Reduction of nitrate leaching from intensive arable cropping by specific crop management

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Abstract

The nitrogen fertilization of an arable farming system which is common for the South-eastern part of the Netherlands could be reduced by 25-50% compared to the generally accepted advisory amounts, without affecting crop yields and crop quality negatively. Groundwater nitrate concentrations were reduced from ca 100 to ca 50 mg l^{-1} simultaneously. Key factors to obtain these results were: (i) careful tuning of expected N-demand and N-supply, (ii) accounting for N from deposition and for N from mineralization and (iii) using catch crops as far as possible.

Background and objectives

Nitrate leaching from agriculture is a serious problem in the Netherlands. Nitrate concentrations in shallow groundwater exceed the EU-Nitrate Directive level of 50 mg l^{-1} in large areas of the country. Nitrate leaching is, at least partly, the result of excess nitrogen inputs in agriculture. Dutch arable agriculture is characterized by a high level of crop production and quality, partly the result of high nutrient application rates. Under arable and horticultural production fields, the nitrate concentrations in shallow groundwater are the highest in the Southeastern part of the Netherlands. The objective of the present study was to decrease nitrate leaching and simultaneously maintain high production rates and high crop quality. In this paper we describe the results of a number of different measures to reduce nitrate leaching in arable and horticultural farming.

Materials and methods

An experiment was performed during three years on experimental farm 'Vredepeel', where the arable rotation included a number of horticultural crops and maize. The soil is a reclaimed peat soil (mesic typic Haplaquod) with on average 3.8% organic matter in the upper 30 cm and less than 0.5% below. The phosphate level is high (water soluble is 40 mg phosphate l^{-1} soil). The average highest ground water level is at 90 cm below the surface. Two systems were studied, the first of which very much resembled the current situation of the farms in the local area (integrated farming system IFS), while the second one (experimental farming system EFS) was developed to meet the environmental conditions regarding nitrate in groundwater. The crop rotation included potato, sugar beet, carrot, triticale or spring barley, maize, and fresh peas followed in the same year by fresh beans (the latter crop was replaced by a catch crop in EFS). Fertilization for each crop was based on the Dutch fertilization recommendation scheme and was similar for EFS and IFS except for nitrogen fertilization. Measures to reduce nitrate leaching included the application of fertilizer N only instead of a mixture of animal slurry and fertilizer N; split application of N, using catch crops where possible, accounting for atmospheric N deposition and from N mineralization and removing crop residues (final year only). N mineralization was estimated using a simple spreadsheet model (Zwart, 2001). In addition, a crop of peas followed by beans was replaced by peas followed by a catch crop. Crop production and nitrogen uptake was established for each crop and groundwater nitrate concentrations were measured frequently.

Results and conclusions

On average, nitrogen input, nitrogen uptake and crop production were 67%, 92% and 98%, respectively in EFS compared to IFS (Figure 1). In the final year N input was even reduced to 50% in EFS (Figure 2) without affecting crop production negatively. In the final year N from mineralization during the crop uptake period was estimated using XCLNCE. In previous years the results of this model with respect to inorganic N in the soil, corresponded fairly well with measured data (Figure 3). The average groundwater nitrate concentration was 50 mg l^{-1} in EFS and 98 mg l^{-1} in IFS (Figure 1), with a high variation during the year and between crops.

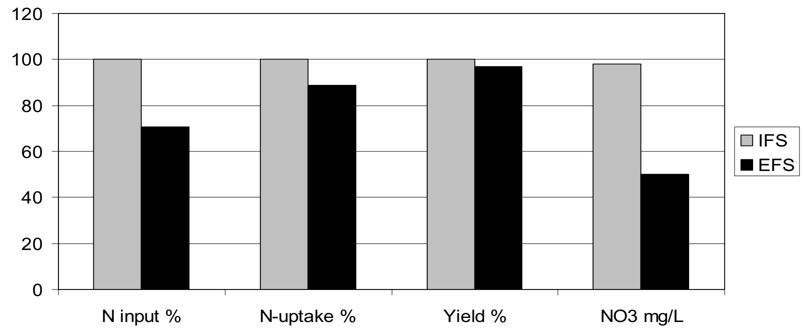

Figure 1. *Average N input, N-uptake and yield in EFS as % of IFS and average groundwater nitrate concentration in IFS and EFS (mg l^{-1}).*

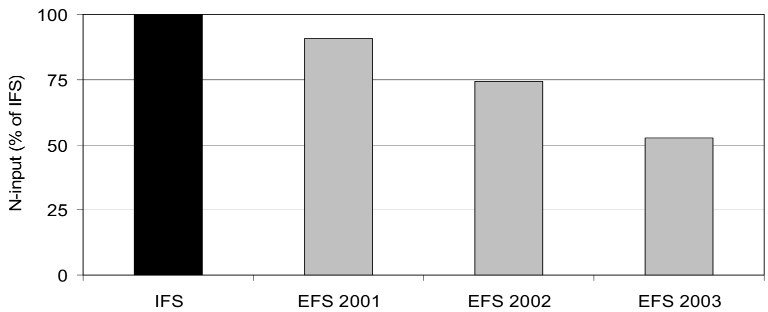

Figure 2. *Average N-input in IFS (2001-2003) and EFS as % of IFS*

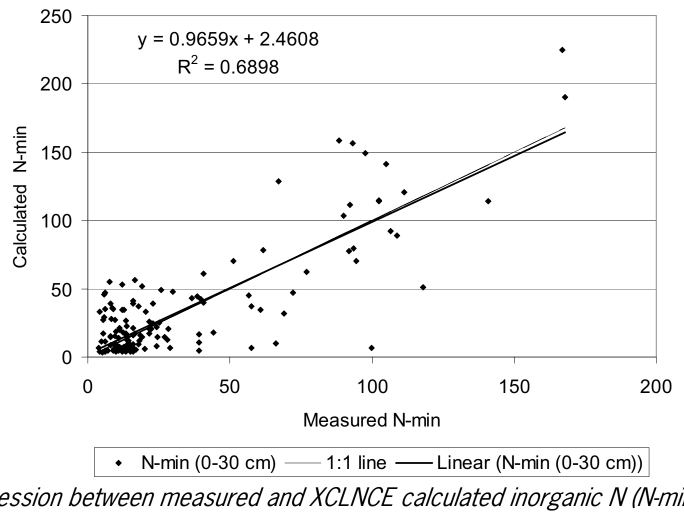

Figure 3. *Linear regression between measured and XCLNCE calculated inorganic N (N-min, kg ha^{-1}) in the upper 30 cm of arable soils at experimental farm Vredepeel.*

We concluded that (i) it was possible to reduce nitrate leaching without affecting crop production, (ii) application of a catch crop and accounting for N from mineralization was a critical factor, (iii) Dutch N fertilization recommendations need a revision and (iv) even more stringent management measures are needed to reduce nitrate leaching further.

References

Zwart, K.B. (2001).
XCLNCE, a spreadsheet to calculate carbon and nitrogen contents in soil. Alterra Wageningen, Report 427 (in Dutch).