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UK P flows with focus on proposed indicators for decision makers

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The original project: Towards closed-loop P management for the UK Water Industry

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12 UK Water Companies

- Understanding global P supply & demand
- EU / UK drivers (economic, political, environmental, technological)
- Scenarios & strategies for economic recovery of P from wastewater

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A substance flow analysis of phosphorus in the UK food production and consumption system

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ABSTRACT

Phosphorus (P) is both an essential resource, required for plant growth and food production, and a costly pollutant, capable of causing eutrophication in water courses. The possibility of future phosphorus scarcity and the requirement to improve the quality of UK waters necessitates the development of a UK phosphorus management system, which increases use efficiency, reduces losses and recycles wastes more effectively. A vital first step towards creating such a system is to conduct a substance flow analysis (SFA), which maps and quantifies the relevant stocks and flows, allowing specific measures to be implemented that target identified losses and areas of inefficient resource use. This paper presents the results of a SFA for phosphorus in the UK, focussing in particular on the food production and consumption system for the year 2009. The SFA results suggest that the UK population consumed around 31.0 kt P in 2009, which was largely achieved by importing food, feed and fertilisers, with net imports totalling 113.5 kt P. Imported fertilisers accounted for 56% of the total imports, containing 77.5 kt P. The largest losses within the systems were those to water, estimated at around 41.5 kt P/yr, and soil accumulations are estimated at 37.5 kt P/yr. The efficiency of UK crop production is estimated at 81%, whereas the efficiency of producing animal products is only 16.5%. Wastewater treatment works (WwTW) received around 55.0 kt P within wastewater, with 57% being removed in sewage sludge. The 23.5 kt P discharged within final effluent represented the largest loss to UK waters. Around 71% of the sludge was recycled to land, containing 22.5 kt P, although the rate of application was around 5× higher than the uptake rate for crops, demonstrating the challenges of effectively recycling bulky wastes. Existing measures aimed at tackling water pollution and climate change have acted to improve P management in the UK, although additional measures focussing particularly on P as a resource are required. The results from this analysis suggest focussing on P removal and recovery at WwTW, as well as developing more effective methods for recycling bulky wastes such as animal manure, food waste and sewage sludge in order to reduce soil accumulations and replace imported fertilisers. Conducting additional SFAs at smaller scales may be necessary in order to develop more specific measures, such as regional recycling strategies.

1. Introduction

Phosphorus (P) is an essential nutrient required for plant growth. Without regular applications, crop yields would be limited and it would not be possible to feed the world's population. Modern agriculture relies heavily on mineral fertilisers which contain phosphorus derived from phosphate rock. Since phosphate rock is a non-renewable resource, there are growing concerns regarding future phosphorus scarcity and the sustainability of modern agriculture.

Previous estimates suggested that phosphate rock reserves could be completely depleted within 50–100 years (Steen, 1998; De Haes et al., 2009; Smit et al., 2009; Vaccari, 2009; Cordell, 2010) and that peak phosphorus could occur around 2033 (Cordell et al., 2009). However, the U.S. Geological Survey (USGS) now estimate that there is enough phosphate rock to last around 370 years at current extraction rates (Jasinski, 2011). Despite this, resource scarcity concerns have not been completely dismissed, since it is estimated that Morocco controls over 77% of the global reserves and China, Morocco and the U.S. combined control over two-thirds of the world's production (Jasinski, 2011). Also, the reserves in most countries, most notably China and the U.S., will be depleted before the end of the century and therefore production will become increasingly concentrated to just a few countries, predominantly Morocco (Cooper et al., 2011). Also, longer-term indicators such as rising demand, declining quality and increased production costs suggest that the price of phosphate rock will increase in the future, which would affect the affordability of food worldwide.

