1. Grassland renovation in the Netherlands; agronomic, environmental and economic issues

R.L.M. Schils[1], H.F.M. Aarts[2], D.W. Bussink[3], J.G. Conijn[2], W.J. Corré[2], A.M. van Dam[4], I.E. Hoving[1], H.G. van der Meer[2] & G.L. Velthof[5]

[1] Research Institute for Animal Husbandry, P.O. Box 2176, 8203 AD Lelystad, The Netherlands. e-mail: r.l.m.schils@pv.agro.nl
[2] Plant Research International, P.O. Box 16, 6700 AA Wageningen, The Netherlands. e-mail: h.f.m.aarts@plant.wag-ur.nl
[3] Nutrient Management Institute, P.O. Box 250, 6700 AG Wageningen, The Netherlands. e-mail: d.w.bussink@nmi-agro.nl
[4] Applied Plant Research, P.O. Box 176, 6700 AD Wageningen, The Netherlands. e-mail: a.m.van.dam@ppo.dlo.nl
[5] Alterra, P.O. Box 47, 6700 AA Wageningen, The Netherlands. e-mail: g.l.velthof@alterra.wag-ur.nl

Abstract

The Netherlands has a total grassland area of approximately 1 million ha, which is about 25% of the total land area. The majority consists of permanent grassland, but rotation with maize, potatoes and flower bulbs is found in certain regions. Grassland on sand, clay and peat soils is -on average- renovated every 5, 10 and 30 years, respectively. Generally, the motivation for grassland renovation is the poor agronomic performance of a sward, caused by factors as drought or winter damage, sometimes in combination with mismanagement. The costs of a standard grassland renovation range from € 550 ha^{-1} on peat soil to € 825 ha^{-1} on heavy clay soil. A cost-benefit analysis showed that grassland renovation is financially attractive if the new sward produces 10 to 25% more than the old sward. This suggests that farmers might have other motives for grassland renovation that have not been identified yet. Furthermore, scientifically sound and practically applicable criteria are needed to support farmers in decisions on grassland renovation.

Experimental studies into the effects of grassland renovation on environmental and agronomic parameters are scarce in the Netherlands. The effects of grassland renovation have been estimated for three cases of permanent grassland on sand, clay and peat soil, and an additional case for a grass-maize rotation on dry sandy soil. Although it is possible to determine the soil N balances for these cases, there is much uncertainty about the changes of soil organic N and the pathways of N losses. Therefore, there is need for a further quantification of the effects of grassland renovation on N cycling in the plant-soil system, with respect to soil type, renovation strategy and crop management.

Introduction

In the Netherlands, dairy farmers use approximately one million ha of grass, either as permanent grassland or in a ley-arable rotation. Permanent grassland is renovated if thought necessary by the farmer. Farmers have a wide variety of reasons for grassland renovation, predominantly related to herbage production and quality. Grassland renovation is economically only justified if the increased production and quality offsets the costs. At present, there is a lack of transparent criteria on which farmers can base decisions on grassland renovation. Grassland in ley-arable rotations is ploughed after one to five years to allow for arable cropping. On dairy farms with ley-arable rotations, maize (*Zea mays* L.) is the most widely used crop. In addition to the agronomic and economic aspects, grassland renovation can have a major environmental impact. Ploughing of grassland increases the release of soil nitrogen (N), which leads to an increased risk of nitrate losses to groundwater and surface water, and N_2O emissions.

The objectives of this paper are to (i) describe the current farming practices regarding grassland renovation, (ii) identify agronomic, environmental and economic consequences of current grassland renovation practices, and (iii) describe the state of the art in research concerning grassland renovation.

The available information on grassland renovation was gathered from literature and statistics. Based on these data, expert knowledge and simple models were used to estimate the environmental, agronomic and economic effects of grassland renovation.

1.1 General information

1.1.1 Nutrient policy in the Netherlands

From the 1950s onwards, dairy production systems in the Netherlands have shown a strong intensification and became increasingly dependent on imports of fertilisers and concentrates (e.g. Aarts *et al.*, 1992; Van der Meer, 1994). This intensification was economically justified in view of the high costs of land and labour, the low costs of fertilisers and concentrates, and the relatively high milk price. The amount of fertiliser N applied to grassland has increased from around 75 kg ha^{-1} $year^{-1}$ in 1950 to approximately 300 kg ha^{-1} $year^{-1}$ in the middle of the 1980s (Bussink & Oenema, 1998). The introduction of milk quota in the European Union (EU) in 1984 marked a turning point. The number of dairy cows reached a maximum of 2.55 million head in 1984 with a total milk production of 13 million t. Since then, the number of dairy cows has decreased to 1.5 million head with a total milk production of 11 million t.

Simultaneously, it was recognised that intensive dairy farming contributes to excessive nitrogen and phosphate (P_2O_5) losses to the environment. Therefore, from 1985 onwards, the Dutch government has introduced a series of regulations aimed to reduce the N and P_2O_5 losses (Henkens & Van Keulen, 2001). In 1998, the Mineral Accounting System (MINAS) was introduced. The MINAS balance is a ‘farm-gate’ balance, taking into account the N inputs such as fertilisers and feeds, and the N outputs through milk and animals. Nitrogen input through biological fixation and deposition does not have to be accounted for. By the year 2003 the allowed, levy-free, MINAS N surpluses are 140 kg ha^{-1} $year^{-1}$ for grassland on dry sandy soils and 180 kg ha^{-1} $year^{-1}$ for grassland on the other soil types.

In addition to the MINAS targets, the government has also imposed a variety of specific measures with which farmers have to comply. For instance, slurry has to be applied with techniques that minimise ammonia losses. The latest of these Directives, issued in January of 2002, prohibits the ploughing of grassland between 16 September and 31 January.

Furthermore, the EU Nitrate Directive sets the maximum amount of N from animal excreta at 170 kg ha^{-1}. The Dutch government has requested a derogation for grassland of 250 kg ha^{-1} (Willems *et al.*., 2000). The request is based on the favourable climatic conditions, the high N uptake of grass, and the additional Dutch nutrient policy. However, with respect to grassland renovation, the EU questions the uncertainty around nitrate losses towards ground and surface water.

1.1.2 Grassland in the present situation

The grassland area in the Netherlands decreases slowly by an average annual rate of 1%. In the year 2000, the total grassland area was 1.025.000 ha (CBS, 2000). Grassland covers approximately 25% of the total area, and can be found anywhere in the Netherlands (Figure 1). Approximately 44% of the total grassland area is situated on sandy soils, mainly in the South and East. Another 39% can be found on clay and loam soils. The remaining 17% is found on the peat soils in the North- and Midwest. Approximately 90% of the total grassland area is permanent grassland, but the proportion of temporary grassland is increasing. Temporary grassland in rotation with maize is mainly found on the relatively intensive dairy farms on dry sandy soils in the South and East. Additionally, temporary grassland is found in rotations with potatoes or flower bulbs. During the arable year of the rotation the land is rented by an arable farmer.

Perennial ryegrass (*Lolium perenne* L.) is the main grass species present in sown grasslands. The use of other species like timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis* Hudson) and smooth-stalked meadowgrass (*Poa pratensis* L.) has decreased significantly since the early 1960s. Grasslands on clay, loam and sandy soils can generally be characterised as perennial ryegrass dominant swards. On peat soils, the proportion of perennial ryegrass is usually not higher than 30%. Other species like rough stalked meadowgrass (*Poa Trivialis* L.) are very common on peat soils.

