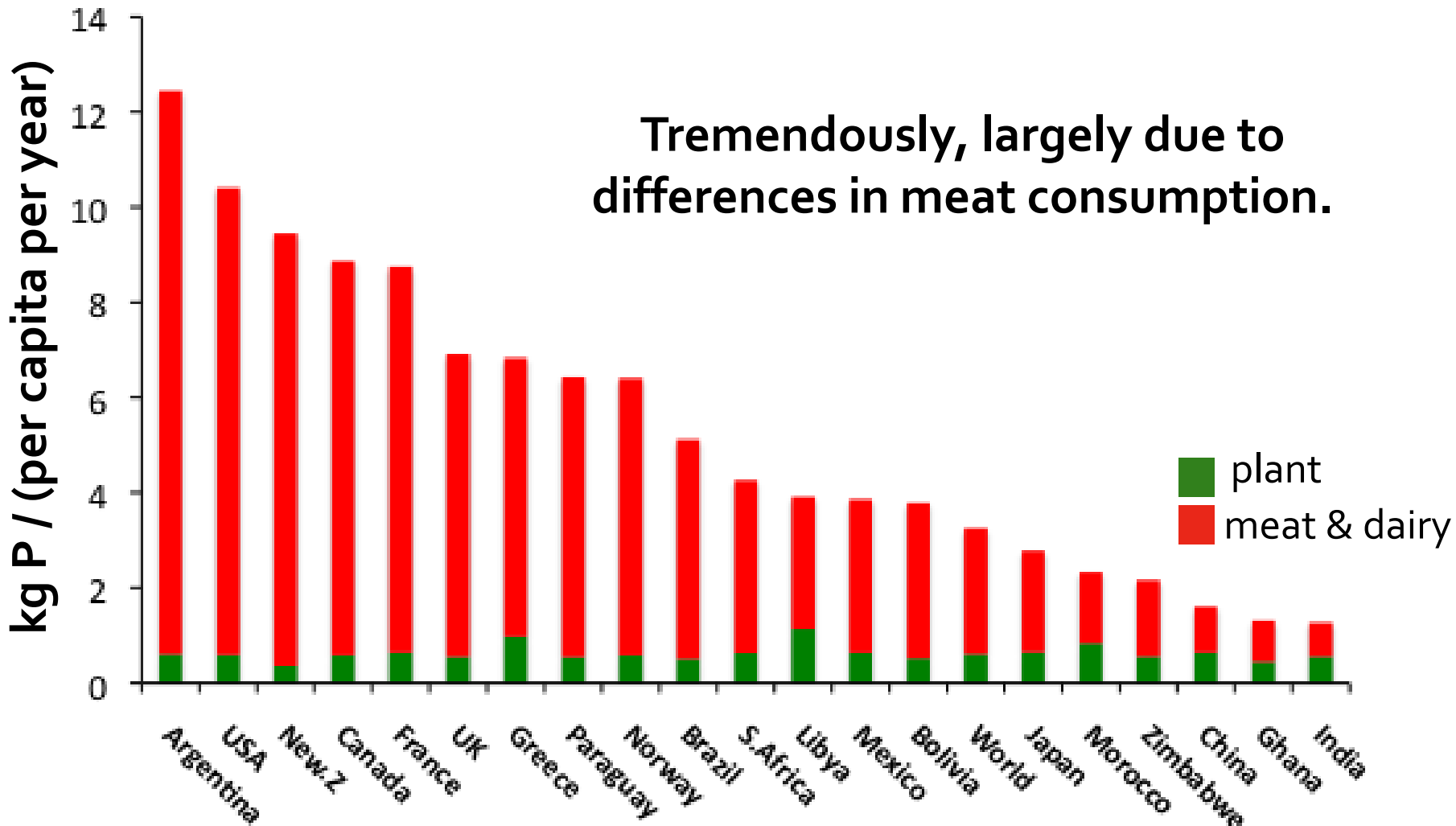
Gen Metson

How does P intensity vary for different foods?



