Danish Research Centre
for Organic Farming

Progress Report 2005 and Application for Continuation in 2006

For research projects financed by grants from
The Directorate for Food, Fisheries and Agro Business
under the Danish Ministry of Food, Agriculture and Fisheries

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1. Research program

Research in organic farming 2000-2005 (DARCOF II)

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2. Project title and number

Nitrate leaching from dairy farming. Effect of grassland composition and frequency. (I.15)

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3. Head of project

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6. Project period (month, year)

Start of project: 01-2003
End of project: 12-2006

7. Description of the project, its results and progress, and application for continuation in 2005.

A. Project summary

In nitrate vulnerable zones with agricultural production organic dairy farming may present an opportunity to reduce nitrate leaching if grassland N is efficiently utilised. The objective of the project is to determine the importance of the grassland composition and frequency in the crop rotation for residual effects on yield and nitrate leaching during grazing and following ploughing in order to 1) increase the total N use efficiency of the crop rotation and reduce N leaching losses from dairy crop rotations, 2) suggest specific changes to management and rotation, that may be carried out in e.g. nitrate vulnerable zones within the short term, and 3) establish a scientific sound basis for giving advise on these matters in both organic and conventional farming. The work includes determination of precrop effect and nitrate leaching following ploughing of grassland as affected by grassland frequency in the crop rotation and with comparison between grass-clover and fertilised pure ryegrass.

The results from the experiment are relevant for planning organic crop rotations, especially in nitrate vulnerable zones. The relevance of this type of information increases with the development towards increasing farm size. On large farms grazing on fields distant to farm buildings is more difficult resulting in a high grassland frequency in the rotation near the farm and a cash-crop rotation furthest away. It is important to determine N utilisation and environmental consequences of this. The results are also relevant for conventional farmers having ryegrass as the experiment includes a comparison between grass-clover and ryegrass.

Table A.1: Work package list (from application)

No.	Work package title	Participants*	Budget (1.000 DKK)	Start	End	Deliverable no(s):
1	Determination of precrop effects and nitrate leaching of grazed grassland rotations	JE, EMH	900	04/03	01/06	1, 2
2	Nitrate leaching on coarse sandy soils	EMH, JE	1.190	01/03	04/06	3
3	SOAR Ph.D. study: Mineralisation of grassland nitrogen	HHJ, JR	200	07/03	07/06	4, 5
4	Optimising the N Cycle of organic dairy farms	JE, EMH, JEO, ISK, MA, HHJ	100	04/03	12/06	6, 7
Total			2.390			

* Responsible participants are underlined

B. Objectives and expected achievements

The objective of the project is to determine the importance of the grassland composition and frequency in the crop rotation for residual effects on yield and nitrate leaching during grazing and following ploughing in order to:

- increase the total N use efficiency of the crop rotation and reduce N leaching losses from dairy crop rotations
- suggest specific changes to management and rotation, that may be carried out in e.g. ni-

trate vulnerable zones within the short term, and

- establish a scientific sound basis for giving advise on these matters in both organic and conventional farming.

C. Midterm results and progress

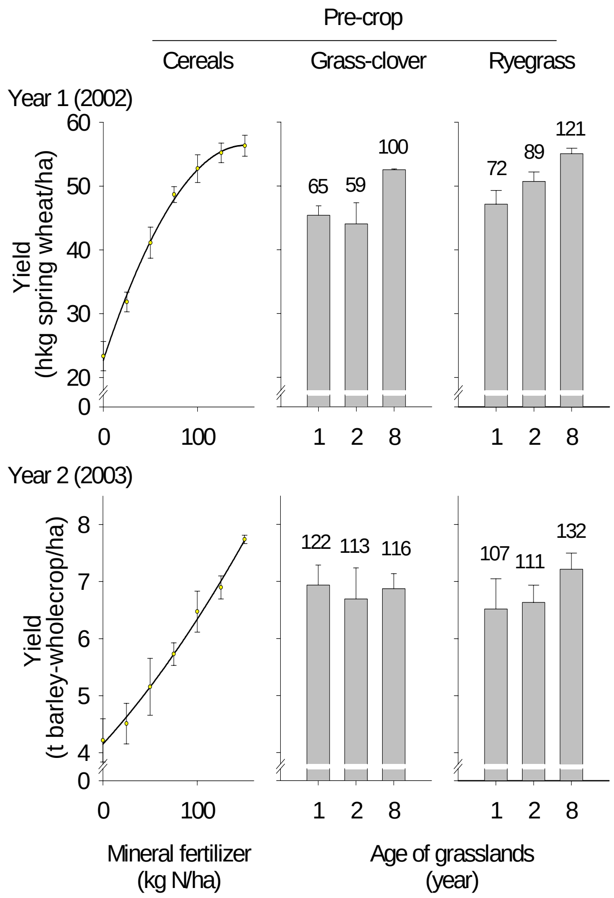
C.1 Description (summary) of main results and conclusions

WP1: Determination of precrop effects and nitrate leaching of grazed grassland rotations
The experimental area in Foulum for investigating residual effects of grassland hosts this part of the project. Over the last 9 years, three crop rotations have been build up with different frequency of grazed grassland (Table 1) including both unfertilised grass-clover and fertilised pure ryegrass. In 2003 we re-established grass-clover and ryegrass in all rotations for grazing in 2004. In 2005 grasslands similar managed during the last three years (2002-2004) but with widely different grassland frequency in the rotation have been ploughed out. In these crop rotations during 1997-2004 grazed grassland has been present 2, 3 and 6 times equivalent to 25, 38 and 75% of the crop rotation. Thus, the long-term effect of composition and frequency of grasslands can be studied in a block design with four replicates.

Table 1: Crop rotations at the experimental area in Foulum for investigating residual effects of grassland. In brackets is indicated the proportion of grassland in the rotation during 1997-2004.

