Planbureau voor de Leefomgeving

Peak phosphorus!

Is it a threat?

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Published in Global Environmental Change. Phosphorus demand for the 1970-2100 period: A scenario analysis of resource depletion. (2010) Global Environmental Change, 20 (3), pp. 428-439.

2008: Attention to phosphorus depletion takes off

Scientists warn of lack of vital phosphorus as biofuels raise demand
(Times June 2008)

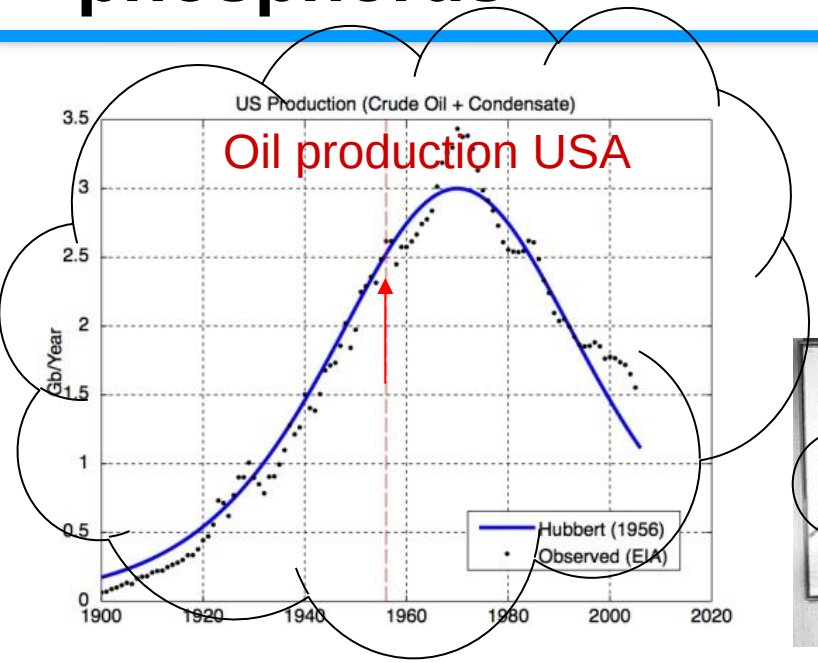
Phosphorus depletion: the invisible crisis

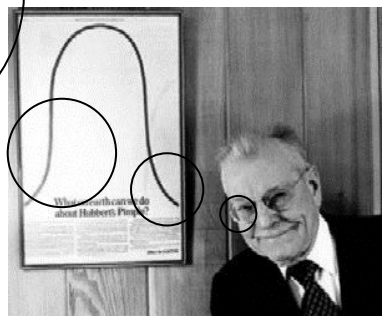
Some initial analyse … h the Global Phosphorus Researc… that there will not be sufficien… s from mining to meet agri… 30 to 40 years.
(Foreign Policy)

Should we not have a look whether this is correct?