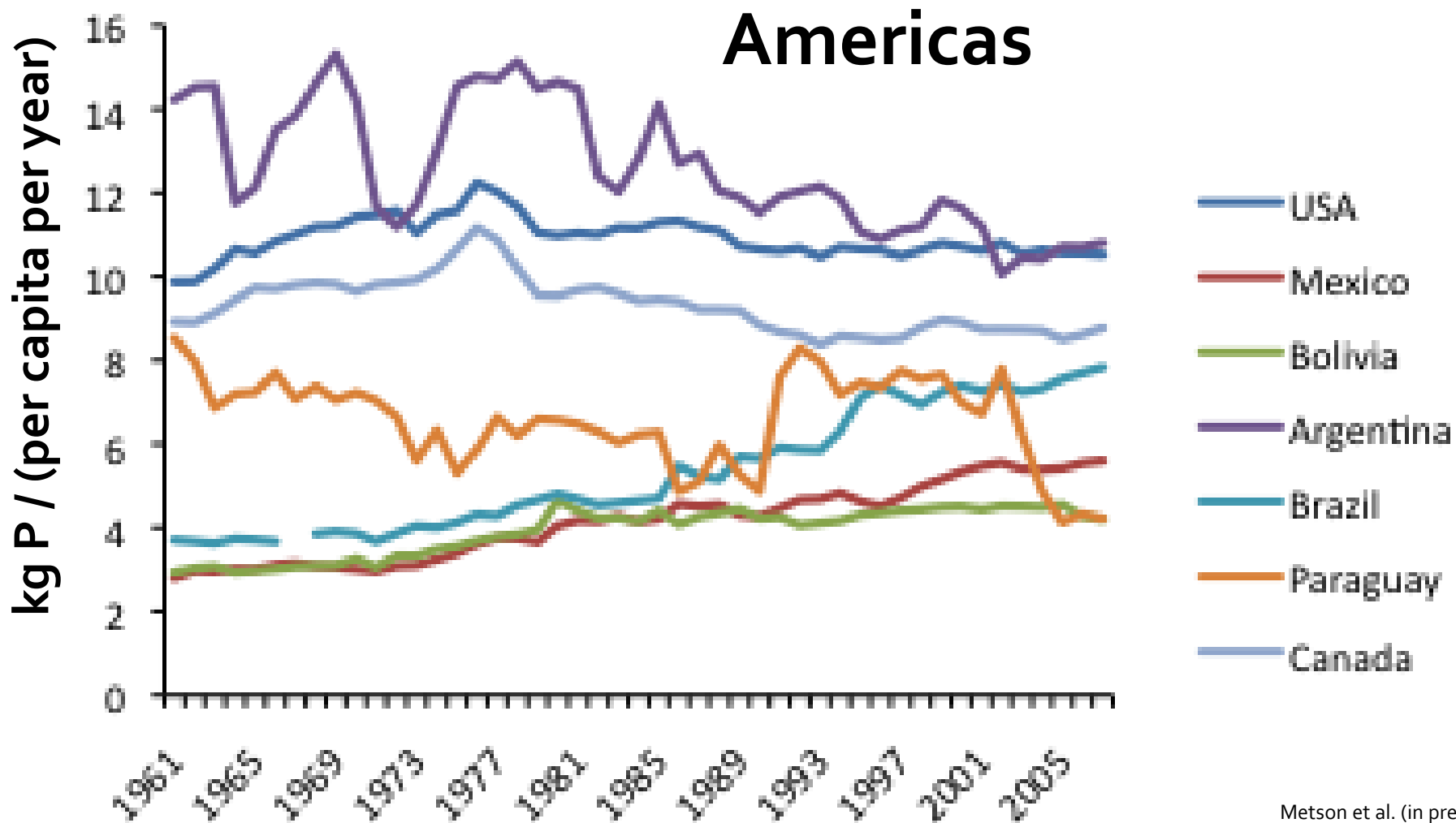
How do P footprints vary among countries?

Tremendously, largely due to differences in meat consumption.