Year	Rotation 1 (25%)	Rotation 2 (38%)	Rotation 3 (75%)
1994	1st year grass	1st year grass	1st year grass
1995	2nd year grass	2nd year grass	2nd year grass
1996	3rd year grass	3rd year grass	3rd year grass
1997	Barley	Barley	4th year grass
1998	Wheat	Wheat	5th year grass
1999	Barley	Barley	6th year grass
2000	Barley	1st year grass	7th year grass
2001	1st year grass	2nd year grass	8th year grass
2002	Wheat	Wheat	Wheat
2003	Barley	Barley	Barley
2004	1st year grass	1st year grass	1st year grass
2005	Barley	Barley	Barley

In the spring 2005 the combinations of grassland composition (grass-clover and ryegrass) and frequency (25, 38 and 75% grassland) are ploughed and within each of the four replicates in the block design are established four plots of 12 by 12 m with barley. The barley has ryegrass undersown as a catch crop. To determine precrop effects of N an adjacent reference area without grassland history and with increasing mineral fertiliser N application is established for comparison of yields. In 2002 the pastures of grass-clover and ryegrass were ploughed after 1, 2 and 8 production years. As reference were used associated cut grassland and continuos cereal cropping. The yield in spring wheat was greatly increased by the grassland pre-crop (Fig. 1). The pre-crop effect ranged from about 70 kg N/ha following 1 year of pasture to 100-120 kg N/ha following 8 years of grazed pasture with the highest pre-crop effect following ryegrass. In 2003 the residual effect was even higher probably as a consequence of very low nitrate leaching in the winter 2002-2003, but this year differences between different grasslands seemed negligible.



In each of the 12 x 12 m plots are installed three ceramic suction cups at a depth of 1 m and 2 m apart, and every two weeks samples of soil water are collected by applying suction. The accumulated nitrate leaching is calculated after modelling the water balance. This method has been identified as the best practicable method for freely drained, structureless soils, which makes it suitable for this soil type. Nitrate leaching following the ploughing of grasslands was determined using the suction cup method in the winters 2002/2003 and 2003/2004 (Fig. 2). Due to low drainage in the first winter (234 mm), nitrate leaching was only moderate, but still differences appeared. Generally, nitrate losses were smallest following ploughing of young grass-clover swards only grazed for 1 year (6 kg NO_3-N/ha) and highest following ploughing of older swards grazed for 2 or 8 years (35 kg NO_3-N/ha). The results followed to some extent what would have been predicted by looking at the differences in pre-crop effect of the swards. It was striking that the EU Drinking Water Directive upper limit of 50 mg nitrate per litre was on average not exceeded in any of the plots where grass-clover was ploughed out but was exceeded in all plots where ryegrass had been grazed for more than 1 year. In the following winter (2003-2004, drainage: 290 mm) the 50 mg nitrate per litre was on average not exceeded in any case (Fig. 2) although nitrate leaching following grazed ryegrass was higher than following grazed grass-clover. Overall the results indicate that when using good management practices following ploughing of grazed grassland it is possible to limit nitrate leaching losses to a minimum, especially in the case of grass-clover.

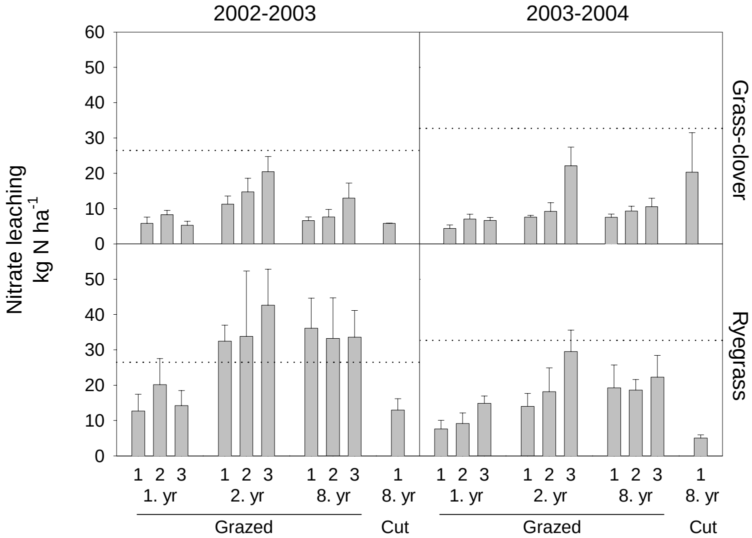


***Fig. 2**: Nitrate leaching in two years following ploughing of grasslands of different composition, age and management. Dotted lines indicate losses equivalent to the EU upper limit for nitrate content in drinking. Error bars: SE.*

In the winter 2004-2005 was determined nitrate leaching following 1 year of grass as a function of grassland type, frequency in the crop rotation and fertiliser application in the previous years. Nitrate leaching from grass-clover was only 9 kg ha^{-1} whereas from ryegrass it was 31 kg ha^{-1}. There was no effect of grassland frequency in the crop rotation (25, 38 or 75% grassland) but in ryegrass there was an effect of fertiliser application in the previous years (2002-2002).

In 2005 has been determined the residual effect, by means of grain yield, of the different management and grassland histories (Fig. 3). For comparison was determined yields in reference plots without grassland history. From the data it appears that there was no effect of previous fertiliser application and type of grassland, but the frequency of grassland in the crop rotation affected yields. In the crop rotation with 75% grassland since 1997 was harvested 4.2 t grain DM ha-1 compared to an average of only 3.2 t in crop rotations with 25 or 38% grassland and without any other fertiliser application besides the residual effect.

