A quantification of phosphorus flows in The Netherlands through agriculture, industry and households

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Abstract

Phosphorus (P) is a prerequisite for life. The natural resource for P fertilizer, rock phosphate, is a non-renewable resource and is concentrated in only a few countries in the world. The Netherlands have a large national P surplus and recycling is limited. To quantify all P flows and locate accumulation in the Netherlands, a study has started by assessing the year 2005. Analysis of the P flows in the Netherlands was performed by dividing the national system into a number of P-related subsystems: agriculture, industry, society, environment and waste handling. The national P balance of the Netherlands shows a large surplus, 59.7 Mkg P in 2005. The surplus accumulates in arable land (8.3 Mkg P), grassland + silage maize (23.0 Mkg P) and in waste, where a proportion is made unavailable (21.4 Mkg P). The loss to surface water is 6.8 Mkg P. The P in waste should be recycled. However, as long as animal manure is used and exceeds the output of agricultural land, recycling P from waste to Dutch agriculture will increase environmental problems. The P from waste and part of the animal manure should be processed and exported to regions where it is profitable and useful.

Keywords: phosphorus, phosphorus flow, national phosphorus flow, grassland, arable land

Introduction

Phosphorus (P) is a prerequisite for life. Phosphorus is a major growth-limiting factor for plant production in the world. In 1850, P fertilizer was introduced into agriculture and its use has been increasing ever since. The natural resource for P fertilizer, rock phosphate, is a non-renewable resource and is concentrated in only a few countries in the world. Many western European countries, like the Netherlands, have a large national surplus and recycling is limited. Not only is a valuable resource wasted, but surface-water quality is deteriorating as a consequence of the accumulation of P in the soil. It is necessary to reduce the P surplus and increase recycling. Agriculture plays an important role in P flows in the Netherlands. The flows to and from agriculture are fairly well quantified. The soil P balance of agriculture is calculated annually by the Central Bureau of Statistics (CBS, 2007). The P flows in the non-agricultural part of the national system, e.g. industry and society, is not well quantified. To quantify all P flows and locate accumulation in the Netherlands, a study has started by assessing the year 2005. With the results of this study, it is possible to decide in which process most P accumulates in the country, and to decide where (more) recycling methods should be developed.

Materials and methods

Analysis of the P flows in the Netherlands was performed by dividing the national system into a number of P-related subsystems (Figure 1): agriculture, industry, society, environment and waste handling. Agriculture includes grassland + silage maize, arable land, grazing animals

(cattle, goat and sheep), intensive animal husbandry (poultry, pigs, fur animals) and manure. Industry includes food, feed and non-food industry. Waste includes subsystems which are outside the scope of this paper. They are described in Smit *et al.* (2010).

The data that are necessary to estimate and calculate the P flows in the Netherlands, e.g. acreages and yields of crops, number of animals, animal production, use of fertilizer, import and export of food and feed components, were retrieved from national statistics (CBS, 2008). Animal manure was calculated by a balance method: intake minus production results in manure. Mineral- and organic-P fertilization was divided over grassland + silage maize based on data from the BIN-farm network (farm accountancy network; LEI, 2005). The data were processed in a Material Flow Analysis (MFA) which provides a systematic assessment of the flows and stocks of materials within a system defined in space and time (Brunner and Rechberger, 2004). In MFA the subsystems and flows were defined. Some subsystems were allowed to accumulate P (e.g. agricultural land) and from other subsystems (e.g. industry and households) the flows were defined as results from other flows and no accumulation was assumed. The P leaching from agricultural ground was used from the emission registration in the Netherlands (www.emissieregistratie.nl) and was not (yet) a function of surplus.

Results and discussion

The results are given in million kg P in a scheme representing the Netherlands (Mkg P, Figure 1). The results show that the national P-balance of the Netherlands had a surplus of 59.7 Mkg P in 2005.

This surplus accumulated on land for arable crops (8.3 Mkg P, 12.5 kg P per ha), grassland and silage maize (23.0 Mkg P, 18.7 kg P per ha), through waste (21.4 Mkg P) and part was