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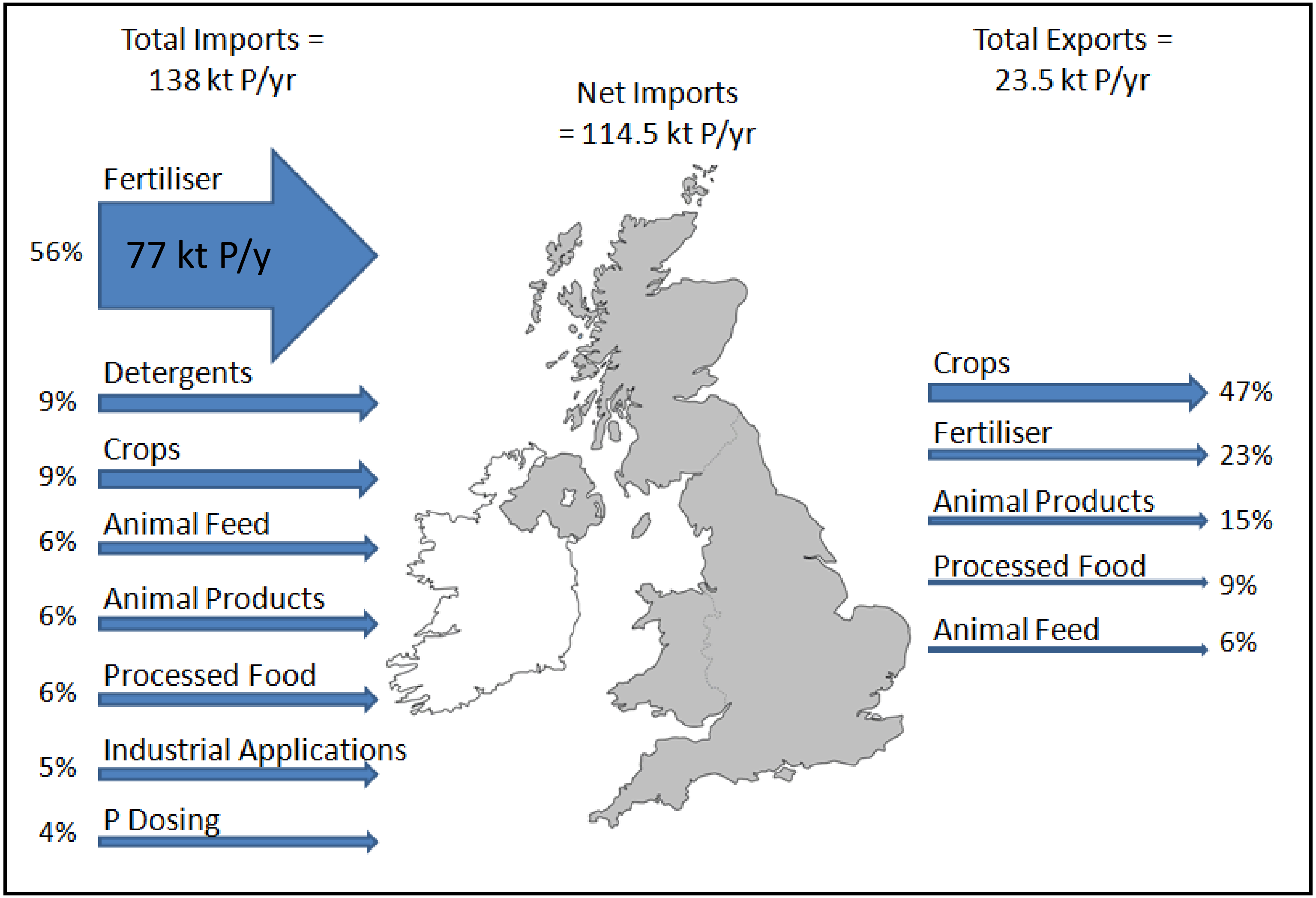
UK P imports and exports in 2009



