PLANT RESEARCH INTERNATIONAL
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Grassland resowing and grass-arable crop rotations

Third and fourth workshop of the EGF-Working Group
'Grassland Resowing and Grass-arable Rotations'

Luzern, Switzerland, 21-24 June 2004
Maastricht, the Netherlands, 24-26 October 2005

J.G. Conijn (ed.)

Report 148
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EGF is a forum for research workers, advisors, teachers, farmers and policy makers with active interest in all aspects of grasslands in Europe. These aspects include management of all types of grasslands for production, utilization, amenities and conservation purposes.

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Foreword

This report contains contributions of members of the EGF-Working Group 'Grassland Resowing and Grass-arable Rotations', mostly from two workshops organized by the Working Group in the context of (a) the 20th General Meeting of the EGF in Luzern (June, 2004) and (b) the 14th N-workshop in Maastricht (October, 2005). The proceedings of both occasions (see references below) also contain these contributions, but in some cases contributions in this report have been extended with additional information. Besides these contributions. this report also contains three original papers: two country reports on grassland renovation (cf. the country reports of the first publication of the Working Group) and one dealing with an extension of the explanation of the working hypothesis of the Working Group. Together, all contributions reflect the main part of the efforts that the Working Group members have undertaken in the past years in the context of the EGF-Working Group 'Grassland Resowing and Grass-arable Rotations'.

This volume is the third report of the EGF-Working Group (first report published in 2002 and second report in 2004).

Sjaak Conijn (ed.)

References

Lüscher, A., B. Jeangros, W. Kessler, O. Huguenin, M. Lobsiger, N. Millar & D. Suter (Eds.).
Land Use Systems in Grassland Dominated Regions. Proceedings of the 20th General Meeting of the European Grassland Federation, Luzern, Switzerland, 21-24. June 2004.

Schröder, J.J. & J.J. Neeteson (Eds.).
N management in agrosystems in relation to the Water framework Directive. Proceedings of the 14th N workshop, Maastricht, the Netherlands, 24-26 October, 2005. Plant Research International, report 116.

1. Extending the working hypothesis on grassland resowing to include grass-arable rotations and organic farming systems

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The working hypothesis (see Conijn and Aarts, 2004), shown in Figure 1, illustrates the potential for short term herbage yield benefits of renewing an old sward which is nearing an equilibrium in terms of organic matter (OM) accumulation. Nutrient losses begin to increase, as yields tend to decline. A difficult judgement for farmers and agronomists is assessing the point at which the stage has been reached when resowing is justified in order to introduce new grass varieties and to enhance the vigour of the sward. It must be recognized that some loss in production is inevitable whilst the new sward is becoming established, and the improvements may only be temporary (i.e. 2-3 years), as production from the new swards will again begin to decline in subsequent years as the newly sown sward ages.

1.1 Grassland resowing

There are practical farm management considerations which will influence these decisions when assessing the economics of lost production during cultivation and establishment and these will vary between different farming situations. However, in practice, these decisions are often based on subjective assessments of sward quality. A challenge for this EGF Working Group is to develop diagnostic techniques to clearly identify the changes which take place during the two phases of old and new swards to better recognize and define the benefits (in terms of sward quality and nutrient efficiency). An important research need is to determine whether the changes in sward production between the old and new phases are due to differences in the N response potential of the plants or to the direct effects of reseeding e.g. soil aeration and increased OM turnover.

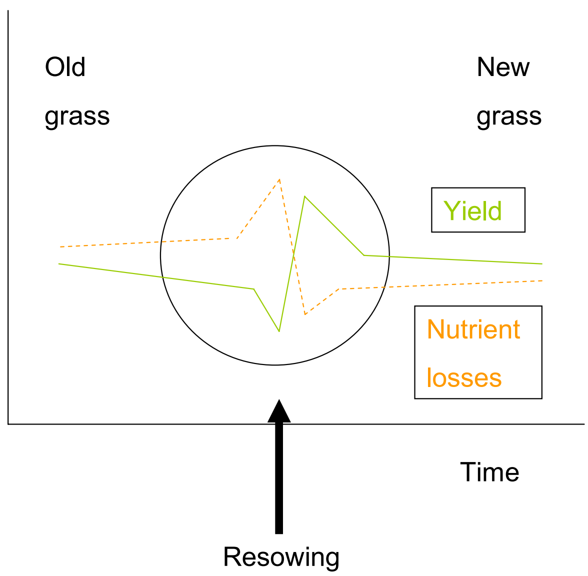

Figure 1.

1.2 Grass-arable crop rotations

The previous section has considered grassland renovation by ploughing and resowing as a direct sward renewal. In many situations there are practical advantages for including an arable or non-grass crop within a cropping cycle (Stapledon and Davies, 1948). Significant changes (Figure 2) also occur in rotations involving a transition from grassland to arable cropping; in many ways this is analogous to grassland resowing. In this situation, a grass ley is grown to improve soil quality and as a 'break' from continuous arable cropping to help suppress diseases and to build up soil OM in order to improve soil structure. Figure 2 illustrates how the arable crop yield may decline with the falling supply of nutrients and poorer soil structure associated with the loss of soil OM, although this decline can be largely arrested by applications of appropriate fertilisers (see Jenkinson, 1991).

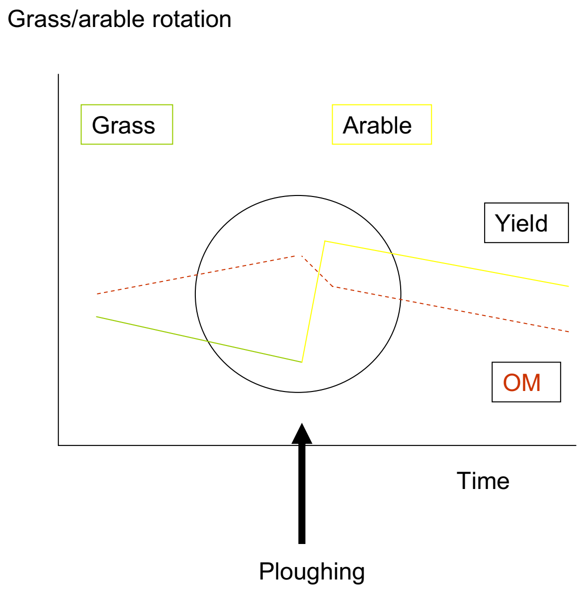

Figure 2.

1.3 Organic farming and restricted nutrient inputs

Finally, the working hypothesis can be further extended to a third situation: where the application of fertilisers is not appropriate, as in organic farming rotations, or restricted by environmental measures. An alternative N source to mineral N fertiliser, or imported manures, is through N fixation by a leguminous crop, or forage based on a grass-legume mixture. This may be a cash crop, such as peas or beans, although the benefit will be lessened if the produce is exported, rather than used on the farm as animal feed. Alternatively, clovers or vetches etc. may be grown and then ploughed in as a green manure to maximize the amount of N added to the soil.

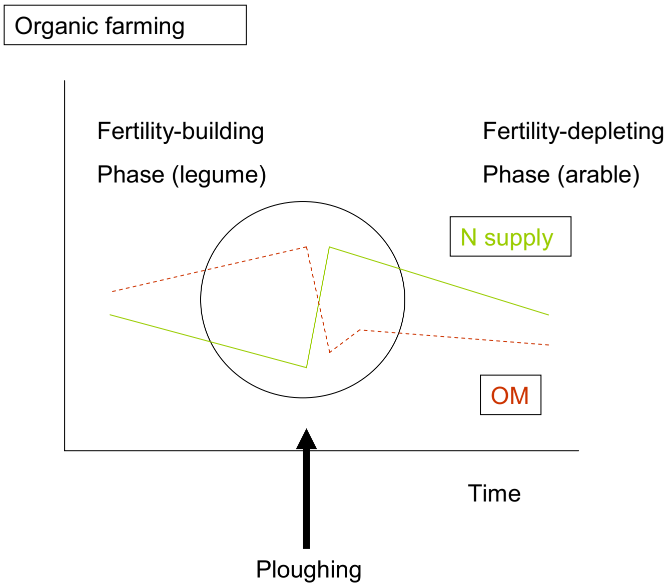

Figure 3.

Nitrogen accumulation will decline as the legume improves the overall soil N supply due to a negative feedback effect on N fixation because legumes show a preference for available soil N over the more energy requiring process of fixation. Organic matter will also build up (as with the grass ley), but then declines under the fertility-depleting phase (i.e. arable cropping). Figure 3 shows the fall in N accumulation/supply from N fixation in either a pure legume crop or a mixed sward containing grass. In the latter case, unfertilised grass will utilise excess soil N (Parsons *et al.*, 1991), which will encourage the legume to continue to fix atmospheric N, but this advantage is largely offset by competition for light, water, space and other nutrients, so that the overall longer term effect on fixation may be somewhat similar to the monoculture legume crop.

The below ground accumulation of OM may be greater under organically farmed soils and low input systems since, with less readily available nutrients, plants tend to develop more extensive and deeper root systems than under highly fertilised crops so that more residual root biomass will be returned to improve the soil OM content.

1.4 Conclusions

In all three of the above scenarios, the common feature is the extent of soil disturbance brought about by ploughing to prepare a seed bed for the next crop. The challenge is to manage the soil improvement phase to maximise OM and N accumulation. However, the optimum timing for ploughing out pastures/legume crops is difficult to predict and will involve many operational and economic considerations. Even more problematic (especially in organic systems) is judging the optimum duration of the arable (i.e. fertility depleting phase), although this may be prolonged by the use of manures which, in many ways, simulates a fertility-building crop (e.g. leys and legumes) by supplementing the native soil OM and nutrient supply. The changes that occur in the soil with ploughing, in terms of the disturbance to the chemical, physical and biological processes, are only poorly understood and documented. Within the areas of ploughable grassland and arable land in Europe, there is wide variation in soil texture, depth, drainage and OM content. Research into the effects on soil changes of ploughing and of alternative methods of cultivation, including minimal tillage and direct drilling, needs to take account of these physical differences and spatial variability.

1.5 References

Conijn, J.G. & H.F.M. Aarts, 2004.
In: Grassland resowing and grass-arable rotations. Consequences for performance and the environment. J.G. Conijn and F. Taube (eds). Second Workshop of the EGF-Working Group 'Grassland resowing and grass-arable rotations', Kiel, Germany, 27-28 February 2003. Report 2, 75-77.

Jenkinson, D.S., 1991.
The Rothamsted long-term experiments – are they still of use. Agron. J. 83: 2-10.

Parsons, A.J., R.J. Orr, P.D. Penning & D.R. Lockyer, 1991.
Uptake, cycling and fate of nitrogen in grass-clover swards continuously grazed by sheep. J. Agric. Sci. Camb 116: 47-61.

Stapledon, R.G. & W. Davies, 1948.
Ley Farming. London: Faber and Faber.

Part I.

Country reports

2. Grassland renovation in Austria - specific aspects of grassland improvement in mountainous regions

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Introduction

For most of the Austrian grassland and dairy farmers the home-grown forage from their meadows and pastures is a substantial element of their farm management system. Different measures, aiming at the improvement of forage quality, are therefore of great interest. Beside aspects of fertilisation, weed control and forage conservation, grassland renovation is one of the basic keys to succeed. Due to the specific climatic and topographical conditions, renovation of mountainous and alpine grassland is a special challenge both from a technical and ecological point of view.

2.1 General information

More than 90% of the Austrian farm land, grown with grasses, clover and herbs, is permanent grassland, which by the definition of Schechtner (1978) is at least 20 to 25 years old and has never been ploughed up and renewed within that period. Due to climatic (low temperatures, frost periods, long period with snow cover) and topographical constraints (steepness) as well as for shallow and stony soils most of the Austrian grassland has to be described as obligatory grassland (Schechtner, 1993; Taube *et al.*, 2002). Figure 1 points out the geographical distribution of grassland (not including appr. 500.000 ha of alpine meadows and pastures, wherefore no INVEKOS-data are available at the moment) and ley farming areas in Austria. Grassland, especially extensive grassland is the dominating culture in the western and central production areas 'Hochalpen', 'Voralpen' and 'Alpenvorland', whereas ley farming areas are basically concentrated in the more favourable regions in the eastern and southern part of the country.

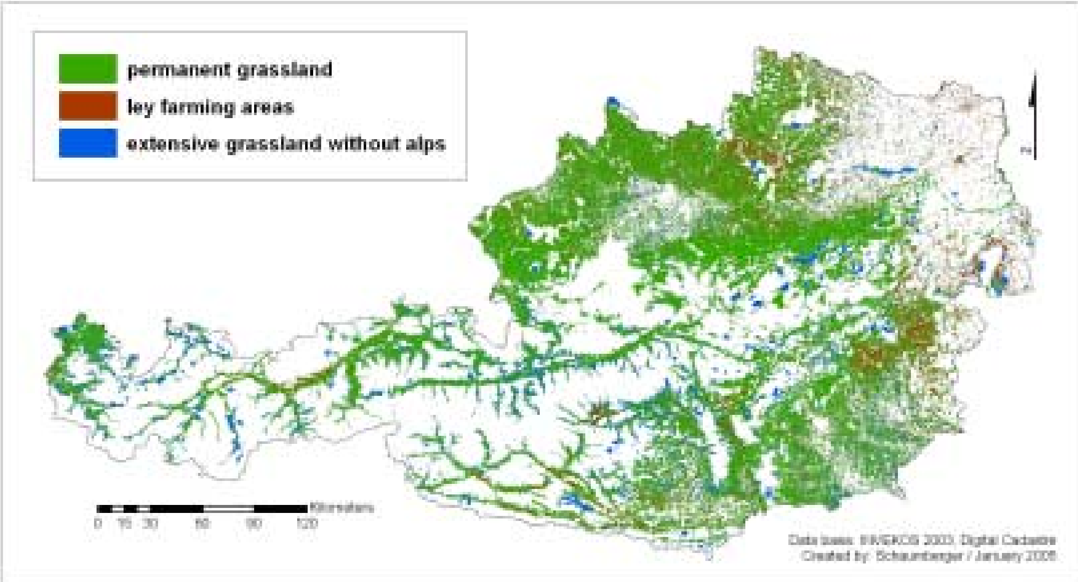

Figure 1. Geographical distribution of grassland and ley farming areas in Austria.

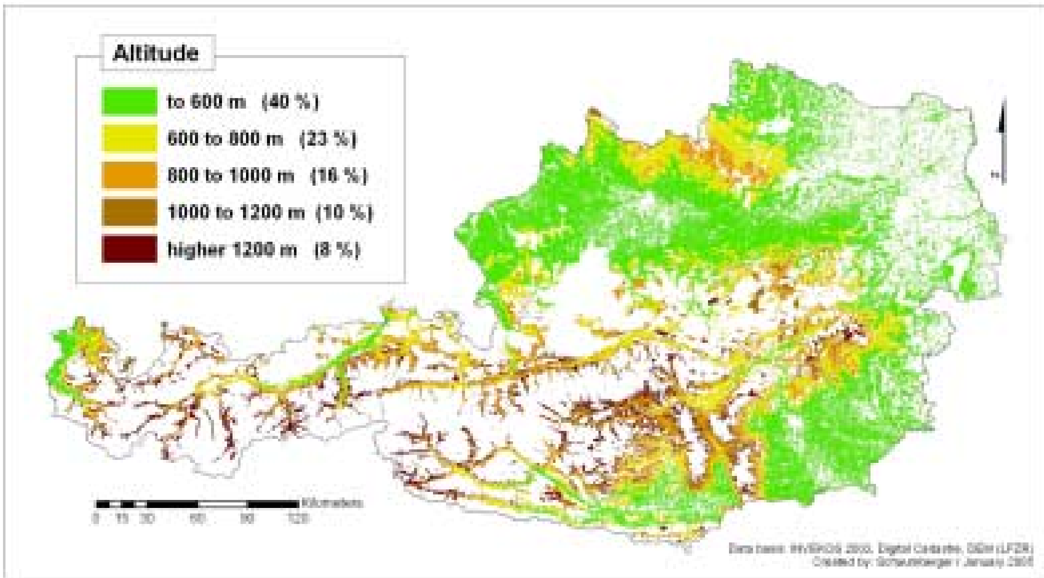

Figure 2. Distribution of grassland and ley farming areas in Austria according to the altitude.

40% of the grassland and ley farming areas are located lower than 600m above sea, 23% can be found between an altitude of 600 and 800 m and 34% are located higher than 800m above sea (Figure *2*). Due to the therefore decreasing vegetation period, there is just a short time available for setting up renovation measures on grassland in higher altitudes. More than 70% of all grassland and ley farming areas are exposed from south-east to south-west (>90° < 270°).
Approximately 40% of the grassland areas have a slope higher than 25%, even ranging up to more than 50%, which causes comprehensive problems in the management, especially concerning aspects of harvesting, fertilizing and resowing.

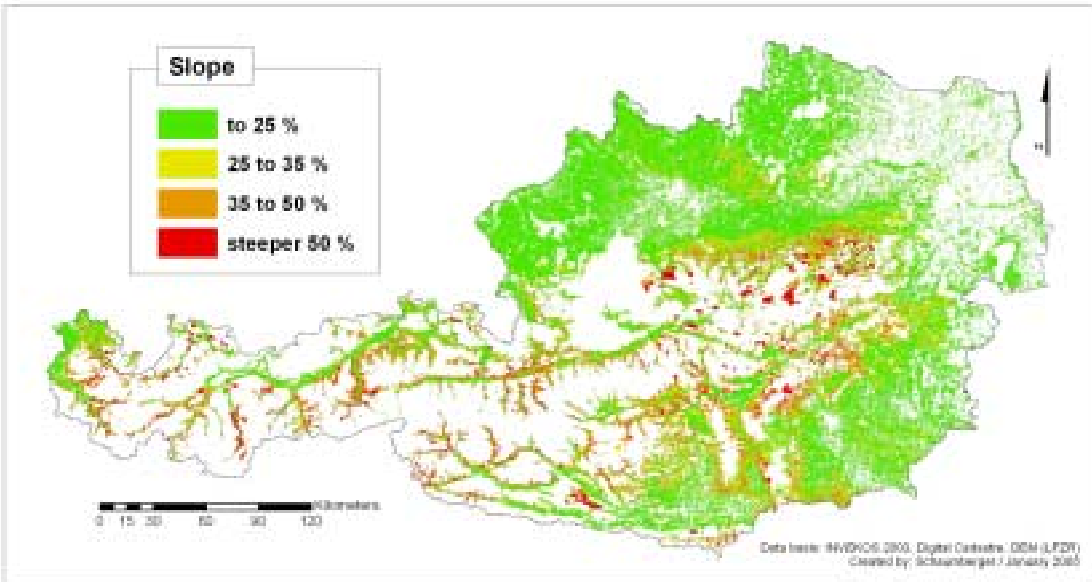

Figure 3. Distribution of grassland and ley farming areas in Austria according to the slope.

About half of the total permanent grassland is used in a very extensive way with a low stocking rate and is cut or grazed once or twice a year (Table 1). The renewing of these permanent pastures and meadows is basically ensured by self-seeding of grasses clover and herbs. So normally there is no need for any artificial renewing measures, with the exception of sward damage caused by drought or destructive insects (grubs of common cock chafers, june bugs or garden chafers). In the year 2003 approximately 500.000 ha of grassland were negatively influenced by drought (yield reduction up to 80%) and around 15.000 ha grassland were strongly damaged by grubs of the above named chafers (Buchgraber, 2004).

Table 1. Proportion, structure and productivity of permanent grassland and ley farming areas in Austria (Buchgraber, 2004).

land use system	ha	net yield 1000 t DM	energy yield 1000 GJ NEL	protein yield 1000 t
one cut grassland	58.065	86	724	7,7
extensive pasture	80.199	114	1.008	11,9
alpine meadows/pastures	505.000	328	2.954	32,8
more cut meadows	870.568	3.835	35.805	475,4
cultivated meadows	67.749	347	3.466	49,4
permanent grassland	**1.581.581**	**4.710**	**43.957**	**577,2**
grass/clover	54.105	371	3.764	63.1
temporary grassland	69.108	429	4.276	64,3
pure clover	6.648	51	513	9,2
lucerne	7.636	63	592	11,9
ley farming areas	**137.497**	**914**	**9.145**	**148,5**
(% of permanent grassland)	(8,7%)	(19,4%)	(20,1%)	(25,7%)

Permanent grassland in more favourable regions of the mountains can be at least used three times per year (silage cut, hay cut, second cut hay or alternatively grazing in the autumn). In some very productive lowland areas even up to five cuts per year can be harvested. In this case the natural regeneration of the sward by self-seeding is not possible and therefore re-sowing measures have to be set to improve sward density and the composition of the plant community.

2.2 Resowing methods for alpine and mountainous grassland

The main methods and technique equipment for grassland resowing/renewing in Austria as described afterwards are offered by more than 90 machinery rings and are available for the whole country. Which method finally is selected by the farmer, strongly depends on the topographical situation and climatic conditions.

2.2.1 Simple over-seeding

This is the most used method for improving permanent meadows and pastures in Austria. Beside self-constructions, combined machines (curry-comb + seed hopper + roller), which with a special adaptation also can be used for steep grassland, are mainly used. The recommended amount of seed mixture for this kind of resowing method ranges from 12 to 15 kg/ha. The total costs (including machinery and seed mixture) amount from 80 to 110 €/ha.

2.2.2 Slot row seeding

This method is especially recommended for dry regions and is also used for the application of infected barley to control grubs in the soil (Poetsch *et al.*, 1997). The total costs (including machinery and seed mixture) amount from 130 to 160 €/ha.

2.2.3 Band rotavator seeding

Only few machines for band rotavator seeding are available in the Austrian machinery rings, so therefore this re-sowing technique is not very common. The recommended amount of seed mixture for 3.2 and 3.3 ranges from 15 to 20 kg/ha. The total costs (including machinery and seed mixture) amount from 170 to 190 €/ha.

2.2.4 Ploughing up

Basically turning over of grassland is strictly limited by the Austrian Environmental Programme for Agriculture (ÖPUL). In most cases grassland is only ploughed or rotavated if there is no other way to improve the sward or to control weeds. The recommended amount of seed mixture for a blank seed ranges from 25 to 30 kg/ha, depending on the kind of utilisation (pasture, meadow, ley farming) and on specific conditions (high altitude, lucerne as part of the mixture etc.). The total costs (including machinery and seed mixture) amount from 160 to 230 €/ha (Buchgraber *et al.*, 2004).

Beside permanent grassland, approximately 140.000 ha farmland are used for ley farming with grass, clover or grass/clover mixtures. Especially for extensive grassland farming systems, organic farms and integrated farms, biological N-fixation plays an important role for their nutrient fluxes and nitrogen budget. The development of legumes on permanent grassland and the use of legumes in seed mixtures for ley farming is an efficient strategy to save external N-input. The last mentioned aspect especially seems to be important, regarding the European wide discussion about protein substitution in feeding. Ley farming areas, including grass/clover mixtures, reseeded grassland, pure clover stands and lucerne only amount to appr. 9% of the total Austrian grassland areas but provide around 19% of the total net yield, 20% of the total energy yield and 26% of the total protein yield (Table 1).

Although consisting of typical grassland plants, these ley farming stands are declared as arable land and completely renewed within 5 years according to the EC-ordinance 796/2004. Concerning the high costs of establishment and the ecological risks, for alpine and mountainous grassland regions the 5 years regulation should be changed and prolonged up to a period of 10 years.

2.3 General requirements to seed mixtures for alpine and mountainous grassland

Apart from the risk of nutrient losses via leaching and erosion, the establishment of new grassland causes some additional problems under the harsh conditions of the mountains. Deep temperatures (average annual temperature +/- 6.5°C), frost, snow (up to 120 days of snow cover), and the short vegetation period demand for a special strategy concerning the quality and the composition of seed mixtures.

2.3.1 Breeding and testing activities on grasses and clover

BAL Gumpenstein is nowadays the only Austrian institute, dealing with breeding activities of grasses and clover, including species for the restoration of Alpine environments (Krautzer *et al.*, 2003, Krautzer & Wittmann, 2004). In addition to the demand of the official variety testing, the range of available varieties of forage grasses and clover is steadily tested all over Austria, for up to seven growing periods. Beside yield amount some important parameters are detected in these variety testing trials, so as weed infestation, growing height, flowering, re-growth and post winter performance, snow mould, mildew etc.. All theses criteria are used to find out the best possible varieties for the Austrian grassland.

2.3.2 Seed mixtures for Alpine grassland

On the basis of the variety testing for clover and grasses, seed mixtures for different utilisation on grassland are created and tested at BAL Gumpenstein. Research in Alpine regions (Austria and Switzerland) has already shown that legume-grass mixtures can be sustained and utilised for up to five years provided that more than two forage species are involved.

In contrast to intensively managed grassland in some European countries, Austrian grassland shows a very high floristic diversity, ranging up to an average of more than 50 species on mountainous meadows and extensive pastures (Table 2).

Table 2. Number of plant species on different grassland types in Austria (Poetsch & Blaschka, 2003).

type of grassland	n	∅	median	min.	max.	variation	s
alpine meadow	4	**43,3**	41,5	34	56	22	9,64
alpine pasture	39	**39,2**	33,0	21	115	94	18,14
mountainous meadow	5	**52,6**	49,0	37	75	38	14,93
one cut meadow	235	**49,0**	46,0	8	91	83	16,07
two cut meadow	693	**39,4**	38,0	14	88	72	10,38
three cut meadow	328	**33,2**	32,0	13	58	45	8,53
four cut meadow	28	**28,6**	27,5	7	52	45	8,03
ley farming areas	15	**32,0**	33,0	23	48	25	6,60
extensive pasture	120	**54,4**	55,0	6	111	105	19,33
cultivated pasture	73	**45,7**	44,0	24	86	62	12,83
moor land	6	**26,5**	27,0	4	48	44	16,99
mowing pasture	105	**38,0**	38,0	18	64	46	9,64
fallow grassland	27	**27,0**	27,0	7	60	53	14,23
litter meadow	50	**40,7**	43,0	9	62	53	13,82

Several grass and clover species (a number of up to ten) have been used for such seed mixtures with special consideration of productivity and forage quality (digestibility of organic matter and energy value). Such diverse seed mixtures also reduce the risk of unforeseeable problems with unfavourable weather conditions. In terms of the harsh climatic conditions in alpine regions, aspects of persistence, endurance and winter hardness are of great interest. There are different seed mixtures available for permanent grassland (meadows and pastures), for reseeding activities and for ley farming areas. For the last mentioned mixtures, the content of legumes (white clover, red clover, Swedish clover and lucerne) amounts to 65%, depending on the length of the utilisation period. All these seed mixtures have a very high quality level compared to the European standard (double rumex control, higher germinative capacity, seed purity etc.).

To improve the competitive power of grass-clover mixtures, they mostly are grown as an under-seed or with a covering crop and used for a longer duration to compensate the costs of establishment and relatively low productivity in the first year. Only the best varieties of the different grass and clover species should be used for such quality seed mixtures - the official procedure of variety-testing in Austria has therefore been prolonged to six or even seven years to identify the top varieties.

In Austria, a seed production of different species of grasses and legumes for quality seed mixtures has been established during the last decade. Mainly varieties of BAL are now being produced on approximately 1.000 ha. The average usage of grass and clover seed in Austria amounts to 7.200 t/year, of which 75% is imported – in 1995 the import rate was nearly 90%. The yearly consumption of seeds for permanent grassland, temporary grassland and ley farming areas amounts to 1.800t (Table 3), for landscape restoration and the establishment of lawns 2.400t are used. Another 3.000t of grass/clover seeds are used for fallow land planting and catch crops.

Table 3. Seed consumption for permanent grassland, temporary grassland, ley farming areas and the potential share of organic seeds.

land use system	seeded area (ha)	yearly seed consumption (t)
permanent grassland	35.000	550
ley farming areas	36.000	900
temporary grassland	15.000	350
total	**86.000**	**1.800**
thereof:		
organic grassland	6.500	100
organic ley farming	10.000	250
total organic	**16.500**	**350**

At the moment some selected Austrian seed mixtures are tested in comparison with international seed mixtures (CH, G, I, DK, NL) on eight different locations. The preliminary results clearly indicate the advantage of those mixtures, which are well adapted to the alpine conditions.

2.4 Requirements to seed mixtures and resowing techniques for special usage

2.4.1 Seed production for organic farming

Austria has been playing a leading role in organic farming with nearly 20.000 farms, which manage approximately 10% of the total agricultural land. According to the EU-ordinance 2092/91 and the planned regulation AGRI/02/61449, organic farmers have to use organically produced seed and seed mixtures from the year 2003 on.

There are some general rules existing for organic seed production:

- Seed production is only allowed at an authorised organic farm under observance of all rules for organic production
- Basic seed must also be organic or if not being organic must not be treated with fungicides
- Basic seed must not be genetically modified
- Beside the normal standards for seed production concerning germination and purity the organic seed must be kept separate and traceable all the way from the field to the farmer

In practice there are some general problems with the production and therefore with the availability of organic seed for grassland and ley farming areas. Apart from a higher production risk with significant lower yields and worse seed quality, there is only a limited number of species and varieties available for seed propagation and for the composition of seed mixtures. As a consequence of these aspects, the price for organically produced seed mixtures is distinctly higher compared to conventional products.
At present the total area for organic seed production in Austria amounts to 160 ha, where red clover, lucerne, Italian ryegrass, annual ryegrass, bastard ryegrass, meadow fescue, oat grass and timothy are propagated. 43t of organic seed mixtures, at least consisting of 3 organically produced species were sold in the year 2004, mainly used for ley farming areas. There is the need for building up an efficient structure, regarding seed propagation and marketing to fulfil the criteria of the above named EU- regulations.

2.4.2 Restoration of Alpine ecosystems

Restoration activities at high altitudes, following terrain corrections in the course of constructing ski runs, forest and alpine-meadow trails, measures for the improvement of tourism infrastructure or torrent and avalanche barriers are a special challenge. Only the combination of highly qualitative plant or seed material, well adapted to the site, with optimum restoration technique ensures sustainable success.

The conventional 'high-zone mixtures' available on the market mainly comprise high-growing non-site-specific lower plants originally bred for grassland economy in valley locations or as grasses for sporting events. These species are adapted to lower, warmer locations and are generally not suitable for restoration in high zones (Florineth, 1992). Site-specific subalpine and alpine plants are adapted to an optimum degree to the high-zone climate. They produce little biomass, but with an appropriate choice of species, they do produce high-quality feed. Seeding with site-specific seeds generally require only slight amounts of nutrition, and short-term management measures lead quickly to natural, generally extensive self-maintaining grass, which has high persistency against subsequent uses for tourism and agriculture. With the use of site-specific seed mixtures, the required sowing volumes commonly used in practice can be lessened from 200 to 500kg per hectare to 80 to 160 kg per hectare. Grasses and clover were selected within the sphere of several international research projects, which are suitable for seed production in valley locations and can be used in various site-specific alpine seed mixtures (Krautzer *et al.*, 2003). In the meantime, the ecological species suitable for high zone restoration will multiply over a broad area, graded according to altitude, original rock and usage in high-quality restoration mixtures and brought to the market. The use of such site-specific seed mixtures (e.g. www.saatbau.at) should be obligatory when sowing in high zones.

2.5 References

BMLFUW, 2004.
Grüner Bericht 2004. Bericht über die Situation der österreichischen Land- und Forstwirtschaft im Jahr 2003.

Buchgraber, K., 2004.
Auswirkungen der Trockenschäden für Grünland- und Viehwirtschaft. 10. Wintertagung für Grünland und Viehwirtschaft 'Unternehmertum in der Land- und Forstwirtschaft als Chance einer erweiterten Europäischen Union'. Ökosoziales Forum Österreich.

Buchgraber, K., E.M. Poetsch & B. Krautzer, 2004.
Wie können Trocken- und Engerlingschäden am Grünland regeneriert werden? Der Fortschrittliche Landwirt 'Grünlanderneuerung', Info 4/2004.

Florineth, F., 1992.
Establishment of greens in high altitudes in Southern Tyrol, Rasen-Turf-Gazon 3.

Krautzer, B., 2002.
Biosaatgut für Dauergrünland und Feldfutterbau – Probleme und Möglichkeiten. Bericht über die 53. Tagung der Vereinigung der Pflanzenzüchter und Saatgutkaufleute Österreichs, BAL Gumpenstein.

Krautzer, B. & H. Wittmann, 2004.
Restoration of Alpine ecosystems. In: Restoration Ecology: the new frontier. Edited by J. van Andel & J. Eronson, Blackwell Publishing, Oxford, in print.

Krautzer B., G. Peratoner & F. Bozzo, 2004.
Site-specific grasses and herbs. Seed production and use for restoration of mountain environments. Food and Agriculture Organization of the United Nations, Rome.

Krautzer, B., G. Parente, G. Spatz, C. Partl, G. Perathoner, S. Venerus, W. Graiss, A.Bohner, M. Lamesso, A. Wild & J. Meyer, 2003.
Seed propagation of indigenous species and their use for restoration of eroded areas in the Alps. Final report CT98-4024, BAL Gumpenstein, Irdning.

Poetsch, E. M., H. Strasser & H.K. Berger, 1997.
Was Sie über tierische Schädlinge am Grünland wissen sollten. Der Fortschrittliche Landwirt, Heft 6/97.

Poetsch, E.M. & A. Blaschka, 2003.
Abschlussbericht über die Auswertung von MAB-Daten zur Evaluierung des ÖPUL hinsichtlich Kapitel VI.2.A 'Artenvielfalt', BMLFUW.
Schechtner, G., 1978.
Auswirkungen von Düngung und Nutzung auf die botanische Zusammensetzung von Dauerwiesen und Dauerwiesenneuanlagen im Alpenraum. Bericht über die internationale Fachtagung 'Bedeutung der Pflanzensoziologie für eine standortgemäße und umweltgerechte Land- und Almwirtschaft', BAL Gumpenstein.
Schechtner, G., 1993.
Unveröffentlichtes Vorlesungsskriptum an der Universität für Bodenkultur, Wien – BAL Gumpenstein.
Taube, F., M. Wachendorf & H. Trott, 2002.
Future challenges in grassland cultivation in Germany. Grassland resowing and grass-arable crop rotations. International Workshop on Agriculture and Environmental Issues, Wageningen.

3. Grassland renovation in Poland

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3.1 General information

Grasslands occupy in Poland the total area of 4.1 million hectares, which constitutes 21% of the total agricultural land or 13% of the entire area of the country. The above-mentioned area comprises permanent natural and semi-natural (i.e. periodically subjected to renovation) grasslands. However, this area does not include leys established on arable land covering about 0.2 million ha, whose time of utilisation does not exceed 4-5 years. In recent years, the area of grasslands which are not utilised for fodder production has increased considerably reaching, in 2004, the level of approximately 1 million ha (GUS, 2005).
The distribution of grasslands in Poland varies with their higher proportion in the structure of agricultural land in north-eastern Poland where, in Warmia and Mazury Voivodeship and Podlasie Voivodeship, they reach the level of 30-32% (Figure 1). Majority of grasslands are situated in river valleys, in land depressions as well as on mountain slopes, which are impossible for the cultivation of ordinary crop plants. The characteristic of Poland's surface features causes that 89.5% of grasslands are taken up by lowland meadows.

Figure 1. Grassland areas (light green) in Poland.

3.1.1 Grassland in the present situation

On the basis of average values, grasslands in Poland must be described as extensive. Mean annual yields reach about 5.0 t ha^{-1} DM from meadows and 4.0 t ha^{-1} DM from pastures (Kozłowski & Stypiński, 1997). According to the latest statistical data (GUS, 2004), the mean hay yield from permanent grasslands reached the level of 3.78 t ha^{-1}. The fodder low quality from permanent grasslands is confirmed by the fact that they occupy 69.9% of the total fodder area in Poland, whereas 30.1% of the area occurs in the form of fodder crops on arable land (incl. temporary grasslands). However, permanent grasslands provide only 36.0% of nutritional (oats) units production in comparison with 64.0% from fodder crops on arable land (Zastawny, 2000)

The majority of grasslands is utilised for cutting. Polish meadows are utilised, primarily, for hay production. In recent years, the proportion of pastures in the total area of grasslands dropped from 35% in 2000 to 25% in 2004 (GUS, 2005). The input of NPK (nitrogen, phosphorus, potassium) in the period from July 2003 – June 2004 was at the level of 99.3 kg ha^{-1} of agricultural land, of which nitrogen takes 54.8 kg ha^{-1}, phosphorus - 19.7 kg ha^{-1} and potassium - 24.8 kg ha^{-1} (GUS, 2005). It is estimated that the annual input of nutrients in fertilisers on grasslands is smaller and does not exceed, in the case of nitrogen, 40 kg ha^{-1}.

There are 1 851 800 farms in Poland with the average farm size of 7.5 ha (GUS, 2005). Farms over 15 ha in size manage on 45.4% of agricultural land, although they constitute only 10.5% of the total number of farms. It turns out that 90% of agricultural production is derived from 35% of farms, while 10% - from 65% of farms, whose size does not exceed 2 European Size Units (ESU).

In 1990, there were 10.049 million of cattle in Poland, of which 4.919 million were dairy cows, and 4.159 million – sheep. Since then, the number of ruminants in Poland has been showing a declining trend. In 2004, there were 5.353 million cattle in Poland, of which 2.796 million were dairy cows. In the same year, there were 315 000 sheep and 123 000 horses. The average stocking rate calculated per 100 ha of agricultural land was at the level of 31.8 LSU (GUS, 2005).

Milk production in Poland in 2003 reached the level of 11 546 million kg and, in comparison with 1991-1995, it was by over 1 000 million kg lower. In the same period of time, the annual milk yield per cow increased from 3.085 kg to 3.969 kg. During the accession talks to the European Union, Poland negotiated milk quota at the level of 9 380 million kg of which 8 500 million kg is the wholesale quota, 464 million kg – the retail quota and 416 million kg – restructuring reserve (Ministry of Agr., 2004).

One of the leading milk production regions in Poland is Podlasie situated in north-eastern part of the country. There are 50 500 dairy farm in that region and they produce 18% of milk purchased in Poland and 87% of this amount fulfils EU standards. The stocking rate of dairy cows per 100 ha agricultural land in that region in 2004 was 33.9 LSU, while the average stocking rate of dairy cows in Poland was 17.1 LSU (GUS, 2005). Milk production in 2003 calculated per 1 hectare of agricultural land reached in the discussed region the level of 1 349 kg – the highest in Poland, whereas the average level for the country was 714 kg ha^{-1}. A significant dynamics of milk production growth has been observed in recent years both in the above-mentioned region and also in the area of Warmia and Mazury Voivodeship. In 2003 the increase of milk production in comparison with 2002 reached 5.3% and 11.6%, respectively. For this reason, the north-eastern part of Poland can be described as the region specializing in milk production based on grassland, where their cultivation plays an important role.

From the point of view of market output which results from the transfer of fodder derived from grasslands, meat and wool are also important. The dramatic decline was observed when we compare years 1991-1995 and 2003 in the following areas of animal production: beef cattle – from 2 524 to 1 343 thousand heads, lambs – from 1 519 to 203 thousand heads and horses z 106 to 64 thousand animals. Wool production dropped from 5 386 tons in years 1991-95 to the level of 1 317 tons in 2003.

After Poland's accession to the EU on May, 1st 2004, the situation of Polish agriculture changed considerably. The following aspects deserve mention when grassland management is taken under consideration:

- Direct subsidies calculated per 1 ha in years 2004-2006 at the level of 25%, 30% and 35%, respectively in relation to EU-15. They will be paid on the condition that grasslands are utilised – at least one-time cutting or grazing.
- Financing of programs connected with the protection of natural environment and rural landscape for which 5 billion EUR is earmarked for years 2004-2005. The financial resources are intended for funding various activities in areas of 420 biotopes, which, from the point of view of EU, possess special significance for natural protection and which form part of the NATURE 2000 program and which include approximately 21% of the area

of the country. The above-mentioned activities include, among others, maintenance of extensive meadows (one-time and two-time cuttings) as well as extensive pastures (xerothermic plant communities, mountain pastures) and on which renovation – both resowing and complementary seeding - is banned. EU financing covers 85% of payments associated with the activities.

- Subsidies intended for milk production modernization, for instance, purchase of machines for the production-, harvesting-, and conservation of feed, pasture establishment and renovation etc., as well as restructuring of farms specializing in beef cattle and sheep. EU assistance includes financing investment in this sector of farming production, e.g. through the SAPARD program up to 37.5% of the investment value.
- Increase of milk and meat prices on the market. Comparing November 2003 and 2004, in the case of milk, the observed price increase was from 0.193 to 0.246 EUR kg^{-1}, while in the case of beef – from 0.628 to 0.945 EUR kg^{-1} live weight.
- Increase of farm produce exports in May 2004 by 25% in comparison with the previous period.

Some of the above elements, especially those referring to milk production, are intended to stimulate renovation of grasslands and ley farming. The more so, since after Poland's accession to the EU, the economy of cereal production decreased.

3.1.2 Grassland cultivation

Economical transformations that took place in Poland at the beginning of 1990s caused wide-ranging changes in Polish agriculture. This also refers to changes in the management on grasslands, including the attitude to grassland renovation.