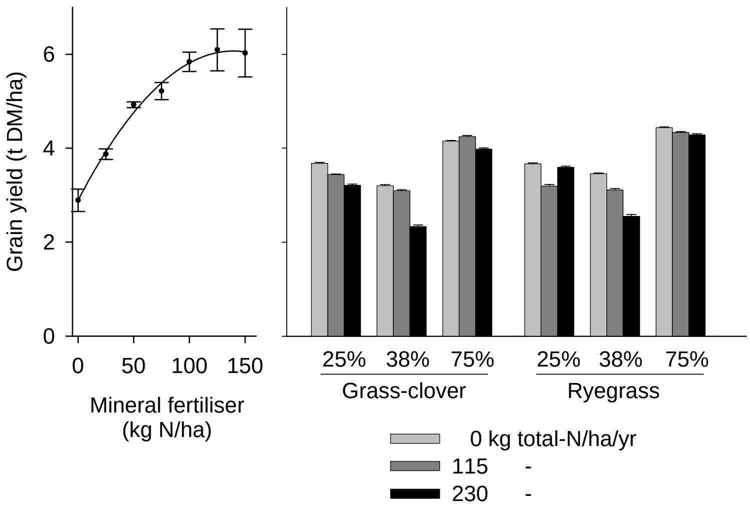


***Fig. 3**: Grain yield in barley 2005. a) reference plots without grassland history. b) as a function of grassland type, frequency in the crop rotation since 1997 and fertiliser application in 2002-2003.*

<u>WP2: Nitrate leaching on coarse sandy soils</u>

On a dairy farm on coarse sandy soil were selected fields with different grassland history aiming at a minimum of bias caused by soil type and climatic conditions. The two fields were ploughed in spring 2003 and cropped with cereals in 2003 and 2004. The following factors were included in 2003.

Table 2: Treatments in the experiment on coarse sand.

Factor	Treatments and abbreviation
Accumulated N in grassland	1. 5-year-old pasture in grass-rich rotation 2. 3-year-old pasture in cereal-rich rotation
Establishment of catch crops	1. Spring barley with catch crop (Italian ryegrass) undersown – harvested green as fermented whole crop “FWC” 2. Spring barley with catch crop (perennial ryegrass) undersown – harvested at maturity “+CC” 3. Spring barley without catch crop – harvested at maturity “-CC”
Fertilisation of barley following grassland	1. No fertiliser “0N” 2. Low fertiliser application (60 kg NH_4-N ha^{-1} in cattle slurry) “60N” 3. Moderate fertiliser application (120 kg NH_4-N ha^{-1} in cattle slurry) “120N”

In the experimental period was used best management practice regarding other factors that may influence N use efficiency. The experiment contained four replicates of each combination of treatments and 2 ceramic suction cups were installed in selected plots for determination of nitrate leaching. Nitrate leaching was determined in the two years from 1 April to 31 March with termination in 2005. Prior to ploughing of grasslands, quantity and chemical composition of above- and below-ground plant material was determined. In 2004 the residual effects were determined in spring barley undersown with a catch crop of perennial ryegrass and fertilized 60 kg/ha ammonium-N in slurry.

<u>Results 2003</u>

The effect of a perennial ryegrass catch crop on yield of spring barley harvested at maturity was insignificant for both grain and straw. However, grain yields showed a significant effect of N application after the 3-year-old pasture while no effect of N application was observed after the 5-year-old pasture. Increasing the N application from “Low” to “Moderate” tended to increase yield in the 3-year-old pasture but the increase was not significant. These facts imply that more readily available N was present after the 5-year-old than after the 3-year-old pasture. Yields of fermented whole crop increased with increasing N application on both fields, but the increase from “Low” to “Moderate” was not significant.

Table 3: Yield of barley and fermented whole crop following ploughing of 5-year-old and 3-year-old pastures. No significant interactions between crop and N application was found.

		Barley		Fermented whole crop[*1]	
	Abbre-viation	Grain[*2], hkg ha^{-1}	Straw dm, hkg ha^{-1}	Barley and grass dm[*3], hkg ha^{-1}	1. cut of grass dm[*4], hkg ha^{-1}
5-year-old pasture					
Crop					
Without catch crop	- CC	46.8	48.8	-	-
With catch crop	+CC	45.4	52.0	-	-
Ferm. whole crop[*3]	FWC	-	-	-	-
$LSD_{.95}$		ns	ns	-	-
N application					
No	0N	45.7	45.6[b]	46.1[b]	36.3
Low	60N	47.5	49.2[b]	61.0[a]	41.9
Moderate	120N	45.0	56.4[a]	66.3[a]	41.3
$LSD_{.95}$		ns	4.0	11.8	ns
3-year-old parsture					
Crop					
Without catch crop	- CC	44.4	35.1	-	-
With catch crop	+CC	44.0	35.5	-	-
Ferm. whole crop[*3]	FWC	-	-	-	-
$LSD^{.95}$		ns	ns	-	-
N application					
No	0N	39.7[b]	25.7[b]	28.8[b]	26.1
Low	60N	45.0[a]	38.4[a]	48.3[a]	24.8
Moderate	120N	48.0[a]	41.8[a]	57.5[a]	31.4
$LSD_{.95}$		5.1	4.0	10.0	ns

Within each factor and column, means followed by the same letter are not significantly different from each other. [*1] Barley and grass harvested at beginning of heading. [*2] 85% dry matter. Harvested on 11 August 2003 at maturity. [*3] Harvested on 17 June 2003. [*4] Harvested on 15 August 2003

Table 4: Annual leaching of nitrate and organic N (kg N ha^{-1}) 2003-04 following ploughing-in of grass-clover and growth of spring barley with different catch crop situations. In brackets is shown the percentage of organic N compared to nitrate. Within each column, means followed by the same letter are not significantly different.