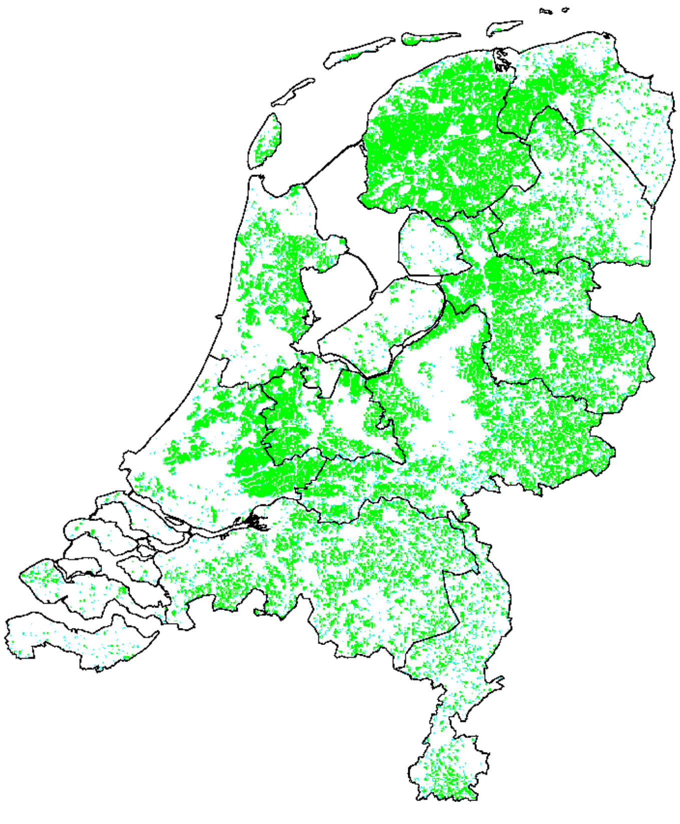

Figure 1. Grassland areas (green) in the Netherlands.

The Netherlands has some 28,000 dairy farms with an average of 53 dairy cows on 27 ha of grassland and 6 ha of fodder crops, mostly maize (Table 1). The farms in the North, mainly clay and peat, are relatively large farms. Farms on the sandy soils in the South and East are relatively small, but more intensive. The proportion of grassland on dairy farms in the North, West and South & East is 92, 84 and 77%, respectively.

Table 1. General characteristics of dairy farms in the Netherlands, in 1999 (LEI, 2002).

	North	West	South & East	Total
Dairy farms (n)	5,410	5,790	16,610	27,810
Area per farm (ha)	41.9	35.4	30.1	33.5
- grassland	37.2	30.7	22.2	26.9
- fodder crops	3.5	4.1	6.9	5.7
Dairy cows (n)	62.9	56.9	48.9	53.3
Milk quota (kg)	472,700	408,400	371,100	398,600
Milk quota (kg/ha)	11,282	11,537	12,329	11,906
Mineral fertiliser on grass (kg N/ha)	270	215	257	251

The differences between farms and their grassland management are much larger than suggested by the average figures in Table 1. For instance, 25% of the dairy farms produce less than 10,000 kg milk per ha, and 20% produce more than 15,000 kg milk per ha.

The dairy farms in the North and West have a stocking rate of 1.5 to 1.6 cows per ha, and produce approximately 11,500 kg milk per ha. The fertiliser N application is 270 kg ha^{-1}. Additionally, grassland on these farms will annually receive an estimated 35 t cattle slurry per ha, containing 85 kg inorganic N per ha, and a similar amount of inorganic N. N application is lower on the -mainly peat soils - in the West, due to the high soil nitrogen supply (SNS).

The farms on sandy soils in the South and East have an average stocking rate of 1.6 cows per ha and annually produce 12,300 kg milk per ha. The grassland annually receives 257 kg N ha^{-1} from fertiliser, plus an estimated 50 t cattle slurry per ha, containing 120 kg inorganic N per ha.

Grazing has always played an important role in Dutch dairy husbandry, as it is widely recognised as the cheapest way to convert grass into milk. On the major part of the grassland area, rotational grazing is integrated with cutting for silage in such a way that grazing at the right stage has first priority and that surpluses are cut for silage to support this.

Until the end of the 1960s, dairy cows usually grazed day and night, only interrupted by milking times. The introduction of the cubicle housing system with a separate milking parlour, made it possible to adopt a more flexible feeding management. Simultaneously, maize was introduced on the sandy soils in the South and East of the Netherlands. In thirty years the area grown with maize increased from approximately 6,000 ha to the present-day 220,000 ha. So gradually, more diverse grazing systems have developed throughout the country. The systems range from traditional day-and-night grazing, dominating on clay and peat soils in the North and West, to restricted or zero-grazing systems with supplementation of maize silage, dominating in the South and East. At present, it is estimated that the proportion of day-and-night grazing, day-only grazing and zero-grazing is 45%, 45% and 10%, respectively.

1.1.3 Grassland renovation

From the 1970s onwards, the area of renovated grassland has increased steadily. Presently, approximately 125.000 ha is renovated each year. However, there are considerable differences between years (Table 2), probably linked to weather conditions in certain years. For instance, the considerable area of sod-seeding in 1996 was caused by the severe winter of 1995/1996. In normal years, the area renovated by sod seeding is quite small. It is mainly practised on soil types on which tillage is difficult, such as heavy clay soils or peat soils with high groundwater tables.

In the ley-arable rotations, approximately 50% of the grassland is sown after a maize crop. In areas with a mix of specialised dairy and arable farms, grassland is often sown after a break with flower bulbs or potatoes.

Table 2. Annual grassland renovation (x 1000 ha) in the Netherlands (CBS, 2000).

Year	Permanent grassland		Ley-arable	Total
	Sod-seeding	Ploughing		
1990	14	61	52	127
1993	13	45	31	88
1996	50	59	44	153
1999	11	70	58	140

In 1999, 18% of the grassland area on sandy soils was ploughed and sown with grass (Table 3). On clay and peat soils, 10 and 3% of the grassland area was renovated, respectively. In other words, based on the data of 1999, grassland on sand, clay and peat soils is renovated on average every 5, 10 and 30 years, respectively. On sandy soils, two thirds of the renovated area was permanent grassland, whereas on clay soil two thirds of new grassland was sown following an arable crop.

Table 3. Grassland renovation in 1999 (x 1000 ha), in relation to soil type (CBS, 2000).

Soil type	Total grassland area	Renovated permanent grassland	Ley-Arable
Sand	450	55	29
Clay/Loam	400	12	26
Peat	175	3	3

1.1.4 Legislation

Only recently, the Dutch government announced that ploughing of grassland is prohibited between 16 September and 31 January. In common grassland farming this legislation generally does not conflict with the present practice. However, the bulb-growing sector opposes this legislation because it hampers the practice of autumn ploughing of grassland, followed by bulb planting.

1.2 Farmer's situation

1.2.1 Motivation for grassland renovation

In general, farmers decide to renew grassland if the performance of the existing sward, in terms of herbage production or quality, is lower than the potential performance. The lower performance is often caused by a single or a series of incidents.

Perennial ryegrass-dominated swards are relatively sensitive to periods of drought or frost. Considerable frost damage was observed in the winters of 1985/1986, 1986/1987 and 1995/1996.

Especially swards that had received high rates of N until late in the autumn were badly affected (Keuning *et al.*, 1988). A period of prolonged rainfall can have several negative effects on grassland swards. Direct damage during wet periods is caused by poaching of grazing livestock or by tyres of machinery. Indirect damage occurs through delayed silage cutting. The high grass yields lead to a slower aftermath regrowth and a lower sward density, thus creating opportunities for weed invasion.

High N application rates on sandy soils can cause urine scorching (Keuning *et al.*, 1988; Deenen, 1994) and a weaker root system (Sibma & Ennik, 1988). The use of incorrectly adjusted cutting equipment can also have detrimental effects on grass swards. Furthermore, pests, such as moles, mice or leather jackets, or fungal diseases may cause sward deterioration.

On clay and peat soils grassland renovation is also carried out if a field needs to be levelled. As the use of fertiliser N is gradually being reduced, a renewed interest in white clover may be expected, especially since nitrogen fixation by legumes is not included in the MINAS system so far. Grassland renovation creates a good opportunity to introduce white clover into the sward.