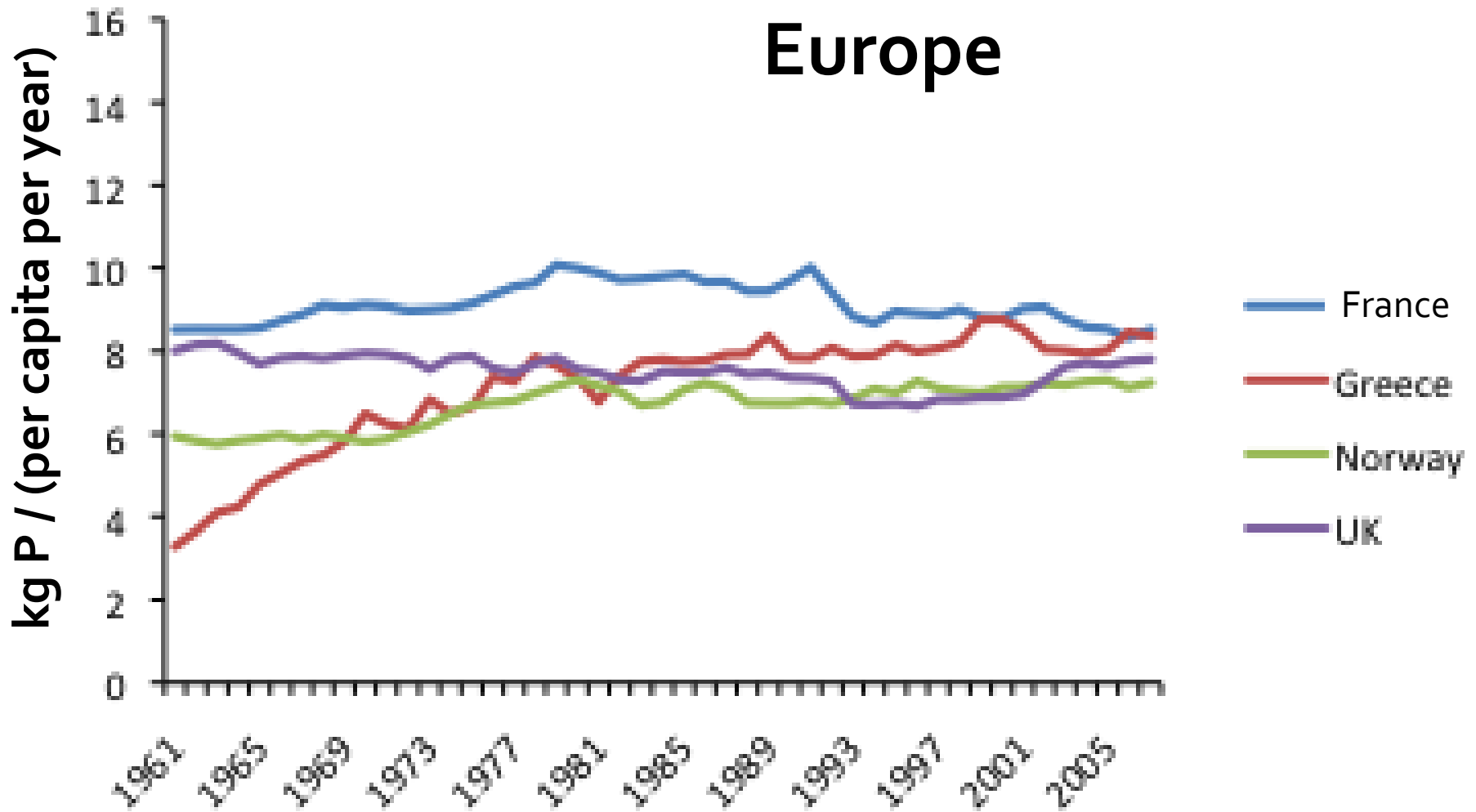


Metson et al. (in prep.)

