Phosphorus management in a changing world

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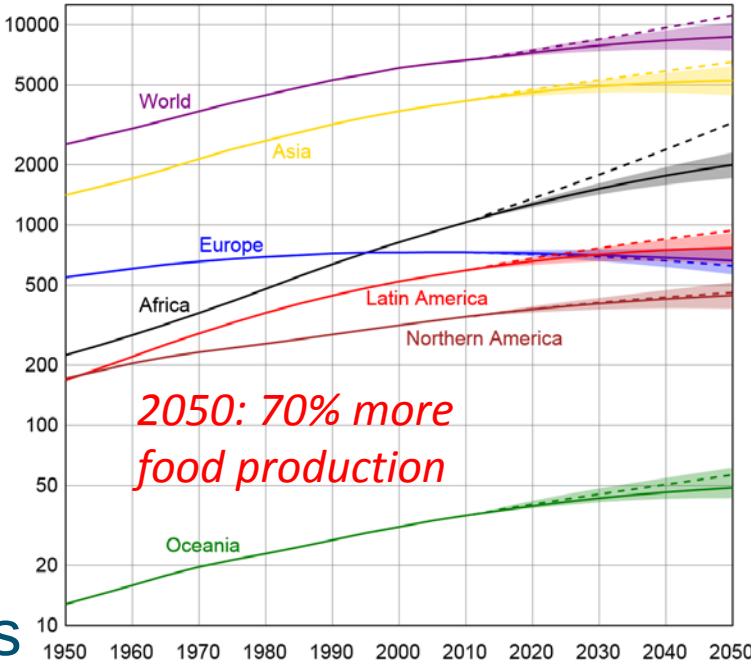
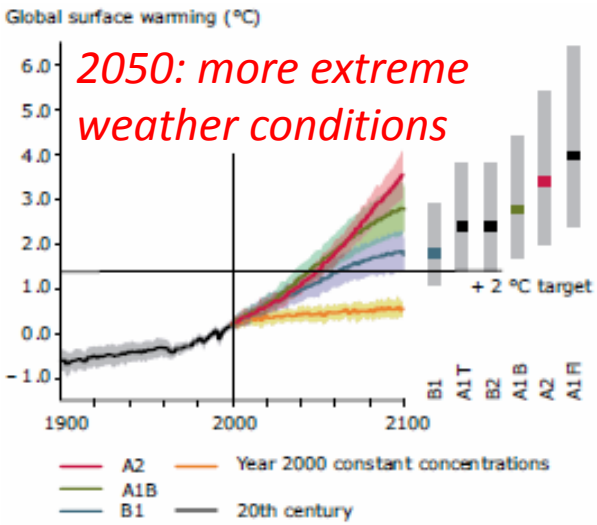
1. Challenges
2. European food security
3. Strategies for closing the P balance
4. Impact of climate change
5. Conclusions

1. Challenges

- Demographic changes
  - From 7 to 9+ billion people
  - Consumption pattern change
  - Urbanization
- Competing claims for resources
  e.g. food vs biofuel
- Climate change