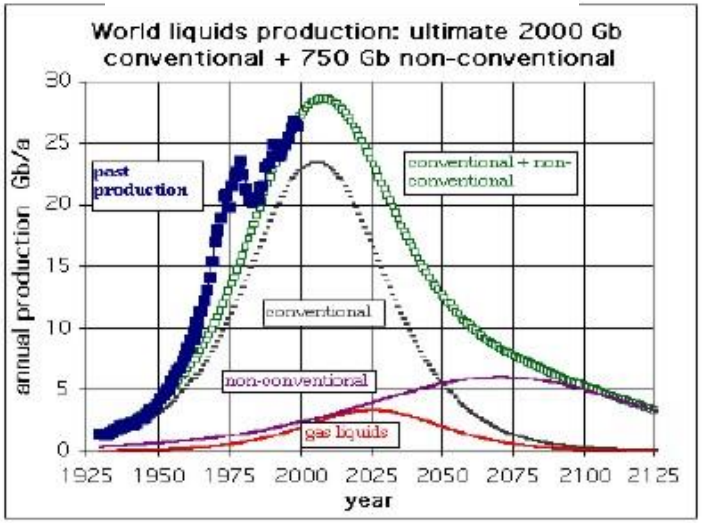
Motivation of behind peak phosphorus

Oil production USA

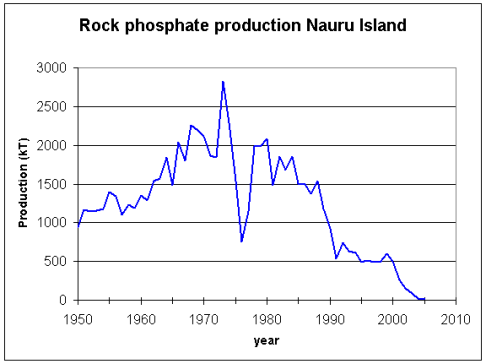




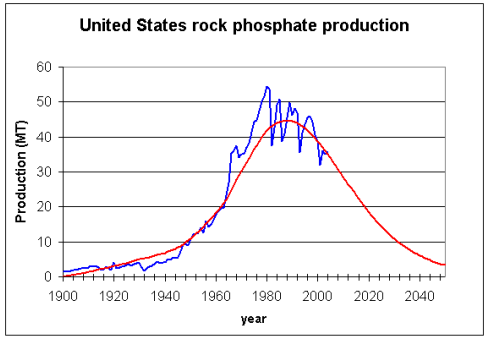
Oil production World

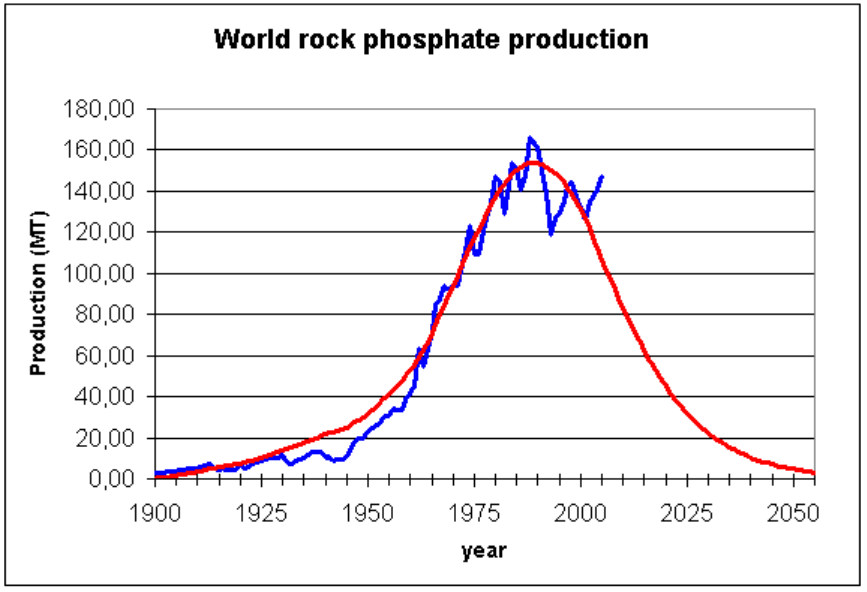


P, Nauru

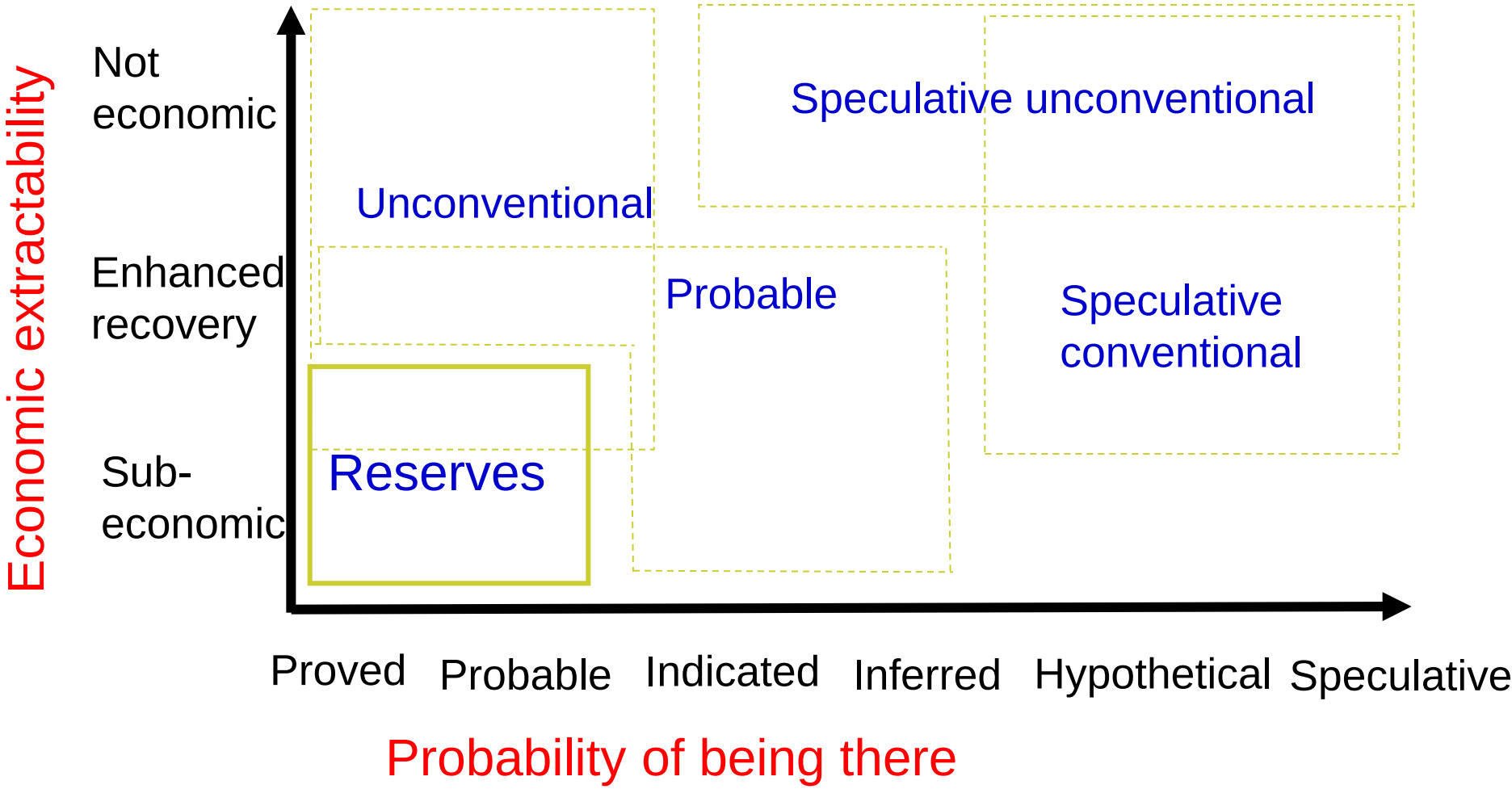


P, USA



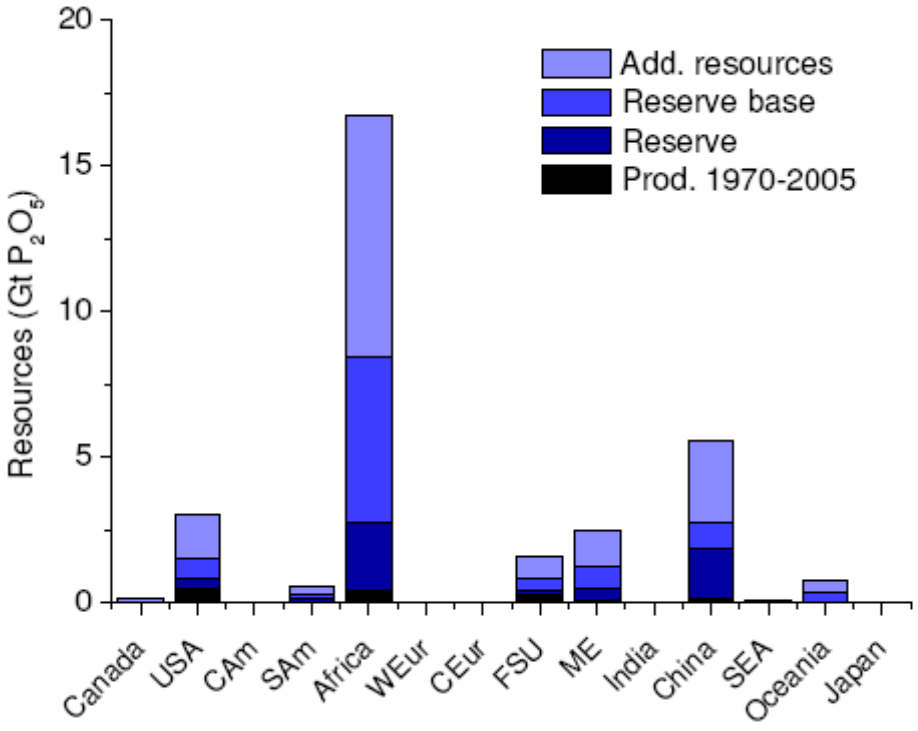


Resources and reserves



McKelvey diagram/ Rogner 1997

Resource estimates in the literature



USGS

Table 1
Q4 Estimates of global P resources from the literature and the range used in this study

Q5

	Phosphate resource estimates		
	Resource base		
	Reserves	Reserve base	Additional resources
	Gt P_2O_5		
USGS (2008)	5.0	14.1	
Smil (2000)	5.7	16.1	29.5
Fantel (1984)		10.7	29.3
Kraus et al. (1984)		8.7	18.9
Cathcart (1984)		6.0	21.8
Steen (1998) high	8.0	22.0	30.0
Steen (1998) low	3.6	11.0	30.0
Brinck (1977)			46.0
Average	4.8	11.1	21.9
This study			
Medium	5.0	14.1	29.5
High	6.0	22.0	80.0
Low	4.0	7.5	15.0

Table 1