	N-appl. kg/ha	After 3 years gr./cl.		After 5 years gr./cl.	
		Nitrate-N	Organic-N	Nitrate-N	Organic-N
Ferm. whole crop - Ital. ryegr. Green	0	8 c	10 b (125)	35 b[1]	16 b (46)
Ferm. whole crop - Ital. ryegr. Green	120	9 c	10 b (111)	7 b	12 b (171)
Barley maturity –per. ryegr. +CC	0	34 c	10 b (29)	81 b	14 b (17)
Barley maturity – bare soil –CC	0	174 b	13 b (7)	240 a	23 ab (10)
Barley maturity – bare soil –CC	120	302 a	19 a (6)	316 a	29 a (9)

[1] This value was caused by one suction cup with extremely high concentrations. Excluding this cup the level is similar to that of other fermented whole crop treatments.

In Table 4 is shown nitrate and organic N leaching following spring barley. Annually, 174-

240 kg NO_3-N and 13-23 kg organic N per ha was leached when unfertilised barley was harvested at maturity and followed by bare soil subject to mechanical weed control. In the same situation but with application of 120 kg NH_4-N to barley gave nitrate and organic N leaching of 166-309 and 19-29 kg/ha, respectively. A well-established Italian ryegrass following very early harvest of barley in mid-June reduced nitrate leaching by 166-309 kg N/ha or 95-98%. Perennial ryegrass following barley harvested at maturity was not as efficient as this, but still reduced nitrate leaching by 66-80% compared to 'bare soil'. These results are very encouraging. It seems possible to reduce (almost eliminate) nitrate leaching following grassland ploughing even on course sand if efficient catch crops are established. It is also new that organic N is leached to this extent. Furthermore it is important to adjust fertiliser application to the actual need of the cereal crop – in many cases there is no yield response to fertiliser application following grassland ploughing.

Results 2004

The residual effects of the treatments in 2003 (Table 2) were determined in spring barley/catch crop, fertilized with 60 kg/ha ammonium-N in slurry. After FWC there was a significant higher yield of barley in the 3-year-old pasture than after –CC and +CC indicating a positive effect of the Italian ryegrass residues on the following crop. This effect was not observed in FWC in the 5-year-old pasture. In contrast, there was a significant yield decrease after +CC compared to FWC and –CC. The inconsistency between the two pastures is believed to be the result of differences in development of couch grass (Table 5). Apparently rotovating of –CC on 26 September and 21 October 2003 was an effective method to control couch grass. Further more, the amount of couch grass in FWC (estimated 3 November 2004) suggests that a dense Italian ryegrass crop was better to outdo couch grass than the more sparsely developed perennial ryegrass in +CC.

N uptake in grain and straw was not significantly different between treatments (Table 5) but tended to be 12 –18 kg/ha N less in the 3-year-old pasture than in the 5-year-old.

Table 5: Average barley grain yield (85% DM) and N-uptake in grain and straw, 2004, following ploughing-in of plots with different treatments after grass-clover. In brackets is shown characters for the amount of couch grass (10 = 100%) on 3 November, 2004. There was no interaction between previous establishment of catch crop and fertilization.

Treatments, 2003	N, kg/ha[*1]	After 3 years gr./cl.		After 5 years gr./cl.	
		Grain yield, hkg/ha	N uptake in grain and straw, kg/ha	Grain yield, hkg/ha	N uptake in grain and straw, kg/ha
FWC	60	41.4 [a] (0)	108	28.4 [a] (3,1)	120
+ CC	60	34.4 [b] (0)	102	19.3 [b] (6,4)	120
- CC	60	35.2 [b] (0)	103	30.7 [a] (1,0)	119
$LSD_{.95}$	60	4.1	ns	5.0	ns
0N	60	40.6 [a] (0)	105	25.3 (3.3)	120
60N	60	35.1 [b] (0)	105	26.4 (3,4)	119
120N	60	35.3 [b] (0)	103	27.1 (3.8)	119
$LSD_{.95}$	60	4.1	ns	ns	ns

[*1] N-application to barley in 2004.

Nitrate-N concentrations in spring, 2004 was different in the different treatments (data not shown) which means a certain overlap from 2003 to 2004. Since the summer 2004 was wet with percolation occurring, leaching in 2004-05 is divided into two periods, summer and autumn/winter (Table 6). In summer, leaching after FWC was very low in both pastures compared to –CC treatments. Apparently the barley grown in 2004 was not able to take up nitrate, which was probably situated in the bottom of then rootzone in –CC. In Autumn/winter there was no difference in leaching between treatments in either of the pastures. In comparison with other previous experiments on coarse sandy soil leaching during autumn/winter was rather high with averages of 71 and 56 kg N/ha in the 3-year and 5-year-old pasture, respectively. The relatively high leaching despite the catch crop may be due to wet weather in August in combination with late harvest of barley (26 August), and a sparse development of perennial ryegrass. This seems to have caused leaching of nitrate before the ryegrass catch crop was fully developed. However, we do not know how much nitrogen there would have been leached, if the soil was keep bare.

Table 6: Annual leaching of nitrate (kg N ha^{-1}), 2004-05 following ploughing-in of plots with different treatments after grass-clover. Within each column, means followed by the same letter are not significantly different.

Treatments, 2003	N-appl. kg/ha	After 3 years gr./cl.[*1]		After 5 years gr./cl.	
		Summer 2004	Autumn/winter 2004-05	Summer 2004	Autumn/winter 2004-05
FWC	0	1 [c]	73	1 [b]	40
FWC	120	1 [c]	65	1 [b]	52
+CC	0	3 [c]	69	5 [b]	53
–CC	0	13 [b]	77	22 [a]	64
–CC	120	22 [a]	73	24 [a]	72
LSD.95		8	ns	5	ns

[*1] Omitted replication no. 3, due to one suction cup with extremely high concentrations.

