Peak Phosphorus, The Next Inconvenient Truth?

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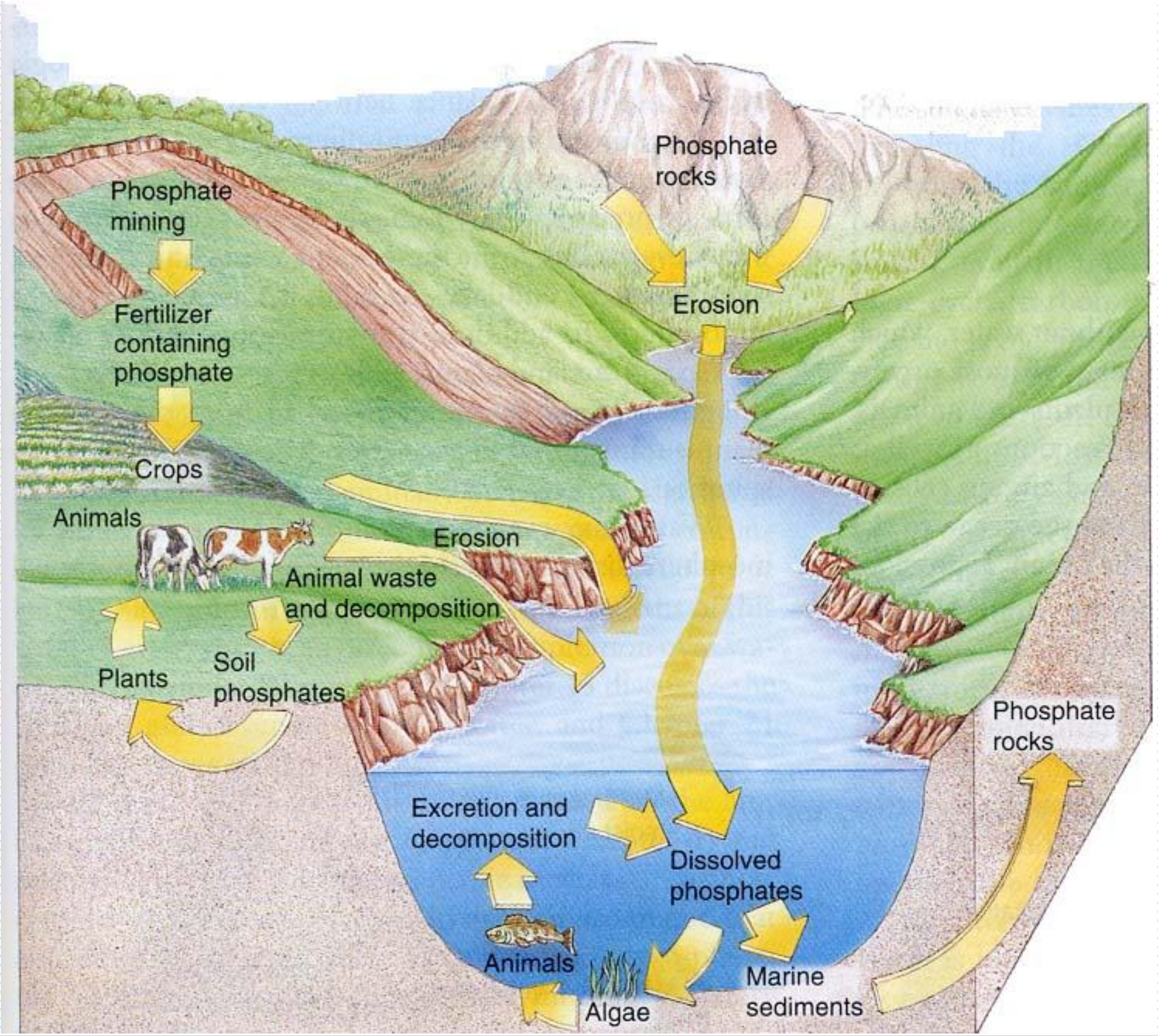
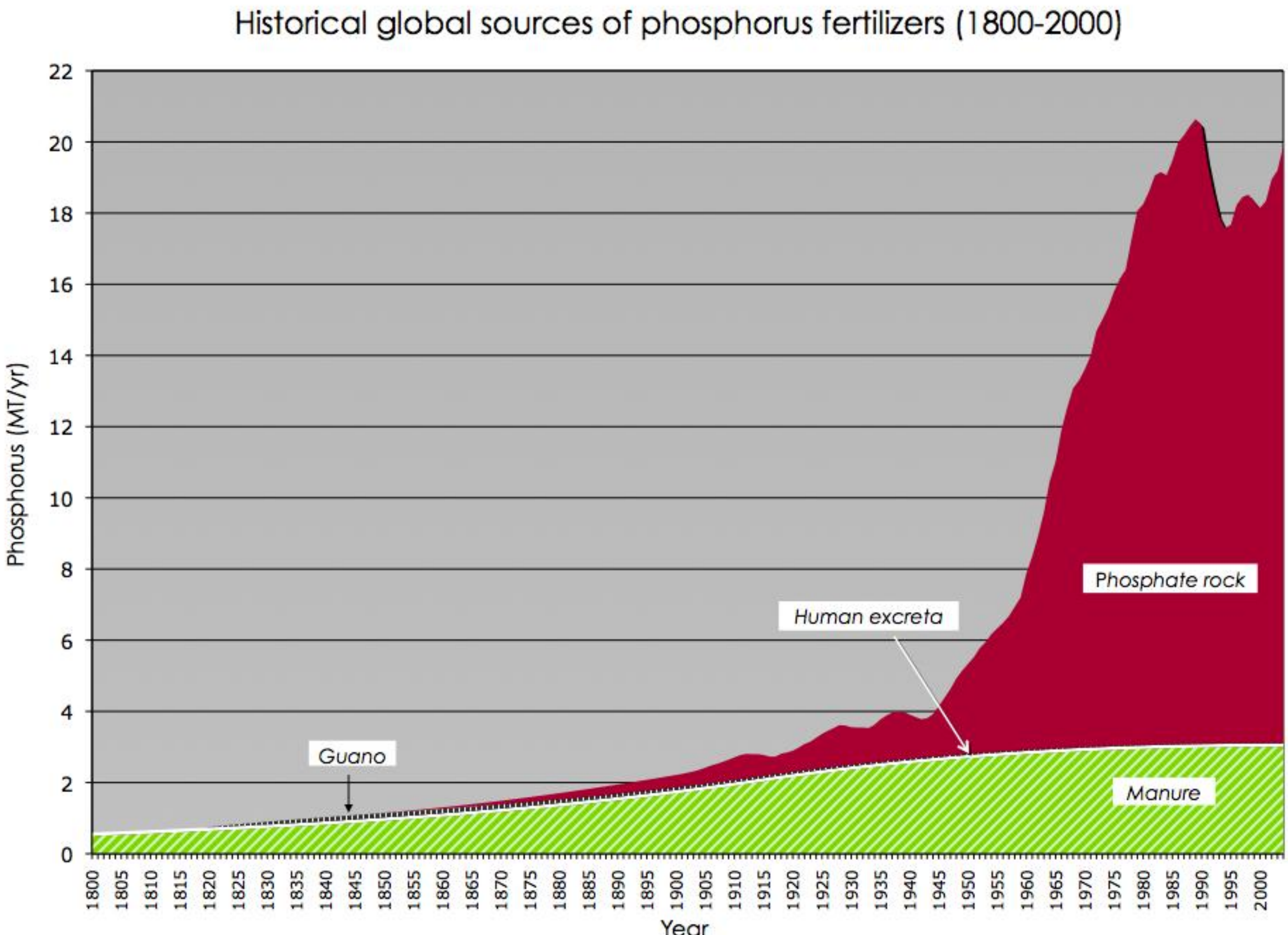
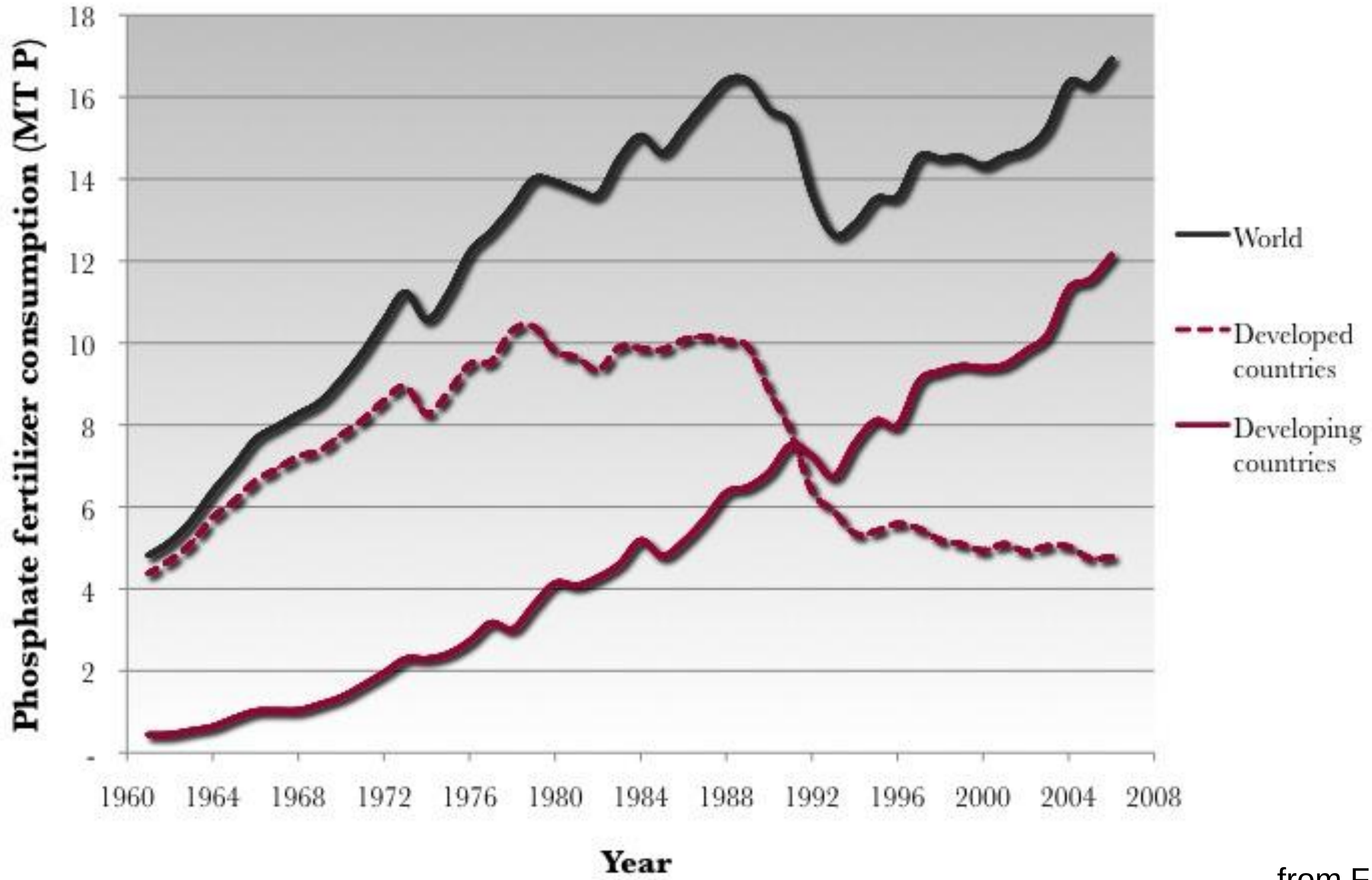
The linear path of phosphorus in modern times (Princeton Univ.)





