Optimizing N management through improving transitions of temporary grassland and maize in rotation

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Abstract

Crop rotation in which grass and maize are alternated may contribute to efficient production of feeds for dairy production. However, in particular on dry sandy soils, proper transitions from the arable into the grassland phase and *vice versa* are crucial to control N leaching. From 1993 to 2010 we implemented four different systems on the experimental dairy farm De Marke on the basis of a grass-grass-grass-arable-arable-arable rotation scheme. Each consecutive system was implemented to solve problems of the former system. This paper presents results on how various sources of information contributed to developments of crop rotation schemes on De Marke. Fodder beet was replaced by maize as first-year arable crop to avoid storage problems associated with fodder beet. This change tended to result in higher nitrate leaching to groundwater under first- and last-year arable crops. This was solved by leaving out N fertilization in the first-year maize. Smoothing the transition of arable land into new temporary grassland resulted in a more continuous presence of vegetation during winter. However, this had no clear effect on nitrate leaching to groundwater.

Keywords: barley, dairy, fodder beet, nitrate leaching, system development

Introduction

Silage maize is a highly valued crop on dairy farms, in particular on dry sandy soils, because of its high production potential, its capacity to use nutrients and water efficiently and its value in the ration as a complement to grass silage. However, maize is associated with high nitrate leaching to groundwater and with a poor soil quality in terms of soil organic matter content. It is crucial to solve these problems by improving management practices. Application of crop rotation in which maize is alternated with grassland is widely accepted as a method to preserve soil quality. On the experimental dairy farm 'De Marke', located in the eastern part of the Netherlands, a crop rotation was developed with the focus on reducing nitrate leaching, in particular during the delicate transitions from grassland to arable land and *vice versa*.

Materials and methods

'De Marke' is a prototype dairy farm and defines, in addition to a location, a research approach. Since the start, the farm has been continuously developed to meet as close as possible pre-defined targets using a method called system development. This is a cyclic procedure, consisting of: design of strategies and measures, implementation of the design, monitoring, analysis and evaluation of its performance (Aarts, 2000). This procedure was also applied on the production of grass and fodder crops. To support this process a monitoring programme was established comprising land use and crop management, nutrient flows (on farm scale and on field scale), crop yields, soil fertility, N mineralization, nitrate leaching and conversion of feeds by the cattle in meat and milk. Nutrient flows were established on each of 30 parcels of 1-3 ha. Nitrate leaching was established annually by sampling the upper metre of groundwater in a density of 3 boreholes per ha in February. The rotation systems were evaluated through extensive analyses of data and expert meetings. The climate is sufficiently stable to allow comparison of performance of rotation systems that were practised in subsequent periods of at least three years. Nitrate leaching was corrected for dilution by inter-annual variation of precipitation (Boumans *et al.*, 2001). System development resulted

in four rotation schemes (A, B, C and D). In all systems, on maize land, Italian ryegrass was sown as a catch crop between the rows in June and ploughed-in in the first week of March.

Results and discussion

From 1993-1996 fodder beet was the first arable crop after grassland (system A, Figure 1). A major concern in crop rotation is to capture the high amounts of N that are released by ploughing-in the former grassland sod in the first-year arable land. Fodder beet has a high N uptake capacity (Nevens and Reheul, 2002). Therefore, beet was considered the most suitable crop in the first-year arable land. However, storage of beet was technically problematic and their incorporation in the ration of the cattle put pressure on the conversion of feeds into milk. Therefore, in system B (1996-1999) fodder beet was replaced by first-year maize. This change entailed a risk of increasing nitrate leaching. Indeed, the nitrate concentrations in groundwater in first-year fodder crops (Figure 2a), tended to be higher in system B than in system A, although the differences were not significant. The same holds for nitrate leaching in the final-year fodder crops in system B compared to system A (Figure 2b), which might be explained by a delayed effect of the replacement of fodder beet by first-year maize. This is consistent with the observation of higher residual N in soil after first-year maize than after fodder beet (data not shown), which could have caused the increase of nitrate leaching in later arable years. Therefore, this urged us to improve the tuning of the N fertilization to the crop needs. N-application rates for maize were established by correcting the required N rates for release of N from the ploughed-in grass in first-year maize and second-year maize (90 and 45 kg N per ha respectively), which implies that no fertilization was required in first-year maize. This approach was not yet fully implemented in system B – with application rates of 50-100 kg N per ha.