Within the framework of centrally controlled economy from before 1990, huge areas of grasslands were sown with grass and grass-legume mixtures as part of land reclamation investments which were financed from the state budget and carried out by state water-melioration enterprises operating in each voivodeship. Their responsibilities comprised works associated with the regulation of water-air relationships in soil on a given area (removal of bushes and tree plants, levelling of the ground, construction of melioration ditches, system of sluices etc.) performed within the framework of basic melioration works, mostly in river valleys and marshes and later renovation of such areas using the method of ploughing and sowing of seed mixtures containing intensive grass species. Grassland renovated in this way were then handed over to local farmers for utilisation, which was not always reasonable and justified from the point of view of the type of animal production carried out on these farms. Up to 1990, the total of 2 million hectares of grasslands were meliorated and sown and another 0.9-1 million ha did not need any regulation of water-air relationships in soil (Baryła, 2004; Nazaruk, 1995). However, the utilisation intensity and fertilisation levels applied on grassland in the last two decades varied significantly. Yields from meadows and pastures in years 1980-1990, especially those meliorated, ranged from 5.70 to 6.15 t ha^{-1} DM, while in years 2000-2001 dropped to the level of about 3.8-4.1 t ha^{-1} DM. The decline in yields observed in recent years was caused, apart from factors connected with unfavourable weather conditions, primarily by reduced even complete abandonment of fertilisation as well as by the lower intensity of utilisation. This explains the degradation of permanent grasslands observed on considerable areas.

At the present time, decisions concerning grassland renovations are taken exclusively on the economical basis and depend on the demand for high quality feed for ruminants. In fact, it refers only to farms specialising in dairy cattle production. At the moment, no reliable data is available about the renovation scale of permanent grasslands and sowing of leys. On the basis of information obtained from the Polish Seed Chamber about the quantities and structure of sold seeds of grasses and legumes it can be estimated that in the last three years seed mixtures were sown on the area of 85 000 ha annually. Most of these mixtures were used to establishment of temporary grassland. Grasslands on farms specialising in milk production are renovated systematically every 5-6 years. As expected, the operation is carried out more frequently if it is warranted by the appearance of factors resulting in their degradation. The feed base is frequently supplemented by sowing grass-legume and grass mixtures on arable land and their cultivation is competitive for maize. Due to the specificity of site conditions, temporary grasslands are established more frequently in northern and eastern Poland than in the central and western parts of the country where maize cultivation is preferred. The trend to increase acreage under maize in dairy farms observed in recent

years has been strengthened by the marketing of new maize cultivars, which are better adjusted to regions with shorter vegetation periods or in years with drought period resulting in yield drops from grasslands.
Two groups of soils are distinguished on permanent grasslands. Soils of mineral origin include: brown soils, chernozems, black turf soils, alluvial soils, rendzinas and gley soils created from non-silted and silted formations (called muck-bog soils), whereas soils of organic origin comprise: bog soils, also called hydrogenic or hydromorphic soils. These soils include: moss-peat, sedge-peat, rush-peat and alder-peat. The classification of meadow soils depends on their mechanical composition and organic matter content. Grasslands localised on mineral soils are better suited for renovation.
There is a rich marketing offer of grass and legume seeds in Poland at the moment but the mixtures of these seeds are characterised by considerable diversity even though they appear to be intended for the same purpose. In addition, there are also frequent mistakes both with regard to the species composition and quantities of individual components to be sown. That is why, the Polish Seed Chamber introduced on the Polish market in 2004 standard mixtures intended for grasslands (Goliński *et al.*, 2004). Their application by seed companies is not compulsory but should be treated only as recommendation. These proposals include three mixtures for temporary grasslands and four mixtures to be used on permanent grasslands (the proportions given in brackets refer to the sward composition the farmer should obtain after sowing; the proposed standard mixtures also give acceptable ranges of proportion of individual components in the mixture). The standard mixture 1 (SM 1), intended for 1-2 year utilisation includes: *Lolium westerwoldicum* (80%) and *Trifolium pratense* (20%), which can be replaced by large-leaved varieties of *Trifolium repens* or *T. resupinatum*. The SM 2, intended for intensive fodder production for 2-4 years comprises: *Lolium multiflorum* or *Festulolium* (40%), 4n cultivars of *Lolium perenne* (40%) and *Phleum pratense* (20%). The grass-legume mixture SM 3 should guarantee production of fodder with a high level of protein for 2-4 years. Its composition includes: *Lolium multiflorum* or *Festulolium* (60%) and alfalfa or *Trifolium pratense* (40%). The SM 4 mixture, which is designed for the establishment and renovation of pastures situated in good sites contains: 2n and 4n cultivars of *Lolium perenne* (25% + 25%), *Phleum pratense* (15%), *Festuca pratensis* (10%) and *Trifolium repens* (20%). The SM 5 mixture intended for permanent grasslands established on mineral soils in sites with optimal moisture conditions and intensive cutting utilisation for the production of silage contains: *Lolium perenne* 4n (30%), *Phleum pratense* (25%), *Festuca pratensis* (20%), *Lolium hybridum* or *Festulolium* (15%) and *Dactylis glomerata* (10%). Mixture SM 6 was designed for permanent grasslands situated on soils of organic origin, in wet sites – especially in spring and preferred for cutting utilisation. Its composition is as follows: *Phleum pratense* (25%), *Festuca pratensis* (15%), *Festuca arundinacea* or *Alopecurus pratensis* or *Phalaris arundinacea* (10%), *Poa pratensis* (10%), *Festuca rubra* (10%), *Lolium perenne* late cultivars (10%), *Trifolium hybridum* or *T. repens* (20%). Mixture SM 7 for permanent grasslands situated on mineral soils on periodically dry sites intended for both pasture and cutting utilisation is made up of: *Dactylis glomerata* (20%), *Festuca pratensis* (20%), *Poa pratensis* (20%), *Lolium perenne* (15%), *Festuca rubra* (5%), *Lotus corniculatus* or *Trifolium repens* (20%).

3.1.3 Legislation

There are no special regulations concerning grassland renovation in Poland, although the issue is mentioned in passing in a number of legislative acts concerning agriculture. One of them is the Code of Good Agricultural Practice (Code, 2002) which comprises a number of recommendations concerning, among other, rational management of grasslands and the implementation of the Nitrogen Directive. In chapter H it is stated that #65…permanent grassland should be renovated. The basic method of renovation is complementary seeding, possibly with a partial damage of the old sward and improvement or change of utilisation and fertilisation. #66 Ploughing and resowing of grassland are applied only in exceptional situations. The application of this method leads to the release of large quantities of nitrogen which can result in the contamination of ground waters, particularly when the water table is shallow. When the sward is ploughed under, it is recommended to grow for the period of one year fodder plants characterised by high nitrogen requirements, for example rye for green fodder followed by maize as a secondary crop so that grass can be resown in the optimal term. #67 The swapping of grassland to arable land should be only used as the last resort. The inclusion of grassland in the rotation system should take into account the inevitable mineralisation of large quantities of nitrogen with all the negative consequences for the environment…
However, the regulations found in the Code are only recommendations. In practice, it is not very uncommon to find grassland management systems which are contradictory to the regulations found in this Code.

3.2 Farmer's situation

3.2.1 Motivation for grassland renovation

The main causes of the process of grassland degradation in Poland include:

- Unfavourable site changes caused either by excess (in 1997, floods damaged huge areas of grassland in river valleys) or deficit of water (Figure 2 and 3) during the vegetation season (in recent years droughts occurred in Poland in 2000 and 2003; drought spells are particularly unwelcome in spring).
- Overwintering conditions unfavourable for fodder grass and legume species (last time in 2003/2004; the disappearance of *Lolium sp.* coincides most often with freezing of winter barley and rape).
- Negligence on the part of farmers in the area of grassland management, especially concerning fertilisation and utilisation.

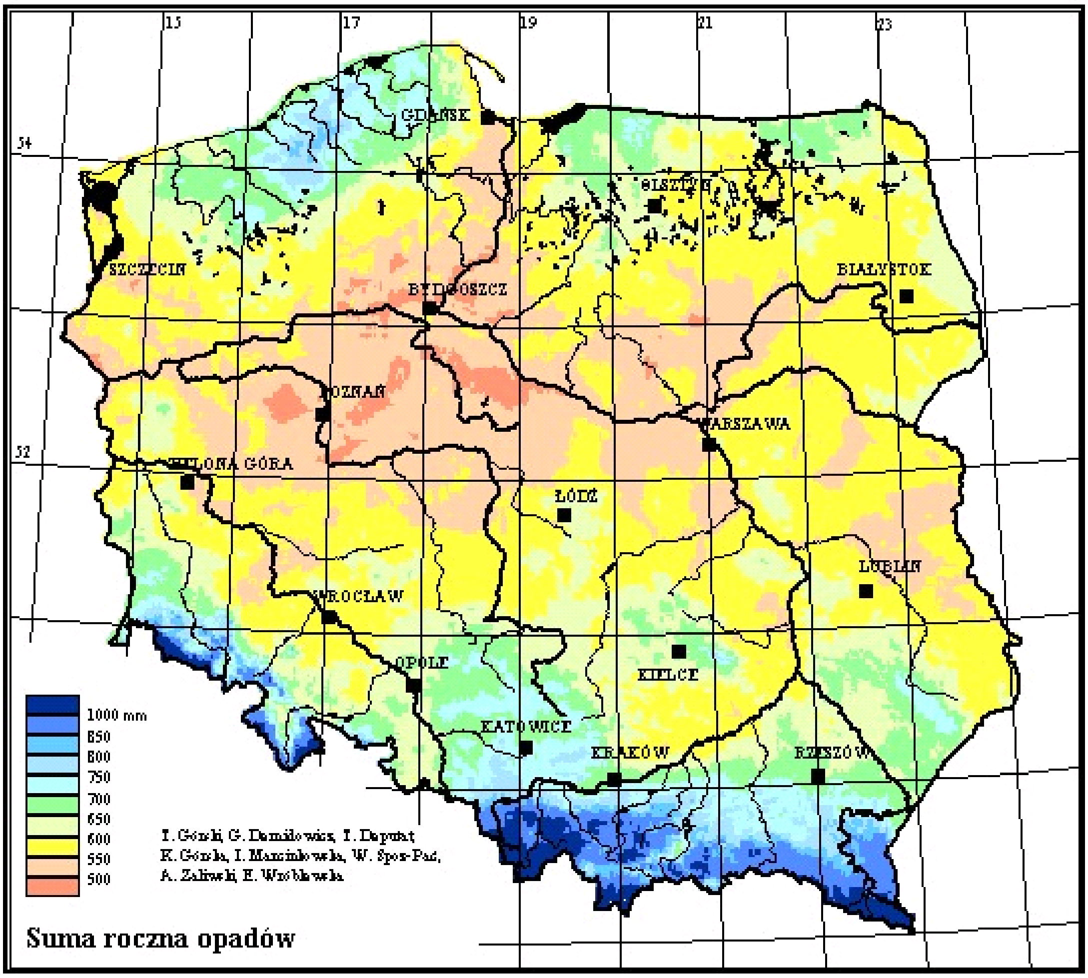


Figure 2. Yearly sum of precipitations.

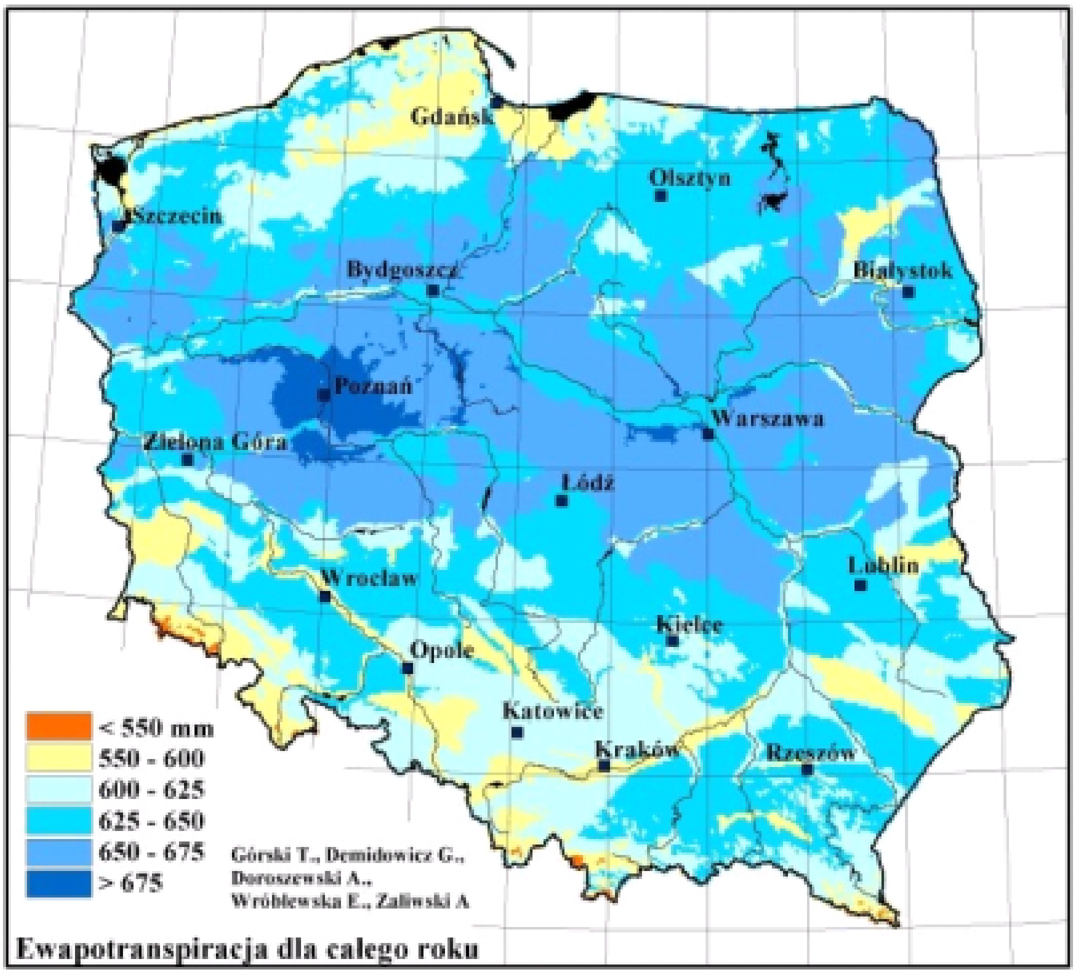


Figure 3. Potential evapotranspiration (annual mean).

In the course of the degradation process of grasslands we observe a decrease in the proportion of fodder grasses and legumes sown in the mixture, while the sward becomes loose. The appearing empty spaces/gaps facilitating oxygen access to the soil – make it easier for weed seeds to germinate and take roots and with the passage of time the amount of weeds in the sward steadily increases. These unfavourable changes in the sward botanical composition result in the decline in harvested dry matter yields and have a negative influence of herbage quality as the concentration of energy and protein as well as digestibility all decline. In addition, fodder palatability also drops resulting in smaller intakes of dry matter in the basic feed ration by ruminants. Therefore, poor quality of fodder from grasslands contributes to the poor production results of animals.

3.2.2 Criteria for grassland renovation

Criteria for grassland renovation were developed in 1970s. Resowing involving the destruction of the old sward and sowing of a new mixture is recommended in situations of a strong degradation of grasslands which includes:

- Very small presence in the sward of valuable grasses and legumes.
- High proportion in the sward (over 40% in coverage) of undesirable and troublesome rhizomatous (*Cirsium sp.*, *Rumex sp.*), toxic (*Ranunculus sp.*), hydrophilic (mainly *Juncus sp.*, tussock-forming *Carex sp.*) weeds and mosses.
- Over 20% share in the sward of *Deschampsia caespitosa*.
- Soil impoverishment, its destroyed structure with content of acid humus.
- Considerable sward destruction by moles, rodents and wild boars.

3.2.3 Methods

Two terms are recommended for grassland renovation in Poland: the first one in early spring (beginnings of April) and second - late summer (second part of August). There are two variants of resowing; traditional ploughing and application of non-selective herbicides. The destruction of old sward in the more frequently applied traditional variant consists in ploughing to the depth of 20-25 cm frequently preceded by the removal of the old vegetation, levelling of the surface and disking of the old sward. In order to turn under the ridge accurately and cover the remains of the old sward, it is recommended to use ploughs with auger-like mould-boards. In addition, soil for sowing is prepared by supplement doses of phosphorus, potassium and magnesium in the form of mineral fertilisers and, if necessary, liming. Recent investigations have shown pure sowing has a clear advantage over the sowing with the companion crop, for example addition of 5 kg ha^{-1} Italian ryegrass. The sowing is carried out either by drilling or broadcasting with a ordinary drill and the recommended seed rates ranges from 35-45 kg ha^{-1}. After emergence, it is necessary to perform one or two cleaning cuts to control annual weeds which compete with grass seedlings for light. The first of the cuttings should be carried out 4-6 weeks after sowing. The cut forage should be removed from the surface immediately and the plants should be fortified with a dose of nitrogen of 30-40 kg ha^{-1}. It is recommended to utilise meadows and pastures in the year of sowing only by cutting.

An alternative method of grassland renovation is recommended for soils of organic origin. The traditional method of renovation based on ploughing can be simplified thanks to the development and marketing of non-selective herbicides containing glyphosate. The old sward can be destroyed by spraying 5-7 l ha^{-1} of glyphosate. The compound is most effective when it is applied in the autumn, at least three weeks before the end of the vegetation season at the height of sward ranging from 10-15 cm. After removing the dry vegetation, the mixture can be sown in spring. In the method, however, it is necessary for the farmer to use a special drill for direct drilling. The difficulty may be overcome if the sod is not very dense by loosening the soil surface with a rototiller and sowing the seed mixture using on ordinary grain drill.

3.2.4 Economics

The economic stimulator encouraging farmers to take the decision to renovate their grasslands or intensify feed production by sowing of grass in rotation with arable crops is the profitability of milk production. Recent studies carried out by the Institute of Agriculture Economy indicate that in recent years dairy cattle rearing has been giving the highest net agricultural income per 1 hectare (about 400 EUR), second in the entire agricultural production to potatoes.

Animal production specialisation necessitates a different organisation of the feed base and this, in turn, leads to the improvement of grassland management and a decline in the demand for land often characteristic for animal production. According to Okularczyk (2000), polarisation of herd of dairy cows in Poland will proceed towards farms with the animal stocking rate commonly referred to as ‘parity rate’, i.e. one in which the income of a farm family will be at least comparable with the average income of the non-agricultural sector. This stocking rate depends on the milk yield of cow which, in turn, is determined, to a large extent, by the effectiveness feed production and herbage quality obtained from grasslands. In the case of high-yielding cows (8 500 kg milk annually), the parity stocking rate is 15 heads, but when the quantity of milk per cow does not exceed 3 500 kg, then this index increases to 36 heads (Okularczyk, 2000).

In order to restore degraded grasslands to their initial value using various types of renovation methods, it is necessary to invest substantial sums of money and the sums spent are of investment character. They add to the annual costs of meadow and pasture utilisation connected with the fodder production. The costs of forage will depend on the duration of grassland utilisation – the shorter this period, the more expensive the produced feed becomes. Figure 4 shows costs of the renovation of 1 hectare of grassland using different methods.

Complementary seeding is a low-cost method of improving the botanical composition of grasslands and this refers both to oversowing and overdrilling.

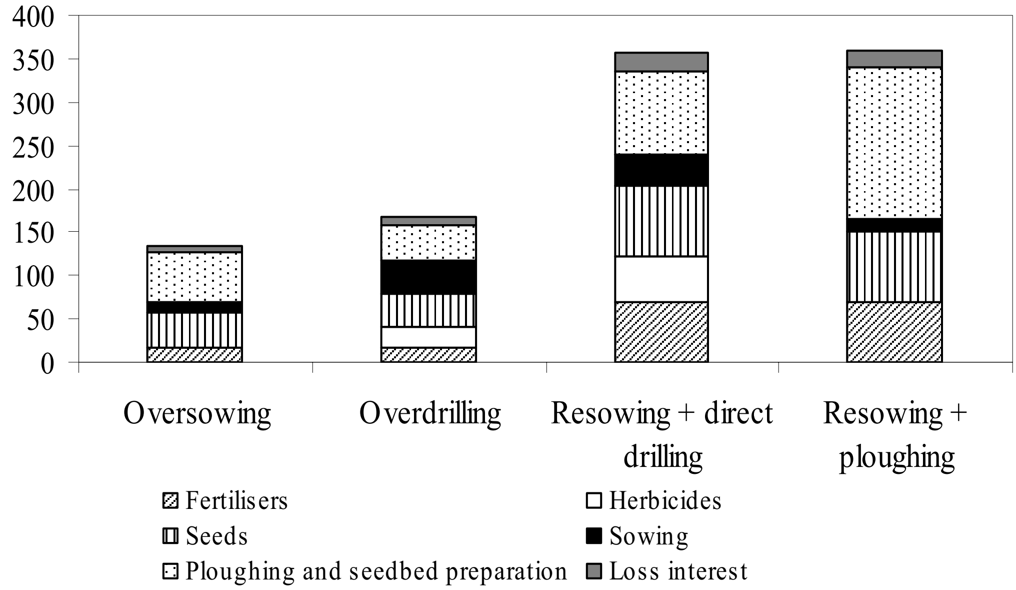


Figure 4. Costs (EUR ha^{-1}) of different methods of grassland renovation.

It turns out that the costs of oversowing of the sod damaged by a rototiller amount to 135 EUR ha^{-1}, whereas overdrilling with the assistance of specialised drills in conditions of chemical weakening of the old sward costs 167 EUR ha^{-1} (Goliński, 1998). When the treatment with herbicides is left out, the two methods of complementary seeding are comparable from the point of view of their costs. Resowing is the most expensive method of grassland renovation and its costs, depending on the applied variant, may range from 357 to 360 EUR ha^{-1}.
The outcome of the process of grassland renovation resulting from the improvement of the botanical composition of its sward should include both the increase of yields and herbage quality and the two elements can occur jointly or separately. The resultant increase of yields or quality improvement of forage should fully recompense the costs incurred by the renovation.
The profitability of the applied grassland renovation can be determined using the following formula (Goliński, 1998):

$$\frac{K_{REN}}{\Delta P\ n} < \frac{K_{PASZ}}{P}$$

where:

K_{REN}	-	costs of performing grassland renovation (PLZ ha^{-1})
K_{PASZ}	-	costs borne every year to produce feed from grassland (PLZ ha^{-1})
ΔP	-	yield increment of dry matter, energy or protein after renovation (dt DM ha^{-1}, MJ ha^{-1}, kg protein ha^{-1})
P	-	dry matter, energy or protein yield before renovation (dt DM ha^{-1}, MJ ha^{-1}, kg protein ha^{-1})
n	-	persistence of the renovation process (number of years)

When assessing the duration of the renovation effects, it is necessary to take into account the specificity of site conditions, including weather conditions as well as the persistence of the cultivars or species of grasses and legumes used in course of the process of grassland renovation.

3.3 Research: the state of the art

3.3.1 Nutrient (N & P) cycling, incl. emissions to the environment

There is a considerable lack of information in studies on the subject carried out in Poland concerning soil nutrient fluxes after the renovation of grasslands employing different methods and carried out on different types of soils. Little is also known about the quantities of nitrogen and phosphorus released into the environment.
In studies carried out on peat soils, it was found that the degradation of grasslands on organic soils speeds up the mineralisation process and mineral nitrogen emission. Nazaruk (1995) claims that during the period of 25 years, the loss of organic matter under root crops amounted to 26.7%, whereas in the case of grasslands, this loss was only 10.4%. Organic matter mineralisation is closely connected with the degree of soil moisture content. In the case of peat soil in conditions of grass/arable crop rotation and lower moisture content, 357 kg ha^{-1} nitrogen was released annually on the field of temporary grassland, while on the field of arable crop - 430 kg ha^{-1} nitrogen (Okruszko, 1991). In the same experiment, 571 kg ha^{-1} nitrogen was released from the soil on which a forest was planted. In the case of peat soil, in a site typical for permanent grasslands but with higher moisture content, nitrogen mineralisation amounted to 138 kg ha^{-1}.

3.3.2 Soil quality and water balance

The influence of grassland renovation on soil physical, chemical and biological properties has not been adequately investigated and calls for comprehensive research. Some investigations in the area have been carried out on organic soil sites. It turns out that organic matter mineralisation becomes apparent in the decline of the depth of the peat soil. Okruszko (1991) maintains that, in conditions of grass/arable crop rotation on peat soil, the annual loss of soil dry matter on the temporary grassland amounted to 15.6 t ha^{-1}. This caused the annual sinking of the soil surface by 1.34 cm as the result of compaction (22.8%) and mineralisation (77.2%). The sinking of the peat soil surface on the field of arable crop was greater – 1.8 cm per year. For comparison, when permanent meadows are utilised properly and no renovation is applied, the annual sinking of the peat soil surface is at the level of 0.2 cm.
Successful renovation of grasslands depends on site conditions of which soil moisture content appears to play the most important role. Investigations carried out by Pawluśkiewicz *et al.* (2000) in lysimeters showed that high levels of ground waters increased yields, especially on loamy soils (Table 1).

Table 1. DM yield (g $lysimeter^{-1}$) in dependency on soil type, level of ground water and method of renovation (Pawluśkiewicz et al., 2000).

Level of ground water (cm)	Soil type			
	sand		loam	
	Renovation method			
	ploughing	sod-seeding	ploughing	sod-seeding
45	46.5	28.6	125.8	78.8
60	86.6	51.5	109.3	90.6
90	39.6	25.3	117.3	47.8

3.3.3 Crop/animal performance

The effectiveness of different grassland renovation methods and techniques in Poland depends on site conditions in which investigations are carried out (Mikołajczak, 1998). Results of studies carried out by Fatyga (1998) in conditions of the Sudety Mountains, indicate that higher yields of dry matter following grassland renovation can be achieved in lower basin-valley areas in the two first years after resowing (Table 2). Grassland renovation 600 m above the sea level is very unreliable and the resowing fails to give good results.

Table 2. Annual DM yield (t ha^{-1}) in dependency on method of grassland renovation (Fatyga, 1998).

Method of grassland renovation	Utilization year		
	sowing	first	second
Ploughing	0.85	8.37	4.93
Oversowing	0.86	7.29	5.67
Rototiller + oversowing	0.70	7.87	6.26
Non-selective herbicide + oversowing	0.74	5.97	4.83
Non-selective herbicide + tooth harrow 5 times + oversowing	1.97	7.52	5.15
Non-selective herbicide + tototiller 3 times + oversowing	1.02	7.97	4.96
Without renovation	0.60	3.60	1.32

Results of numerous investigations indicate that grassland renovation has a positive impact on the herbage quality rather than the yield. Goliński & Kozłowski (2000) come to the conclusion that overdrilling increased yield and the chemical composition of the herbage (Table 3), but no significant differences were observed in the case of production of 1 kg DM. The herbage with higher protein and energy concentration was used to feed cows either in the form of fresh material or wilted silage and this allowed to reduce concentrate rations in individual farms by 200-289 kg head^{-1} annually.

Table 3. Effect of grassland overdrilling on herbage yield and quality (Goliński & Kozłowski, 2000).

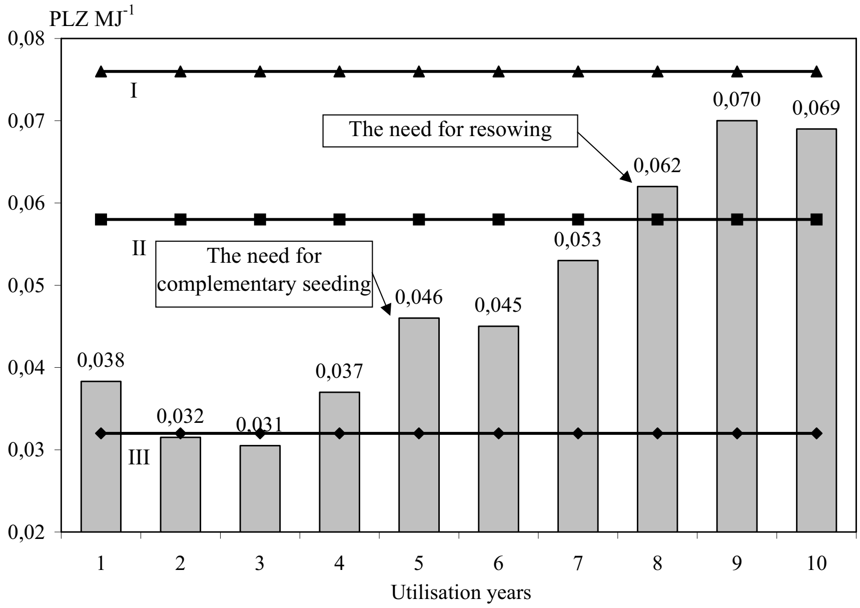
Item	Farm A		Farm B		Farm C		Farm DA	
	K[1]	O[2]	K[1]	O[2]	K[1]	O[2]	K[1]	O[2]
DM yield (t ha^{-1})	7.475	8.485	7.195	8.273	8.134	9.401	7.439	7.902
Chemical composition of herbage (g kg^{-1} DM)								
Crude protein	151.6	166.0	150.4	177.8	133.7	164.0	114.8	140.9
Cellulose	235.3	224.2	235.9	264.2	257.0	243.5	256.8	261.1
Lignins	20.8	14.5	26.7	23.8	20.3	14.3	37.3	27.5
NEL (MJ kg^{-1} DM)	4.88	5.30	4.88	5.21	4.63	5.29	5.02	5.45

[1] control plot [2] overdrilled plot

3.3.4 Farm management and economics

Numerous economical analyses indicate that the improvement of herbage quality from grasslands after renovation is justified by milk production. Goliński (1998) maintains that in view of the progressing degradation of meadows and pastures, the ratio of the production costs of 1 kg DM, 1 MJ energy and 1 kg protein of feed to the upgrading value of feed in animal production is very important. This relationship was shown on the basis of investigations on DM yields and herbage quality of a meadow established on mineral soils in the region of Wielkopolska during the period of 10 years of utilisation beginning from the moment of resowing after ploughing (Figure 5). It turned out that the harvested forage generated profit following its transformation into milk from dairy cows only in the second and third years of meadow utilisation. The cost of production of 1 MJ of feed energy was lower than the upgrading value of the feed No. III (taking into account direct costs, costs of labour and stand depreciation in dairy cattle rearing) at the

level of 0.032 PLZ MJ^{-1}. In the consecutive years of utilization, unit costs of energy production from the feed obtained from the renovated meadow were observed to increase. The above-described phenomenon can be attributed to unfavourable changes in the sward botanical composition. Both the dry matter yield and energy concentration declined. In the process of meadow degradation assessed on the basis of economic indices (Goliński & Golińska, 1998), the need to carry out renovation with the assistance of available methods is quite evident. It can be assumed, on the basis of the example shown in Figure 5, that small deviations of the production cost of 1 MJ in relation to the upgrading value of feed No. III are acceptable and can arise from unfavourable weather conditions in a given year. This situation occurs up to the fourth year of meadow utilisation. During this period, sward should be improved using suitable tending operations, rational fertilisation and appropriate utilisation.
In the consecutive years, following the intensifying process of meadow degradation, the applied renovation treatments should include complementary seeding and, if production cost of 1 MJ energy continued to increase, the old sward should be destroyed and new grass-legume mixture sown. It is worth emphasizing that complementary seeding should be applied appropriately early.



Upgrading value 1 MJ of feed in rearing of dairy cows:
I – taking into account only direct costs; II – I + labour costs; III – II + depreciation costs of the stand

Figure 5. Changes of production costs of 1 MJ NEL feed in the period of 10 utilization years of meadows in Wielkopolska region (Goliński, 1998).

A rational indicator of the moment to perform meadow oversowing or overdrilling is when the value of the ratio of the production cost of 1 MJ feed energy to the upgrading value of feed in dairy cows production reaches 1.2-1.5. A later application of complementary seeding can be justified on condition that the old sward are increasingly damaged (mechanically or chemically) and amounts of seeds for oversowing or overdrilling keep increasing. On the other hand, further grassland degradation associated with increasing ratio of the production cost of 1 MJ energy to the upgrading value of feed requires the type of renovation involving the resowing.

3.4 Conclusions and prospects

Grassland resowing and grass/arable rotations in Poland should be treated as a significant factor increasing feed production and improving herbage quality on dairy farms. The organization of the feed base on individual farms is affected by the structure specificity of agricultural land. Permanent grasslands constitute a natural feed source and should be the first in the queue of optimal utilization. On the other hand, the importance of ley farming based on

grass mixtures and, in particular, on grass-legume mixtures will depend on how good climatic and soil factors for the growth and development of grasses exist in a given region. The decisions concerning the feed structure on dairy farms depend, first and foremost, on the soil moisture. In this respect, maize cultivation may be treated as an alternative or complementary crop.
At the present time, in regions with the domination of milk production, for example in north-eastern Poland, the observed improvement in the feed base on dairy farms occurs in the result of application of grass-legume seed mixtures used rather on temporary than permanent grasslands. The mixtures are used both for the establishment of temporary grasslands and the renovation of permanent grassland. The problem of grassland durability and persistence on the above farms seems to be of secondary importance, which must be somewhat disturbing from the point of view of natural environment.
The following research aspects associated with grassland resowing and grass/arable rotations require further investigations:

- Indication of practical criteria for the qualification of permanent grasslands for renovation.
- Determination of the role of other agronomic factors, such irrigation, mineral and slurry fertilization, in the process of grassland renovation.
- Determination of nitrogen and phosphorus fluxes in soil on permanent and temporary grasslands in relation to the applied renovation method.
- Effect of permanent grassland renovation on soil physical, chemical and biological properties.
- Evaluation of the impact of grassland cultivation on natural environment from the point of view of differentiation in site conditions, especially in micro-regions with a high concentration of dairy farms.
- Quantification of grassland renovation and fodder production from grass/arable crop rotations on DM yield, herbage quality, animal performance, feed base organization, effects of animal production and economical indices.

3.5 References

Baryła, R., 2004.
Zakładanie i odnawianie użytków zielonych [Sowing and resowing of grassland]. In: M. Rogalski (ed.) Łąkarstwo [Grassland Science], Wydawnictwo Kurpisz, Poznań, pp. 138-161 (in Polish).
Code, 2002.
Kodeks dobrej praktyki rolniczej [Code of a good agriculture practice]. Ministry of Agriculture and Rural Development, Warszawa (in Polish).
Fatyga, J., 1998.
Possibilities of improving floristic composition of sward and yielding of grassland in the Sudety Mountains through complementary seeding and reseeding. Grassland Sciences in Poland 1: 111-122.
Goliński, P., 1998.
Factors affecting complementary seeding of grasslands – economics. Grassland Sciences in Poland 1: 65-78.
Goliński, P. & B. Golińska, 1998.
Assessment of the degree of degradation of permanent grasslands on the basis of economic indices. Grassland Science in Europe 3: 59-62.
Goliński, P. & S. Kozłowski, 2000.
Role of grassland overdrilling in the increase of feed economical efficiency and protection of meadow soil. Grassland Science in Europe 5: 191-193.
Goliński, P., M. Warda & J. Kaszuba, 2003.
Pastewne mieszanki standardowe na użytki zielone [Fodder standard mixtures for grassland]. Hodowla roślin i nasiennictwo [Plant breeding and seed production] 4: 32-36 (in Polish).
Górski, T., G. Demidowicz, T. Deputat, K. Górska, I. Marcinkowska, W. Spóź-Pać, E. Wróblewska & A Zaliwski, 1998.
Yearly sum of precipitation. IUNG Puławy, www.zazi.iung.pulawy.pl/Images/Maps/opad_rok.jpg.
Górski, T., G. Demidowicz, A. Doroszewski, E. Wróblewska & A. Zaliwski, 2002.
Potential evapotranspiration in Poland (annual mean). IUNG Puławy, www.zazi.iung.pulawy.pl/Images/Maps/ewapo_r.jpg.

GUS, 2004.
Rocznik statystyczny [Statistical Yearbook]. Main Statistical Office, Warszawa.
GUS, 2005.
Rolnictwo w I półroczu 2004 [Agriculture in 1st half of 2004]. Main Statistical Office, www.stat.gov.pl/dane_spol-gosp/rolnic_lesnict_srodowi/rolnictwo_2004.
Kozłowski, S. & P. Stypiński, 1997.
The grassland in Poland in the past, present and future. Grassland Sciences in Europe 2: 19-29.
Mikołajczak, Z., 1998.
Factors affecting complementary seeding of grasslands – agricultural practise. Grassland Sciences in Poland 1: 53-64.
Nazaruk, M., 1995.
Natural and economic aspects of meadows and pasture sward renovation. Annales UMSC, Sectio E, Suppl. 50: 185-188 (in Polish with English summary).
Okruszko, H., 1991.
Wpływ sposobu użytkowania na glebę torfową oraz związane z tym zjawiska i trudności [Effect of the utilisation way on peat soil and phenomena and difficulties connected therewith]. Biblioteczka Wiadomości IMUZ 77: 105-118 (in Polish with English summary).
Okularczyk, S., 2000.
Efektywność ekonomiczna żywienia zwierząt gospodarskich paszami z użytków zielonych [Economic efficiency of livestock nourishment by grassland forage]. Materiały Konferencji Naukowej 'Nowoczesne metody produkcji pasz na użytkach zielonych i ocena ich wartości pokarmowej' [Proceedings of the Scientific Conference 'Modern methods of forage production on grassland and evaluation of its nutrition value'], IMUZ Falenty pp. 245-254 (in Polish with English summary).
Ministry of Agr., 2004.
Ministry of Agriculture and Rural Development. Warszawa, www.minrol.gov.pl
Pawluśkiewicz, B., M. Nazaruk & K. Piekut, 2000.
Wpływ wybranych metod renowacji na wschody i skład botaniczny runi w zróżnicowanych warunkach poziomu wody gruntowej i gleb mineralnych – na podstawie badań lizymetrycznych [The improvement of meadow green growth composition in the dependence to the renovation methods on the basis of lysimetric investigations]. Materiały Konferencji Naukowej 'Nowoczesne metody produkcji pasz na użytkach zielonych i ocena ich wartości pokarmowej' [Proceedings of the Scientific Conference 'Modern methods of forage production on grassland and evaluation of its nutrition value'], IMUZ Falenty pp. 106-115 (in Polish with English summary).
Zastawny, J., 2000.
Country pastures/forage resource profiles. Poland. FAO, www.fao.org/ag/AGP/AGPC/doc/Counprof/Poland.html.

Part II.

Luzern contributions

4. Grassland renovation in Northwest Europe: current practices and main agronomic and environmental questions

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Abstract

During two international workshops on grassland cultivation and grass-arable crop rotations, central agronomic and environmental consequences relating to the ploughing of grassland were examined and discussed. Some initial questions could be answered yet; other questions still required significant scientific efforts. There was general agreement that experimental data, experiences and knowledge from different European countries needed to be synthesized in order to derive information that is relevant to different environments and farming practices. The present paper gives a brief overview on activities and first results of the EGF Working Group on Grassland Resowing and Grass-arable Rotations.

Keywords: grassland renovation, nitrogen, soils, crop rotation, leaching

Introduction

Ploughing and reseeding of grassland has become increasingly questioned with regard to environmental aspects such as nutrient loss and soil fertility. Scientists from seven Northwest European countries tried to identify present gaps of knowledge, and to work out solutions for sustainable forage production during a workshop on grassland cultivation held in Wageningen in April 2002 (Conijn *et al.*, 2002). The term 'grassland cultivation' is used here as a common term for ploughing + reseeding of permanent grassland as well as for short-term grassland (leys) in rotation with arable crops. During the 19th EGF General Meeting in La Rochelle, France, a Working Group on Grassland Resowing and Grass-arable Rotations was officially launched. In February 2003, the Working Group met again in Kiel, Germany (Conijn *et al.*, 2004). While the first workshop in Wageningen focused mainly on the relevance and reasons for grassland cultivation in different Northwest European countries, the second meeting in Kiel placed emphasis on agronomic and environmental consequences, with particular interest to N and C cycles, soil processes and crop performance.

Fields of work

The basic working hypothesis of the Working Group is illustrated schematically in Figure 1. It is assumed that grassland productivity declines with increasing age of the sward, but increases during the first production years after cultivation. However, a significant yield loss is likely to occur in the year of grassland renewal. N losses are also likely to increase due to increased mineralization after ploughing. Both magnitude and time scale of these effects depend largely on soil type, climatic conditions and cropping practices.
There exist a number of questions related to this hypothesis. In the following, general information gathered from the two workshops is summarized, and remaining questions which require further scientific efforts are formulated. Other specific topics that have been discussed and evaluated during the workshops are addressed in the respective publications.

Hypothesis: Grassland productivity decreases over time

Empirical data

Apart from Danish cutting experiments, data from most Northwest European countries do not support this assumption. However, the time scale is an important factor in this context. In the case of very old grassland, which has not been cultivated for decades, productivity might be at a stable level. Different cropping practices hamper the comparison of experimental results. In Denmark, where grass-arable crop rotations are common, an 'old' sward is a sward of 3-5 years age. However, in Northern Germany, 50% of the grassland is older than 30 years under climatic and soil conditions similar to Denmark.

Remaining questions

- To what extent are grassland yields affected by climatic and soil conditions over time? How is this affected by: sward composition (pure grass, grass/clover, clover content, varieties), management practices (cutting / grazing, stocking rate on pasture and fertilization) and measures that maintain sward productivity (weed control, overseeding and cleaning cuts)?
- Which parameter (DM yield, energy / protein yield, herbage quality, animal intake, or animal production) is most important to the farmer and which should be used to describe sward productivity?

