Report of Working Group 4

Grassland renovation: prudent or risky?

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Introduction

This working group gathered to discuss aspects of grassland renovation in relation to nitrogen (N) emissions and the Water Framework Directive. Five participants had been asked to give a presentation of their work (E.M. Hansen, G.L. Velthof, J.G. Conijn, L. Bommelé and F. Vertès). After each presentation a short discussion followed and at the end of all presentations a more general discussion was held. The working group focussed on two important questions: (1) under which conditions (climate, soils, species) is grassland renovation an appropriate (or prudent) option for farmers and (2) which measures are effective in reducing the risk of N emissions after grassland ploughing. Before the five presentations started, the theme was briefly introduced by presenting some general background information on grassland renovation and its relation with N emissions.

Why grassland renovation?

For most dairy systems across the European Union (EU) home-grown feed is an indispensable resource. Especially in intensive dairy farms with high-yielding cows productive swards and arable crops, e.g. maize, are needed to produce at low costs. Farmers will therefore aim at sustaining the productivity of their fields at a high level suited for their farm situation. However, crop productivity may decline due to various reasons, some of which can hardly be influenced by the farmer. Swards may deteriorate by adverse weather conditions (frost or drought) and soil organic matter level on arable land may become too low for sufficient crop production. In addition, a farmer may want to (re)introduce clover into his grassland or remove persistent weeds or pests (Conijn *et al.*, 2002). Grassland renovation, in this report used for both grass-to-grass reseeding and grass-arable rotations, is often practised by farmers to overcome these situations and mostly includes ploughing of grassland before sowing grass or an arable crop. Crop productivity can be improved e.g. by using the best grass varieties at grass reseeding and by amelioration of the soil conditions during the grass phase of a grass-arable rotation system. If crop productivity is improved, N use efficiency, defined here as N output / N input, will likely to be improved as well from which not only the farmer but also the environment may benefit.

The extent at which grassland renovation is practised by farmers has been reported in Conijn *et al.* (2002) for North-west European countries and there it ranges from 2 to 10% per year of the total grassland area on a (sub)national scale and to even 20% per year of the grassland area on a regional or local scale (figures mainly based on grass seed sales).

Is there a problem?

Grassland renovation is one of the many management activities farmers perform in the execution of their profession and before starting a discussion on the relation between grassland renovation and N emissions, as in this working group, one would like to know whether there is a problem or not? What makes it worthwhile to discuss grassland renovation in the context of the Water Framework Directive? Most grassland renovation involves ploughing of grassland, which usually causes an accumulation of inorganic N in the soil, because the release of N from fresh and old organic matter tends to exceed the uptake potential of the newly sown crop for some time after killing of the ‘old’ sward (e.g. Velthof and Hoving, 2004). This high N availability may be lost from the soil depending on the susceptibility of the soil to N loss and on weather conditions (such as a high or low precipitation surplus) and may then contaminate the atmosphere with N_2O or surface and ground waters with NO_3. Large N losses have indeed been reported after grassland ploughing (e.g. Adams and Jan, 1999; Shepherd *et al.*, 2001 and Springob, 2004). Combined with the extent at which grassland renovation is practised, there may be a problem with N emissions from ploughed grassland to the environment.

Society is concerned about N emissions to the environment, because it may threaten other functions of rural areas. In the EU this has lead to the definition of water quality goals (e.g. Nitrate Directive, Water Framework Directive). Legislation in EU countries has been developed to comply with these water quality goals and grassland renovation (among others) has drawn the specific attention as being a potential risk. In order to limit the N emissions, regulations have already been formed that restrict farmers’ practice of grassland renovation in a number of countries. Examples are: N fertilization of arable crops on ploughed grassland should be lowered compared to the same crops grown on arable land (e.g. in Denmark) and grassland ploughing on sandy soils is only allowed during spring (e.g. in the Netherlands). These examples illustrate that grassland renovation is considered to give environmental problems if not regulated properly and that investigating the effects of grassland renovation on N emissions is important in relation with the Water Framework Directive.

Prudent or risky?