Q4 Estimates of global P resour

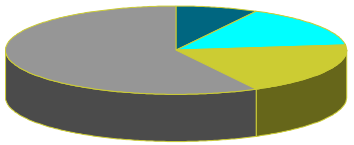
Q5

	Resource base		
	Reserves	Reserve base	Additional resources
	Years of 2000 production		
USGS (2008)	117	325	
Smil (2000)	131	373	683
Fantel (1984)		248	677
Kraus et al. (1984)		201	437
Cathcart (1984)		139	503
Steen (1998) high			
Steen (1998) low			
Brinck (1977)			
Average	124	243	865
This study			
Medium	117	325	683
High			
Low			

Model

1. For each region, we identify 8 resource categories. Model “eats” through these categories one-by-one

$$Q_{j,q} = \text{MIN}\left[Q_{0,j,q}, \text{MAX}\left[0, Q_{0,j,q} - \left(\int_{t=0}^{t} \text{Prod}_j - \int_{1}^{q-1} Q_{0,j,q}\right)\right]\right]$$



2. Each category is assigned a typical production costs. Costs rise linearly within each category. Regional production costs equal currently producing category.

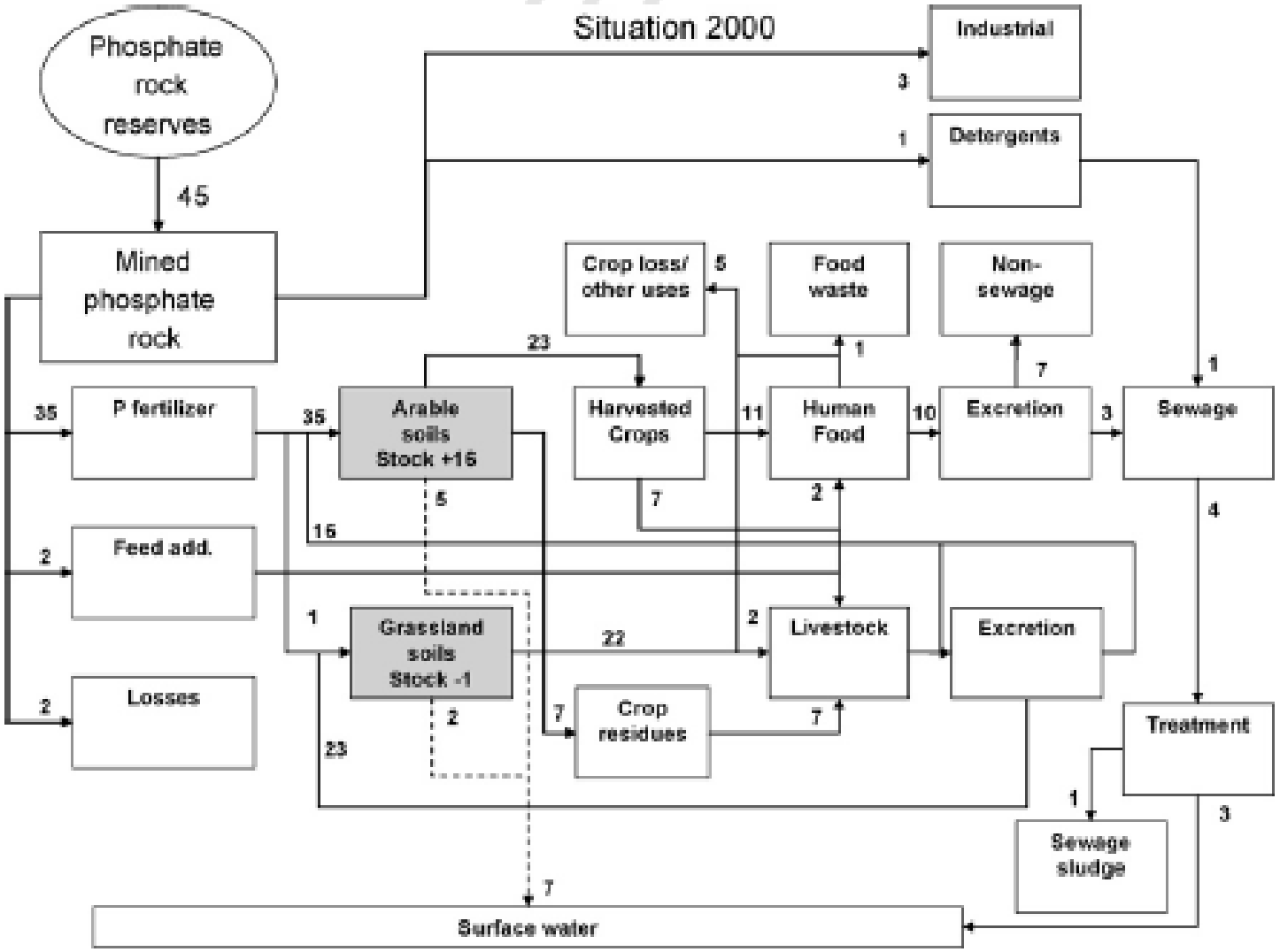
$$C_j = C_{0,j,q} + \frac{Q_{0,j,q} - Q_{j,q}}{Q_{0,j,q}}\left(C_{0,j,q+1} - C_{0,j,q}\right)$$