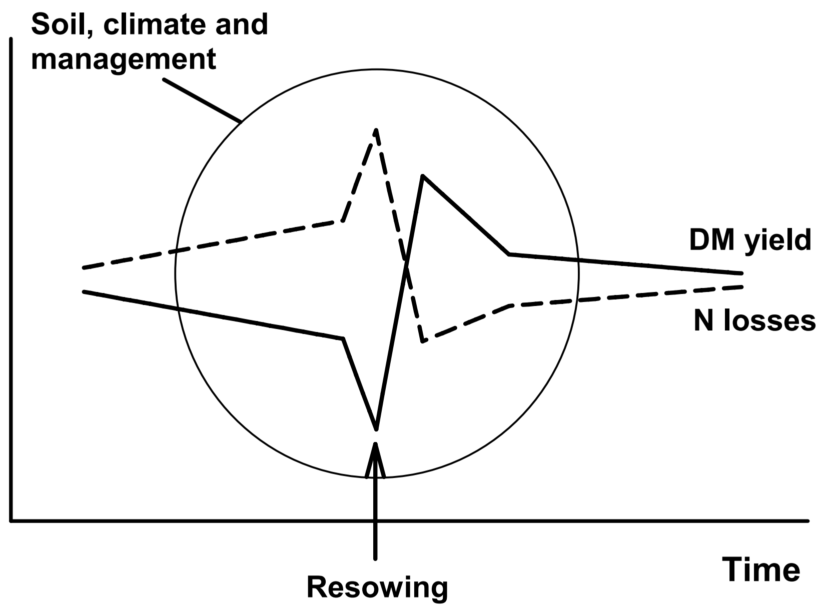

Figure 1. Working hypothesis: assumed effects of grassland renovation on DM yield and N losses.

Hypothesis: Grassland productivity increases after cultivation

Empirical data

Even though many reasons for higher yields of newly established swards have been formulated (e.g., the use of new varieties, a higher feeding value, lower grazing losses), empirical data from different countries shows that the effect may be negligible. Again, an exception was found in Danish cutting experiments where young swards exhibited significant increases in herbage production. Herbage quality was found higher, lower or similar after resowing compared to 'old' swards. Experiments from other countries supported a general trend towards a declining yield response to N fertiliser during the first years after cultivation.

Remaining questions

- As for the first hypothesis, effects of soil and climatic conditions, sward composition and management practices need to be quantified. This holds true for both the young sward and the old sward which serves as 'reference' in the comparison.

Hypothesis: N losses increase after ploughing of grassland swards

Empirical data

Concerning permanent grassland that is ploughed and reseeded in spring, there is no experimental evidence that cultivation leads necessarily to significantly increased nitrate leaching losses. First, the amount of N mineralised after ploughing was estimated between 120 and 400 kg N per hectare during the first year. This is not only due to site-specific and agronomic factors, but also to different methods of estimating N mineralization. Second, newly established grassland accumulates a considerable proportion of mineralised N in herbage, stubble, roots and litter. However, small trends in soil organic N can have significant effects on N losses, and this requires further investigation. Concerning grass-arable crop rotations, experiments from Denmark and The Netherlands showed that nitrate leaching losses were higher during the arable phase than under grassland.
There is general evidence that grassland cultivation may significantly increase gaseous losses of N compounds such as N_2O or NH_3, and this aspect should be considered as well.

Remaining questions

- To what extent does grassland management (cutting / grazing, fertilization, sward composition and N_2 fixation) and abiotic conditions (soils, weather) affect changes in soil organic compounds (organic matter, N and C), mineralization, and N losses after ploughing?
- Do N losses increase with increasing sward age?
- To what extent does the ratio between denitrification and leaching change?
- How can the methods of estimating mineralization be harmonized?

Outlook

During the second meeting in Kiel, three specific groups were appointed. These groups will investigate the effects of grassland cultivation on:

I. N and C cycles and soil quality dynamics (Vertès *et al.*, 2004)
II. Crop/animal performance (Søegaard *et al.*, 2004)
III. Farm-gate N balances (Kristensen *et al.*, 2004).

The groups will continue working on the respective topics in order to synthesize the data from different Northwest European countries, provide further insight into the relevant processes and develop model approaches that may help to disentangle the environmental and experimental 'noise' which hampers the comparison of results from different countries. There was general agreement in the Working Group that more on-farm research was needed, and that the entire production chain from grassland DM yield to animal production required particular attention. A holistic approach that accounts for all agronomic, environmental and economic effects was expected to be much more meaningful than focusing on one or two aspects only.

References

Conijn, J.G., G.L. Velthof & F. Taube (eds), 2002.
Grassland resowing and grass-arable crop rotations. *International workshop on agricultural and environmental issues*, Wageningen, The Netherlands, 18-19 April, 2002. Plant Research International B. V., Wageningen, Report 47

Conijn, J.G. & F. Taube (eds), 2004.
Grassland resowing and grass-arable crop rotations - consequences for performance and environment. *Second workshop of the EGF-Working Group 'Grassland Resowing and Grass-arable Rotations'*, Kiel, Germany, 27-28 February, 2003. Plant Research International B. V., Wageningen *(in press)*

Kristensen, I.S., M. Kelm, M. Wachendorf & F. Taube, 2004.
Effects of grassland renovation on farm-gate nitrogen balances and losses. *This proceedings*

Søegaard, K., A. Hopkins A., L. Bommelé & M. Gierus, 2004.
Effects of grassland renovation on crop and animal performance. *This proceedings*

Vertès, F., D.J. Hatch, G.L. Velthof, S. Abiven, A. Hopkins & G. Springob, 2004.
Effects of grassland renovation on N and C cycles and soil quality dynamics. *This proceedings*.

5. Nitrogen mineralization kinetics after destruction of grazed swards: effects of preceding grassland management

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Abstract

The purpose of this study is to quantify the net nitrogen mineralization rates in field after destruction of grasslands, which may vary according to their management (nitrogen fertilisation, grazing or mowing, plant species).
Investigations have been carried out on three former experiments located in the West of France, previously set up to study the effects of nitrogen fertilisation of grazed swards or the impact of mowing once or twice a year on the grass production and the nitrate leaching.
After destroying the grassland chemically in February, the soil was kept bare by using herbicides for two years and the mineral nitrogen was measured monthly. The use of LIXIM model (Mary *et al.*, 1999) allowed to calculate the nitrogen mineralization rates.
The effect of grassland destruction was much greater than the effect of the previous fertilisation or pasture type (pure grass or grass white clover mixture). Mowing once or twice was not systematically effective: mineralization decreased after destruction of pure swards; it was ineffective after destruction of the grass clover mixture.

Keywords: nitrogen fertilisation, grassland management, destruction, N mineralization

Introduction

The effects of grassland destruction are very important to take into account in the context of sustainable agriculture because of the large amount of nitrogen mineralised. Many studies have been carried out on the mineralization of organic matter previously accumulated under grassland, more specifically regarding evolution of organic carbon contents in soils. The induced effects on nitrogen mineralization have also been studied in numerous reports (e.g. Cameron *et al.*, 1984; Conijn *et al.*, 2002), but few of them have established the kinetics of the process.
The knowledge of the kinetics is required to optimize following crop management by synchronising its N absorption capacity with soil N mineralization and thus to minimize nitrate leaching.
Three experiments were carried out to study the effect on N leaching of nitrogen fertilisation, grassland type (pure grass vs. grass/clover swards) and grazing/cutting ratio.

Materials and methods

The experiments presented here were carried out on three sites in the west of France, on pure perennial ryegrass (*Lolium perenne)* and rye-grass/white clover (*Trifolium repens*) grasslands, 5 to 7 years old at destruction date. The soils are sandy silt loams with a free drainage. Table 1 give details on previous managements before destruction. Grassland were chemically destroyed with glyphosate in mid February. The plots were then kept bare fallow during 2 years (addition of herbicides 4 times per year) without any soil disturbance.

To study the effects of grassland destruction on nitrogen mineralization, 8 soil cores were taken every 3 or 4 weeks to a depth of 80 or 90 cm, and mixed. Three layers (0-25, 25-50 and 50-80 cm) were distinguished and analysed for NO_3^-, NH_4^+ and water content in triplicate.

Table 1. Experimental sites and previous management of the sward.

Site	Soil C g/kg	Previous experimental treatments	Grazing (G) or cutting (C)	N fertilisation kg $N.ha^{-1}.yr^{-1}$
Kerlavic MP1 (1989-1997)	37	T1 : perennial ryegrass	grazed 7-8 times per year	0
		T7 : perennial ryegrass		200
		T4 : perennial ryegrass		400
		T5 : perennial ryegrass + white clover		50
Kerbernez (1989-1997)		T1 : perennial ryegrass	grazed 5-6 times per year	250
		T2 : perennial ryegrass + white clover		0
Kerlavic MP2 (1993-99)	30	T1 : perennial ryegrass	grazed 7 times	250
		T2 : perennial ryegrass	1 cut + 5 graze	250
		T3 : perennial ryegrass	2 cuts + 2 graze	250
		T4 : perennial ryegrass + white clover	grazed 7 times	50
		T5 : perennial ryegrass + white clover	1 cut + 5 graze	50
La Jaillière MP1 (1989-97)	15	T1 : perennial ryegrass + white clover		0
		T2 : perennial ryegrass	grazed 4-5 times per year	100
		T3 : perennial ryegrass		300
		T4 : Perennial ryegrass		400

We then used these results as input data in LIXIM model (Mary *et al.*, 1999) in order to calculate the rates of N mineralization and leaching, assuming that these are the dominant processes affecting N in bare soil. LIXIM is a layered, functional model, with a daily time step. Input data also include climatic conditions and simple soil characteristics. The variations in N mineralization with temperature and moisture are accounted for, providing calculation of the 'normalized time'. An optimization routine is used to estimate the actual evaporation and the N mineralization rates that provide the best fit between observed and simulated values of water and nitrate contents in all measured soil layers.

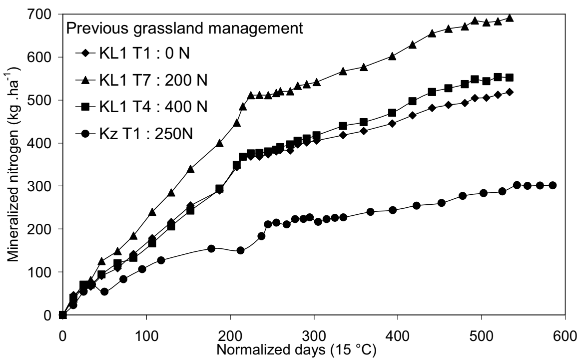
Results and discussion

LIXIM model was able to reproduce accurately the water content and the mineral N in soil during the two years experiments (Laurent *et al.*, 2004). The mean RMSE between observed and simulated values were 11, 6, 6 and 15 kg N ha^{-1} for Kerlavic MP1, Kerbernez, Kerlavic MP2 and La Jaillière MP1, respectively. They were comparable to standard errors on measurements. A satisfactory relationship (Vertès *et al.*, 2001) was established between N leaching simulated and measured, on 1 site with lysimeters, (Vertès *et al.*, 1994), on the other 3 sites with porous cups. This suggested that the model was to calculate well N mineralisation.
The N mineralization kinetics calculated showed remarkable consistency between the different sites studied.
The kinetics were composed of two successive phases: a rapid mineralization during phase 1 over a period of 160-230 'normalized' days; a slow mineralization in phase 2, the mineralization rate (*Vp2*) being 1.6, to 3.5 times smaller than in phase 1 (*Vp1*). Comparing the mineralization rates *Vp1* and *Vp2* with those calculated in other fields without grassland during the last 20 years suggested that phase 2 could correspond to a return close to the 'basal' mineralization of the soil organic matter. The variability of the ratio Vp1/Vp2 (from 1.8 in La Jaillère to 3.2 for KL MP1) should be linked to the different long term agronomical histories of the sites.

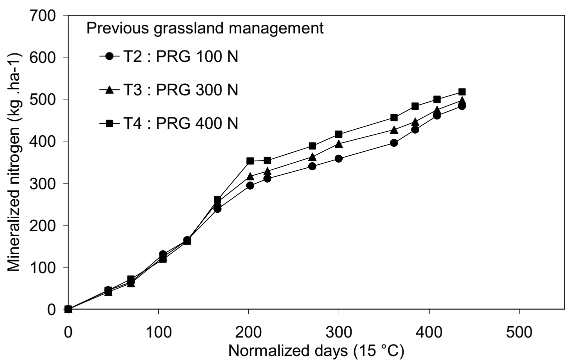
The effect of previous N fertilisation on N mineralization after grassland destruction was small compared to the amounts mineralised over two years. In Kerlavic MP1 experiment, net mineralization reached 520, 690 and 550 kg $N.ha^{-1}$ after pure ryegrass having received 0, 200 and 400 kg $N.ha^{-1}.yr^{-1}$, respectively, and 670 kg $N.ha^{-1}$ after the low fertilised grass-clover mixture (Figure 1a). Extreme N fertilisations (0 or 400 kg $N.ha^{-1}.yr^{-1}$) did not bring about significant differences in mineralization after destruction, and surprisingly N mineralisation was higher after the middle treatment (200 kg $N.ha^{-1}.yr^{-1}$). In La Jaillière experiment, the mineralization rates ranked in the same order than the fertilisation levels previously applied to grasslands: 445 kg $N.ha^{-1}$ in the unfertilised grass-clover mixture, 485, 495 and 515 kg $N.ha^{-1}$ after pure grass having received 100, 300 or 400 kg $N.ha^{-1}.yr^{-1}$, respectively (Figure 1b). The effect grassland destruction was calculated as follow: (Vp1-Vp2) * nb normalised days phase 1, to compare N mineralisation occurring in the 4 experiments after the same treatment, i.e. pure grass 5 to 7 years old, only grazed, receiving 200-250 kg $N.ha^{-1}.yr^{-1}$. Values ranged from 120 to 360 kg $N.ha^{-1}$, which corresponds to the variability observed in all grazed treatments. Explanation could be linked to long term history of the sites, as studied by Springob (2004), whose late-effect should exceed the effect of recent management practices.

The effect of mowing frequency was analyzed in Kerlavic MP2 (Figure 1c). Cumulative mineralization over 2 years following destruction of purely grazed pastures (7-8 times per year between 1995 to 1998) was 405 and 445 kg $N.ha^{-1}$ for pure grass (T1) and mixture (T4), respectively. The N mineralization following destruction of grazed and mowed pastures of ryegrass was smaller: 350 kg $N.ha^{-1}$ when pasture had been mowed once a year (T2) and 315 kg $N.ha^{-1}$ when mowed twice (T3). The same effect was observed in La Jaillère. On the other hand, this effect was not noticed after destruction of the mixed sward: the mineralization kinetics was identical when the grass-clover had been either grazed (T4) or mowed once a year (T5).

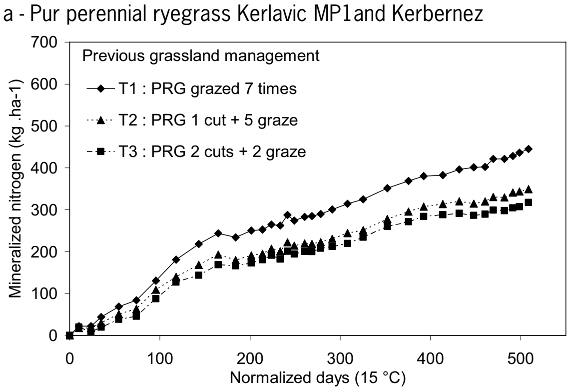
Mineralization rates following destruction of a grass-clover sward were greater (at Kerlavic) or nearly equal (at Kerbernez and La Jaillière) than after destruction of ryegrass (Figure 1d). In all case, lower residues biomass was measured (55-70% of pure grass residues values), the same for total N in plant residues (60 to 85% of pure grass values). On the other side, clover residues are richer in N (3% vs 1.5-2% for associated grass) and their degradability is higher (incubation results, not shown). Thus part of the high variability observed among several trials and reported in the literature (Hogh-Jensen *et al.*, 1997; Davies *et al.,* 2001).should be linked to differences in clover content in fresh and old organic matter (resulting of all the grassland life), that has scarcely been quantified.



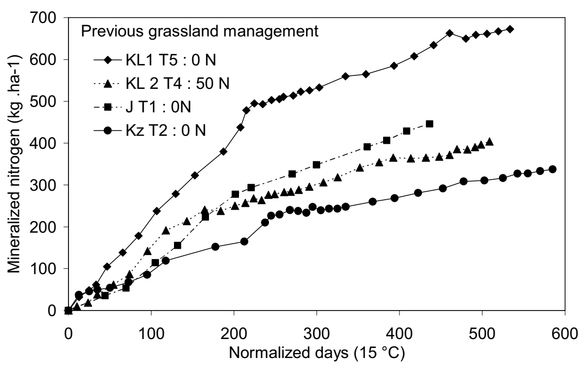
a - Pur perennial ryegrass Kerlavic MP1and Kerbernez



b - La Jaillière MP1



c - Kerlavic MP2



d - Perennial ryegrass + white clover

Figure 1. Nitrogen mineralization kinetics after grassland destruction (versus normalized time).

Symbols of the figures: PRG = perenial rye-grass, WC = white clover, C = cut, G = grazed

Discussion and Conclusion

The good agreement between model and experiments, and the consistency in the mineralization rates obtained, enables us to re-consider the effect of grassland destruction on N release kinetics. Net mineralization rate decreased by a 2-3 fold factor after a period of 160-230 'normalized' days. The N release due to grassland destruction is important during the next two years, and mainly during the first year. The first year effect is higher than what was admitted previously.

For the 5-7 years old grasslands studied, the previous grassland management has little effect on the N release: the little effect of previous fertilisation level and grass species was already mentioned by several authors, and mowing frequency is the main factor to account that reduces N release. Some indicators were tested to predict N mineralisation after destruction (Laurent *et al.,* 2004): amounts of residues, their C and N content or C:N ratio were not explicative variables, in particular because their C and N mineralisation rates were low as measured in controlled incubation (Vertès *et al.,* 2002, in Conijn *et al.*, 2002), accounting only for 15-20% of total C or N mineralisation. Soils characteristics, such as C and N content, C:N ratio and microbial biomass were not good predictors of total N mineralisation, neither N balance cumulated on the grassland life duration. As gazeous losses were not quantified, those results may be linked to uncertainties on total N mineralisation estimations, but as all soils are well drained, losses could be similar between sites.

To improve our understanding of processes and predict more accurately N and C mineralisation in grassland based rotations, it appears necessary to characterize better soil organic matters, which represents large amounts of particulate organic matters accumulated during grassland life, as quantified by Whitehead *et al.* (1990). This pool importance is also suggested while using STICS model (Brisson *et al.*, 1998), and work is in progress to predict more accurately C and N mineralisation after grassland destruction.

References

Brisson, N., Mary B., Ripoche D., Jeuffroy M.H., Ruget, F., Nicoullaud B., Gate P., Devienne-Barret F., Antonioletti R., Dürr C., Richard G., Beaudoin N., Recous S., Tayot X., Plenet D., Cellier P., Machet J.M, Meynard J.M. & Delécolle R., 1998.
STICS: a generic model for the simulation of crops and their water and nitrogen balances. I. Theory and parametrization applied to wheat and corn. Agronomie (18): 311-346.

Cameron, K.C. & Wild A., 1984.
Potential aquifer pollution from nitrate leaching following the plowing of temporary grassland. J Environ. Qual., 13: 274-278.

Conijn, J.G., Velthof G.L. & Taube F. (eds), 2002.
Grassland re-sowing and grass-arable crop rotations. International workshop on agriculture and environmental issues, Wageningen, 18-19 April 2002, PRI report n° 47, 128 p.

Conijn, J.G. & Taube F. (eds), 2002.
Grassland re-sowing and grass-arable crop rotations: Consequences for performance and environment. 2nd International workshop of EGF working group, Kiel (D), 27-28 February 2003, PRI report n° 80, 78 p.

Davies, M.G., Smith K.A. & Vinten A.J.A., 2001.
The mineralisation and fate of nitrogen following ploughing of grass and grass-clover swards. Biol. Fertil. Soils, 33: 423-434.

Mary, B., Beaudoin N., Justes E. & Machet J.M., 1999.
Calculation of nitrogen mineralization and leaching in fallow soil using a simple dynamic model. Eur. J. Soil Science, 50: 549-566.

Hogh-Jensen, H. & Schjoerring J.K., 1997.
Residual nitrogen effect of clover-ryegrass swards on yield and N uptake of a subsequent winter wheat crop as studied by use of ^{15}N methodology and mathematical modelling. Eur. J. Agronomy, 6: 235-243.

Laurent, F., Kerveillant P., Besnard A., Vertès F., Mary B. & Recous S., 2004.
Effet de la destruction de prairies pâturées sur la minéralisation de l'azote: approche au champ et propositions de quantification. Synthèse de 7 dispositifs expérimentaux. Rapport ARVALIS – INRA, 76 p.

Springob, G., 2004.
C and N losses in sandy soils of NW Germany after conversion of grasslands. In: 'Land Use systems in grassland dominated region's, XX EGF Congress Lucern 21-24 juin 2004, Grassland Science in Europe, 9, 529-531.

Vertès, F., Hatch D., Velthof G.L., Abiven S., Hopkins A. & Springob G., 2004.
Effects of grassland renovation on N and C cycles and soil quality dynamics. In: 'Land Use systems in grassland dominated region's, XX EGF Congress Lucern 21-24 juin 2004, Grassland Science in Europe, 9, 526-528.

Vertès, F., Laurent F., Recous S., Leterme P. & Mary B., 2001.
Nitrogen mineralization under bare soils after the destruction of grazed pastures. In: Sustainable management of soil organic matter; Edited by Rees R.M., Ball B.C., Campbell C.D. and Watson C.A.: P.240-246.

Vertès, F., Simon J.C. & Le Corre L., 1994.
Nitrate leaching under pastures: study of the soil-plant system in a lysimeter experiment. Grassland and society, 15th General Meeting of the European Grassland Federation, Wageningen, 466-470

Whitehead, D.C., Bristow A.W. & Lockyer D.R., 1990.
Organic matter and nitrogen in the unharvested fractions of grass swards in relation to the potential for nitrate leaching after ploughing. Plant and soil, 123: 39-49.

6. Nitrate leaching losses under a forage crop rotation

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Abstract

In the presented study a three-year crop rotation was established, including a grass/clover mixture (two cuts in spring and two succeeding grazings), silage maize and triticale for one year each. It is hypothesised that the short grassland period would prevent excessive nitrogen accumulation in the soil and that the succeeding crops would take up most of the remaining surplus N, resulting in reduced nitrate (NO_3) leaching losses. Three levels of mineral fertiliser (0, 75, 150 kg N ha^{-1}, average over the three crops) and two levels of slurry (0, 25 m^3 ha^{-1}) were applied. Nitrate leaching losses were measured in all crops by suction cups over three years and N balances on a field scale were calculated. The results show that in the crop rotation N-losses from grazed grassland are lower than the losses from the maize and triticale crop. In all crops nitrate losses increased with increasing N surpluses. N-leaching losses under maize are highest while the surpluses are negative, indicating that the maize took up large amounts of the remaining N from the ley, but N mineralised later was highly prone to NO_3-leaching.

Keywords: crop rotation, nitrate leaching, groundwater, grassland

Introduction

In northern Germany intensive dairy farming is mainly located in the Geest region, which has freely draining sandy soils for which the nitrogen recovery is known to be low. This causes serious environmental problems due to increased losses of NO_3 to the groundwater (Wachendorf and Taube, 2002). On the permanent grassland, high N returns from grazing animals result in leaching losses far-exceeding the EU limit for nitrate in drinking water (Büchter, 2003). Silage maize is known to have high N use efficiency (Volkers *et al.*, 2002) and with fertiliser rates based on the demand of the plant, leaching losses are relatively low (Büchter, 2003). The intention of the project was to determine whether the inclusion of grassland as a short term ley in a rotation before a maize crop and following a cereal crop may reduce NO_3 leaching losses through an efficient uptake of possible surpluses from the ley period by the maize crop. Possible negative effects of maize grown in monoculture such as soil erosion or humus degradation, might be reduced as a side effect. To evaluate the potential of this strategy a forage crop rotation as a field experiment was established in 1999 at the same site as a previous permanent grassland (Trott *et al.*, 2002) and maize trial (Volkers *et al.*, 2002). The crop rotation included a grass/clover mixture (two cuts in spring and two succeeding grazings), silage maize and triticale for one year each (Wachendorf *et al.*, 2003). The aim of the this study was to show whether the nitrate leaching losses were reduced within this experimental design and whether N balances on a field scale provided information about the nitrate concentration in the leachate.

Materials and methods

The field trial was conducted at the experimental farm ´Karkendamm` of the Institute of Crop Science und Plant Breeding of the University of Kiel in northern Germany. The whole project deals with quantitative measurements of nitrogen flows in a ´soil-plant-animal` system (Taube and Wachendorf, 2000). The mean annual precipitation is 824 mm and the mean annual temperature 8.4 °C. The soil type is a Treposol (deep ploughed gleyic podzol) and the texture is sand with less than 5% clay and a pH of 5.6. The clover/grass ley was managed as a mixed system with two cuts and two succeeding grazing periods. The last cut remained on the field and was incorporated in spring prior to maize sowing. Silage maize was used as a whole crop silage and triticale as whole crop silage and grain, respectively. The experiment consisted of three nitrogen intensity levels as shown in Table 1.

Table 1. N supply by mineral fertiliser and slurry at various intensity levels in the crop rotation trial.

	High Intensity (kg N ha^{-1})			Reduced Intensity (kg N ha^{-1})			Low Intensity (kg N ha^{-1})		
Crop	Fert.†	Slurry#	Total	Fert.	Slurry	Total	Fert.	Slurry	Total
Clover/grass (CG)	150	75	225	100	75	175	0	75	75
Silage maize (SM)	100	75	175	25	75	100	0	75	75
Triticale (TR)	200	75	275	100	75	175	0	75	75
Mean	150	75	225	75	75	150	0	75	75

†: Mineral N fertilizer
#: 3.1 kg total N m^{-3} slurry

In order to achieve an increased variation of N intensity in the trial, all intensity levels were used with and without slurry. All crops were grown for one year. In the experiment, every crop was grown in each of the three years. N balances on a field level only considered external N sources and were calculated as follows:

N input	N output
Mineral fertiliser N	N yield in harvestable biomass
+ slurry N	- residual biomass N (grazed swards)
+ N biologically fixed by clover	- excrement N (grazed swards)
+ deposition N	

N surplus = N input – N output

Nitrate leaching losses were measured by means of ceramic cup samplers located at 60 cm soil depth and collected weekly during the winter months. A central pumping station maintained the suction. In each plot four suction cups were installed. With each treatment replicated four times, mean concentrations were obtained from 16 ceramic suction cups. The leaching data are weighed means over 3 leaching periods. Ceramic cup were installed in each autumn and removed in spring at the end of the leaching period.

Results and discussion

There are strong positive correlations between N surpluses and nitrate concentration in the leachate for each crop and for the mean crop rotation (Figure 1). Nitrate concentrations in the leachate after maize and triticale exceed the critical EU limit for drinking water (50 mg l^{-1}), whereas concentrations after grassland are below the critical value. N-leaching losses are highest after maize, while the corresponding surpluses were even negative. This emphasises the fact that maize took up N that was being released after ploughing the grass/ clover sward in spring. Therefore the high leaching losses after maize may have resulted from increased mineralisation after incorporation of the stubble and a low N uptake in autumn by the following triticale (on average 10-15 kg N ha^{-1}). High losses after triticale probably resulted from the cultivation during establishment of the grass sward in autumn causing increased mineralisation.

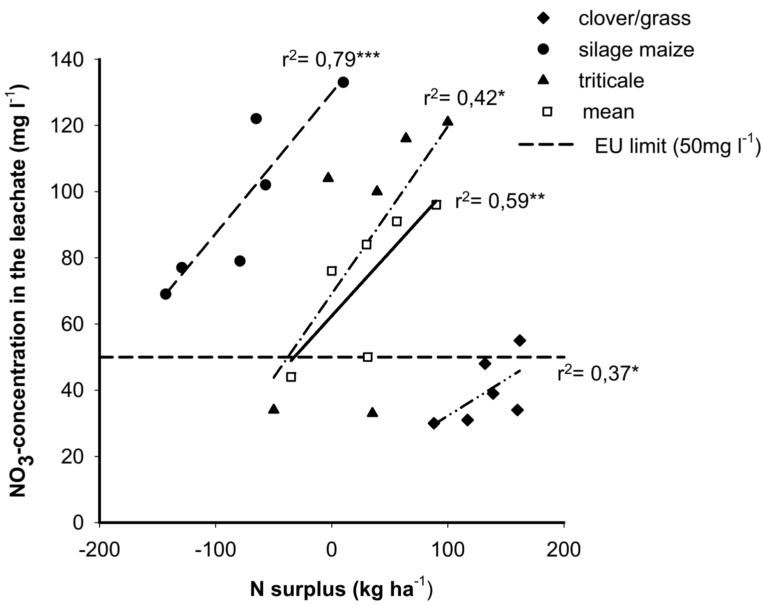

Figure 1. Correlations between N surplus (kg ha^{-1}) and NO_3 concentration (mg l^{-1}) in the leachate after a clover/grass ley, silage maize and triticale in a crop rotation.

Conclusions

The results show that a short-term grassland ley in a crop rotation prevents excessive NO_3 leaching and that the succeeding crops (mainly silage maize) take up parts of the remaining surplus N. NO_3 concentrations above the EU limit for drinking water could be found after maize and triticale. Evaluation of N surplus on a field scale allows the prediction of nitrate concentrations in leachate with satisfactory accuracy.

References

Büchter, M., Wachendorf M. & Taube F., 2002.
Nitrate leaching from permanent grassland on sandy soils – Results from an integrated research project. *Grassland Science in Europe* 7, 668-669.

Büchter, M., Wachendorf M., Volkers K. & Taube F., 2003.
Silage maize production on sandy soils in northern Germany: Impact of under storey, slurry and mineral N fertiliser on nitrate leaching *(In German). Pflanzenbauwissenschaften* (In press).

Taube, F. & Wachendorf M., 2000.
The Karkendamm Project: A system approach to optimise nitrogen use efficiency on the dairy farm. *Grassland Science in Europe* 5, 449-451.

Trott, H., Wachendorf M. & Taube F., 2002.
Management of permanent grassland for reduced nitrogen surpluses - Results from an integrated research project. *Grassland Science in Europe* 7, 740-741.

Volkers, K., Wachendorf M. & Taube F., 2002.
Management of forage maize for reduced nitrogen surpluses - Results from an integrated research project. *Grassland Science in Europe* 7, 744-745.

Wachendorf, M. & Taube F., 2002.
Management impacts on nitrogen fluxes and nitrogen losses in grassland systems - Results from an integrated project. *Grassland Science in Europe* 7, 746-747.

Wachendorf, M., Volkers K. & Taube F., 2004.
Forage production in a crop rotation: impact of N intensity on performance and N surplus. *This volume*.

7. Performance of potatoes established in ploughed down grassland of different ages

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Abstract

Ploughing down grassland releases nitrogen available for the following crops and/or is prone to leaching. At the experimental site of Ghent University, we installed in 2002 potatoes following three different crops: (1) 3-year old grassland (TG), (2) 35-year old grassland (PG), and (3) maize grown on permanent arable land (PA). Nitrogen levels applied to the potatoes were 0, 75 and 200 kg N ha^{-1}. The ranking of dry matter yields for potatoes fertilised with 200 kg N ha^{-1} was TG = PA > PG; the yield ranking for potatoes fertilised with 75 kg N ha^{-1} was PA < PG < TG. The nitrogen fertiliser replacement value (NFRV) for the potatoes in PG was half of the NFRV in TG. The residual NO_3-N in the soil profile was always highest after PG and lowest after PA.

Keywords: grassland, rotation, nitrogen mineralisation

Introduction

From previous research we know that 3-year old ploughed grassland releases high amounts of nitrogen (Nevens and Reheul, 2002). We demonstrated that, after ploughing down 3-year old grassland, both silage maize and fodder beet produced high yields without any supplied nitrogen. We wanted to know if the potato crop can be recommended as a first crop following ploughing down of grassland. In the research presented here, we monitored (1) the yield and quality of the potato crop, (2) the nitrogen mineralisation pattern during the growing season, (3) the final nitrogen uptake by the potato crop, and (4) the residual nitrogen in the soil profile during the autumn.

Materials and methods

The experiments were established on a sandy loam soil at the experimental farm of Ghent University in Melle (Belgium, 11 m above sea level). In spring 2002, we planted potatoes after forage maize grown in permanent arable land (PA) and in ploughed down grassland (spring ploughing). Part of the grassland was permanent grassland (PG) and part of it was in a rotation of 3 years arable land – 3 years grassland (TG). Permanent means 35 years. A part of the prepared seed bed was left uncultivated (fallow, bare soil) to study the N-mineralisation of the soil organic matter. The trial was a split plot design with four replicates. The different preceding crops (PA, PG, TG) was the main factor; the N-fertilisation prior to planting (0, 75 or 200 kg N ha^{-1}) was the sub-plot factor. To avoid deficiency, P and K were applied at 80 kg P_2O_5 ha^{-1} and 250 kg K_2O ha^{-1}. Tuber dry matter (DM) yield and total N uptake by the tubers were determined at the end of the growing season. We calculated the nitrogen replacement values (NFRV) of the ploughed grassland, on the basis of quadratic response curves. At the end of the growing season the mineral N content of the soil profile (0 – 90 cm) was determined.
The plant available nitrogen from mineralisation was calculated as available nitrogen under fallow plots minus N under 0 N plots (both measured on a monthly basis; May-September 2002).

$$Y = \mathrm{Sum}[(N_{fallow,t} - N_{0,t}) - (N_{fallow,\,t\text{-}1} - N_{0,t\text{-}1})]$$

Where:
Y is plant available nitrogen from mineralisation over the period May till September 2002;
$N_{fallow,t}$ and $N_{fallow,t\text{-}1}$ is mineral N (nitrate + ammonium) content in the soil profile (0 – 90 cm) under fallow plots in month t and t-1 respectively;

$N_{0,t}$ and $N_{0,t\text{-}1}$ is mineral N (nitrate + ammonium) content in the soil profile (0 – 90 cm) under 0 N plots in month t and t-1 respectively.

The N supply was then calculated as the sum of the plant available nitrogen from mineralisation and mineral N application.

Results and discussion

1. Dry matter yield, yield responses to mineral N fertilisation and N uptake during 2002 (Table 1)

On average, the DM yield ranking was TG > PG > PA.

At 200 kg N ha^{-1} PA out-yielded significantly PG which was not significantly different from TG. At 75 kg N ha^{-1} and 0 kg N ha^{-1}, TG gave the highest yields: TG out-yielded PG and PA with 5 and 18% respectively at 75 kg N ha^{-1} and with 15 and 90% at 0 kg N ha^{-1}.

Potatoes grown after preceding grassland took no advantage of N fertiliser application since yields did not differ significantly at 0, 75 and 200 kg N ha^{-1}.

Using a quadratic N response curve, we calculated the NFRV values of the ploughed swards to be 172 kg ha^{-1} for TG and 85 kg ha^{-1} for PG.

Table 1. Potato tuber yield (kg DM ha^{-1} y^{-1}) on the permanent arable plots (PA), on the plots after temporary grassland (TG) and after permanent grassland (PG) in 2002.

Preceding crop	Mineral N fertilisation (kg N ha^{-1} y^{-1})				
	0 N	75 N	200 N	Average	*Relative*
PA	6 855	10 982	13 084	10 317	*100*
TG	13 011	12 940	12 975	12 975	*126*
PG	11 274	12 366	11 279	11 640	*113*
Average	10 390	12 096	12 446	11 644	
Relative	*100*	*116*	*120*		

lsd (P = 0.05) within same preceding crop = 1 110 kg ha^{-1};
lsd (P = 0.05) within same mineral N fertilisation = 1 705 kg ha^{-1} (SAS Statistical Package).

Table 2. Nitrogen uptake (kg ha^{-1} y^{-1}) by potato tubers on permanent arable plots (PA), on plots after temporary grassland (TG) and after permanent grassland (PG) in 2002.

Preceding crop	Mineral N fertilisation (kg N ha^{-1} y^{-1})				
	0 N	75 N	200 N	Average	*Relative*
PA	51	111	199	120	*100*
TG	147	183	258	196	*163*
PG	157	205	230	198	*165*
Average	118	166	229	171	
Relative	*100*	*141*	*194*		

lsd (P = 0.05) within same preceding crop = 22.2 kg ha^{-1};
lsd (P = 0.05) within same mineral N fertilisation = 29.6 kg ha^{-1} (SAS Statistical Package).

Compared to PA, the average nitrogen uptake by the potato tubers was higher in TG and in PG: 63% and 65% respectively. The comparison with the N unfertilised plots shows that at a fertilisation rate of 75 kg N ha^{-1} on average 64% of the applied nitrogen is recovered in the tubers; at a fertilisation rate of 200 kg N ha^{-1} on average 55% is recovered (Table 2). Figure 1 shows the relationship between the N-supply (0-90 cm) and the N-uptake by the tubers. The slope of the relationship N-uptake/N-supply (Figure 1) illustrates that only half of the N-supply (mineralisation + external dressing) had been taken up by the potato tubers.

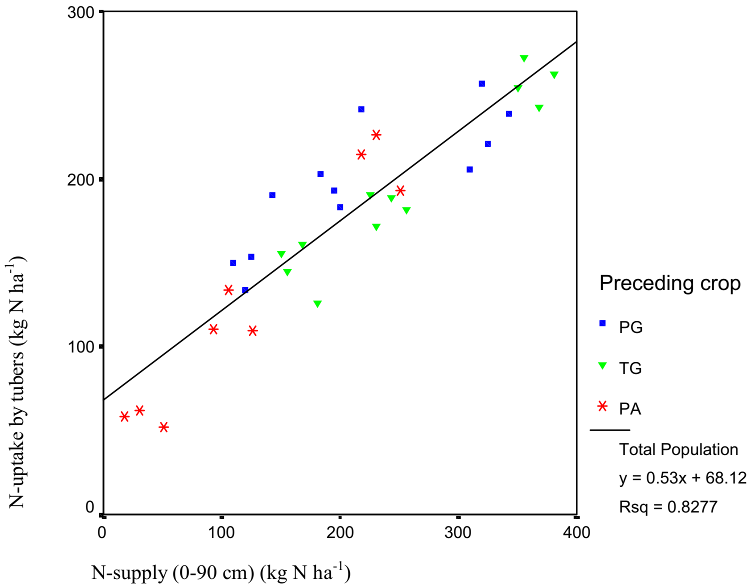

Figure 1. *N-uptake by potato tubers (kg ha^{-1}) as a function of the N supply (kg ha^{-1}) in 2002.*

2. Amounts of residual soil nitrate-N

In October 2002 (one month after the growth stopped), residual soil nitrate-N was very low in PA (Table 3), but we found very high figures in TG and PG fertilised with 200 kg N ha^{-1}. In all cases, more than 50% was located in the upper zone of the soil profile (0-30 cm) (data not shown).

Table 3. *Residual nitrate-N (kg ha^{-1} y^{-1}) in the soil profile (0-90 cm) on the permanent arable plots (PA), the plots after temporary grassland (TG), and after permanent grassland (PG) in October 2002.*

Preceding crop	Mineral N fertilisation (kg N ha^{-1} y^{-1})			
	0 N	75 N	200 N	Average
PA	16	25	24	22
TG	49	62	102	71
PG	77	90	153	107
Average	47	59	93	66

lsd (P = 0.05) within same preceding crop = 28.7 kg ha^{-1};
lsd (P = 0.05) within same mineral N fertilisation = 20.9 kg ha^{-1} (SAS Statistical Package).

Conclusion

The less nitrogen is applied, the higher the positive yield effect of TG and PG. Both at 0 and 75 kg N ha^{-1}, TG out-yielded PG and PA. At 200 kg N ha^{-1} PA gave the highest yield.

N-supply corresponded well with the nitrogen uptake by the tubers. Owing to the high residual nitrogen concentrations in the soil profile, our preliminary results recommend potatoes should not be grown after PG.

References

Nevens, F. & D. Reheul, 2002.
The nitrogen- and non-nitrogen-contribution effect of ploughed grass leys on the following arable forage crops: determination and optimum use. *European Journal of Agronomy*, 16, 57-74.

8. Establishing a grass-clover sward in arable land and ploughed down grassland

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Abstract

The performance of grass-clover established (spring 2002) under four nitrogen levels and in four fields with different preceding crops was studied in Melle during the growing seasons 2002 and 2003. Nitrogen supply levels were 0, 100, 300 and 400 kg N ha^{-1} y^{-1}. Background treatments were: (1) 35 year old grassland, (2) 3 year old grassland, rotating with 3 year old arable land, (3) 35 year old arable land, and (4) 3 year old arable land rotating with 3 year old grassland. Additionally, the performance of the newly established grass-clover was compared to the 35 year old permanent grassland. Dry matter yield (DMY) in the year of establishment (2002) was lower for the four background treatments as compared to the 35 year old permanent grassland due to the spring sowing. The lowest yield under all nitrogen levels was found when grass-clover was introduced into 3 year old grassland. During the year of establishment the highest clover content was found under low N-input (=< 100 kg N ha^{-1} y^{-1}) when the sward was established in arable land. Establishing grass-clover in a ploughed down grassland keeps the clover content low. The conflict between clover performance and N-mineralisation explains the differences during the establishment year.

Keywords: resowing grassland, grass-clover, nitrogen mineralisation

Introduction

Research into grassland science in North-western Europe has moved away from maximizing the forage yield (based on a very high nitrogen input) towards a more sustainable use of nitrogen. An appropriate proportion of white clover in the sward is a prerequisite in order to benefit from the advantages of the clover. A good establishment of white clover after sowing is the first step to success. In order to guarantee the persistence of the mixture, Loiseau *et al.* (2001) recommend that the N-supplying capacity of the soil should be taken into account prior to sowing a new pasture.

