Danish Research Centre
for Organic Farming

Midterm Status Report 2002 and Application for Continuation in 2003

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The Directorate for Food, Fisheries and Agro Business
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1. *Research program*

Research in organic farming 2000-2005 (DARCOF II)

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2. *Project title and number*

I.13. Dinitrogen Fixation and Nitrous Oxide Losses in Organic Grass-Clover Pastures: An Integrated Experimental and Modelling Approach (DINOG)

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6. Project period (month, year)

Start of project:	11-2000
End of project:	05-2004

7. Midterm description of the project, its results and progress, and application for continuation in 2003

A. Project summary

Organic farming practices, and in particular dairy production systems, are becoming increasingly abundant within Danish agriculture. Grazed pastures may be a significant source of nitrous oxide (N_2O), an important greenhouse gas, and data in the literature suggest that N_2O emissions from e.g. organic dairy farms may be smaller than from conventional systems. The difference in N_2O emissions, however, may depend on the intensity with which dinitrogen (N_2) fixed by the legumes in grass-clover mixtures are recycled in the grazed fields. Particularly urine induces N_2O emissions, which also constitutes a major loss of N.

Dinitrogen fixation in grass-clover pastures is influenced by grazing and excretal deposits, which thus needs to be taken into account when estimating total N_2 fixation. Secondly, hitherto total N_2 fixation estimates usually has not accounted for contributions from plant compartments below grazing-height, which causes a severe bias in estimates on N_2 fixation.

The IPCC guidelines for making inventories of greenhouse gases recommend a N_2O release rate of 1.25% for all N inputs, including N_2 fixed by legumes. Because of the uncertainties in quantifying N_2 fixation, no contribution from N_2 fixation to N_2O emissions from legume pastures has actually been estimated so far. Inventories of N_2O emissions for organic farming systems may therefore be severely biased.

The proposed work will investigate magnitudes and describe characteristics of N_2O emissions, denitrification and N_2 fixation in organically managed grass-clover pastures under different grazing intensities and variable sandy soil textures. Quantitative results will be implemented in submodules of a whole-farm N flow model. To meet these goals a number of field experiments will be initiated at organic farming experimental trials, supplemented by microcosm experiments under fully controlled conditions.

The information provided by this project will (i) provide information necessary for a holistic evaluation of the environmental impact of organic farming practices, (ii) be a significant support for decision making by local and regional organic farming extension services, and (iii) supply very useful information for the construction of national and regional inventories of greenhouse gas emissions.

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

No.	Work package title	Participants*	Budget (1.000 DKK)	Start	End	Deliverable no(s):
1.1 – 1.2	Process studies of nitrogen exchange between soil and atmosphere	<u>Risø</u> DIAS	1454	11/00	05/04	D1.1-1.7
2.1 – 2.3	Field studies of nitrogen exchange between soil and atmosphere	<u>DIAS</u> Risø	1816	01/01	05/04	D2.1-2.6
3	Modelling of nitrogen exchange between soil and atmosphere	<u>DIAS</u> Risø	390	10/02	05/04	D3.1-3.2

* Responsible participants are underlined

Objectives and expected achievements

The proposed work will investigate magnitudes and describe characteristics of N_2O emissions, denitrification and N_2 fixation in organically managed grass-clover pastures under different grazing intensities and variable soil textures. The results will be implemented in submodules of a whole-farm N flow model. In particular the objectives of the work are to:

- investigate and elucidate relationships between gross rates of mineralization and nitrification and losses of N_2O and N_2
- investigate the translocation and fate of biologically fixed N_2 with emphasis on gaseous losses and the accompanying plant uptake
- determine the total N_2 fixation including the contribution from stolons and roots
- estimate N input through N_2 fixation, and gaseous N losses through N_2O emission and denitrification under field conditions
- adapt, parameterise and validate a soil-plant-atmosphere model of nitrogen turn-over for simulation of N_2O emission, including simulation of spatial variability caused by urine and dung patches on grazed pastures

In order to meet these goals, a number of field experiments will be initiated at the organic farming experimental trials of Research Centre Foulum. These activities will be supplemented by microcosm experiments under fully controlled conditions at the Risø National Laboratory. Results from the experimental activities will be made available for incorporation into the FASSET whole-farm model.

Organic farming practices, and in particular dairy production systems, are becoming increasingly abundant within Danish agriculture. In Denmark, grass-clover pastures are predominantly located on sandy soils, and data on N_2 fixation from these soils are very sparse. Therefore, the information provided by this project will be a significant support for decision making by local and regional organic farming extension services. Data from this work also provides information necessary for a holistic evaluation of the environmental impact of organic farming practices, and it will supply very useful information for the construction of national and regional inventories of greenhouse gas emissions.

C. Midterm results and progress

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

WP 1.1: Gross N turnover and losses of N_2O and N_2
The relationship between gross N mineralization and nitrification, respectively, and N_2O and N_2 emissions have been investigated during 2001-2002. Intact soil monoliths, confined by 30 cm diam. PVC sleeves, were established in March 2001 in grass-clover fields at Research Centre Foulum comprising 1st, 2nd and 8th year trials. At four times during the season in 2001, May, June, August and October sets of the monoliths were collected for transportation to Risø National Laboratory where the root zone of the intact monoliths subsequently was labelled ^{15}N as either NH_4^+- or NO_3^-. In order to handle the high number of injections of ^{15}N-solutions into the root zone necessary to meet assumptions about homogeneity we developed a semi-automatic injection system based on the use of a Hamilton precision liquid processor.