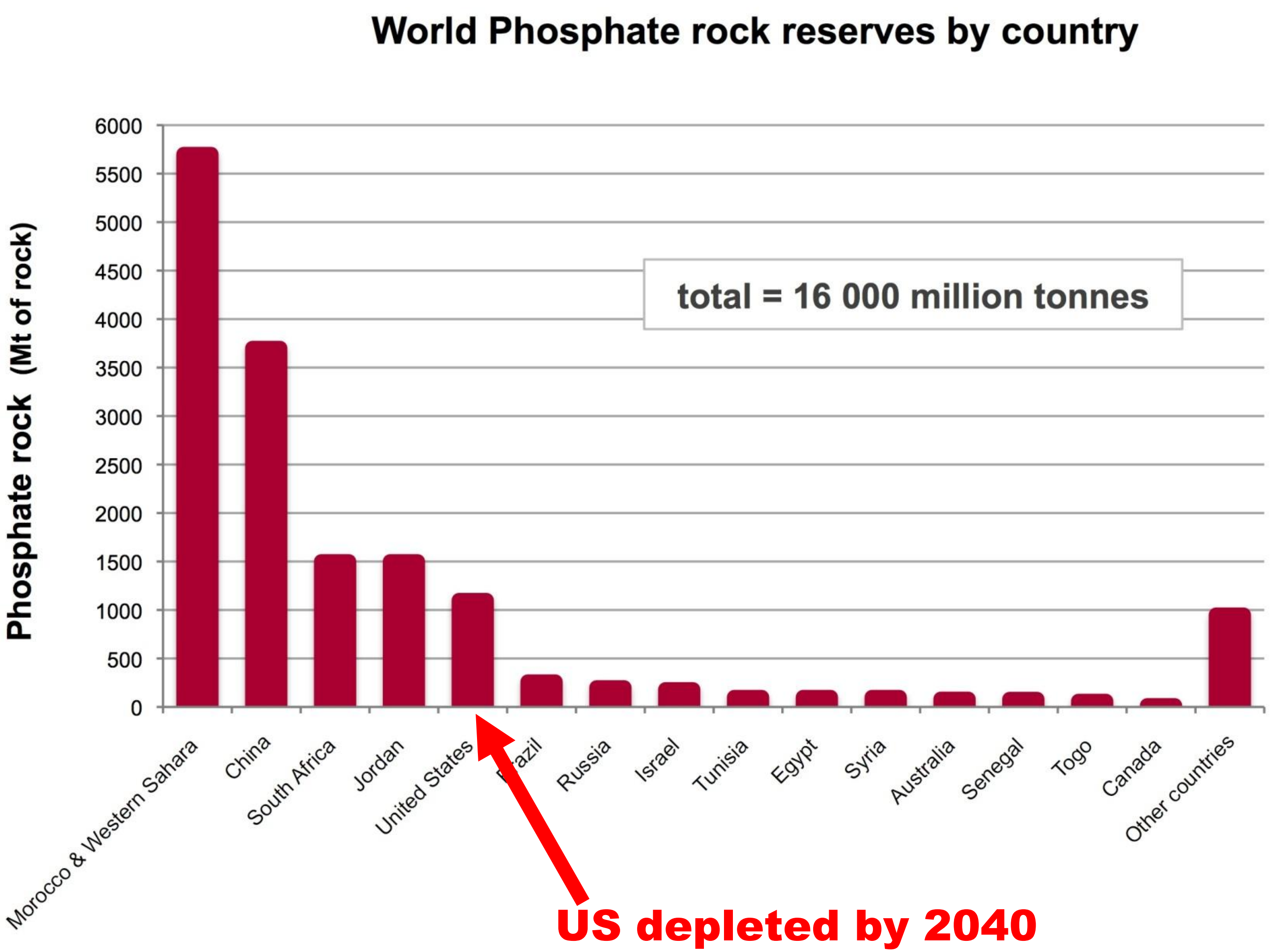
(Cordell, 2009)

Fertilizer Consumption is Increasing in the Developing Countries



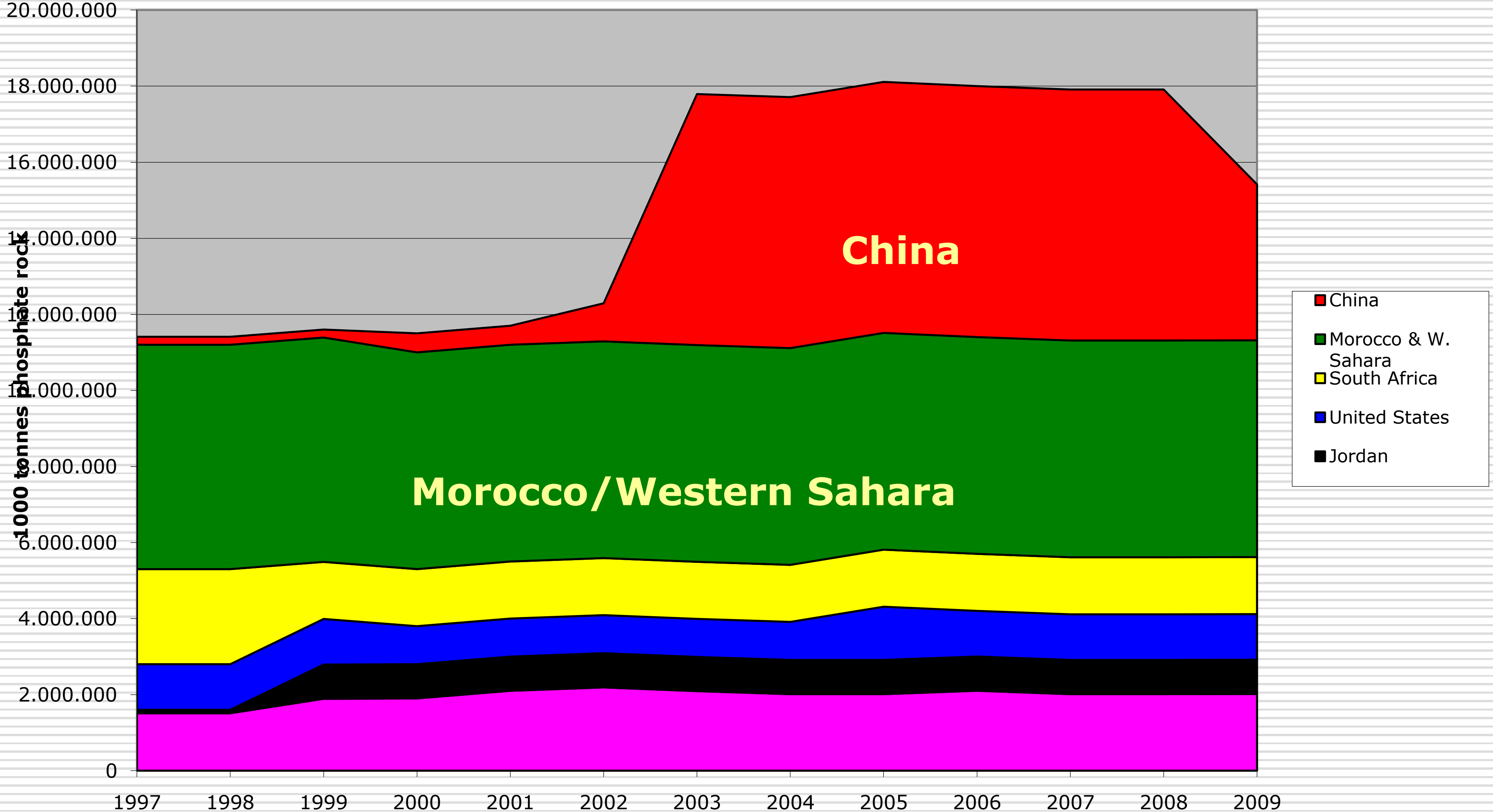
from FAOstat

ca 90% of the global phosphorus reserves are in 5 countries

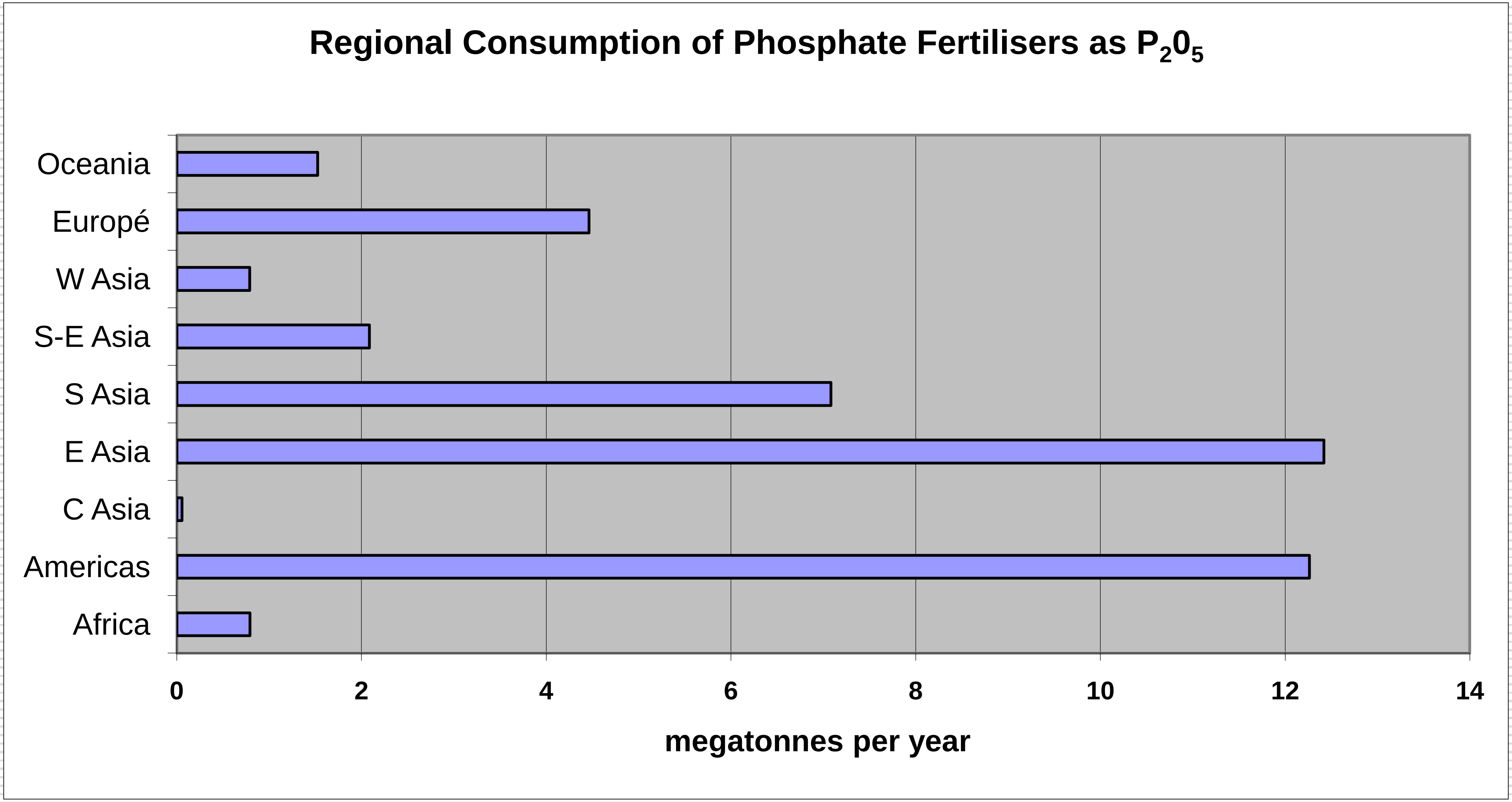


(USGS, 2009)

Phosphate Rock Economic Reserves, 1997-2009
(from USGS summaries)



The definition of economic rock reserves is not standardised. China has changed the definition twice after joining the WTO in 2003. In 2009 they downgraded their economic reserve by 30%. There is a need for a world standard and global governance – still non-existent. Estimates from IFDC say that the potential reserves in Morocco may be almost 10 times the size. Industry keeps their data secret.