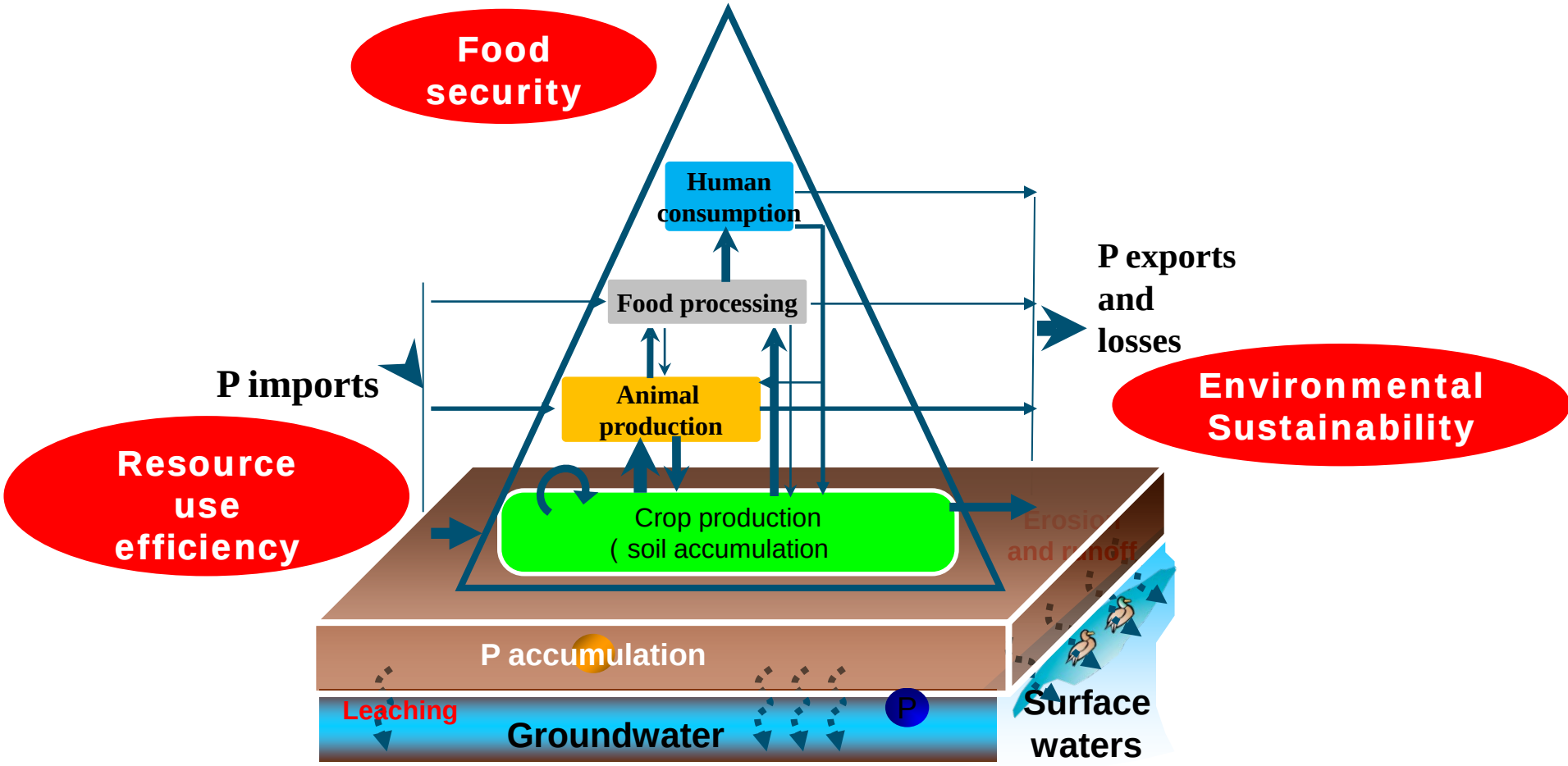
2050: 70% more food production



2050: more extreme weather conditions

2050: 70% of population in cities 'massive resource drains'

Food pyramid and triple management issues



Ma et al., 2010

P management has to deal with all three issues (BMP)