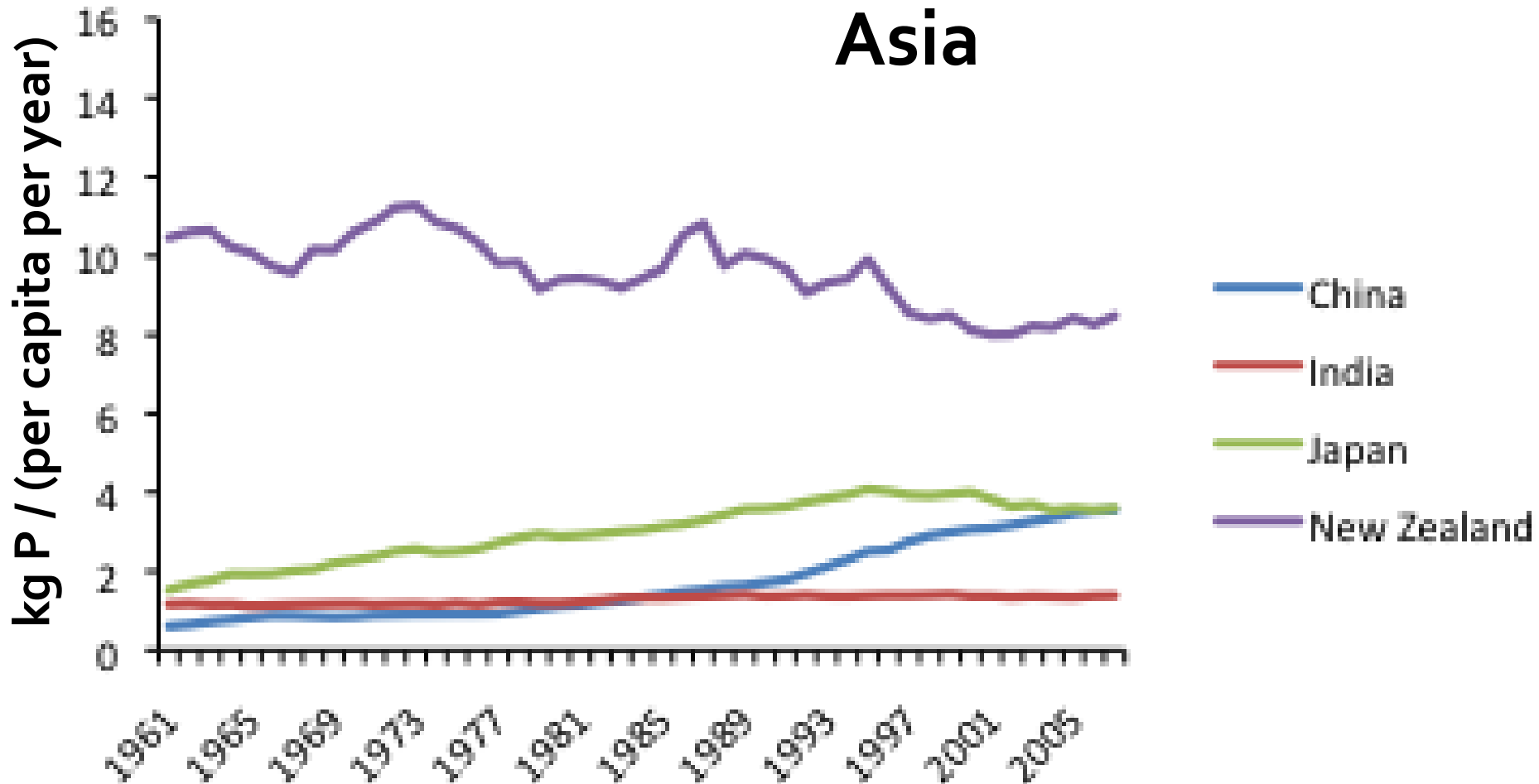
How have P footprints changed over time?