Dominated by East Asia, the Americas and South Asia, followed by Europe

FAOSTAT, 2009

Poverty indicator: Africa uses 2-3 Kg P/ha compared to world average of 35

Estimates of Remaining Phosphate Reserves

Author	Estimated lifetime of reserves	Assumptions/notes
Steen (1998)	60–130 years	2-3% increase demand rates, ‘most likely’ 2% increase until 2020 and 0% growth thereafter if efficiency and reuse measures are implemented
Smil (2000)	80 years	At ‘current rate of extraction’
Smit *et al.* (2009))	69–100 years	Assuming 0.7-2% increase until 2050, and 0% increase after 2050
Vaccari (2009)	90 years	At ‘current rates’
Fixen (2009)	93 years	At 2007-2008 production rates

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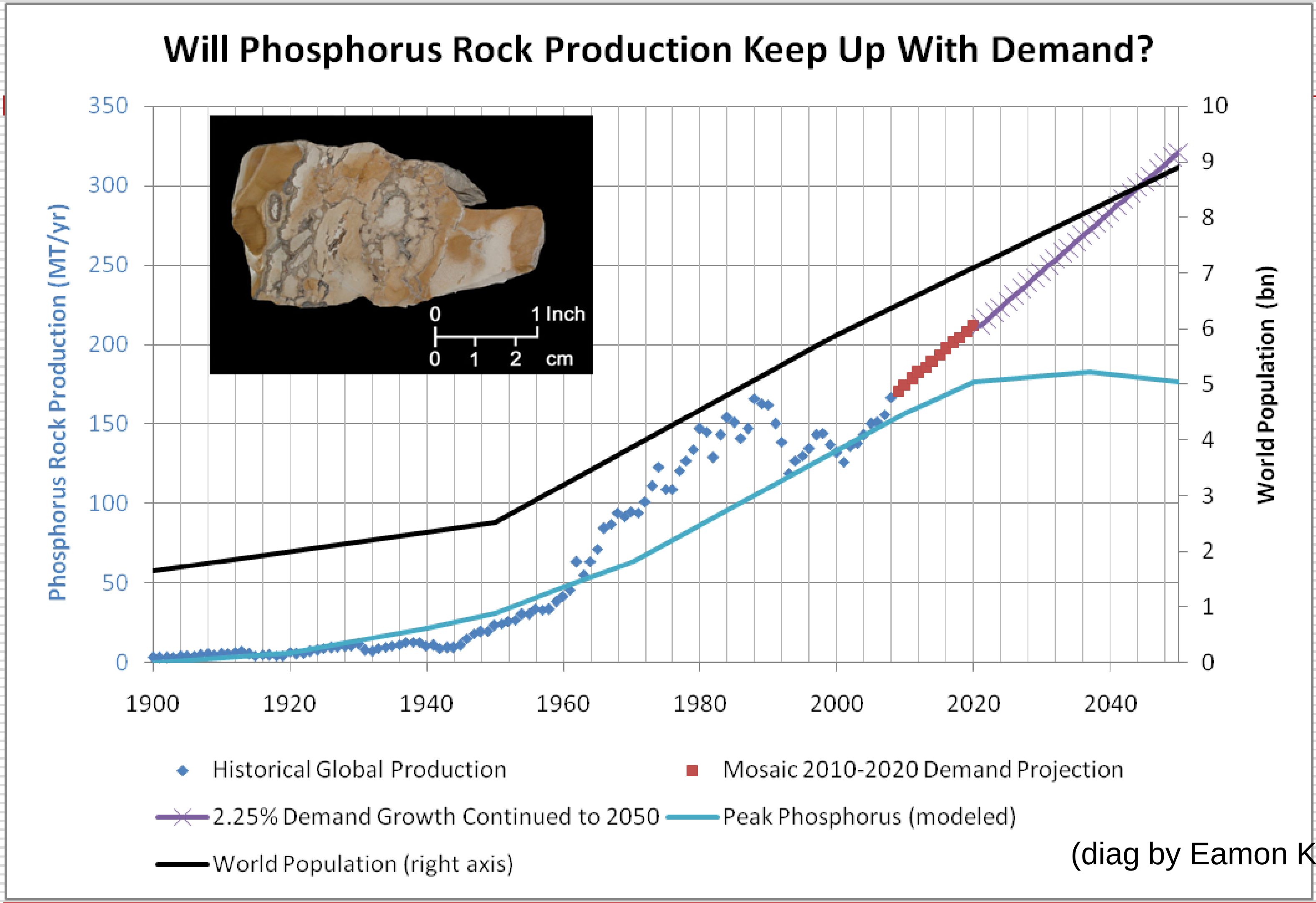
Peak phosphorus – a reality by 2035



(diag by Eamon Keane, UCD)

Industry is attempting to silence the discussion around peak phosphorus since they are not prepared to have a monitoring agency to force transparency.

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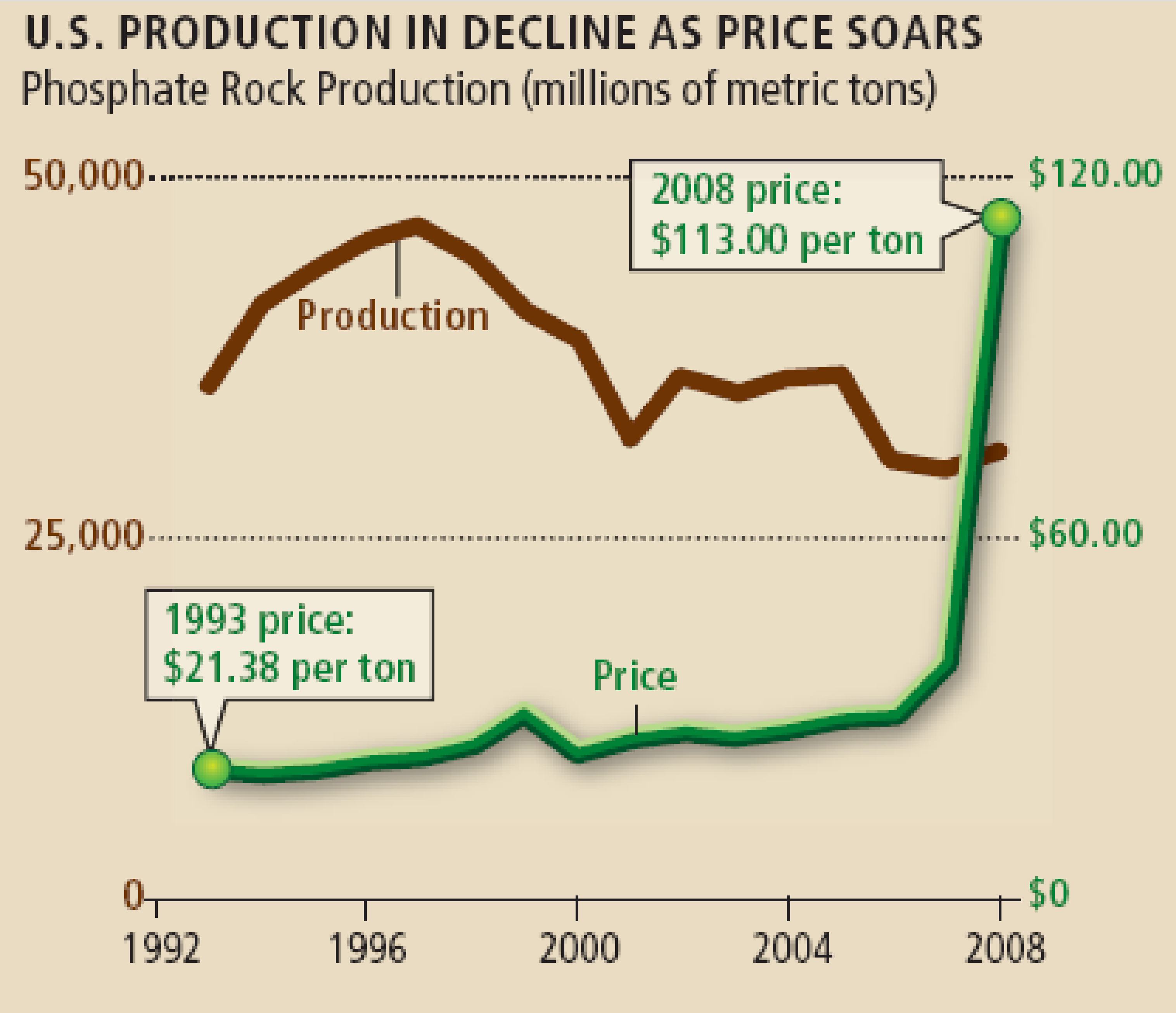
Phosphorus price soared in 2008



(Vaccari, 2009)

2008 saw the highest increase in food prices in 100 years

Figure 1: Changes in the prices of major commodities from 1900 to 2008 reveal a general decline in food prices, but with several peaks in the past century, the last and most recent one the most extreme. (Source: World Bank, 2009).

After the peak in 2008, phosphate prices fell in 2009 due to the general economic collapse in the world to about double the level in 2006.

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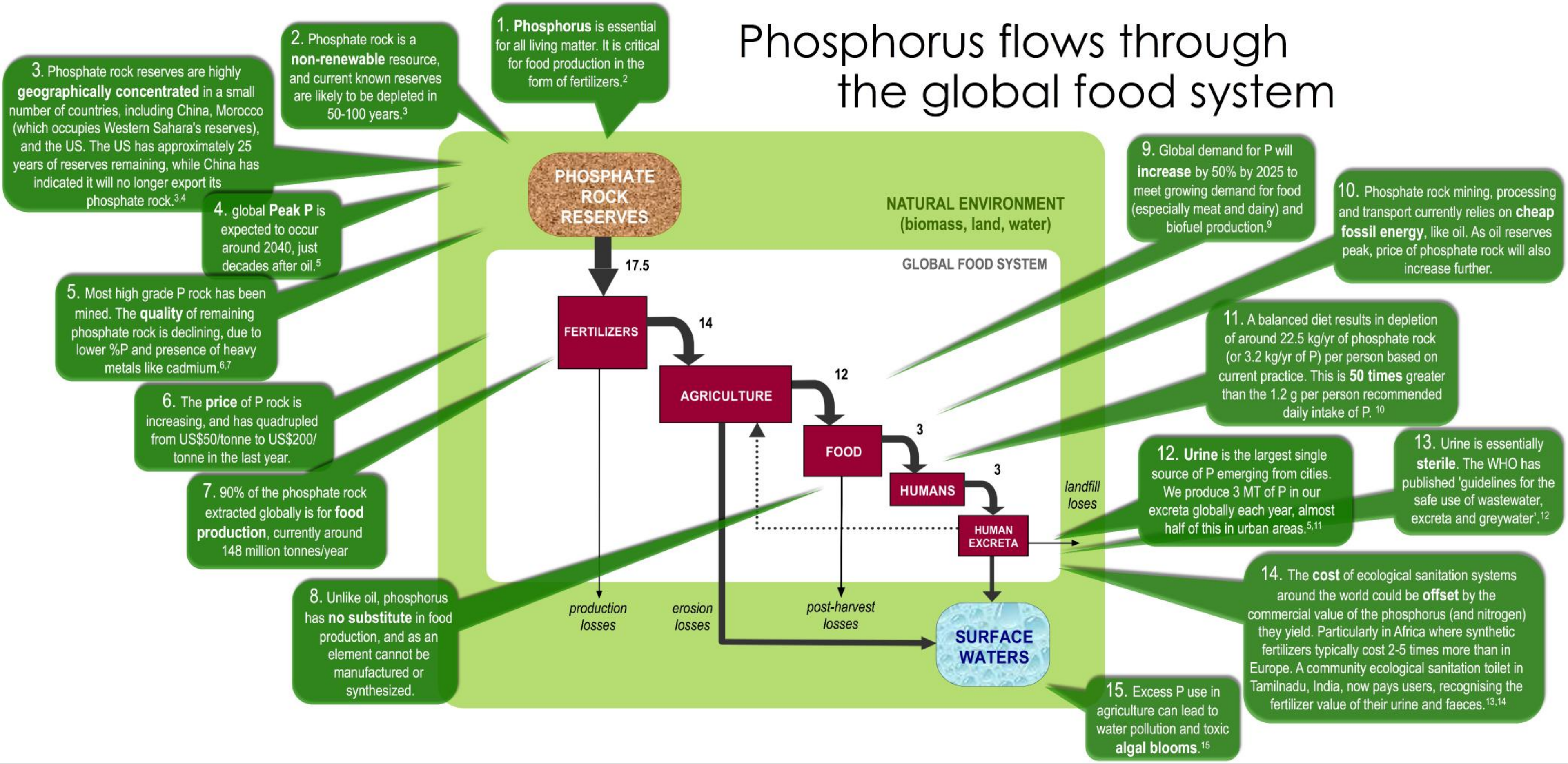
Only 20% of the mined phosphorus for fertiliser ends up in the food we eat