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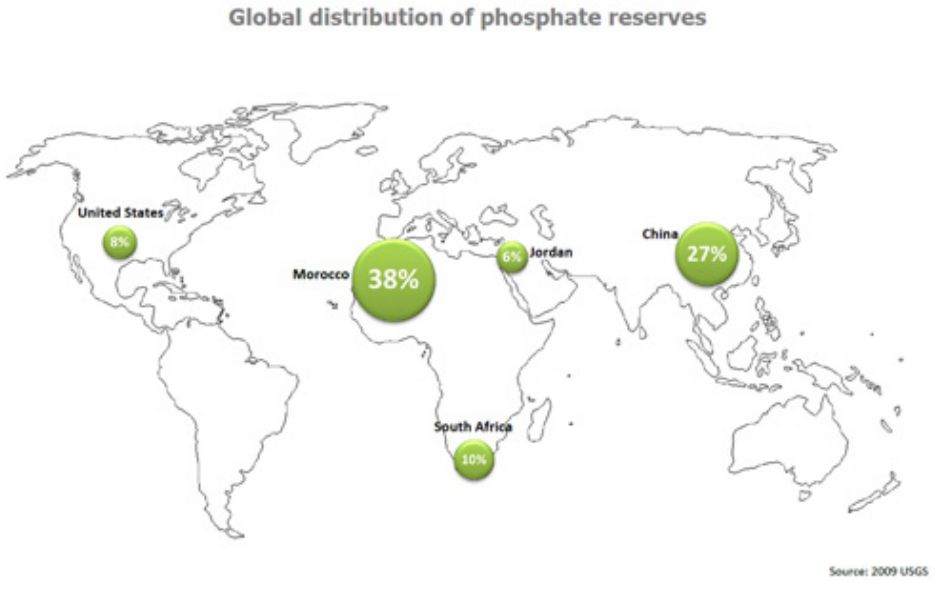
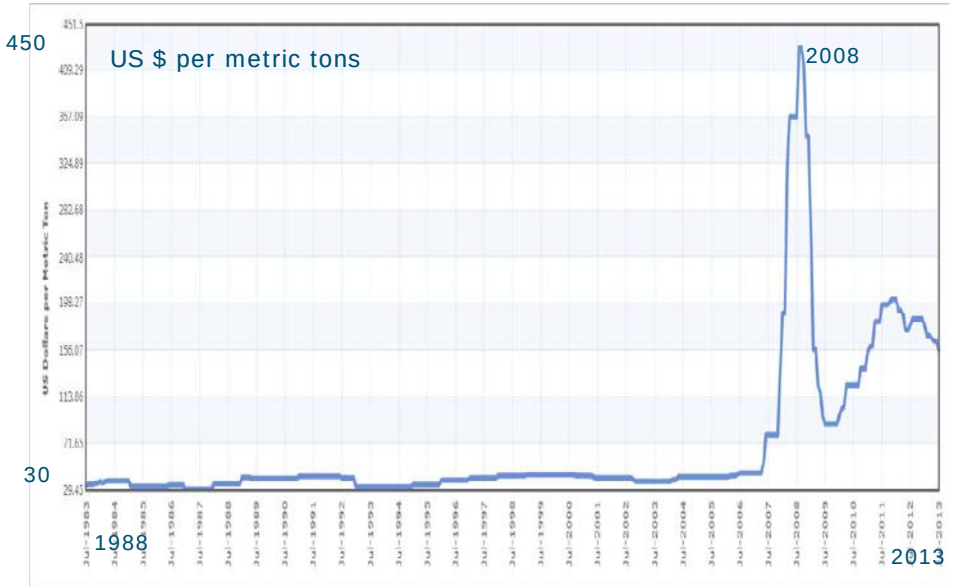
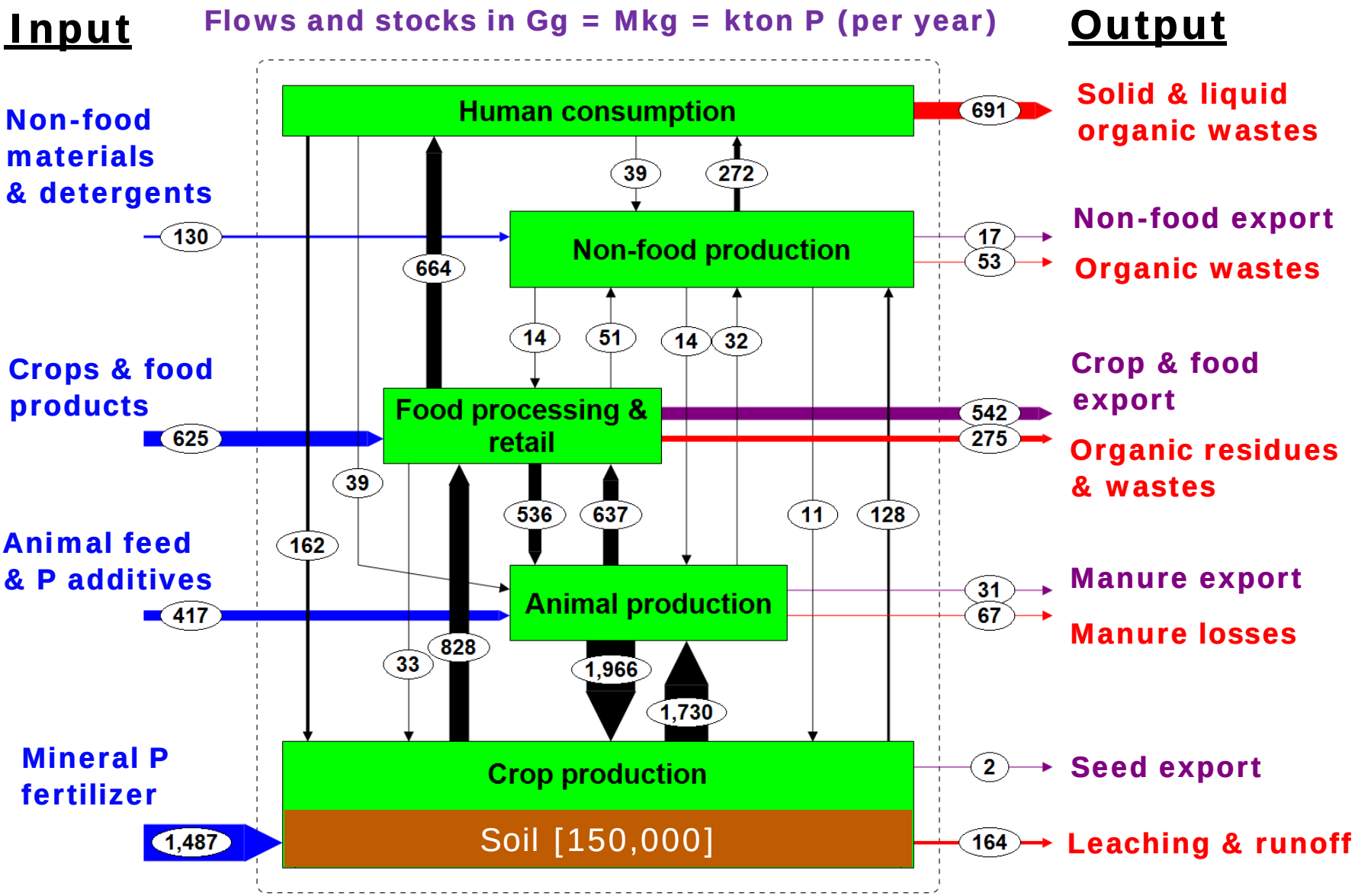
2. Food security; important role of P

- Phosphorus is a life essential finite irreplaceable resource.
- USGS (2012) P reserves worldwide 71 billion tons, world mining production in 2011: 0.19 billion tons (“400 years”).
- BUT: Europe has significant no P rock mines, P dependent, geo-political changes can increase P market prices (e.g. 2008).