Following labeling the monoliths were sealed gas tight with a lid for periods of 100 mins.

and headspace samples were collected in order to monitor the evolution of N_2O and N_2 and the ^{15}N-enrichments of the two gases. Subsequently, after 48 hrs of exposure to the ^{15}N-label, soil samples from each monolith were collected for determination of the total N and ^{15}N contents in the inorganic and organic soil N pools in order to assess the short term pool dilution and calculate gross N mineralization and nitrification in the incubated soils.

Figure WP1.1a Adding ^{15}N-label to soil monoliths with grass-clover.

Evolutions of N_2O from the monoliths prior to N-additions did not show significant difference among the different production years (*Fig. WP1.1b open circles*). After application of the ^{15}N-label solutions, equivalent to 2 g N m^{-2}, N_2O emissions increased temporary (24 hrs, open squares), but after 48 hrs (open triangles) the N_2O evolution in all samples tended to approach the pre-labeling level. Assuming that the N_2O evolution rates prior to N-label additions are representative for the entire growing season, the accumulated N_2O evolution can be estimated to range between 166 g N ha-1 (8th year) to 291 g N ha-1 (1st year), which corresponds to 0.1 – 0.2 % of the annual input from biological N fixation (*see WP2.1*). However, as pointed out in a later section (*WP2.3*) we observed a discrepancy between N_2O emissions measured from incubated monoliths compared with *in situ* field measurements, the latter being at least 30-fold higher. A possible explanation for this might be presence of a significant N_2O source in deeper soil layers.

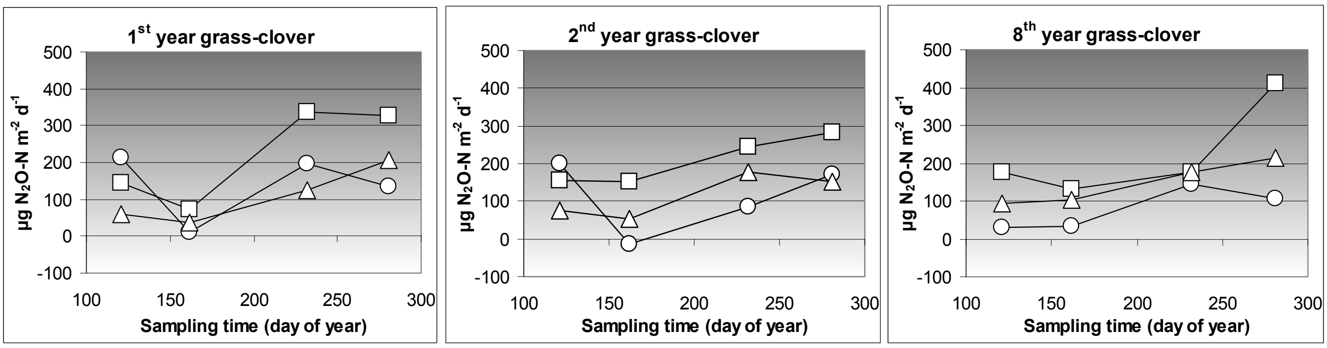

Figure WP1.1b Evolution of N_2O from soil monoliths prior to ^{15}N-label applications (open circles), 24 hrs (open squares) and 48 hrs (open triangles) after the application. The three plots show (left to right) values for 1st, 2nd and 8th year grass-clover, respectively

Based on the short term dilutions of the labelled NH_4^+ and NO_3^- pools gross rates of mineralization and nitrification was calculated (*Fig. WP1.1c*). As for N_2O emissions we did not observe significant differences among the different production years. Generally, the mineralization turnover of organic N was multiple folds higher than the nitrification turnover of NH_4^+. Nevertheless, we did not observe significant accumulations of NH_4^+ most likely due to plant uptake and microbial assimilation (not shown). The NH_4^+ -> NO_3^- flux of N was 6-7 orders of magnitude greater than the N_2O evolution observed.

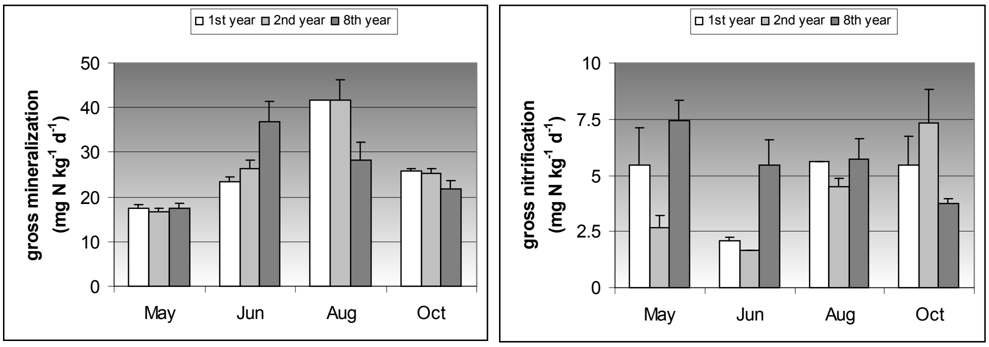

Figure WP1.1c. Gross mineralization (left) and gross nitrification (right) determined from pool-dilution in incubated soil monoliths.