(Cordell, 2010)

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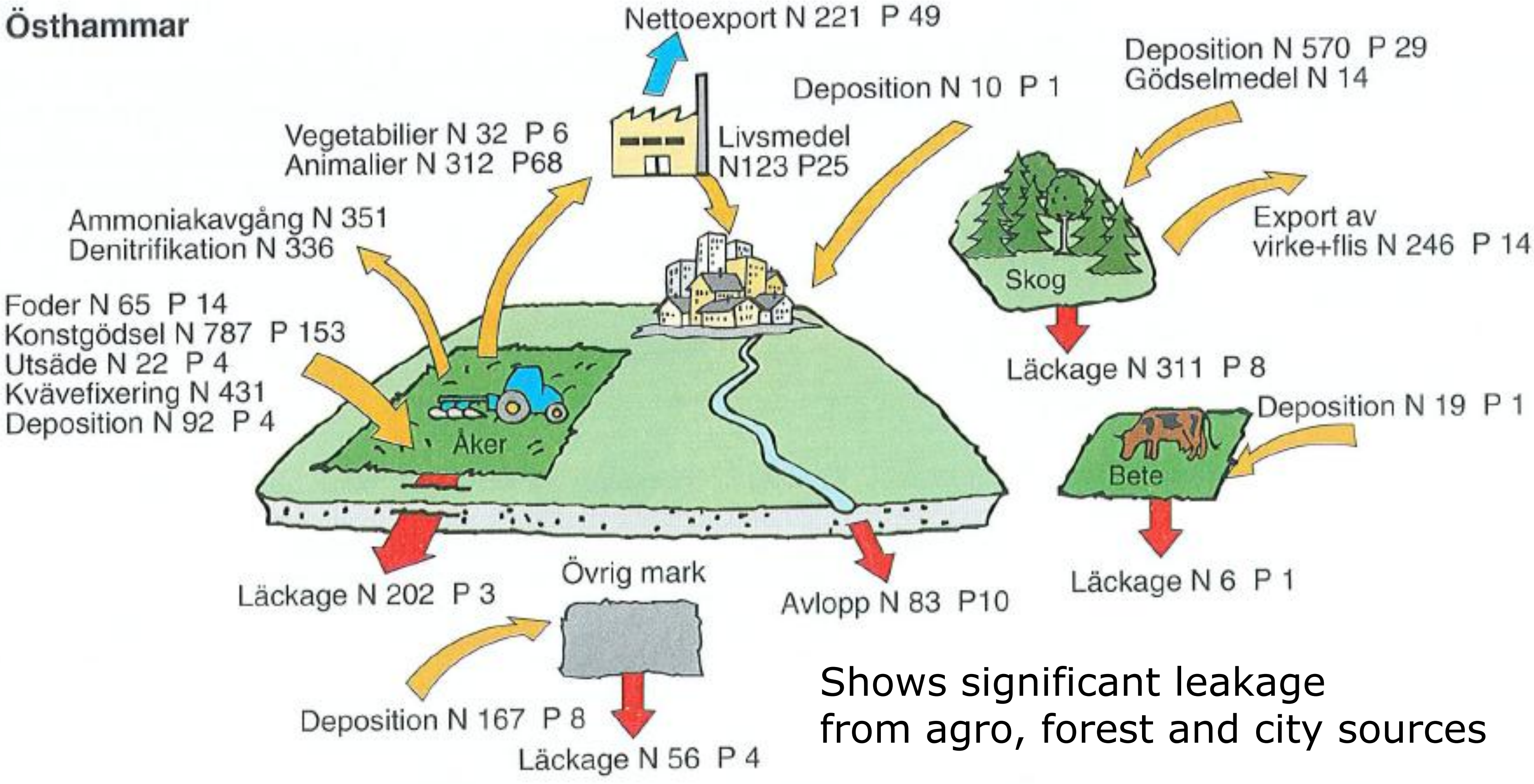
N and P flows through the City of Östhammar, Sweden (T/yr)



Shows significant leakage
from agro, forest and city sources

Fig. H1. *Kväve- och fosforflödet till och från Östhammars kommun i ton per år.*

Phosphorus Flow in Hong Kong

Shows the lack of reuse
and poor STP resulting in major losses of 7 tons of P per day just in the wastes and effluents.

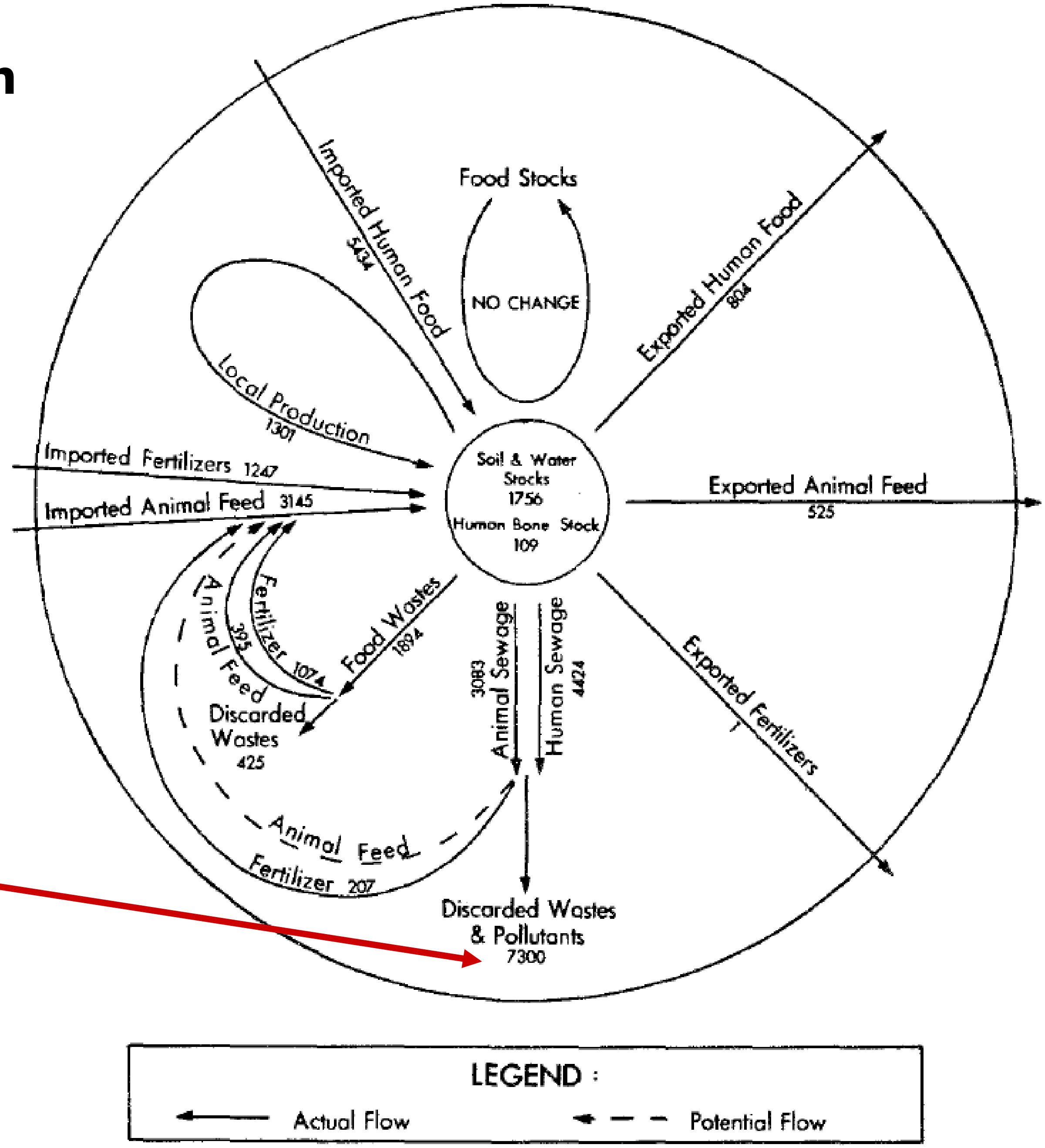


Fig. 2. A schematic representation of the flow of mineral phosphorus in the Hong Kong food system in 1971 (kg of P per day).

- Newcombe, K. 1977

Added Factors that Increase the Challenge of Phosphorus Limitation

- Population increase
- Increased urbanisation
- Increased relative wealth and consumption
- Agriculture and food systems still in ”green revolution” mode and not set up to adapt
- Agro subsidies are large (1 billion Euros per week in the EU) masking the true price for food
- Sanitation and waste systems not capable of easily recycling phosphorus

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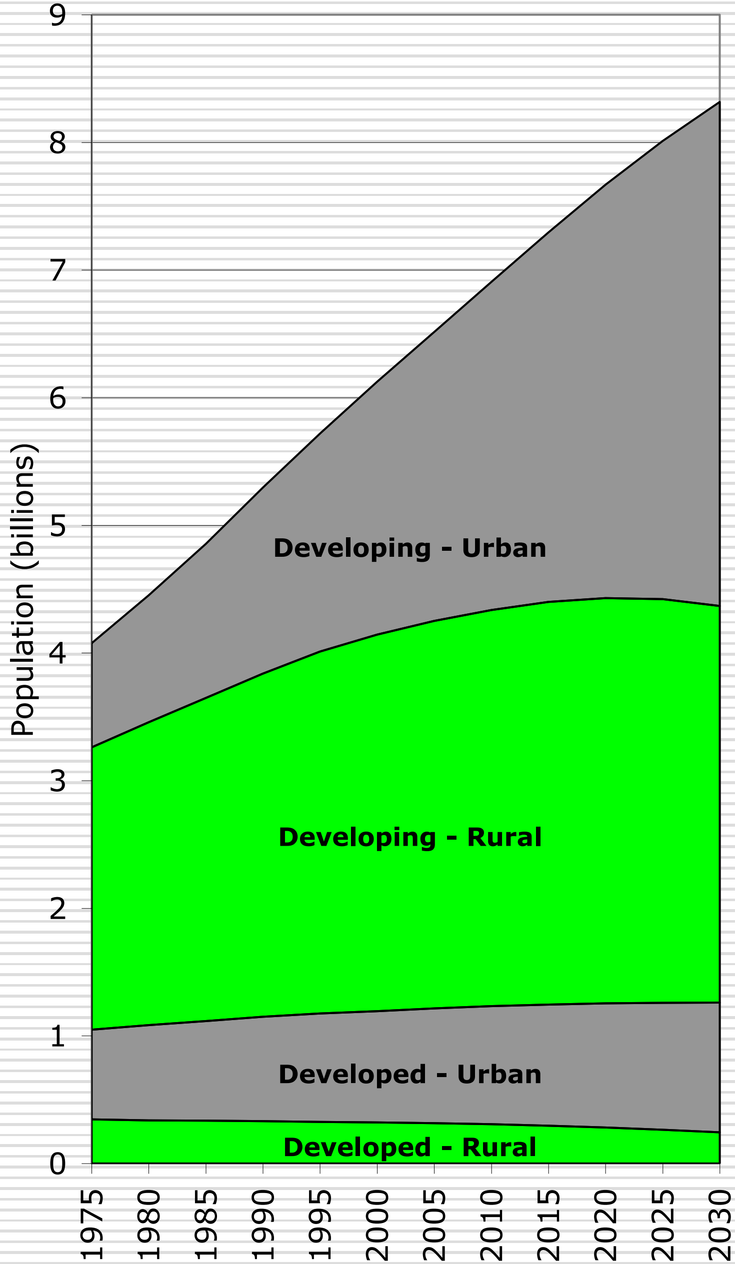
Urban population in the developing world increases plus rural development lagging



