Nutrients Waterproof: Post harvest measures and treatment of drainage water to meet water quality targets

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Abstract

The EU Nitrate and Water Framework directives impose stringent demands on groundwater and surface water quality. In many cases, arable and horticultural farms in the Netherlands are unable to meet water quality targets set by these directives. In the project Nutrients Waterproof, arable and horticultural farming systems are developed in order to comply with the water quality targets set for nitrate leaching. In these systems, efficient fertilization strategies, post harvest measures, such as catch crops and removal of crop residues, are implemented, as well as treatment of leached nutrients in constructed wetlands. First calculations show that the objectives are still not met after taking all feasible fertilization and post harvest measures. To reach the objectives, removal of nutrients in drainage water using constructed wetlands may be an effective but expensive option. Combination with other functions of wetlands may enhance their feasibility. From this year onwards, field measurements have to demonstrate whether expectations are fulfilled and whether changes are needed for further reduction of nitrate leaching.

Keywords: catch crop, crop residues, drain water, fertiliser management, water pollution

Background and objectives

The EU Nitrate and Water Framework directives impose stringent demands on groundwater and surface water quality. In many cases, arable and horticultural farms in the Netherlands are unable to meet water quality targets set by these directives. Only about 30% of the arable farms on sandy soils meet the EU-norm of 50 mg nitrate per litre in groundwater. Between 1998 and 2003, no decline in leaching occurred and fertilizer inputs remained constant (Milieu en Natuurplanbureau RIVM, 2004). Field and model studies show that reduction of fertilizer inputs results to only a small decline in nitrogen leaching, while increasing risks of yield reduction. The studies also show that growing catch crops and especially the removal of nutrient-rich crop residues may reduce nitrate leaching more than further reductions in fertilizer input (Assinck and Willigen, 2004, Smit *et al.*, 2005). Removal or retention of leached nutrients in buffer strips and constructed wetlands may further reduce nutrient export to surface waters (Carpenter *et al.*, 1998).

Post harvest measures and treatment of drainage water are explicitly taken into account in the project 'Nutrients Waterproof'. In this project, arable and horticultural farming systems are developed which comply with the EU Nitrate and Water Framework directives. The systems were developed in 2004. From 2005 onwards, the systems are tested and monitored on the experimental farm Vredepeel in the S.E. of the Netherlands. 'Nutrients Waterproof' builds on results from earlier work in the project 'Farming for a future' (Langeveld *et al.*, 2005, Zwart *et al.*, 2005). This paper describes the design and ex-ante assessment of the systems in 'Nutrients Waterproof'.

Materials and methods

The prototyping method was used to develop farming systems (Vereijken, 1999; Haan and Garcia Diaz, 2002). Two integrated systems differing in mineralization capacity have been developed. Both systems have a six-year crop rotation with potato, triticale, lily, peas, leek, maize and sugar beet. Cropping and fertilization strategies have been developed for both systems in order to reduce leaching, while maintaining high yield levels. Catch crops are grown after triticale and maize. Crop residues of triticale, leek, sugar beet and catch crop are removed in the system with a low mineralization capacity only. The effects of the cropping strategies on leaching are calculated with a simple spreadsheet model (XCLNCE, Zwart *et al.*, 2001).

An assessment of economic perspectives of the system was made by comparing the fertilization related costs of the designed systems with those of conventional strategies.

A system was designed to collect and treat drain water in three different types of constructed wetlands: a surface flow system which is easily combined with nature development, and two (with or without common reed) horizontal subsurface flow systems. The medium of the wetland without reed consists of a mixture of sand and straw. This system is a new cheap concept for arable farming. The horizontal subsurface flow system designed according to conventional guidelines, uses the smallest surface area, but is the most expensive.

Results and discussion

Calculations shows that the adopted fertilization strategy results in a 50% lower nitrogen input from fertilizers and manure compared to conventional fertilizer recommendations (Table 1). Calculated N-surpluses are low compared to conventional systems, as expected yield levels and removal of N are at least equal to regional averages. The removal of crop residues reduces N-surpluses even further in the system with low mineralization capacity. First results of cropping season 2005 confirm that yield levels can be maintained, with the low input of fertilisers.

Nitrate leaching, calculated with XCLNCE, is expected to exceed the EU-limit of 50 mg/l for ground water in both systems. In view of earlier results with XCLNCE, nitrate leaching may be somewhat overestimated. Differences in nitrate leaching between the two systems are small. For that reason, the systems have been slightly altered to increase differences in mineralization rates.

In both systems, costs of fertilization related measures are lower than conventional strategies. Direct fertilization costs are lower because of lower fertilizer input. Post harvest measures are more expensive since these measures are maximally implemented in the systems whereas they are almost absent in conventional systems in the region.

Table 1. Calculated N-surplus, N-input and N-leaching and costs (costs for constructed wetlands excluded).

	Available N-input from fertilizers and manure (% of conventional recommendations)	N-surplus (kg N ha^{-1})	Nitrate leaching (mg NO_3 l^{-1})	Costs fertilization (€ ha^{-1})	Costs post harvest measures (€ ha^{-1})	Difference in costs fertilization related measures compared to conventional strategies (€ ha^{-1})
High mineralization capacity	51	77	88	301	73	-21
Low mineralization capacity	43	21	85	270	49	-78

All three types of constructed wetlands are expected to have the same efficiency: it is expected that 80% of the incoming N is removed. About 6-8% of the cropping area is needed for the water reservoir and wetlands. The costs of the constructed wetlands are estimated to be between € 10,000 – 20,000 per ha of arable land. The cost-effectiveness is about € 15 – 20 kg^{-1} N removed. Constructed wetlands are effective but expensive. Combination with water storage and nature development increases perspectives (green/blue services).
From 2005 onwards, measurements in the systems have to demonstrate whether nitrate leaching, N-input, N-surplus, yield levels and N-removal in wetlands meet expectations.

Conclusions

Model calculations using XCLNCE do not confirm the hypothesis that integrated farming systems with efficient nutrient management strategies and maximum use of post harvest measures have low nitrate leaching. This is not in line with earlier field experiments and model calculations in 'Farming for a future'. Fertilization related costs of these systems are comparable to conventional systems; however, risks of yield reduction are higher.

When after implementation of all feasible on field measures nitrogen leaching is still too high, the removal of nutrients in buffer strips or wetlands might be an effective but expensive option. Combination with other functions may enhance its feasibility.

From 2005 onwards, measurements have to demonstrate whether expectations are fulfilled and whether adjustments are needed to reduce nitrate leaching further.

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