During the incubations significant amounts of ^{15}N-labelled N_2O was evolved both when the label was added as NH_4^+ and as NO_3^- (not shown). This suggests that both biological nitrification as well as denitrification may contribute to the production of N_2O in these grass-clover pastures. We examined the relationship between ^{15}N in evolved N_2O and ^{15}N present in the soil NH_4^+ and NO_3^- pools (*Fig. WP1.1d left plot*). This revealed a positive correlation between amount of label in N_2O and in the NH_4^+ pool and negative correlation with the soil NO_3^- pool suggesting that nitrification is the dominant process in the formation of N_2O in these soils. A further examination between gross nitrification rates and N_2O evolution is also shown (*Fig. WP1.1d right plot*), which shows a weak yet significant relationship between the two variables in support of this conclusion.

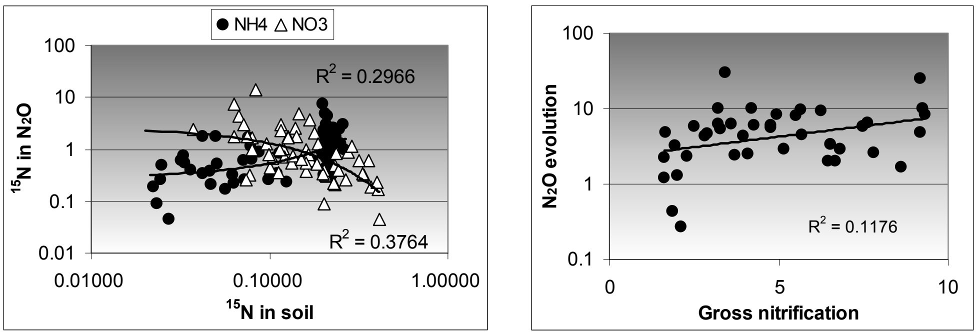

Figure WP1.1d. Relationship between ^{15}N in evolved N_2O and ^{15}N in soil NH_4^+ and NO_3^- (left). Relationship between total N_2O evolution and gross nitrification (right).

These findings leads to the hypothesis that nitrification is a dominant process for N_2O formation also in spots in the field exposed to urine, which will be subject for investigation in 2002/2003 where monoliths under controlled conditions will be exposed to ^{15}N-labelled urine in combination with examination of ^{15}N dynamics in the soil pools and evolved N_2O.

WP 1.2: N_2 fixation, N_2O emission and N translocation in $^{15}N_2$-labelled soil-plant systems.

A $^{15}N_2$-tracer-experiment has been initiated to assess the contribution of recently fixed N_2 as a source of N_2O and translocation to companion plants. In March 2002, grass-clover was sown in pots using soil from an organic rotation maintained at Højbakkegård, the experimental farm of the Agricultural University. In the initial description of this work, it was suggested that the root compartment was sealed from the aboveground compartment and ^{15}N- labelled N_2 then introduced into the soil gas atmosphere to trace the symbiotic fixation. However, this approach was found not to be appropriate for clover plants due to potential of stolon formation in the root compartment, and it was decided to label both the above- and below-ground atmosphere.

Due to the high cost of gaseous ^{15}N, a first task was to construct a minimum-volume gastight growth cabinet suitable for this experiment since this facility was not in our possession. Briefly, a chest freezer was found useful for this purpose, as it already contained a cooling system, required to remove excess heat from growth lamps. Light is introduced from external lamps through a translucent window of Plexiglas mounted in the lid of the freezer. Temperature, light and CO_2 in the growth cabinet are controlled by computer, an application developed in cooperation with University of Copenhagen. The growth cabinet can host 12 pots of 12 cm × 12 cm size.

Figure WP1.2a Pots with grass-clover for $^{15}N_2$-labelling and close up of growth cabinet. Water is provided through a silicon tube to each pot connected to a valve on the outside.

Three incubations are planned with grass-clover at 3, 6 and 9 months age. At each incubation event the pots are situated in the sealed growth cabinet for 14 days during which period the atmosphere is enriched in $^{15}N_2$ (approx. 2% excess). After the labelling period, half of the grass-clover pots are harvested and N_2 fixation is calculated from ^{15}N enrichment of clover. ^{15}N content of the companion grass is also established to determine the amount of fixed N, which has been transferred from clover to grass. During the following seven days, emission of $^{15}N_2O$ and $^{15}N_2$ is measured from the remaining half of the pots using a static chamber method. Finally, the $^{15}N_2O$ emission is related to the $^{15}N_2$ fixation to calculate the contribution of recently fixed N_2 as a source of N_2O.

So far, an experiment with 3 month old grass-clover plants has successfully been carried out. Incubation with 6 month plants is currently undertaken. The final incubation experiment is planned for December.

WP 2.1: N_2 fixation: Contribution from stolons and roots

The input of nitrogen through symbiotic N_2 fixation (SNF) in a grass-white clover pasture was studied during 2001 using existing experimental subplots from a nitrate leaching study. This made it possible to compare the effect of pasture age (1st, 2nd or 8th year) on SNF, to estimate the amount of fixed N stored in stolons and roots (*WP2.1*) finally incorporated into the soil when ploughed under, and to evaluate parameters in the empirical N_2 fixation model used to estimate SNF based on dry matter yield (*WP2.2*). Further, the influence of soil type on SNF (*WP2.1*) is under study, but so far no results are ready for presentation.

In short, the experiments on effects of pasture age were conducted by labelling plots (1 m^2) with ^{15}N in the early spring 2001. The plots were harvested 8 times during the growing season for determination of dry matter production, proportion of clover and SNF using the ^{15}N dilution method. Shortly after the last harvest (5/12-01) monoliths (20 cm diam., 20 cm depth) were dug out, and the plant material was separated into grass and clover below harvest height (c. 3 cm), grass roots and clover roots. Dry matter, total N and ^{15}N were determined on each of the components.