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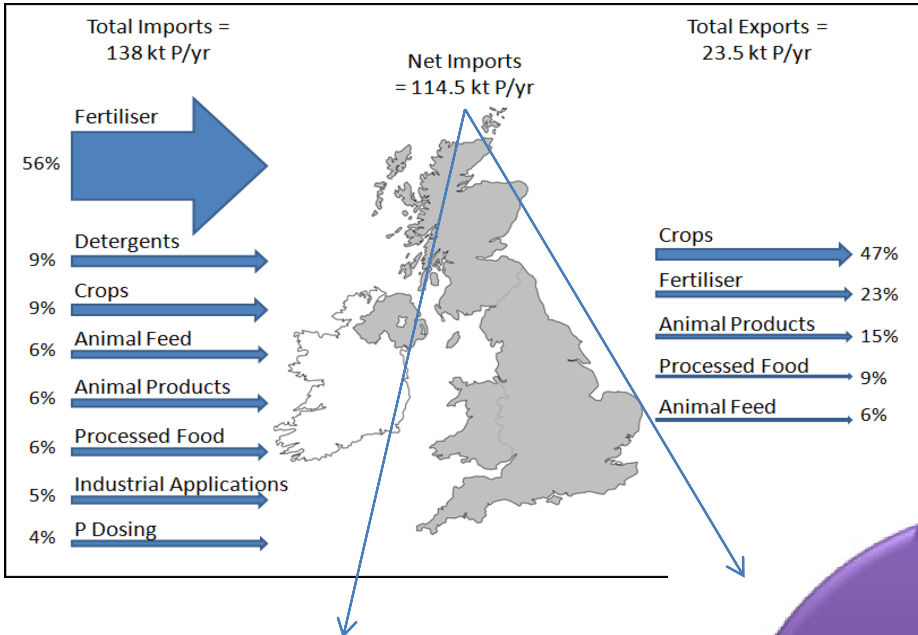
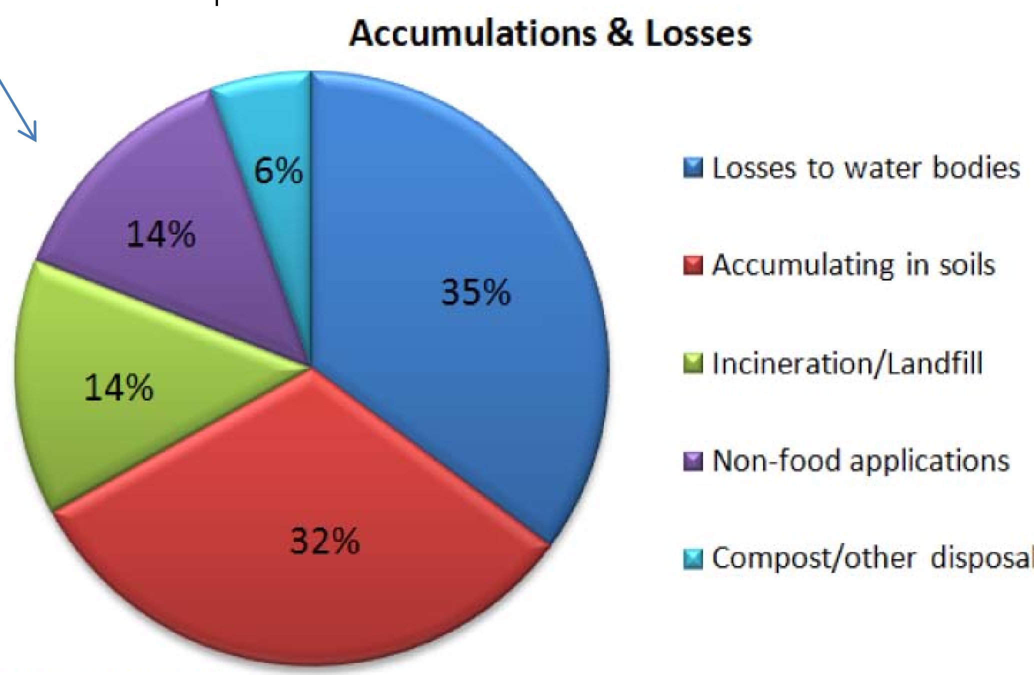