Phosphorus use in the EU-27 in 2005



Phosphorus use in the EU-27 in 2005

Gross balance EU27 (roughly)					
IN	**kton**	**%**	**OUT & Accumulation**	**kton**	**%**
No-food & detergents	100	4%	**Products (exported)**	600	**23%**
Crops & food products	600	23%	**Waste & losses**	1200	**46%**
Animal feed & P additives	400	**15%**	**Accumulation**	800	**31%**
Mineral fertilizer	1500	**58%**			
	2600	100%		2600	100%

- High P input mainly to agricultural production system (73%)
- High P losses (46%; including organic waste)
  (mainly Human consumption & Food processing; total 42%)
- High P accumulation 31% (mainly in soils; 29%)

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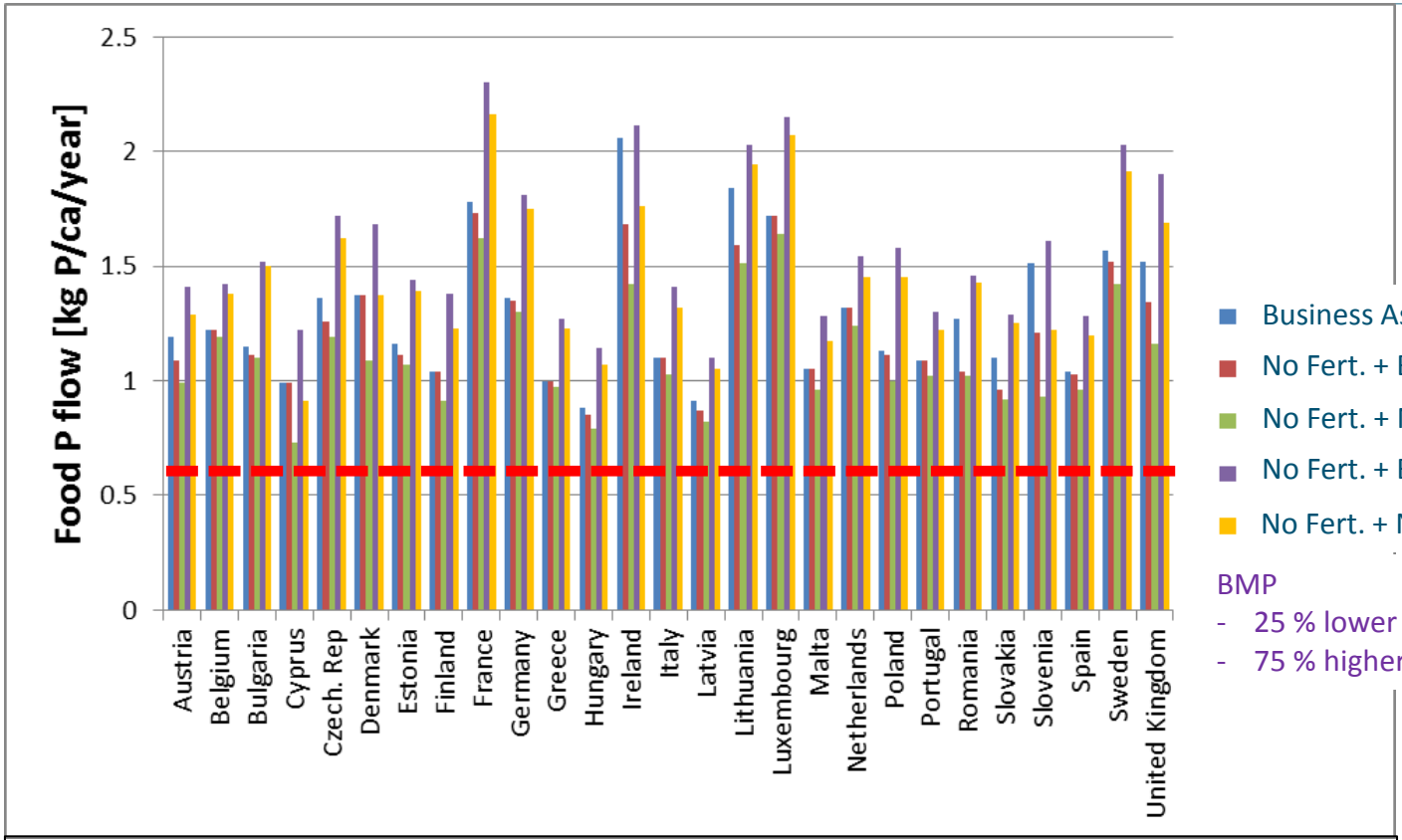
Total P in food available per capita per Member State per scenario in 2050