3. Each region can supply “P” in each other region. Market shares are assigned on the basis of productions and transport costs

$$P_{ij} = D_i \frac{e^{\lambda(C_j + T_{i,j})}}{\sum_j e^{\lambda(C_j + T_{i,j})}}$$

4. Demand for phosphorus is determined for each region on the basis of population, agricultural production (exogenously to the model)

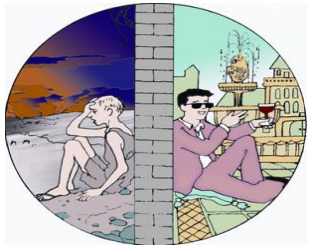
Current phosphorus flows



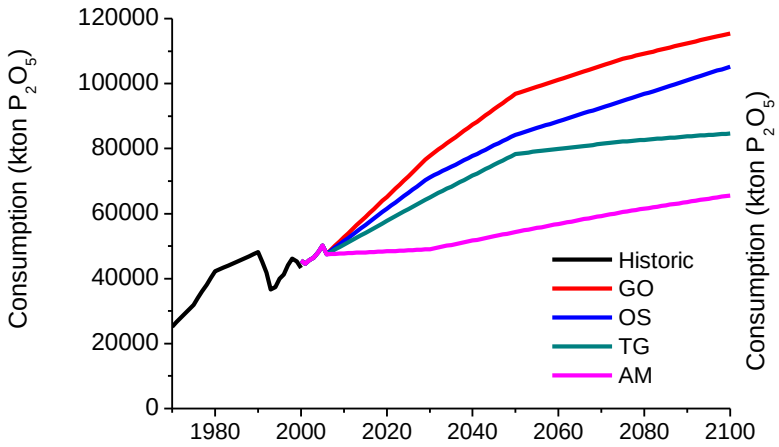
Use the 4 MA scenarios to create P demand projections

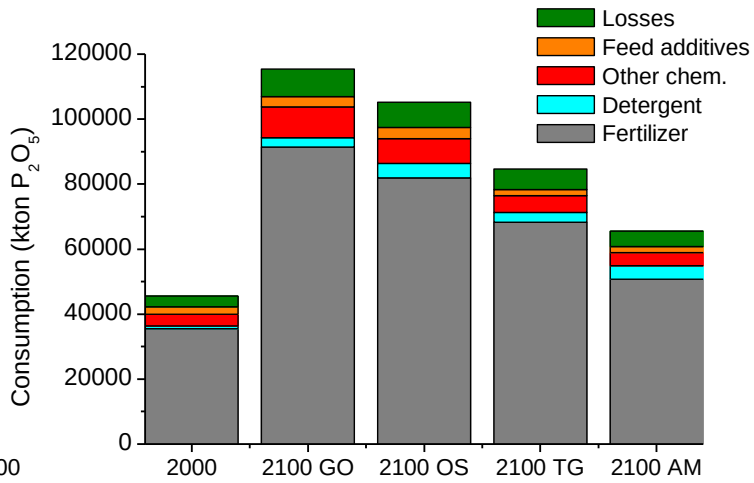
Table 3
Main drivers of the four MEA scenarios.

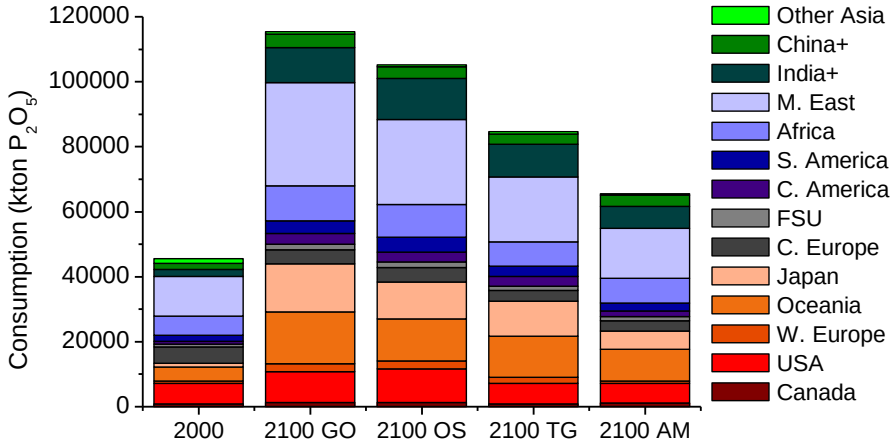
	Global coordination	Order from strength	Technogarden	Adaptive mosaic
Storyline	Rapid economic growth; focus on development; global cooperation	Divided world; focus on security issues; l ow economic growth in developing countries	Rapid technology development; focus on ensuring ecosystem services	Focus on regional development; protection of ecosystem services
World population (billions)	2000: 6.1 2020: 7.3 2050: 8.2 2100: 6.9	2000: 6.1 2020: 7.8 2050: 9.7 2100: 10.6	2000: 6.1 2020: 7.5 2050: 8.9 2100: 8.7	2000: 6.1 2020: 7.8 2050: 9.6 2100: 9.9
GDP pc (US$/pc)	2000: 5380 2020: 7800 2050: 21870 2100: 66460	2000: 5380 2020: 6850 2050: 9330 2100: 17190	2000: 5380 2020: 8830 2050: 16420 2100: 49850	2000: 5380 2020: 7010 2050: 12540 2100: 31420
Agriculture	Rapid expansion of agricultural production, animal husbandary	Expansion of agricultural areas in developing countries	High yields compensate roughly the increase in agricultural demand	Slow expansion of agricultural areas in developing countries