The question whether grassland renovation is prudent or risky with respect to N emissions, can not simply be answered uniformly for all situations. This has two main reasons: (1) in general, we face both a positive (higher N use efficiency) and a negative (higher inorganic N level in the soil) effect of grassland renovation on N emissions and (2) management choices related to grassland renovation have a large influence on the risk of N emissions. An example was given by Nevens and Reheul (2004) who concluded that a grass-maize rotation could save mineral N fertiliser and that growing fodder beet in the first year after ploughing could prevent excessive high residual soil N levels, unlike the situation with silage maize. Figure 1 illustrates a working hypothesis on the positive and negative effects that may occur around grassland renovation (Conijn & Taube, 2004). The overall net effect on yield and nutrient losses depends on soil type, climate conditions and management, and the consequence of this is that we have to look carefully at various situations of grassland renovation and define for each situation the conditions in terms of soil, climate and management whether renovation is prudent or risky. It is then important to have a long term view instead of focussing on one or two years after grassland ploughing. In many situations risks are highest on the short term, while advantages work at the long term, which means that a complete balance can only be made after analysis of a whole grass-to-grass reseeding cycle or grass-arable rotation in a farm context. In the five presentations of this working group various topics and measures were highlighted that are relevant for the evaluation of grassland renovation in relation with N emissions.

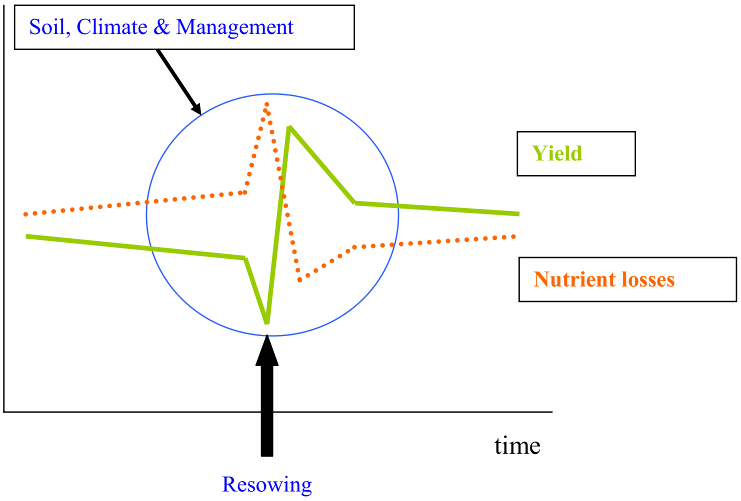

Figure 1. *Hypothesised development of yield (continuous line) and nutrient losses (dotted line) before and after renovation of old grassland.*

For grass yields: decreasing yields with grassland age, loss of production in the year of ploughing, increased yields in the first year(s) after resowing followed by higher production levels of the new sward relative to the old sward. Yield may be expressed in terms of dry matter, nitrogen, protein or metabolic energy and refers to net yield or net intake.

For nutrient losses: increasing losses with grass sward ageing, a high risk of losing nutrients shortly after ploughing, lower emissions in the first years after resowing followed by lower levels of nutrient losses relative to the old sward.

Presentations and discussion

In the first presentation Hansen (Hansen *et al.*, 2006) dealt with the effects of cultivation of grazed grass clover swards on coarse sandy soils on N leaching. They tested the effectiveness of an early catch crop (Italian ryegrass) undersown into a barley crop used as a green crop and cut twice for forage production during late summer/autumn. The control treatment was a barley crop used as a mature crop and followed by mechanical weed control in late summer/ autumn. Leaching losses of N were measured during the following winter using ceramic suction cups. The catch crop treatments resulted in low N losses (7 - 9 kg N ha^{-1}) while the control treatments caused very high losses ranging from 174 to 316 kg N ha^{-1}. It was concluded that catch crops established via undersowing are a very effective measure in order to reduce N losses following reseeding of short or mid term clover grass swards. Additional forage production as well as carbon (C) storage are positive trade off effects.
In the second paper Velthof presented results of an experiment dealing with the effects of grassland resowing procedures on gross productivity and on N losses via leaching and via nitrous oxide emission due to soil type and time of cultivation. The hypothesis of increasing dry matter yields following grassland resowing was not confirmed by the presented multi-site experiment. The results showed that risk of N leaching is much higher when grassland is renovated in autumn than in spring. Risk of nitrous oxide emission was high both at spring and at autumn renovation. The intensity of soil cultivation (direct drilling without tillage versus resowing after ploughing) had a minor effect on N losses. It was concluded that the relevance of both investigated pathways of N losses have to be taken into consideration in order to evaluate the effects of soil type and time of resowing on negative environmental consequences in a well balanced way.
The model N*fate* was presented by Conijn (Conijn, 2006) aiming to calculate the short and long term effects of grassland resowing in Dutch agriculture. N*fate* is a dynamic model using yearly time steps to calculate N yield, N losses and the change of N in the soil/plant system as a function of N inputs, soil/climate characteristics, crop species and management. The model was calibrated with short term data. Simulation showed a reliable prediction of N losses due to grassland renovation in autumn and spring via leaching and highlighted the differences between