Source: World Population Prospects: The 2006 Revision, medium variant

Sources of Competing Claims

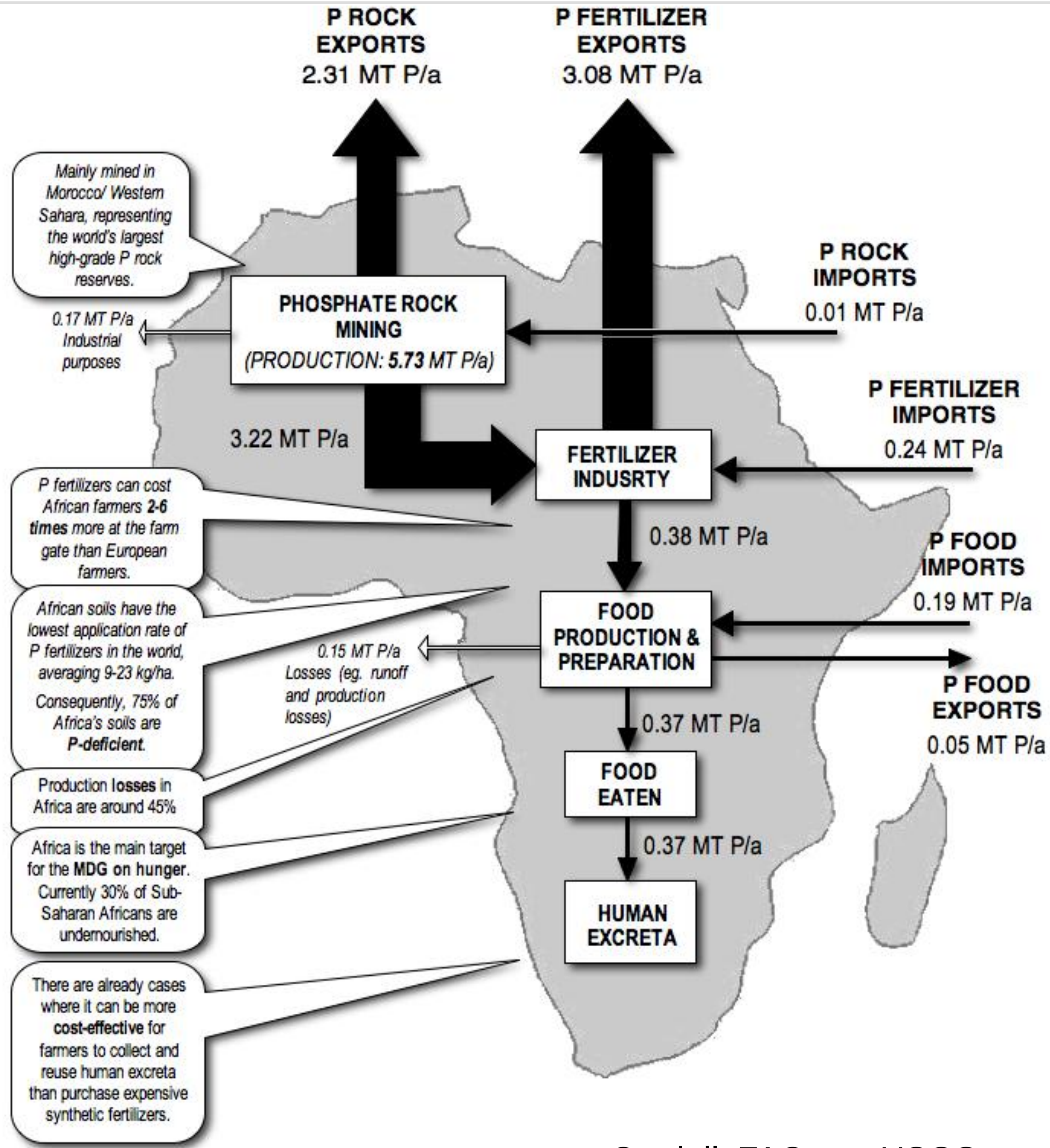
- **Agriculture**
  - **Agro subsidies** (1 billion Euros per wk in the EU) lobbying group that want to use conventional ploughing, crop choices and fertiliser
  - **Fertiliser industry** lobby
  - **Meat consumption** intensifies the need for nutrients
  - **Food industry** more interested in volume, storage & bulk transport systems than in nutritional quality or local agro supply markets
  - **Biofuels** causing spiralling fertiliser prices
  - **Land use** - less intensive eco-agriculture may need more land; problem in urban areas
- **Eutrophication**
  - **Marine environmentalists and conservationists** lobby against excessive use of fertiliser
  - **Detergent industry** using excessive phosphates as water softeners
- **Waste Flows**
  - **Consumers** prefer to keep things simple with one place for flushing and one place for throwing waste away
  - **Water supply utilities** want to use the existing mixed sanitation systems that do not promote recycling
  - **Solid waste sector** not interested in source separation & composting

The ”other” Agriculture Challenge

- 800 million people in 46 countries malnourished
- each day 40,000 die of hunger and hunger-related diseases
- 75-80% of Africa's farmland is degraded
- Africa loses 30-60kg of nutrients/ha/yr - highest rate in world
- 2002/03 Sub-Saharan Africa used 8kg fertiliser/ha
- compared to South America (80kg), North America (98kg), Western Europe (175kg), East Asia (202kg), South Africa (61 kg) & North Africa (69kg)
- cost of fertiliser in African countries is 2-4 times that in the US and Europe
- as fertiliser prices continue to rise, the billion malnourished will increase

The Serious Inequity Equation for Africa

- producing 50% of the global phosphorus
- using only 10% of the world average/ha
- and paying 2-4 times the world price due to poor infrastructure



Cordell, FAOstat, USGS

And The Sanitation Challenge

- 5000 **child mortalities** per day caused by lack of basic sanitation
- **Diarrhoea** 60-75 million DALYs per year (disease-adjusted life years)
- 3.5 billion people infected with STHs (soil-transmitted **helminths;** %age unchanged since the 1950s)
- 700 million people in 50 countries eat food irrigated with **untreated sewage,** >20 million ha of farmland
- 2.6 billion people lack basic sanitation

Ref: WHO/UNICEF, 2006; UNESCO, 2006; IDRC, 2004: JMP, 2009

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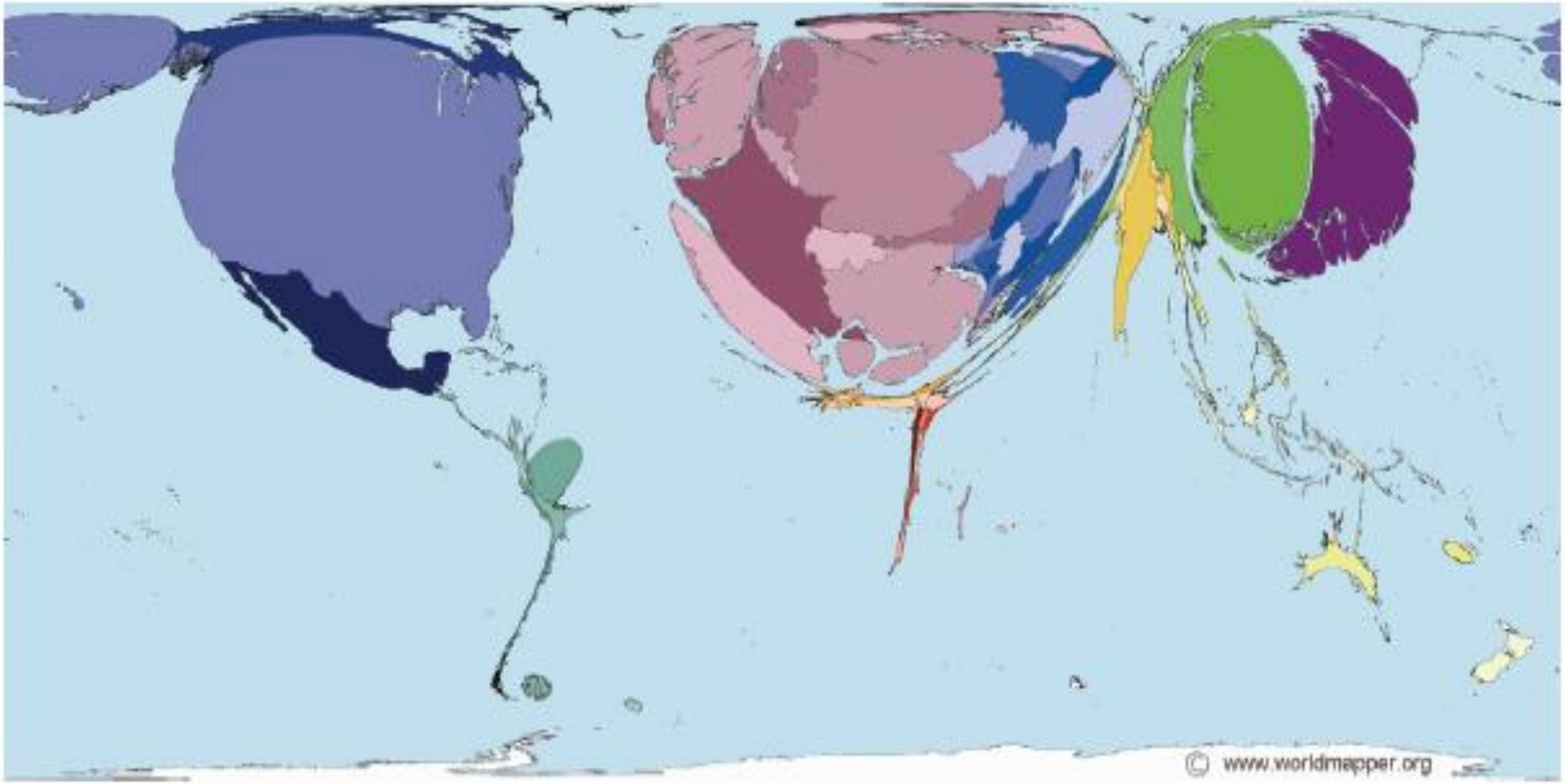
Sewage sludge production from public sewerage systems mapped in terms of relative proportion of the global total for 1999



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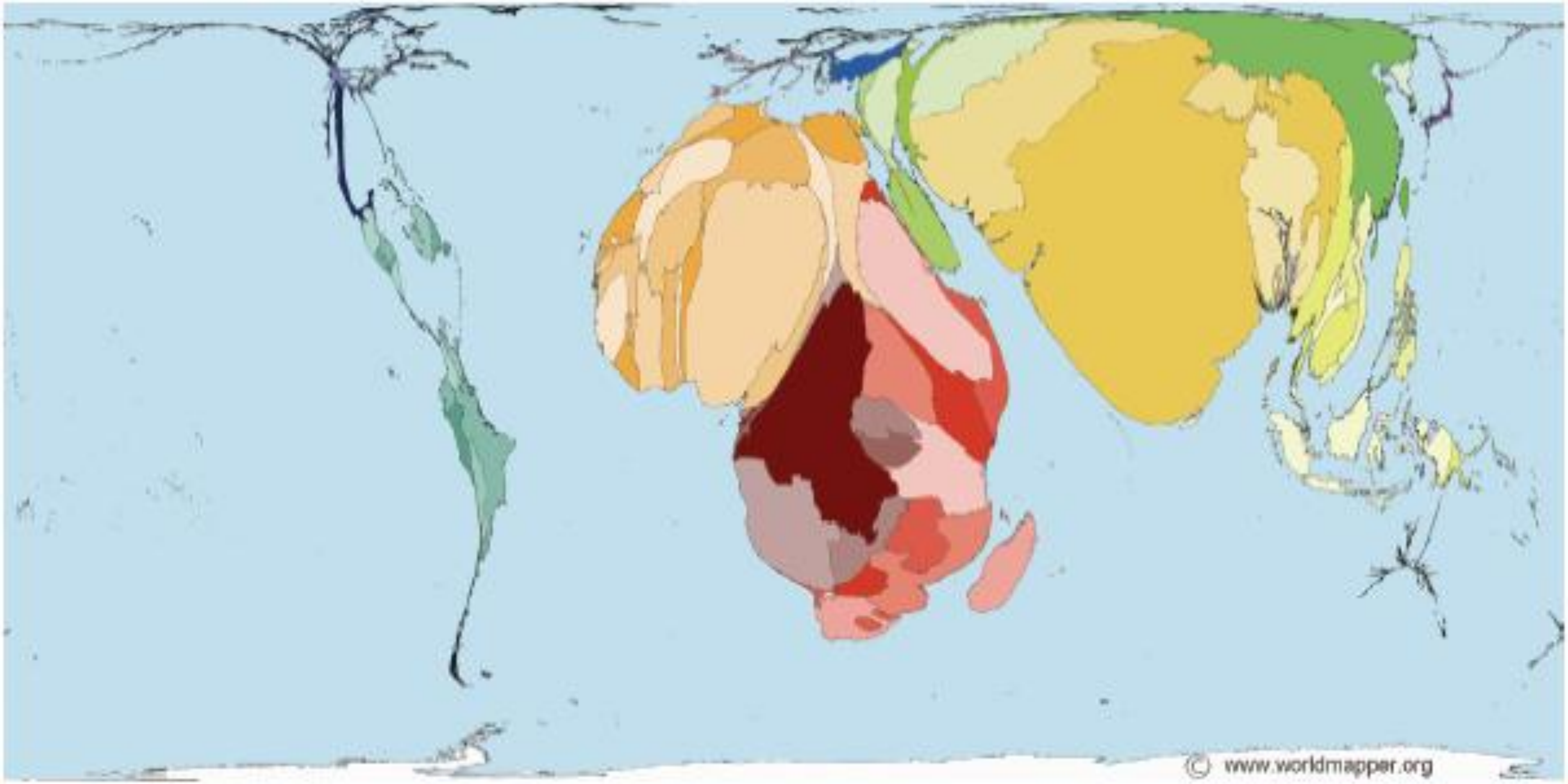
Diarrhoea-caused mortality mapped in terms of relative proportion of the global total for 2002