Use the 4 MA scenarios to create P demand projections

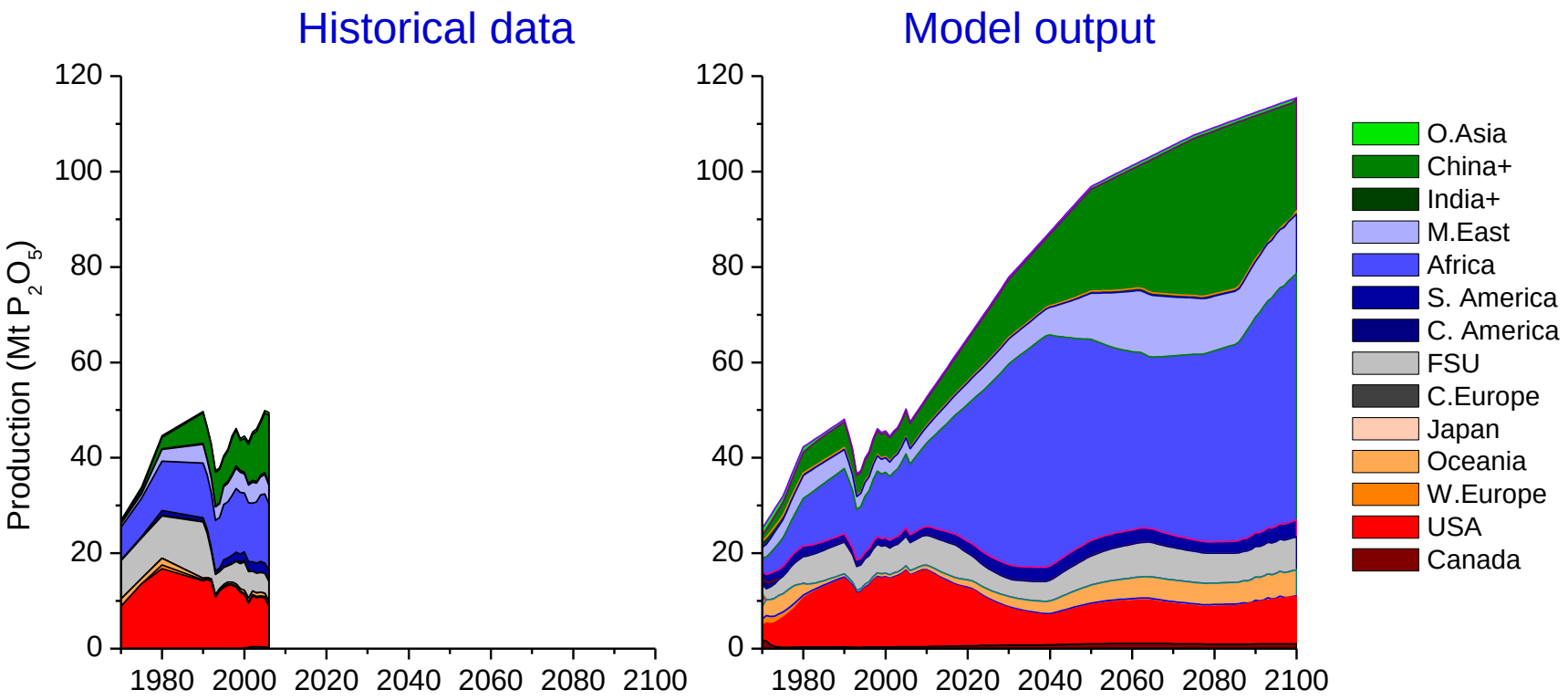






2-3 times growth in P demand

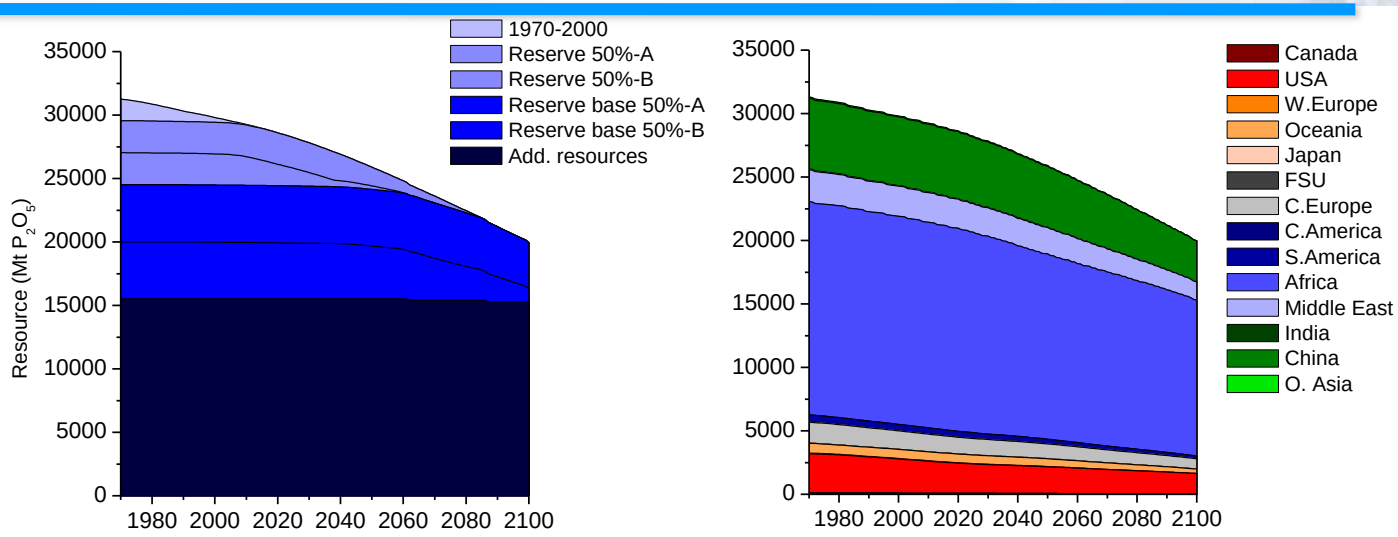
Global P-rock production

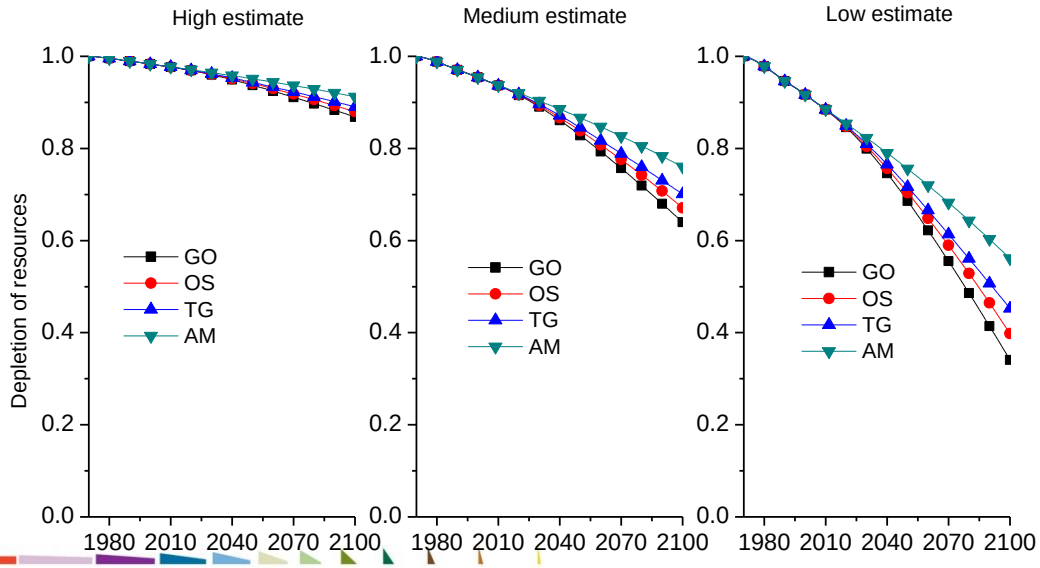


Model performs (surprisingly ☺) well