We have established a mixture of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) into four fields with a different preceding crop, ranging from permanent arable land (35 years old) to permanent grassland. We studied the evolution of white clover in these different backgrounds during the first 2 seasons after establishment. In this contribution we will discuss the results of the year of establishment. During the Meeting of the European Grassland Federation, the results of the first full year after establishment will also be presented.

Materials and methods

The experiments were conducted on a sandy loam soil in Melle (11 m asl) at the experimental farm of Ghent University (Belgium). During spring 2002 we sowed a mixture of 40 kg perennial ryegrass (cvs. ‘Plenty’ + ‘Roy’) and 4 kg white clover (cv. ‘Huia’) in ploughed arable land and in ploughed down grassland. Part of the arable land had been arable land for 35 years (PA), part of it was arable land in a 35-year rotation of 3 year grassland – 3 year arable land (TA). Part of the ploughed grassland was permanent grassland (PG) (for 35 year) and part of it was grassland in a 35-year rotation 3 year arable land – 3 year grassland (TG). The performance of the newly established grass-clover was compared to the permanent grassland (PGG). A part of the prepared seed bed was left uncultivated (fallow) to study the N-mineralisation of soil organic matter. The trial design was a split plot; the preceding crop being the main factor. Swards were fertilised with 0, 100, 300 and 400 N. P and K were supplied at an appropriate amount to avoid shortages. Plots were mown 5 or 6 times in 2002. DMY as well as the clover content were

determined each time. At the end of the growing season the mineral N content of the soil profile (0–90 cm) was determined.
The plant available nitrogen from mineralization was calculated as available nitrogen under fallow plots minus N amount under 0 N plots (both measured on a monthly basis).

Results and discussion

A. Dry matter (DM) yield and clover content of mixed swards of perennial ryegrass and white clover.
None of the resown swards outyielded the permanent grassland (PGG), due to the spring sowing (Table 1a). Swards established in TG were the least productive when averaged over all mineral N applications. The clover establishment and its persistence were dependent on the mineral N application rate and on the preceding crop of the newly sown plots. Under low N fertilisation (0 N, 100 N), the clover content differed significantly with the preceding crop. We found the highest clover content when the sward was established in arable plots (Table 1b).

Table 1a. DM yield (kg ha^{-1} y^{-1}) in 2002 in swards of Lolium perenne L. and Trifolium repens L. under four different N-fertilisation rates and five different preceding crops.

Preceding crop	DM (kg ha^{-1} y^{-1})				
	mineral N fertilisation (kg N ha^{-1})				
	0	100	300	400	*Average*
TA	8175^{b}	8903^{ab}	11503^{a}	12901^{ab}	*10371*
PA	7983^{b}	10203^{bc}	11718^{a}	13325^{b}	*10807*
TG	6133^{a}	8213^{a}	11253^{a}	12118^{a}	*9429*
PG	9193^{b}	9523^{ab}	11595^{a}	12000^{a}	*10578*
PGG	8529^{b}	11280^{c}	15154^{b}	15389^{c}	*12588*
Average	*8003*	*9624*	*12245*	*13147*	*10755*

[a] *Values within the same column with different letters are significantly different at alfa = 0.05 (Duncan's T-Test)*

Table 1b. Clover content (g kg^{-1} DM) in 2002 in swards of Lolium perenne L. and Trifolium repens L. under four different N-fertilisation rates and five different preceding crops.

Preceding crop	Clover content (g kg^{-1} DM)				
	mineral N fertilisation (kg N ha^{-1})				
	0	100	300	400	*Average*
TA	770^{c}	410^{d}	70^{ab}	40^{a}	*323*
PA	780^{c}	600^{e}	140^{b}	110^{b}	*408*
TG	210^{a}	20^{a}	0^{a}	10^{a}	*60*
PG	410^{b}	150^{c}	40^{a}	40^{a}	*160*
PGG	140^{a}	70^{bc}	60^{a}	30^{a}	*75*
Average	*462*	*250*	*62*	*46*	*205*

[a] *Values within the same column with different letters are significantly different at alfa = 0.05 (Duncans's T-Test)*

The clover content in the sward of 0 N plots was related to the plant available N amount in the soil during the growing season (Figure 1). Arable backgrounds are characterized by a significant lower plant available N content. Averages in the period July – October 2002 were: TA 10 kg N; PA 17 kg N; PG 129 kg N and TG 142 kg N ha^{-1}.

B. Amounts of residual soil nitrate N following the grassland cultivation.
The residual soil N never exceeded the limit of 90 kg ha^{-1} (data not shown), a legally defined threshold in Flanders. The low nitrate residue found in the swards established after TG was surprising. Nevens and Reheul (2001) found a high release of mineralised nitrogen in the growing season following the ploughing-down of a 3-year old grass sward. Probably, a large part of this N was taken up by roots of the new grass sod and fixed to soil particles (Velthof and Hoving, 2003). The residual soil N at the end of 2002 under high N fertilisation (400 N) was lower in swards with a preceding arable crop than in swards with preceding grassland. About 50 to 98% of the total residual N was present in the upper soil profile (0–30 cm).

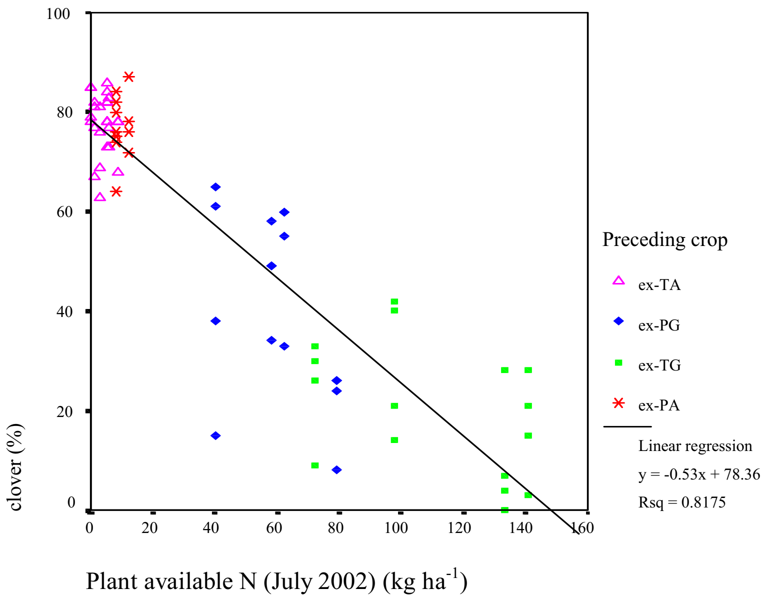

Figure 1. Clover content (% in total DM) during year of establishment of 0 N plots as a function of the plant available N in July 2002.

Conclusion

The yield performance of permanent grassland was higher than the yield performance of the newly installed swards during spring 2002. The establishment and the persistence of white clover were related to the mineralised soil nitrogen. We found the highest clover content when a sward was installed in arable land.

References

Loiseau, P., J.F. Soussana, F. Louault & R. Delpy, 2001.
Soil N contributes to the oscillations of the white clover content in mixed swards of perennial ryegrass under conditions that simulate grazing over five years, *Grass and Forage Science*, 56, 205-217.

Nevens, F. & D. Reheul, 2001.
Crop rotation versus monoculture: yield, N yield and ear fraction of silage maize at different levels of mineral N fertilization. *Netherlands Journal of Agricultural Science*, 49, 405-425.

Velthof, G. & I. Hoving, 2003.
Proeven naar graslandvernieuwing; resultaten van het eerste jaar ('Grassland resowing; first year results'), Information Sheet 398.36, 2 pp.

9. Nfate: a N flux model for grassland resowing and grass-arable rotations

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Abstract

The model *Nfate* (*N*itrogen *f*luxes in *a*gricultural soils and *t*o the *e*nvironment)) has been developed to offer a synthesis of all relevant nitrogen processes at field level related to grassland resowing and grass-arable rotations and to calculate the effects of management on both the agronomic (e.g. crop N yield) and the environmental (e.g. nitrate leaching) aspects. The current version of the model calculates the dynamics of soil organic and inorganic nitrogen, and crop nitrogen for a number of years as a function of management decisions such as time of ploughing, ploughing depth, crop species and amount and type of applied fertiliser. The results of some calculations concerning grass and maize cropping on sandy soils in the Netherlands are presented here to illustrate the model. According to these results, total N input via fertilization on cut grassland may amount to 350 - 400 kg N ha^{-1} y^{-1} without causing excessive N leaching. Calculations also indicate that first year maize on ploughed grassland needs additional measures to limit N leaching to acceptable levels, even if nil fertilization has been applied.

Keywords: model, nitrogen, grassland renovation, maize, mineralization, leaching

Introduction

Farmers regularly renovate their grasslands throughout a large part of Europe (Conijn *et al.*, 2002). In most situations grassland is ploughed before resowing with grass or another crop species. This has a large influence on all processes related to the nitrogen balance of the soil-crop system. Motive for grassland renovation is to produce sufficient high-quality animal feed, but the society is concerned about the risk of increased nutrient losses and pollution of the environment (e.g. ground- and surface water). It is necessary to develop management rules for grassland resowing and grass-arable rotations, which are acceptable for both farmers and society. A quantitative model that calculates all relevant nitrogen fluxes in the soil-crop system and links management decisions to nitrogen losses, has therefore been developed, in addition to experimental work. A short description of this model is given here, including preliminary results of some calculations.

Model description

Nfate calculates N yield, N losses and changes in the amount of N in the soil-crop system as a function of N inputs, soil characteristics and crop species. The in/outputs of the model refer to the field-level and a whole year. Three N pools have been distinguished in the model: soil organic N, soil inorganic N and plant N. For each pool the inputs and outputs of N are determined and integrated over time and their dynamic behaviour can be studied (Figure 1).
The dynamics of the soil organic N pool are described by three fluxes: (1) net input of organic N via organic fertiliser application, (2) net input of organic N by plant residues and (3) output of nitrogen via net mineralization from the soil organic N pool. In the model (3) is calculated as a fraction of the amount of soil organic N. This fraction has been derived from the N yield of unfertilised fields (Schröder and Van Keulen, 1997). The net inputs of organic N via organic fertilisers and plant residues refer to the amount of N which is still organically bound after one year. The fraction that mineralises within the first year has been modelled as a function of the N concentration of the organic material.
The dynamics of the amount of plant N also depend on three fluxes: (4) total plant uptake, (5) net N yield, i.e. the removal of N from the field and (6) the formation of plant residues which are left on the field. Net N yield is modelled

as a function of the N yield of unfertilised fields, the applied amount of effective N and the apparent N recovery (Ten Berge *et al.*, 2001). Total plant uptake is calculated by multiplying (5) with a factor to account for the amount of N in non-harvested plant parts (6). In case of ploughing, (6) also includes the amount of N in the ploughed grass sward and after resowing, (4) also includes the extra N uptake that is needed to build up the new grass sward.
The dynamics of the soil inorganic N pool are determined by integrating seven fluxes over time. Two of them have already been mentioned, i.e. (3) and (4). The other five fluxes are: (7) net input of inorganic N by plant residues, (8) by organic fertiliser application, (9) by mineral fertiliser application, (10) by atmospheric deposition and (11) the output of inorganic N due to losses. The net input of inorganic N via plant residues (7) equals (6) minus (2) and the net input of inorganic N via organic fertilization (8) equals the total N input via organic fertilization minus (1). The size of the inorganic N pool is assumed constant between successive years, which means that total N loss (11) can be found by balancing the sum of the other relevant fluxes ((3), (4) and (7) up to (10)). After subtracting NH_3 volatilization (11a), the remainder of the N loss is distributed among denitrification (11b) and leaching (11c) by using a ratio that depends on soil type and crop management.
In cases where grassland is ploughed and resown with grass or an arable crop, several processes are influenced. This applies mainly to (3), because soil cultivation may enhance organic matter decay, to (5) due to loss of grass yield in the year of ploughing, but also due to expected higher yields of grass and arable crops after soil cultivation and to (6), where the amount of N in the old grass sward is added to the soil N pools. The outcome of the calculations also depends on the time of the year at which grassland ploughing takes place.

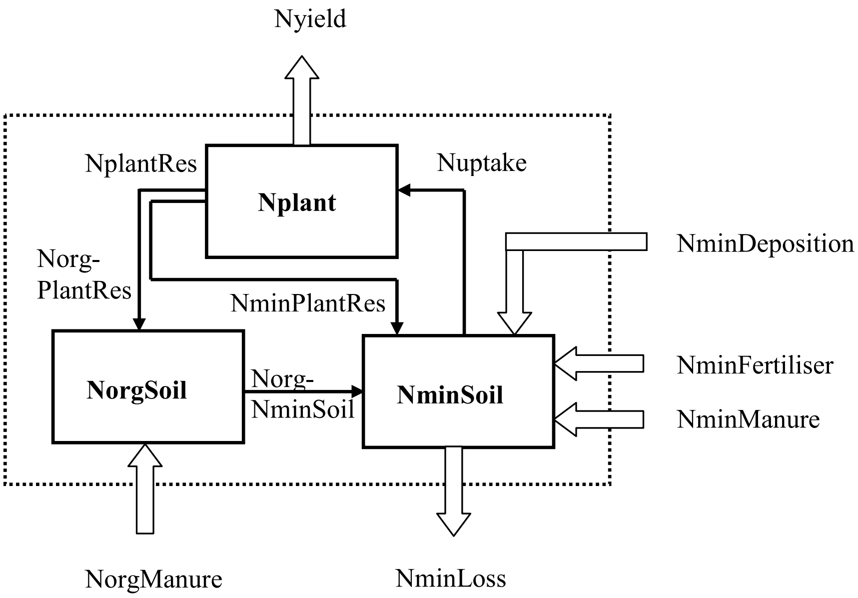

Figure 1. N fluxes and N pools in the soil-crop system of Nfate.

Results and discussion

The model is used to calculate the N fluxes in the crop-soil system of three typical cropping situations for one year (Table 1). The results apply to a sandy soil in the Netherlands with 3,000 - 4,200 kg organic N ha^{-1} in the upper 0.2 m (cf. Aarts *et al.*, 2001; Schröder *et al.*, 1996). Grass N yield equals 338 kg N ha^{-1} y^{-1} with a N fertilization of 200 kg N ha^{-1} y^{-1} (mineral fertiliser) and 184 kg N ha^{-1} y^{-1} (slurry). Total losses amount to 127 kg N ha^{-1} y^{-1} of which 33 kg N ha^{-1} y^{-1} is lost by leaching. The amount of N in the soil organic pool decreases in this example. Table 1 also shows a situation of continuous maize cropping without a cover crop, where only slurry has been applied via injection (171 kg N ha^{-1} y^{-1}). Maize N yield is 145 kg N ha^{-1} y^{-1} and total N losses equal 112 kg N ha^{-1} y^{-1} of which 69 kg N ha^{-1} y^{-1} is lost by leaching. Also in this situation the amount of soil organic N decreases. In both cases the organic N inputs do not completely compensate for the calculated mineralization (3). An equilibrium could be obtained by using more slurry; the results however correspond with the current trend in the Netherlands of decreasing animal manure application. As a consequence, the amount of organic N in the soil will decrease over time and both N yield and N loss are likely to be lower in the future, if N input is constant. This means that N leaching may decrease, while N field surplus (N input - N yield) increases. A relation between N surplus and N leaching is therefore difficult to interpret with respect to its predictive value without additional information on the possible changes in the soil organic N pool.

The third example refers to a situation where grassland is ploughed and maize is grown afterwards. For these calculations, it has been assumed that ploughing occurs at the beginning of April and that the net mineralization from the soil organic N pool is stimulated with + 25% in the first year. The results show that maize can benefit very much from the N released by the former grass sward, but also that the N losses are comparable to those calculated in the continuous maize cropping example, despite the fact that no fertilisers have been used. Both cropping strategies need additional measures to limit the N losses, e.g. a cover crop to extend the period of N uptake from the soil.

Table 1. The calculated N fluxes of the crop-soil system in three different situations of crop species and field history. The numbers in the first column are explained in the text.

N fluxes (kg N $ha^{-1}y^{-1}$)	Grass (permanent, cut only)	Maize (continuous cropping)	Maize after grass (1^{st} year)
NorgManure (1)	56	52	0
NorgPlantRes (2)	84	29	92
NorgMinSoil (3)	181	120	164
Change in NorgSoil	*-41*	*-39*	*-71*
Nuptake (4)	548	199	200
Nyield (5)	338	145	146
NplantRes (6)	210	53	229[a]
Change in Nplant	*0*	*0*	*-175*
NminPlantRes (7)	126	32	136
NminManure (8)	128	119	0
NminFertiliser (9)	200	0	0
NminDeposition (10)	40	40	40
NminVolatilised (11a)	18	9	0
NminDenitrified (11b)	77	34	47
NminLeached (11c)	33	69	93
Change in NminSoil	*0*	*0*	*0*

[a] *Including the N content of the ploughed grass sward*

Significant uncertainties still exist in the values of some input parameters of the model. Notably, the extra mineralization due to soil cultivation, the leaching fraction in various situations, the uptake of N in non-harvestable parts and the development of net crop N yields in the years after soil cultivation are difficult to assess. Further research is needed to overcome these knowledge gaps. Validation of the model outcome with experimental data will also be part of future research.

References

Aarts, H.F.M., J.G. Conijn & W.J. Corré, 2001.
Nitrogen fluxes in the plant component of the 'De Marke' farming system, related to groundwater nitrate content. *Netherlands Journal of Agricultural Science* 49, 153-162.

Conijn, J.G., G.L. Velthof & F. Taube (eds), 2002.
Grassland resowing and grass-arable crop rotations. *International workshop on agricultural and environmental issues*, Wageningen, The Netherlands, 18-19 April, 2002. Plant Research International B.V., Wageningen, 128 pp.

Schröder, J.J. & H. van Keulen, 1997.
Modelling the residual N effect of slurry applied to maize land on dairy farms in the Netherlands. *Netherlands Journal of Agricultural Science* 45, 477-494.

Schröder, J.J., W. van Dijk & W.J.M. de Groot, 1996.
Effects of cover crops on the nitrogen fluxes in a silage maize production system. *Netherlands Journal of Agricultural Science* 44, 293-315.

Ten Berge, H.F.M., J.C.M. Withagen, F.J. de Ruijter, M.J.W. Jansen & H.G. van der Meer, 2000.
Nitrogen responses in grass and selected field crops. Report 24, Plant Research International B.V., Wageningen, 68 pp.

10. Optimum management intensity of legume- and grass-based new sown grassland swards

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Abstract

The optimum management intensity of grassland swards is mainly judged by dry matter (DM)- and protein-yields. The efficiency of the applied nitrogen and technical equipment has to be considered for the sustainable use of grassland systems.

In an experiment in Aulendorf, South Germany, 9 different variants of grassland swards (renewed grassland with late and early varieties of *Lolium perenne, Trifolium repens* and *Medicago sativa)* with different cutting frequencies (4 to 6 per year) and different date of first harvest of primary growth were compared and judged to their efficiency in view of yields of dry matter, crude protein and net energy. Moreover the N-efficiency has to be determined. After 3 experimental years (2001 - 2003), first results of the on-going experiment show, that legume based grassland swards are much higher in N-efficiency than grass based swards (in average 46,7 kg DM kg^{-1} N for grass-based swards compared with 114,8 for white clover and 220,5 kg DM kg^{-1} N for lucerne). Dry matter yields were highest in lucerne variants with 4 cuts, also even the amount of net-energy was highest in both lucerne swards. In grass based swards net-energy could be increased by high utilisation frequency. The results suggested, that the optimum intensity of grassland use in South-Germany depends on the reference factor. Highest forage quality in grassland growths will be obtained with high cutting frequency; highest N-efficiency by 4 cuts. A main factor for sustainable farming systems is the use of legumes.

Introduction

The intensity of grassland production depends on local attributes of the grassland site and the specific use of the produced forage. Moreover „optimum intensity' is depending on economic factors and agropolitical structures. Doubtless high yielding dairy cows need a high energy density in their forage. If such forage should be produced from permanent grassland, it is to investigate if highest cutting intensity gave the highest yields and a sufficient energy density. Further it is to ask, if the use of the applied mineral nitrogen, as a main factor in energy consumption on farm level is efficient. Results of former investigations show (Whitehead, 1995; Elsaesser, 1999; Kelm *et al.*, 2003), that N-delivery is rather low for grassland, but could be increased fundamentally by using legumes. Additionally the efficiency of nitrogen application is to increase by legumes. The objectives of the 2001 installed experiment in Aulendorf were to investigate the effects of high intensive production on grassland with different yield parameters.

Materials and methods

In spring 2001, 9 seed-variants of grassland and forage mixtures were sown on a field of the experimental station in Aulendorf, which was used before as temporarily grassland (South Germany, altitude mASL 590, average rainfall: 900mm). The variants are tested under different utilization conditions with 4 replications. Plot size is 1,5 x 6,0 m. All variants were sown with a basic seed mixture and received additional species (Table 1). Details of seed mixtures and utilization regime are given in Table 2.

Table 1. Basic seed mixture.

Species	Cultivars	Var. 1-5	Var. 6,7	Var. 8,9
Lolium perenne	Toledo, Respect, Recolta: middle	6 kg ha^{-1}	8kg ha^{-1}	3 kg ha^{-1}
Festuca pratensis	Cosmolit	5 kg ha^{-1}	7kg ha^{-1}	8 kg ha^{-1}
Phleum pratense	Tiller, Lirocco	5 kg ha^{-1}	5 kg ha^{-1}	7 kg ha^{-1}
Poa pratensis	Lato, Oxford	4 kg $ha^{-1;}$	6kg ha^{-1}	4 kg ha^{-1}
Festuca rubra	Gondolin	3 kg ha^{-1}	3 kg ha^{-1}	0 kg ha^{-1}
Trifolium repens	Lirepa	2 kg ha^{-1}	6kg ha^{-1}	6 kg ha^{-1}

Table 2. Mixture variants and cutting frequency.

Variant	Basic seed mixture (see Table 1) plus	Cultivars	Date of 1st cut 2001/02/03	Cutting frequency	Fertilisation kg N ha^{-1}
1	*Lolium perenne* 10 kg ha^{-1}	Labrador, Sambin (early)	9.5./8.5./6.5.	6	340
2	*Lolium perenne* 10 kg ha^{-1}	Labrador, Sambin (early)	9.5./8.5./6.5.	5	250
3	*Lolium perenne* 10 kg ha^{-1}	Parcour, Linocta (late)	9.5./8.5./6.5.	5	250
4	*Lolium perenne* 10 kg ha^{-1}	Parcour, Linocta (late)	9.5./8.5./6.5.	4	180
5	*Lolium perenne* 10 kg ha^{-1}	Parcour, Linocta (late)	16.5./16.5./16.5.	5	250
6	*Trifolium repens* 6 kg ha^{-1}	Lirepa	9.5./8.5./6.6.	5	90
7	*Trifolium repens* 6 kg ha^{-1}	Lirepa	16.5./16.5./16.5.	4	90
8	*Medicago sativa* 3 kg ha^{-1}	Europe	16.5./16.5./16.5.	4	90
9	*Medicago sativa* 3 kg ha^{-1}	Europe	25.5./16.5./5.6.	3	60

Results and discussion

Dry matter and energy yields

The seed variants differed widely in DM-yield per ha and year (Table 3 and Figure 1). Highest yields were obtained with 16,3 and 15,6 t DM ha^{-1} for both of the lucerne variants, but the first cut at optimum stage (early = beginning of May) had higher dry matter and energy yields. Grass variants were lower and some of them were significantly different to lucerne. The rise of cutting frequency from 4 to 5 and moreover to 6 cuts per year gave DM yields of 10,3, 11,5 and 12,5 t ha^{-1} and increased the energy yields from 62,3, 69,5 to 77,0 GJ NEL ha^{-1}. The comparison between early and late cultivars of *Lolium perenne* (var. 2 and 3), both used in optimum stage, showed slightly higher DM-yields for late cultivars, but gave no significant differences in energy yield, N-yield and N-efficiency. Also the effects of date of first cut were negligible, because parameters gave no significant difference between the same cultivars of *Lolium perenne* (variants 3 and 5). Even the energy yields were nearly the same, however the amounts of net energy differed markedly. The swards with *white clover* gave no significant effect on drymatter and net energy yields.

Great variations are visible between the experimental years. The dry conditions in 2003 resulted nearly in all variants in lower drymatter yields. Similar yields could only be observed in *lucern*e variants, which were both nearly the same and much higher than all of the other variants (Figure 1).

Table 3. DM- and Energy yields, N delivery and N efficiency (2001 - 2003).

Variant and cultivar	Cutting time	Cutting frequency	DM-yield t ha^{-1}	Energy-yield MJ NEL ha^{-1}	N-yield kg N ha^{-1}	N efficiency kgDM kgN^{-1}
1 *Lolium per.* early	early	6	12,5 ab	77 037 ab	342 ab	36,9
2 *Lolium per.* early	early	5	11,5 ab	69 485 ab	300 ab	46,0
3 *Lolium per.* late	early	5	11,7 ab	70 849 ab	306 ab	46,7
4 *Lolium per.* late	early	4	10,4 a	62 255 b	262 b	57,5
5 *Lolium per.* late	late	5	11,6 a	70 781 ab	296 ab	46,3
6 *Trifolium repens*	early	5	10,8 a	65 763 ab	310 ab	119,4
7 *Trifolium repens*	late	4	10,0 a	59 760 b	262 b	110,1
8 *Medicago sativa*	late	4	16,4 b	94 698 a	431 a	181,8
9 *Medicago sativa*	very late	4	15,6 b	88 676 a	434 a	259,3

Different letters indicate significant differences at the 0.05 level of significance

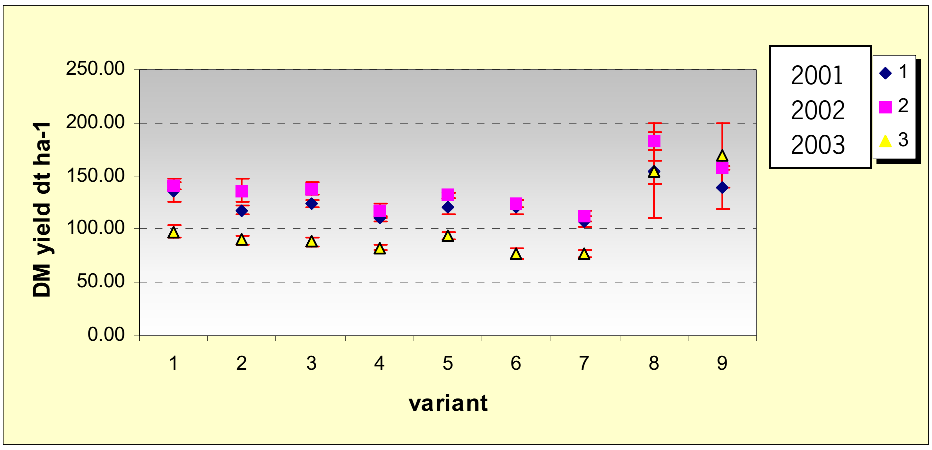

Figure 1. Dry matter yields per year in dt ha^{-1}.

Nitrogen yields and efficiency of nitrogen use

Nitrogen yields, calculated with the crude protein contents, were highest for the Lucerne variants. Significant deeper were variant 4 and 7, *Lolium perenne* with late cultivars and late cut of primary growth and *Trifolium repens* with 4 cuts and also a late cutting date (Figure 2 and 3). The efficiency of nitrogen use was reverse for these variants: Highest efficiency was observed by 4 cuts with 57,5 kg DM per kg used N. Compared with this the highest cutting frequency (6 cuts a^{-1}) gave only an N efficiency of 36,9 kg DM kg N^{-1}. Legume based variants resulted in highest N-efficiency, whereas the *lucerne* variants with 181,8 and 259,3 kg DM kg N^{-1} were much higher than those with *Trifolium repens*.

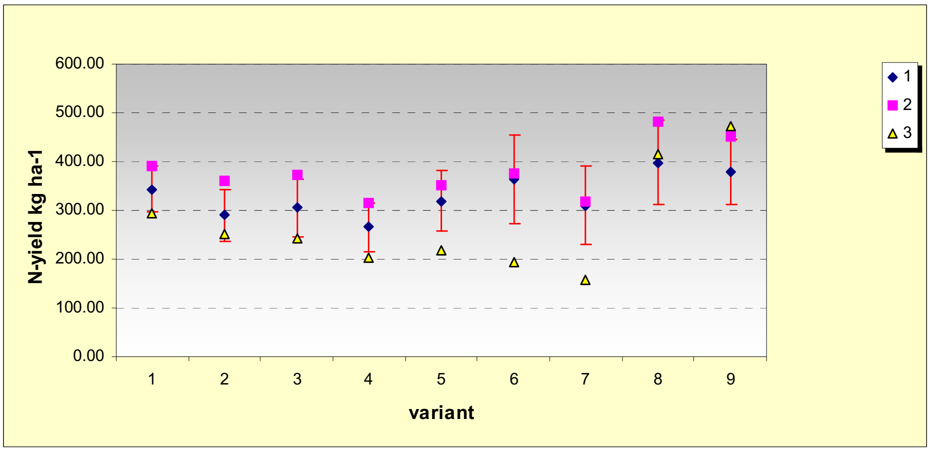

Figure 2. *Nitrogen yield per year in kg ha[1].*

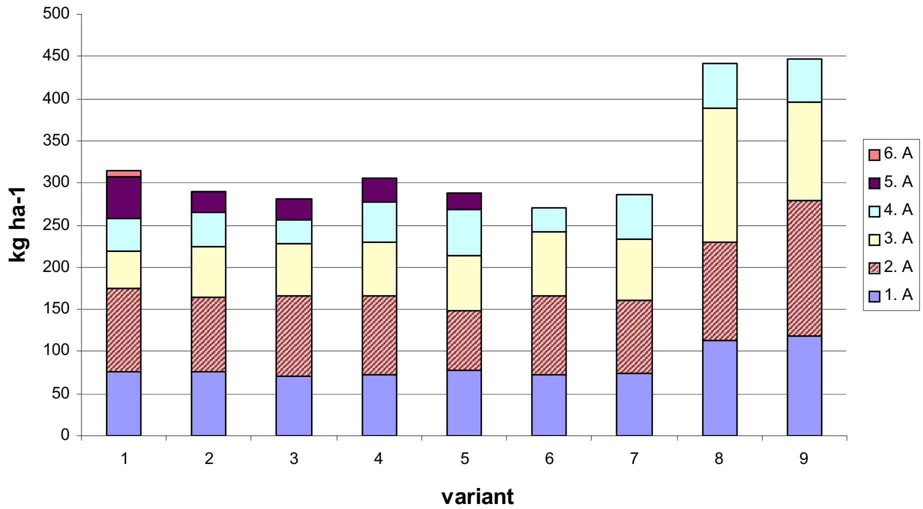

Figure 3. *Average nitrogen yield in kg N ha[1] (2001 - 2003) (A = Aufwuchs = regrowth).*

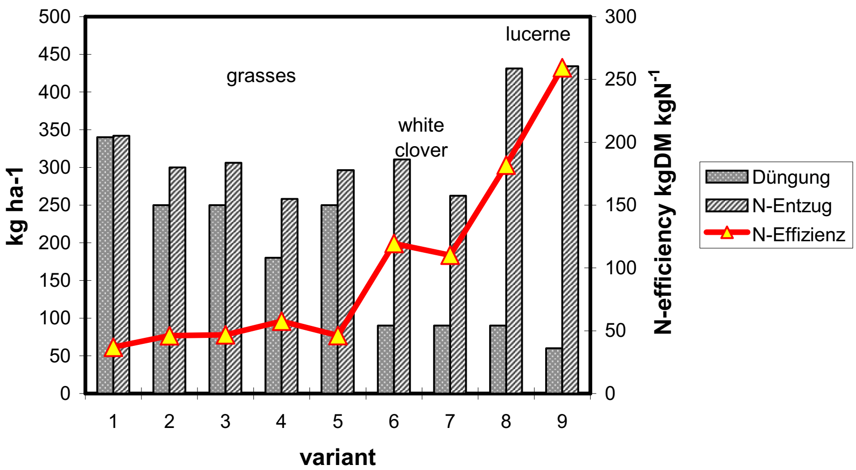

Figure 4. *Fertilization of nitrogen (kg ha[1]), N- yield (kg ha[1]) and N-efficiency in % (2001 - 2003).*

The use of legumes gave great increase of productivity because of the much higher N efficiency, but there exist significant differences between *white clover* and *lucerne*. It seems to be absolutely crucial to use *white clover* based grassland swards with higher cutting frequency. Only 4 cuts and a late date of the first cut gave lowest DM and energy yields. Whereas *lucerne* used with 4 cuts per year and an early harvest of primarily growth had best results in this experiment. Even a late first cut had the same DM- and net energy yields like the most intensive grass variant.

Conclusion

Highest cutting frequency gave highest dry matter and energy yields of grass-based swards. Optimum date of first cut in intensive grassland has maybe effects on energy density, but the energy yields showed no differences. Similiar observations could be made for the comparison of early and late cultivars of *Lolium perenne* under the conditions of this experiment. Four cuts were too less for producing highest dry matter and energy yields. Legume based grassland swards had much better results for nitrogen efficiency than grasses. The use of legumes has to be forced even for reaching highest amounts of net energy.
Observations in 2003, a year with an exceptional drought, show, that the advantage for legume based grassland swards compared with grass based swards was still higher than in the first two experimental years. Best success gave the lucerne variants.

References

Elsaesser, M.,1999.
Auswirkungen reduzierter Stickstoffdüngung auf Erträge, Futterwert und Botanische Zusammensetzung von Dauergrünland sowie Nährstoffverhältnisse im Boden. Habilitationsschrift, Universität Hohenheim, Wissenschaftsverlag Dr. Fleck, Gießen.

Kelm, M., M. Wachendorf, H. Trott, K. Volkers & F. Taube, 2003.
Energieeffizienz im Futterbau - Ergebnisse aus dem N-Projekt Karkendamm. Mitteilungen Pflanzenbauwissenschaften, 15, 202-204.

Whitehead, D.C., 1995.
Grassland nitrogen. CAB International, Wallingford.

11. A method for predicting N offtake in reseeded grassland based on measurements relating to soil N supply

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Abstract

A regression model for predicting N offtake in newly reseeded grassland was developed, based on four main parameters. In order of importance these were: accumulated mean daily temperature, % total soil N, % clay content, and potentially mineralizable N as estimated using a soil chemical (hot KCl) extraction method. Based on 15 experimental sites, for which N offtake in herbage and other required data were available, a value of r^2=0.84 was obtained between fitted values and measured N offtake in herbage. The lowest N offtake rates were on upland sites. The approach used has wider potential applications for improving fertiliser recommendations for renovated (resown) grasslands.

Keywords: grassland, renovation, resowing, cultivation, available nitrogen

Introduction

Grassland cultivation, followed by resowing with seeds of grass (or another crop), is a long-established agricultural management practice (Stapledon and Davies, 1948) that enables a short-term gain in productivity associated with the mineralization of the soil N that has accumulated under a long-term grassland sward. Soil N available for a succeeding crop, or newly renovated sward, varies with site conditions and recent sward history. In this paper, we present preliminary results for a simple regression model derived for N offtake (N content of harvested grass DM) from nil-N (i.e. unfertilised), newly sown perennial ryegrass at 15 sites in England and Wales (see Figure 1). This measure of soil-derived N was correlated with results of a soil analysis (hot KCl extraction) of available N at each site. The aim was to develop a simple model for predicting nitrogen dynamics in resown grasslands, which could be tested using using existing experimental data.

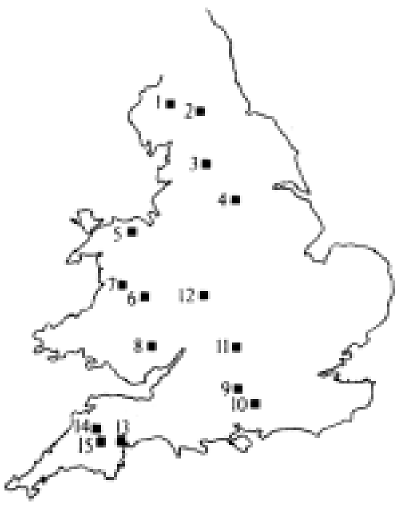

Figure 1. Location of UK experimental sites (all reseeded from permanent grassland in 1983).

Materials and methods

Potentially mineralizable N
Air-dried soil (10g), sieved (<2mm) was placed in a 150ml *Pyrex* beaker with 50ml 2M KCl and boiled for 1 h, adding water to maintain the volume. The supernatent was filtered and made to 100ml with 2M KCl and analysed for inorganic N (Whitehead, 1981).

Development of a regression model
Various combinations of parameters were identified as potential descriptors for the regression model to predict N offtake, including soil type, soil texture, soil organic matter content, soil total N content, soil bulk density, potentially mineralizable N (from hot KCl extraction) and meteorological data.

From a review of results of N-response experiments at 66 grassland sites in England and Wales (Hopkins, 2000), data from one multi-site experiment, conducted in 1984-86 and representing a range of grassland environments, was found to include all the required parameters (Hopkins *et al.,* 1990; 1994). The experimental treatments included five rates of N fertiliser (including a nil-N rate) on both permanent and reseeded swards. All the sites had a similar cropping history and were previously in permanent grassland. Data used in the model were restricted to newly reseeded swards from 15 sites, receiving no N fertiliser, which were cut 6-7 times per year. At some sites, data were available for 4 years, but the fourth year was not used, for two reasons. Firstly, reseeded swards were selected for use in the model because, following breaking of the old sward, they are somewhat analogous to the situation after ploughing for cereal crops with the incorporation of plant residues. Secondly, grassland receiving no N often becomes colonized by legumes, and particularly white clover after several years, and this increases the amount of N available to the grass. Available data included initial assessments of the following: soil type, soil texture, soil organic matter content, soil total N content (0-10cm soil depth), soil bulk density and also nil-N offtake in herbage (assessed at each cut). Potentially mineralizable N from the hot KCl method had also been assessed annually. The site elevation and meteorological data (mean monthly air temperature and rainfall, April to September) were also available. Data for soil temperature at 10 cm depth was sought, by examination of Meteorology Office data held on the British Atmospheric Data Centre Internet site (http://badc.nerc.ac.uk). Soil temperatures were not available for all sites and air temperature data were used instead. The data used were the accumulated mean (of maximum and minimum) daily temperature (^{o}C) from 1 April to 30 September. The mean of the three-years' data was used.

Field History

Sites were selected from the main grass-growing areas of England and Wales to represent a range of grassland environments and soil types under both high and low rainfall regimes. Elevations ranged from 15 to 400m above sea level. Existing permanent swards were mostly over 20 years old. Swards were of mixed species composition, with *Lolium perenne* contributing not more than 30% (and absent at some sites). Previous management had been relatively extensive, with inputs of N less than 200 kg ha^{-1} yr^{-1}; most sites had received considerably less.

The permanent swards were treated with a herbicide (glyphosate), then rotovated and resown to *Lolium perenne* during late summer 1983. Prior to reseeding, 100 kg N ha^{-1} was applied to the permanent sward in spring 1983. The seedbed received NPK fertilisers at rates which supplied 60, 50 and 50 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. From 1984, no further N was applied to these treatments. In the spring of each subsequent year, PK fertilisers were applied at rates of 150 and 100 kg ha^{-1} of P_2O_5, K_2O, respectively. On the basis of soil tests carried out at the start of the experiment, soil pH values below 6.0 were raised with appropriate lime applications. The wide variation in topography and site environment is illustrated in Figures 2, 3 and 4.

Figure 2. Site 7 (310m elevation).

Figure 3. Site 10 (100m elevation).

Figure 4. Site 11 (60m elevation).

Statistical analysis

Multiple regression analysis on data from the 15 sites was used to select the most suitable predictors of herbage N offtake from reseeded swards which received no fertiliser N (subsequently referred to as nil-N, N-offtake). N offtake in herbage (mean of 3 years) was used as the dependent variate and the following site descriptors (single estimates of each) were the independent variables: % sand, % clay, % silt, % total soil N, % soil organic matter, soil bulk density and elevation. The seasonally affected descriptors (annual estimates only) comprised: potentially mineralizable N (kg ha^{-1}), accumulated daily mean temperature (April to September) and rainfall. A step regression (i.e. forward selection) procedure was then used to rank the predictors identified as being the best descriptors of (nil-N) N offtake. The selected descriptors were then used in a multiple regression analysis to produce the fitted values for (nil-N) N offtake. The regression estimates were verified using a Bootstrap procedure.

Results and discussion

The difficulty in estimating N supply is clearly demonstrated by the sample of three sites (shown in Figs. 2, 3 and 4) selected for their contrasting soil %N contents (Table 1). The DM yields and N uptakes from these sites were found to be *inversely* related to soil %N which suggests that factors other than total N are also important in determining the overall soil N supply.

Table 1. *Three sites selected to demonstrate that at some sites, herbage N yield was not positively correlated with total soil N content.*

Site	DM yield t/ha	Herbage N uptake kg/ha	Soil total %N	% soil OM	% clay	N uptake as % soil N
7 Ponterwyd	2. 29	56	0.68	16.8	15	0.89
10 Selborne	4. 70	123	0.51	10.8	28	1.93
11 Oxford	6. 56	157	0.42	9.6	22	2.63

The explanation for the inverse relationship between soil N and plant uptake in the three sample sites may be different in each case. In the upland soil (Site 7) the topsoil was shallow and, therefore, represented a smaller reservoir of N for plant growth. In addition, the cooler temperatures and more exposed aspect of Site 7 would have restricted plant growth. At Site 10, the soil N content was nearly as high as Site 7, but the higher clay content (28%) would have protected some of the organic N residues from microbial degradation. At Site 11, there was evidence of an ancient ridge and furrow system of cultivation (see Figure 4) which had resulted in a very deep topsoil layer which was very productive and produced the highest DM yield despite having a lower soil N content.