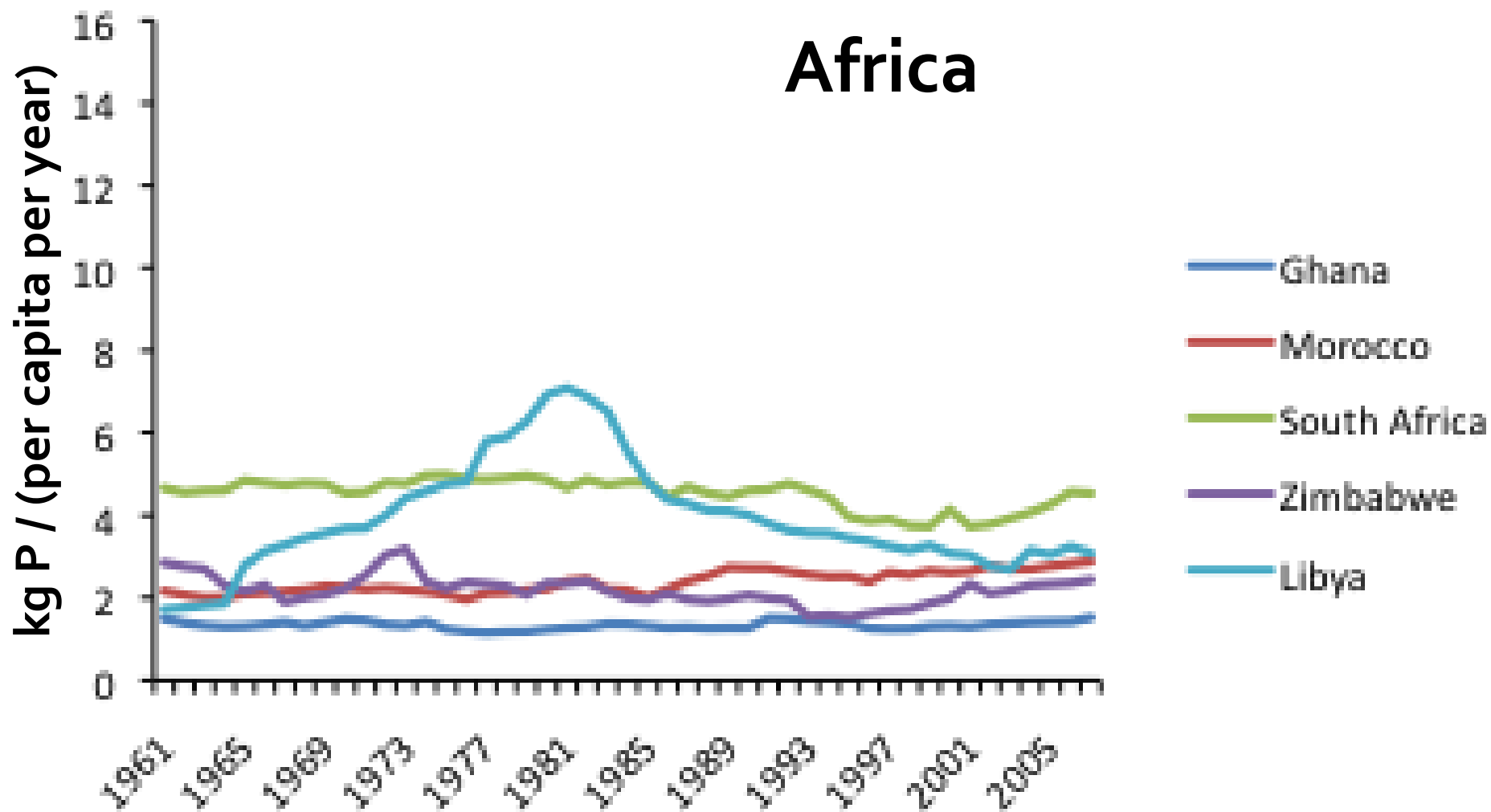
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