Future production: Especially production in Africa, China…. USA, Middle East, FSU

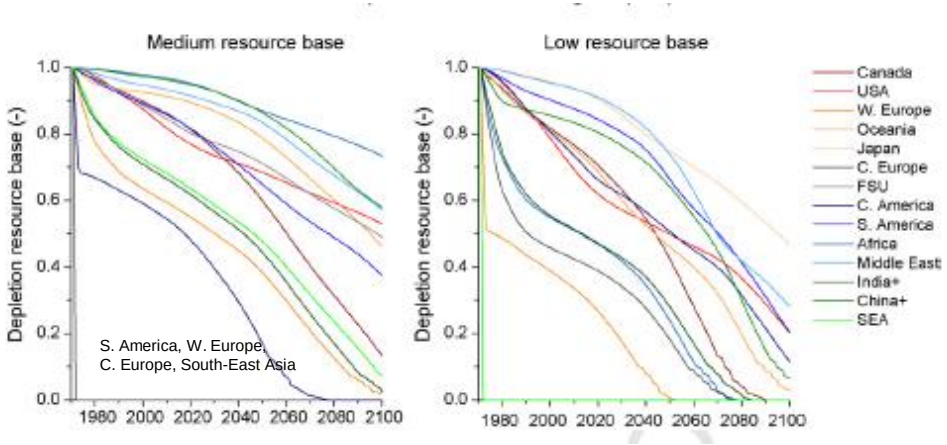
Depletion of resources (global)

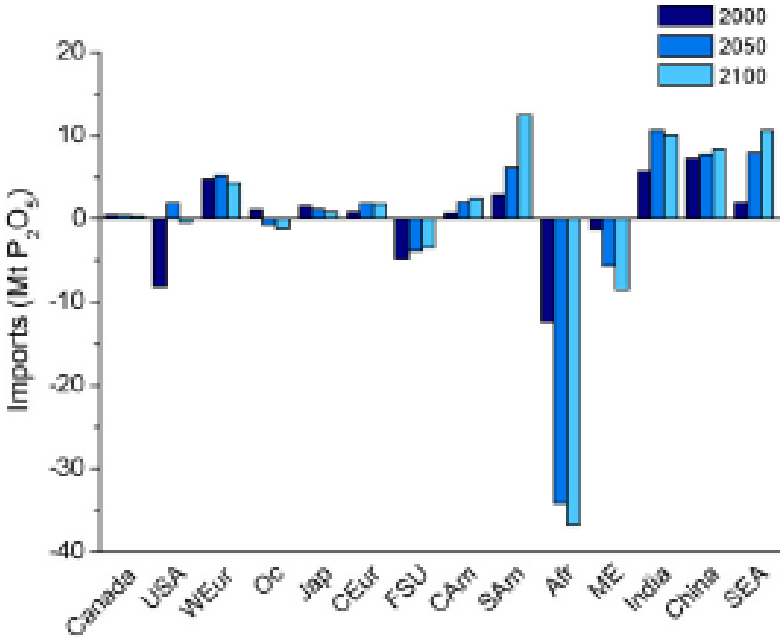




By the end of the century 40-90% of resources left.
But certainty of resources being there decreases.

Depletion of resources (regional)