1.2.2 Criteria for grassland renovation

The present criteria for grassland renovation were developed in the 1970s and are only based on agronomic factors, of which sward composition is by far the most important. Grassland renovation is recommended if the proportion of perennial ryegrass is less than 50%. Furthermore, renovation is recommended if a sward contains more than 10% of couch grass (*Elymus repens* L.). On soils with high ground water tables the criteria are: (i) less than 50% perennial ryegrass and rough-stalked meadowgrass, or (ii) more than 15% couch grass.

If a field is uneven in such a way that it hampers good agricultural practice, it is recommended to level the field and establish a new sward.

1.2.3 Methods

At present, renovation of permanent grassland is normally carried out between mid-July and the end of September, although on sandy soils renovation in October occurs as well. This is usually indicated as 'autumn-sowing'. If the sward contains couch grass, it is recommended to kill off the old sward with glyphosate. However, the sward is often sprayed anyway because in farmers experience this makes tillage of the old sward easier. It is widely preferred to destroy the old sward with a rotatory cutter, followed by ploughing. Only if the soil does not allow tillage, such as heavy clay soil or peat soil, direct seeding into the old sward is recommended. The old sward is usually ploughed to a depth of 20 to 25 cm. Seed bed preparation is carried out shortly before sowing in such a way that there is a loose soil layer of approximately 2 to 3 cm on top of a firm soil.

In case a standard mixture of 100% perennial ryegrass is sown, the recommended amount of seed is 25 to 40 kg ha^{-1}, but farmers usually tend to be on the safe side and sow the maximum amount.

To make sure that the nutrient status of the newly sown sward is adequate, soil analysis is recommended, followed by application of the required nutrients, if necessary. Irrespective of the sowing time, a basic N application of 30 kg ha^{-1} is recommended (PR, 1998). Generally it is advised to be very cautious with the newly sown sward and if possible to graze lightly under good soil conditions for the first time.

1.2.4 Economics

Grassland renovation implies that costs are made for tillage, seeds, herbicides and pesticides (Table 4). The total costs depend on soil type, additional fertiliser needs and additional soil levelling. The basic costs for grassland renovation vary from € 557 ha^{-1} on peat soil to € 826 ha^{-1} on old clay soils. Additional fertiliser and soil levelling may increase the total costs to € 1392 ha^{-1}.

Table 4. Grassland renovation costs (€ ha^{-1}).

	Sand	Heavy clay	Light clay	Peat
Soil analysis	57	57	57	57
Herbicides				
Glyphosate	*27*	*27*	*27*	*27*
Other herbicides	*34*	*34*	*34*	*34*
Seeds	127	127	127	127
Fertilisers				
Basic application (P, K)	*84*	*45*	*45*	*36*
Additional application	*354*	*226*	*226*	
Contractor				
Spraying	*58*	*58*	*58*	*58*
Rotary cutting	*68*	*127*	*123*	*91*
Ploughing	*73*	*125*	*100*	
Seedbed preparation	*41*	*113*	*86*	*45*
Sowing	*54*	*113*	*60*	*82*
Levelling	*91*	*340*	*195*	*177*
Total				
Standard renovation	623	826	717	557
+ additional fertiliser	977	1052	943	557
+ additional fertiliser and levelling	1068	1392	1138	734

The benefits of grassland renovation are harder to quantify than the costs, mainly because there are only few studies in which renovated grassland has been compared with old grassland. Moreover, in most situations it is unclear what the production level of the old sward was before it was renovated. In order to determine whether grassland renovation is economically justified, the required production increase has been calculated for several soil types (Table 5). The calculations are based on the following presumptions:

- There is a direct loss of grassland production between the moment of ploughing and the first new cut, which is 25% for spring renovation and 12.5% for autumn renovation. Furthermore it is assumed that, compared to an existing sward, new grassland has a higher production in the first full production year of 8 to 15%, depending on soil type (peat > sand > clay). This annual extra production decreases to zero over the next four years (Figure 2).

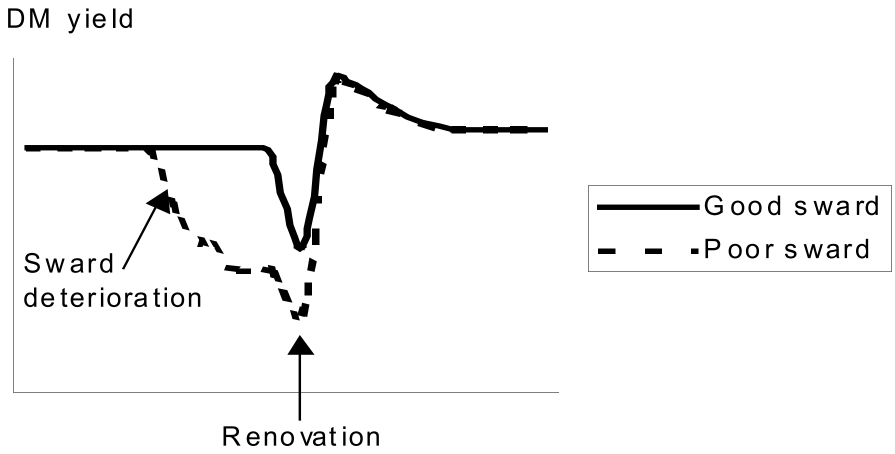

Figure 2. Assumed effect of grassland renovation on the DM yield.

- Due the use of new varieties, the potential yield of the new sward is higher than the potential yield of the old sward. This genetic improvement was estimated at 0.5% year^{-1} (Van Wijk & Reheul, 1991).
- The difference in net energy production between the new and old sward is higher than the difference in gross production, because of the higher feeding value (up to 7%) of the newly sown species and the lower grazing losses (up to 6%).
- The N losses are 100 kg ha^{-1} with spring-sowing and 300 kg ha^{-1} with autumn-sowing. As MINAS restricts the N input on a farm, this loss of N is valued as a loss of DM production, through the marginal N efficiency for grass production.
- An interest rate of 6%.

The calculations show that a substantial production increase is required to reach break-even, on top of the already assumed higher production. In other words, the production of the old sward must have deteriorated considerably, before grassland renovation is economically justified. On sand and clay soils a yield improvement of 23% is required, in case of a 5-year cycle. Longer depreciation periods of 10 or 15 years require a yield improvement of 13 and 10%, respectively. On peat soils, the required yield improvements are somewhat lower due to the lower costs.

It is remarkable that in farming practice grassland renovation is carried out more often than would be expected on the basis of these financial calculations. Clearly, farmers have a different view or take other factors into account, which have not been identified.

The economy of grass-maize rotations has been studied by Nijssen *et al.* (1996), based on results of field experiments on sandy soil. The yield of maize in rotation with grass was up to 7% higher than continuously grown maize. Due to the late harvest of maize, the new grass sward was established in spring next year. Consequently, the yield of first year grassland was 19% lower than the yield of the older swards. Together with the costs of grassland renovation, this means that the grass-maize rotation system was financially unattractive in comparison with a system of permanent grassland and continuous maize cropping. Under the present conditions, the MINAS regulations will also determine whether grass-maize rotations are used. De Haan (2001) concluded that on dry sandy soils grass-maize rotations are a good option to meet the MINAS targets, without negative effects on farm income.

Table 5. Required increase in grassland production to reach the economic breakeven point.

