Present and future phosphorus use in Europe: food system scenario analyses

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Overview

- Phosphorus (P) cycling
- Present P flows in Europe
- Sustainable P use options in society
- Dynamic food system model
- Future P use scenario analyses
- Summary & conclusions
Geological versus anthropogenic cycles

Anthropogenic cycle = days to years

Geological cycle = millions of years

Inputs [90% fertilizer, and other mineral P use]

Losses

SINKS

Direct IMPACTS

INPUTS

RESOURCE RESERVES

Society

Consumers

Industry & retail

Animals

Crops

Non-food

Non-food
Phosphorus use in the EU-27 in 2005

**Input**
- Detergent, wood, paper & fibers
- Crops, fish, food products & mineral additives
- Animal feed, mineral additives & live animals
- Mineral fertiliser, seeds & pesticides

**Output**
- Solid & liquid organic waste
- Wood, paper & fibers
- Organic wastes
- Crops & food products
- Slaughter residues, solid & liquid waste
- Live animals
- Manure losses
- Seeding materials
- Leaching & runoff

Flows & stocks in Gg = Mkg = kton P per year

Soil [150,000]
Fertilizer P consumption in EU-27 in 2010

FAOSTAT data 2010
Animal feed P origin in EU-27 in 2005

Source: Miterra-Europe model, CAPRI & FAOSTAT data 2003-2005
Agronomic P balances in the EU

Estimated cumulative P balances [kg P/ha] of EU countries during 1991–2005

Annual regional agricultural P balances [kg P/ha] for EU-15 in 2000

Source: Csathó & Radimszky 2012
Domestic food P supply in EU-27 in 2005

Domestic food P supply necessary to fulfill human dietary P intake requirements at consumption level

Minimum P intake requirement

Mean EU P intake

Maximum P intake level

Van Dijk et al. (in preparation)
Reuse of organic waste in EU-27 in 2005

Compost use as fraction of total potential organic waste quantity [%]

Based on Barth et al. 2008
Sludge destinations in EU-27 in 2010

P concentrations in rivers and lakes in EU regions, period 1990 - 2005

Potential phosphorus losses in society

- Three ‘types’ of potential P losses:
  - Sequestration: incineration, landfilling, co-firing or use in the cement industry
  - Accumulation: in agricultural soils or the environment
  - Export: flows with unclear destinations
- Avoidable and unavoidable losses
- Point and diffuse sources
- Direct and indirect actors
Transition towards sustainable P use

- **Realign P inputs**
  - remove non-essential P inputs (e.g. detergents)
  - match P requirements more closely (precision agriculture)
  - utilise legacy P stores

- **Reduce P losses to water**
  - optimise input management
  - minimise runoff and erosion
  - strategic retention zones

- **Recycle P in bioresources**
  - avoid wastage
  - improve utilization efficiency
  - adopt integrated production systems

- **Recover P in wastes**
  - recover P in societies' wastes
  - produce fertilizer substitutes

- **Redefine P in the food chain**
  - influence dietary choice
  - define end-user P requirements
  - re-connect crop and animal production systems

Withers, Van Dijk, et al. (submitted)
## P recycling potential in EU-27

<table>
<thead>
<tr>
<th>[Gg P/year]</th>
<th>Total</th>
<th>Recycled</th>
<th>Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sewage sludge</strong></td>
<td>297</td>
<td>115</td>
<td>182</td>
</tr>
<tr>
<td><strong>Biodegradable solid waste</strong></td>
<td>130</td>
<td>38</td>
<td>92</td>
</tr>
<tr>
<td><strong>Meat &amp; bone meal</strong></td>
<td>128</td>
<td>6</td>
<td>122</td>
</tr>
<tr>
<td><strong>Total (minimum)</strong></td>
<td>427</td>
<td>153</td>
<td>274</td>
</tr>
<tr>
<td><strong>Total (maximum)</strong></td>
<td>555</td>
<td>160</td>
<td>396</td>
</tr>
</tbody>
</table>

| **Mineral fertiliser use**       | 1448   |          |           |
| **Manure use**                   | 1763   |          |           |

Van Dijk et al. (in preparation)
EU-27 P use scenario analyses

OF COURSE
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Objectives & research questions

- To develop a dynamic model for the analysis of the effects of changes in drivers and nutrient management strategies on P dynamics in the food chain.

- What would be the P dynamics & food production in EU-27 in case of a stop of P import via
  - Q1: mineral fertilizers?
  - Q2: mineral fertilizers and animal feed?
- Q3: What are effects of best management practices (BMPs) on food production and P use efficiency?
Dynamic Food System model

- Mass balance principle
- Data: Miterra-Europe, CAPRI, FAOSTAT, Eurostat, reports, articles and experts
- EU-27 at country level, timesteps of one year
- Entire food system + non-food
- P imports, exports, losses and internal flows
- Flows described dynamically as function of sector input
- Crop P uptake as function of soil P stock and P application
Scenarios & best management practices

- The scenarios are:
  - BAU: present (~2005), Business as Usual
  - S1: no P import via fertilizer
  - S2: no P import via fertilizer + compound feed
  - S3: as S2 + BMPs

- The best management practices (BMPs) are 90 % less:
  - biowaste + waste water P losses (HC)
  - forestry sector losses (NF)
  - slaughter waste losses (FP)
  - stable manure losses (AP)

- No changes in other drivers and factors, such as population, agricultural area, crop types etc.
Per ha EU-27 crop P uptake per scenario for 2005-2300

Van Dijk et al. (in preparation)
Per ha EU-27 soil P stock per scenario for 2005-2300

Van Dijk et al. (in preparation)
Per capita food P supply per Member State per scenario in 2050

Van Dijk et al. (in preparation)
Changes in per capita food P supply in EU-27 per scenario for 2005-2300

Van Dijk et al. (in preparation)
Changes in dry matter crop yield in EU-27 per scenario for 2005-2300

Van Dijk et al. (in preparation)
Conclusions for the present state

- Europe is largely dependent on P imports via:
  - Mineral fertilizers (60%), animal feed & additives (20%), food (10%) & non-food materials (10%)

- Ongoing P accumulation in agricultural soils, especially in western Europe by P surplusses

- Various recycling rates, generally low (except manure):
  - Sewage sludge P recycling ranging from 0 - 90%
  - Compost P re-use ranging from 0 - 70%

- Significant P losses via:
  - Waterways: sewage discharge, leaching & erosion
  - Sequestration: incineration, landfilling, infrastructure

- High potential to improve P use efficiency
Conclusions for future scenarios

- Soil P is an important stock to take into account in P dynamics, because of its buffering capacity and large size (~150,000 Gg P)
- A stop on P fertilizer import has a large effect on food production, mainly on the longer term
- A stop on P import via fertilizer and animal feed makes the effect even more pronounced, causing a larger and earlier drop in food production
- The effects can be mitigated by the implementation of best management practices in nutrient management
- Additional data is necessary, especially for downscaling to the regional level
Thank you for your attention

Questions? Comments? Suggestions?

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