short and long term effects. Due to the year step structure of the model it can be used to simulate the whole cycle from resowing to resowing over a long term.
Bommelé (Bommelé *et al.*, 2006) highlighted the effects of rotocultivation of young and old grassland on N delivery in the succeeding crop (potatoes). Average additional net N from mineralization following cultivation of both grassland types compared to an arable rotation ranged between 232 kg ha^{-1} in the first succeeding crop and 144 kg ha^{-1} in the second succeeding crop. This indicates that net mineralization following cultivation of grassland is much higher than often documented in the literature, especially in the second year after cultivation. Bommelé concluded from their experiment that growing potatoes after grassland caused high soil mineral N residues in autumn, even in the non-fertilized treatment.
Finally, Vertès (Vertès *et al.*, 2006) focussed on the long term effect of fodder crop rotations on soil organic matter quality using a long term data set covering 30 years of measurements. Six rotations covering a range of grass/maize ratios were compared indicating that the grass/maize ratio was a powerful driving force in order to understand soil C and N dynamics in a long term. Organic N content of the soil was only remaining constant when at least three years of grass were combined with one year of maize, even if organic inputs were taken into consideration. However, soil organic N content did not fully explain the differences in N mineralization rates between the rotations. The ratio N mineralization rate/total N content increased with the grass/maize ratio indicating that changes in soil organic matter quality, viz. distribution of C and N among various soil organic matter fractions, also influenced the mineralization rate.

The general discussion was highlighting the links between the different topics presented in this working group. It was evident that grassland cultivation and grass-arable rotations cause different results in terms of N release and N losses related to arable rotations without grass crops due to a wide range of accumulation of C and N in the soil under grassland and ley systems as well. The huge variation in N losses due to grassland cultivation is due to a wide range of soil properties, weather conditions and management options covered by the presented experiments. In order to generalize the presented results methods were discussed allowing a prediction of C and N fluxes following grassland renovation. The group agreed that multi-site experiments with a common protocol would be a powerful tool in order to calibrate dynamic models simulating C and N fluxes following grassland renovation.

Conclusions

Grassland renovation and grass-arable rotations are of major concern regarding the economic benefits of dairy farms as well as regarding the consequences for the environment. Time of grassland ploughing and choice of the following crop(s) are effective ways to manipulate nutrient losses. The hypothesis of increasing grass yields following grassland reseeding was not confirmed by the results presented in the working group, which is in line with results from the literature. As a consequence the focus should be switched to measures maintaining permanent grassland performance without killing of the grass sward. On the other hand grass-arable rotations were identified as a promising production system, but questions still remain to be resolved with respect to the nutrient use efficiency of the whole system in relation to soil and climatical conditions. The ratio of grass in grass-arable rotations is a key issue in order to maintain soil fertility from which the arable crop may benefit. Dynamic models are a powerful tool in order to simulate consequences of grassland renovation and grass-arable rotations at different sites and due to different management options, but more data are needed for calibrating such models.

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Poster presentations

Different methods for quantifying actual denitrification for a permanent and temporary grassland

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Abstract

Nitrogen emissions from agricultural soils to the surrounding environment are controlled by field management and physical conditions in the soil. Measuring denitrification under field conditions is difficult and expensive. This study compared several methods to quantify denitrification for a wet and a dry sandy soil with grass: a balance method, a (complex) deterministic model, a simplified process model and measurements. The first three methods were either used with generic data or with plot-specific data. Most methods show that denitrification is highest in the permanent grassland with shallow groundwater levels (wet field). Taking into account plot-specific circumstances (weather, N surpluses) results in different estimates for denitrification in comparison to the generic input data. For the dry field, temporary grassland with deep groundwater levels, the differences between the estimated denitrification were the largest. The best suitable method probably depends on the available data, but should be as plot-specific as possible.