Required food flow to households per capita: 0.6 kg P/ca per year
P recommended daily amount(RDA adult) = 800 mg P/day ≈ 0.3 kg P/year

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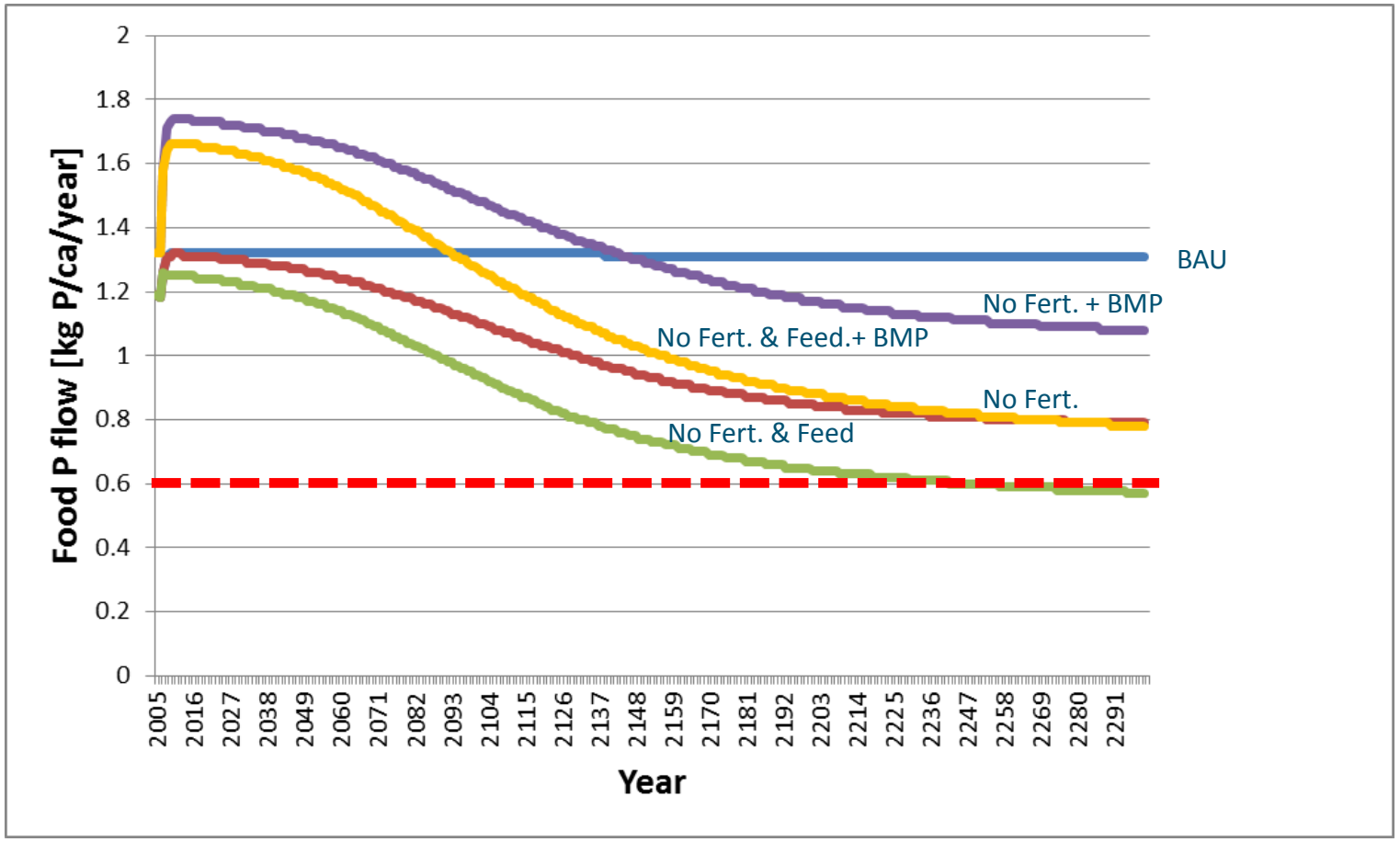
Source: Van Dijk et al., 2013

No really a topic at the short term, but when?

Changes in total P in food per capita in EU-27 per scenario for 2005-2300



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Source: Van Dijk et al., 2013

At the end of 23th century an issue in EU27, but ....
still a need to increase the P efficiency & reuse of P !!