<u>WP3: SOAR Ph.D. study: Below ground C and N transformation processes in perennial grass-clover mixtures with impact on the farming system and the environment</u>

The C and N dynamics in perennial grass-clover mixtures are not fully understood although such mixtures dominate temperate grassland. The co-existence of clover and grass involves both competition for and transfer of nutrients between the species. The nutrients may originate from leaky root systems, from a rapid turnover of the fine root systems, or from degradation of more stabile organic material. A better understanding of the processes involved in the C and N dynamics, especially the role of organically bound C and N, will form the basis for better modelling of grass-clover mixtures and thereby optimising the utilization of the nutrients which benefits both the farmer and the environment.

The aim of the study is to investigate the C and N dynamics in grass-clover mixtures with special attention to 1) the origin of DOC and DON in grass-clover mixtures, 2) the source of C and N taken up by grass and clover, and 3) the transfer of C and N between grass and clover.

The aim of the 2004 studies have been to investigate the origin of C and N from both grass and clover, to investigate the composition of C and N in a general sense by dividing it into inorganic and organic bound pools, and if possible to look for transfer of C and N between the two species.

In a second year grass-clover ley field mezotrons were installed to depths of 20, 40 and 60 cm. Underneath the mezotrons suction cups were installed in order to collect percolating pore water from the root zone. Grass or clover in the mezotrons was labelled using leaf labelling with ^{15}N- and ^{14}C urea. During the labelling period of 5 days and at regular intervals thereafter pore water from the root zone was collected. The canopy was harvested three times during the experimental period with an interval between harvesting of three weeks. At the end of the experimental period the mezotrons were excavated and divided into soil and plant compartments.

In order to model the water transport in the mezotrons bromide was added before the leaf labelling, and in order to have a surplus of pore water the mezotrons was irrigated at regular intervals. Pore water samples were immediately analysed for total content of ^{14}C-labelled compounds. Still analysis of ^{15}N content of the pore water has to be undertaken together with measurements of inorganic parameters like pH and content of bromide.

It will be possible to determine the origin of DOM in a grass-clover mixture when the data on ^{15}N in the leachates becomes available. The current data from the ^{14}C-labelling shows that leaching of ^{14}C occurs immediately after the tracer has entered the plant leaves and that the majority of the leached ^{14}C is in the form of $^{14}CO_2$. In general the amount of ^{14}C leached is very low (less than 0.001 percent of initially added ^{14}C). Ryegrass leads to a higher leaching of ^{14}C than clover. The detection of ^{14}C decreased with depth and only from labelled grass ^{14}C was detected at the depth of 60 cm. Based on these results we conclude that leached DOC beneath the roots zone is not likely to originate from depositions from the living root system.

The mezotrons were supplied with water in surplus. Despite this situation, analysis of plant material show that ^{14}C and in particular ^{15}N are transferred between the species, with the highest transfer of N occurring from clover to grass and the highest transfer of ^{14}C occurring from grass to clover (figure 4). The amount of ^{15}N transferred is in agreement with other studies using leaf labelling[1]. In figure 4 the distribution of ^{14}C and N derived from the roots is shown for the upper 20 cm in the field mezotrons. It is seen that generally ^{14}C in roots and soil comes from grass, while N comes from clover. No ^{14}C is found beneath the plough layer when clover is labelled whereas a small fraction is found when grass is the labelled species. The deposition of N occurs mainly in the plough layer for both grass and clover.

The results from this dual-labelling study with ^{14}C and ^{15}N confirms the hypothesis that clover acts as the N-donor and grass as the C-donor in grass-clover mixtures. Simultaneously to contributing to the co-existing specie, large amounts of carbon and nitrogen is deposited in the soil (Figure 4). It is therefore deduced that large fluxes of both carbon and nitrogen is occurring below grass-clover sods.

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[1] Gylfadóttir T and Høgh-Jensen H (2005) unpublished results from Island,; Høgh-Jensen H, Nielsen B and Thamsborg SM (2005) Productivity and quality, competition and facilitation of chicory in ryegrass/legume-based pastures under various nitrogen supply levels. *European Journal of Agronomy, accepted.;* Høgh-Jensen H and Schjoerring JK (2000) Below-ground nitrogen transfer between different grassland species: Direct quantification by ^{15}N leaf feeding compared with indirect dilution of soil ^{15}N. *Plant and Soil* **227**, 171-183.

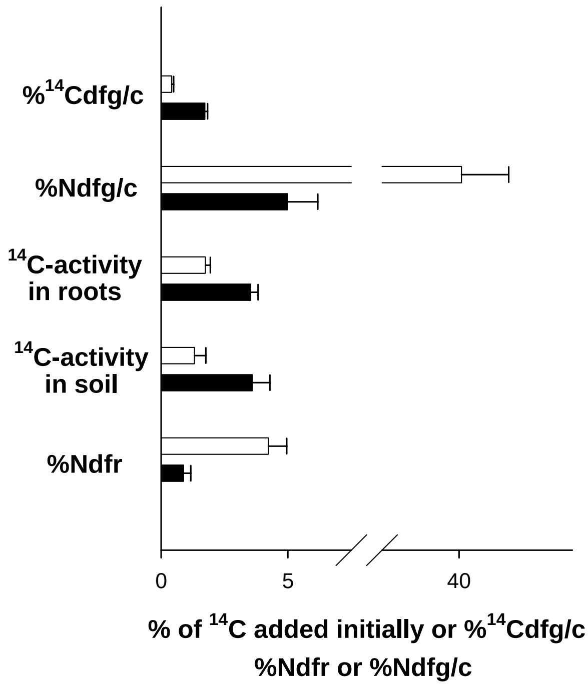

Figure 4. *Transfer of ^{14}C (%^{14}Cdfg/c) between grass (black) and clover (white), transfer of N (%Ndfg/c) between grass and clover, transfer of N (%Ndfr) from root to soil and distribution of ^{14}C in root and soil. Data from the upper 20 cm (9 replicates) of field mezotrons with labelled grass or clover.*