			Sand		Heavy clay		Light clay		Peat	
			Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
Renovation costs*	(€)		623	623	826	826	717	717	557	557
Extra yield new sward	(€)		30	-88	-14	-142	-14	-145	-33	-191
Nitrogen losses	(€)		84	251	84	251	84	251	84	251
Total costs	(€)		736	786	896	935	787	823	607	617
Interest	(€)		22	24	27	28	24	25	18	19
Annual depreciation	(€ yr^{-1})	5	169	181	206	215	181	189	140	142
over period of …. years		10	96	102	116	122	102	107	79	80
		15	71	76	87	90	76	80	59	60
Required yield increase	(kVEM yr^{-1})	5	2117	2260	2576	2688	2261	2365	1745	1774
over …. years		10	1197	1278	1456	1519	1278	1337	987	1002
		15	890	950	1083	1130	950	994	734	745
Required yield increase	(% yr^{-1})	5	23	25	25	26	22	23	18	18
over …. years		10	13	14	14	15	12	13	10	10
		15	10	10	11	11	9	10	8	8

* *See Table 4*

VEM = Net Energy for Lactation with kVEM = 1000 VEM

1.3 Research: state of the art

In the Netherlands, experimental studies into the effects of grassland renovation are scarce. There have been some studies that focussed on specific aspects, but an integrated study into the environmental, agronomic and economic consequences of grassland renovation has not been carried out yet.

1.3.1 Nutrient cycling

Ploughing of grassland has significant effects on nutrient processes in the soil (Figure 3). In a ploughed grassland soil there is increased mineralisation of plant material and soil organic matter. Therefore, the organic N content in the soil decreases after ploughing (Velthof *et al.*, 2000). In the case of grassland renovation, the organic N content will increase to the old level in several years. In the case of conversion to an arable situation, the organic N content steadily decreases until a certain equilibrium is reached. Vice versa, if arable land is converted into permanent grassland, the organic N content increases over the years. In ley-arable rotations, there is an alternation of increasing N contents in the grassland phase with decreasing N contents in the arable phase. In the ley-arable rotation as shown in Figure 3, it is assumed that the soil N content is more or less in equilibrium. However, there is no experimental support for this assumption. A relatively small upward or downward trend can have considerable effects on N losses.

It is evident that the increased N mineralisation increases the risk of N losses. The quantity and fate of mineralised N is related to the history of the old sward, the time of ploughing, the newly sown crop and the weather conditions. Model calculations indicate that in the first year, after ploughing a five-year old grass sward, the amount of soil organic N decreases by 100 to 300 kg ha^{-1} (Velthof *et al.*, 2000), indicating considerable mineralisation.

A literature review of Velthof & Oenema (2001) states that in the first 6 to 8 years, following grassland renovation, there is an N accumulation of 40 to 80 kg ha^{-1} in the stubble, 100 to 250 kg N ha^{-1} in the living roots and 100 to 200 kg ha^{-1} in plant and root litter. There is a higher N accumulation in clay soils than in sandy soils, due to the better protection of organic matter in clay soils. Soils with high groundwater tables accumulate more N than soils with low groundwater tables. Furthermore, the rate of N accumulation in grassland soils depends on the level of N input by fertiliser, slurry and biological fixation, and grassland management. However, due to lack of data, these effects are not quantified.

The longer a soil remains uncropped after ploughing the higher the risk of N losses. Generally, ploughing and sowing in spring or summer leads to a higher uptake of mineralised N than ploughing and sowing in autumn. Therefore, there is a lower risk of N losses with grassland renovation in spring or summer than in autumn.

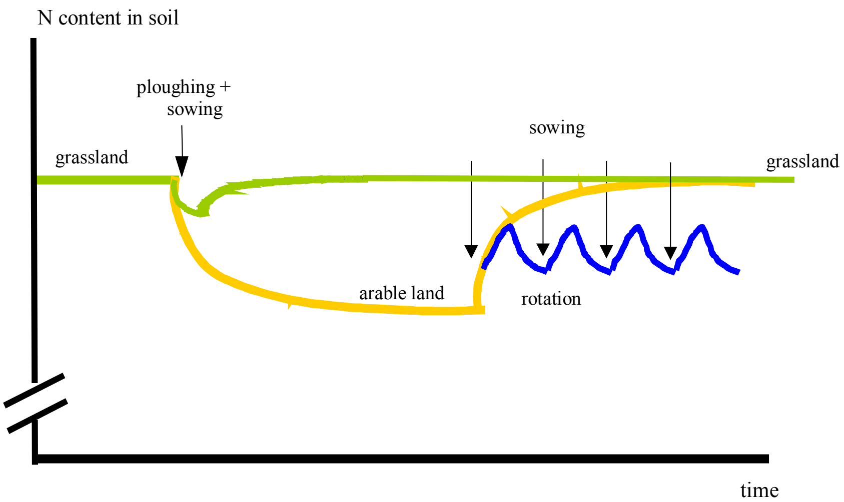

Figure 3. *Schematic representation of changes in the organic N content in the soil of permanent and temporary grassland and arable soils.*

In the Netherlands, there are hardly any direct measurements of N losses after ploughing grassland. Van Dijk (1997) compared the nitrate concentrations in drain water of newly sown grass/clover and maize on clay soil. Existing grass/clover fields were ploughed in January 1994. In April 1994, fields were sown with grass/clover or maize. During the winter of 1994/1995 the nitrate concentrations under grass/clover were always lower than 25 mg l^{-1}, whereas the nitrate concentrations under maize were between 50 and 200 mg l^{-1}. Nitrate concentrations under older existing grass/clover fields were between 25 and 50 mg l^{-1}.

Vellinga *et al.* (2002) calculated that ploughing of grasslands might contribute significantly to the emission of N_2O in the Netherlands. Recent measurements on clay soil indicate that, compared to permanent grassland, the N_2O emissions were 7 and 113 times higher after ploughing in spring or autumn, respectively (Van den Pol-Van Dasselaar; personal communication). The autumn measurements were carried out under extremely wet conditions.

On a dry sandy soil, Aarts *et al.* (2002) measured average nitrate concentrations of 62 mg l^{-1} under a grass-maize rotation, with lower leaching losses during the grass phase than during the maize phase. In the same period, the average nitrate concentration under permanent grassland was 69 mg l^{-1}.

Table 6. Estimates of soil N balances (kg ha⁻¹ year⁻¹), changes in soil N and pathways of N losses, for four types of dairy farms in the Netherlands.

	Permanent grassland												Ley-arable rotation, dry sand						
	Sand			Clay				Peat					g	g	g	m	m	m	
	1 yr	2-6 yr	mean	1 yr	2-6 yr	7-10 yr	mean	1 yr	2-6 yr	7-10 yr	10-20 yr	mean	1 yr	2 yr	3 yr	1 yr	2 yr	3 yr	mean
Input																			
Animal excreta (excluding NH_3 losses) [1]	64	87	84	74	106	106	103	69	97	92	92	92	85	120	120	0	0	0	54
Cattle slurry (excluding NH_3 losses) [1]	135	189	180	99	140	140	135	81	135	126	126	126	240	240	240	0	90	105	153
Fertiliser	140	135	136	205	175	175	178	250	200	200	195	200	125	120	120	0	0	0	61
Deposition	40	40	40	35	35	35	35	30	30	30	30	30	49	49	49	49	49	49	49
Biological fixation	20	20	20	40	30	20	27	0	0	0	0	0	11	11	11	0	0	0	6
Total	399	471	459	453	485	475	478	430	462	448	443	448	510	540	540	49	139	154	322
Output																			
Removed crops	270	350	337	250	325	300	308	240	365	357	357	353	290	310	310	135	125	120	215
Surplus	129	121	123	203	160	175	171	190	97	91	86	95	220	230	230	-86	14	34	107
Change in soil organic	-125	25	0	-73	11	5	0	-310	-38	-52	-50	-60	100	70	70	-168	-48	-24	0
Leaching and denitrification losses	254	96	123	276	149	170	171	500	134	143	136	155	120	160	160	82	62	58	107
Denitrification (%)	55	55	55	70	70	70	70	85	85	85	85	85	40	40	40	25	25	25	33
N_2O -emission (%)	5	5	5	7	7	7	7	8	8	8	8	8	5	5	5	5	5	5	5
NO_3 - leaching groundwater (%)	38	38	38	3	3	3	3	0	0	0	0	0	55	55	55	70	70	70	62
NO_3 - leaching surface water (%)	2	2	2	20	20	20	20	7	7	7	7	7	0	0	0	0	0	0	0

[1] *Estimated ammonia losses: 10% for slurry and 8% for animal excreta during grazing*

[2] *g = grass ; m = maize*

Data from dairy farms in the 'Cows & Opportunities' project (Oenema *et al.*, 2001) and expert judgement were used to compile soil N balances for four situations on dairy farms (Table 6). It has to be emphasised that these data are only examples and do not intend to cover the whole picture of grassland renovation in the Netherlands.