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3. 4R-Strategy for closing the P balance

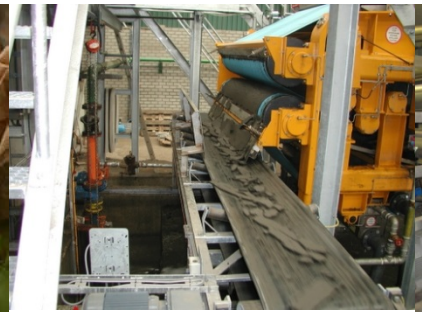
1. Reduce the inputs, where possible

2. Reuse P from organic residues and manures

3. Recover P from waste (& if needed manure)

4. Redefine systems, where needed





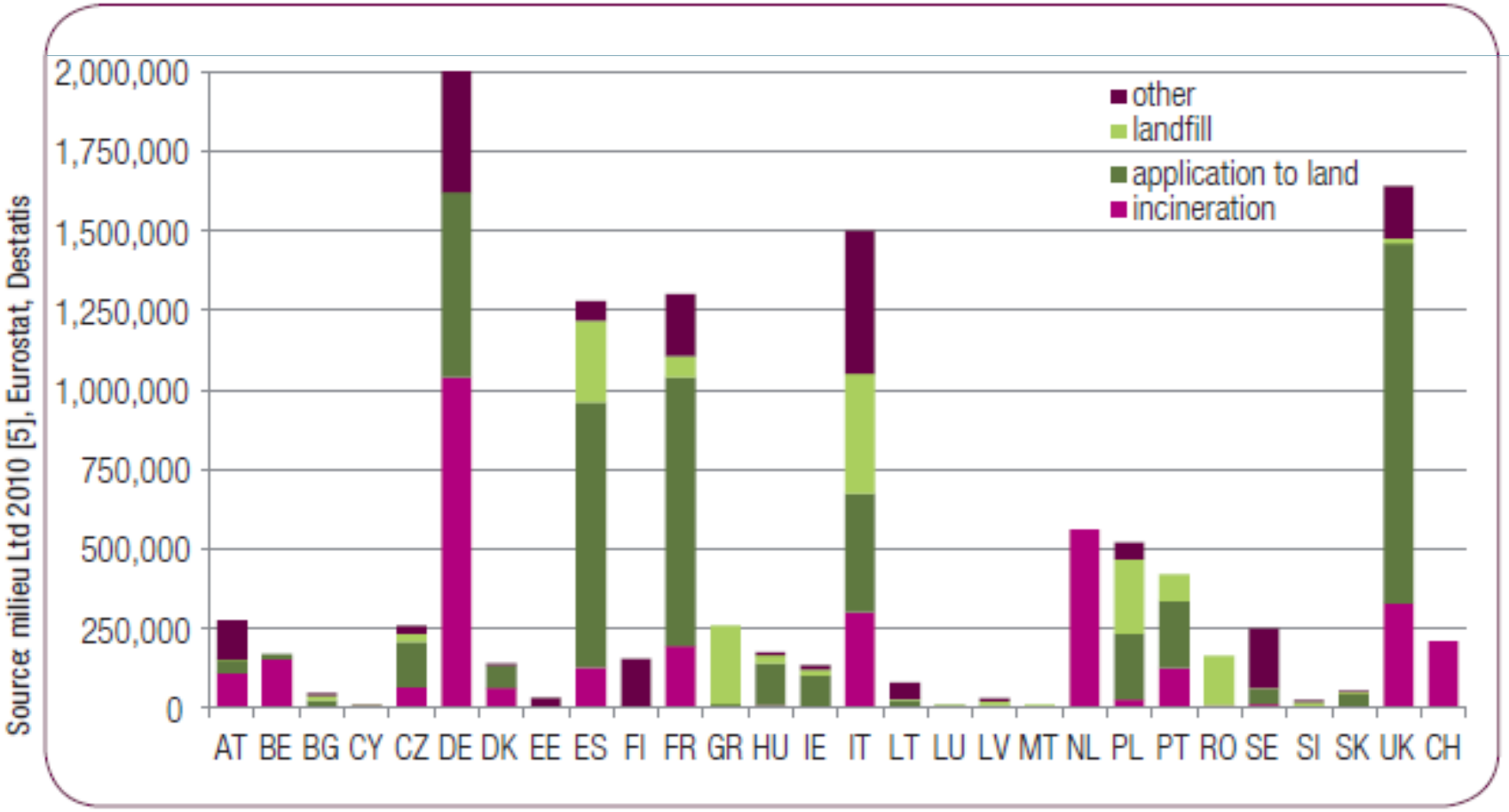
3. Implementation of the 4R-strategy

1. Reduce total P content in feed and increase digestible P (bio-refinery) → 20-25% reduction (Van Krimpen, 2012).
2. Reuse: Better use of manure reduces P fertilizer input:
   - ✓ make use of manure separation techniques
   - ✓ 4R-stewardship; right source, amount, time, place
3. Recover nutrients from household / industrial waste and from excess of manure.
4. Redefine systems:????????