Using data from all 15 sites, the step regression (forward selection) analysis identified four parameters (a-d) which were used in determining herbage N uptake.
These were, in the following order of importance:

- accumulated mean daily temperature (c)
- % total soil N (a)
- % clay (d)
- potentially mineralizable N as kg N ha^{-1} (b)

The value of the constant was -292.

The model produced by a regression analysis is shown in Figure 5, including the line of equality for comparison. Within the data range, the model performed reasonably well. A larger database would be desirable to validate this regression model, but we are unaware of any with this complete range of information. Year-to-year variation was considerable, and the small size of the database necessitated the use of means of the first three harvest years for the seasonally affected descriptors. The five sites with the lowest N offtake were upland sites in northern England and Wales. The remaining sites formed a separate group with higher rates of N offtake.

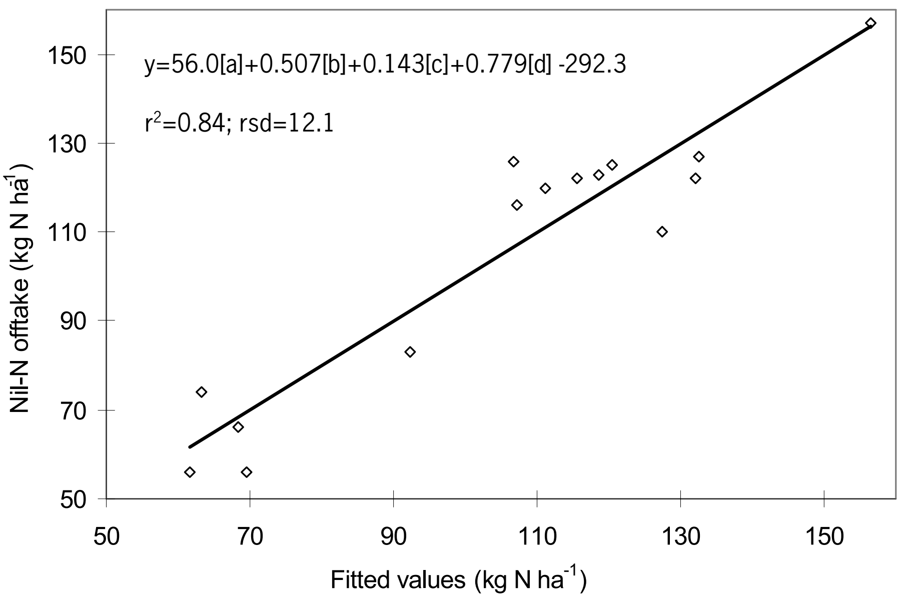

Figure 5. *Model for predicting N offtake from nil-N fertilised, newly resown grass at 15 sites in England and Wales (means for 1984-86), using four descriptors. [1:1 line is also shown].*

Conclusions

From information on the four main soil parameters, an estimate of OM turnover (i.e. net N release) can be obtained from the simple regression model and this can be made more site-specific by including local soil temperature measurements for refining fertiliser N recommendations for recently renovated grassland.

References

Hopkins, A., A.H. Adamson & P.J. Bowling, 1994.
Response of permanent and re-seeded grassland to fertilizer nitrogen. 2. Effects on concentrations of: Ca, Mg, K, Na, S, P, Mn, Zn, Cu, Co, Mo in herbage at a range of sites. *Grass and Forage Science*, 49, 9-20.

Hopkins, A., 2000.
A review of grassland production and fertilizer response data with references to the basis for management agreements. *Technical Report for MAFF, under project BD1438*, IGER, North Wyke.

Hopkins, A., J. Gilbey, C. Dibb, P.J. Bowling & P.J. Murray, 1990.
Response of permanent and re-seeded grassland to fertilizer nitrogen. 1. Herbage production and herbage quality. *Grass and Forage Science*, 45, 43-55.

Stapledon, R.G. & W. Davies, 1948.
Ley Farming. London: Faber and Faber.

Whitehead, D.C., 1981.
An improved chemical extraction method for predicting the supply of available soil nitrogen. *Journal of Science, Food and Agriculture,* 32, 359-365.

12. Economy of grassland renovation: a model approach

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Abstract

Grassland renovation is a relatively expensive activity. However, a cost/benefit analysis is hard to make, since financial benefits are difficult to determine. The benefits involve mainly the temporary increase of net grass production. The focus of this paper is on a model simulating the grass production over time. It assumes that the gross grass production, the nutritive value and the intake of grass by cattle decline over time due to an increasing content of undesirable grass species, like *Poa trivialis* and *Elymus repens*. This model approach is the basis for the 'Grassland Renovation Guide', a computer program which runs on the Internet site of our institute (www.asg.wur.nl). Farmers can use this program for a cost/benefit analysis, depending on factors such as actual costs, present content of desirable grasses and clover, soil type, groundwater level, irrigation and N fertilisation level. The tool provides a cost benefit analysis and a nitrogen balance. For the given situation, it states whether grassland renovation is profitable under a wide range of circumstances

Keywords: grass, renovation, production, nutritive value, economy, nitrogen balance

Introduction

Farmers often do not have a clear insight in the costs and benefits of grassland renovation. Therefore, a computer program has been introduced, which is available on the Internet site of our institute (www.asg.wur.nl). This so-called 'Grassland Renovation Guide' is a practical tool, which calculates the difference between the financial costs and benefits of renewing for a time period of five years after renewing. The costs of renewing should at least be compensated by the benefits: a higher production level of the new grass sward, a higher nutritive value and a better intake of the grass during grazing. The benefits are difficult to determine, mainly because the increased net production level after renovation is temporarily. The assumed effect of grassland renovation on the DM yield is schematically illustrated by Schils *et al.* (2002).
In this paper a model simulating the net grass production over time is presented. The Grassland Renovation Guide is based on this model.

Model approach

The main benefit of resowing is the increase of net grass production. To simulate this production, a model has been developed that estimates grass production over time. The model calculates the increase of production depending on the time of renewing in the year (spring or late summer), the growing conditions and the actual botanical composition. The growing conditions include soil type and groudwater table, use of irrigation and N fertilization level. Usually a grass sward deteriorates over time and needs to be renovated at a certain moment. Concerning the development of net grass production over time the following facts are taken into account: 1) gross production declines with an increasing content of undesirable grass species, such as *Poa trivialis* and *Elymus repens*, 2) the nutritive value of grass and the intake by cows during grazing and as silage are influenced by the presence of undesirable grasses (Keating & O'Kiely, 2000) and 3) in the year of renovation the production is lower, because of the destruction of the old sward and establishment of a new sward. An example of the results of this model is given in Figure 1 for a drought sensitive sandy soil over 30 years.

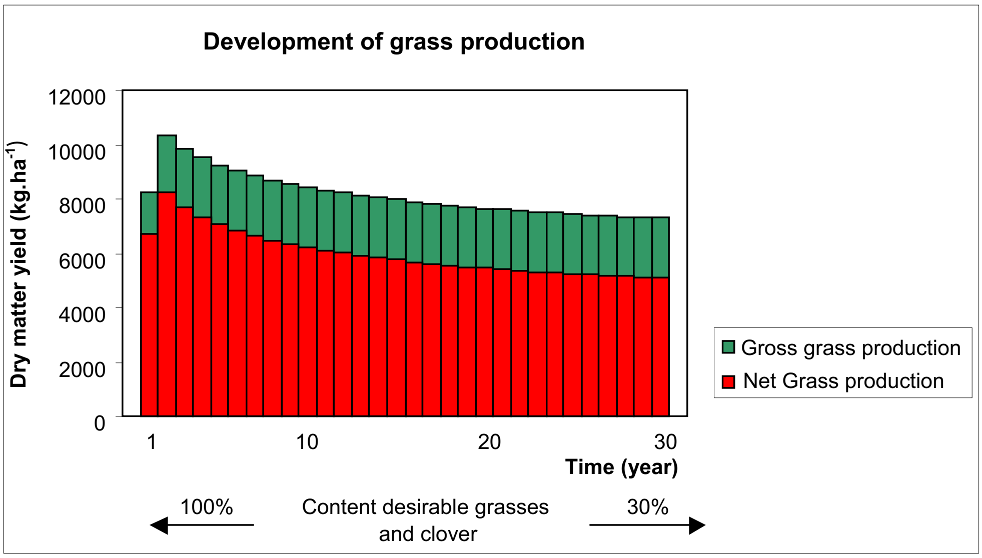

Figure 1. *Model approach of the development of grass production (dry matter) for a long term period. Renovation during spring. Example for a drought sensitive sandy soil.*

For the production curve two main reference points are chosen, namely a potential production and a long-term production level where production is approximately in a steady state. Both levels are dependent on soil type and groundwater table. The potential production is defined as the production under optimal growing conditions, by a homogenous botanical composition of a sward consisting entirely of grasses and white clover with high agricultural value. Both potential production and the content of desirable grasses and clover are determined to be 100%. The long-term production is characterised by a sward containing a high proportion of undesirable grass species and a relatively low proportion of high-value grasses and clover of less than 40%. The model is based on practical knowledge of a team of experts at our institute, literature (Korevaar, 1986) and unpublished research data.
In the model, the direct loss of production after renewing depends on the time of renewing in the year; during spring 25% and during late summer 12.5% of the total year gross production. In the first year of production following renovation, comparatively high production is assumed, namely an increase of 10% compared to potential production (Luten *et al.*,1976).
After renovation nitrogen is immobilised in the new sward. This is assumed to be 150 kg N in spring and 300 kg $N.ha^{-1}$ in autumn (Vellinga, 2000). In the model these amounts are translated into a decrease of grass production.

Grassland Renovation Guide
The Grassland Renovation Guide is a program, which calculates a cost/benefit analysis, depending on factors such as costs, present content of desirable grasses and clover, soil type, groundwater level, irrigation and N fertilisation level. The tool provides an economic evaluation, a nitrogen balance and a recommendation on whether to resow or not. Cost benefit analysis and N balance are calculated over a time period of five years. To give an impression of the program some calculated results are presented in Table 1. The value to which the percentage of high-value grasses, including clover, needs to fall before renewing should be recommended is calculated for different combinations of soil type and hydraulic situation. As the importance of high quality grass also depends on nutritional requirements of dairy cows, the protein availability for dairy cow nutrition on farm level is also included in the program.

Table 1. Percentage high-value grasses at which renewing is recommended. Fertiliser N input was 300 kg.ha^{-1} on sand and clay soils and 200 kg.ha^{-1} on peat soils (no irrigation).

Soil type	Sand		Clay		Peat	
Hydraulic situation	Moist	Dry	Moist	Dry	Moist	Wet
No protein shortage	52	40	56	48	55	40
Protein shortage	70	68	75	76	75	68

Protein availability has a major influence on the program results, as protein has more economic value than energy and the gain of protein by grassland renovation is significant. If there is a protein surplus, grass quality has to be very poor before renewing is economically beneficial. Furthermore, renovation is more profitable when the growing conditions can be improved by influencing the hydraulic situation.

Discussions and conclusions

The botanical composition of the sward is the most important factor influencing the cost-benefit of renovation, as calculated by the Grassland Renovation Guide. The protein availability on farm level has a huge influence on the recommendations of the program, as renovation of grassland is more attractive with protein shortages on a dairy farm than with protein surpluses. Furthermore, grassland renovation is more profitable with an improved hydraulic situation. Finally, there is a need for research data concerning productivity and nutritive value related to the botanical composition of a grass sward in order to calibrate the model as the net productivity is based on practical knowledge and unpublished data.

Acknowledgements

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References

Schils, R.L.M., H.F.M. Aarts, D.W. Bussink, J.G. Conijn, W.J. Corré, A.M. van Dam, I.E. Hoving, H.G. van der Meer & G.L. Velthof, 2002.
Grassland renovation in the Netherlands; agronomic, environmental and economic issues. In: Conijn, J.G., Velthof, G.L., Taube, F., 2002. Grassland resowing and grass-arable crop rotations. International workshop on Agricultural and Environmental Issues, 18 & 19 April 2002. Report 47, Plant Research International B.V., Wageningen: 9-24.

Korevaar, H., 1986.
Productie en voederwaarde van gras bij gebruiks- en bemestingsbeperkingen voor natuurbeheer. Proefschrift. Proefstation voor de Rundveehouderij, Schapenhouderij en Paardenhouderij (PR), Lelystad. Rapport nr. 101

Keating, T. & P.O. O'Kiely, 2000.
Comparison of old permanent grassland, *Lolium perenne* and *Lolium multiflorum* swards grown for silage. 3. Effects of varying fertiliser nitrogen application rate. *Irish Journal of Agricultural and Food Research* 39: 35-53

Luten, W., J.J. Klooster & L. Roozeboom, 1976.
Herinzaai van grasland. Verslag van een vergelijkend onderzoek met verschillende methoden van herinzaai in de periode 1971 t/m 1974. Rapport 39, Proefstation voor de Rundveehouderij, Lelystad: 26 pp.

Vellinga, Th.V., P.J. Kuikman & A. van den Pol-van Dasselaar, 2000.
Beperking van Lachgasemissie bij het scheuren van grasland: een systeemanalyse. Alterra, Wageningen. Rapport nr. 114-5

13. Energy efficiency in forage production

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Abstract

Based on experimental data gathered in the 'Karkendamm' project in Northern Germany, energy balances were drawn for forage production systems with permanent grassland and silage maize. Both experiments comprised different cropping practices (defoliation regime in grassland, ryegrass under-story in maize) and different rates of mineral N fertiliser and slurry application. In permanent grassland, each change from grazing to cutting decreased the energy efficiency. In both grassland and maize energy efficiency declined significantly with increasing rates of mineral N application. Net energy yields of silage maize were much higher than of grassland when compared at the same level of fossil energy and nitrogen fertiliser input. It is suggested that a high proportion of silage maize in combination with N-unfertilised grass / clover swards can improve the efficiency of fossil energy use in forage production.

Keywords: defoliation system, grassland, maize, nitrogen, fossil energy

Introduction

Studies on the environmental impacts of intensive dairy farming have mostly addressed nitrogen (N) losses. This aspect, however, represents only one area of negative environmental impacts. Energy balances provide a more integrative approach since all inputs and outputs of the farming system and those at the site of production of external inputs (fertilisers, concentrates, etc.) are accounted for. In intensive dairy farming, most of the input of fossil energy is related to the acquisition of feedstuffs (e.g., concentrates, home-grown roughage). Thus, a less energy-intensive production/acquisition of feedstuffs is a key factor for improved energy efficiency and, at the same time, can reduce N surpluses in dairy farming.

Materials and methods

The present analysis is based on experimental data obtained in the 'Karkendamm' project in Northern Germany (Taube and Wachendorf, 2000). The grassland experiment was carried out with white clover/grass swards. Four defoliation regimes were analyzed: grazing-only (GO), mixed systems with one (MS I) and two (MS II) silage cuts, and cutting-only (CO). Mineral N application rates were 0, 100, 200 and 300 kg N ha^{-1}. Slurry application was 0 and 20 m^3 slurry per hectare, which corresponds to 0 and 70 kg N ha^{-1}, respectively (Trott *et al.*, 2002).
Silage maize was grown in monoculture with and without undersown perennial ryegrass. Mineral N application rates were 0, 50, 100 and 150 kg N ha^{-1}. Cattle slurry was applied at three different rates (0, 20 and 40 m^3 per hectare, corresponding to 0, 50 and 100 kg N ha^{-1}) (Jovanovic *et al.*, 2000). 2000-2001 yield data was provided by K. Volkers (unpublished).
Energy input in forage production was calculated at the field scale, assuming management conditions (farm machinery, cropping practices, *etc.*) typical for Northern German dairy farms on sandy soils. The required data for direct (diesel) and indirect (manufacturing and distribution of fertilisers, pesticides, seeds, machinery, lubricants) was taken from the most up-to-date literature. In some cases, our own calculations were applied. In the following text 'total energy input' (E_t) refers to the sum of direct and indirect energy input related to forage production and conservation per hectare and year. The energy efficiency is the net energy yield [GJ NEL] obtained per GJ total energy input.

Results and discussion

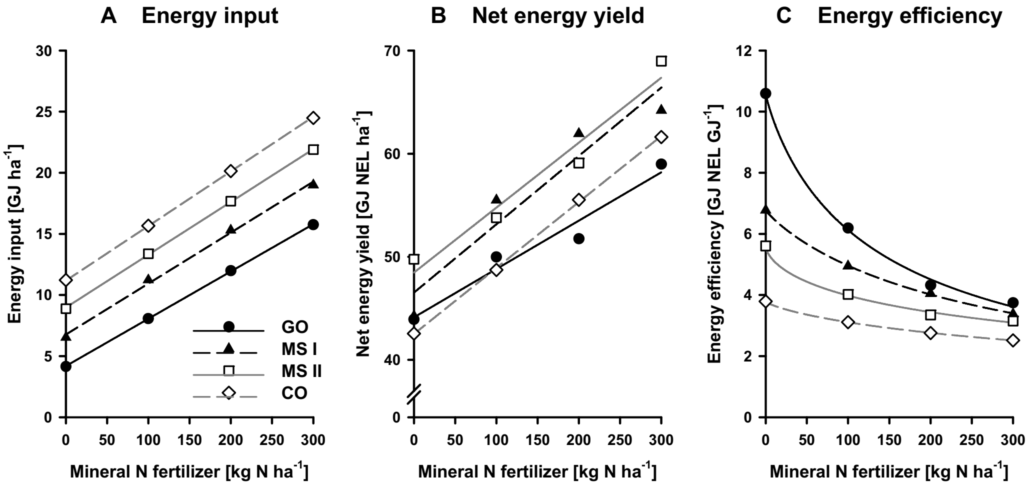

Figure 1. *Fossil energy input (A), net energy yields (B) (means of 1997-2001; Trott et al., 2002), and energy efficiency (C) in permanent grassland as affected by mineral N fertilisation and defoliation regime (GO: grazed-only pasture, MS I: mixed system I, MS II: mixed system II, CO: cutting-only) (all graphs for the treatment with 20 m³ slurry per hectare).*

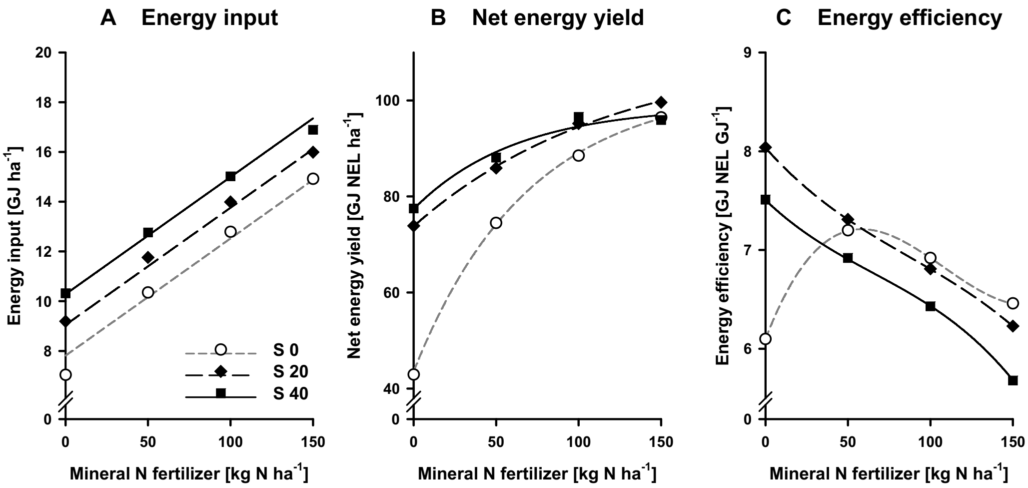

Figure 2. *Fossil energy input (A), net energy yields (B) (means of 1998-2001; Jovanovic et al., 2000; Volkers (unpublished)), and energy efficiency (C) in silage maize as affected by mineral N fertilisation and slurry application (S 0: without slurry, S 20: 20 m³ slurry per hectare, S 40: 40 m³ slurry per hectare) (all graphs for the treatment without undersown ryegrass).*

The total input of fossil energy E_t consistently increased with increasing rates of mineral N application (Figures 1A, 2A). In grassland, each change from grazing to cutting increased E_t due to the use of direct energy for harvest operations and silage making. Slurry application increased E_t in both grassland and maize. A significant yield response, however, could be observed only in silage maize at low levels of mineral N fertilisation (Figure 2B). As net energy yields did not differ markedly between defoliation systems on grassland (Figure 1B), energy efficiency was highest on grazed-only pasture (Figure 1C). In silage maize, energy efficiency was highest when N supply was 50 kg N ha^{-1} from slurry without additional mineral N fertilisation. As the production of synthetic N fertiliser requires high amounts of fossil energy, energy efficiency consistently declined with increasing rates of fertiliser-N application except for silage maize grown without slurry (Figures 1C, 2C). In the case of grassland this can be explained by the linear and relatively weak response of the white clover / grass swards to increased N fertilisation (Figure 1B). Maize showed a high efficiency of N utilisation at low levels of N supply, but a weak response to additional N at high levels

of N supply (Figure 2B). Undersown ryegrass in maize decreased the energy efficiency because a higher N input was necessary to obtain a given yield level (data not shown). Comparing grassland and maize, silage maize produced much higher net energy yields than grassland at a given level of N fertiliser and fossil energy input.
Taking into account the leaching of nitrates, which is an important environmental aspect on sandy soils in Northern Germany, grassland was always more 'leaky' than silage maize. In grassland, nitrate concentrations in the drainage water always exceeded 50 mg NO_3 l^{-1} on grazed plots even if no additional N was applied (Büchter *et al.*, 2002). In contrast, leaching losses were only low to moderate in silage maize (Büchter *et al.*, 2003).

Conclusions

A high proportion of silage maize can be regarded positively with respect to efficient resource use in terms of both nitrogen and fossil energy, in intensive dairy farming. In grassland, mixed cutting / grazing systems can represent a good trade-off between nitrate leaching and energy efficiency. Reduced N fertilisation, e.g., through the inclusion of white clover into grassland swards, helps to reduce both nitrate leaching and fossil energy use.

References

Büchter, M., M. Wachendorf & F. Taube, 2002.
Nitrate leaching from permanent grassland on sandy soils – Results from an integrated research project. In: Durand J.-L., Emile J.-C., Huyghe C. and Lemaire G. (eds) Multi-function grasslands. Quality forages, animal products and landscapes. *Proc. 19th Gen. Meeting Europ. Grassl. Fed.*, La Rochelle, 27-30 May 2002, pp. 668-669.

Büchter, M., M. Wachendorf, K. Volkers & F. Taube, 2003.
Nitratausträge unter Silomais auf sandigen Böden Norddeutschlands (Nitrate leaching under silage maize on sandy soils in Northern Germany) (in German, with English summary). *Pflanzenbauwissenschaften* (in press).

Jovanovic, N.-J., M. Wachendorf & F. Taube, 2000.
Impact of a grass understory on the performance of silage maize. In: Søegaard K., Ohlsson C.; Sehested J., Hutchings N. J. and Kristensen T. (eds) Grassland farming. Balancing environmental and economic demands. *Proc. 18th Gen. Meeting Europ. Grassl. Fed.*, Aalborg, 22-25 May 2000, pp. 446-448

Taube, F. & M. Wachendorf, 2000.
The Karkendamm project: A systems approach to optimize nitrogen use efficiency on the dairy farm. In: Søegaard K., Ohlsson C., Sehested J., Hutchings N. J. and Kristensen T. (eds) Grassland farming: balancing environmental and economic demands. *Proc. 18th Gen. Meeting Europ. Grassl. Fed.*, Aalborg, 22-25 May 2000, pp. 449-451

Trott, H., B. Ingwersen, M. Wachendorf & F. Taube, 2002.
Management of permanent grassland for reduced nitrogen surplus – Results from an integrated project. In: Durand J.-L., Emile J.-C., Huyghe C. and Lemaire G. (eds) Multi-function grasslands. Quality forages, animal products and landscapes. *Proc. 19th Gen. Meeting Europ. Grassl. Fed.*, La Rochelle, 27-30 May 2002, pp. 740-741.

14. Effects of grassland renovation on farm-gate nitrogen balances and losses

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Abstract

Nitrogen (N) balances were calculated at the farm, field and herd level for specialized Danish (DK) and Northern German (GE) dairy farms. The hypothesis was that crop rotations with short-lasting leys could help to reduce N surpluses at the farm scale, as a result of the carry-over of N from the grassland phase to the succeeding crop. Calculations revealed that under both DK and GE conditions, the farm-gate N surplus could be reduced through the inclusion of crop rotations with 2/3-year leys, at the expense of permanent grassland. The reduction was more pronounced on GE (-11%) compared to DK (-4%) dairy farms.

Keywords: grassland resowing, nitrogen balance

Introduction

During two European workshops on nutrient management in dairy farming systems (Taube and Conijn, 2004; Pflimlin *et al.*, 2004), it was suggested that grass-arable crop rotations offered the possibility of reducing the currently high farm N surpluses observed in intensive dairy farming. This hypothesis is based on the observation that soil-N accumulated during the grassland phase (especially on grazed swards), can be utilized more efficiently by the succeeding arable crop than by permanent grassland. This N-saving effect has been proven at the plot and field scale, and is already part of fertilising regulations in Denmark. In order to provide an estimate of this effect at the farm scale, N balances have been estimated for typical DK and GE dairy farms combined with two different methods for grassland renovation.

Materials and methods

In DK, grass is usually grown in rotation with other forage and cereal crops. This contrasts with GE dairy farms, which depend on a high proportion of permanent grassland (similar to the situation in many other European regions). Such typical farming systems are described by data sets from a large number of commercial dairy farms (Anonymous, 2001; Kristensen *et al.*, 2004). However, due to many interacting factors in crop and livestock production, a simple comparison of N balances as calculated at farm level cannot be used to quantify the effect of grassland duration at the farm scale. In this paper the effect at the farm scale is estimated by adjusting two major factors simultaneously. Factor 1, was the crop rotation; representative farms were ‘converted’ in an opposite direction: i.e. DK to permanent and GE to rotation grassland. The crop rotation system (CR) was defined as a 2-year ley (grass/clover in DK, pure grass in GE) in rotation, while the permanent grassland system (PG) was defined to be resown every 6 years. This was done using the relationship between grassland age and productivity, as determined in DK trials (Table 1). Factor 2 accounted for the carry-over affect equivalent to a reduction of 65 kg N ha^{-1} in the fertiliser applied to the arable crop sown after grassland has been ploughed. This amount was determined at both the plot and the field scale in several trials (Eriksen, 2001), and has become part of DK fertilising regulations. These were the only factors used to calculate N balances of 'untypical' systems (permanent grassland in DK, and crop rotation in GE). All other factors remained constant *within each country* in order to estimate the pure effect of grassland duration at the farm scale.

The change of grassland duration influence the grass-yield (DM * N) and change the amount of manure on grass and slurry, and thereby the utilization of N in manure. At the system level, these effects are adjusted by changes in imports of concentrate and fertiliser N. Also the direct effect of soil-N carry over is adjusted by changing N fertiliser import. In GE, only 15% of the farm area was grown with cash crops, which is only sufficient to allow 45% of the area to be grown with 3-year-old rotational grass.

Table 1. Yields in Danish field trials as affected by ley age (absolute [t DM ha^{-1}], rel [%] yields).

	Production year after establishment									
	1		2		3		4		5	
	abs.	rel.	abs.	rel.	abs.	rel.	abs.	rel.	abs.	rel.
L. perenne / T. repens [1]	8.8	112	7.9	100	7.9	101	8.3	106		
L. perenne (intermediate cultivars) [1]	13.3	118	11.3	100						
L. perenne (late cultivars) [1]	13.1	120	11.0	100						
L. perenne / T. repens [2]	10.9	115	9.5	100	7.9	83	7.3	77	7.3	77

[1] *Jensen (1987), pers. comm.: average of 10 experimental years at 8 sites, 4-6 cuts per season, N fertilisation: 0 kg N ha^{-1} to grass/clover, 450 kg N ha^{-1} to pure ryegrass. Average of +/- irrigation.*

[2] *Gregersen (1980): 2 × 5 experimental years at 5 sites, 5 cuts per season, 150 kg N ha^{-1}. Unirrigated.*

Results and discussion

According to observed 'real farm data', there is a considerable proportion of grassland in both countries which cannot be ploughed (9% and 14%, respectively, Table 2). On average the farm-gate N surplus on DK dairy farms with a high proportion of leys, is 18 kg N ha^{-1} lower than on the corresponding GE farms. By keeping the prevailing management conditions in each country constant, increasing the proportion of leys at the expense of permanent grassland reduced the farm-gate N surplus in both countries. The reduction was greater under GE (-20 kg N ha^{-1} or -11%) than under DK conditions (-7 kg N ha^{-1} or -4%). As the total proportion of grassland is higher on GE dairy farms, a higher permanent grassland area could be replaced by leys (28% of the farm area vs. 13% in DK, Table 2). In the calculated GE crop rotation (CR) system, 15% of the farm area could be grown with cash crops in the first year after the ley. In these crops, the carry-over effect meant 65 kg fertiliser-N ha^{-1} could be saved, which reduced the N-fertiliser input at the farm level by 10 kg N ha^{-1}. The young grassland gave a higher DM- and N-yield compared to permanent grass (Table 1). As the herd N efficiency was constant, the extra N yield reduces the N import through concentrates by 13%.

Even though the calculated 'untypical' systems (DK-PG and GE-CR) cannot be validated by measured farm data, the present calculations give a reasonable estimation since the documented typical farm management practices in DK and GE remained unchanged. The effects measured at the plot and field scale can contribute to reduced N surpluses and, consequently, N losses to the environment, irrespective of other management practices which differ between DK and GE dairy farms (e.g., feeding, herd management etc.). The area of permanent grassland, which can be converted into ley-arable crop rotations, has a predominant role on the amount of N that can be saved within the system. The optimal grass area in relation to reduced losses is probably between the two countries: higher than 20% in DK because of the 4 years between grass/clover, and lower than the 42% grass plus 23% maize in GE, because only one year of cereals can be grown between grass. In DK organic farms, the calculated N-surplus was 40% lower than the shown DK CR system. Organic farms have 42% grass/clover-area and low fertilisation level (Kristensen *et al.*, 2004).

Conclusions

The present analysis, based on empirical farm data and observations at the plot and field scale, show that grass-arable crop rotations can help reduce farm-gate N surpluses under the soil and climatic conditions of DK and GE. The proportion of permanent grassland, which can potentially be converted into ley-arable rotations, was found to be an important factor for the magnitude of the N-saving effect at the farm scale.

Table 2. N balances (farm-gate, field and herd level) for dairy farming systems in Denmark and Northern Germany, compared for permanent grassland-based (PG) versus ley-arable crop rotation (CR) systems.

	Denmark		N. Germany	
System	CR	PG	CR	PG
Stocking rate [LSU ha^{-1}]	1.43	1.43	1.28	1.28
Milk production [kg FPCM ha^{-1}]	6614	6614	6922	6922
Permanent grassland + ley [% of farm area]	9 + 20	22 + 7	14 + 42	42 + 14
N import (farm gate) [kg N ha^{-1}]				
Mineral fertiliser	95	99	120	130
Biological N_2 fixation	26	23	0	0
Atmospheric N deposition	16	16	30	30
Concentrates	85	91	75	85
Other (livestock, manure, roughage, seeds, *etc.*)	2	2	1	1
N export (farm gate) [kg N ha^{-1}]				
Milk	35	35	34	34
Livestock	8	8	7	7
Cash crops	12	12	19	19
Field N surplus† [kg N ha^{-1}] (field efficiency)	151 (46%)	159 (44%)	148 (53%)	168 (48%)
Herd N surplus$ [kg N LSU^{-1}] (herd efficiency)	113 (21%)	113 (21%)	143 (19%)	143 (19%)
Farm-gate N surplus [kg N ha^{-1}]	169	176	166	186

† *Field N surplus = (mineral N fertiliser + N_2 fixation + atmospheric deposition + seeds + manure + excreta) – (cash crops + fodder crops).*

$ *Herd N surplus (amount of manure produced) = (Fodder crops + concentrates + imported livestock) – (milk + exported livestock).*

Data sources: Anonymous (2001) (GE-PG), Kristensen *et al.* (2004) (DK-CR), calculated DK-PG, GE-CR) as described in the text.

References

Anonymous, 2001.
Rinderreport 2001 (Dairy Report 2001) (in German). Landwirtschaftskammer Schleswig-Holstein (ed.), Betriebswirtschaftliche Mitteilungen 554/555.

Eriksen, J., 2001.
Nitrate leaching and growth of cereal crops following cultivation of contrasting temporary grasslands. *Journal of Agricultural Science Cambridge*, 136, 271-281.

Gregersen, A.K., 1980.
Irrigation and N-fertilization of perennial grass/clover (in Danish). *Tidsskrift for Planteavl*, 84, 191-208.

Kristensen, I.S., N. Halberg, A.H. Nielsen, R. Dalgaard & N. Hutching, 2004.
N turnover on Danish mixed dairy farms. In: Bos J.F.F.P., Pflimlin A., Aarts H.F.M. and Vertès F. (eds) *Nutrient management on farm scale: how to attain European and national policy objectives in regions with intensive dairy farming?* Proceedings of a workshop held in Quimper, France, June 23-25, 2003 (in press). *http://www.agrsci.dk/jbs/isk/DK_country_report_partII.pdf*.
Pflimlin, A., H.F.M. Aarts, F. Vertès & J.F.F.P. Bos, 2004.
Diversity in European dairy farming systems and its environmental consequences. *This Volume.*
Taube, F. & J.G. Conijn, 2004.
Grassland renovation in Northwest Europe: current practices and main agronomic and environmental questions. *This Volume.*

15. Reducing fertiliser N use by application of ley-arable rotations

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Abstract

On farm level as well as on soil level, the surplus on the N balance of Flemish dairy farms was reduced substantially during the past decade. This is good news considering the important policy focus on reduction of various N losses from agriculture to the environment. Still, more progress can be made: to come closer to a theoretically attainable N use efficiency of 70% on soil level, the N-input to the soil would have to decrease by another 90 kg ha^{-1} (assuming an unchanged N-output). The most obvious track to save on N-input is the further reduction of fertiliser-N use. In a 35-year field trial, we investigated how much fertiliser-N could be saved in a three-year ley / three-year arable rotation relative to a system of permanent grassland and silage maize monoculture. Subsequently we applied the results on the 'average Flemish dairy farm', based on data from our national Farm Accountancy Data Network. We conclude that applying the ley / arable system could result in a saving of ± 50 kg mineral fertiliser-N per ha of silage maize. Applying the system on half of the Flemish maize land would save more than 4 million kg of fertiliser-N, while yields would be as high as before.

Keywords: fertiliser-N use, grassland, ley / arable rotation, N use efficiency, silage maize

Introduction

It is well known from literature that on dairy farms, the efficiency of N use can be tackled most effectively at the soil-plant level. On Flemish dairy farms, this soil-plant N use efficiency increased significantly during the past decade, mainly owing to a decrease in fertiliser-N use (Figure 1). Nevertheless, the attained N use efficiency of about 58% in 2000 is still well below a technically feasible target of at least 70%. So more progress can be made and the most obvious track to follow is a further reduction of fertiliser-N use (another 90 kg less N use ha^{-1} year^{-1} would be required to obtain the 70% efficiency). A possibility to – at least partially- realise this objective is the (re-)introduction of ley / arable rotations: these successions of fertility build up under the short-term grasslands and fertility release during the following short term arable periods could be a serious option to cut on fertiliser-N while maintaining high yield levels.

Materials and methods

In a long-term experiment (1966 – 2001) on a Flemish sandy loam soil, we compared a system of continuous grassland and continuous arable forage crops (mainly silage maize) with a three-year ley / three-year arable rotation system. We measured and compared the feed energy yields of the temporary and the permanent grasslands (both fertilised at an average rate of 300 kg N ha^{-1} year^{-1}). On the arable plots we determined the forage crop dry matter yields and -based on response curves of yields to mineral N rates- we calculated the economic optima of fertiliser-N use ('N_{opt}'). More specific data on the experimental procedures and the results can be found in Nevens and Reheul (2001, 2002, 2003) and Nevens (2003).

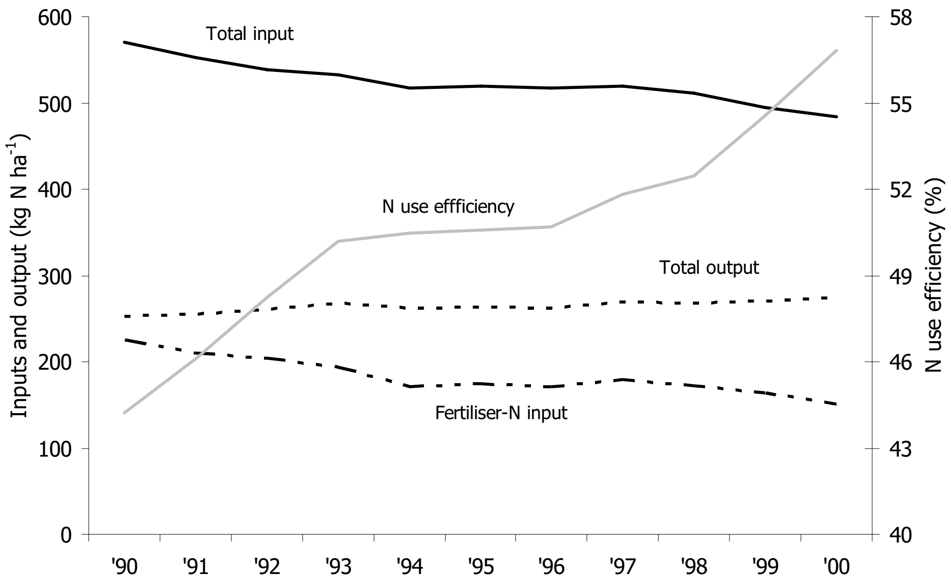

Figure 1. *Components of soil level N - balance of Flemish dairy farms comprised in the Farm Accountancy Data Network (n = 116) and the efficiency of the N use (= 100 * total Noutput / total Ninput).*

Results and discussion

A first important result of the long-term rotation experiment was that the yields (expressed as feed energy) of the permanent grassland plots and the temporary grassland plots were comparable, at the same level of N-fertilization (300 kg N ha^{-1} $year^{-1}$).

Secondly, we found that while for silage maize on permanent arable land the average N_{opt} was 175 kg N ha^{-1} $year^{-1}$, on temporary arable land this N_{opt} was 2, 139 and 154 kg N ha^{-1} $year^{-1}$ in the first, second and third year following the three-year grassland, respectively. Thus, while attaining equal yields in both systems, during a three-year temporary arable land period 231 kg N (77 kg N ha^{-1} $year^{-1}$) could be saved compared to permanent arable land.

However, our experimental system only considered application of mineral N fertilization and Flemish practice works different: slurry is applied and supplemented with mineral fertiliser-N. If we assume that on maize land slurry is applied but limited to a maximum rate of 230 kg total N ha^{-1} $year^{-1}$ at an N-use-efficiency of 60% (Nevens and Reheul, 2004) this corresponds with 138 kg fertiliser-N ha^{-1} $year^{-1}$. As a result, the amount of fertiliser-N to be supplemented on ley / arable maize plots would be 0 (1st yr) + 1 (2nd yr)+ 16 (3rd yr) = 17 kg N ha^{-1} (or 6 kg N ha^{-1} yr^{-1}).
Thus, during the first season following the 3-year grassland, it would be advisable to go without slurry- and fertiliser-N. During the second season, slurry-N (230 kg N ha^{-1}) without additional fertiliser-N should do; during the third season small amounts of about 20 kg fertiliser-N are to be applied in addition to the slurry.

On the permanent maize plots the optimum amount of additional fertiliser-N in practice would be 175 (= N_{opt}) – 138 (efficient slurry-N) = 37 kg N ha^{-1} yr^{-1}.

From these calculations, it can be concluded that growing maize in the ley / arable rotation could result in an average saving of 37 – 6 = 31 kg N ha^{-1} yr^{-1}.

However, the actual average N fertiliser use on the arable land of monitored Flemish dairy farms of the official Farm Accountancy Data Network ('average' farms usually apply slurry but few have ley-arable rotations) was 57 kg N ha^{-1}. Thus, even higher effective savings of N fertiliser input in maize of up to ± 50 kg ha^{-1} could be realised in practice when applying ley / arable rotations adequately. Applying 50 kg less N ha^{-1} on 25% of the Flemish silage maize land would mean a yearly saving of more than 2 million kg of fertiliser-N.

The risk of excessive nitrate leaching following the cultivation of the three-year grassland can be reduced by using fodder beet or silage maize with undersown Italian ryegrass as catch crop following grassland.

Conclusion

(Re-)introduction of ley / arable rotations (a typical but regrettably forgotten traditional Flemish agricultural practice) on dairy farms could be an effective tool for a significant further reduction of the use of external mineral N-input and an increase of the N use efficiency on Flemish dairy farms.

References

Nevens, F., 2003.
Nitrogen use efficiency in grassland, silage maize and ley / arable rotations. Ph.D. Thesis, Ghent University, Belgium, 231 pp.