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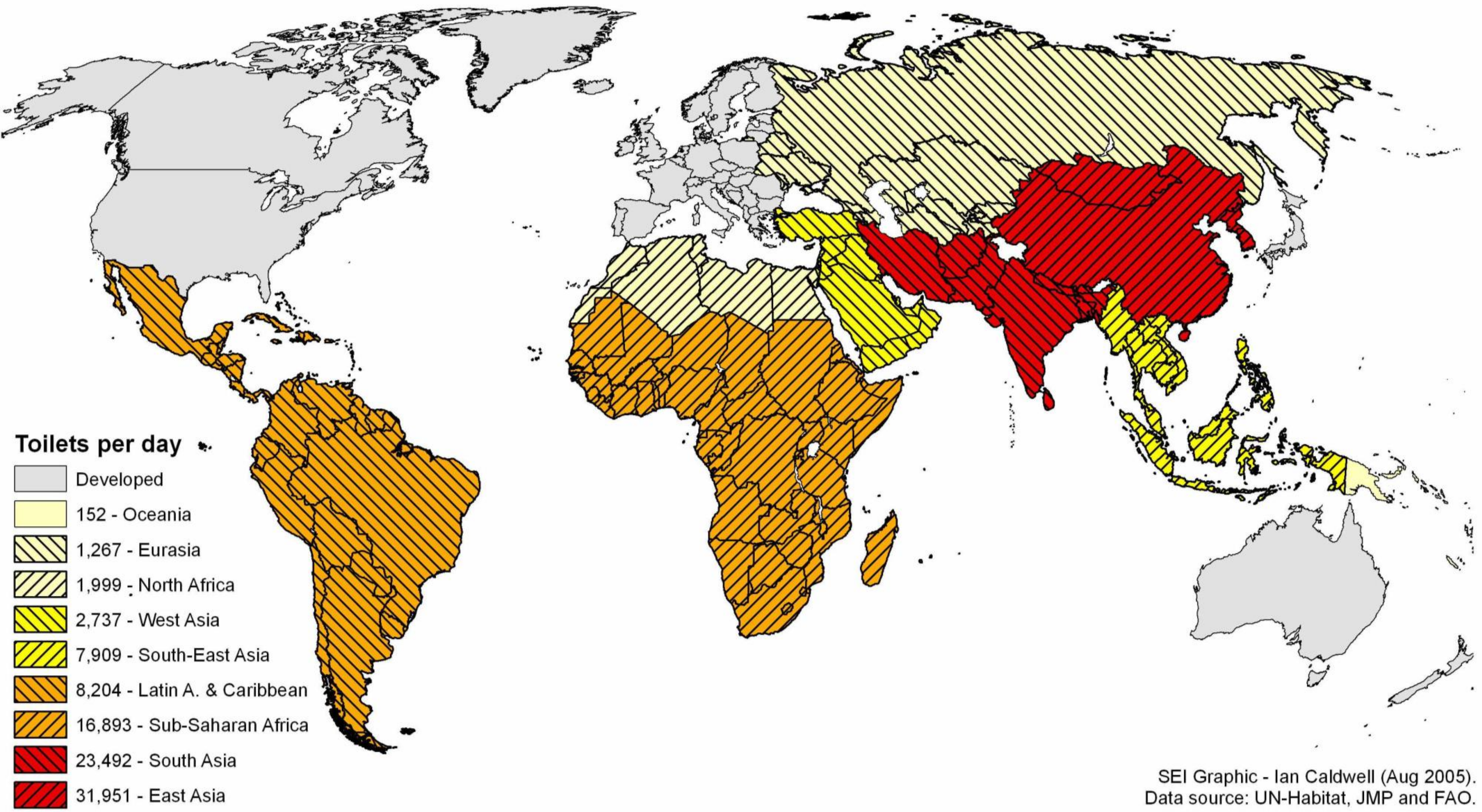

Number of toilets (nutrient pumps) in the different UN regions of the world to be installed through to 2015 per day in order to meet the MDGs; 95,000 installations per day; 60% is in urban areas

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Solutions Integrating Agriculture and Sanitation Systems for the North and the South

Opportunities for Alternative Sanitation Solutions

- Humans produce only 50 L of faeces and 500 L of urine per year per person or 5.5 kg NKP (4:1:0.5) enough for 300 to 400m^2 crop
- 80% of the nutrient excreted from the body are in the urine
- A normal flush toilet uses 15,000 L of drinking water per person per year
- The greywater from kitchens and bathrooms adds an additional 35,000 L per person per year
- Mixing the above and adding storm water makes centralised sewage systems often unaffordable
- Source separation allows for containment and the development of new sustainable alternatives which can be dry or waterborne depending on the local conditions

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Human excreta – a neglected treasure!

N = 2,8 kg
P = 0,4 kg
K ~ 1,3 kg
Per person
per year

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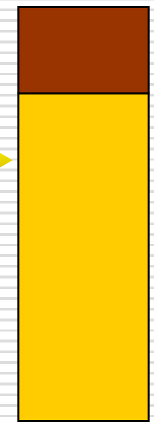
P = 0,4 kg
K ~ 1,3 kg
Per person
per year



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Urea = 6 kg
TSP = 2 kg
KCL ~ 2,6 kg

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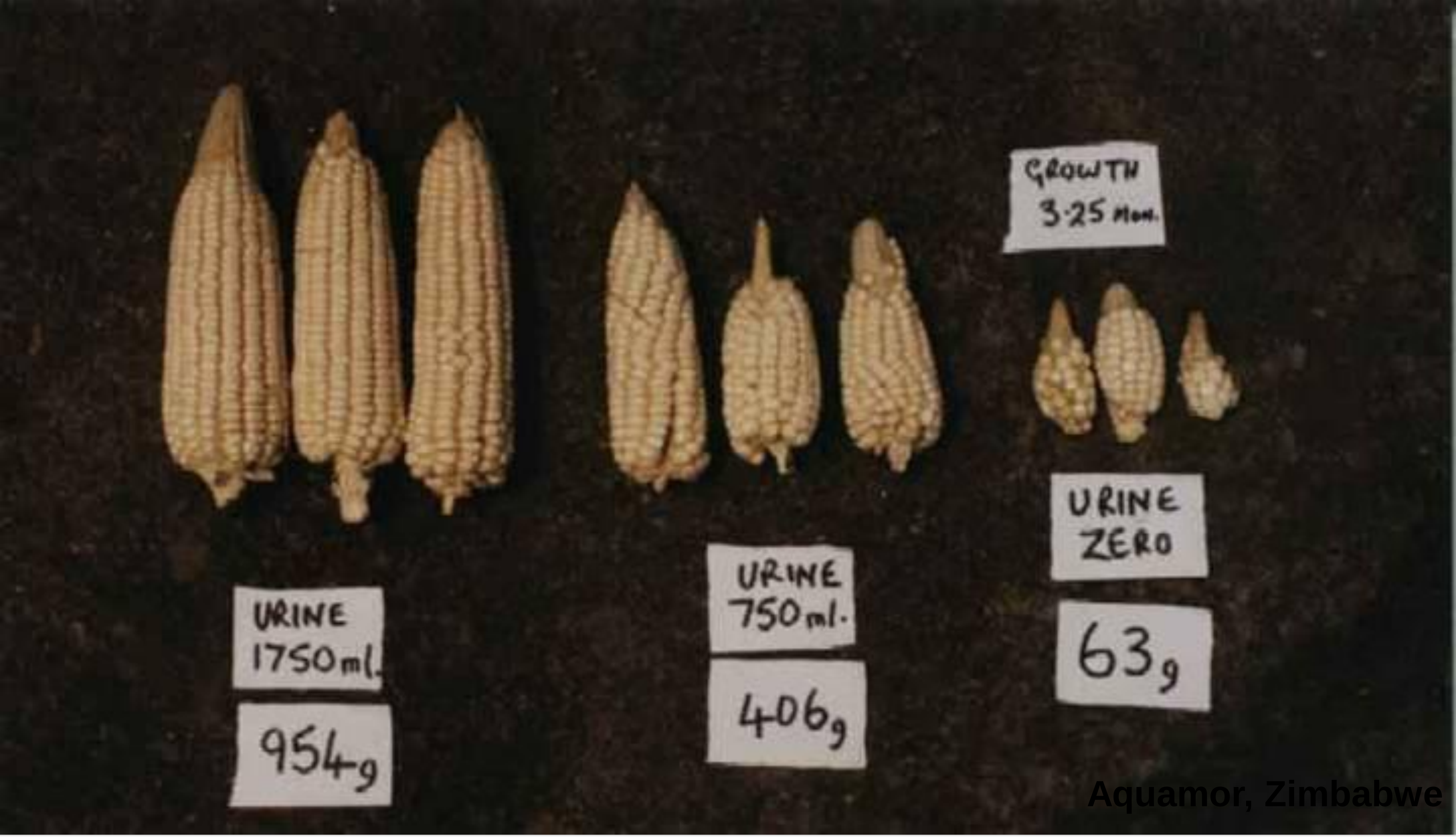
NIGER

URINE **CONTROL**



One day’s urine from an adult produces a kilo of food (Aquamor, Harare)

Double-vault urine-diverting dry ecotoilet
used in e.g. China, Vietnam, Mexico, Bolivia, India, Sri Lanka, W. Africa, S. Africa, Ethiopia, Uganda, Kenya, etc…..