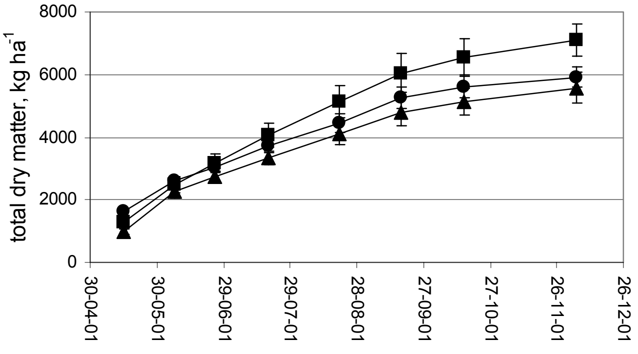

Figure WP2.1a Total dry matter production in the 1st (●), 2nd (■) and 8th (▲) year pasture (mean ± S.E., n = 4)

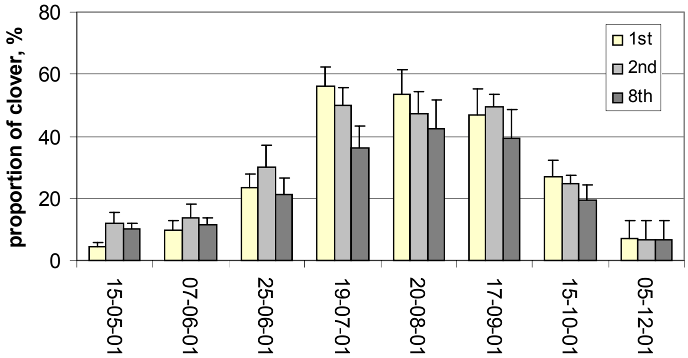

Figure WP2.1b Proportion of clover in the 1st, 2nd and 8th year pasture (mean ± S.E., n = 4).

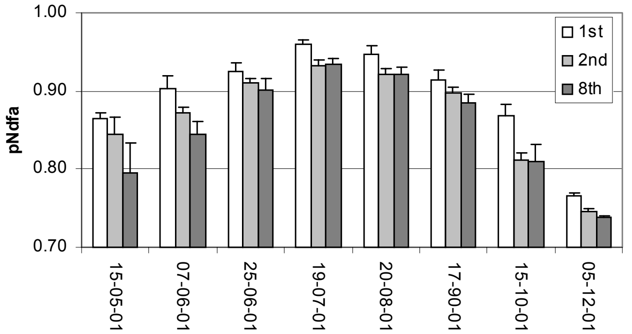

Figure WP2.1c Proportion of clover N derived from the atmosphere (pNdfa) in the 1st, 2nd and 8th year pasture (mean ± S.E., n = 4).

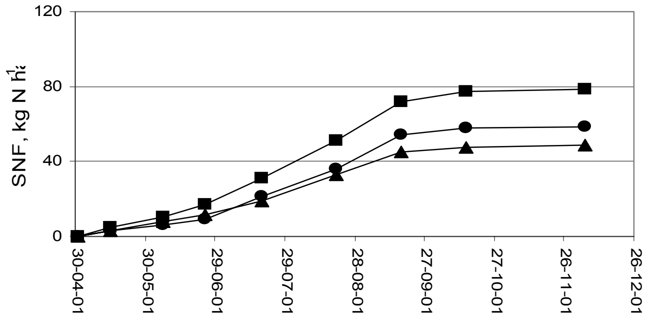

Figure WP2.1d Symbiotic N_2 fixation (SNF) in the harvested plant biomass in the 1st (●), 2nd (■) and 8th (▲) year pasture.

The total dry matter production, i.e. white clover plus ryegrass, was significantly higher in the 2nd year than in the 1st and 8th year pasture (*Fig. WP2.1a*). A significant seasonal variation was observed in the proportion of clover (*Fig. WP2.1b*), with about 10% clover in the beginning and in the end of the growing season, and up to 50% during the late summer period. There was no significant effect of pasture age on proportion of clover. The proportion of clover N derived from the atmosphere (pNdfa) tended to decrease with increasing pasture age (*Fig. WP2.1c*). This resulted in SNF shown in Fig. *WP2.1d*, where the total fixation in the harvested clover biomass during the entire growing season was 59, 79 and 49 kg N ha^{-1} in the 1st, 2nd and 8th year pasture, respectively.

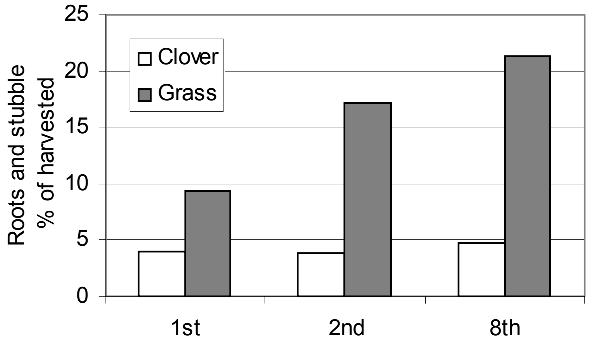

Figure WP2.1e Proportion of roots and stubble as % of harvested biomass during the entire growing season in the 1st, 2nd and 8th year pasture.