Waste water treatment plants (WWTP)

Sludge valorization (2010; tons dry matter)



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P recovery methods WWTP

	Scale	Product
Sludge		
AirPrex®	full	MAP
Lysogest®	full	MAP
NuReSys®	full	MAP
PHOSPAQ	full	MAP
CRYSTALACTOR®	full	CaP
Gifhorn process	full	MAP
Fix-Phos	full	CaP
Stuttgart process	pilot	MAP
Budenheim process	pilot	Cap
sludge liquor/process water		
REPHOS®	full	MAP
PEARL® (PEARL 500)	full	MAP
NuReSys®	full	MAP
P-RoC	pilot	CaP
PHOSTRIP	pilot	MAP or CaP
P recovery during or after incineration		
MEPHREC®	full	P fertilizer
SUSAN	full	P fertilizer
Thermphos*	full	White P4
LeachPhos	pilot	MAP or CaP
EcoPhos/SNB/HVC	full	DCP

full-scale units

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P recovery from manure

Potential value of pig slurry

	content[1] (kg/m^3)	Resource market price[2] (€/kg)	Total min (€/m^3)	Total max (€/m^3)
Nitrogen anorganisch (N)	0.8 - 6.8	0.167 - 0.389	€ 0.13	€ 2.64
Protassium (K_2O)	2 - 14	0.095 - 0.222	€ 0.19	€ 3.10
Phosphate (P_2O_5)	0.6 - 6.2	0.157 - 0.365	€ 0.09	€ 2.26
Organic matter (solid phase)	35 - 45	0.091 - 0.117	€ 3.19	€ 5.27
Potential value (€ m^{-3})			€ 3.60	€ 13.28

[1] Römkens and Rietra (2008); content of inorganic N, P_2O_5 and organic matter; content of K_2O assessment

[2] LEI, 2012; resp. **15% - 35%** of the fertilizer market prices based on KAS (N), TSP(P_2O_5) and K60 (K_2O) and value of energy production of organic matter (based on 0.07 - 0.09 € per kWh)

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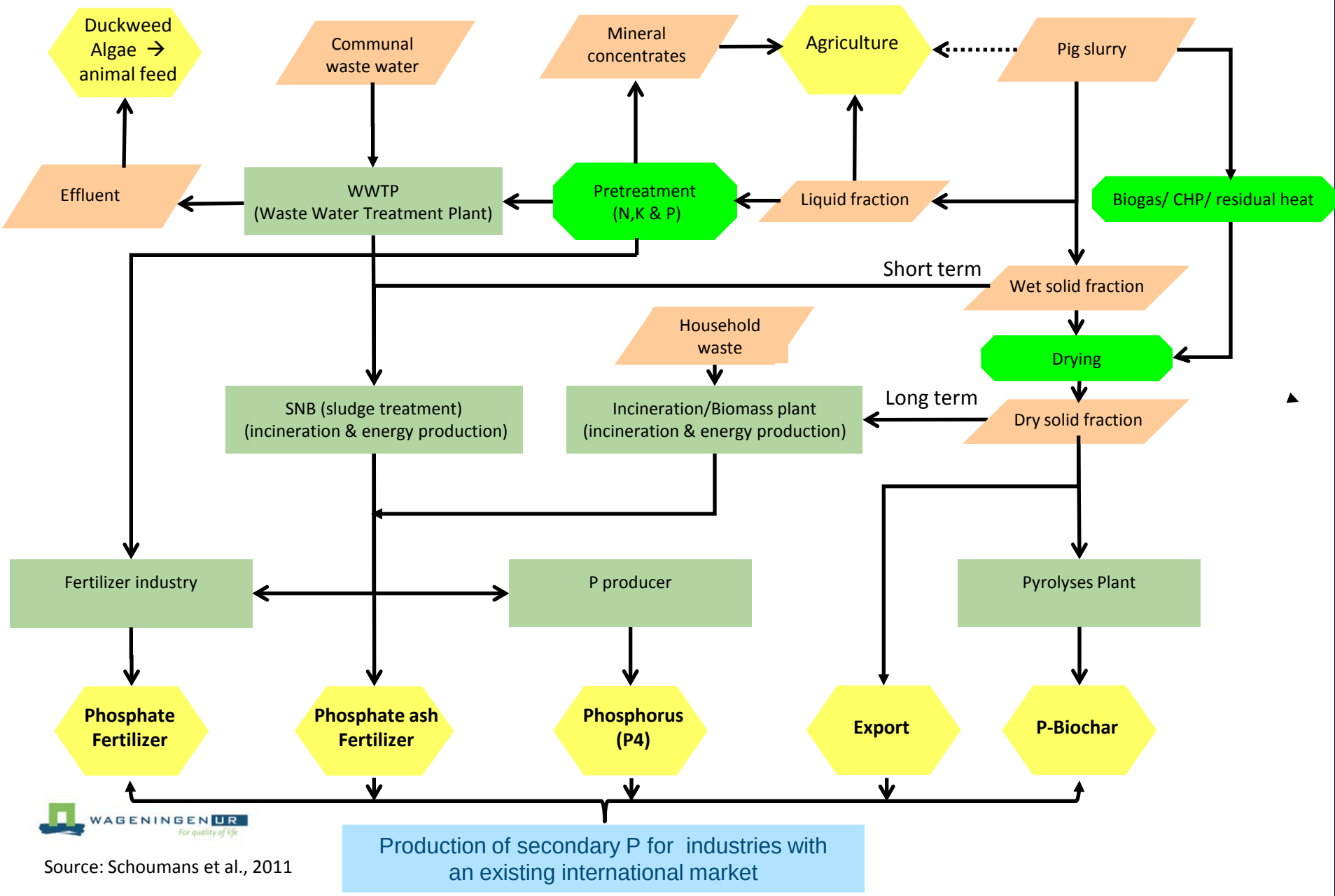
Source: Schoumans et al. (2010)