The aim of the 2005-2006 studies is to investigate the fate of root and leaf material from grass and clover respectively during two growth seasons. In April 2005 dual-labelled (^{14}C and ^{15}N) plant material was incubated in field mezotrons inserted in a first year grass clover ley. In the growth seasons of 2005 and 2006 leaf material is harvested and analysed for content of ^{14}C and ^{15}N to investigate the possible uptake of C and N from degrading plant material. In May and September 2005 a number of mezotrons were excavated and incubated plant material, soil and roots were separated. Also in April and September 2006 mezotrons will be excavated to determine the distribution of the two tracers in the soil and roots. During the winter period of 2005 percolating pore water from the mezotrons will be samples using Teflon suction cups. The content of ^{14}C and ^{15}N in the pore water will be analysed and if possible separated in organic and inorganic pools.

WP4: Optimising the N cycle of organic dairy farms

At the end of the project all the data that has been collected from the experimental area since establishment of the different grasslands in 1994 will be included in a summarising exercise. This includes N-uptake and nitrate leaching effects from the arable and grassland phase of the crop rotation caused by differences in grassland history, age and frequency – all of which has been combined with unfertilised grass-clover and fertilised ryegrass. Furthermore, N_2-fixation and denitrification has occasionally been determined as well as the N-balance of grazing cows. All this information will be used for constructing crop rotation N-balances and make simple scenarios for the effects of different crop combinations/frequencies. The effect of different management on the experimental area will be related to investigations from practical farms where the overall balance are known and to the results of the model exercises going on in other DARCOF projects.

C.2 Fulfilment of deliverables and milestones

(To be completed for each work package)

WP number and title	Time schedule according to application	Deviations, if any*
Deliverables		
1 Paper on precrop effects of combinations of grass-clover/ryegrass and different frequencies of grassland in the rotation submitted for international reviewed journal.	Jan 2006	
2 Paper on nitrate leaching from different grassland rotations submitted for international reviewed journal.	May 2006	
3 Paper on nitrate leaching and management options on coarse sandy soils submitted for international reviewed journal	May 2006	
4 Ph.D. study on grassland nitrogen initiated.	July 2003	April 2004
5 Ph.D. study completed	July 2006	March 2007
6 Paper on nitrogen management in dairy farming systems published in farmers magazine.	Jan 2006	
7 Paper on environmental consequences of ploughing different grasslands published in farmers magazine.	May 2006	
Milestones		
1 The effect of soil type, grassland composition and frequency in crop rotations on precrop effects following ploughing has been determined.	Jan 2006	
2 The environmental consequences of grassland composition and frequency in the rotation has been determined.	May 2006	

** Deviations are to be further discussed in D*

D. Description of deviations and subsequent adjustments of plans

In April 2004 Jim Rasmussen was engaged for the Ph.D. study. The delay in the initiation of the Ph.D. study will result in a similar delay of the study to be completed; affecting deliverable No. 5. The Ph.D. study is expected to be completed in March 2007.

E. Project publications and other products

1. Products from Organic Eprints archive

Peer-reviewed and accepted

English

Eriksen, J.; Askegaard, M. and Kristensen, K. (2004) Nitrate leaching from an organic dairy crop rotation: the effect of manure type, N-input and improved crop rotation . *Soil Use and Management* 20:pp. 48-54.*

Eriksen, J. and Vinther, F.P. (2003) Nitrate leaching and N2-fixation in grasslands of different composition, age and management. Poster presented at 12th N workshop "Controlling N Flows and Losses", University of Exeter, Devon, UK, 21st - 24th September, 2003; Published in *Abstracts for the 12th N workshop "Controlling N Flows and Losses"*.

Eriksen, J.; Vinther, F.P. and Søegaard, K. (2004) Nitrate leaching and N2-fixation in grasslands of different composition, age and management. *Journal of Agricultural Science* 142:pp. 141-151.

Hansen, J.P.; Eriksen, J. and Jensen, L.S. (2005) Residual nitrogen effect of a dairy crop rotation as influenced by grass ley management manure type and age. *Soil Use and Management*.

McNiel, A.M.; Eriksen, J.; Bergström, L.; Smith, K.S.; Marstorp, H.; Kirschmann, H. and Nilsson, I. (2005) Nitrogen and sulphur management: challenges for organic sources in temperate agricultural systems. *Soil Use and Management* 21:pp. 82-93.

Watson, C.A.; Öborn, I.; Eriksen, J.E. and Edwards, A.C. (2005) Perspectives on nutrient management in mixed farming systems. *Soil Use and Management*.

Dansk - Danish

Vinther, F.P.; Hansen, E.M. and Eriksen, J. (2005) Udvaskning af organisk kulstof efter kløvergræs [Leaching of organic carbon following grass-clover], in Olesen, J.E., Eds. *Drivhusgasser fra jordbruget - reduktionsmuligheder*. DJF rapport no. 113, chapter 11, page pp. 129-140. Department for Agroecology, Danish Institute of Agricultural Sciences.

Vinther, F.P.; Hansen, E.M. and Eriksen, J. (2005) Udvaskning af organisk kulstof efter kløvergræs [Leaching of organic carbon and nitrogen], in Olesen, J.E., Eds. *Drivhusgasser fra jordbruget - reduktionsmuligheder*. DJF rapport no. Markbrug nr. 113, chapter 11, page pp. 129-140. Afdeling for Jordbrugsproduktion og Miljø, Danmarks JordbrugsForskning.