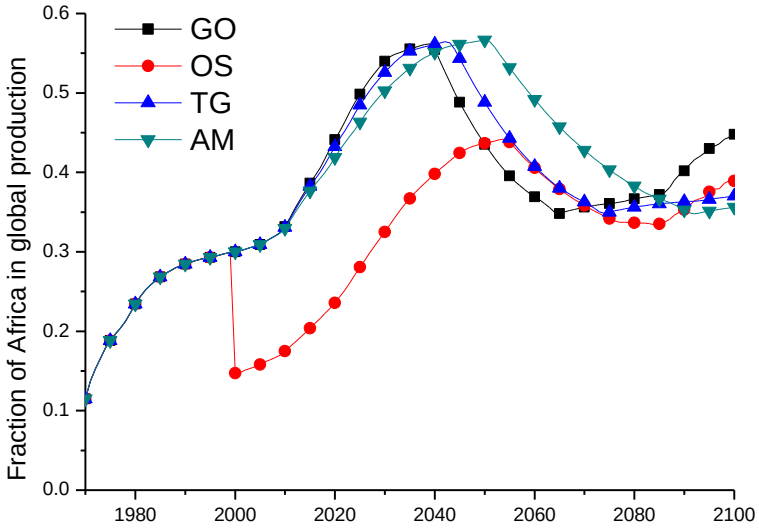




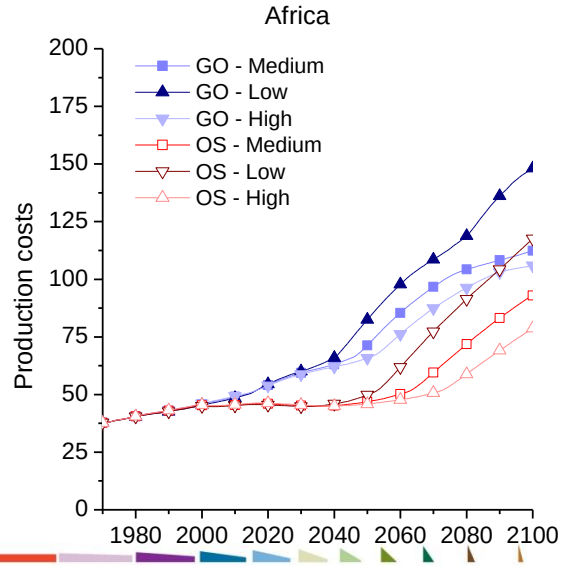
USA, SAm, ME, India, China, South-East Asia, Western Europe major importers (2050)

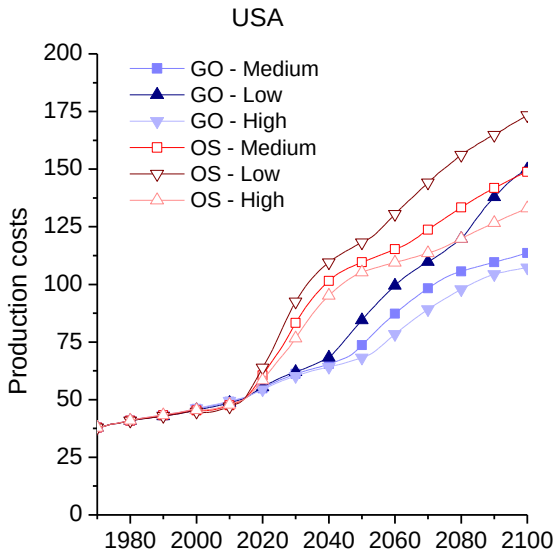
Northern Africa is likely to dominate production (much more oligopolistic market than oil)

Concentration of supply

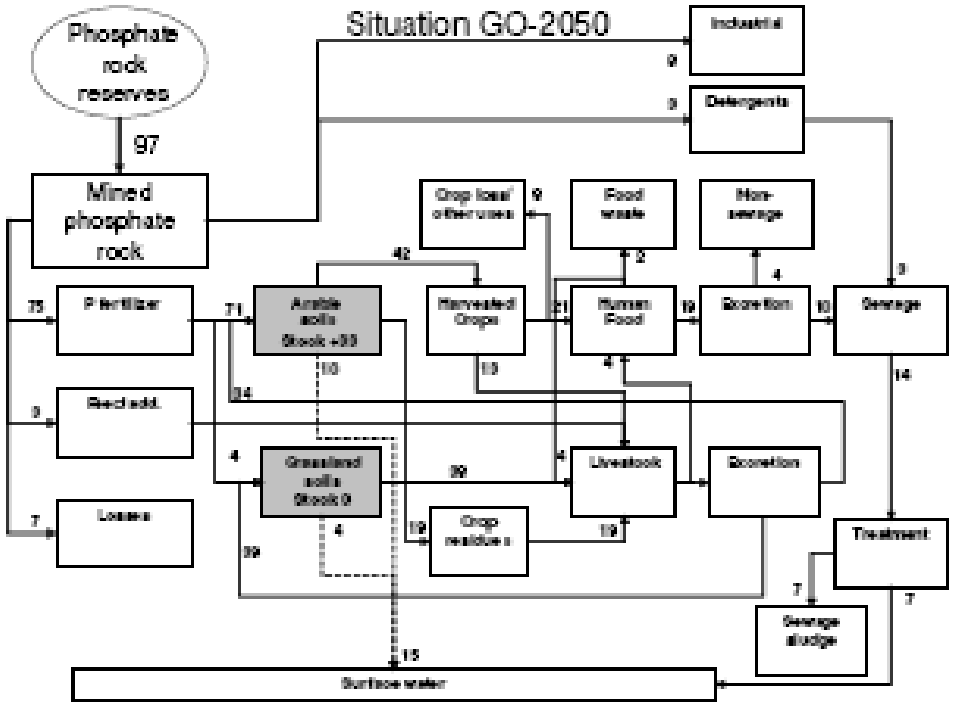


Share of Africa increases to nearly 60% of all production.
Focus on limiting inputs works only partly.