Phosphate and Phosphorus recovery



Production of secondary P for industries with an existing international market

Source: Schoumans et al., 2011

Costs of P recovery from manure

Example to produce P ash as secondary resource

	no drying	limited drying (50%)	drying (90%)
separation, optional drying and transport liquid and solid	10- 12	14 -17	16 -19
Treatment solid fraction	9.8	-0.5	-2.3
Treatment liquid fraction	11 - 14	11 - 14	11 - 14
Total	31 - 36	24 - 30	25 - 31

P recovery from manure still rather expensive
Cheaper and simpler techniques are needed

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Source: Schoumans et al. (2010)

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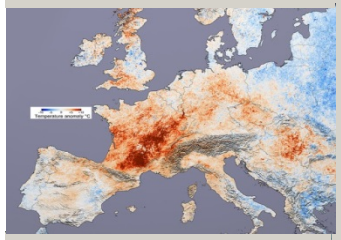
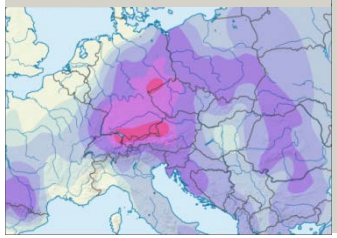
4. Impacts of climate change

- Expected direct changes
  - Temperature rising: 2.5–4° C warmer (2100 compared to 1961–1990).
  - Precipitation decreasing southern regions, increasing in northern Europe
  - More extreme weather events
    - Increase frequency and length of heat wave
    - Increase river flooding (N-EU) & river flow droughts (S-EU)
- Impacts on Health, Nature, Agricultural, Environmental, Economy

Heat wave 2003



Flood June 2013



Droughts:

- **Past thirty years to a total of 100 billion € at EU level.**
- **It reached an average 6.2 billion €/year (economical costs)**
- **2003: France 14.000 people died (Europe total: 30.000 deaths)**

Source DG Env. (2007; latest report)

Floods

- **1960-2009, 298 floods in current EU member states**
- **Past 10 years 1000 persons died.**
- **Main events: several billions € (2013 central EU: total €12.4 billion)**

Source: WHO regional office Europe (2013)

- But how does climate change effects P cycle????

4. Impact of climate change; Nutrient load

- *No overall effect of CC on nutrient losses reported for whole Europe, only some catchment, river basin & coastal studies*

		Changes (%) annual			
catchment	Country	Water	N	P	Reference
Vantaanjoki	Finland	3.3	2.8	2	Bouraoui et al (2004)
Ouse	England	5	6 - 27	5 - 34	Bouraoui et al (2002)
Gjern	Denmark	12.3	6.9 - 8.5	-	Andersen et al. (2006)
Streams & lakes	Denmark		-	3.3 - 16.5	Jeppersen et al (2009)
4 Catchmenst	Norway	12 -22	-	increases	Øygarden et al (2011)
Baltic Sea	Sweden e.a.	increased	decreases	increases	The BACC-porject (2006)
Baltic Sea	Sweden e.a.		decreases	increases	Arheimer et al., (2012)

4. Impact of climate change

- Nutrient losses and eutrophication: common effects based on catchment studies
  - Higher temperatures stimulate mineralisation, denitrification, P sorption, shift in crop production, higher evapotranspiration, higher nutrient uptake, ... but not much attention on harvest loss.
  - Increases in floods and extreme precipitation events will increase the nutrient load to surface waters due to increased erosion and (surface) run-off.
  - Decreases in summer stream flow will lead to higher nutrient concentration.
  - Variations between years were found to be much larger than an eventual long-term trend for each climate projection

Seldom combined effect of 4R-strategy (res. eff., nutrient recovery) studied & management highly determines the nutrient losses

Can management (4R-strategies) compensate the increase of nutrient losses ?

5. Conclusions

- Phosphorus plays key role in the triangle Food security, Resource use and Environmental Sustainability.
- The EU-27 is heavily dependent on the import of P via mineral fertilizer and animal feed (73%). Efficiencies food system low.
- A stop on P fertilizer & feed import has a large effect on the European food security in the long term (23th century).
- 4R-strategy needed to optimize P management to deal with the food pyramid / triangle issues as a whole.
- Effects of climate change on the *whole* P cycle still quite uncertain. 4R-strategy can help to reduce additional P losses, like management did in the past.

Thank you for your attention

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