The first year after ploughing permanent grassland, there is a high N mineralisation with a high risk of N losses. On the other hand, the establishment of a new sward immobilises N. The N losses can be minimised by ploughing and sowing in spring and by a fertiliser strategy that takes the high N mineralisation into account. Especially on peat soils, the N losses after ploughing can be considerable. The proportion of losses through denitrification increases from dry sandy soils to peat soils. In the ley-arable situation, it is assumed that the proportion of losses through denitrification will not be similar under grass and maize, due to a changed availability of degradable organic matter.

1.3.2 Soil quality

As discussed earlier, grassland ploughing has considerable effects on soil organic matter dynamics. Besides the mineralisation and immobilisation of nutrients, organic matter also affects the rooting capacity, the water holding capacity, the bearing capacity and the susceptibility to soil compaction. The effects of grassland renovation on soil quality and the subsequent effects on other factors are variable and usually hard to quantify (Table 7).

Newly sown grass roots deeper (Sibma & Ennik, 1988), thereby increasing the proportion of nutrient and water uptake from deeper soil layers. Especially on dry sandy soils, the increased water availability is an important advantage. In later years, roots, organic matter and nutrients concentrate in the 0-5 cm top layer.

On clay and peat soils the physical qualities of the soil, such as soil aggregate stability and bearing capacity, are generally negatively affected by grassland renovation.
Overall, grassland renovation of permanent grassland has positive effect on the soil quality of sandy and clay soils and a negative effect on the soil quality of peat soils. On dry sandy soils, ley-arable rotations have positive effects on the soil quality.

Table 7. The estimated effect of soil quality changes, due to grassland renovation.

Factor	Renovation of permanent grassland			Ley-arable	
	Sand	Peat	Clay	Dry sand	
				grass	arable
Nutrient supply	0/-	+	+	-	++
Water supply	+/++	0	0/+	+	++
Soil aggregate stability	0	---	--	0	0/+
Slaking susceptibility	0/-	0	0/--	0	0
Poaching susceptibility	0	---	--	0	0
Bearing capacity	0	--	-	0	+
Rooting depth	+	+	+	0	+
Air content	0/-	0/-	0/-	0	-/--
Levelling	+	+	+/++	0/+	+
Rooting capacity	++	0	+	++	+
General	+	--	+/0	+	++

1.3.3 Agronomic performance

In the Netherlands, there is no recent research into the effects of renovating botanically poorly valued grasslands. In recent experiments with comparisons between old and new grassland, the old grassland could be qualified as good grassland, not necessary to be renovated. Therefore it is difficult to quantify the performance of old and renovated grassland.

The yields of grass in a cutting experiment on sandy soil (Van Dijk *et al.*, 1996) were used to estimate the effects of grassland renovation on agronomic performance (Table 8). In these experiments, grass was sown in subsequent years, on a soil with a history of continuous maize cropping. Therefore, temporary grass swards of different ages could be compared. It is assumed that grass is sown in spring and that therefore the yield depression in the first year is 20%. Furthermore, it is assumed that there is a positive but varying effect in the second year, mainly based on experiments by Hopkins *et al.* (1990; 1995).

Table 8. Estimated effects of grassland renovation on DM and N yield, with annual N application rates of 280 kg ha^{-1} for sand, 245 kg ha^{-1} for clay and 240 kg ha^{-1} for peat.

	Year				100 % =… kg ha^{-1} year^{-1}
Sand	*1*	*2*	*3 - 6*	*mean*	
DM yield (%)	80	106-144	103	100-106	8430
N yield (%)	80	100-129	98	95-100	290
Clay	*1*	*2*	*3 - 10*	*mean*	
DM yield (%)	80	106-144	103	101-105	8400
N yield (%)	80	100-129	98	96-99	270
Peat	*1*	*2*	*3 - 20*	*mean*	
DM yield (%)	70	110	105	104	9346
N yield (%)	70	106	100	99	340

An annual yield increase of 0.5% may be expected through genetic improvement of grass varieties (Van Wijk & Reheul, 1991; Vellinga & Van Loo, 1994) . Next to yield improvements, the forage quality may be enhanced by grassland renovation. Observations in farming practice suggest a higher intake and lower grazing losses on newly sown swards. However, this can not be confirmed by experimental data.

1.3.4 Gaps in knowledge

As stated earlier, the major objective of further research should be to attain a complete picture of the environmental, agronomic and economic consequences of grassland renovation. More specifically, the main knowledge gaps are:

- Quantification of the effects of grassland renovation on N cycling and N losses in the plant-soil system, with respect to soil type, renovation strategy and crop management.
- Development of management strategies minimising the risks of N losses during grassland renovation'.
- Development of scientifically sound and practically applicable criteria to support farmers in decisions on grassland renovation.
- Further identification of farmers motives for grassland renovation.
- Quantification of the effect of grassland renovation on DM yield, herbage quality and animal performance.

Acknowledgements

This study was funded by the Ministry of Agriculture, Nature Management and Fisheries (research programmes PO-9, DLO-317 and DWK398-II).

References

Aarts, H.F.M., E.E. Biewinga & H. van Keulen, 1992.
Dairy farming systems based on efficient nutrient management. Netherlands Journal of Agricultural Science 40: 285-299.

Aarts, H.F.M., G.J. Hilhorst, F. Nevens & J.J. Schroder, 2002.
De betekenis van wisselbouw voor het melkveebedrijf op lichte zandgrond. Een analyse van de resultaten van proefbedrijf 'De Marke'. In press.

Bussink, D.W. & O. Oenema, 1998.
Ammonia volatilisation from dairy farming systems in temperate areas: a review. Nutrient Cycling in Agroecosystems 51: 19-33.

CBS, 2000.
Veel gras ingezaaid na maïs. Persbericht PB00-A3. Centraal Bureau voor de Statistiek, Voorburg.

Deenen, P.J.A.G., 1994.
Nitrogen use efficiency in intensive grassland farming. Doctoral Thesis, Wageningen Agricultural University.

De Haan, M.H.A., 2001.
Economics of environmental measures on experimental farm 'De Marke'. Netherlands Journal of Agricultural Science 49: 179-195.

Henkens, P.L.C.M. & H. van Keulen, 2001.
Mineral policy in the Netherlands and nitrate policy within the European Community. Netherlands Journal of Agricultural Science 49: 117-134.

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

Hopkins, A., P.J. Murray, P.J. Bowling, A.J. Rook & J. Johnson, 1995.
Productivity and nitrogen uptake of ageing and newly sown swards of perennial ryegrass (Lolium perenne L.) at different sites and with different nitrogen fertiliser treatments. European Journal of Agronomy 4: 65-75.

LEI, 2002.
Farm Accountancy Data Network (www.lei.wageningen-ur.nl). Agricultural Economics Research Institute, The Hague.

Keuning, J.A., P.J.M Snijders & H. van Dijk, 1988.
Vorstschade in grasland. Rapport 113. Proefstation voor de Rundvee-, Schapen- en Paardenhouderij, Lelystad.

Nijssen, J.M.A., W. van Dijk, T. Baan Hofman & A.P. Wouters, 1996.
Economie van mais-gras wisselbouw. Publikatie 113, Praktijkonderzoek Rundvee, Schapen en Paarden, Lelystad.