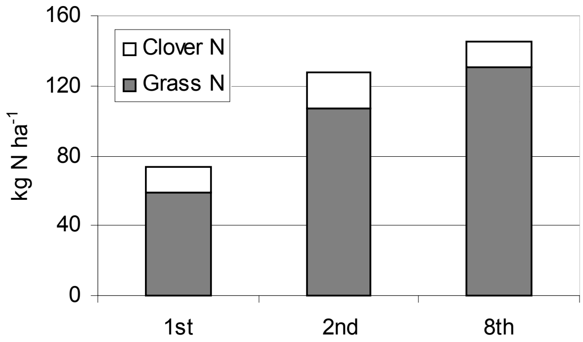

Figure WP2.1f Amount of N stored in roots and stuble at the end of the growing season in the 1st, 2nd and 8th year pasture.

The proportion of clover roots and stubble was considerably lower (4 – 5%) than expected, and there was no influence of pasture age, whereas the proportion of grass roots and stubble increased with age (*Fig. WP2.1e*). The total amount of N stored in stubbles and roots at the end of the growing season amounted 74, 127 and 146 kg ha^{-1} (*Fig. WP2.1f*). In parallel experiments, where plots on a sandy loam soil (Foulum) and a coarse sandy soil (Jyndevad) were labelled with ^{15}N in the spring 2001, the contribution of stubbles and roots to the total SNF will be studied in further details.

WP 2.2: Field estimates of N_2 fixation in grass-clover

Field estimates, where calculations of SNF were based on dry matter production of the clover, were conducted during the growing season of 2001 at the two farmers fields used in the DARCOF II project BIOMOD.

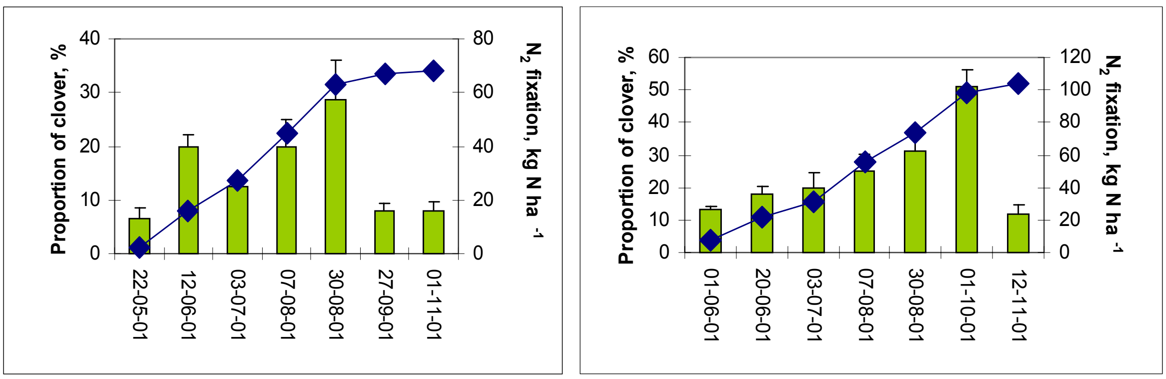

Figure WP2.2a Proportion of clover (bars) and SNF at two farmers fields (mean ± S.E., n = 4-5).

Estimates of SNF were calculated using an empirical model, which basically use measured values of clover dry matter as input, and a number of parameters from the literature, i.e. %N, pNdfa, transfer from clover to grass, and SNF from below harvest height (stubbles and roots). Measurements of clover dry matter production were carried out within the grazing field in plots, where grazing was excluded for periods of 3-4 weeks. Deviations in growth dynamics due to cutting at intervals of 3-4 weeks compared to continuous grazing are studied in a separate field experiment, but results are not yet ready for presentation.

WP 2.3 Spatial variation and field estimates of N_2O emission

The spatial distribution of nitrous oxide (N_2O) emissions and associated soil conditions was studied in a grazed grass-clover pasture during 2001 using existing experimental subplots from a nitrate leaching study (*Fig. WP2.3a*). This made it possible to also compare the effect of pasture age (1st, 2nd or 8th year) on the N_2O emission level. On each of two occasions (11 June and 13 August), soil was sampled from a total of 99 points within 11 plots; this followed N_2O flux measurements in three randomly selected points per plot. The two campaigns were carried out in separate fields. Fig. *WP2.3b* shows average N_2O fluxes in the two campaigns. The results indicated that N_2O fluxes decrease with pasture age. The flux level was higher than observed with intact soil monoliths within WP1.1; the background for this discrepancy is currently being investigated.

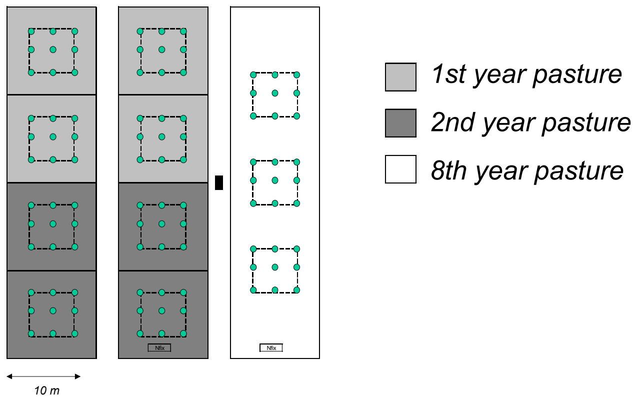

Figure WP2.3a An overview of the 11 plots with pastures of different age. Sampling points are indicated.