Submitted for peer-review but not yet accepted

English

Vinther, F.P.; Hansen, E.M. and Eriksen, J. (2005) Leaching of soil organic carbon and nitrogen in sandy soils after cultivating grass-clover swards. [preprint]

Not peer-reviewed

English

Eriksen, J. (2004) Efficient use of grassland nitrogen. *DARCOFenews*(1). Online at <http://www.darcof.dk/enews/april04/grassland.html>

Eriksen, J. and Vinther, F.P. (2004) Nitrate leaching and N2-fixation in grasslands of different composition, age and management. Paper presented at 12th N Workshop; Published in Hatch, D.J.; Chadwick, D.R.; Jarvis, S.C. and Roker, J.A., Eds. *Controlling nitrogen flows and losses*, page pp. 434-436. Wageningen Academic Publishers, The Netherlands.

Eriksen, J.P.; Vinther, F.P. and Søegaard, K. (2004) Low nitrate leaching from long-term grass-clover. *DARCOFenews*(3). Online at <http://www.darcof.dk/enews/sep04/lowleach.html>

Hansen, E.M.; Eriksen, J. and Vinther, F.P. (2005) High yield and low N leaching with barley as a green crop for silage after grass-clover. *DARCOFenews*(1). Online at <http://www.darcof.dk/enews/mar05/roughage.html>

Hansen, E.M.; Eriksen, J. and Vinther, F.P. (2005) Nitrogen leaching following cultivation of grazed grass-clover on coarse sandy soil. Poster presented at N-workshop, Maastricht, 23-26 Sept.

Rasmussen, Jim and Høgh-Jensen, Henning (2004) Origin and composition of Dissolved Organic C and N from grass-clover mixtures . Poster presented at Cost Action 627 - Carbon Storage in European grasslands, Ghent, Belgium, June 3-6 2004.[*]

Vinther, F.P.; Eriksen, J. and Hansen, E.M. (2004) Leaching of dissolved organic carbon (DOC) and nitrogen (DON) from grass-clover pastures after ploughing. [oral] Presentation at *DOM 2004 - International workshop: Dissolved Organic Matter and the Cycling of Carbon, Nutrients and Metals*, Bayreuth, Germany, October 3-6 2004.

Dansk - Danish

Eriksen, J. (2004) Udvaskning før og efter ompløjning af kløvergræs. In *Månedsmagasinet Mark*, January, Volume 1, page 18.

Eriksen, J. (2003) Afgræsningsmarkers eftervirkning [Residual effect of grasslands]. In *Økologisk Jordbrug*, No 283, page 6.

Eriksen, J. (2003) Afgræsningsmarkers eftervirkning. In *Økologisk Jordbrug*, 21. February, No 283, page 6.

Eriksen, J. (2003) Afgræsningsmarkers eftervirkning. *FØJOenyt*(2). Online at <http://www.foejo.dk/foejo/enyt2/enyt/april03/efterv.html>

Eriksen, J.; Hansen, E.M. and Christensen, B.T. (2005) Tilførslen af organisk stof og jordens aktuelle udbyttepotentiale. Paper presented at Plantekongres, Herning Kongres Center, 11-12 Jan; Published in *Sammendrag af indlæg*, page pp. 230-231.

Eriksen, J.; Vinther, F.P. and Søegaard, K. (2004) Ældre marker med kløvergræs kan beskytte grundvandet mod nitrat. *FØJOenyt*(4). Online at <http://www.foejo.dk/enyt2/enyt/aug04/udvask.html>

Hansen, E.M.; Eriksen, J. and Vinther, F.P. (2005) Stor produktion af grovfoder og lav nitrat-udvaskning ved dyrkning af grønbyg med italiensk rajgræs efter kløvergræs. *FØJOenyt* 1. Online at <http://www.foejo.dk/enyt2/enyt/feb05/groenbyg1.html>

Hansen, E.M.; Eriksen, J. and Vinther, F.P. (2004) Øget udnyttelse af kvælstof efter ompløjning af afgræsset kløvergræs. In *Grøn Viden, Markbrug*, November.

Vinther, F.P. (2004) Organisk kvælstof kan også udvaskes [Organic nitrogen can also be leached]. In *Økologisk Jordbrug*, 26. November, No 325, page 6.

Vinther, F.P.; Hansen, E.M.; Eriksen, J. and Jacobsen, O.H. (2004) Udvaskning af organisk bundet kvælstof og kulstof [Leaching of organic nitrogen and carbon]. *FØJOenyt*(6). Online at <http://www.foejo.dk/enyt2/enyt/dec04/don.html>

2. Other products (oral presentations, public meetings, field days, etc.)

Jørgen Eriksen and Margrethe Askegaard presented a poster on "Nitrogen management in the organic dairy crop rotation" at the organic field day in Foulum, June 12, 2003.

Jørgen Eriksen and Margrethe Askegaard presented an organic field experiment with grassland and maize at the organic field day in Foulum, June 10, 2004.

Jørgen Eriksen gave a presentation on "The effect of catch crops on the supply of N and S in organic crop rotations" at the Organic field course in Årslev on June 19, 2003.

* 25-75% financed by DARCOF
** 5-25% financed by DARCOF

F. Scientific education

The project includes part of a Ph.D. study for Jim Rasmussen starting April 2004 and a Master student have been associated from February 2003 to February 2004: Jens Prior Hansen M.Sc. project: Residual effect of ploughing out grasslands as a function of grassland age, management and fertilisation.

