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CAN INTENSIVE ARABLE FARMING SYSTEMS ON SANDY SOILS IN THE NETHERLANDS MEET THE TARGETS IN THE NITRATE DIRECTIVE?

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Introduction

Arable and horticultural farms on sandy soils in the South East of the Netherlands are until now unable to meet the EU-target of 50 mg nitrate per litre in groundwater. In the last 20 years nitrate levels have decreased from 180-200 mg nitrate per litre to 70-100 mg per litre. However, little progress has been made in recent years (Hooijboer et al., 2007). In the project Nutrients Waterproof, an integrated and an organic farming system with arable and horticultural crops have been developed and tested between 2005 and 2008 in order to comply with these water quality targets. In these farming systems different measures are combined to reduce nitrate leaching (Haan et al., 2006).

Materials and Methods

The integrated system contained the crops potato, triticale, lilies, peas, leek, maize and sugar beet in a six year rotation. The integrated system consisted of two parts. In one part only chemical fertilizers were used whereas in the other part a combination of organic manure and chemical fertilizer were applied. The organic system contained the crops potato, alfalfa, leek, broccoli, maize, spring barley and tree nursery crops. In the organic system, only organic manure was used and no chemical crop protection was used. In both the integrated and organic systems, all practically available measures with positive effect on nitrate leaching were applied. Examples of these measures are: an efficient fertilization strategy based on crop uptake, taking into account uptake efficiencies, available mineral nitrogen (from soil, preceding green manure crops, crop residues and fertilization). Further, efficient fertilization techniques such as row fertilization (in maize and leek), split fertilization strategies (based on soil mineral N and crop reflection measurements) as well as the use of catch crops were applied where possible.
The systems were developed in 2004 and tested between 2005 and 2008. All operations and inputs were registered; yield and N-content was assessed of both the crop and the crop residues. Mineral nitrogen contents in the soil were measured before and after a crop and before the start of the leaching season. During the leaching season every three weeks nitrate concentrations in ground water and surface water were measured.

Results

An overview of the results is presented in Table 1. Nitrate concentrations in groundwater in the organic system (41 mg NO_3^- l^{-1}) met the targets of the nitrate directive due to extensive use of cover crops and leguminous crops. Nitrate concentrations in the integrated system were more than twice the target concentration when organic manure was used (116 mg NO_3^- l^{-1}). The rotation of the integrated system contains more vulnerable crops and hardly any green manure crops because most crops are harvested late in the season. Total nitrogen input of the systems was about equal however available nitrogen for crop growth was higher in the integrated systems. Besides, mineral nitrogen in the organic system comes gradually available by mineralization during the growing season. Fertilization levels in the integrated system were conform to current legal limits, indicating that lower levels would have negative

effects on yield levels (data not shown). Fertilization levels in the organic system were about half the legal limits.
Nitrate concentrations of groundwater in the integrated system decreased with 25 mg l^{-1} to 91 mg NO_3^- l^{-1} where no organic manure was used. However, after two years crop yields seems to decline as well. In 2007, crop yields were on average 5.4% lower in the integrated system with chemical fertilizer only; in 2008 2.4% lower.
Crop yields in the integrated system with manure were on average comparable to average yields in the region and on average about 10% less than the crop yields aimed at in the region. Yield levels aimed at in the organic system are lower than in the integrated system.
Only 57-59% of the available mineral nitrogen during crop growth is taken up by the main crops. This means that a large quantity of mineral nitrogen is available for leaching. However partly this is taken up by catch crops, especially in the Organic system.

Tab. 1. Average results of the cropping systems 2005-2007.

Cropping system	Nitrate concentration groundwater mg NO_3^- l^{-1}	Crop yield / Regional good crop yield	Total N input chem. & org. fert. kg ha^{-1}	Available mineral N for crop growth[1] kg ha^{-1}	N uptake / Available mineral N
Integrated system chem. and org. fert.	116	100.0%	294	305	57%
Integrated system chem. fertilizer only	91	97.5%	255	294	57%
Organic system	41	95.5%	298	231	59%

[1] including mineralization and deposition

Discussion
The integrated system did not comply with the water quality targets. The organic system did, mainly because of a more extensive crop rotation and larger possibilities for cover crops. In general the ratio between N uptake and available mineral N is low. Improvement of N-efficiency is difficult without changes in rotation. Innovative technical measures are needed to reduce nitrate leaching in the integrated systems as extensification of conventional agriculture is not seen as an option because of loss of income and employment. These measures are currently in development. First example is the development of new catch crops which establish better after late sowing and do not propagate plant parasitic nematodes. A second example is the removal of nitrogen rich crop residues from e.g. broccoli, leek or sugar beet. When harvested around 1 November, 20-60% of the 100-150 kg nitrogen from the crop residues of leek and broccoli was leached. For sugar beet this was only 5-15% (Ruijter, 2008). When harvested more early in autumn the losses are supposed to be higher. Another solution for horticultural crops is the use of drip irrigation and fertigation. Yields and nutrient uptake may be somewhat higher at comparable fertilization levels. However costs are higher as well. The question is however, if these measures are sufficient to lower nitrate leaching sufficiently. Therefore new research is started about cropping outdoor horticultural crops out of the soil in recirculating hydroponic systems. Nitrogen leaching can be controlled much better and yield levels and labour circumstances are expected to be much better, although profitability of these systems is doubted. (Haan et al., 2009).

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