Nevens, F. & D. Reheul, 2001.
Crop rotation versus monoculture; yield, N yield and ear fraction of silage maize at different levels of mineral N fertilization. *Netherlands Journal of Agricultural Science,* 49, 405 – 425.

Nevens, F. & D. Reheul, 2003.
Permanent grassland and 3-year leys alternating with 3 years of arable land: 31 years of comparison. *European Journal of Agronomy,* 19, 77 – 90.

Nevens, F. & D. Reheul, 2002.
The nitrogen- and non-nitrogen effect of ploughed grass leys on the following arable forage crops: determination and optimum use. *European Journal of Agronomy,* 16, 57 – 74.

Nevens, F. & D. Reheul, 2004.
Moderate slurry application in Flemish silage maize: yields and nitrate leaching risk at economical optimal inorganic nitrogen supplementation. Submitted to *European Journal of Agronomy.*

16. Nitrate leaching from reseeded grassland: The effect of season, technique of renewal and former N fertilisation

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Abstract

Reseeding of grassland may increase the mineralization of organic material and lead to a greater amount of mineral nitrogen in soil, which can be leached during the winter-period.
In this experiment nitrate leaching was measured after reseeding of an 8-year old pasture on a sandy soil in northwest Germany. Several factors, which may influence the intensity of the mineralization, were investigated in two years after reseeding: the season of reseeding, spring or late summer/autumn; the technique, rotary cultivator or direct drilling; the amount of N-fertilisation, 0 or 320 kg N ha^{-1} y^{-1} in seven years before the reseeding. Nitrate-N leaching losses during winter were significantly higher following late summer reseeding (36-61 kg N ha^{-1}) compared to reseeding in spring (1-6 kg N ha^{-1}). This effect was only seen in the first, not in the second winter after the reseeding. The technique had no significant influence on the nitrate-N leaching losses. The highest N losses (on average over 60 kg N ha^{-1}) appeared after reseeding high-fertilised grassland in late summer. To reduce N-leaching losses after reseeding it is therefore necessary to postpone the reseeding from late summer/autumn to spring or to reduce the amount of N-fertiliser before a reseeding in autumn, respectively.

Keywords: grassland, nitrate, leaching, reseeding

Introduction

A break-up of grassland for renewal will often increase the mineralization of accumulated organic material and release nitrogen (N) that may leach during the following winter periods. Sandy soils especially, are prone to N leaching losses from high amounts of soil mineral nitrogen in autumn. The potential for mineralization and the intensity of the actual mineralization are influenced by several factors, among which are: age and former use of the grassland, previous N fertilisation, and season and technique of reseeding. Shepherd *et al.* (2001) observed a relationship between the mineral-N-content in soil and the age of the grassland. The actual amount of N fertilisation can be of greater influence on N losses after reseeding than the previous management, for example the use as cut or grazed grassland (Eriksen, 2001). More technical aspects like season and technique of reseeding have also been found to have an effect on N mineralization (Lloyd, 1992; Djurhuus and Olsen, 1997).
The aim of this experiment was to analyse the effects of the factors 'previous N fertilisation', 'season of reseeding', and 'technique of reseeding' on N leaching after renewal, and to make recommendations for a reseeding practice with less adverse effects on groundwater quality in a water catchment area.

Materials and methods

The experiment was carried out on a sandy soil in northwest Germany. Factors and levels are shown in Table 1. After being used for several years as arable land, the field was converted to mown grassland in 1991.
The experiment lasted three years from 1999 to 2002. Each plot was 72 m^2 in size; three ceramic suction cups were installed at a depth of 75 cm in order to collect water for analysis of N concentrations in leached water.

Table 1. Design of the experiment.

Factor	Level		Notes
1. Season of reseeding	1.1	spring	reseeding in two years (1999 and 2000)
	1.2	late summer/autumn	
2. Previous N fertilisation	2.1	0 kg N ha^{-1} y^{-1}	over a period of 6-7 years
	2.2	320 kg N ha^{-1} y^{-1}	
3. Technique of reseeding	3.1	rotary cultivator	grassland sward killed with a total-herbicide
	3.2	direct drilling	

Number of replications is 2.

A few weeks before the intended reseeding date in spring (April) or late summer (August/September) the respective swards were killed with a herbicide (glyphosate). Plots were tilled with a rotary cultivator and re-compacted by a roller, and then sown or sown by direct drilling without prior tilling. After sowing all plots were carefully rolled again. The seed mixture used for sowing was a (German) standard GIIo, composed mainly of *Lolium perenne* (>50%) but without white clover. The previously fertilised plots (320 kg N ha^{-1} yr^{-1} as calcium-ammonium-nitrate) received N before the actual date of reseeding: 80 kg N ha^{-1} for the reseeding in spring and about 160-240 kg N ha^{-1} for the date of reseeding in late summer/autumn. No N fertiliser was applied after reseeding or in the following growing season. After harvesting in spring, forage could be harvested two to three times, while after the sowing date in late summer/autumn time was usually too short for harvesting the new sward before winter
The soil mineral N content (Nmin) up to 90 cm was measured in autumn before the beginning of the leaching period. During the period of leaching from mid-October to April (1999/00, 2000/01 and 2001/02), the leachate was sampled weekly and analysed for nitrate concentration.

Results and discussion

The time of reseeding had a significant influence ($p<0.001$) on the soil mineral N content (Nmin) in autumn following reseeding in 1999 and 2000 (Figure 1). After renewal of grassland in late summer the autumn Nmin was 70-74 kg N ha^{-1} compared to 17-26 kg N ha^{-1} when reseeding was done in spring. Also Francis *et al.* (1995) found a decrease in Nmin (119 to 21 kg N ha^{-1}) when they shifted the date of reseeding from autumn to spring. On a loamy soil, Shepherd *et al.* (2001) measured soil mineral nitrogen contents in autumn of 64 kg N ha^{-1} after the reseeding of a 5-year-old grassland sward in Great Britain. This figure compares well with the 72 kg N ha^{-1} determined on the 8-year-old sward on the sandy soil of this investigation. In the second year after the reseeding the Nmin showed hardly any differences between the two dates of reseeding and values were generally at a rather low level (18-29 kg N ha^{-1}).
The previous level of N fertilisation (0 or 320 kg N ha^{-1}) and the technique of reseeding, rotary cultivator or direct drilling, showed no significant effect on autumn Nmin for both years of reseeding.
There was, however, a statistically significant interaction between the time of reseeding and the previous N fertilisation on Nmin in autumn for the year 1999 ($p<0.05$), but not after reseeding in 2000 (Figure 1). While autumn Nmin after reseeding in spring was lower for the 320 kg N ha^{-1} plots compared to 0 kg N, the highest values were observed for the combination of previously high N fertilisation (320 kg N ha^{-1}) and reseeding in late summer (81-96 kg N ha^{-1}). These plots had received mineral N during spring and summer of about 160-240 kg N ha^{-1} until the date of renewal.

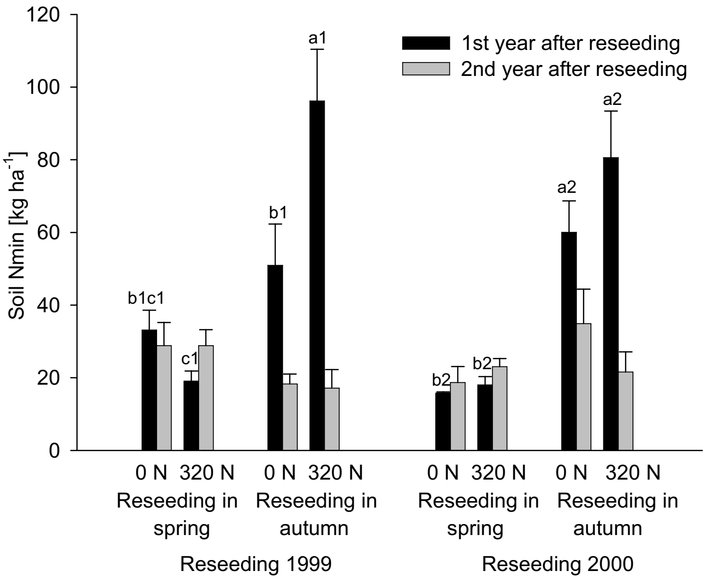

Figure 1. The effect of time of reseeding and the previous level of N fertilisation on the soil mineral N content (0-90 cm) in autumn for the first and second year after reseeding in 1999 and 2000; error bars are standard errors.

For the reseeding in 1999, the NO_3-N concentrations in the leachate showed a statistically significant influence of the season of reseeding ($p<0.001$) and the previous N fertilisation ($p<0.05$) (Figure 2A). Reseeding in spring generally resulted in NO_3-N concentrations below 10 mg NO_3-N l^{-1}, while a renewal in late summer led to higher NO_3-N concentrations.

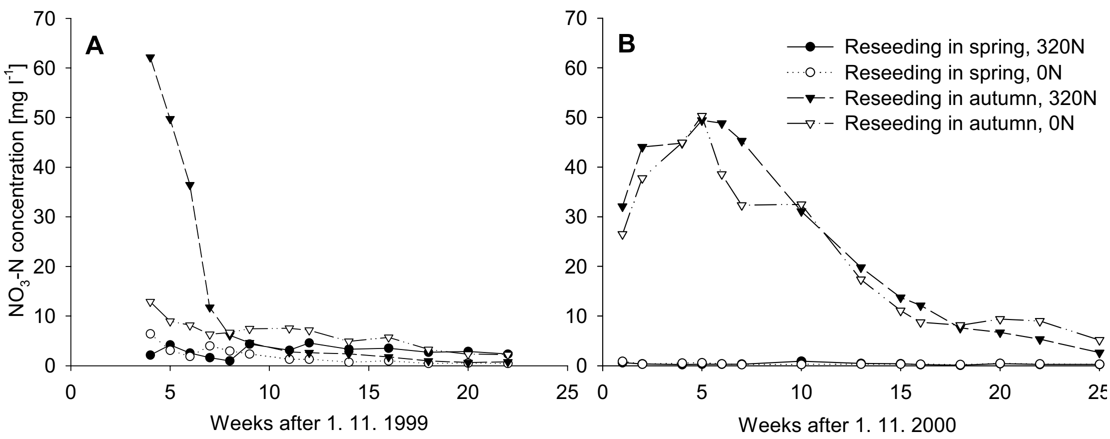

Figure 2. The effect of season of reseeding and previous N fertilisation on the nitrate concentration in leachate during the first leaching period after reseeding 1999 (A) and 2000 (B).

Below the fertilised plots, that were reseeded in late summer, NO_3-N concentrations of about 38-62 mg N l^{-1} were measured during the first three sampling dates. This is about five times the EU critical value for drinking water of 11.3 mg NO_3-N l^{-1}. After the fourth sampling date, concentrations fell below this critical value.
After reseeding in 2000, the season of reseeding had a statistically significant effect on NO_3-N concentrations, whereas the previous N fertilisation had no influence. As in 1999, reseeding in spring resulted in very low NO_3-N concentrations, while reseeding in late summer, for both, fertilised and unfertilised plots, resulted in concentrations which peaked at over 50 mg NO_3-N l^{-1}.

Nitrate-N leaching losses during the first winter were significantly higher following autumn reseeding (36-61 kg N ha^{-1}) compared to reseeding in spring (1-6 kg N ha^{-1}). This effect did not appear in the second winter after reseeding (Figure 3). Francis *et al.* (1995), in experiments in New Zealand, found decreasing N losses with leached water (89 to 9 kg N ha^{-1}) by shifting the reseeding from early autumn to spring. Shepherd *et al.* (2001) also measured nitrate-N losses as low as 3-10 kg N ha^{-1} after reseeding in spring.
During the second winter after reseeding, N losses were quite low. The significantly higher N losses for the 1999 reseeding in spring of about 15 kg N ha^{-1} compared to the 4 kg N from plots reseeded in late summer/autumn are somewhat unusual. N leaching losses in the second winter after reseeding of 1-7 kg N ha^{-1}, which is not higher than that from undisturbed cut grassland, were also found by Shepherd *et al.* (2001).

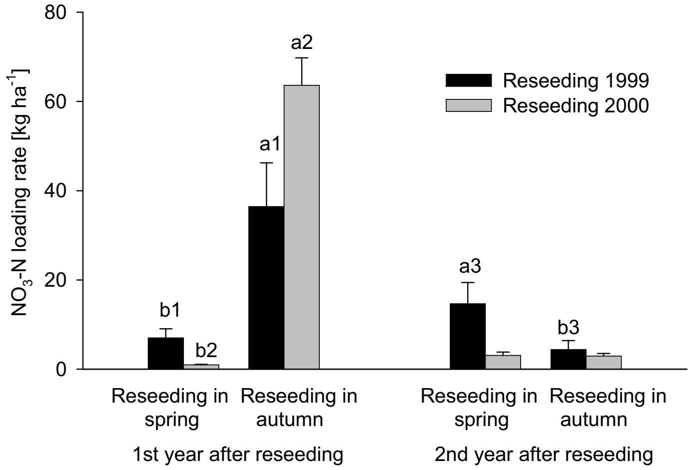

Figure 3. The effect of season of grassland renewal on N leaching losses for the following two winter leaching periods (mid-October to April); error bars represent standard errors.

The previous N fertilisation had relatively little effect on N leaching after reseeding (Figure 4). This is true especially for reseeding in spring. However, there were more pronounced N losses from the highly fertilised plots that were reseeded in late summer/autumn. This can, at least partly, be explained by the fertiliser-N these plots had received during summer, before the reseeding in late August or early September.

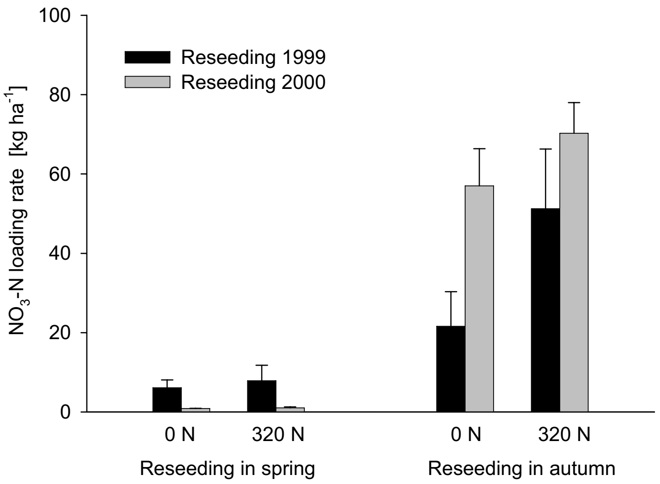

Figure 4. The effect of time of reseeding and the previous level of N fertilisation on N leaching losses during the first winter after reseeding (mid-October to April); error bars are standard errors.

The technique of reseeding, either direct drilling or rotary cultivator, had no significant influence on the nitrate-N leaching losses.

Conclusions

In order to minimize the risk of groundwater pollution in water catchment areas, grassland renewal in spring should be chosen over reseeding in autumn. For fields with similar conditions as described here, the influence of the previous level of N fertilisation and the technique of reseeding can be disregarded, when grassland is reseeded in spring.
If it is necessary to reseed grassland in late summer/autumn, fertilisation in the summer before should be avoided to prevent high N leaching losses.
It might not be appropriate to directly transfer the results from these experiments to sites on heavier soils with higher clay content. While the effects of date of reseeding might also hold true for other soils, the impact of the previous N fertilisation and follow-up effects in the coming years might be of greater importance on heavier soils and direct drilling could be more beneficial.

References

Djurhuus, J. & P. Olsen, 1997.
Nitrate leaching after cut grass/clover leys as affected by time of ploughing. Soil Use and Management, 13, 61-67.
Eriksen, J., 2001.
Nitrate leaching and growth of cereal crops following cultivation of contrasting temporary grasslands. Journal of Agricultural Science, 136, 271-281.
Francis, G.S., R.J. Haynes & P.H. Williams, 1995.
Effects of the timing of ploughing-in temporary leguminous pastures and two winter cover crops on nitrogen mineralization, nitrate leaching and spring wheat growth. J. Agric. Sci. 124, 1-9.
Lloyd, A., 1992.
Nitrate leaching under arable land ploughed out from grass. The Fertilizer Society. Proceeding No. 330. International Conference in Cambridge, 16-17 December 1992.
Shepherd, M.A., D.J. Hatch, S.C. Jarvis & A. Bhogal, 2001.
Nitrate leaching from reseeded pasture. Soil Use and Management, 17, 97-105.

17. Effects of grassland renovation on crop and animal performance

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Abstract

Evidence for the expected increases in crop and animal performance following sward renovation of permanent grassland, and in the early grass phase of grass-arable rotations, is reviewed. There is considerable variation in actual yield increases obtained. Grassland management (e.g. fertiliser inputs, irrigation, utilization methods, and botanical composition) influence the changes in herbage yield and animal performance over successive years, with implications for length of the grass-phase in the grass-arable cropping system. Opportunities for maintaining yield levels are less well documented; this aspect warrants further research.

Keywords: renovation, grass-arable, permanent grassland, yield-increase

Introduction

The main reason for grassland renovation is an expected improvement in crop and animal performance. Intensively used grasslands exist within grass-arable systems and in permanent grassland systems. The grass-arable rotation system, with a grass phase of 2-4 years duration, has its origin in the positive residual effects of the grass on the following arable crops, in terms of increased soil fertility, and reduced crop diseases and weeds. These benefits are especially important in organic and other low-input systems, and for some climatic regions this grass-arable system is considered essential for adequate crop yield levels to be maintained. Furthermore, there is an assumption that higher yields will be obtained in the grass phase, when compared with longer term grasslands, and the net gain of the whole crop rotation is assumed to be higher than from crops in monoculture. Unlike grass-arable rotation systems, sward renovation in permanent grassland is for the sole objective of grassland improvement. Sward renovation usually involves complete reseeding after destruction and cultivation, but may also take a partial form, e.g. oversowing an existing sward with minimal disturbance. In all cases there is an assumption that net gains in herbage production and/or quality will offset the cultivation costs, short-term production loss etc. during establishment. Before the widespread availability of artificial fertilisers, ploughing and reseeding of old swards was advocated as a means of releasing accumulated fertility to enable increased production from new swards of improved cultivars. The aim of this paper is to review if the expected yield-increase takes place in the two grassland systems, the possible effects of different managements and the implications for animal performance.

Crop yield after renovation

Under cutting conditions the yield is often reported to decrease over succeeding years, with the highest yield in the first harvest year, and the decrease from the first to the second year is often greater than between the other years. Examples are shown in Table 1, with and without clover in the sward, and at different yearly N-rates. The examples show mostly a decrease, but the decreases are of different size. Under grazing conditions the reports show a greater variation in the yield progress and there seems not to be a specific trend, which is illustrated with examples in Table 2. This can indicate that the yield-decrease is not so distinct under grazing conditions; this was also formulated a long time ago by Pollitt (1947) 'the yield decline often observed in aging swards under cutting regime was not to be expected to same extent on grazed grassland' (from Nevens & Reheul, 2003).

Table 1. Herbage yield (year 1 = 100) under cutting conditions after renovation at different yearly N-rates.

	Years after renovation					
	1	2	3	4	5	
Grass/clover						
0 N	100	105	103			Laidlaw (1980)
90 N	100	92	92			
0 N	100	78	79	78	72	Schils (1997)
100 N	100	77	79	81	72	
Pure grass						
200 N	100	88	93	83		Jackson & Williams (1979)
400 N	100	83	72	83		
150 N	100	84	74			Hopkins *et al.* (1990)
300 N	100	87	78			

Table 2. Herbage yield (year 1 = 100) under grazing conditions after renovation at different yearly N-rate.

	Years after renovation					
	1	2	3	4	5	
Grass/clover						
60 N	100	104	78	105	80	Steen & Laidlaw (1995)
360 N	100	106	91	92	69	
230 N	100	106	109			Nevens & Reheul (2003)
350 N	100	105	97			
Pure grass						
250 N	100	87				Lantinga *et al.* (1999)
400 N	100	83				
200 N	100	84	70	71		Jackson & Williams (1990)
400 N	100	84	67	71		

With a high level of N-application it is well known that the content of clover in the sward highly decreases just as the tiller density of grass. The yield-decrease over years could, therefore, be expected to be greater at a high N-level. This is supported by Gregersen (1980), who found, for pure grass swards, that the yield decrease from the first to the third years, under cutting conditions, was 10, 17, and 21% at a yearly N-level of 100, 300 and 450 N ha^{-1}, respectively. Some of the examples in Tables 1 and 2 also support this, but mostly there were no effect of the N-rate.

In grass/clover swards the effects of strategic N-fertilization has been examined very well, especially under cutting conditions (e.g. Frame & Newbould, 1986). Strategic N-fertilization involves the use of nitrogen to improve the seasonal herbage production, mainly in spring, when the growth of white clover is low due to low temperatures. In that way the growth profile can be manipulated just as the clover content and the density of clover growing points. With spring N-application the white clover content is low in spring and increases during the growing season. The persistence of the sward could, therefore, be expected to increase compared with a more even application of N. However, this topic has not been examined as far as is known.

N-response after renovation

Nitrogen is a management factor that greatly influences the production profile and yield. The grass-arable system is characterized by a build-up of soil-N during the grass-phase, especially under grazing, and a decrease of soil-N during the arable phase. Although a greater yield-response to N at the beginning of the grass phase might be expected because of the lower soil-N content, this has not been confirmed unambiguously (Table 3). The greatest decrease was found in the two cutting experiments, which indicates an effect of grazing/cutting regime. In low input systems other nutrients could have a contributory effect for the variable results, as Baars (2002) found that P and K level should be sufficient for a yield increase.

Table 3. The N-response rate (yield per kg N applied).

	Years after renovation					
	1	2	3	4		
Grass/clover (200 ⟶ 400 kg N)						
Grazing	5.9	3.9	2.9	4.4	(kg DM kg^{-1} N)	Jackson & Williams (1979)
Grass/clover (230 ⟶ 355 kg N)						
Grazing	0.021	0.054	-0.005		(GJ NEL kg^{-1} N)	Nevens & Reheul (2003)
Grass/clover (0 ⟶ 225 kg N)						
Cutting	15.7	8.5			(kg DM kg^{-1} N)	Søegaard (2004)
Pure grass (150 ⟶ 300 kg N)						
Cutting	26.8	14.1	15.4		(kg DM kg^{-1} N)	Hopkins *et al.* (1990)

Yield increase after renovation of permanent grassland?

Reseeding of permanent swards might not always result in net benefits. Permanent and reseeded grassland were compared in northern England: increased productivity from sown swards under low N inputs, was attributed to more clovers in the new sward, whereas under high N inputs (>250 kg ha^{-1}) the DM production differences between sown and permanent swards were negligible (Mudd, 1971). The results of multi-site comparisons of permanent and sown swards under identical management showed that the amount of additional DM production obtained was, on average, 40% more DM yield ha^{-1} than permanent grassland in the year following reseeding (Table 4). Differences in DM yield between the sward types were much reduced in subsequent years except under high inputs N (e.g. 450 kg ha^{-1}) and where white clover was included in nil-N reseeds. Under 4-weekly harvesting, mean N response rate was lower for permanent swards (15 kg DM per kg N) than for the reseeded swards (19 kg DM per kg N). Furthermore, there may be higher forage quality from reseeded grassland, improved ensilability and seasonal distribution of production, e.g., under 4-weekly harvesting, mean DOM values were 0.66-0.70 for permanent swards and 0.70-0.72 for perennial ryegrass reseeded swards (Hopkins *et al.*, 1990). In a Belgian research over 31 years the yield from permanent grassland was the same as from grass in a grass-arable system (Figure 1) (Nevens & Reheul, 2003). The permanent grassland was established with a mix of grass species and developed gradually to a sward composed of primarily perennial ryegrass (*Lolium perenne*) and rough-stalked meadow grass (*Poa trivialis*). The grass in the grass-arable system consisted of a high proportion of perennial ryegrass and white clover (*Trifolium repens*), but the clover content was low due to N-fertilisation (230-350 kg N $year^{-1}$).

Table 4. Resowing of permanent swards at 16 sites, four weekly cuttings (after Hopkins et al., 1990).

	Year 1			Mean of year 1-3		
kg N ha^{-1}	0	150	300	0	150	300
DM yield of permanent sward (t ha^{-1} y^{-1})	3.73	6.26	8.17	4.35	7.08	9.01
% gain in DM yield from reseeded swards						
Pure grass	44	41	44	2	7	15
Grass/clover	48			31		

Effect of management

Climatic factors – through the effects of summer drought and winter cold - could have a crucial effect on the persistence, exemplified by Lien *et al.* (2003) who considered winter damage to be the main reason for yield decrease under colder climates, and by Gregersen (1980), who showed that there was a lower rate of yield decrease over the years with irrigation than without irrigation, 55% and 68% over five years respectively. However, management factors also affect the persistence. The challenge is to realise these effects and to combine the managements to maintain a high rate of herbage production with a high herbage quality.

Effect of species

Early experiments and observations showed increased livestock production and grazing days following renovation, except where the permanent swards contained high proportions of perennial ryegrass and white clover (Williams & Davies, 1954). This indicates that the botanical composition of the old sward is important for the effect of renovation. In more countries the criteria for renovation is based on the botanical composition (Table 5) with limits for undesirable or desirable (high productive and high quality grass) species.

Incorporation of white clover in the sward seems, in some instances, to give rise to a lesser yield decrease over years. In a multi-site experiment, incorporation of white clover in the reseeded sward increased the yield compared with the old sward over a longer period than without white clover (Hopkins *et al.*, 1990; Table 4). In another multi-site experiment, Gregersen (1980) also found a lower yield reduction over five years in nil-N grass/clover (51%) than in 300 N pure grass (58%). In the examples shown in Table 1 and 2 there is, especially under grazing, a tendency for a lower rate of yield decrease in grass/clover than in grass swards.

Table 5. Criteria for ploughing grass swards (after Conijin et al., 2002).

the Netherlands	Lower than 50% perennial ryegrass More than 10% couch grass
Belgium	More than 15% couch grass
Ireland	Lower than 40% perennial ryegrass More than 30% undesirable species

Effect of varieties

Expected higher yield of new varieties can underlie renovation of old permanent grassland. However, it is difficult to prove this statement. Even though new cultivars with higher persistence have been bred, and a lower yield decrease over years could be expected, there still seems to be a yield decrease with these cultivars under cutting conditions (Wilkins *et al.*, 2000). Furthermore, in the long-term experiment of Nevens and Reheul (2003), there was not a higher yield in a grass-arable system under grazing conditions, even though new varieties were used in the grass-arable system (Figure 1). During the whole experimental period of 31 years the reseeded grass did not out-yield the old permanent sward.

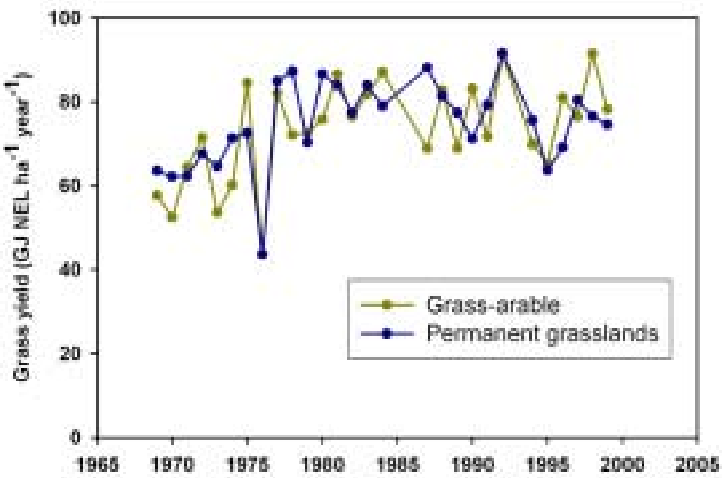

Figure 1. *Grass yield of permanent grassland and grass in a grass-arable system with two transposed three-year grass and three-year arable crops. Results from years with the same N-rates in the two systems within years (after Nevens & Reheul, 2003).*

Effect of cutting/grazing

Grazing and cutting have a great effect on the sward, both because of the high return of N-excretion from the grazing animal and because of the effect on the herbage composition, morphological development etc. In Tables 1 and 2 it was indicated that the yield-decrease over successive years could, in some instances, be lower under grazing than under cutting.

In a direct comparison, Schils *et al.* (1999) found a lower yield decrease with grazing, including one cut, than in a cutting-only system. The overall mean clover content was 30%. The positive after-effect of grazing was measured to be highest in the first cut the following year (Søegaard, 2004). The after-effect on both dry matter yield and percentage of white clover was the same in a wide rage of N-rates (Figure 2). The effect of grazing could be due to a higher tillering under grazing and to a higher soil N-level because of N-excretion.

Table 6. *Yield of grass/clover after reseeding under a cutting and a grazing regime. Mean of 0 and 50 N-rates (after Schils et al., 1999).*

	Years after renovation			
	1	2	3	4
Rotational grazing+ 1 cut	1.00	1.03	0.72	0.90
Cutting only	1.00	0.91	0.70	0.82

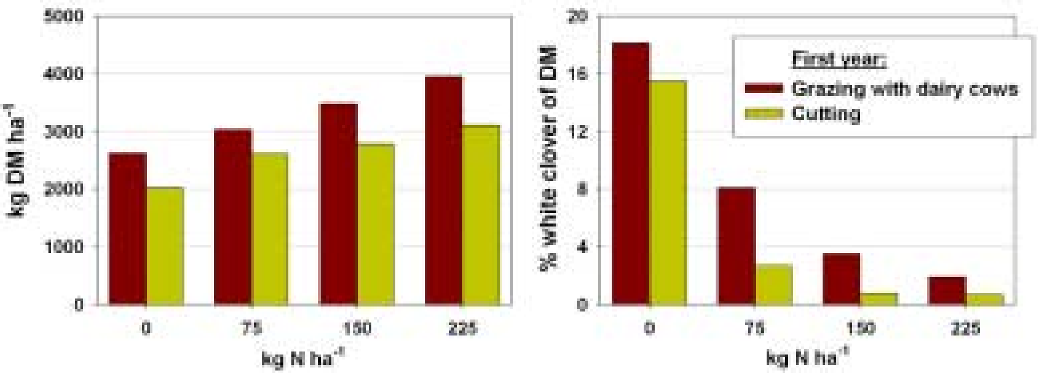

Figure 2. *Yield and clover content of grass/clover in the first cut after grazing or cutting in the previous year (after Søegaard, 2004).*

Effect of autumn management

With the decreasing level of yearly N-rates due to legislation, a greater part or the whole part is applied in the first half of the growing season, and especially in pure grass this could have an effect on the overwintering. The effect of autumn N-application on the following spring production was examined by Culleton *et al.* (1991). They found examples of both a positive effect and no effect (Figure 3). In the French experiment N-application encouraged tillering and N-content in the leaves in the autumn, which was not the case in the Irish experiment. They concluded that at an N level of 4 g kg^{-1} leaf dry matter autumn-N is not needed.

It has been well described that a high tiller density is necessary, if early grass is needed. Culleton *et al.* (1991) also examined the time for the last harvest in autumn. The tiller number was greatly affected; with about 1000 tillers m^2 more in the earliest harvest, and the spring growth was higher (Figure 3).

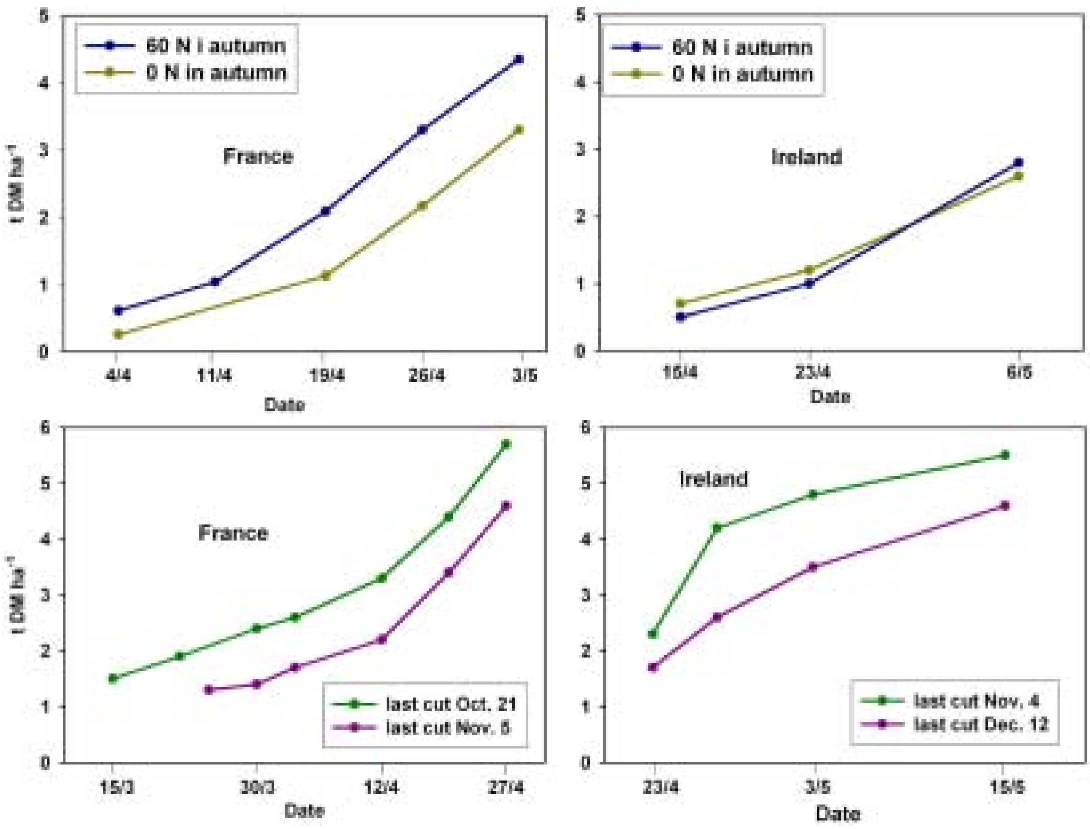

Figure 3. *Grass growth in spring after different N-rates and time for last cut in the previous year (after Culleton et al., 1991).*

Animal performance

The decline in qualitative and quantitative productivity is one of the criteria used to support renovation of permanent grassland swards. When the point is achieved that decreased feed potential is observed, farmers feel motivated to renovate their permanent grassland. However, renovation of permanent grassland involves a number of issues and few studies have compared the direct effect of forage produced from permanent and arable grassland on animal performance. The influence of grassland renovation on animal performance needs to take into account the following three points:

1. Expecting an improvement in animal performance, most farmers renovate their permanent grassland.
2. The influence of grassland renovation on animal performance may be confounded by external factors.
3. Animal physiological stage may influence performance and efficiency of nutrient utilization.

The three points mentioned above are discussed in more detail. First, the performance of animals receiving forage produced from permanent or arable grassland is closely dependent upon the achieved forage quality and DM yield. It is assumed that grassland renovation affects the animal performance and the value of animal output positively and therefore the decision to renovate old grassland relies mainly on the point when decreasing crop performance is observed. However, grassland renovation by ploughing and seeding may improve concomitantly soil compaction, soil drainage, soil fertility and presence of desirable species. Second, external factors others than grassland productivity have a significant influence on animal performance, i.e. improvement in the value of animal output can be achieved by adapting the diet composition in order to fulfil animal requirements. This might be the case with concentrates supplemented for dairy or beef cattle (Keating & O'Kiely, 2000; Coffey *et al.*, 2002). Animal performance is affected by supplementation, and animals receiving concentrate supplementation may excrete larger amounts of N, masking the effect of crop performance obtained with renovation of the old sward, especially under grazing. Over the long term, it might be expected that improving the productivity with grassland renovation reduces the concentrate input at farm level, because more animals can be maintained per unit of area of grazed grassland after renovation or, if fed silage from improved swards, there is the potential for conserved forage to supply an increased proportion of their dietary requirements. Third, the efficient nutrient use by ruminants may be influenced by animal physiological stage, e.g. lactating vs. dry cows, older vs. young animals. Comparisons among animal of different physiological stages result in different efficiencies in nitrogen utilization (Gierus *et al.*, 2001). For instance, younger animals are less efficient in nitrogen utilization than high yielding dairy cows.

Results from several studies investigating the effects of sward renovation on animal performance are summarized in Table 7. The experiments were carried out under different circumstances and decision to renovate grassland taken under different criteria. In this literature, criteria for renovation involved poor soil drainage and presence of less desirable species (Tyson *et al.*, 1992), low qualitative and quantitative productivity (Keating & O'Kiely, 2000), seasonal feed shortage with yearly introduction of annual grass species (Thom & Bryant, 1996; Coffey *et al.*, 2002) and legumes (Koch *et al.*, 1987), and sward improvement on poor soils (Koch & Mitchell, 1988). As shown in Table 7, grassland renovation improved animal performance at different levels, being closely dependent on DM yield. In comparison to the old pasture, the negative animal performance in the study of Thom and Bryant (1996) was attributed to difficulties in the establishment of the new seedlings and a low area from the old pasture used for reseeding. The low area reseeded affected the overall DM yield of the sward.

Table 7. Overview of grassland renovation types on animal performance results.

Renovation	Plant species introduced	Animal performance	Treatments	Relative results, %	Source[1]
Ploughing + reseeding	*Lolium perenne (LP)*	Animal grazing days/ha	200 N, old pasture (OP)	100	1
			400 N, OP	110	
			400 N, reseed	130	
Ploughing + reseeding	*Lolium perenne* *L. multiflorum (LM)*	Carcass gain kg/ha	OP	100	2
			LP-pasture	124	
			LM-pasture	127	
Herbicide + Oversowing	LP LM	Milk, kg/cow (whole season)	OP	100	3
			OP + LP (15% of OP)	93	
			OP + LM	98	
				Year 1	4
Oversowing	LM Rye Wheat	Life weight gain kg/day	OP	100	
			OP + LM	164	
			OP + Rye	146	
			OP + Wheat	152	
				Year 2	
			OP	100	
			OP + LM	168	
			OP + Rye	158	
			OP + Wheat	145	
				Year 3	
			OP	100	
			OP + LM	102	
			OP + Rye	101	
			OP + Wheat	105	
				Year 1	5
Herbicide + Oversowing	*Panicum frumentaceum* (Japanese millet, JM)	Life weight gain kg/ha	OP	100	
			OP + JM	107	
		Animal grazing days/ha	OP	100	
			OP + JM	144	
				Year 2	
			OP	100	
			OP + JM	102	
			OP	100	
			OP + JM	122	
				1. harvest, seeding year	6
Herbicide + Oversowing	alfalfa	N-intake, g/day	OP	100	
			alfalfa	135	
				1. harvest, following year	
			OP	100	
			alfalfa	106	
				2. harvest, following year	
			OP	100	
			alfalfa	116	

[1] *Tyson et al. (1992)*
[2] *Keating and O'Kiely (2000)*
[3] *Thom and Bryant (1996)*
[4] *Coffey et al. (2002)*
[5] *Koch and Mitchell (1988)*
[6] *Koch et al. (1987)*

It is known that the main difference between arable and permanent grassland after renovation is the potential mobilization of N from the soil bulk, increasing considerably the risk of nitrate leaching and, consequently the increase in non-protein nitrogen (NPN) content in plants as an immediate result. To avoid substantial N losses, the establishment rate of the new sward is an important attribute (Bussink *et al.*, 2002). In terms of forage quality, the high crude protein (CP) content and the fast protein degradation rate in the forestomach of the ruminant are in close relationship to the urine N excretion (Bannink *et al.*, 1999), especially when energy in the diet is limiting. The proportion of N excreted via urine varies from 40 to 80% of total N excreted (Oenema *et al.*, 2001), with high yielding animals also showing the highest N excretion rate in urine or milk on a per animal basis (Kirchgessner *et al.*, 1988). Measurements in high yielding dairy cows on nitrogen excretion demonstrated that increasing the amount of undegradable protein (UDP) as percent of CP in the diet, without limiting microbial growth in the rumen, is related to a lower urinary N excretion (Gruber *et al.*, 1998; Davidson *et al.*, 2003). Efforts to improve efficient N use of animals fed on arable or permanent grassland need to consider the forage quality, especially in terms of CP fractions (non-protein N, degradable protein and UDP) in the diet in combination with the overall digestibility.

Because several factors are involved to generate an animal response after grassland renovation, the single effect of grassland renovation, i.e. ploughing and reseeding old swards, may be confounded by several other effects. Fertilization is one of the key effects. Nitrogen fertilization level affects the form of N in herbage and N utilization by ruminants as well as the species composition and many herbage growth parameters. Fertiliser use and stocking density have implications not only for animal production but also for the sward persistence and by that the need for renovation. Other factors are: botanical composition of the new sward, genetic merit of the new forage specie(s), nutritional value of the introduced forage, tillage system, soil physical, biological and chemical properties after grassland renovation, defoliation system, spring/autumn renovation, climatic constraints throughout Europe (Conijn *et al.*, 2002; Conijn & Taube, 2003). In order to provide reliable results about the influence of grassland renovation on animal performance, such effects need to be considered in order to provide direct effects on animal performance in a multi-site experimental design.

Conclusions

At the present time, information in the literature concerning the long term effects of grassland renovation on forage yield and quality stability remains scarce. Animal performance is closely related to the forage quality obtained, and animals may be an interface between N utilization by plants and N losses on grassland areas.

References

Baars, T. (2002)
Reconciling scientific approaches for organic farming research. Part II. Effects of manure types and white clover (*Trifolium repens*) cultivars on productivity of grass-clover mixtures grown on a humid sandy soil. *Dissertation. Louis Bolk Institute*, pp. 345.