Oenema, J., G.J. Koskamp & P.J. Galama, 2001.
Guiding commercial pilot farms to bridge the gap between experimental and commercial dairy farms; the project 'cows & opportunities'. Netherlands Journal of Agricultural Science 49: 277-296.

PR, 1998.
Adviesbasis bemesting grasland en voedergewassen. Themaboek, Praktijkonderzoek Rundvee, Schapen en Paarden, Lelystad.

Sibma, L. & G.C. Ennik, 1988.
De ontwikkeling van productiegras onder Nederlandse omstandigheden. Pudoc, Wageningen.

Van Dijk, W., T. Baan Hofman, K. Nijssen, H. Everts, A.P. Wouters, J.G. Lamers, J. Alblas & J. van Bezooijen, 1996.
Effecten van maïs-gras vruchtwisseling. Verslag 217, Proefstation voor de Akkerbouw en de Groenteteelt in de Vollegrond, Lelystad, 140 pp.
Van Dijk, W., 1997.
Mais na oud grasland op klei vraagt weinig stikstof en fosfaat. Praktijkonderzoek 10, nr.1: 12-14.
Van der Meer, H.G., 1994.
Grassland and society. In: L. 't Mannetje & J. Frame (Eds.), Grassland and Society. Proceedings of the 15th General Meeting of the European Grassland Federation, Wageningen, pp. 19-32.
Van Wijk, A.J.P. & D. Reheul, 1991.
Achievements in fodder crops breeding in maritime Europe. Proceedings of the 16th meeting of the Fodder Crops Section of EUCARPIA 'Fodder crops breeding: Achievements, novel strategies and biotechnology', Wageningen.
Vellinga, Th.V., A. van den Pol-van Dasselaar, J. Dolfing & P.J. Kuikman, 2002.
Effect of grassland renovation, grassland ploughing and ley-arable rotations on nitrous oxide emissions in the Netherlands. (in prep).
Velthof, G.L., J.J. Neeteson, H.G. van der Meer & O. Oenema, 2000.
Schatting van de netto mineralisatie en biologische stikstofbinding in landbouwgronden. Rapport 117, Alterra, Wageningen, 35 pp.
Velthof, G.L. & O. Oenema, 2001.
Effects of ageing and cultivation of grassland on soil nitrogen. Rapport 399, Alterra, Wageningen, 55 pp.
Willems, W.J., Th.V. Vellinga, O. Oenema, J.J. Schroder, H.G. van der Meer, B. Fraters & H.F.M. Aarts, 2000.
Onderbouwing van het Nederlandse derogatieverzoek in het kader van de Europese Nitraatrichtlijn. RIVM rapport 718201002, Bilthoven.

2. Ecological, environmental and economic aspects of grassland cultivation in Belgium

F. Nevens[1], I. Verbruggen[1], A. De Vliegher[2] & D. Reheul[1]

[1] Ghent University, Department of Plant Production, Coupure Links 653, 9000 Gent, Belgium
[2] Ministry of Small Enterprises, Traders and Agriculture, Agricultural Research Centre, Department Crop Husbandry and Ecophysiology, Burg. Van Gansberghelaan 109, 9820 Merelbeke, Belgium

2.1 General information

Grassland renovation or reseeding is necessary if the quality of the existing grassland leaves something to be desired. In Flanders, grassland is intensively used, particularly on dairy farms located on sandy soils. On these farms, grassland renovation is carried out frequently. The grassland used for beef cattle is less intensively managed and less frequently renovated. Also on loamy soils less reseeding is carried out because sward degeneration is more exceptional.

2.1.1 Grassland use in Belgium

In Flanders, the total agricultural area is 636,000 ha, in Wallonia this is 757,000 ha; a total of 1,393,000 ha. The most important type of agricultural land use is grassland (620,254 ha or 44.5%), followed by cereals, mainly winter wheat (276,734 ha). The remaining 35% is used to produce silage maize, industrial crops (e.g. sugar beet), potatoes and horticultural crops. In Flanders, the grassland area is 241,313 ha (38% of the total agricultural area in Flanders).

An average dairy farm in Belgium has about 38 ha of cultivated land, of which 67% is grassland and 33% is silage maize land. An average beef cattle farm has about 45 ha of cultivated land, 66% is grassland (NIS, 2001). The average stocking rate of a Flemish cattle farm is 3.16 LSU per ha of green fodder crops. In Wallonia this stocking rate is 2.49 LSU ha^{-1}. For Belgium as a whole, the stocking rate is 2.79 LSU ha^{-1}. Most dairy farmers in Belgium apply a grazing system keeping the middle between rotational and continuous grazing on three to four plots. This system is more flexible than pure continuous grazing and less flexible than rotational grazing. Beef cattle farms most often apply continuous grazing systems.

The average N-fertiliser use on Flemish dairy farms grassland is 265 kg N ha^{-1}. The average mowing percentage is about 150%. An average Flemish dairy farm has a milk production of 11,750 l ha^{-1}. The average milk production per cow is 5,731 l. The N-, P- and K-surpluses for the Flemish dairy farms are 295, 23 and 106 kg ha^{-1}, respectively (Michiels *et al.*, 1998; Verbruggen, 2001; Mullier *et al.*, 2001).

2.1.2 Grassland cultivation

The major part of the Belgian grassland is permanent (505,524 ha). The other part is temporary grassland (in particular Italian ryegrass). The area of red clover and lucerne is negligible. Figure 1 illustrates the evolution of the fodder crop areas in Belgium in the past century. There was a large decrease in temporary grassland since the 70’s as result of the introduction of silage maize. In the early 90’s the area of temporary grassland was increasing again, caused by the CAP legislation. Recently, the difference between permanent and temporary grassland in statistics is more or less artificial: to maximise the arable crop support more grassland is reported as temporary grassland instead of permanent grassland.

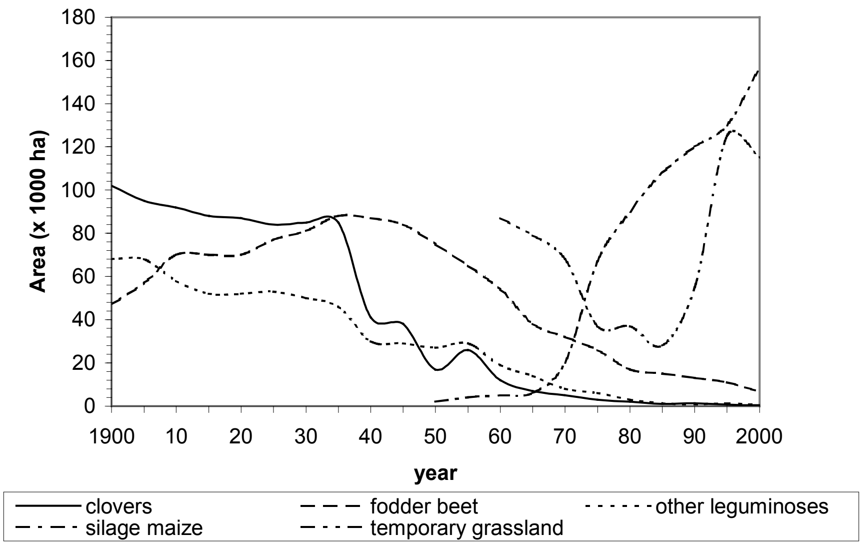

Figure 1. Area of fodder crops in Belgium (1900–2000).

On many dairy farms on sandy soils, Italian ryegrass is sown following the September-October silage maize harvest. One spring cut is taken before ploughing and seeding maize again. This strategy allows farmers to apply 25% more fertiliser (Flemish Manure legislation, Ministry of the Flemish Community, 1991-2000) and hence to place more of their manure production on their own fields (except for farms in nitrate-vulnerable zones).