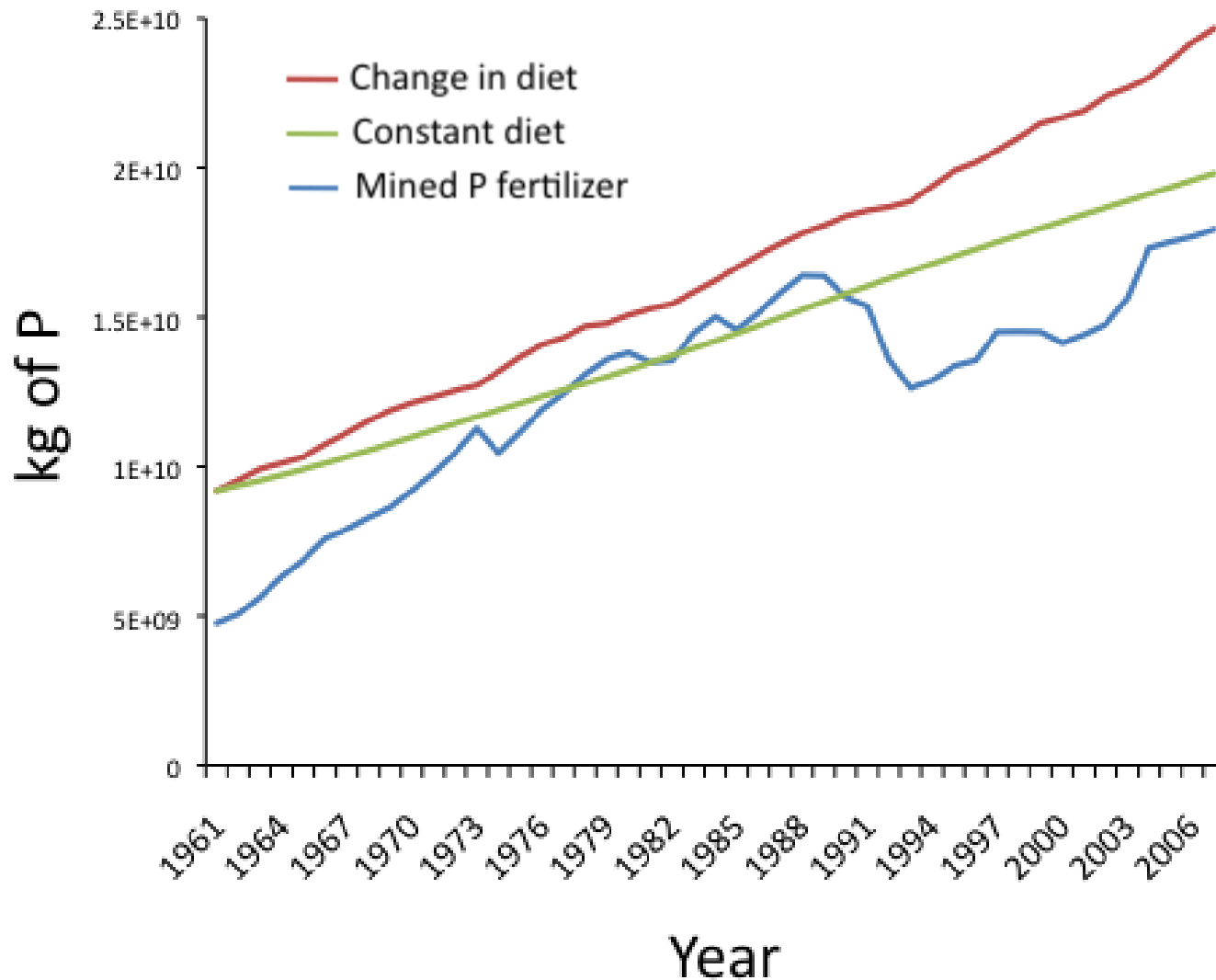
P footprints: 1961 vs 2007