Options to reduce demand

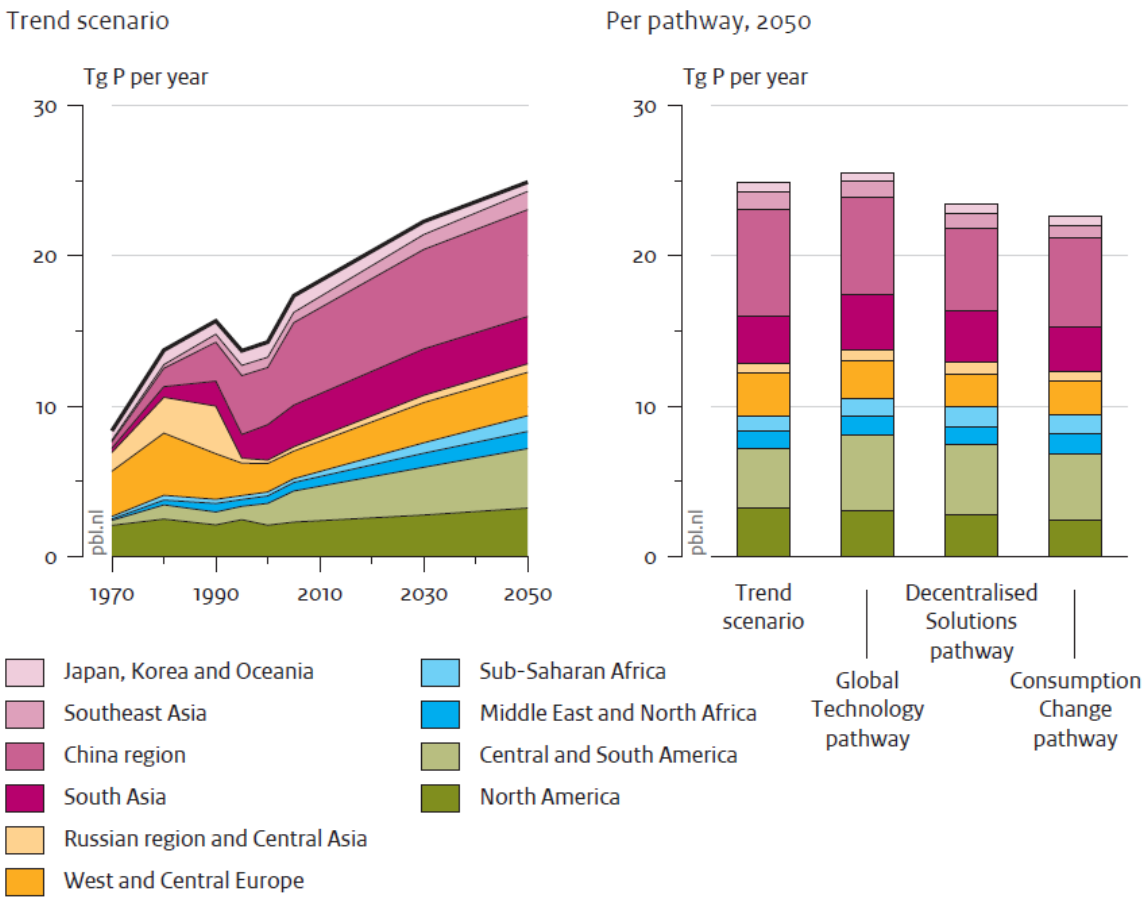


Options for improvement:

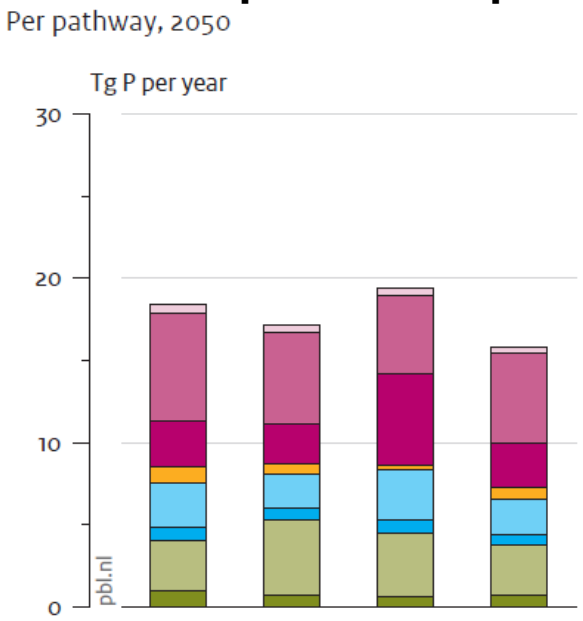
1. Reducing food waste
2. Optimise (reduce) fertiliser use in developed countries
3. Reducing soil erosion
4. Recycling of manure, human excreta, crop losses, sewage waste
5. Reduce extraction losses

Policy scenarios

Phosphorus demand

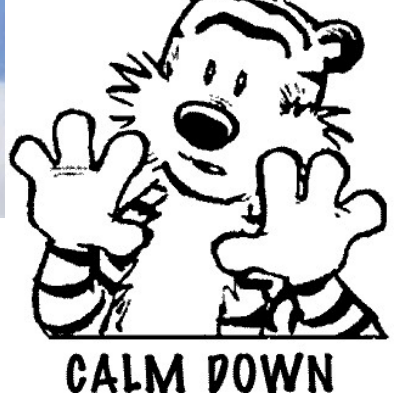


Phosphorus surplus



Measures could help, but in sustainable development scenarios avoiding soil depletion, more bio-energy production and hunger reduction could also increase production.

Conclusions



- **Our analysis indicates that there are no signs of short-term to medium-term depletion.**
- **In the longer term, the depletion of low-cost and high-grade resources will have consequences for future production trends.**
  - Optimistic viewpoint: lot of P left even at the end of century
  - Pessimistic viewpoint: Risk that less than 50% is left at end of the century. As there are no substititutes to P this is a serious threat.
- **It is important to pay more attention to data on P resources.**
  - Relatively little data (resources, consumption of different categories, ultimate fate)
- **Phosphate rock depletion may lead to concentrating production to a few countries**
- **Major reductions in the use of fertiliser P can be achieved by improving plant nutrition management, better integrating of animal manure and recycling P content in human and/or animal excreta.**


Calvin and Hobbes
IT'S TRUE, HOBBES. IGNORANCE IS BLISS!
ONCE YOU KNOW THINGS, YOU START SEEING PROBLEMS EVERYWHERE...
..AND ONCE YOU SEE PROBLEMS, YOU FEEL LIKE YOU OUGHT TO TRY TO FIX THEM...
..AND FIXING PROBLEMS ALWAYS SEEMS TO REQUIRE PERSONAL CHANGE..
...AND CHANGE MEANS DOING THINGS THAT AREN'T FUN! I SAY PHOOEY TO THAT!
BUT IF YOU'RE WILLFULLY STUPID, YOU DON'T KNOW ANY BETTER, SO YOU CAN KEEP DOING WHATEVER YOU LIKE!
THE SECRET TO HAPPINESS IS SHORT-TERM, STUPID SELF-INTEREST!
WE'RE HEADING FOR THAT CLIFF!
I DON'T WANT TO KNOW ABOUT IT.
WAAAUGGHHH!
I'M NOT SURE I CAN STAND SO MUCH BLISS.
CAREFUL! WE DON'T WANT TO LEARN ANYTHING FROM THIS.