Exact figures of grassland reseeding in Belgium are not directly available. Only an estimate can be made, based on the grass seed sales for agricultural purposes. Considering these sales and assuming an average use of 45 kg of grass seed per ha, the area of grassland reseeding in Belgium should be about 43,200 ha each year, corresponding with about 7% of the grassland area. This would also mean that the average age of grasslands is about 14 years.

2.1.3 Legislation

In Belgium there is no specific legislation with respect to grassland cultivation. Only when the farmer has entered into a nature management agreement on a grassland field (in order to enhance the botanical diversity or the meadow bird populations) he is not allowed to plough the grassland or to reseed it during the period of the agreement.

2.2 Farmer's situation

2.2.1 Causes of grassland renovation

The general view is that under Belgian conditions grassland should contain a high proportion of perennial ryegrass (*Lolium perenne* L.) which is a highly productive grass species with a high nutritive value and which is very suitable for grazing. Especially in Flanders farmers prefer and are encouraged to keep a high percentage of perennial ryegrass in their swards. In Wallonia, where grassland is used more extensively, other grasses like timothy (*Phleum pratense*), meadow fescue (*Festuca pratensis*) and smooth stalked meadow grass (*Poa pratensis*) are also considered valuable under the applied regimes of lower N-fertiliser use.

On 'good' soils, particularly the loamy soils, grasslands can keep a good botanical composition for a long period: 20 years or more are not exceptional. In these regions it is not usual to renew the grassland very frequently. Here we find old grasslands that still have a good botanical composition.

On sandy soils farmers are more used to renovate their grassland. Especially on soils with compacted layers in the underground, it 'is difficult to maintain a desired botanical composition following years with abnormal weather conditions (drought). On such soils the invasion of annual meadow grass (*Poa annua*) or couch grass (*Elymus Repens*), both low quality grasses, is often a problem. Under dry conditions there can be a quick shift from a good sward to a less productive and less palatable one. This is also the reason to renovate those grasslands more frequently. Quite often incorrect management is also a major reason of sward deterioration and hence the need for grassland renovation. Too late cutting or grazing or driving with heavy machinery (during harvest or when animal slurry is brought on) under wet conditions can degenerate the sward quality. In some cases winter killing of e.g. perennial ryegrass can also cause negative changes in botanical composition. On the heavy clay soils, slurry injection under dry conditions can also contribute partly to sward deterioration. Abundant presence of weeds, like dandelion (*Taraxacum officinale*), docks (*Rumex obtusifolius*) and chickweed (*Stellaria media*) can be a major reason for quality of a grass field to drop. However, these weeds can be controlled chemically.

2.2.2 Criteria for grassland renovation

Farmers make the decision to renovate or reseed if the quality of the grassland leaves something to be desired. This is the case when they consider production to be insufficient or when the animals apparently leave large amounts of grass after grazing. A change in the botanical composition of the sward quite often is the main reason for this conception of lower quantity and quality.
This implies that real criteria do not exist; the decision to renovate is more induced by subjective parameters.

Objective criteria exist but are not commonly used. An example: according to Behaeghe (1991), renovation should be considered seriously when couch grass presence is more than 15%,.

2.2.3 Methods and time of grassland renovation

In Belgium grassland renovation is usually carried out during August and September. In this period, the weather conditions are somewhat better than in spring (drought risk). The new grass plants can develop rather quickly and the competition of weeds is less than in spring. Another advantage of reseeding in August or September is that the yield losses are lower compared to spring reseeding.

Reseeding of grassland or sowing of grass after another crop can be carried out after thorough tillage of the soil, but also through direct sowing into the old sward (sod-sowing), with or without minimum tillage. The latter method is regularly used in Wallonia on grassland in strongly hilled areas (larger erosion risk). In Flanders the use of a special rotary tiller system, destroying small strips of the sward in which clover is seeded, is in an experimental stage.

The common way to reseed Flemish grasslands is the following. The sward is always destroyed chemically (glyphosate). This is considered necessary to avoid that old sward rests regrow, resulting in a less successful renewing of the grassland. After this killing of the vegetation, the old sward is destroyed with a rotary tiller. This enhances the breakdown of the old vegetation after ploughing and prevents that the old sward is brought up again during cultivation. Ploughing loosens the soil and buries the topsoil, which mostly contains the seeds of undesired species of grasses and weeds. The usual ploughing depth is about 25 cm. Sometimes levelling is carried out with special levelling machinery (laser controlled). Seedbed preparation is usually carried out with a rotary harrow (on loamy or clay soils) or, on sandy soils, with a cultivator, possibly combined with a packer. Seedbed preparation and sowing can be executed in one operation, e.g. with a heavy tractor provided with a powered rotary harrow and a sowing machine. The grass can be sown with a fertiliser broadcaster. On mixed farms with arable crops a grain-sowing machine is often used. In that case, because of the higher row distance, broad sowing coulters are sometimes used or criss-cross sowing is applied. Some farmers obtain good results with a grain-sowing machine without pipes, which simply drops the seed on the surface (on top of the seedbed with a fine weeding harrow after that).

2.2.4 Economic costs/benefits of grassland renovation

Grassland renovation is expensive. It should only be carried out if the botanical composition is insufficient. Grassland improvement is only justified if the costs involved are repaid by the subsequent higher yields, better forage quality and possibly by easier working. However, making a cost-benefit analysis is not easy.

The costs of grassland renovation in Belgium show a high variability. Farms with less fertile soils have to renew their meadow frequently (every 3 to 4 years) due to the fast botanical degradation of the sward. Other farms with good loamy soils don't have to keep to this frequency. Every 6 years is a good average of renewing the sod. So the costs of reseeding should be spread over these six years. The costs of grassland renovation under average Belgian conditions are shown in Table 1. The total costs are estimated at € 365 per ha. In a scheme of renovation every six years this means a yearly cost of 365/6 = € 61 per ha. In Belgium it is estimated that 100 kg dry matter of grass has a value of about € 8.63 (Coomans *et al.*, 2000). This means that new grassland should yield an extra 700 kg DM ha^{-1} year^{-1} (€ 61) to repay for the renovation costs. This means that the new grassland should produce 5 to 7% more than the 'old' one.

Table 1. Costs of grassland renovation (€ ha^{-1})

Treatment	Costs
Chemical destruction	55
Rotary tilling	56
Ploughing	63
Seedbed preparation	50
Sowing	41
Seeds	100
Total costs	365

2.3 Research: results in Belgium

2.3.1 Grassland cultivation and the environment

Specialised dairy farms in Belgium have only two crops in their rotations: grass and silage maize. Maize cropping in monoculture causes major problems and is not compatible with sustainability principles

(Nevens & Reheul, 2001). On the other hand, grassland renovation in autumn is not always environmentally friendly because of of the high nitrogen release, not sufficiently taken up by the reseeded grass and hence prone to overwinter leaching. Introduction of an arable crop for at least one year could deal with these problems. Recently, the Flemish Landbouwcentrum Voedergewassen of the Belgian Ministry of Small and Medium Enterprises and Agriculture studied the consequences of grassland cultivation on subsequent silage maize at 3 different locations (Mertens *et al.*, 2001 and Mertens & Bries, 2002). The grass sward was destroyed at 2 different times in spring (January and April) with a rotary tiller before maize was sown. Two N-fertiliser rates were applied to the silage maize (Table 2).

Table 2. Survey of the treatments.

Treatment	Time of sward destruction	Nitrogen fertilisation
1	January	0
2	January	150 kg N ha^{-1}
3	April	0
4	April	150 kg N ha^{-1}

After the maize was harvested, residual soil nitrate-N (0–90 cm) was determined. The results are given in Table 3.

Table 3. Survey of nitrate (kg N ha^{-1}) in the soil profile (0-90 cm).