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Well-functioning dry vault

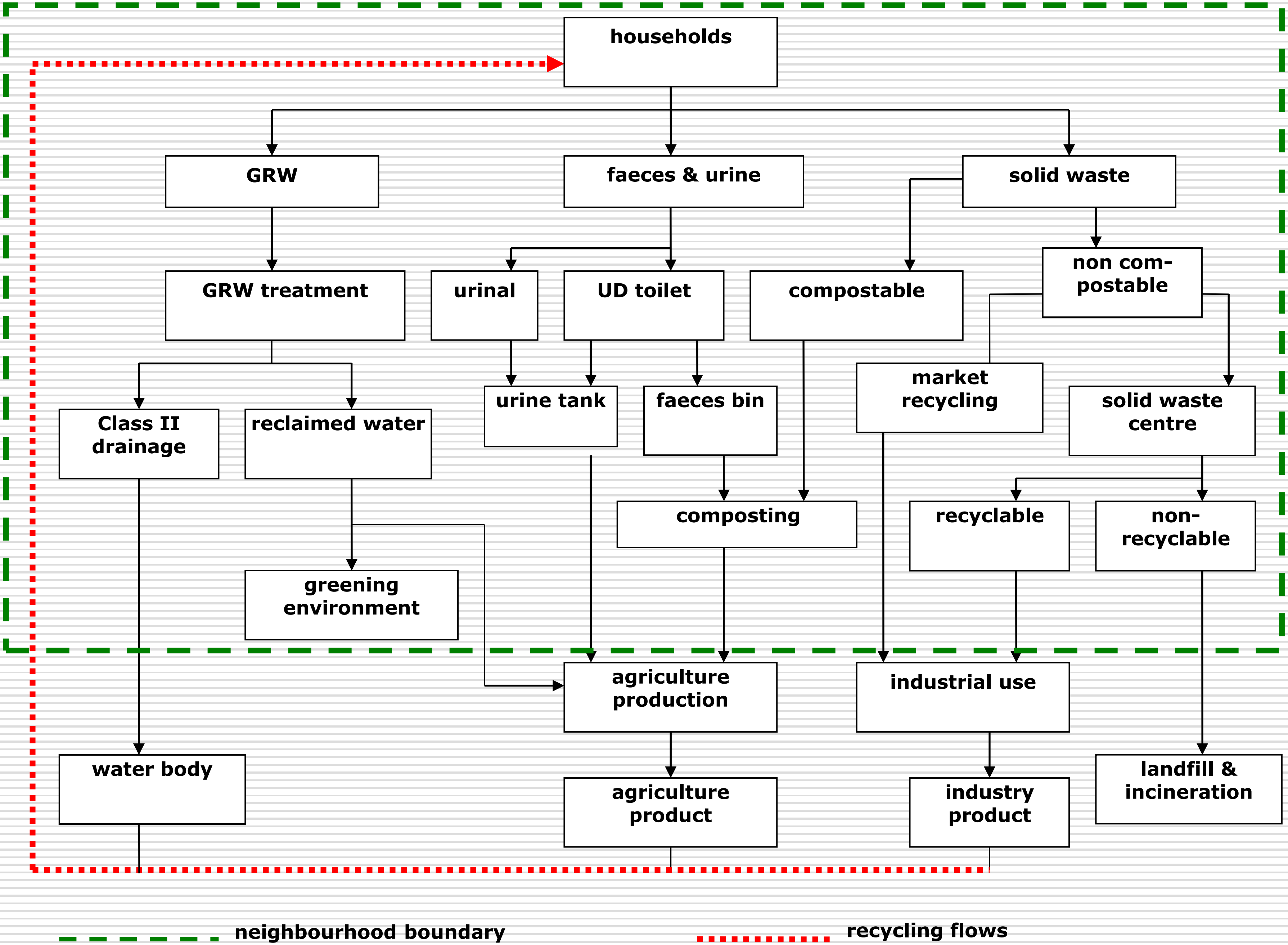
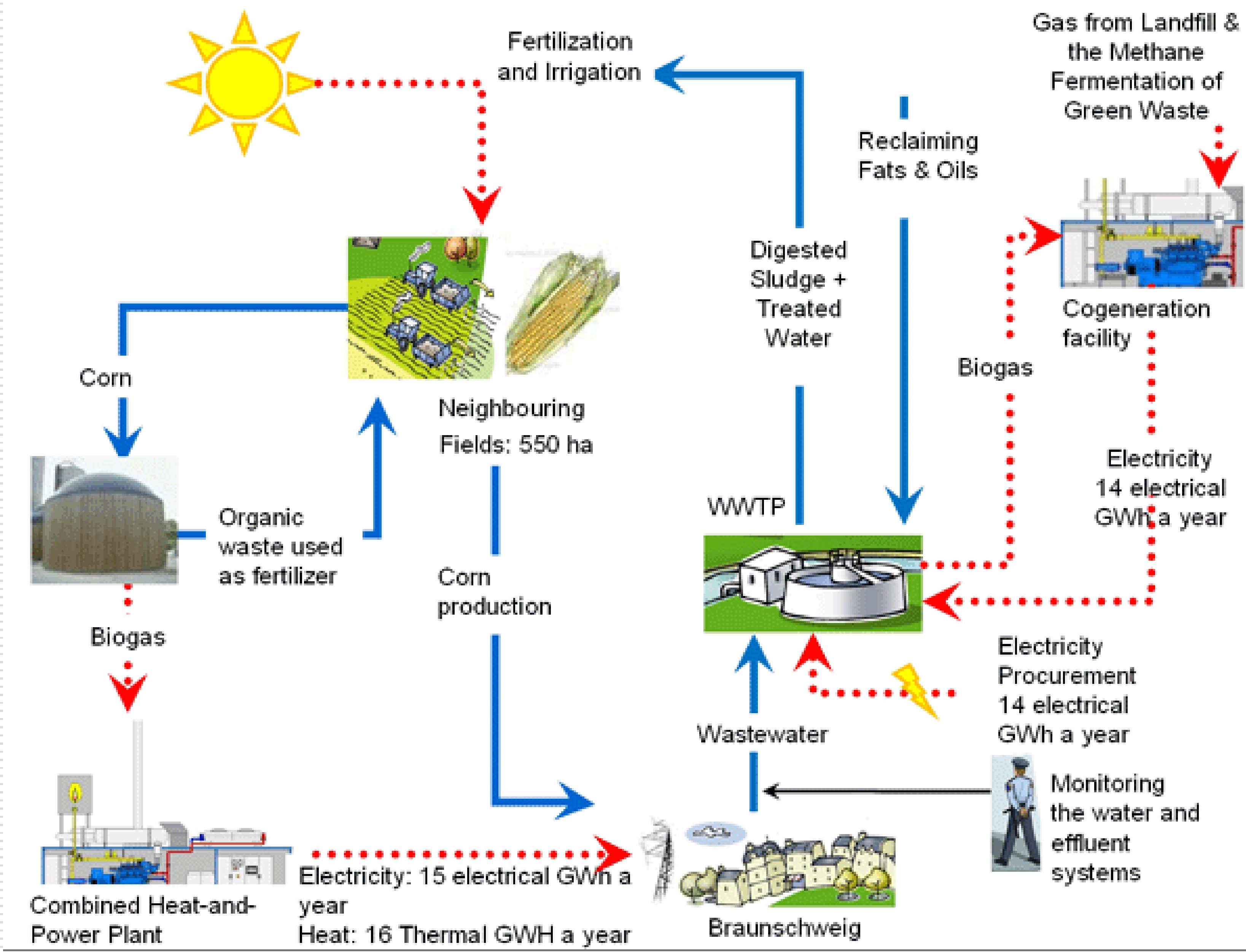


Diagram showing the overall materials flow in the Erdos eco-town, China (diagram by Prof. Zhu Qiang)

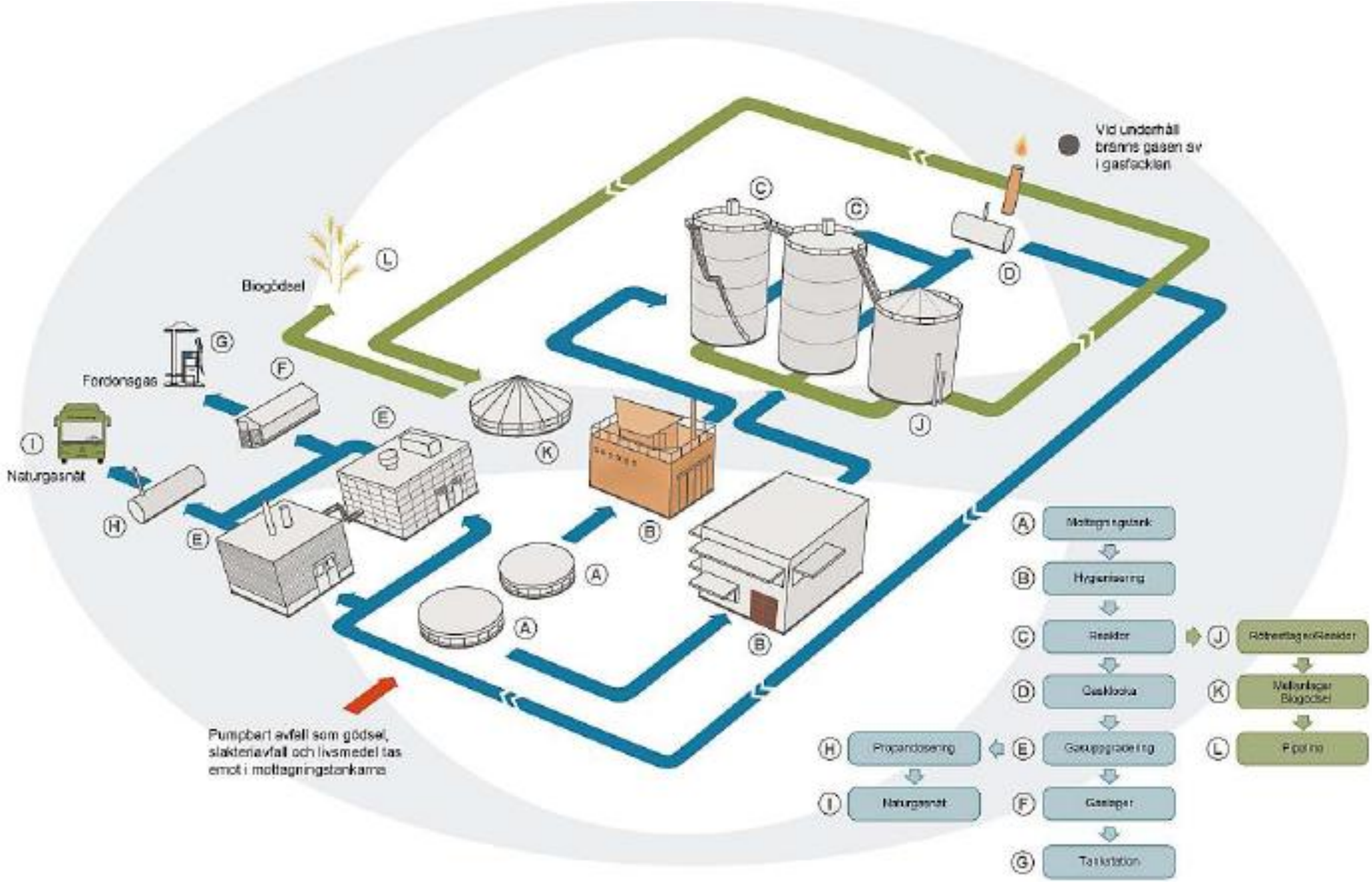



Thermal compost chambers (each 6 m³)
in onsite plant at Erdos – 35 day cycle that reaches 55-60°C.

Braunschweig Hannover



Helsingborg (Sweden) Biogas and Bio-Fertiliser Plant



Bio-Fertliser Pumped by Pipeline to Farms

Trosa, Sweden - constructed wetland system for wastewater

Urine-diverting Toilets, Gebers - Sweden

Potential to Recycle P in the EU

- EU uses 1.34 M tonnes of P/yr
- the animal manure produced is ca 1.6 M tonnes of P
- 2005, the EU produced at least 9.4 M tonnes of dry solids from sewage sludge, equivalent to 0.3 M tonnes of P
- if fully implemented, the EU Urban Wastewater Treatment Directive could probably double the potential P recovery from STPs

- Haarr (2005)

Recycling Phosphorus from Sludge in the EU

- 10 million tons DS produced by EU26
- 36% (3.7 M tons) is being recycled back to agriculture
  - France 58%
  - Germany 50%
  - Netherlands 0%
  - Denmark 59%
  - Italy 18%
  - Sweden 20%
  - Ireland 63%
  - Portugal 46%
  - Spain 65%
  - UK 68%
- Germany P recycling from sewage treatment plants will increase the running costs only 2-5%

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Cadmium Levels

- Natural contaminant in sedimentary apatite rock
- chemical fertiliser in EU contains 2-15 mg Cd/kg P
- German regulations for use of sludge on agrolands 16-17 g Cd/ha/yr
- Morocco phosphate rock contains 60 mg Cd/kg P_2O_5 or 14 mg Cd/kg P
- EU Commission discussing three classes of fertiliser (60, 40 and 20 mg Cd/kg P_2O_5)
- Sweden avg sludge contains 37 mg Cd/kg P (aim is to reduce this to 17 on the avg by 2025
- human urine contains only 1 mg Cd/kg P

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The World is Waking Up to the Problem of Limited Phosphorus