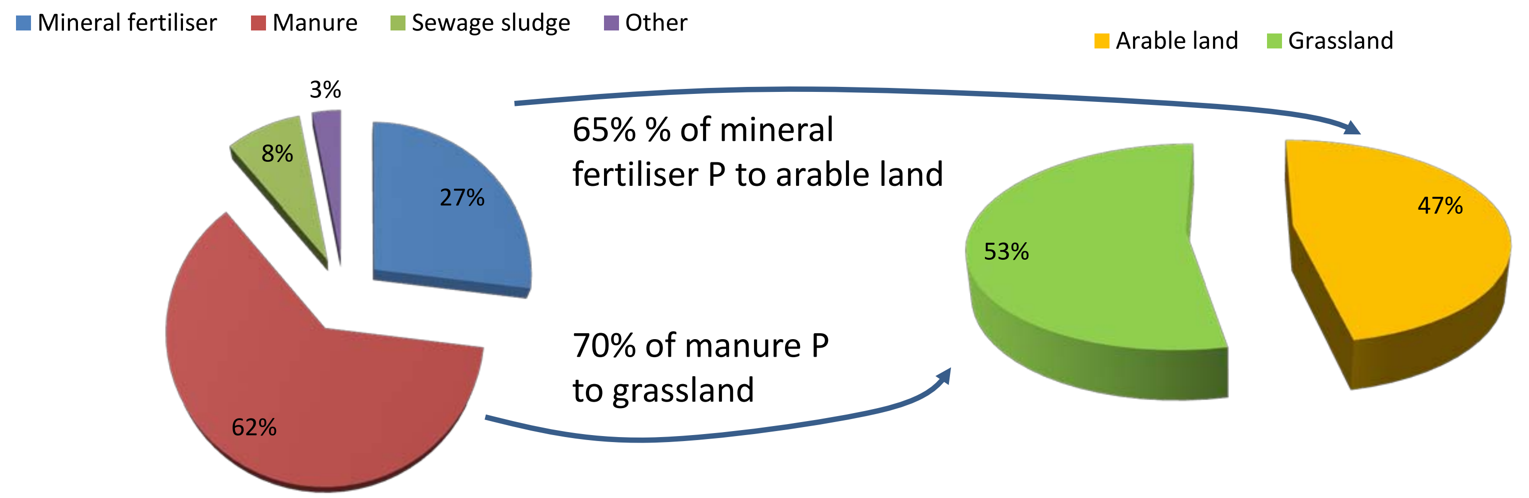


31 kt P / yr as food consumed by UK population (imported + produced)

P in UK agriculture (arable and grassland)