G. National and international cooperation

The project has a life of its own, but it is also an integrated part of other activities in the DARCOF programme and in international programmes. This includes:

- DARCOF project VII.12 will intensively be using the experimental area for detailed studies on leaching of dissolved organic carbon, denitrification and simulation using the DAISY model. The two projects will work in close collaboration experimentally and in the interpretation of data (Contact: Ole H. Jacobsen, DIAS).
- DARCOF project VII.16 will be using the experimental area in communication of results from organic farming research to practical farming (Contact: Jørgen E. Olesen, DIAS).
- DARCOF project I.4 uses the area in research for increased quality of wheat for bread-making (Contact: Bent T. Christensen, DIAS).
- DARCOF project I.13 uses the area for determination of N_2-fixation of grass-clover and denitrification from grazed grassland (Contact: Per Ambus, RISØ).
- DARCOF project I.3 will be using data from the experimental area for modelling N cycling in organic farming systems (Contact: Jørgen E. Olesen, DIAS).
- The EU-project "Greenhouse Gas Mitigation for Organic and Conventional Dairy Production (MIDAIR)" will be using the two grassland types present in a block design on the area (Contact: Søren O. Petersen, DIAS).
- The project leader and project staff are involved in collaboration with a range of European partners through the EU-COST-action 627 "Carbon Storage in European Grasslands" and 852 "Exploiting the Agronomic Potential of Forage Legumes in Contrasting Environments of Europe".

H. Critical reflection on the project

Results from different projects within the DARCOF framework indicated that nitrate leaching on coarse sandy soils might constitute a substantial problem. Although the NIMAB project showed that nitrate leaching following the ploughing of grassland could be controlled on sandy loam soil, the EX_UNIT project and measurements on private farms in the BIO_MOD project indicated large losses on coarse sandy soils. Keeping in mind that a major part of organic dairy farming is located on coarse sandy soils, the previous experimental work within DARCOF may not have been representative. Therefore, at this stage it is not clear whether the recommended management following grassland ploughing is sufficient to avoid large leaching losses from these soils. In order to overcome this, a supplementary experiment was initiated on coarse sandy soil (WP2) and a Ph.D. study is associated with this. It is our expectation, that this expansion of the NIT_GRASS project will provide a better possibility for generalising results from the DARCOF projects.

In WP2 the suction cups were installed at 100 cm depth in spring 2003. During the following winter the ground water table rose to less than 100 cm and therefore we re-installed the cups at 70 cm depth in December. To check if rising the suction cups to 70 cm missed a peak of nitrate, extra cups were installed at 40 and 100 cm in two treatments. On the basis of this it was clear that for the low-nitrate-concentration treatments this was certainly not the case and for the high-nitrate-concentration treatments this may have caused a slight underestimation of annual nitrate leaching. So on the basis of this we feel confident that sound conclusions can be made based on the dramatic treatment differences observed.

Recently, it has been reported, especially in the UK, that leaching may not only be restricted to nitrate in grasslands but also some dissolved organic nitrogen has been found in leachates. Whether this is relevant to lighter soils under Danish conditions may be questioned but to get some indication extra measurements of dissolved organic N has been carried out in leachates from the coarse sand and has to some extent confirmed quantitative leaching of organic N.

In 2004-05, where the residual effects of the treatments in WP2 were measured in barley/catch crop, it would have been an advantage with at least one treatment without a catch crop. However, this was not possible within the budget of the project.

We have experienced that, for the reductions of nitrate leaching, a successful catch crop strategy has a down side at some sites: The development of weed problems, especially with thistle. Although some weed control has been carried out between sowing of cereal and sowing of catch crops in the cereals, this has not been efficient. In WP1 in 2005 we therefore use more severe weed control in the autumn following harvest. As this may affect negatively the tightness of the N cycle we will during this winter investigate experimentally the effect of this on nitrate leaching.

8. Budget

A. Account for any change in budgets

B. Budget for the whole project (1.000 DKK)

Total consumption of funds from DARCOF and expected consumption this year and coming years

Year:	Consumption before 2004	Expected consump-tion 2004	2005	2006	Total
Man-months	6.75	15.75	15	4	41,5
Scientific personnel	1.25	10.75	8	2	22
Technical personnel	5.5	5	7	2	19.5

Year:	Consumption before 2004	Expected consump-tion 2004	2005	2006	Total
Salaries	217	614	634	173	1,638
Scientific personnel	61	460	406	104	1,032
Technical personnel	156	153	228	69	606
Other operational costs	22	201	101	29	680
Equipment					
Others (please specify)					
Direct costs	239	815	735	202	1,991
Indirect costs (20% of direct costs)	47	164	147	41	399
Total	286	979	882	243	2,390

Comments:

9. Signatures and stamps

Name	Institute	Date	Signature
Jørgen Eriksen	Danish Institute of Agricultural Sciences		

Appendix I. Detailed budget

A. Budget for each participating institute (1.000 DKr)

NIT_GRASS Danish Institute of Agricultural Sciences

Year:	Consumption before 2004	Expected consumption 2004	2005	2006	Total
Man-months	6.75	11.25	15	4	37
Scientific personnel	1.25	6.25	8	2	17.5
Technical personnel	5.5	5	7	2	19.5

Year:	Consumption before 2004	Expected consumption 2004	2005	2006	Total
Salaries	217	479	634	173	1,503
Scientific personnel	61	326	406	104	897
Technical personnel	156	153	228	69	606
Other operational costs	22	169	101	29	648
Equipment					
Others (please specify)					
Direct costs	239	648	735	202	1,824
Indirect costs (20% of direct costs)	47	131	147	41	366
Total	286	779	882	243	2,190

Comments: Two scientific man-months and 93,000 kr in operational costs have been moved from 2003 to 2004.
Two technical man-month have been moved from 2004 to 2005.

A. Budget for each participating institute (1.000 DKr)

NIT_GRASS Royal Veterinary and Agricultural University

Year:	Consumption before 2004	Expected consump-tion 2004	2005	2006	Total
Man-months		4.5			
Scientific personnel		4.5			
Technical personnel					

Year:	Consumption before 2004	Expected consump-tion 2004	2005	2006	Total
Salaries		135			
Scientific personnel		135			
Technical personnel					
Other operational costs		32			
Equipment					
Others (please specify)					
Direct costs		167			
Indirect costs (20% of direct costs)		33			
Total		200			200

Comments: This project only in part funds the Ph.D. study and is therefore used in 2004.