Influence of P-status and hydrology on phosphorous losses to surface waters on dairy farms in the Netherlands

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Introduction

The contribution of agriculture to the contamination of Dutch surface waters has increased from 43 % in 1985 to 57 % in 2002 (ref). Dairy farming is the largest producer of animal manure in the Netherlands (circa 75% of the total annual manure production). Information on nutrient budgets and leaching of nutrients from dairy farms was, however, limited. To mitigate this problem, monitoring programs were set-up at three dairy farms, namely one in the sandy area of the Netherlands, one in the peat-district and one on a river-clay soil. The three farms together represent the environmental conditions encountered in the Dutch dairy region. This study focuses on the losses of phosphorus from grazed grasslands on a clay soil a sandy soil and a peat soil, with different soil P-status and different hydrological pathways.

Experimental design

Phosphorous losses to ground- and surface waters were measured for a period of two to three years on a site with a heavy clay soil, a peat soil and a sandy soil. All sites were almost level and were draining on a dead-end ditch. At the end of each ditch a weir was placed with a flow meter connected to a sampling device for flow proportional sampling. The sandy site was well drained and drain-pipes were absent. About 3.5 m below the surface, a confining loam layer prevents exchange of water and solutes with deeper groundwater. The clay site was drained by tile-drains and trenches. The subsurface drains were located at a depth of 80 cm below the surface. The ditches were shallow (50 cm depth) and located at intervals of 46 m. Due to the low permeability of the heavy clay there was no seepage and groundwater recharge. The peat site has a man-made topsoil (0-40 cm) consisting of organic matter rich sandy clay. The subsoil consisted of woody peat. At 3 m below the soil surface a dense clay layer prevented extensive groundwater recharge. At the clay site the phosphorus losses to surface water were determined by flow proportional measurement of the discharge of trenches and drains. For sand and peat soil, the soil solution in the unsaturated zone was sampled using porous suction cups, which were placed in transects perpendicular to the ditches. Phosphate leaching fluxes at these sites were based on measured soil solution concentrations and simulated water fluxes. Surface run-off was assessed based on measurements using catchment plates and simple balance models for the peat soil (Van Beek et al., 2003a and was modelled for the sand soil (Torenbeek and Voskamp, 2003). At the clay site surface runoff was collected by the trenches, direct runoff form the field to the ditch was negligible (van der Salm et al., 2006, 2007).

Hydrological pathways, phosphate saturation of the soils and phosphate leaching losses.

The three sites differed considerably with respect to the main hydrological pathways. The clay site had a very low hydraulic conductivity and large part of the discharge took place by runoff or interflow through the upper soil layers to the trenches (Table 1). The peat and sand sites were better drained and most of the water was conducted through the soil matrix.

Table 1. Distribution of discharge to surface water and phosphate sorption capacity, DPS and phosphorus sorption characteristics of the sites (0-40 cm) and phosphate balance.

		Sand	Clay	Peat
Discharge to surface water (%) [1]	$Q_{Surface}$	8	67	12
	$Q_{shallow}$	53	32	4
	Q_{deep}	29	-	84
Al_{ox} (mmol/kg)		65	59	144
Fe_{ox} (mmol/kg)		8	172	209
Langmuir adsorption constant (K)		0.37	0.11	0.18
Max.amount of P bound to Al + Fe (β) (-)		0.21	0.09	0.19
DPS (%)2		37	7	15
Phosphorus surplus (kg P/ha/yr)		20	21	14
Phosphorus surplus		2	3	5

1) $Q_{surface}$= Run-off, matrix flow (0-10 cm), trenches; $Q_{shallow}$ = Matrix flow (10-70 cm) and drains, Q_{deep} = matrix flow (> 70 cm). Due to differences in methodologies $Q_{sum} \neq 100$
2) DPS = $P_{ox}/(0.5*(Al+Fe_{ox}))$ for 0-40 cm depth

Phosphate binding capacity increased from sand to clay, resulting in a high degree of phosphate saturation in the sandy soil and a low phosphate saturation in the clay soil. Losses of P from the sandy site and the clay site were comparable although the DPS was much higher for the sandy site than for the clay site. Highest P losses were found at the peat site, which had an intermediate DPS. These differences in P losses can be explained by differences in sorption characteristics, differences in hydrological pathways and differences in the distribution of P within the soil profile between the sites. The sandy site was quite deeply drained and 84% of the water discharge is through deeper soil layers where the DPS was relatively low (Table 3). At the clay site 67% of the discharge was by means of drainage through trenches. This route leads to 75% of the P losses to surface water at this site and also a large part of the total P losses (60-80%) to surface water occurred as a response to incidental heavy rainfall following manure application in early spring (Van der Salm et al., 2006). The peat site had an intermediate position with a somewhat higher DPS and drainage through deeper soil layers (Tables 3 and 5). This intermediate position contributes to the high P losses observed at the peat soil. Another reason for the high losses from the peat soil is the release of P from eutrophic layers in the peat, contributing to about 50% of the total discharge.

A rough estimate of the impact of a reduction on manure application on the leaching was made using the Langmuir isotherms and the sorption characteristics of the sites (van Beek et al., subm). Changes in P surpluses had the largest impact on P leaching on the sandy soil, followed by peat soil and finally the clay soil. This sequence is strongly influenced by the fraction of reversible bound P which decreased from sand to clay.

Conclusions

P losses were strongly determined by the hydrologic pathways in combination with the DPS and adsorption characteristics. Relatively high losses were found at the clay site, despite the low DPS, due to the important role of trenches and the resulting shallow drainage of the site. The highest losses were found at the peat site due to a combination of DPS, an intermediate sorption constant, shallow drainage and presence of eutrophic peat layers. Reducing P inputs as measure to reduce N and P leaching to surface water is likely to be most effective on sandy soils, but for clay and peat soil hydrological conditions and release of P from eutrophic peat layers hamper the effectiveness of such measures. For these soils additional measures should be considered.

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