Keywords: denitrification, grassland, leaching, modelling, nitrate

Background and objectives

Nitrogen (N) emissions from agricultural soils to the surrounding environment are controlled by N application rates, field management and physical conditions in the soil. Measuring denitrification under field conditions is difficult and expensive due to temporal and spatial variations and methodological difficulties. The objective of this study is to compare different methods to quantify total denitrification under field conditions. The difference between the total amount of N emission and the total denitrification is an estimate for nitrate leaching, as there is a general trade-off between N losses.

Material and methods

We present the results of a desk study focusing on different modelling approaches, supplemented with a variety of field and laboratory measurements as input to different models. The field measurements were carried out on two fields on the experimental farm 'De Marke' in the Netherlands. Field A, a permanent grassland, was situated on a sandy soil with shallow groundwater levels during winter (Mean Highest Groundwater level (MHG) between 25 and 40 cm below soil surface (-ss)). Field B, a temporary grassland (ley), was situated on a dry sandy soil (MHG below 140 cm -ss) and is considered to be vulnerable for nitrate leaching.

During the winter of 2004-2005 soil samples were taken from six layers of each field plot. The soil samples were used to determine potential denitrification (Van Beek *et al.*, 2004), actual denitrification using isotope pairing (Arah, 1992), mineral nitrogen content, bulk density and volumetric water content. During this period groundwater levels, precipitation, and air temperature were monitored. Nitrate concentrations in groundwater were measured once.

The used methods are described in Table 1. They were applied to calculate the total denitrification for each plot (period March 2004 - March 2005; soil layer 0 - 1 m -ss).

Table 1. Description of the seven methods used to compute denitrification.

Method	Description
1	The balance method: denitrification and nitrate leaching were calculated using representative values for nitrogen surpluses, leaching fractions and precipitation surpluses following Schröder *et al.* (2004).
2	The plot-specific counterpart of (1) uses the actual nitrogen and precipitation surpluses and measured nitrate concentrations (in spring).
3	Denitrification was taken from the Dutch national scale model STONE (Wolf *et al.,* 2003) for two STONE plots resembling the two fields of 'De Marke'.
4	With SWAP (Kroes and Van Dam, 2003) and ANIMO (Groenendijk and Kroes, 1999) (both incorporated in STONE) plot-specific denitrification was computed by adapting input of (3) to site-specific conditions of the two plots.
5	A widely used simplified denitrification process model (Heinen, 2005a,b) was used to calculate actual denitrification based on potential denitrification and three reduction functions for nitrate content, degree of water saturation and soil temperature. The required time series (per decade) for nitrate content, degree of saturation and temperature came from method (4).
6	Instead of using a standard parameter valueset (as in (5)), plot-specific parameter values were used in the simplified denitrification process model. The plot-specific parameter values were estimated from the measurements in the soil samples.
7	The last method calculates the total denitrification by integrating the measured actual denitrification over depth and time.

Results and discussion

The calculated denitrification per plot, using methods (1) - (7), is presented in Figure 1.

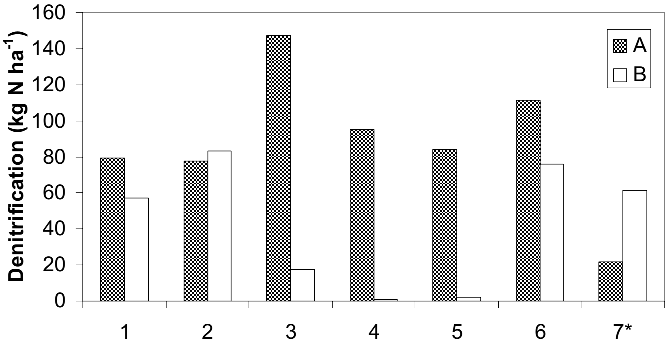

Figure 1. Total denitrification in kg N ha^{-1} for the permanent (A) and temporary (B) grassland using different methods. (1) balance method based on Schröder et al. (2004), (2) plot-specific balance method, (3) STONE model for representative plots, (4) STONE model with plot-specific input, (5) simplified denitrification process model with representative parameter values, (6) simplified denitrification process model with plot-specific parameter values, (7) integration of denitrification measurements over time and depth. (*) Method (7) is applied over a shorter period, i.e. 120 days instead of 365 days.