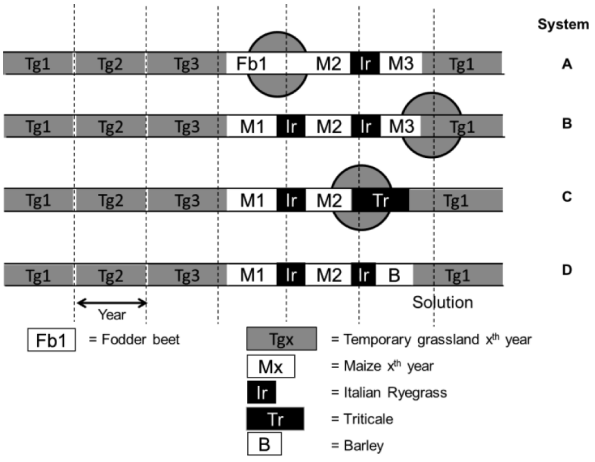

Figure 1. Rotation systems at 'De Marke'; grey circles mark components that needed improvement.

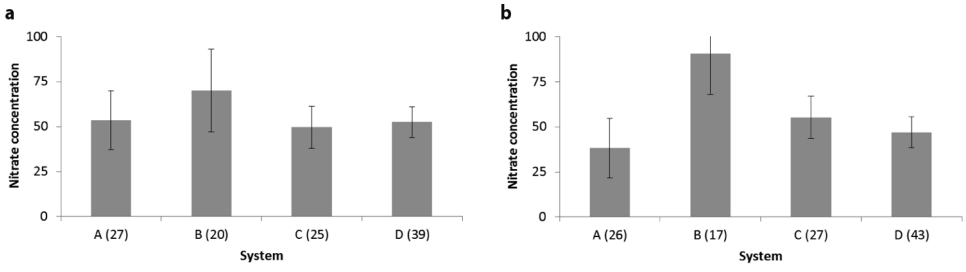

Figure 2. Mean nitrate concentration (mg l^{-1}) in the upper metre of groundwater for crop rotation systems (A, B, C and D). (a) first-year arable land; (b) final-year arable land. n = number of observational units; vertical bars show 95% confidence limits.

Since 2000, fertilization was completely omitted in first-year maize (system C). This adjustment probably contributed to the recurrence of a tendency to lower nitrate concentrations in groundwater in system C and D (Figure 2a).

A major concern during the transition from arable land to grassland is to minimize N leaching through preventing the incidence of bare soil without vegetation that can capture mobile N. In systems A and B, at the end of the arable phase, grass was sown directly after harvest of maize to form a new temporary grassland sod (Figure 1). However, maize was often harvested by the end of September, which is too late for establishment of the new grass sod before the onset of winter. Therefore, in system C (2000 to 2003) triticale was implemented to replace maize as the last arable crop. Triticale was sown after the second maize crop, to function during winter as a catch crop instead of Italian ryegrass. It was assumed it would develop faster in winter than perennial ryegrass. After winter, it was harvested in mid-summer, after which grass was sown and could develop more strongly before the onset of winter. However, triticale was still associated with excessive nitrate leaching (Verloop, 2013). This was explained as an effect of the mediocre development of triticale as a catch crop after maize (Figure 1). The development of triticale was below expectations and in harsh winters it tended to completely disappear. This observation led to replacement of triticale by spring barley in combination with Italian ryegrass as catch crop in the preceding maize (system D). The barley was harvested in summer after which grass was sown. The effects of these adjustments in the final-year arable crops were probably corroborated with the effects of the replacement of fodder beet with maize (system B). However, when system B is neglected in the analysis, we see that our efforts to provide an increasingly smoothened transition for arable crop to grassland was not clearly reflected by a tendency to lower nitrate leaching (compare system A, C and D in Figure 2b).

Conclusions

System development on the experimental dairy farm De Marke on dry sandy soil shows that:

Replacement of fodder beet as first-year arable crop after grassland by maize seems to be associated with higher nitrate leaching to groundwater under first- and last-year arable crops, unless N fertilization in maize is left out.

Replacement of maize by subsequent crops of triticale and spring barley as last-year arable crops to obtain a more continuous green cover during winter did not clearly affect nitrate leaching to groundwater in the transition from arable into temporary grassland.

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