Bannink, A., Valk H. & Van Vuuren A.M. (1999)
Intake and excretion of sodium, potassium and nitrogen and the effects on urine production by lactating dairy cows. *Journal of Dairy Science,* 82, 1008-1018.

Bussink, D.W., Aarts H.F.M., Velthof G.L., Hoving I., van der Meer H. & van der Meer H.G. (2002)
Grassland renewing in relation to environmental and economical targets. *Grasland Science in Europe,* 7, 364-365.

Coffey, K.P., Coblentz W.K., Montgomery T.G., Shockey J.D., Bryant K.J., Francis P.B., Rosenkrans Jr. C.F. & Gunter, S.A. (2002).
Growth performance of stocker calves backgrounded on sod-seeded winter annuals or hay and grain. *Journal of Animal Science*, 80, 926-932.

Conijn, J.G. & Taube F. (2003)
Grassland resowing and grass-arable crop rotations. *Second Workshop of the EGF-Working Group*, Kiel, Germany, 27-28/2/2003. 78 pp.

Conijn, J.G., Velthof G.L. & Taube F. (2002)
Grassland resowing and grass-arable crop rotations. *International Workshop on Agricultural and Environmental Issues, Wageningen*, The Netherlands, 18-19/4/2002. 128 pp.

Culleton, N., Lemaire, G. & Keane, G. (1991)
The effects of autumn management on grass growth in winter and spring. *Irish Journal of Agricultural Research,* 30, 41-51.

Davidson, S., Hopkins B.A., Diaz D.E., Bolt S.M., Brownie C., Fellner V. & Whitlow L.W. (2003)
Effects of amounts and degradability of dietary protein on lactation, nitrogen utilization, and excretion in early lactation Holstein cows. *Journal of Dairy Science*, 86, 1681-1689.

Frame, J. & Newbould P. (1986)
Agronomy of white clover. *Advances in Agronomy,* 40, 1-88.

Gierus, M., Meijer G.A.L.& van Vuuren A.M. (2001)
Appearance of aminogenic nutrients in the portal vein as a tool for feed protein evaluation in the DVE/OEB System. *Proceedings of the Society of Nutrition Physiology*, 10, 56.

Gregersen, A. (1980)
Water and nitrogen fertilization to grass and grass/clover lasting for several years. *Tidsskrift for Planteavl*, 84, 191-208 (In Danish)

Gruber, L., Steinwidder A., Stefanon B. & Steinwidder R. (1998)
Impact of cutting frequency and fertilization of permanent grassland, and concentrate feeding level, on N excretion of dairy cows. *Grassland Science in Europe*, 3, 707-711.

Hopkins, A., Gilbey J., Dibb C., Bowling P.J. & Murray P.J. (1990)
Response of permanent and re-seeded grassland to fertilizer nitrogen. 1. Herbage production and herbage quality. *Grass and Forage Science,* 45, 43-55.

Jackson, M.V. & Williams T.E. (1979)
Response of grass swards to fertilizer N under cutting or grazing. *Journal of Agricultural Science*, Cambridge 92, 549-562.

Keating, T. & O'Kiely P. (2000)
Comparison of old permanent grassland, *Lolium perenne* and *Lolium multiflorum* swards grown for silage. 1. Effects of beef production per hectare. *Irish Journal of Agricultural and Food Researc*h, 39, 1-24.

Kirchgessner, M., Paulicks B.R. & Schwarz F. J. (1988)
Veränderungen im Harnstoffgehalt der Kuhmilch bei unzureichender oder überhöhter Proteinversorgung. *Journal of Animal Physiology and Animal Nutrition*, 59, 79-84.

Koch, D.W., Holter J.B., Coates D.M. & Mitchell J.R. (1987)
Animal evaluation of forages following several methods of field renovation. *Agronomy Journal*, 79, 1044-1048.

Koch, D.W. & Mitchell, J.R. (1988)
Potential of Japanese millet as an initial crop in a no-till forge renovation program. *Agronomy Journal*, 80, 471-474.

Laidlaw, A.S. (1980)
The effects of nitrogen fertilizer applied in spring on swards of ryegrass sown with four cultivars of white clover. *Grass and Forage Science,* 35, 295-299.

Lantinga, E.A., Deenen P.J.A.G. & van Keulen H. (1999)
Herbage and animal production responses to fertilizer nitrogen in perennial ryegrass swards. II. Rotational grazing and cutting. *Netherlands Journal of Agricultural Sciences,* 47, 243-261.

Lien, G., Kristensen A.R., Hegrenes A. & Hardaker J.B. (2003)
Optimal length of leys in an area with winter damage problems. *Grass and Forage Science*, 58, 168-177.

Mudd, C.H. (1971)
Yields of natural and artificial grassland under five levels of fertilizer treatment. *Proceedings of the 4th General Meeting of the European Grassland Federation, Lausanne*, 1971, 69-72.

Nevens, F. & Reheul D. (2003)
Permanent grassland and 3-year leys alternating with 3 years of arable land: 31 years of comparison. *European Journal of Agronomy*, 19, 77-90.

Oenema, O., Bannink A., Sommer S.G. & Velthof G.L. (2001)
Gaseous nitrogen emissions from livestock systems. In: Follet, R.F., Hatfield, J.L. (eds) *Nitrogen in the environment: sources, problems and management,* Elsevier, Amsterdam, NL, pp. 255-290.

Schils, R. (1997)
Effect of spring application of nitrogen on the performance of perennial ryegrass-white clover swards at two sites in the Netherlands. *Netherlands Journal of Agricultural Sciences,* 45, 263-275.

Schils, R., Vellinga Th.V. & Kraak T. (1999)
Dry matter yield and herbage quality of a ryegrass/white clover sward in a rotational grazing and cutting system. *Grass and Forage Science,* 54, 19-29.

Søegaard, K. (2004)
Nitrogen fertilization of grass/clover at different managements. Grazing, cutting, age of the sward and seasonal N-fertilization. *DJF-report* nr. 106, 42 pp.

Steen, R.W. & Laidlaw A.S. (1995)
The effect of fertiliser nitrogen input on the stock-carrying capacity of ryegrass/white clover swards continuously grazed by beef cattle. *Irish Journal of Agricultural and Food Research,* 34, 123-132.

Thom, E.R. & Bryant A.M. (1996)
Use of Italian ryegrass on seasonal dairy farms in northern New Zealand. 2. Milk production. *New Zealand Journal of Agricultural Research*, 39, 237-244.

Tyson, K.C., Garwood E.A., Armstrong A.C. & Scholefield D. (1992)
Effects of field drainage on the growth of herbage and the liveweight gain of grazing beef cattle. *Grass and Forage Science*, 47, 290-301

Wilkins, P.W., Allen D.K. & Mytton L.R. (2000)
Differences in the nitrogen use efficiency of perennial ryegrass varieties under simulated rotational grazing and their effects on nitrogen recovery and herbage nitrogen content. *Grass and Forage Science*, 55, 69-76.

Williams, T.E. & Davies W. (1954)
Cattle fattening on permanent grass and leys. *Journal of the Royal Agricultural Society of England,* 115, 98-111.

18. Effects of grassland cultivation on N and C cycles and soil quality dynamics

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Abstract

Recent research on grassland cultivation in ley-arable rotations was reviewed in an EGF Working Group. This paper draws on that report and summarises the effects of ploughing grassland on C and N cycles and the interactions of soil organic matter with soil quality.

Keywords: grassland cultivation, soil quality, environmental impacts, nitrogen

Introduction

The cultivation of permanent pasture and re-sowing to grass leys has long been recognized as a means of exploiting the accumulated biological, chemical and physical fertility of the soil. However, the consequences of grassland cultivation are now also becoming increasingly important because of their environmental impacts. The recent reports of the EGF working group on grass-arable rotations reviewed and discussed those components (Conijn *et al.*, 2002). This paper reviews the effects of grassland renovation on C and N cycles and soil quality.

Soil organic matter (SOM) and carbon cycling

Soils perform a number of key agronomical and environmental functions, and SOM, as a result of abiotic conditions and biotic activities, is the 'hub' of these functions: e.g. plant nutrition, structural stability enhancing rooting and water use, filtering effects influencing water and air quality, microbiological processes and biodiversity. Three important characteristics of SOM and C and N cycling under grasslands are:

- organic matter accumulation (litter, roots, animal returns etc.),
- large amounts of fresh, easily degradable plant biomass are present at the time of cultivation,
- net mineralization is close to that observed in arable soils and results from higher gross fluxes (Recous *et al.*, 1997, Tlustos *et al.*, 1998).

Long-term SOM accumulation under grassland, especially grazed grassland, is well understood (Johnston *et al.*, 1986; Conijn *et al.*, 2002). However, the information on short term C and N storage (Whitehead *et al*, 1990, Velthof *et al.*, 2001) and the quality of this 'new' SOM, is limited (Springob, *In*: Conijn *et al.*, 2003). In permanent grasslands, SOM accumulation is often due to physico-chemical limitations on mineralization. A high proportion of organic inputs is derived from roots, and grass roots are more resistant to decomposition than roots of annual crops because of higher contents of lignin and phenolic compounds. Grass roots are better protected from degradation within the undisturbed soil matrix, where high microbial biomass activity promotes aggregation and soil structural stability (Six *et al.*, 2002). The SOM accumulation in ley-arable soils is less than in permanent grasslands, but greater than in continuous arable systems. It depends on the length of the grassland period, N inputs, type of crop and soil cultivation (Recous *et al.*, 1997; Velthof *et al.*, 2001). Tillage of grassland increases the rate of breakdown of litter and SOM by disrupting aggregates and increasing soil aeration: high C losses have been recorded (up to 2.6 t C ha^{-1}) during 3 months after cultivation, i.e. twice the emission from the untilled soils (Eriksen and Jensen, 2001). Balesdent *et al.* (In: INRA Expertise 2002) noted that if C loss is greatest just after ploughing (mean value of 1t C ha^{-1} yr^{-1} released), it is still important after 20 years. However, when arable land was returned to permanent grassland, net C accumulation was only *c.* 0.5t C ha^{-1} yr^{-1}. Carbon sequestration rate depends on sward age, and half the C accumulation potential is reached after *c.* 6 years (range 4-11 years).

Thus, high net N (and C) mineralization fluxes after grassland destruction occurs because SOM accumulation temporarily ceases and the large pool of easily degradable organic residues decomposes rapidly on exposure to increased aeration and microbial attack.

Nitrogen mineralization

Cultivation of grassland increases the risk of nutrient losses. Recent work has quantified N and C mineralization, modelled the mineralization kinetics after grassland destruction and explained the determining factors (Conijn *et al.*, 2002). Large variability in N mineralization has been observed, varying with site, measurement methods, management and also vegetation (e.g. grass/clover vs. pure grass) and previous fertilization. Several methods have been developed, that try to minimise both soil disturbance and soil aeration, enable random soil sampling and provide an integrated estimate over a growing season (Jarvis *et al.*, 1996). In order of the simplest to the more complicated, the main methods were:

- N uptake of unfertilised crop or grass (+ mineral N remaining in soils at harvest)
- Mineral N and leaching profiles under bare soils (plus modelling)
- Laboratory incubations (bare soils, soil + grass residues)
- Field incubation methods
- Gross flux measurements
- Indicators research, such as testing chemical extraction methods (hot KCl), and labile organic components, OM fractions

Some common features are a high N mineralization rate (<100 to 400 kg.ha^{-1}) occurring during the 6 months following grass destruction. In grass-arable systems, the soil N supply of the cultivated grassland often exceeds the N uptake of the following crop (Nevens *et al.*, In: Conijn *et al.* 2002). There are two phases: a short-term one, with high potential rate of mineralization (1-2.5 kg N ha^{-1} day^{-1}) for 5-8 months, then a longer phase with rates equal or near to 'basal' soil mineralization rates (Vertès *et al.* In: Conijn *et al.*, 2002). Around 70 to 90% of cumulative mineralisation due to grassland destruction occurs during the first year. Between 3 and 10 years, grassland age is not a critical factor affecting mineralization rates, but less N mineralization occurs after cultivation of cut grass than after grazed grass. Incubation studies showed that N mineralization of fresh plant residues accounted for only 20% of total mineralization (25% for C), demonstrating the quantitative and qualitative importance of SOM accumulated in grassland.
More work is needed to find the most efficient way to benefit from nutrient release (economy on N fertilisers), and to reduce environmental risks by avoiding pollution swapping.
In particular, the determinant of N and C mineralization kinetics are not fully understood: observed variability was not well explained by N balance (including fertilization and management), neither amounts of N in grassland residues (or C/N), nor soil characteristics (%C, %N, C/N etc., Laurent *et al.,* 2004).
The strong effect of the destruction date on N use efficiency and N losses: (e.g. + 30-50% N losses if autumn vs early spring grassland destruction), the type of crop grown and the differential effects of rotations on N losses necessitates an integrated approach and the use of computer simulations at a system level to compare different managements (Morvan *et al.*, 2000).

Soil quality as affected by ley-arable rotations

The main environmental and agronomic issues concern:

- What are the effects of resowing on the C balance, and how it is related to soils in the context of climate change?

- What happens to soil biodiversity after to ploughing and resowing?
- Does soil structure and porosity dammages increase with swards age, and to what extent does ploughing improve the situation, for different soil types?
- Is there more water available to the grass (or arable) vegetation and how does it affect groundwater recharge, drainage fluxes and plant productivity ?

Physical properties (i.e. rooting capacity, water holding capacity, bearing capacity and susceptibility to soil compaction) are linked to SOM characteristics. The effects of grassland cultivation on these physical components are variable, usually difficult to quantify, and vary with soil type. For example, on peat soils in the Netherlands, some physical qualities (such as soil aggregate stability and bearing capacity) are rather negatively affected by grassland renovation (Schils *et al.*, In: Conijn *et al.*, 2002), but rooting capacity is often improved in new grassland, compared with old swards. Overall, the results of positive, neutral and negative effects of permanent grassland renovation on the soil quality varies with soil types and agricultural practices. Treading or scorching damage causes bare patches, resulting in infestation by annual weeds or resistant species (e.g. *Elymus repens)*, and in soil compaction. A better understanding of the capacity of soil to resist compaction, or to recover previous porosity and associated processes would help to prevent soil and grassland degradation.
Biological activity, which is a key factor influencing the changes in soil physical properties, is also affected by soil cultivation. Lamandé *et al.* (2003) observed differences in the abundance and structure of earthworm populations in a 12-year-old, vs. a 3-year-old pasture (in short rotation with maize for 20 years), with more effective soil porosity and better water circulation in the ley-arable rotation. Soil management affects the microbial community (Hatch *et al.*, 2000), with large differences in functional diversity between grassland and arable crops (Garland and Mills, 1991) and with a decrease in microbial diversity after grassland cultivation. Moreover, some indirect positive effects of grassland cultivation on following crops, such as better resistance to fungal diseases (Eriksen, 2001) may be linked partly to soil structural modifications.

Gaps in the knowledge and conclusion

- Theoretical models are currently unable to explain fully the integration of 'new' OM in the SOM pool and the decay of the 'old' OM. The different factors associated with this are important, not only when OM accumulates, but also when there are changes, e.g. following cultivation. Theoretical compartments are needed to describe measurable SOM fractions. Although significant results have been obtained from SOM fractionation methods, there is no general agreement on methodology. Finally, most SOM models are additive and little is known about the interactions between these compartments under field conditions.
- Turnover of roots under grassland is poorly understood, in terms of both rooting morphology and architecture. Sward botanical composition, including weeds present, and the previous management (N inputs etc.) will also affect root density and rooting depth and thereby affect the potential for root matter to contribute to the SOM. The location of 'new' SOM can affect C and N dynamics, and structural stability.
- There are some methodological problems (which cannot be fully reproduced in laboratory tests) e.g. how far can results of soil incubations be used to understand field processes? Moreover, the role of living roots in determining i) N uptake and competition with microbial N immobilization; ii) root exudation, which is likely to interact with other OM substrates for microbial activity; and iii) extension of the rhizosphere and interaction with the soil surface litter layer,
- Biological activity (microbes and fauna) performs functions that not only influence C and N fluxes, OM transformations, and nitrification and denitrification potentials, but also explains the status and fate of mineral N. As all these components depend partly on farming practices (e.g. C inputs from cattle excreta and manures), the accuracy of C budgets needs to be improved to accommodate the requirements of environmental policies.

One of the challenges now is to develop a widely applicable scheme with measures to maintain or increase soil quality and decrease nutrient losses from grass-arable rotations under different conditions, using the ideas and results of studies in different countries. One requirement should be to optimize the length of the grass and arable period in a rotation, according to production needs and environmental considerations.

References

Conijn, J.G., Velthof G.L. & Taube F. (2002)
Grassland re-sowing and grass-arable rotations. *PRI report* 47, 128 pp.

Conijn, J.G. *et al.* (2004)
Grassland Renovation. Report 2, PRI report n°80, 78 pp

Eriksen, J. & Jensen L.S. (2001)
Soil respiration, nitrogen mineralisation and uptake in barley following cultivation of grazed grasslands. *Biology and Fertility of Soils,* 33: 139-145.

Expertise INRA (2002)
C storage in French agricultural soils?. http://www.inra.fr/actualites/rapport-carbone.html.

Garland, J.L. & Mills A.L. (1991)
Classification and characterisation of heterotrophic microbial communities on the basis of patterns of community-level soil-carbon source utilisation. *Applied and Environ. Microbiology*, 57, 2351-2359

Hatch, D.J., Lovell, R.D., Antil, R.S., Jarvis, S.C. & Owen, P.M. 2000.
Nitrogen mineralisation and microbial activity in permanent pastures amended with fertiliser or dung. *Biology and Fertility of Soils*, 30, 288-293.

Jarvis, S.C., Stockdale, E.A., Shepherd, M.A. & Powlson, D.S. 1996.
Nitrogen mineralization in temperate agricultural soils: processes and measurement. *Advances in Agronomy*, 57, 188-235.

Johnston, A.E. 1986.
Soil organic matter, effects on soils and crops, *Soil Use & Management*, 2, 97-105.

Lamandé, M., Hallaire V., Curmi P., Pérès G. & Cluzeau D., 2003.
Changes of pore morphology, infiltration and earthworm community in a loamy soil under different agricultural managements. *Catena*, 54, 637-649

Laurent, F., Kerveillant P., Besnard A., Vertès F., Mary B & Recous S. (2004).
Effet de la destruction de prairies pâturées sur la minéralisation de l'azote: approche au champ et propositions de quantification. Synthèse de 7 dispositifs expérimentaux. Rapport ARVALIS – INRA, 76 p.

Recous, S., Loiseau P., Machet J.M. & Mary B. (1997)
Transformations et devenir de l'azote de l'engrais sous cultures annuelles et sous prairies. in *Maîtrise de l'azote dans les agrosystèmes*, éditions.INRA Colloques, 105-120

Six, J., Feller C., Denef K., Ogle S.M., Moraes Sa J.C. & Albrecht A. 2002,
Soil organic matter, biota and aggregation in temperate and tropical soils - effects of no-tillage, *Agronomie*, 22, 755-775

Stockdale, E.A., Hatch, D.J., Murphy, D.V., Ledgard, S. & Watson, C (2002).
Verifying the nitrification to immobilization ratio as a key determinant of potential nitrate loss in arable and grassland soils*. Agronomie,* 22, 831-838.

Tlustos, P., Willison T.W., Baker J.C., Murphy D.V., Pavlikova D., Goulding K.W.T. & Powlson D.S. (1998).
Short-term effects of nitrogen on methane oxidation in soils. Biol. Fert. Soils, 28; 64-70

Velthof, G.L. & Oemena O. (2001)
Effects of ageing and cultivation of grassland on soil nitrogen' Alterra Report 399, Wageningen, 55 pp.

Whitehead, D.C., Bristow A.W. & Lockyer D.R. (1990).
Organic matter and nitrogen in the unharvested fractions of grass swards in relation to the potential nitrate leaching after ploughing. *Plant and Soil*, 123, 39-49

19. Forage production in a crop rotation: impact of N intensity on performance and N surplus

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Abstract

Nitrogen (N) recovery in specialised dairy farms is known to be low due to high imports of N with fertiliser and purchased feed whereas only small amounts are exported with milk and meat. The traditional system of forage production in northern Germany comprises permanent grassland and maize in monoculture, and it is hypothesised, that overall N efficiency is higher, when forage is produced in crop rotations. Within an integrated project at the University of Kiel (Taube and Wachendorf, 2001), N fluxes in a forage crop rotation with clover/grass, silage maize, triticale (1 year each) at various levels of N supply were measured over a 3-year-period. N efficiency and energy yield of maize in rotation is high, even at low levels of N supply. Clover/grass and triticale have comparable yields but N surpluses of the ley are much lower. These data provide the potential to compare forage production systems with the help of simulation models (Rotz *et al.*, 2002).

Keywords: Crop rotation, silage maize, permanent grassland, N losses, N surplus, clover/grass

Introduction

From previous experiments with permanent grassland on sandy soils it became evident that N surpluses and leaching losses were low under cutting, but unacceptable high with grazing animals, due to the low N use efficiency of animals (Büchter *et al.*, 2002; Trott *et al.*, 2002; Wachendorf *et al.*, 2003). At the same site maize in monoculture proved a N-efficient crop with low N surpluses and leaching losses at low to moderate levels of N supply (Volkers *et al.*, 2002; Büchter *et al.*, 2003). These results lead to the idea that, inclusion of grassland in a crop rotation preceding maize and following cereals may reduce NO_3 leaching losses through an efficient uptake of N surpluses from the ley phase by maize. On the other hand negative ecological effects of maize cultivated in monoculture, e.g. soil erosion and humus degradation, may also be reduced. To evaluate the potential of this strategy a field experiment was established in 1999 at the same site as the permanent grassland and maize trials. This paper reports from a three year period.

Materials and methods

The experiments were conducted on the experimental farm 'Karkendamm' (mean precipitation 824 mm; mean temperature 8.4°C (1980-99); soil type: deep ploughed gleyic podzol; texture: sand with less than 5% clay; pH 5.6). The underlying data for adjusting stocking densities and amounts of slurry are deduced from a typical specialised dairy farm in with 1.8 LU ha^{-1} and 100 grazing days for cows and young stock per annum northern Germany. About 25 m^3 slurry ha^{-1} $year^{-1}$ would be applied in such farms. The clover/grass ley was managed as a mixed system with 2 cuts and 2 successive grazings. The last cut remained undisturbed on the field and was ploughed in before sowing of maize (catch crop). Silage maize was used for a whole crop silage and triticale as whole crop silage and grain, respectively. Three different scenarios of forage production have been established. For all scenarios the goal is to achieve a certain overall feed supply (roughages plus supplements) in order to obtain a given milk quota in the corresponding farms: Scenario 1, high forage production (average fertiliser N supply 150 kg N ha^{-1} + 25 m^3 slurry ha^{-1}), low supplementation; Scenario 2, reduced forage production (average fertiliser N supply 75 kg N ha^{-1} + 25 m^3 slurry ha^{-1}), medium supplementation; Scenario 3, low forage production (average fertiliser N supply 0 kg N ha^{-1} +

25 m3 slurry ha^{-1}), high supplementation. Mineral N intensity within a treatment was lowest for maize in order to achieve maximum advantage of the high N-use efficiency of maize,. To increase N_2-fixation by white clover, the grass ley received intermediate amounts of N. Assuming that maize takes up most of the available N from the grass ley, it was presumed that triticale needed the highest N supply to produce satisfactory yields (Table 1). In order to obtain an extended variation in N intensity in the trial, all intensity levels were conducted with and without the use of slurry. N balances on a field level only considered external N sources and were calculated as follows:

N input	N output
Mineral fertiliser N + slurry N + N biologically fixed by clover + deposition N	N yield in harvestable biomass - residual biomass N (grazed swards) - excrement N (grazed swards)

N surplus = N input – N output

The field experiment was conducted from 2000 to 2002. All crops were grown for one year. In each winter the soil was covered by a crop. In the experiment every crop was grown in each of the three years. The given results are therefore means over three years.

Table 1. N supply by mineral fertiliser and slurry at various intensity levels in the crop rotation trial.

	High Intensity (kg N ha^{-1})			Reduced Intensity (kg N ha^{-1})			Low Intensity (kg N ha^{-1})		
Crop	Fert.†	Slurry#	Total	Fert.	Slurry	Total	Fert.	Slurry	Total
Clover/grass (CG)	150	75	225	100	75	175	0	75	75
Silage maize (SM)	100	75	175	25	75	100	0	75	75
Triticale (TR)	200	75	275	100	75	175	0	75	75
Mean	150	75	225	75	75	150	0	75	75

†: *Mineral N fertiliser*
#: *3.1 kg total N m^{-3} slurry*

Results and discussion

Energy yield of silage maize is significantly higher than of triticale and about double the yield of clover/grass (Figure 1A). It is remarkable that, even without any N supply from slurry or mineral fertiliser, maize yields are above 90 GJ NEL ha^{-1}. This clearly reflects an efficient use of N released from the soil after incorporation of clover/grass residues prior to the sowing of maize. Energy yields of all crops increase linearly over the whole range of N input via slurry, mineral fertiliser and atmospheric deposition, with maize displaying the lowest marginal yields. Although two cuts were taken in spring removing considerable amounts of N, N still accumulated in the clover/grass year (Figure 1B). This is due to the low N retention of grazing animals in the second half of the growing season. The higher N use efficiency of triticale and particularly of maize results in a relatively low N surplus for the whole crop rotation. As a consequence of low surpluses and high energy yields per hectare, the N surplus per GJ NEL produced is much lower for maize than both other crops (Figure 1C). For all crops N surplus per GJ NEL is lowest at zero N supply by slurry or fertiliser and increases linearly with further increasing N supply.

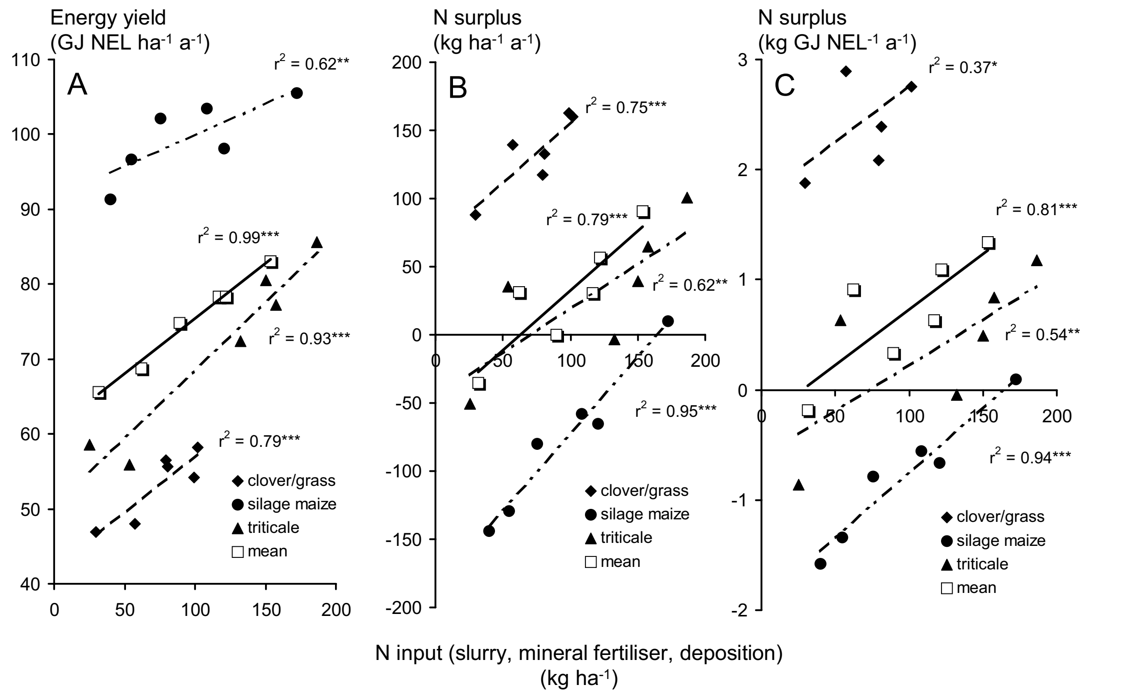

Figure 1. *Relationship between (A) energy yield, (B) N surplus per hectare and (C) N surplus per GJ NEL and N input by slurry, mineral feriliser and atmospheric deposition (Means on an annual basis of 2000 to 2002).*

Conclusion

The reduction of the grassland period to one year and the use of forage maize and cereals in the successive years results in relatively high N use efficiency in forage production. A direct comparison with permanent grassland and silage maize in monoculture, which is the common forage production system in major parts of Europe, is not possible due to different climatic conditions in the experimental years. However, these data provide the potential to compare forage production systems with the help of dynamic simulation models (Rotz *et al.*, 2002).

References

Büchter, M., Wachendorf M. & Taube F. (2002)
Nitrate leaching from permanent grassland on sandy soils – Results from an integrated research project. *Grassland Science in Europe* 7, 668-669.

Büchter, M., Wachendorf M., Volkers K. & Taube F. (2003)
Silage maize production on sandy soils in northern Germany: Impact of understorey, slurry and mineral N fertiliser on nitrate leaching *(In German). Pflanzenbauwissenschaften* (In press).

Rotz, C.A., Wachendorf M., Herrmann A., Kornher A. & Taube F. (2002)
A modelling approach to management impacts on nitrogen fluxes in specialised dairy farms. *Grassland Science in Europe* 7, 728-729.

Rotz, C.A., Satter L.D., Mertens D.R. & Muck R.E (1999)
Feeding strategy, nitrogen cycling, and profitability of dairy farms. *J. Dairy Sci.* 82, 2841-2855.

Taube, F. & Wachendorf M. (2000)
The Karkendamm Project: A system approach to optimize nitrogen use efficiency on the dairy farm. *Grassland Science in Europe*, 5, 449-451.

Trott, H., Wachendorf M. & Taube F. (2002)
Management of permanent grassland for reduced nitrogen surpluses - Results from an integrated research project. *Grassland Science in Europe* 7, 740-741.

Volkers, K., Wachendorf M. & Taube F. (2002)
Management of forage maize for reduced nitrogen surpluses - Results from an integrated research project. *Grassland Science in Europe* 7, 744-745.

Wachendorf, M. & Taube F. (2002)
Management impacts on nitrogen fluxes and nitrogen losses in grassland systems - Results from an integrated project. *Grassland Science in Europe* 7, 746-747.

20. Minutes of the meeting of the EGF-Working Group

J.G. Conijn & F. Taube

During the General Meeting of the EGF the Working Group 'Grassland Resowing and Grass-arable Rotations' met at Wednesday (11:30 – 12:15) for its yearly meeting. The minutes of this meeting are given below.

1) Session in Luzern
Prof. Taube thanked everyone for their contributions and especially those that have given an oral presentation. All presentations were well prepared and gave a good overview of the work of our Working Group in the past year(s).

2) Homepage
There will be a homepage with information of the Working Group at Plant Research International, Wageningen. Information about the Working Group, a member list, products (reports) and future plans will be made available on this homepage. First responsibility for developing and maintenance of this homepage lies in the hands of the secretary of the Working Group, i.e Sjaak Conijn (the Netherlands). It is planned to have the homepage active not later than the 1st of November 2004. The secretary of the EGF (W. Kessler) will be asked to put a link to this new homepage at the existing EGF-website.

3) Report 3
It was decided to publish report nr. 3 of the Working Group. The basis of this report will exist of all papers of our Working Group that have been published in 'Grassland Science in Europe' (Volume 9) with extra information added to those papers, such as tables and Figures from the posters or oral presentations. In many cases the posters and oral presentations contained other information than the written contributions for the proceedings of Luzern and bringing the two together in report 3 gives an extra possibility to communicate our knowledge on grassland renovation and grass-arable rotations. Report 3 will also contain other contributions, like country reports from new members in the same format as used in the Wageningen workshop. Closing date for sending the contributions for report 3 is 31st of October 2004.

4) How to continue?

4.1 Next topic(s)?
An agreement was met on the proposal to focus our work in the coming year(s) on the subject of C and N cycling. This subject links easily to important issues in the EU, like nitrate leaching and greenhouse gas emissions. From a EU-perspective answers are needed not only from the scientific point of view but also on how to apply our knowledge for policy makers and farmers/extension workers that have to respond to the demands of society.
We continue with the teams which have been already at work for Luzern: (1) soil processes, (2) crop & animal performance and (3) integration & modelling. Hatch and Vertès will be first responsible persons for team 1, Soegaard and Gierus for team 2 and Kristensen, Wachendorf and Conijn for team 3. Anyone who is willing to contribute to these teams/subjects should join and contact one of the 'team leaders'. First task of each team is to come with the most relevant questions and make proposals for answering them. This can be discussed in the Working Group (mostly by email) and forms the basis for presentations at next meeting (see 4.2).

4.2 Next presentation(s)?
The Working group decided to prepare presentations for the 14th N-workshop in Maastricht, The Netherlands (24-26 October 2005). The overall theme of this workshop is **'N management in agrosystems in relation to the Water Framework Directive'** and there is room for a special thematic working group on *'Effects of*

grassland renovation on water quality'. Oral and poster presentations will be selected on the basis of offered abstracts. Deadline of sending the abstracts is 24 April 2005.

5) Application for funding
The EGF-Working Group will apply for a COST-action to get financial support from the EU for meetings of the members of the Working Group. The core group that will prepare the application consists of Taube, Hatch, Aarts and Conijn and they will start the preparations for the application in autumn 2004.

6) Other questions

- It was confirmed that the Working Group is open to new members, also from countries that are not yet represented in the Working Group. New members were welcomed at the meeting from southern Germany, Austria and Poland (Elsässer, Pötsch, Golinski).
- David Hatch offered an alternative explanation of our logo which is more applicable to grass-arable rotations. The current explanation of the logo (see report nr. 2) is more or less limited to the situation where permanent grassland is ploughed and resown with grass again. Both explanations will be published with the logo in report nr. 3.

Part III.

Maastricht contributions

21. Grassland renovation: prudent or risky?

J.G. Conijn & F. Taube[2]

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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.

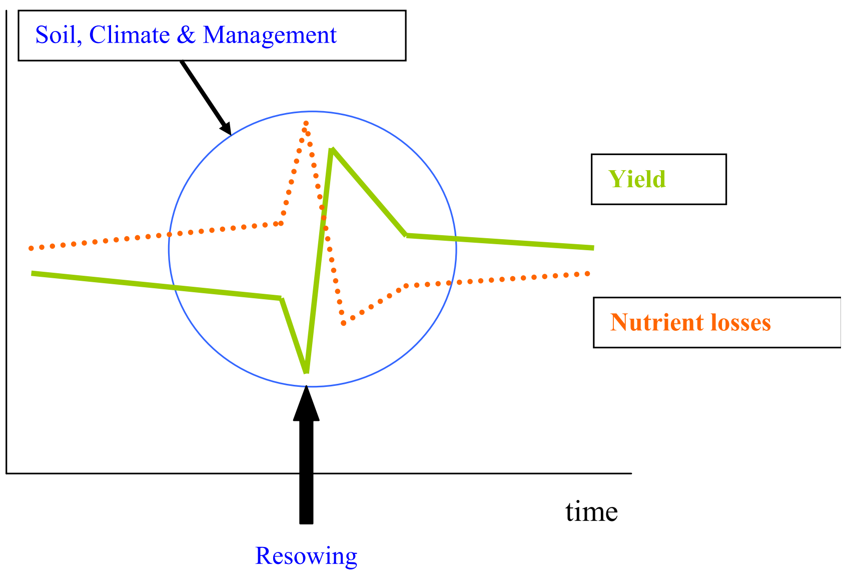

Figure 1. Hypothesised development of yield (continuous line) and nutrient losses (dotted line) before and after renovation of old grassland.

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.

References

Adams, W.A. & Jan M.T. (1999).
Utilization of nitrogen accumulated by a clover containing ley following cultivation. Soil Use and Management 15, 247-253.

Bommelé, L., Reheul D., Dekker P., Nevens F., Maes I. & De Cauwer B. (2006).
Nitrogen delivery after rotocultivated old and young grassland (This volume).

Conijn, J.G. (2006).
Simulated short and long term effects of grassland reseeding on nitrate leaching (This volume).

Conijn, J.G. & Taube F. (eds) (2004)
Grassland resowing and grass-arable crop rotations - Consequences for performance and environment. *Second workshop of the EGF-Working Group 'Grassland Resowing and Grass-arable Rotations'*, Kiel, Germany, 27-28 February, 2003. Plant Research International B. V., Wageningen, The Netherlands, report 80, 78 pp.

Conijn, J.G., Velthof G.L. & Taube F. (eds.) (2002).
Grassland resowing and grass-arable crop rotations. *International Workshop on Agricultural and Environmental Issues*. Plant Research International, Wageningen, The Netherlands, report 47, 128 pp.

Hansen, E. M., Eriksen, J. & Vinther, F. P. (2006).
Nitrate leaching following cultivation of grazed grass-clover on coarse sandy soil (This volume).

Nevens, F. & Reheul D. (2004).
Applying a ley/arable rotation to reduce N input in forages. In: Hatch D.J., Chadwick D.R., Jarvis S.C. and Roker J.A. (eds.). Controlling nitrogen flows and losses. Wageningen Academic Publishers, The Netherlands, 532-533.

Springob (2004).
C and N losses in sandy soils of NW Germany after conversion of grassland. In: Lüscher A., Jeangros B., Kessler W., Huguenin O., Lobsiger M., Millar N. and Suter D. (eds.). Land Use Systems in Grassland Dominated Regions. *Grassland Science in Europe,* Volume 9, Luzern, Switzerland, 529-531.

Velthof, G.L. & Hoving I.E. (2004).
Effects of grassland renovation on herbage yields and nitrogen losses. In: Hatch D.J., Chadwick D.R., Jarvis S.C. and Roker J.A. (eds.). Controlling nitrogen flows and losses. Wageningen Academic Publishers, The Netherlands, 554-556.

Shepherd, M.A., Hatch D.J., Jarvis S.C. & Bhogal A. (2001).
Nitrate leaching from reseeded pasture. Soil Use and Management 17, 97-105.
Vertès, F., Menasseri S. & Morvan T. (2006).
Long term effect of the length of the grass period in ley-arable rotations on the quality of soil organic matter. (This volume).

22. Nitrogen delivery after rotocultivated old and young grassland

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Abstract

Rotocultivated young grassland releases high amounts of nitrogen (Nevens and Reheul, 2002). Due to the increasing potato production in Belgium and the Netherlands, we wondered whether potato is recommendable as a first crop following grassland. [explain why]. Nitrogen delivery by permanent arable land (PA) and converted grassland was estimated and related to potato yield, N-uptake and residual soil N. Potato yield (fresh and DM yield) was determined at three N dressings on plots with PA, permanent (PG) and temporary grassland (TG) as preceding crops. Yield on unfertilised PA was significantly lower during two subsequent years. N mineralisation was studied on fallow plots. The additional net N from mineralisation compared to PA in the first and second year after TG, was 206 and 122 kg N ha^{-1}. Following conversion of 35- (PG) and 36-year old (PG*) permanent grassland, the additional net N was 210 and 307 kg N ha^{-1} respectively. The second year after PG the extra net mineralisation was 166 kg N ha^{-1}. On PA plots, the N-uptake by potatoes exceeded the net N mineralisation; plots after grassland showed the inverse, resulting in a higher residual soil N as compared to PA.

Background and Objectives

Three-year old rotocultivated grassland releases high amounts of nitrogen (Nevens and Reheul, 2002) and the best crop to capture this released nitrogen is a long growing crop as fodder beet. Because of the increasing area of potato production in Belgium and the Netherlands, the question rises whether potato could also be recommended as a first crop following the destruction of grassland.

Material and Methods

The experiment was established on a sandy loam soil at the experimental farm of Ghent University in Melle (Belgium, 50°59' N, 03°49' E, 11 m asl).
In spring 2002, potatoes were planted after forage maize grown in permanent arable land (PA) and in rotocultivated grassland (G). Part of the grassland was 35-year old grassland (PG), the other part had been in a rotation of 3 years arable land-3 years grassland (TG). A part of the seed bed was left uncultivated to study the N mineralisation of the soil organic matter. The net N mineralisation was calculated as the difference between the soil mineral N content of the fallow plots at the beginning and the end of the growing season.
In spring 2003, potatoes were planted on the same plots as in 2002 (this means two subsequent potato crops in the same field) and in rotocultivated 36-year old permanent grassland (PG*). Fresh tuber yield was determined at the end of the growing season at three different N dressings (0, 75 and 200 kg N ha^{-1}). This allowed the calculation of the yield response by Mitscherlich curves. At the beginning (April) and the end (October) of the growing season the mineral N content of the soil profile (0-60 cm) was determined in the unfertilised potato plots and in the fallow plots. Dry matter- and N content (Dumas method) and quality of the potatoes were determined by estimating the scab infestation and the under water weight (UWW). The net N-uptake by the potato tubers was estimated by multiplying potato DM yield by the N content.
To determine the residual mineral soil N, soil samples (sampled monthly until November) were extracted with KCl: ammonia and nitrate were determined colometrically using a continuous flow analyser.

Results and discussion

The soil mineral N content (0-60 cm) of fallow and 0N plots in 2002 increased from April till October and decreased later on. In 2003 N dynamics differed between fallow and 0N plots. On PG* plots for example, the mineral N content of fallow plots increased during May-August 2003 and decreased again from October while the N content of unfertilised PG* plots increased during July-November.