P source inputs to agricultural land

P inputs to arable versus grassland



P inputs to arable & grassland vs outputs as crops and grasses

P inputs

268.5 kt P/yr

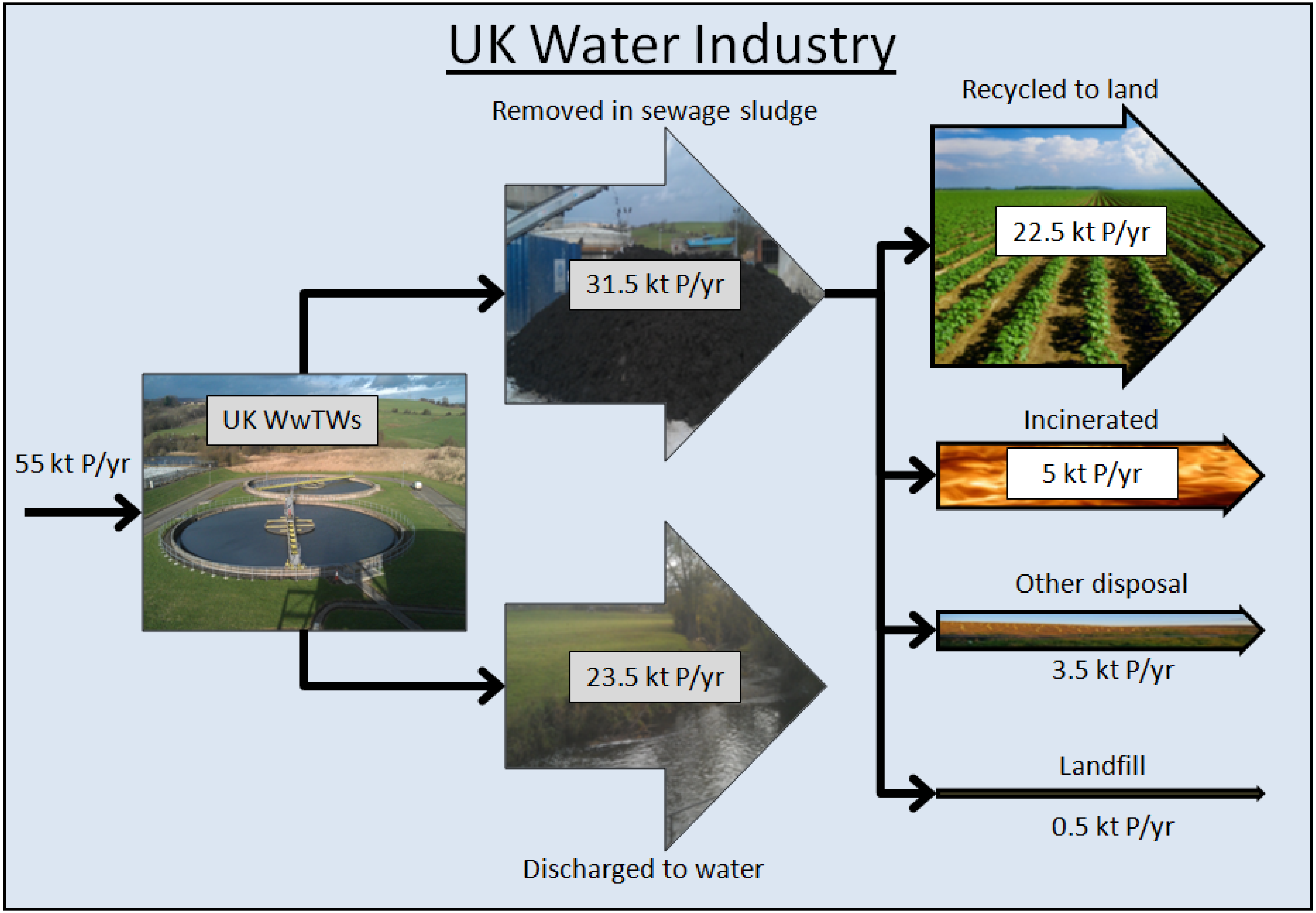
218.0 kt P/yr

P outputs

Annual surplus of 50.5 kt P / yr

Conversion efficiency = 81%

P in UK wastewater (2009 data)



Using country-scale SFA to develop indicators of sustainable phosphorus management

- Suggested indicators:
  - Net imports (kg P/person)
  - Agricultural efficiency (%) (divide P outputs by P inputs)
  - Agricultural input from mineral fertilisers (%)
  - P recycled from wastewater (%)
  - Losses to water bodies and landfill (kg P / person)

Using country-scale SFA to develop indicators of sustainable phosphorus management

Table 4
A comparison of results from other SFA studies.

SFA study	Scale	Year	Net imports (kg P/cap.)	Agricultural efficiency (%)	Agricultural input from mineral fertilisers (%)	P recycled from wastewater (%)	Losses to water bodies and landfill (kg P/cap.)
This study	UK	2009	1.9	81	27	41	0.9
Senthilkumar et al. (2012)	France	2002–2006	4.7	72	37	28	2.2
Smit et al. (2010)	Netherlands	2005	3.8	61	24	6	1.8
Antikainen et al. (2005)	Finland	1995–1999	–	51	61	24	1.1
Seyhan (2009)	Austria	2001	4.0	–	43	18	–
Seyhan (2009)	Turkey	2001	4.0	77	82	0	2.3
Suh and Yee (2011)	US	2007	−4.6	76	81	–	–
Cordell and White (2010)	Australia	2006/07	–	12	47	33	0.4
Matsubae-Yokoyama et al. (2009)	Japan	2002	5.9	25	73	47	1.2
Chen et al. (2008)	China	2004	–	46	52	–	–
Ott and Rechberger (2012)	EU15	2006–2008	4.7	65	37	37	2.0

Using country-scale SFA to develop indicators of sustainable phosphorus management

Remember 2009 was a year of low fertiliser application for the UK!

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Turkey	2001	4.0	77	82	0	2.3
US	2007	–4.6	76	81	–	–
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Japan	2002	5.9	25	73	47	1.2
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Lowest net imports

Highest agricultural efficiency

Lowest mineral fertiliser input

Second highest P recycled from WW

Some conclusions .....

- UK is a net importer of P (56% as fertiliser).
- ~ 60% of P input to agricultural land is from animal manure .
- Major loss of P from the UK system is to water bodies (~ 60% from WTW, rest from diffuse pollution).
- P accumulates in UK soils (~38 kt P/yr) mostly associated with manure application to grassland.
- Disposing sewage sludge incineration ash to landfill loses ~ 6 kt P / yr.