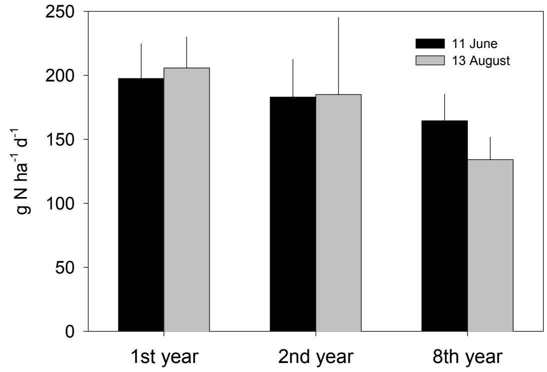

Figure WP2.3b Nitrous oxide emisssions from each sampling time and pasture age (mean ± S.E., n = 11).

A number of soil properties were recorded, and inter-relationships between these and N_2O fluxes were evaluated (*Table WP2.3*). Several strong relations were observed, e.g., electrical conductivity (*EC*) was highly correlated with inorganic N and dissolved organic carbon (DOC), pH was positively related to urea, and N_2O flux was related to water content. Since water content was also related to urea, it may have been associated with previous urine deposition. In contrast, there was no relation between the distribution of N_2O and inorganic N.

Table WP2.3. Correlations between several soil properties and N_2O emissions for the two campaigns in 2001.

	NH4+	NO3-	Urea	Moisture	pH	EC	N2O_flux	DOC	NH4NO3
NH4+		0,29***	-0,09	0,00	0,01	0,83***	-0,12	0,34**	1,00***
NO3-			-0,13	0,06	-0,04	0,53***	-0,08	0,30	0,34***
Urea				0,45***	0,30***	-0,30***	0,00	0,28**	-0,10
Moisture					0,13	-0,06	0,63***	0,03	0,00
pH						-0,07	-0,02	0,07	0,00
EC							-0,13	0,45***	0,84***
N2O_flux								-0,20	-0,12
DOC									0,35**

Corrected for repeated analyses according to the sequential Bonferroni test (Rice, 1989).

Controlled experiments with simulated deposition of urine in a confined section of the pasture showed that the concentrations of both ammonium and nitrate were highly variable over time, and the potential for nitrate accumulation depended on both the amount and composition of the urine (*Fig. WP2.3c*).

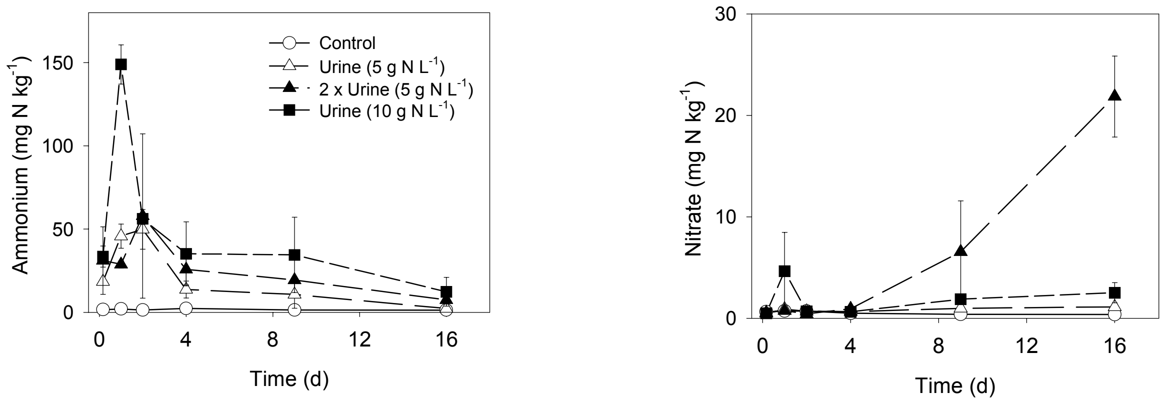

Figure WP2.3c Temporal dynamics of ammonium (left) and nitrate (right) in soil after simulated deposition of water (control), normal urine, a double dose of normal urine, or a urine with an elevated urea-N concentration).

Based on the first year's results it was hypothesized that surplus N intake, which is mainly excreted as urea in the urine, may have a significant impact on N turnover in pasture soil. High levels of urea in urine deposits will result in high ammonia levels that can release carbon via scorching of roots (and lysis of microbial cells), and so there is a potential for accelerated denitrification and N_2O emission in more intensive systems.

This hypothesis is currently addressed in a field study, where seasonal losses of N_2O from an 'organic' system based on unfertilised clover-ryegrass are compared with those from a more intensive 'conventional' system consisting of ryegrass fertilized with 300 kg N ha^{-1} yr^{-1} (*Fig. WP2.3d*). Nitrous oxide fluxes are measured along a transect within each paddock every four weeks, where supplementary feed intake and milk yield by the cattle are also recorded. Cattle from the 'conventional' treatment receive a higher level of protein in the supplements.

Figure WP2.3d An overview of the organic and conventional paddocks (left), the remote sensing camera unit used for mapping a strip of pasture (middle), and the N deposition (indicated by darker green) was more concentration around the water source (right).

In June 2002 a 10-m wide section of the two paddocks was mapped by remote sensing from 14 m height (*Fig. WP2.3d*). The purpose was to obtain a visual description of the distribution of excreta, as revealed by reflectance at defined wavelengths. This information can be used as reference in WP3. Notably, the area around the water source was more affected by excreta than the rest of the paddocks (*Fig. WP2.3d*).