Recent Developments

- Conferences in 2009 on wastewater and sewage sludge reuse of phosphorus in Vancouver in May and Berlin in September
- Article on peak P in Scientific American by David Viccari - June 2009
- Formation of the GPRI Task Force – researchers from Australia, Sweden, Netherlands, Canada, UK - August 2009
- Article on peak P in Nature by Natasha Gilbert in October 2009
- EU first project on sustainable use of phosphorus – Wageningen Univ and Stockholm Environment Institute - 2010

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Recent Developments (cont'd)

- First PhD thesis on peak phosphorus - Cordell (Sydney Univ and Linköping Univ) Feb 2010
- IFA-IFDC industry study on peak phosphorus announced in January 2010, published in Sept
- Phosphates 2010 industry conference in Brussels March 22-24, 2010 – first public discussion on peak P by industry
- Sustainable Phosphorus Initiative (Arizona State Univ 2010)
- UNEP 2011 Year Book to highlight peak phosphorus as the next global issue

Improving Organic Solid Waste Management

Common Forms of Urban Organic Solid Waste

- **Solid waste:** domestic and market wastes, food waste including vegetable and fruit peelings, charcoal ash. This also includes waste from institutions and commercial centres.
- **Horticultural and agricultural wastes:** garden refuse, leaf litter, cut grass, tree prunings, weeds, animal dung, crop residues, waste from public parks etc. Manure: poultry, pig, cow.
- **Agro-industrial wastes:** waste generated by abattoirs, breweries, processing and agro-based industries
- **Sludge and bio-solids:** human excreta from septic tanks and treatment plants

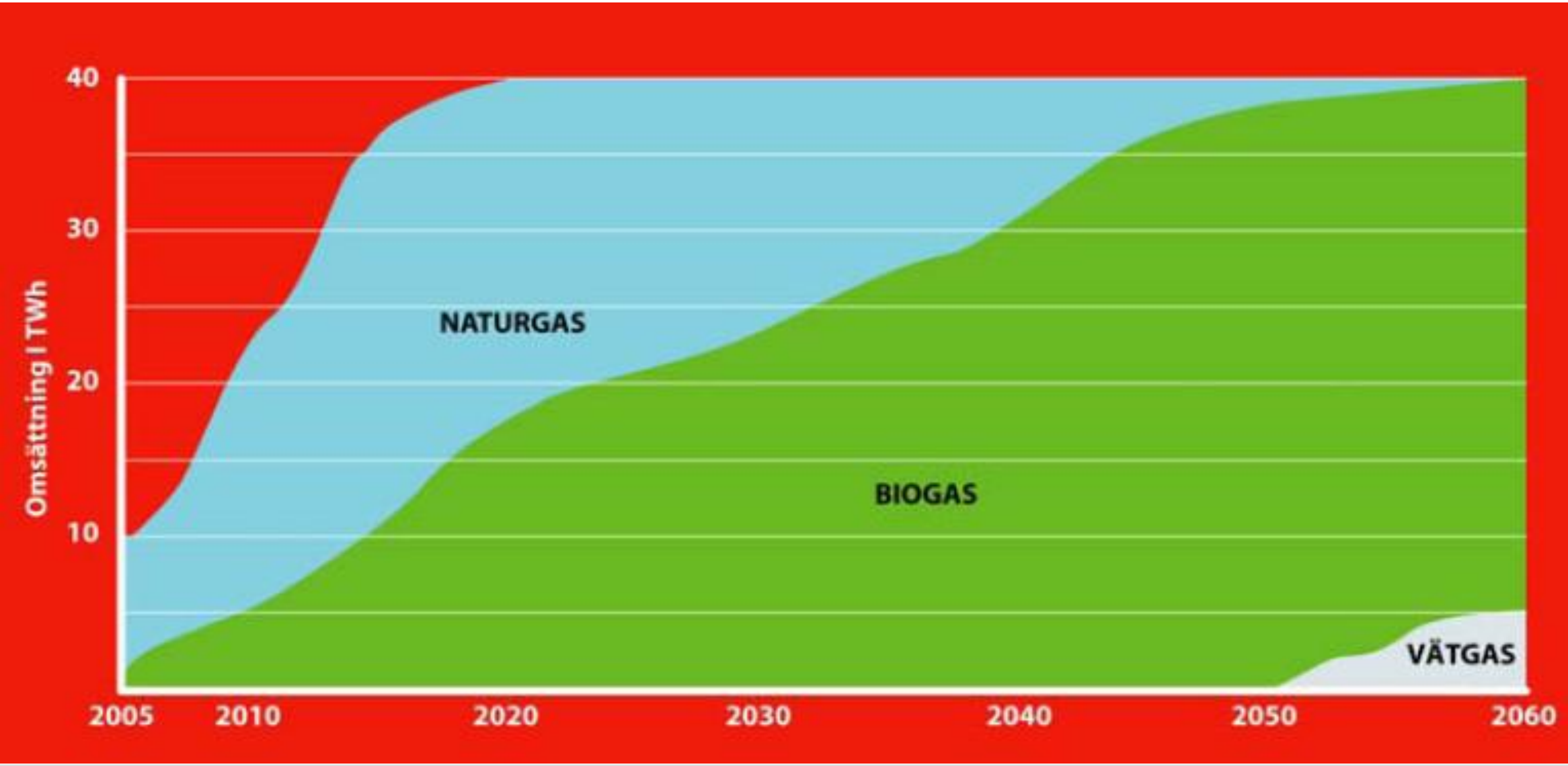
(*Hughes, 1986; Obeng and Wright, 1987; WASTE 1997; Zurbrügg, 2003; Ali, 2004*)

Current Urban Organic Waste Recycling Practices

- Use of fresh waste from vegetable markets, restaurants and hotels, as well as food processing industries **as feed for urban livestock** (Allison et al. 1998)
- **Direct application** of solid waste on and into the **soil**
- **Mining of old waste dumps** for **fertiliser** (Lardinois and van de Klundert, 1993)
- **Application of animal manure** e.g. poultry/pig manure and cow dung to soil
- **Application of human excreta or bio-solids** to the soil (Cofie et al., 2005)
- **Organised composting** of SW or co-composting of SW with animal manure or human excreta

Making Use of the Drive Towards Climate Adaptation

Role of biogas to replace petrol and diesel fuels in Sweden



Prioritising biogas will mean access to P-rich sludge

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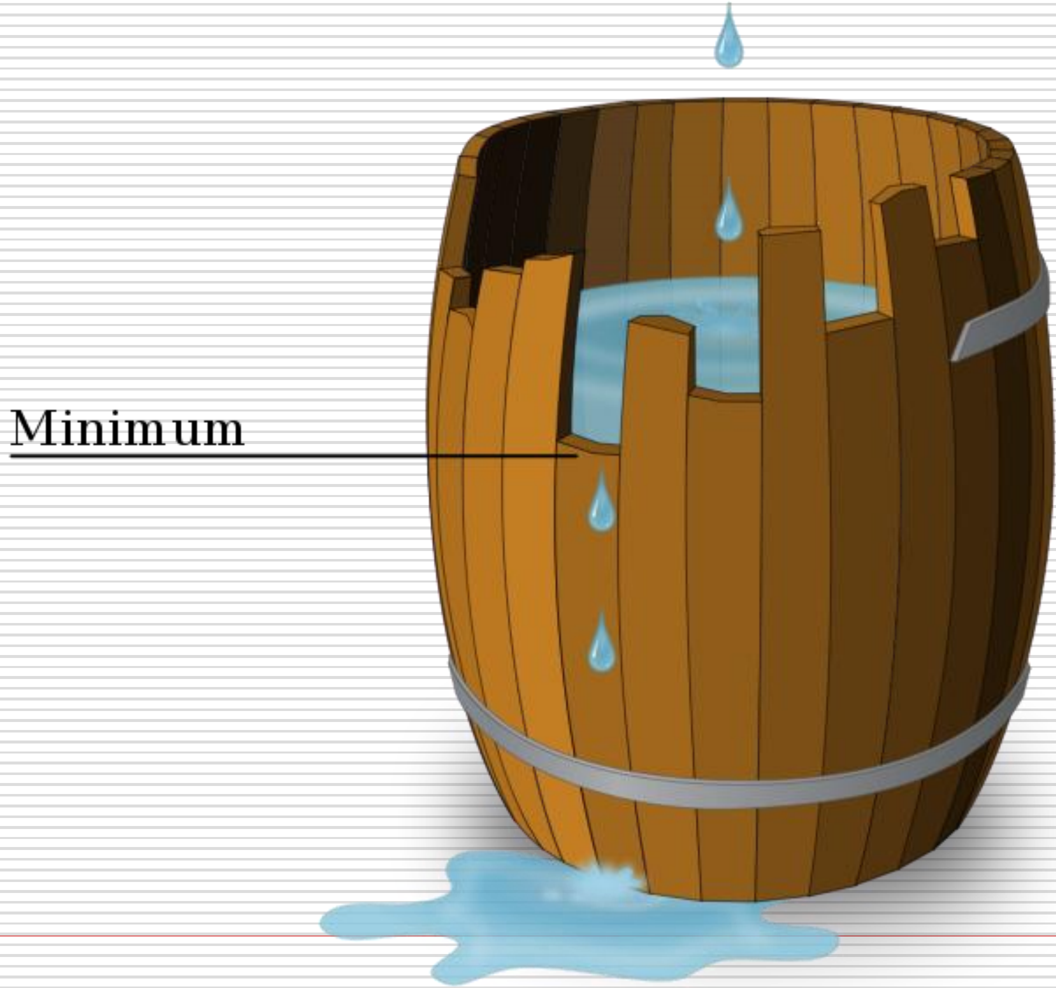
Challenges Ahead Regarding Phosphorus

- **efficiency of extraction** is 50% to 70% and needs to be increased
- **efficiency of use**: 17 Mtons of P are produced per year for fertilizer and only 20% ends up in foodstuffs and most is not recycled
- **agricultural reforms**
  - reduce livestock density to avoid accumulation of P in feedlot areas
  - erosion and runoff control to reduce P loss
  - reduction of over application of P fertilisers
- **recovery and reuse** of phosphorus from organic waste sources
  - animal manure
  - human excreta and ”biosolids” from sanitation systems
  - household organics (green bag programmes)
  - other organics from solid waste
- necessary **changes in food consumption** including less beef
- **slash and burn** practices to mineralize the bound P in agrosoils will cause significant air pollution and even global cooling

Liebig’s Law of the Minimum Makes Phosphorus the Limiting Factor in Food Production



Some Conclusions

- Leibig’s law of limitation now being exemplified in phosphorus
- Use of phosphorus as a macronutrient since the 1950s with the promotion of the Haber-Bosch process to produce large amounts of nitrogen fertiliser is quickly depleting the affordable phosphorus reserves
- P limitation will cause increases in fertiliser and food prices
- Requires changes in agro, waste and sanitation systems enhancing reuse
- Food consumption patterns will need to reflect the real costs for adaptation
- Major challenges are population growth, increased urbanisation, need for urban agriculture solutions using closed loop approaches
- Climate adaptation is a positive driver here promoting biogas and bio-fertiliser solutions
- Present agriculture subsidies (eg in the EU at 1 billion Euros per week) will need to be reformed to encourage reuse

The scenario at hand

- the economic P reserves in the US to be depleted within 25-30 years increasing dependency on Morocco/W Sahara
- the economic global reserves depleted within 75-100 years (new finds & revised estimates could extend this by 50-100 years)
- present phosphate rock extraction to peak by 2035
- use of low-grade P rock, removal of cadmium and expensive offshore mining to cause further price increases
- food prices increase and poor countries cannot afford fertilizer
- global food insecurity

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Problems at hand

- No UN agency monitors the mining of phosphorus which is controlled by industry
- UN, EU and individual countries are not prepared for radical changes in agriculture, waste and sanitation practices
- the 3 UN Food Security Summits since 2008 have not included fertiliser security and do not mention the word phosphorus
- massive agro-subsidies eg **EU's 1 billion Euros per week** mask the real cost of food, create over-production and consumption and render us highly vulnerable to fertilizer insecurity
- already today 1 billion malnourished linked to smallholder farmers can't afford chemical fertiliser

Suggested Next Steps

- International task force
- White paper laying out the facts
- Communications and awareness
- International commission
- Global convention on phosphorus

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