The net N mineralisation during the period April-October 2002 was 43, 249 and 253 kg N ha^{-1} on PA, TG and PG respectively; in 2003 values were 60, 182 and 226 kg N ha^{-1} respectively and on PG* it was 367 kg N ha^{-1}. Compared to PA, the extra net N from mineralisation in the first and second year after TG was 206 and 122 kg N ha^{-1} respectively; in the first year after PG and PG* it was 210 and 307 kg N ha^{-1} respectively while the second year after PG the extra net mineralisation was 166 kg N ha^{-1}.

The fresh tuber yield and the dry matter yield on plots with different preceding crop and N dressings, are given in Table 1.

Table 1. Fresh tuber yield and dry matter yield of the potato crop on plots with different history; (PA: permanent arable land, TG: temporary grassland, PG: permanent grassland (35 y.), PG: permanent grassland (36 y.). Duncan-letters indicate significant differences within columns.*

Preceding crop	Fresh tuber yield (Mg ha^{-1})						DM yield (Mg ha^{-1})					
	0 kg N ha^{-1}		75 kg N ha^{-1}		200 kg N ha^{-1}		0 kg N ha^{-1}		75 kg N ha^{-1}		200 kg N ha^{-1}	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
PA	30.8^{a}	22.4^{a}	53.3^{a}	43.0^{a}	65.9^{b}	56.6^{b}	6.9^{a}	4.6^{a}	11.0^{a}	9.4^{a}	13.1^{b}	12.4^{b}
TG	60.0^{b}	36.4^{b}	60.1^{a}	45.6^{a}	66.8^{b}	59.3^{b}	13.0^{b}	8.3^{b}	12.9^{b}	10.4^{a}	13.0^{ab}	13.4^{b}
PG	53.1^{b}	38.1^{b}	60.3^{a}	43.9^{a}	55.0^{a}	46.8^{a}	11.3^{b}	8.7^{b}	12.4^{ab}	10.1^{a}	11.3^{a}	10.7^{a}
PG*	/	55.4^{c}	/	56.7^{b}	/	55.1^{b}	/	12.5^{c}	/	13.2^{b}	/	12.8^{b}

First year after G: a nitrogen dressing after G did not increase potato yield. Potatoes grown in G outyielded potatoes grown in PA; yield differences in TG and PG did not differ significantly. The advantage of G disappeared at 200N. During the second year, G continued to outyield PA at 0N but differences between G and PA were no more significant at 75N. G amended with 0 or 75N could not substitute the effect of 200N on PA.

The influence of preceding crop and N dressing on potato quality was compared by means of the scab index (mean percentual tuber coverage by scab) and the under water weight (UWW). The N dressing did not influence scab infestation. In 2002 there was significantly more scab between TG or PG and PA: potatoes grown after grassland were significantly more infested by scab: PG>TG>PA. The UWW on PA and TG decreased significantly with increasing N dressing in 2002 and UWW on PA was significantly higher than on PG (no significant difference in 2003).

The N-uptake by the potato crop is given in Table 2. In 2002, N-uptake on PA was significantly lower than on TG and PG. In 2003 overall N-uptake was lower than in 2002; in 2003 the highest N-uptake at each N dressing was found on PG*. On PA plots, the N-uptake by potatoes exceeded the net N mineralisation; on plots after grassland the inverse was seen, resulting in a higher residual soil N as compared to permanent arable land.

Table 2. Net N uptake by potato crop on fields with different preceding crop and N dressing (0, 75 and 200 kg N ha^{-1}) in the first and second year after planting. (PA: permanent arable land, TG: temporary grassland, PG: permanent grassland (35 y.), PG: permanent grassland (36 y.).*

	0 kg N ha^{-1}		75 kg N ha^{-1}		200 kg N ha^{-1}	
Preceding crop	2002	2003	2002	2003	2002	2003
PA	51^{a}	48^{a}	111^{a}	103^{a}	199^{a}	200^{b}
TG	147^{b}	79^{ab}	183^{b}	128^{ab}	258^{c}	229^{c}
PG	157^{b}	103^{b}	205^{b}	136^{b}	230^{b}	173^{a}
PG*	/	169^{c}	/	212^{c}	/	235^{c}

The residual soil mineral N is given in Table 3.

Table 3. Residual soil nitrate-N (kg ha^{-1}, profile 0-90 cm) at the end of the growing season (2002 and 2003) after harvest of potato crop, grown on plots with different history (PA: permanent arable land, TG: temporary grassland, PG: permanent grassland (35 y.), PG: permanent grassland (36 y.) and fertilised with three different N dressings (kg N ha^{-1}). Duncan letters indicate significant differences within columns.*

Preceding crop	2002			2003		
	0 kg N ha^{-1}	75 kg N ha^{-1}	200 kg N ha^{-1}	0 kg N ha^{-1}	75 kg N ha^{-1}	200 kg N ha^{-1}
PA	16^{a}	25^{a}	24^{a}	36^{a}	53^{a}	73^{a}
TG	49^{a}	62^{ab}	102^{b}	96^{b}	75^{a}	122^{b}
PG	77^{b}	90^{b}	153^{b}	129^{b}	112^{b}	113^{b}
PG*	/	/	/	107^{b}	93^{ab}	165^{c}

In 2002, residual soil N in the 0-90 cm profile was significantly higher on PG than on PA. In 2003 soil residual N is significantly lower on PA than on PG or PG* plots.

Conclusions

Nitrogen dressing in potatoes planted in ploughed down grassland does not increase potato yield. Growing potatoes after grassland is not recommended, due to high scab incidence and high soil mineral N residues.

References

Nevens, F. & D. Reheul, 2002.
The nitrogen and non-nitrogen-contribution effect of ploughed grass leys on the following arable forage crops: determination and optimum use. European Journal of Agronomy, 16, 57-74.

23. Simulated short and long term effects of grassland reseeding on nitrate leaching

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Abstract

Intensively used grassland in the Netherlands is frequently reseeded by farmers to improve sward productivity, which may increase the risk of nitrate leaching. A simulation study has been conducted to determine both short and long term effects of grassland renewing on nitrate leaching. With the model N*fate* three 'treatments' have been simulated: no, spring (April) and autumn (September) reseeding and all major N fluxes of the field level have been calculated for each year in a reseeding cycle of seven years. During the first year of the reseeding cycle the N leaching at autumn reseeding is strongly increased, but averaged over seven years N leaching is nearly equal to that of no reseeding, because lower leaching losses during the remaining six years of the reseeding cycle compensate for the higher losses of the first year. At spring reseeding N leaching losses are always below that of no reseeding, even during the first year, accumulating on average in a 15% lower N loss by leaching. Results make clear that short and long term effects of the whole reseeding cycle should be evaluated together.

Keywords: grassland reseeding, nitrate leaching, nitrogen yield, simulation

Background and objectives

Intensively used grassland in the Netherlands is frequently reseeded by farmers to improve sward productivity (Conijn *et al.*, 2002), which often involves ploughing up grassland before resowing. In this situation the risk of nitrate leaching is enhanced, because a surplus of inorganic N usually occurs in the soil during the period between killing of the old sward and full establishment of the new sward. On the other hand, the increased productivity of the new sward increases the nitrogen use efficiency and may therefore reduce nitrate leaching. A simulation study has been conducted to determine the overall effect by calculating both short and long term effects of grassland renewing on nitrate leaching, including the influence of the time of ploughing.

Material and methods

The model N*fate* (*N*utrient *f*luxes in *a*gricultural soils and *t*o the *e*nvironment)) has been used for this study. N*fate* calculates N yield, N losses and changes in the amount of N in the soil-crop system as a function of N inputs, soil/climate characteristics, crop species and management. The in/outputs of the model apply to the field level and refer to a whole year. N*fate* is a dynamic model, which means that the amount of N in the system may change after one time step (i.e. a year), which has consequences for the calculations in the next time step. In the model three N pools are distinguished (Table 1); Figure 1 pictures the major N fluxes that are used/calculated by the model. An outline of the model is given in Conijn (2004).

Table 1. Description of the N pools in Nfate (see Figure 1).

Name	Description	Details	Unit
NorgSoil	Amount of organic nitrogen in the soil organic matter	Age > 1 year, soil layer: 0-20 cm	kg N ha^{-1}
NminSoil	Amount of inorganic nitrogen in the soil	Rooted soil layer, measured in early spring	kg N ha^{-1}
Nplant	Amount of nitrogen in the plant	Below- and aboveground living plant tissue	kg N ha^{-1}

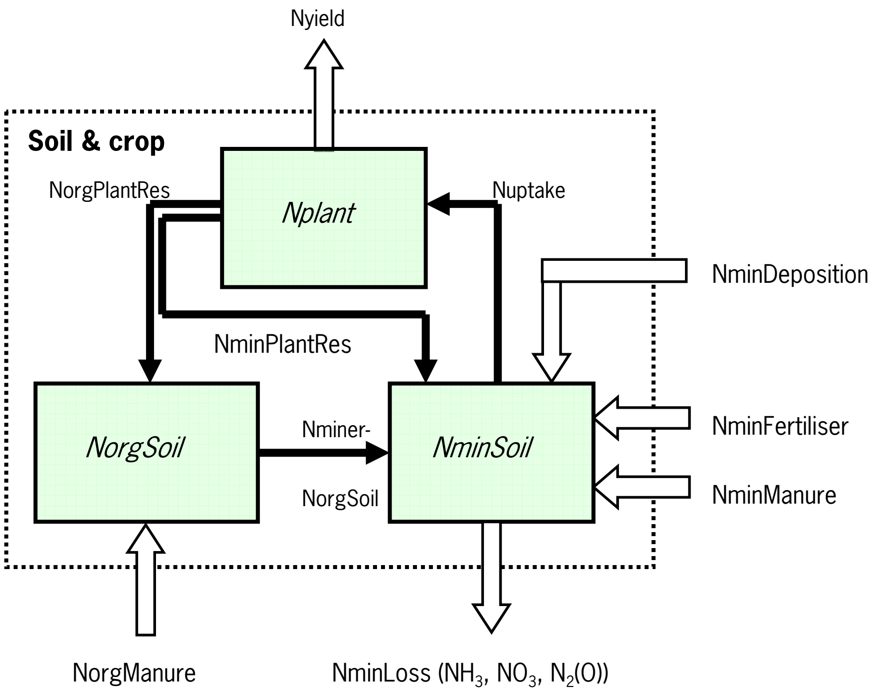

Figure 1. N fluxes and N pools in the soil-crop system of Nfate. Res is used as abbreviation for plant residues, which includes dead plant parts and field harvesting losses.

In this study the model is first used to calculate the equilibrium situation of permanent grassland on a dry sandy soil in the Netherlands with a mixed use of grazing and cutting. Level of N inputs has been derived from the proposed Dutch legislation for dairy farms in 2009. Three 'treatments' have been simulated with N*fate*: no, spring (April) and autumn (September) reseeding, where reseeding occurs once every seven years. Reseeding includes killing of the 'old' sward, which sets *Nplant* to zero by distributing the N content of *Nplant* among *NminSoil* and *NorgSoil*, and a gradual built-up of *Nplant* again up to the level of the 'old' sward during the years after reseeding.

Results and discussion

In the equilibrium situation the N pool sizes amount to circa 4700, 30 and 170 kg N ha^{-1} for *NorgSoil*, *NminSoil* and *Nplant*, respectively. Organic matter content in the upper 20 cm of the soil is 4.6%. Net grass yields equal 9.9 tonne dry matter ha^{-1} y^{-1} and 289 kg N ha^{-1} y^{-1}. Total N input and loss are 428 and 138 kg N ha^{-1} y^{-1}, of which 48 kg N is lost by leaching, resulting in a nitrate concentration of 59 mg l^{-1} in the groundwater. Results compare reasonably well with those from Schröder *et al.* (2005), who determined a yield of 285 kg N ha^{-1} y^{-1} at a total input of 404 kg N ha^{-1} y^{-1}, as average values of (sub)optimal conditions.

In Figure 2 the net N yield and amount of leached N is given for each year during the reseeding cycle, including the average over the whole period for the three reseeding 'treatments'. In the first year, both spring and autumn reseeding cause a drop in N yield relative to no reseeding, because it takes some time before a new sward is productive. Thereafter, the reseeded swards show higher net N yields (at equal N inputs) due to lower losses. Overall, the N yields of the reseeded swards, averaged for the whole 7-year period, differ only slightly from the non-reseeded sward. The amount of N leached during the first year at autumn reseeding is remarkably higher compared to the other two 'treatments'. It illustrates the mismatch between the release of N (partly from the 'old' sward) and the N uptake by the new sward during a period with a high precipitation surplus. On the other hand, spring reseeding is usually followed by a period of precipitation shortage together with a higher N uptake capacity by the new sward, which leads to lower N leaching losses. These results agree with the experimental findings of Velthof and Hoving (2004). After the first year calculated leaching levels of reseeded swards are lower than those from the non-reseeded sward because (a) N is immobilized by uptake into the roots and stubbles of the new sward and (b) more N is removed from the reseeded swards. Overall, averaged over seven years, levels of N leaching are similar for no reseeding and autumn reseeding, whereas it has decreased with 15% after spring reseeding.

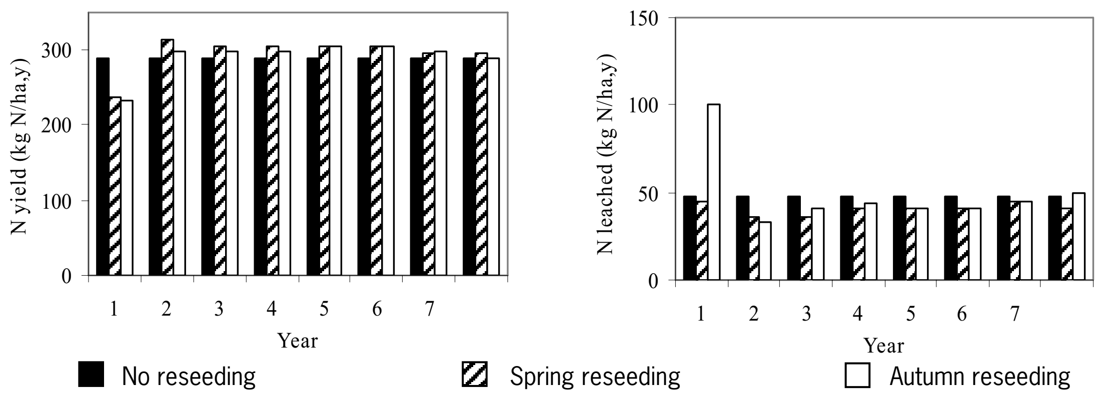

Figure 2. *Calculated net N yield and N leaching during a reseeding cycle of seven years. Ploughing and reseeding takes place in April or September of year 1. N fluxes refer to the period between 1 March of year x until 1 March of year x+1. Bars at the right hand side (beyond year 7) represent the average values for the 7-year period.*

Conclusions

The model N*fate* predicts for grasslands on dry sandy soils in the Netherlands that during the first year of the reseeding cycle spring reseeding causes no increase in N leaching, but autumn reseeding more than doubles the loss of N by leaching compared to no reseeding. However, averaged over the whole reseeding cycle, the results indicate that N leaching is reduced at spring reseeding, whereas at autumn reseeding it is nearly equal to that of no reseeding, despite the relative high losses in the first year. These results make clear that a whole cycle (from reseeding to reseeding) should be evaluated for an adequate estimation of the effect of grassland reseeding on total nitrate leaching.

References

Conijn, J.G. (2004).
Nfate: a N flux model for grassland resowing and grass-arable rotations. In: Lüscher A., Jeangros B., Kessler W., Huguenin O., Lobsiger M., Millar N. & Suter D. (eds.). Land Use Systems in Grassland Dominated Regions. *Grassland Science in Europe,* Volume 9, Luzern, Switzerland, 541-543.

Conijn, J.G., Velthof G.L. & Taube F. (eds.) (2002).
Grassland resowing and grass-arable crop rotations. International Workshop on Agricultural and Environmental Issues. Plant Research International, Wageningen, The Netherlands, report 47, 128 pp.

Schröder, J.J., Aarts H.F.M., van Middelkoop J.C., de Haan M.H.A., Schils R.L.M., Velthof G.L., Fraters B. & Willems W.J. (2005).
Limits to the use of manure and mineral fertilizer in grass and silage maize production in The Netherlands, with special reference to the EU Nitrates Directive. Plant Research International, Wageningen, The Netherlands, report 93, 47 pp.

Velthof, G.L. & Hoving I.E. (2004).
Effects of grassland renovation on herbage yields and nitrogen losses. In: Hatch D.J., Chadwick D.R., Jarvis S.C. and Roker J.A. (eds.). Controlling nitrogen flows and losses. Wageningen Academic Publishers, The Netherlands, 554-556.

24. Nitrate leaching following cultivation of grazed grass-clover on coarse sandy soil

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Abstract

When grass-clover is ploughed in there is a high risk of nitrate leaching. In order to try to minimize leaching an experiment was established on two fields on a commercial organic farm with a coarse sandy soil. A 3-year-old and a 5-year-old grass-clover were ploughed in spring 2003, and the following treatments were established: 1) spring barley (*Hordeum vulgare* L.), harvested at maturity ('Mature') and 2) spring barley harvested early as a green crop for silage with an undersown catch crop of Italian ryegrass (*Lolium multiflorum* Lam.), ('Green'). The treatments were fertilized with 0, 60 or 120 kg ammonium-N ha^{-1} in cattle slurry. Nitrate leaching was measured in 0 and 120 kg N ha^{-1}. The experiments showed that 'Green' treatments could reduce leaching by 166-309 kg N ha^{-1}, corresponding to 95-98% in comparison with 'Mature' treatments. In addition to nitrate, 10-30 kg N ha^{-1} was leached as other N-containing compounds. In contrast to 'Mature' treatments, leaching from 'Green' treatments did not differ from each other, irrespective of whether manure was applied or not. A high production of roughage was possible and the difficulties with clover fatigue experienced by many Danish farmers were avoided.

Keywords: green crop, catch crop, organic N, field experiment

Background and objectives

When grass-clover is ploughed there is a high risk of nitrate leaching (e.g. Djurhuus and Olsen, 1997; Eriksen *et al.*, 1999). The ploughing of grass-clover in spring (Djurhuus and Olsen, 1997) and the undersowing of a catch crop like perennial ryegrass (*Lolium perenne* L.) in the following spring cereal is recognized as a successful way of reducing nitrate leaching the following autumn and winter (Djurhuus, 1992; Thomsen and Christensen, 1999). However, sometimes the effect of the catch crop is less than expected, probably owing to delayed harvest of the main crop and heavy rain after harvest, which may leach nitrate below the root zone of the catch crop (Hansen and Djurhuus, 1997). The objective of this study was to examine the effectiveness of an earlier catch crop than perennial ryegrass in reducing nitrogen leaching from coarse sandy soil. A barley silage crop was undersown with Italian ryegrass in spring and harvested at the beginning of heading, and the Italian ryegrass was subsequently used for roughage production in the autumn.

Material and methods

Experiments were established in spring 2003 on a commercial organic farm with a coarse sandy soil. Two fields with grass-clover were ploughed. A 3-year-old grass-clover field had formed part of a crop rotation dominated by cereals, and another 5-year-old grass-clover field was part of a grass-intensive rotation grazed by dairy cows. After ploughing the grass-clover, the following treatments were established in each of the two fields: 1) spring barley, harvested at maturity and subjected to mechanical weed control in the autumn ('Mature') and 2) spring barley harvested early as a green crop for silage with an undersown catch crop of Italian ryegrass ('Green'), which was mowed twice in the autumn. The treatments were fertilized with 0, 60 or 120 kg ammonium-N ha^{-1} in cattle slurry, injected in the spring following ploughing (Table 1).

Table 1. Treatments, seeds, and treatments including (+) determination of N leaching.

Treatment[1]	Seeds, spring barley[2]	Seeds, Italian ryegrass[3]	Leaching
Mature-0N	350	0	+
Mature-60N	350	0	
Mature-120N	350	0	+
Green-0N	200	25	+
Green-60N	200	25	
Green-120N	200	25	+

[1] *0N, 60N and 120 N indicate kg ammonium-N in cattle slurry injected before sowing.*
[2] *Number of seeds per m² capable of germinating. Variety mixture: Cisero, Punto og Otira.*
[3] *Kg per ha of tetraploid Italian ryegrass, Ajax.*

For calculation of nitrate leaching, soil water isolates were taken using porous ceramic cup samplers installed below the root zone in spring 2003 in selected treatments (Table 1), (Djurhuus and Jacobsen, 1995). Two samplers were installed per plot (i.e. eight per treatment). A suction of approximately 70-80 kPa was imposed 2 to 3 days before sampling. During this period the suction decreased as a result of sampling the water. The soil water isolates from each replication were bulked before analysis, frozen within a few hours and later analyzed for nitrate N (Best, 1976). Total N was analysed as described by Cabrera *et al.* (1993) and dissolved organic N calculated as the difference between total N and nitrate N. Generally, sampling was carried out once every other week, except in periods of drought or frost. Percolation was calculated using the model Evacrop (Olesen and Heidmann, 1990).

Results and discussion

Nitrate leaching after Mature-0N was 174 and 240 kg N ha^{-1} in the 3-year-old and the 5-year-old grass-clover, respectively, when the soil was kept bare by rotovating twice during the autumn (Table 2). In Mature-120N leaching was 302 and 316 kg N ha^{-1}. In Green-0N and Green-120N leaching was only 7-9 kg N ha^{-1}. This means that the 'Green' treatments reduced leaching by 166-309 kg N ha^{-1}, corresponding to 95-98% (Table 2). In addition to nitrate leaching, 10-29 kg N ha^{-1} was leached as other N-containing compounds with the highest amount from Mature-0N and Mature-120N after the 5-year-old grass-clover (Table 2).

Table 2. Leaching of nitrate and dissolved organic N (in brackets), kg N ha^{-1}, from 21 May 2003 to 12 May 2004 following ploughing-in of grass-clover in spring 2003.

Treatment	Following 3-yr-old grass-clover		Following 5-yr-old grass-clover	
		Reduction, %[1]		Reduction, %[1]
Mature-0N	174[b] (13)	-	240[a] (23)	-
Mature-120N	302[a] (19)	-	316[a] (29)	-
Green-0N	8[c] (10)	95	7[b] (16)	97
Green-120N	9[c] (10)	97	7[b] (12)	98

Values followed by different letters are significantly different from each other according to Duncan-test.
[1] *Reduction in nitrate leaching in comparison with Mature-0N or Mature-120N.*

Yields harvested in Mature-0N were 3.4 and 3.9 Mg dry matter ha^{-1}, and total yield harvested in Green-0N were 6.5 and 9.7 Mg dry matter ha^{-1} green crop and grass. A comparison of the treatments Mature-0N and Manure-120N showed additional nitrate leaching of on average 102 kg N ha^{-1} when 120 kg ammonium-N ha^{-1} was applied (Table 2). This is matched by a corresponding lack in yield increase when applying 120 kg N ha^{-1} (Table 3). In contrast to 'Mature' treatments, leaching from 'Green' treatments did not differ, irrespective of whether manure was applied or not (Table 2). This can be explained by an additional N uptake of on average 127 kg N ha^{-1} in Green-120N compared with Green-0N (data not shown). So in the 'Green' treatments most of the manure N was taken up by the ryegrass instead of being leached.

Table 3. Yield of grain, straw and green crop (Mg DM ha^{-1}) in treatments with spring barley and green crop grown after ploughing-in of 3- and 5-yr-old grass-clover in spring 2003.

	Following 3-yr-old grass-clover				Following 5-yr-old-grass-clover			
	Grain	Straw	Green crop	Grass[1] 15/8+ 20/10	Grain	Straw	Green crop	Grass[1] 15/8+ 20/10
Fertilization, kg N ha^{-1}	Mature		Green		Mature		Green	
0	3.4^{b}	2.6^{b}	2.9^{b}	3.6^{b}	3.9^{a}	4.3^{b}	4.6^{b}	5.1^{b}
60	3.9^{ab}	3.8^{a}	4.8^{a}	3.8^{b}	4.1^{a}	4,8^{b}	6.1^{a}	6.2^{a}
120	4.1^{a}	4.1^{a}	5.7^{a}	4.7^{a}	3.9^{a}	5,6^{a}	6.6^{a}	6.4^{a}

Values followed by different letters are significantly different from each other according to Duncan-test.
[1] Grass cut on 15 August and 20 October 2003.

Conclusion

The experiments showed that a barley silage crop undersown with Italian ryegrass could reduce leaching to a minimum. This offers advantages not only for the environment but also for farmers, as a high production of roughage was possible and the increasing difficulties with clover fatigue experienced by Danish farmers could be avoided.

References

Best, E.K. (1976)
An automated method for determining nitrate-nitrogen in soil extracts. Queensland Journal of Agriculture and Animal Science, 33, 161-166.

Cabrera, M.L & Beare, M.H. (1993)
Alkaline persulfate oxidation for determining total nitrogen in microbial biomass extracts. Soil Science Society of America Journal, 57, 1007-1012.

Djurhuus, J. (1992)
N-transformation and N-transport in a sandy loam and a coarse sandy soil cropped with spring barley. II Nitrate leaching. Tidsskrift for Planteavl, 96:137-152.

Djurhuus, J. & Jacobsen, O.H. (1995)
Comparison of ceramic suction cups and KCl extraction for the determination of nitrate in soil. European Journal of Soil Science, 46, 387-395.

Djurhuus, J. & Olsen, P. (1997)
Nitrate leaching after cut grass/clover as affected by time of ploughing. Soil Use & Management, 13, 61-67.

Eriksen, J., Askegaard, M. & Kristensen, K. (1999)
Nitrate leaching in an organic dairy/crop rotation as affected by organic manure type, livestock density and crop. Soil Use and Management, 15, 176-182.

Hansen, E.M. & Djurhuus, J. (1997)
Nitrate leaching as influenced by soil tillage and catch crop. Soil & Tillage research, 41, 203-219.
Olesen, J.E. & Heidmann, T. (1990)
EVACROP. A programme for calculating daily actual evapotranspiration and runoff from the root zone. Version 1.00. (In Danish with English summary). Research Note, Research Centre Foulum, 65 pp.
Thomsen, I.K. & Christensen, B.T. (1999)
Nitrogen conserving potential of successive ryegrass catch crops in continuous spring barley. Soil Use & Management, 15,195-200.

25. Long term effect of the length of the grass period in ley-arable rotations on the quality of soil organic matter.

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Abstract

Crop rotations affect soil organic matter (SOM) dynamics and thus soil quality. Long term effect of the length of the grass period in ley-arable rotations on SOM was studied in a long term experiment (28 years), where Grass/Maize ratio varied from null to 6 (when maize).
SOM decrease was strongly linked to G/M ratio, and 3 types of rotations differed significantly for most of the measured parameters: annual rotation (G/M = 0 or 1), biennial rotation (1<G/M≤3) or long duration rotation (G/M= 6 and permanent grass). C and N mineralisation rates measured at the end of the trial increased with G/M ratio, more than proportionately to soil C or N content, which indicates changes in SOM quality (regarding mineralization). Those changes concerned C and N distribution in size fractions and probably the proportion of active SOM.

Keywords: Ley-arable rotations, soil organic matter mineralisation, long term experiment

Background and Objectives

To achieve sustainable fodder systems, nutrient production has to be considered as well as soil quality and nitrogen loss risks. Soil organic matter (SOM) content is a key attribute of soil quality, as it affects physical, biological and chemical properties of soils. In ley-arable rotations, the nitrogen and carbon storage in soils depends on rotation management, among which the proportion of grass and the frequency of tillage (Haynes, 1999; Velthof *et al.*, 2001). The long-term evolution of SOM quantity is well known (Johnston *et al.*, 1986; Conijn *et al.*, 2002), the changes of SOM quality and the processes involved are less understood. This paper deals with the long term effect of the ratio grass/crops on SOM dynamics.

Material and Methods

A long term experiment was settled in Quimper between 1978 and 2005 to study the effect of fodder rotations on crops yields and soil quality (Simon *et al.*, 1992). This trial compared the effects of 3 annual, 5 biennials and 3 long duration crop rotations, fertilized with cattle slurry. Among the 11 rotations, 6 are compared here: maize monoculture (rotation B), maize + 6 (C), 12 (E) or 18 (D) months *Lolium multiflorum*, maize + 3 years *Lolium perenne* (J) and permanent *Lolium perenne* (I). The grass/maize(G/M) ratio, calculated as relative duration of both crops, varies from 0 to 6 (when maize).The mean crop yields, as silage maize and/or cut grass, were 15.6 (C) > 13.9 (D) > 13.1 (B) > 12.7 (E) > 11.5 (J) > 11.4 t DM.$ha^{-1}.yr^{-1}$ (I).
The soil is a loamy-sandy soil (45.2% sand, 38.4% silt, 16.3% clay), pH =5.8. The initial C and N content were respectively 2.93 and 0.24 g kg^{-1}dry soil. The top soils (0-25 cm) were sampled 7 times during the 28 years, and analysed for total N (Kjeldahl) and C (Dumas). Detailed investigations on possible changes in the active part of SOM were achieved at the end of the experiment (February 2005), with 3 (I, J) or 4 replicates (B,C,D,E) per treatment:

- measurement of potential C and N mineralisation. Soil samples (0-25 cm), sieved at 2 mm to remove fragments of plant residues, were incubated at 15°C and at constant soil water content (90% field capacity) for 220 days. Mineralised C was continuously monitored by CO_2 trapping. Mineralised N was determined at regular intervals on soil samples.

- SOM was separated in 3 pools: < 50 µm, 50-200 µm and 200-2000 µm according to the physical fractionation method proposed by Balabane and Balesdent (1992). The two sand-size fractions were analysed for total C and N content, data for the finest fractions being calculated by difference.

Results and discussion

- *Long term SOM evolution*

After nearly 30 years of constant practices, organic N and C decrease rates vary between -5% (permanent grass) and -30% (maize monoculture). Those decreases are strongly correlated with the G/M ratio, as shown on Figure 1. Total SOM content remained nearly constant when G/M ∃ 6 (I and J). Three classes of rotations are distinguished (Table 1), according to G/M ratio, and corresponding to annual, biennal and long term rotations. The two compartment model of Hénin & Dupuis (1945) was tested to simulate long term SOM evolution, according to the equation: SOM (t) = k_1m/k_2 + (SOMinit - k_1m/k_2) $\exp^{(-k2t)}$. k_1m was calculated from known plant residues and manure inputs, with isohumic coefficients from the literature. The coefficient of annual SOM mineralization k_2 was optimized using the Excel solver tool. As indicated in the Table 1, this coefficient decreases significantly when grass duration increase. Extrapolation of SOM kinetics on a very long period gives asymptotic values for final SOM content about 1.9 (B), 2.5 (C), 3.4 (D) and 2.9% (E).

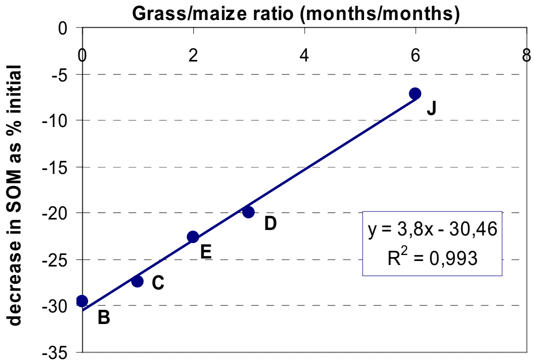

Table 1. Main characteristics of SOM and C and N mineralisation in incubated soils, for the 3 classes of G/M ratio (letters: significant differences P ∃ 0.95).

G/M ratio	Norg final %	Corg final %	k_1m* t.ha^{-1}.yr^{-1}	k_2 moy yr^{-1}	Nf-Ninit /Ninit %	C min. rate	N min. rate	N min rate /Norg final
						kg C (N).ha^{-1}.day^{-1}		
G/M ≤ 1 (B-C)	0.171[a]	2.10[a]	1.14	0.021	- 28.5[a]	3.68[a]	0.283[a]	1.65[a]
1<G/M≤3 (D-E)	0.188[b]	2.31[b]	1.28	0.017	- 21.2[b]	4.26[b]	0.327[b]	1.74[b]
G/M > 3 (I-J)	0.226[c]	2.71[c]			- 6[c]	5.54[c]	0.461[c]	2.04[c]

** k_1m calculated from known plant residues and manure inputs, with isohumic coefficients from the literature*

- *Short term SOM mineralization*

Initial rates of C and N mineralization (first 28 days) differ significantly among the 3 groups, increasing with the G/M ratio (Table 1). Net N mineralisation after 2 months were respectively 15, 17 and 23.5 g N.kg dry soil^{-1}, the last value being intermediate of those observed by Accoe *et al.* (2004) on 14 and 50 years old grasslands. The Nmin-to-Cmin ratio varies between 0.077-0.088 (28 days) and 0.090-0.098 (203 days), slightly higher for grass-based rotations. As the ratio N(C) mineralisation rate/total N(C) content increases with the G/M ratio, soil organic N(C) content does not fully explains the differences in mineralisation rates: high proportion of grass in rotations leads to higher C and N mineralisations, possibly linked to changes in the most labile SOM pool.

- *Results of particle-size fractionation* are shown on the Table 2. Recovery of mass ranged from 98.5 to 100%, without any significant differences on the relative part of fractions between treatments.

Table 2. SOM fractions characteristics for the 3 classes of G/M ratio (letters indicate significant differences P ∃ 0.95).

G/M ratio	C%Ctot	N%Ntot	C/N	C%Ctot	N%Ntot	C/N	C%Ctot	N%Ntot	C/N
Size of fractions		200-2000			50-200			< 50	
G/M≤1 (B-C)	4.1 [ns]	3.24 [a]	26.2 [a]	8.6 [a]	11.1 [a]	13.9 [a]	87.3 [a]	91.5 [a]	11.8 [ns]
1<G/M≤3 (D-E)	3.81 [ns]	3.32 [a]	26.3 [a]	9.0 [a]	13.3 [b]	15.3 [b]	87.2 [a]	91.0 [a]	11.8 [ns]
G/M > 3 (I-J)	4.22 [ns]	5.19 [b]	21.6 [b]	12. [b]	24.6 [c]	16.1 [c]	82.9 [b]	86.5 [b]	11.5 [ns]

Expressed on a whole soil basis, the amounts of organic C and N increased with decreasing particle size, and C/N ratio decreased with decreasing particle size, as observed in the literature. Significant differences were observed for nearly all data between long rotations (I and J) versus short rotations, even when dominated by grass (G/M =1.5 or 3). The largest relative increase in C and especially N content were found in the intermediate (50-200µm) and large fractions (200-2000 µm) under grass based rotations compared to crop rotations, while relatively less C and N was associated to smallest SOM fraction. This result is consistent with the hypothesis of the labile SOM pool increase as observed by Haynes (1999) and Accoe *et al.* (2004).

Strong and highly significant positive correlations are calculated between C and N mineralisations (after 28 and 203 days) and all C and N contents (not shown), while negative correlations are found with C-to-N ratio of the 2 sand-size fractions, but not with Ctot-to-Ntot nor with the < 50µm fraction. Nevertheless linear regression model between C(N) mineralisation and Ctot or Ntot over-estimates mineralisation for rotations with G/M ratio < 3 and under-estimates it for grass-based rotations soils, that is also consistent with the hypothesis of an increase in the proportion of labile soil organic matter as suggested by Accoe *et al.* (2004).

Additional data (from the oral presentation)

Besides the soil organic status evolution as presented above, the comparison between rotations concerned plant production, nitrogen balance at field scale and nitrate losses measurements (in lysimeters). The main results are summarized in Table 3 and Figure 2. Maximum yields were obtained with the annual rotation maize + 6 months Italian ryegrass, where lower production was found at permanent ryegrass. On the other hand; nitrogen uptake is maximum for the permanent cut grassland, that correspond also to maximum N use efficiency and minimum N losses, due to rational fertilisation and lack of bare soil. The input of slurry in autumn on young catch crop, as usually practiced until the Nitrate Directive, increased nitrate leaching proportionally to the slurry N input.

Table 3. Main characteristics of plant production, nitrogen uptake, nitrogen use efficiency and nitrogen leaching in the 6 grass – maize rotations. N inputs concern slurry (% in brackets) and chemical fertilizer. N leaching was measured in lysimeters with similar treatments and period studied.

rotation	Mean yields t DM.ha^{-1}	N inputs kg N.ha^{-1}.yr^{-1}	Plant N uptake kg N.ha^{-1}.yr^{-1}	N out/ N inputs	N leaching risks kg N-NO3.ha^{-1}
B : maize	**13.6**	**245** (75% S)	**140** *(29)*	**0.57**	**100**
C :maize+Lm 6	**16.4**	**335** (55% S)	**177** *(36)*	**0.53**	**35 – 110***
E :maize+Lm 12	**12.7**	**370** (53% S)	**222** *(46)*	**0.60**	**60**
D :maize+Lm 18	**13.9**	**352** (46% S)	**225** *(46)*	**0.64**	**25 – 100***
J :Lp 3yr+maize	**11.4**	**437** (44% S)	**252** *(87)*	**0.58 (0.67)**	**65**
I = Perm. Lp	**11**	**420** (45% S)	**290** *(65)*	**0.69**	**< 20**
Mean (B+I)/2	**12.3**	**332** (56% S)	**215**	**0.65**	***slurry in autumn**

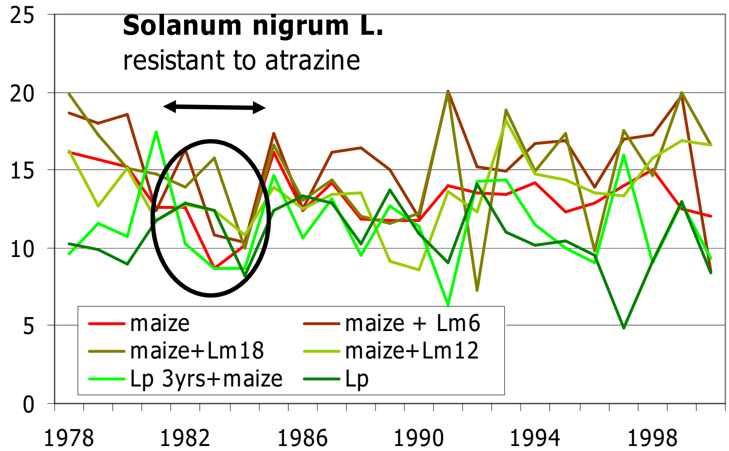

Figure 2. Evolution with time of mean yields in the 6 rotations compared.

No systematic decrease of plant yields was observed during the 25 years of measurements. A strong decreased was observed after 4 to 6 years in maize production due to invading Solanum nigrum, with selection of weeds resistant to used herbicide. Permanent ryegrass has to be renovated after nearly 20 years, after 3 years of 10% reduced production levels.

Main points of the grass part in maize/grass rotations:

- It negatively affects dry matter yields and positively nutrient uptake (N and P)
- It does not imply a decrease with time in production, whatever the rotation is, except in case of specific problems such as weed control
- It affects SOM evolution, in quantity and quality.

To maintain SOM status, biannual rotations are not efficient compared to long term rotations.

Conclusions

Ley-arable rotations usually bring an advantage in terms of higher dry matter and nutrient yields, relative to monoculture, that could include a more efficient use of nitrogen and decrease the risk of N leaching. We actually observed higher SOM decrease rates from permanent grass to maize monoculture, which corresponded to lower plant residues restitution to soils (silage maize monoculture), but were not linked to average crop yields. Large spatial variability of SOM in soils explains that the differences on total organic C and N content between treatments are significant only about 20 years. SOM decrease was strongly linked to G/M ratio, and 3 types of rotations differed significantly for most of the measured parameters: annual rotation (G/M = 0 or 1), biennal ($1<G/M\leq3$) or long duration rotation (G/M= 6 and permanent grass). C and N mineralisation rates increased with G/M ratio more than proportionally to soil C or N content, indicating changes in SOM quality (regarding mineralization) and were associated to higher proportion of C and N in the SOM coarser fractions.
More investigation is necessary to determine how fast SOM fractions differ, and how far some pools indicate potential N and C mineralisation rates. Some progress should also be made in the understanding of SOM dynamics by linking size aggregate in fractions and in stability tests, in order to determine simple indicators to propose diagnostic tools for SOM quality.

References

Accoe, F., Boeckx P., Busschaert J., Hofman G. & Van Cleemput O. (2004)
Gross N transformation rates and net N mineralisation rates related to the C and N contents of soil organic matter fractions in grassland soils of different ages. *Soil Biol. Biochem.*, 36, 2075-2087

Balabane, M. & Balesdent J. (1992)
Input of fertilizer-derived labelled N to soil organic matter during a growing season of maize in the field*. Soil Biol. Biochem., 24(2), 89-96*

Christensen, B.T. (2001)
Physical fractionation of soil and structural and functional complexity in organic matter turnover. *European Journal of Soil Science,* 52, 345-353

Conijn, J.G., Velthof G. & Taube F. (2002)
Grassland re-sowing and grass-arable rotations. *PRI report* 47, 128 p.

Haynes, R.J., (1999)
Labile organic matter fractions and aggregate stability under short-term, grass-based leys. *Soil Biol. Biochem*, 31, 1821-1830

Hénin, S. & Dupuis M. (1945)
Essai de bilan de la matière organique du sol. *Annales Agronomiques*, 15, 17-29

Johnston, A.E. (1986)
Soil Use & Management, 2, 97-105.

Simon *et al.* (1992)
Systèmes de culture prairiaux à rotation rapide: nature de contraintes, effets cumulatifs. In: « Un point sur …les systèmes de culture », INRA éditions, 111-126

Velthof, G.L. & Oemena O (2001)
Alterra Report 399, Wageningen, 55 p.