WP3 Modelling of nitrogen exchange between soil and atmosphere
This work package has not formally started yet. However, preparations of the work have been performed. A running versions and the source code of the DNDC model has been acquired from prof. Changsheng Li, University of New Hampshire. This model is considered state-of-the-art in simulating NO and N_2O emissions from soils. It has, however, not been tested for grasslands. A revised more simple model will be implemented in the FASSET model. This will be an extension of the current denitrification model, which is identical to the DAISY model. It has been agreed with the DAISY modelling group to develop a new common N_2O emission and denitrification model for FASSET and DAISY. This model will be based on the new soil organic model developed in FASSET and probably assume different soil water functions for N_2O emission from mineralization, and from the denitrification depending on the activity of the two microbial pools in the model. Simulations of the DNDC model and the revised FASSET model will be compared with those of the measurements that have been performed in WP1 and WP2 of the project.

C.2 Fulfilment of deliverables and milestones

WP number and title	Time schedule according to application	Deviations, if any*
Deliverables		
D1.1 Development of method for $^{15}N_2$ fixation	05/01	03/02
D1.2 Development of simple method for gross N turnover and gas flux measurements	06/01	
D1.3 Publication on $^{15}N_2$ fixation method	12/01	10/02
D1.4 Publication on $^{15}N_2$ fixation, translocation and gas losses	09/03	
D1.5 Publication on gross N turnover in excreta affected pasture and gas fluxes	05/04	
D1.6 Publication on gross N turnover and gas fluxes in controlled environment	05/04	11/03
D1.7 First year data available for WP3	03/02	
D2.1 Report on the relationship between N_2 fixation and leguminous dry matter production	11/01	01/03
D2.2 Publication on the contribution from stolons and clover roots to the total N_2 fixation	05/04	
D2.3 Publication on the combined effects of grazing and urine deposits on N_2 fixation in grass-clover	07/02	07/03
D2.4 Publication on field estimates of N_2 fixation in grass-clover pastures on sandy soil types	05/04	
D2.5 Publication on field estimates of N_2O emission from grass/clover pastures on sandy soil types	05/04	
D2.6 First year field data made available for WP3	03/02	
D3.1 Revised N_2O and N_2 fixation sub models	02/03	
D3.2 Publication on model work	05/04	
Milestones		
M1.1 Method for $^{15}N_2$ fixation developed	05/01	03/02
M1.2 Method for field gross N-turnover and gas measurements developed	06/01	

M1.3 $^{15}N_2$ fixation measurements completed	08/02	06/03
M1.4 Gross N turnover and gas flux measurements in the field and controlled environment completed.	10/03	
M2.1 Experiments on the combined effects of grazing and urine deposits on N_2 fixation in grass/clover completed.	12/01	12/02
M2.2 Experiments on contribution of stolons and clover roots to N_2 fixation completed.	10/03	
M2.3 Field measurements of N_2O emission and N_2 fixation completed.	10/03	
M3.1 A new N_2O emission sub-model implemented in the whole-farm model FASSET.	02/03	
M3.2 An improved N_2 fixation sub-model implemented in the whole-farm model FASSET.	02/03	
M3.3 Revised FASSET sub-models verified and validated.	11/03	

** Deviations are to be further discussed in D*

D. Description of deviations and subsequent adjustments of plans

No deviations in additions to those explained in the status report of 2001 (as indicated above) are expected. In brief, the reason for the indicated deviations are 1) inclusion of pasture age effects on SNF and N_2O emissions, which was not included in the original plans, has caused some additional work in the initial phase and 2) technical problems delayed *D1.1* and *D1.3*.

E. Project publications and other products

1. Articles in international, scientific journals with review procedures

Eriksen, J. & Vinther, F.P. 2002 Nitrate leaching and N_2 fixation in grazed grasslands of different composition and age. Grassland Science in Europe 7, 682-683.

2. Papers presented at congresses, symposiums, etc.

Petersen, S.O. 2001 Nitrous oxide emissions from grasslands. Poster presented at EU Concerted Action 627 in Dublin, 7-8 April.

Thyme, M. and Ambus, P. 2002 Production of N_2O in grass-clover pastures. In (J. van Ham et al. eds) Non-CO_2 greenhouse gases: Scientific understanding, control options and policy aspects. Proceedings of the Third International Symposium, Maastricht, The Netherlands 21-23 January. pp 149-150.

Ambus, P. 2002 Sources of N_2O in organic grass clover-pastures. NJF Seminar no. 342 Agricultural Soils and Greenhouse Gases in Cool-Temperate Climate, Reykholt, Iceland, 31 July – 3 August.

3. Reports, articles in agricultural journals, etc.

Ambus, P. 2002 Undersøgelse af kvælstofbinding og udslip af lattergas fra kløvergræsmarker. Klumme til Økologisk Jordbrug, nr. 265.

Ambus, P. 2002 Kommer der lattergas fra kløvergræsset? Klumme til Landsbladet Mark, Juni.

4. Oral presentations, public meetings, field days, etc.

2001 Presentation of experimental site in connection to workshop at Foulum within EU Concerted Action 627 'Carbon Storage in Grasslands', 29 September, Foulum, DK.

Thyme, M. 2001 Nitrous oxide emissions in grass-clover fields. Oral presentation at the Ph.D. summer school on "*Linking Ecology and Organic Farming*", organised by SOAR (Research School for Organic Agriculture and Food Systems), 24-28 September, Kongskilde Friluftsgaard, DK.

Thyme, M. 2001 Produktion af lattergas (N_2O) i kløvergræs. Forskerskolen for økologisk jordbrug og fødevareproduktion - SOAR: Halvårsseminar, Kgl. Veterinær- og Landbohøjskole, 16 November, Tåstrup, DK.