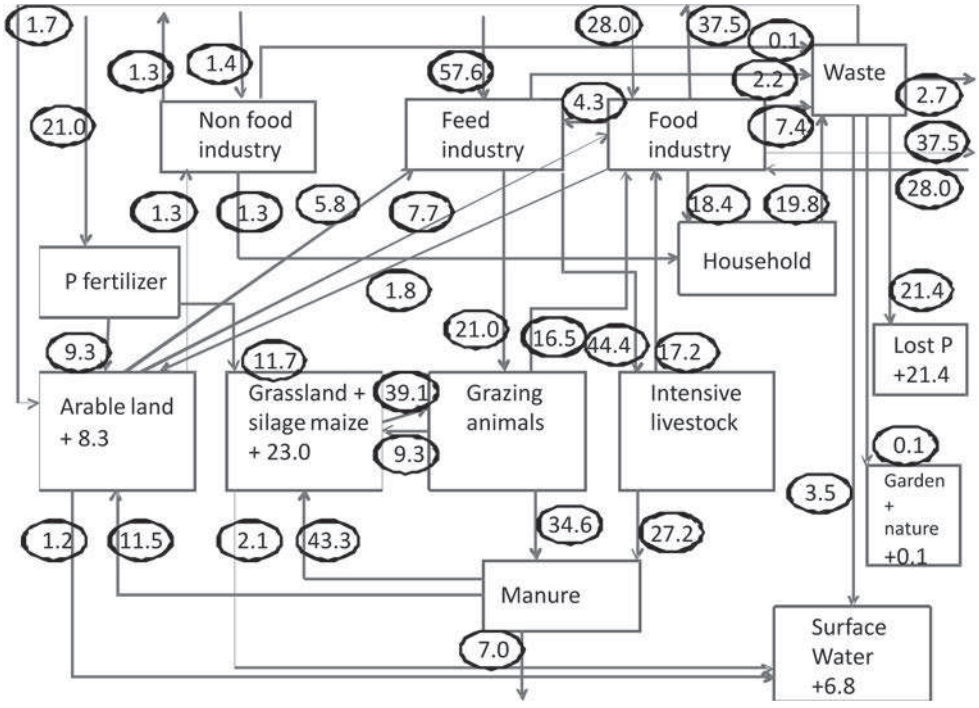

Figure 1. P-flows in the Netherlands (the size of the flow is indicated in the ellipse in Mkg of P; accumulation of P is indicated where appropriate in the square boxes)

lost to surface water (6.8 Mkg P). The P in waste was not (directly) vulnerable to losses to surface or groundwater but it was made unavailable as a nutrient. Half was incinerated and used for other purposes such as foundation for roads, almost a quarter was incinerated and used as an ingredient for cement, and the rest was used as landfill. The total national manure production was 71.1 Mkg P. Grazing animals made the largest contribution to manure production, 43.9 Mkg P, and 9.3 Mkg P of this was directly returned to grassland during grazing. Two-thirds of the intake of grazing animals (39.1 Mkg P) originated from the grassland + silage maize. The intake of manufactured feed was 21.0 Mkg P and production in meat and dairy was 16.5 Mkg P. As manufactured feed intake was larger than the output of products, expressed in P, manure production of grazing animals exceeded the output of grassland by 4.8 Mkg P. Assuming all manure from grazing animals was applied on grassland + silage maize, 8.7 Mkg P of manure from intensive livestock and 11.7 Mkg P of fertilizer was applied on top of that. From grassland + silage maize, 2.1 Mkg P was lost to surface water. This resulted in 23.0 Mkg P of accumulation on grassland + silage maize. The total amount of P in animal manure exceeded the total output of agricultural land by 17.2 Mkg P. From the manure, 7.0 Mkg P was exported, and the import of fertilizer was 21.0 Mkg P. The surplus for all agricultural soil was 31.3 Mkg P (16.5 kg P per ha). In the near future, the accumulation on agricultural land will be limited by law: in 2013 a balanced fertilization (input = output) is required in the Netherlands.

To reduce the surplus in the national balance, P from waste should be recycled. However, due to the P in animal manure and accumulation in agricultural soils, recycling the P from waste to Dutch agriculture would enhance the environmental P problems and the surplus in the national balance would not be reduced. The excess of P should be exported, as long as livestock numbers are not reduced.

Conclusions

The national P-balance of the Netherlands shows a large surplus, 59.7 Mkg P in 2005. The surplus accumulates on arable land (8.3 Mkg P), grassland + silage maize (23.0 Mkg P) and in waste from household and industry (21.4 Mkg P). The loss to surface water is 6.8 Mkg P. The P in waste is for the most part made unavailable as a nutrient because it is used as landfill, as foundation for roads and in cement. Since P is a non renewable resource, P in waste should be recycled. However, as long as the production of animal manure exceeds the output of agricultural land, recycling the P from waste to Dutch agriculture will increase environmental problems. The P from waste and a proportion of the animal manure should be processed and exported to regions where it is profitable and useful.

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