Treatment	NO_3-N (kg N ha^{-1})		
	Location 1	Location 2	Location 3
1	49.9	87.1	197.8
2	240.6	195.3	312.7
3	61.5	32.6	188.5
4	136.7	246.3	233.3

In Flanders, manure legislation considers an amount of residual soil nitrate-N exceeding 90 kg ha^{-1} (0-90 cm, measured between 1 October and 15 November) as environmentally harmful, i.e. resulting in surface or groundwater nitrate concentrations exceeding 50 mg l^{-1}. The experimental results show that it is only possible to remain under this limit when no fertiliser N was applied to the silage maize following the ploughed grassland. In the case of location 3 (wet soil) it 'is impossible, also without any fertiliser, to stay below the 90 kg limit.
We add that the silage maize dry matter yields were similar, with or without fertiliser N application.

From 1990 to 1998, a study was done into the N-release from ploughed 3-year-old grazed grasslands in the subsequent three seasons of forage crops on a sandy loam soil in Melle (Nevens & Reheul, 2002a). Silage maize in the ley-arable rotation outyielded continuous maize on permanent arable plots by 85, 21 and 2% at mineral N fertilisation rates of 0, 75 and 180 kg N ha^{-1}, respectively. This decreasing yield effect with increasing N fertilisation indicated that the ley-arable rotation effect was mainly a N-contribution effect. The N release was highest during the first year; it decreased during the second and third year following grassland ploughing. Economically optimum N-fertilisation rates for silage maize in these years were 2, 139 and 154 kg N ha^{-1}, respectively. Simultaneously, on permanent arable plots this was 152, 191 and 183 kg N ha^{-1}, respectively. This resulted in comparable yields (19.75 t DM ha^{-1} year^{-1}) but with a possible saving of 231 kg of mineral N fertiliser ha^{-1} in a 3-year silage maize period following the ploughed leys compared with continuous silage maize. The N-uptake by silage maize on temporary arable plots following grassland was higher than on permanent arable plots, owing to the higher yields but also to an increased N concentration in the crop on the temporary arable plots. Starting the arable forage crop sequence with fodder beet following grassland ploughing and adjusting the N fertilisation to the enhanced N release minimised the risks of high amounts of residual soil N and hence N leaching losses.

2.3.2 Grassland renovation and dry matter production

An experiment was carried out to determine the quality and the dry matter yield of a 1-, 2-, 3-, 4- and 5-year old pasture under rotational grazing conditions (DM yields were determined by cutting strips, De Vliegher *et al.*, 2002). During five consecutive years (1996–2000) the same grass or grass/white clover mixture was sown. From the results of the past 5 years it is clear that the dry matter yield on reseeded grassland was lower than on well-established older (6 years) grassland. The main causes were the yield losses during the autumn of sowing and the lower yields during the first growing season, when the new pasture is still establishing. The 'old' pasture remained in optimal condition, qualitatively as well as botanically, and hence kept yielding highly. On average, during their first growing season, reseeded ryegrass or grass/clover mixtures yielded 12 and 27%, respectively, less compared to the 'permanent' 1996 pasture. Woldring (1975) and Mott & Ernst (1984) came to the same conclusion that reseeding does not automatically increase the yield when the botanical composition of the old sward is of good quality.

Table 4. Influence of reseeding grass and grass/white clover mixtures on the total net dry matter yield under grazing conditions during the period 1997-2001.

Treatment/harvest year	1997	1998	1999	2000	2001[3)]
Ryegrass					
Sowing 1996 (09 Sept.)	100	100	100	100	100
Sowing 1997 (07 Oct.)	94[1)]	**90**[2)]	102	99	100
Sowing 1998 (29 Sept.)		96[1)]	**92**[2)]	85	92
Sowing 1999 (26 Sept.)			91[1)]	**82**[2)]	91
Sowing 2000 (05 Sept.)				88[1)]	**88**[2)]
Kg DM.ha^{-1} at 100	9537	10326	9961	13418	11275
Grass and white clover					
Sowing 1996 (09 Sept.)	100	100	100	100	100
Sowing 1997 (07 Oct.)	98[1)]	**54**[2)]	85	111	101
Sowing 1998 (29 Sept.)		95[1)]	**73**[2)]	105	105
Sowing 1999 (26 Sept.)			94[1)]	**76**[2)]	72
Sowing 2000(05 Sept.)				86[1)]	**88**[2)]
Kg DM.ha^{-1} at 100	8416	10491	11588	11817	9806

1) *net yield of sowing 1996 up to the sowing date*
2) *net yield in the first year after sowing*
3) *net yield until 1 October*

Permanent grassland was compared with three-year temporary leys alternating with three-year periods of arable forage crops during 31 years (1969 to 1999) on a trial (M66.1) in Melle (Nevens &Reheul, 2002b). The average feed energy yields of both types of grasslands, 75.1 and 73.3 GJ NEL ha^{-1}, respectively, were not significantly different. Possible preconditions for the lasting high production level of the 31-year-old, never reseeded permanent pasture were the high fertilisation level (200 to 350 kg N ha^{-1} $year^{-1}$) and the preservation of a fairly good botanical composition. The temporary grasslands produced as much as the permanent grassland without the necessity to apply higher amounts of fertiliser N during their three-year lifetime.

References

Behaeghe, T., 1991.
Grasland en groenvoeders; Deel 1: Grasland. Cursus Universiteit Gent; Faculteit van de Landbouwwetenschappen.

Coomans, D., G. Rombouts, A. de Vliegher, D. de Brabander, M. Malengier, B. Sonck, E. van Bockstaele, V. Vervaeke, I. Verbruggen, G. van Nieuwerburgh, J. de Wilde, D. Audenaert, G. Vandepoel, G. de Smet, O. Standaert, J. Bries & M. Beke, 2000.
Kostprijsraming ruwvoeders 2000, 2 p.

De Vliegher, A., O. Grunert & L. Carlier, 2002.
The effect of grassland resowing on yield and quality under grazing conditions, 3p. (in press).

Mertens, J., J. Bries, D. Coomans & G. Rombouts, 2001.
Beredeneerde stikstofbemesting van maïs op gescheurd grasland. 3 p.

Mertens, J. & J. Bries, 2002.
Beredeneerde stikstofbemesting van maïs op gescheurd grasland. Resultaten 2001, 23 p.

Michiels, J., L. Carlier & I. Verbruggen, 1998.
Mineralenbalansen en hun gebruik op melkveebedrijven. In: Naar een duurzame grasland- en groenvoederuitbating. Ed. Van Uylenbroek, G. and Jacobs, G. Ministerie van Middenstand en Landbouw, Brussel, pp.27-49.

Ministry of the Flemish Community, 1991–2000.
Decree concerning the protection of the environment against pollution by fertilisers. Belgian Law Gazette (B.S.) 28/02/1991. This decree was amended by the decrees of 25 June 1992 (B.S. 11 July 1992, 18 December 1992 (B.S. 29 December 1992), 22 December 1993 (B.S. 29 December 1993), 20 December 1995 (B.S. 30 December 1995), 19 December 1997 (B.S. 30 December 1997), 11 May 1999 (B.S. 20 August 1999) and of 3 March 2000 (B.S. 30 March 2000).

Mott, N. & P. Ernst, 1984.
Grünlandverbesserung - Nachsaat - Neuansaat In Hrsg.: Auswertungs- und Informationssdienst für Ernährung, Landwirtschaft und Forsten.

Mulier, A., G. Hofman, E. Baecke, L. Carlier, D. de Brabander, G. de Groote, R. de Wilde, L. Fiems, G. Janssens, O. van Cleemput, A. van Herck, G. van Huylenbroeck & I. Verbruggen, 2001.
Emission prevention in agriculture by means of nutrient balances. Final Report. (in Dutch). Ghent, 239 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 fertilisation. Netherlands Journal of Agricultural Science 49, 405–425.

Nevens, F. & D. Reheul, 2002a.
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.

Nevens, F. & D. Reheul, 2002b. (in press).
Permanent grassland and three-year leys alternating with three years of arable land: 31 years of comparison. European Journal of Agronomy.