Table 2. P footprints of developed and developing countries over time (N=124 in 1961 and N=128 in 2007). Statistical relationships were determined along column and row means using the Mann-Whitney U-test. P-values were considered significant if less than 0.001.

	Developed countries (mean P footprint (kg P/ capita*year))	Developing countries (mean P footprint (kg P/ capita*year))	p-value
1961	4.83	2.38	2.26E-08
2007	5.92	2.60	8.55E-15
p-value	0.002	0.134(NS)	

FINDING: Global P footprint has increased, but only in developed countries. Overall, the human P footprint has increased from 3.0 to 3.7 kg P per person per year (~23%).

How have changing diets contributed to overall changes in global P use?



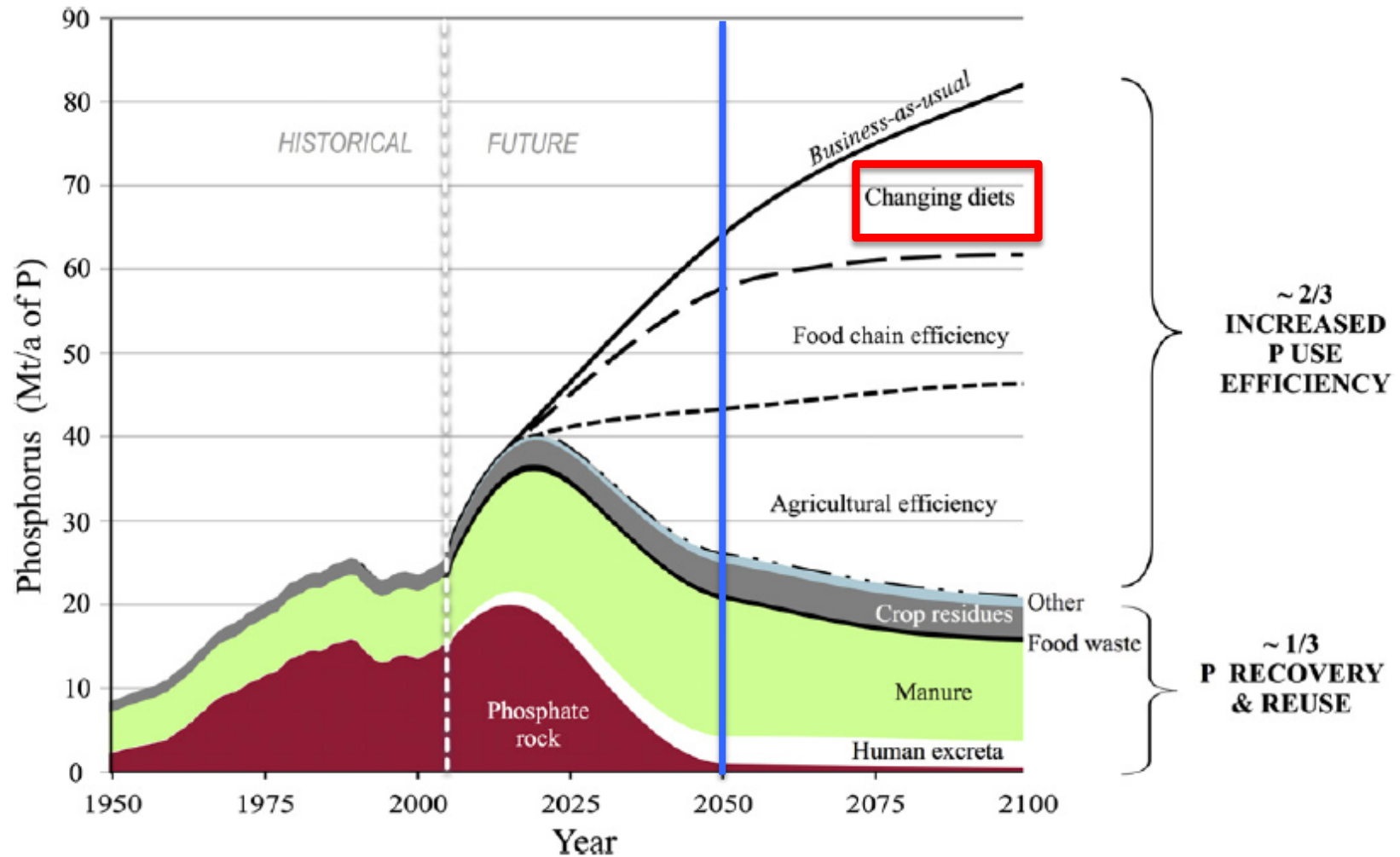
~1/3 of increased P needed for food came from dietary shifts.

Also equivalent to ~1/3 of mined P increase.

Summary

- **The P required to produce different foods varies according to farming practice and region.** However, the largest differences are associated with whether the food is plant-based (fruit, vegetable, grain) or meat.
- **P footprints vary considerably among countries,** largely due to differences in the prevalence of meat in the diet.
- **Global P use for food production has increased** since 1961; ~1/3 of this increase is due to more meat in global diets, mostly in the developed world.
- **Growing affluence** has great potential to amplify future global P demands as developing countries (e.g. China) increase their meat consumption.

Prognosis: a BIG problem for future P sustainability



Cordell, D., A. Rosemarin, J. J. Schroder, and A. L. Smit. 2011. Towards global phosphorus security: A systems framework for phosphorus recovery and reuse options. *Chemosphere* 84:747-758.

Thanks!

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