Thyme, M. 2001 Production of nitrous oxide in grass-clover pastures. Workshop on clover in Northern areas, Swedish University of Agricultural Sciences, 19-21 November, Umeå, SE.

Ambus, P. 2002 Greenhouse gas emission from agricultural and forest soils. Symposium on climate change and plant-ecosystem interactions, 21 March, Risø, DK. Unpublished.

Thyme, M. 2002 Production of nitrous oxide in grass-clover pastures. Ph.D. course: Dynamics of Organic Matter in Soil, 26 May – 1 June, Brorfelde Holbæk, DK.

Thyme, M. 2002 Production of nitrous oxide in grass-clover pastures. Plant Research Department, 6 September, Risø National Laboratory, DK.

F. Scientific education

M.Sc. Mette Thyme joined the project as Ph.D.-student beginning 15 September 2001. The Ph.D.-project receives funding by DARCOF II, The Danish Research Councils and Risø National Laboratory.

G. National and international cooperation

1. DARCOF II project BIOMOD
2. Dr. Roland Bol, Institute of Grassland and Environmental Research, Exeter, UK
3. Dr. Sirwan Yamulki, Institute of Grassland and Environmental Research, Exeter, UK
4. Dr, Stamatis Stamatiadis, Soil Ecology & Biotechnology Lab, Gaia Center - Goulandris Natural History Museum, Kifissia, Greece
5. Dr. Martin R. Weisbjerg, Department of Animal Nutrition, Danish Institute of Agricultural Sciences, Denmark
6. Dr. René Larsen, Deptment of Agricultural Systems, Danish Institute of Agricultural Sciences, Denmark
7. Dr. Jeans-Francois Sussana, National Institute for Agricultural Research (INRA), Clemont-Ferrand, France

8. Dr. Ute Skiba, Centre of Ecology and Hyrology, Bush Estate, Penicuik, Midlothian, UK
9. Dr. Henning Høgh Jensen, Department of Agricultural Sciences, Organic Farming Unit, Royal Veterinary and Agricultural University, Denmark.
10. Dr. Anders Michelsen, Botanical Institute, University of Copenhagen, Denmark.

H. Critical reflection on the project

As mentioned in sections C.1 and C.2 the activities of the study was modified at an early stage to include also effects of pasture age on BNF and N_2O emissions. A long term experimental study on effects of pasture age at DIAS was made available to the project and it was hypothesized that the below-ground accumulation of organic material in old pastures would influence BNF and N_2O emissions. Permanent grasslands represent a significant proportion of the total agricultural area in some countries, e.g., 32% in the UK (DEFRA, 2001; http://www.defra.gov.uk/wildlife-countryside/research/change/14.htm). Extending the study of N dynamics to include pastures of different age may greatly increase the generalizing power of results derived from this study.

Although organic farming still constitutes only a small fraction of Danish agriculture it is necessary to generate knowledge in order to provide overall assessements of environmetal impacts of organic farming practices. The preliminary results from this project indicates that base-line emissions (excluding urine affected areas) of N_2O from organically managed grass-clover pastures might be very low. The focus of the study has initially been on the 'organic' system. As already mentioned (section *C.1 WP2.3*), however, it has been decided to put more emphais on a comparison between organic and conventional systems with respect to the potential for N_2O emission. It is also under consideration to include more emphasis on conventional managed grasslands within WP1.1, associated with activities in an ongoing EU-funded project. Results from these comparative studies will provide a more rigorous basis for the confirmation and justification of the preliminary conclusions.

During the work we have discovered some discrepancies in the observed N_2O evolution rates based on field measurements and soil monoliths. This discrepancy will be target for investigation in 2003. This will likely lead to methodological developments useful not only in the present project but in general for the scientific community

8. Budget

A. Account for any change in budgets

No changes in overall budget.

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 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	12	12	15	4		43
Technical personnel	6	10	8	1		25

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	493	512	667	186		1858
Technical personnel	153	255	217	27		652
Other operational costs	102	159	119	11		391
Equipment	70	0	0	0		70
Others (Travel)	14	14	20	31		79
Direct costs	832	939	1023	255		3049
Indirect costs (20% of direct costs)	167	188	205	51		611
Total	999	1127	1228	306		3660

Comments:

9. Signatures and stamps

Name	Institute	Date	Signature
Head of project			

Appendix I. Detailed budget

Budget for each participating institute (1.000 DKr)

Name of Institute: **Danish Institute of Agricultural Sciences**

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	6	8	11	2		27
Technical personnel	3	7	5			15

Year:	Consumption before 2002	Expected consumption 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	243	338	487	93		1161
Technical personnel	80	179	139			398
Other operational costs	37	119	82	6		244
Equipment						
Others (Travel)	6	6	6	17		35
Direct costs	366	642	714	116		1838
Indirect costs (20% of direct costs)	74	128	143	23		368
Total	440	770	857	139		2206

Name of Institute: **Risø National Laboratory**

Year:	Consumption before 2002	Expected consumptio n 2002	2003	2004	2005	Total
Man-months						
Scientific personnel	6	4	4	2		16
Technical personnel	3	3	3	1		10

Year:	Consumption before 2002	Expected consumptio n 2002	2003	2004	2005	Total
Salaries						
Scientific personnel	250	174	180	93		697
Technical personnel	73	76	78	27		254
Other operational costs	65	40	37	5		147
Equipment	70	0	0	0		70
Others (Travel)	8	8	14	14		44
Direct costs	466	297	309	139		1211
Indirect costs (20% of direct costs)	93	60	62	28		243
Total	559	357	371	167		1454

Comments: