Midterm Status Report 2003 and Application for Continuation in 2004

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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 2004

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

Baseline N_2O fluxes

The experimental work to study the relationship between base-line (not affected by excreta) N_2O emissions and gross N turnover was completed in 2001/2002 and final analytical work completed 2003. From the ^{15}N-tracer study we found that soil concentrations of NH_4^+ was an important indicator for N_2O emissions. The $^{15}N_2O$ evolution was positively correlated with the soil $^{15}NH_4^+$ availability ($R^2=0.22$; $P<0.001$) showing the relationship $F_{15N2O}=0.19\times e^{6.92\times A}$, where A denotes the concentration of $^{15}NH_4^+$. In a contrasting manner, the $^{15}N_2O$ evolution was inversely related to the soil $^{15}NO_3^-$ availability ($R^2=0.19$; $P<0.001$) with the mathematical relationship $F_{15N2O}=1.60\times e^{-5.95\times N}$, where N denotes the concentration of $^{15}NO_3^-$. The validity of this simple relationships was tested against data for soil inorganic N and N_2O emissions in an independent experiment. This test showed that 14% ($P<0.01$) of the variability of the N_2O evolution in te independent study could be predicted from this relationship (Fig. WP1.1).

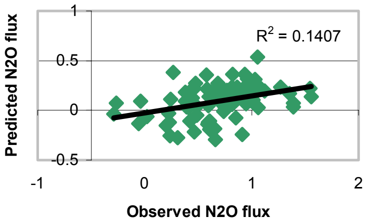

Fig. WP1.1. Predicted vs. observed baseline N_2O flux in grass-clover pasture.

If it is assumed that all the N_2O emitted was produced in the 0-16 cm soil depth, where nitrification was measured, it can be calculated that 0.05% (range 0.004% to 0.29%) of the oxidized NH_4^+ was recovered as emitted N_2O within all combinations of pasture age and season. The N_2O:nitrification proportion was not related to pasture age ($p<0.05$), but changed significantly with sampling time. Thus, for the sequential sampling times of May, June, August and October the N_2O:nitrification proportion was calculated to 0.01%, 0.13%, 0.03% and 0.04%, respectively. Although N_2O emission from this grass-clover was found to be linked to the NH_4^+ availability, the proportion lost as N_2O was much less than the 0.5% - 2% generally anticipated from nitrification (Frolking et al., 1997).

N_2O fluxes associated with urine deposits

Urine patches are strong sources of N_2O and may provide >20% of the annual N_2O loss from a pasture. First of all, the urine patch has a high availability of inorganic N for nitrification and denitrification. However, urine deposits are also known to induce scorching of vegetation and root death, which may lead to increased accessability of easily degradable carbon in the soil and thus accelerate the denitrification and N_2O losses further.

In 2003 a short-term pulse labelling study was carried out to assess the carbon- and N-dynamic in grass-clover pastures. Undisturbed soil cores, 30 cm diam. and 25 cm deep confined in PVC-cylinders were collected at Burrehøjvej, Foulum in 2002 and incubated in the field at Risø under simulated grazing (cutting). In May 2003 six replicate cores were incubated under an $^{13}CO_2$ enriched atmosphere for two consecutive days in order to label above- and belowground plant biomass. Immediately following the ^{13}C-labeling urine was added to the soil plots and emission of CO_2 and N_2O monitored at regular intervals the following six weeks. Supplemental plots were treated with ^{15}N-labeled urine to study the source-relationship for N_2O in simulated urine patches (Fig. WP1.2).

An increased CO_2 evolution was observed from the urine patches only three hours after application. This increased activity persisted for three days, when urine and non-urine affected plots showed comparable CO_2 evolution (not shown). Cumulated CO_2 losses over the course of the experiment, however, indicated a loss of 222 g C m^{-2} from urine affected soil, which was 48 g C m^{-2} more than from the control soil (Fig. WP1.3A). This difference is comparable to the amount of organic C added with the urine (44 g C m^{-2}), mainly as urea and hippuric acid, suggesting that this C may have been subject to mineralization.

Fig. WP1.2. Micro-plot experiment with urine application. A) $^{13}CO_2$ pulse-labeling, B) urine application and C) gas sampling.

Taking into account the ^{13}C enrichment of the evolved CO_2 it was possible to separate the mineralized C into plant and non-plant (mainly urine) sources by a simple isotope pool dilution approach. These calculations showed that during the first 0-3 days 87% of the evolved CO_2 in response to urine application could be identified as non-plant C (Fig. WP1.3B). Over the six week course, however, only ~50% of the surplus CO_2 evolved from the urine patches was identified as of non-plant origin, indicating the the urine application stimulated the breakdown of plant-derived carbon compounds and perhaps also root respiration. On the other hand, this also shows that ~50% of the urine C persisted in the soil after the six week period, likely assimilated into the soil microbial biomass.

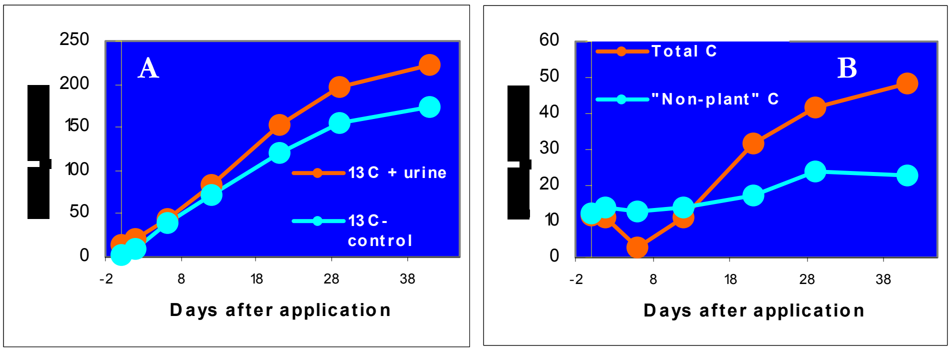

Fig. WP1.3. A) total CO_2 accumulation; B) fraction of non-plant derived C evolved as CO_2

Parrallel measurements indicated that the temporal pattern of N_2O emissions from the urine affected plots was asynchronous with the CO_2 pattern suggesting that N_2O production is delinked with C mineralization in urine patches. However, a further examination of the data is pending the ^{15}N analysis.

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

An experiment has been completed in which grass-clover post have been incubated in an atmosphere with $^{15}N_2$ in order to examine the translocation and losses of recently fixed N. Results of this experiment appear in Figs. WP1.4 and WP1.5. At 4 months, N_2 fixation measured in grass-clover shoots and roots constituted 339 mg N m^{-2} d^{-1} (Fig. WP1.4). This is twice to 10 times larger compared to daily average of field measurements (Høgh-Jensen and Schjoerring, 1997; Vinther and Jensen, 2000), probably because of optimal growth conditions. Following a severe aphid attack, N_2 fixation dropped dramatically at 6 months. The fraction of fixed $^{15}N_2$, which was emitted as $^{15}N_2O$ increased from 0.33 to 0.94 % between 4 and 6 months (Fig. WP1.5). Translocation of fixed N from clover to companion grass represented 0.2, 1 and 1 mg N m^{-2} d^{-1} at 4, 6 and 8 months, respectively (data not shown).

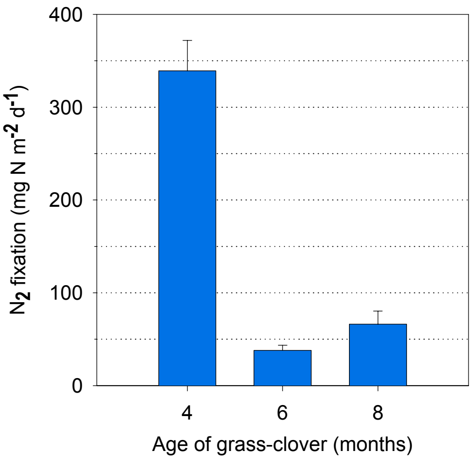

Fig. WP1.4. Symbiotic N_2 fixation measured in grass-clover shoots and roots; n = 4, means ± SE.

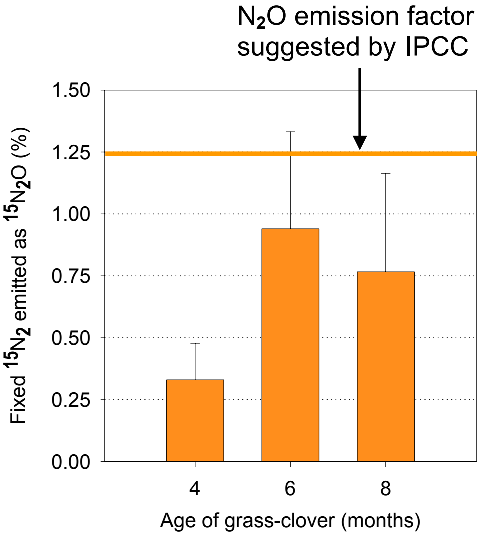

Fig. WP1.5. Fraction of fixed $^{15}N_2$ emitted as $^{15}N_2O$; n = 4, means ± SE. This number only includes $^{15}N_2O$ emission, which was not equalised by $^{14}N_2O$ uptake.

The experiment was conducted at relatively high soil water content, which should promote N_2O production via denitrification. In spite of this, less than 1 % of the fixed $^{15}N_2$ was emitted as $^{15}N_2O$. This indicate that the N_2O emission factor for recently biologically fixed N_2 in a grass-clover pasture might be lower than the standard emission factor of 1.25 % suggested by IPCC. Insect pest status of clover seemed to be an important factor influencing the fraction of recently fixed N_2, which is emitted as N_2O – mainly because of its effect on the N_2 fixation. The aphid attack on clover also led to enhanced translocation of fixed N from clover to companion grass. This was probably because of 1) raised clover rhizodeposition of nitrogenous compounds and/or 2) reduced competition for light - both factors enabling increased growth of grass.

WP 2.1 & 2.2: N_2 fixation. Field estimates and contribution from stolons and roots

Field estimates of total N_2 fixation based on measurements of the harvested dry matter require knowledge about the contribution from the below harvest components, i.e. stolons and roots. Furthermore, the N_2 fixation is often measured under mowing conditions, i.e. less frequent cuttings and no influence from grazing cattle, and to be able to estimate the N_2 fixation under grazing conditions knowledge about the effects of frequent cutting on clover growth is required. These aspects have been studied in combination in a field trial and a greenhouse experiment.

Greenhouse experiment

Briefly, the greenhouse experiment was carried out over a period of four months with red and white clover. *Rhizobium*-inoculated seeds were sown in soil and after emergence the plants were moved to pots with sand as growth medium (Fig. WP2.1). After about 2 months when the plants had reached a height of about 10 cm they were divided into two groups; one continued the growth without disturbance ('uncut') for another two months and one was cut to about 2 cm above surface 5 times ('cut') during the two months. At the end of experiment the amount of dry matter in the both above- and belowground material was determined.

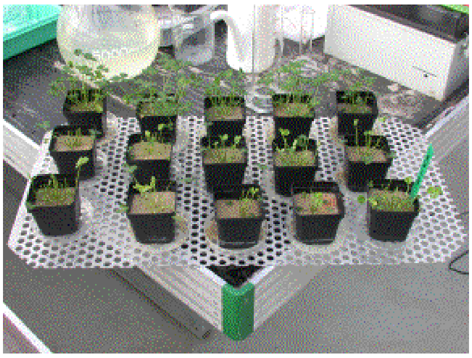

Fig. WP2.1. White clover plants in the greenhouse experiment.

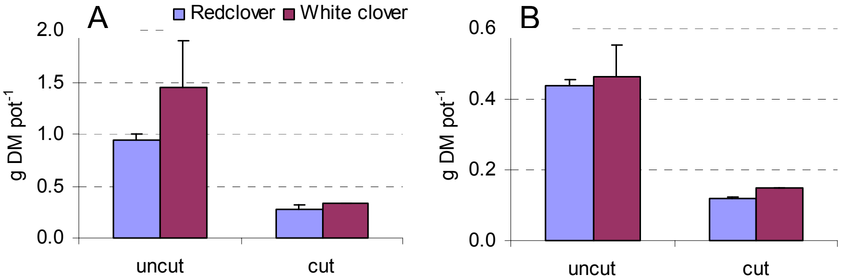

Fig. WP2.2. Accumulated amount of dry matter (DM) in the above ground (A) and below ground (B) parts of 'uncut' and 'cut' red clover and white clover.

The results show that cutting affected the accumulated amount of dry matter both in above-ground and below-ground parts in both red and white clover (Fig. WP2.2). Cutting caused a reduction in the aboveground parts corresponding to 22 and 21% in red clover and white clover, respectively. Similarly, the reduction in the belowground parts (roots) was 25 and 21% in red clover and white clover, respectively.

Field experiment

A field experiment aiming at evaluating the effects of frequent cuttings (simulated 'grazing') versus mowing on grass-clover production and N_2 fixation was initiated in 2002. However, only results from 2003 are briefly presented here.

The accumulated amount of harvested clover, grass and total biomass, as well as proportion of clover is shown in Fig. WP2.3.

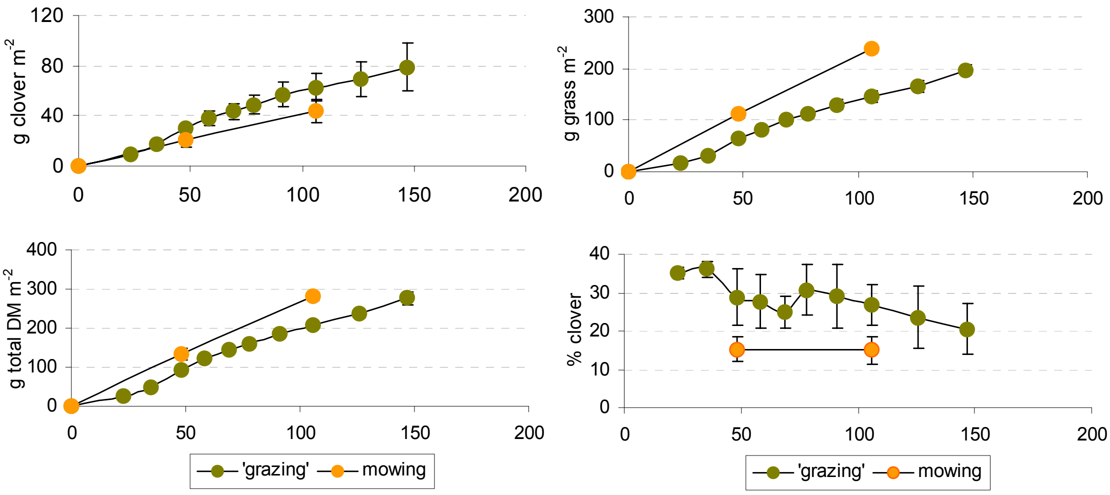

Fig. WP2.3. Accumulated amount of harvested clover, grass and total biomass, as well as proportion of clover during the period from April to August 2003.

In general, the results show that 'grazing' has a slightly positive effect on the harvested amount of clover and a negative effect on harvested amount of grass and total biomass, resulting in positive effect on the proportion of clover.

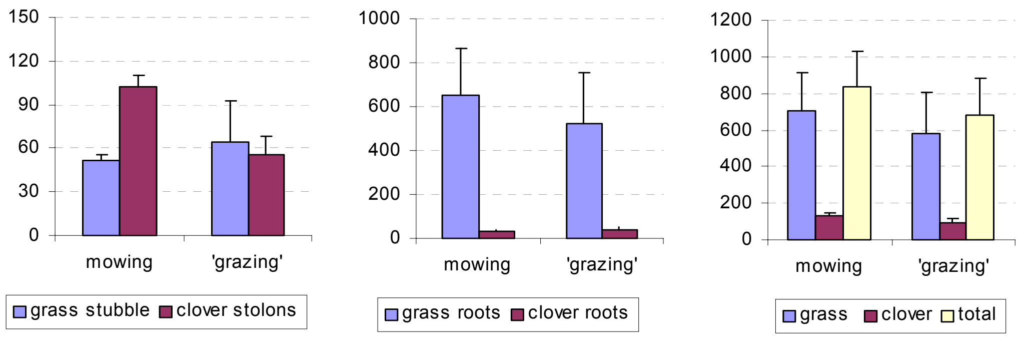

Fig. WP2.4. Effects of mowing and 'grazing' on below harvest biomass (g DM m^{-2}).

In accordance with the greenhouse experiment the results of the field measurements also showed that frequent cuttings ('grazing') had a negative effect on root development and on the total below harvest biomass (Fig. WP2.4). Possible implications on N_2 fixation await the results of the ^{15}N analyses.

WP 2.3: Spatial variation and field estimates of N_2O emission

Summer grazing of pasture can influence soil properties in several ways. Firstly the input of nitrogen via excreta will stimulate soil N turnover and N_2O emissions. Secondly, the treading of animals can lead to soil compaction that may induce oxygen-depleted soil volumes, and this can also promote N_2O emissions. In some parts of the pasture, for example the area around the drinking trough, there could be an interaction between N deposition and soil compaction due to a high level of animal traffic. Such macro-scale variability is of interest since it can be influenced by management practices.

The activities in 2002 and 2003 that are related to N_2O emissions from grazed pastures have focused on characterizing sources of variability (soil compaction, distribution of excreta) and the associated N_2O fluxes. Unfortunately, analytical problems made it necessary to disregard N_2O flux measurements from 2002, and these efforts will not be discussed further.

Soil compaction

Field campaigns during 2002 examined soil compaction before and after a summer grazing season. The pasture was located near Research Centre Foulum. The loamy sand had been in pasture and grazed since 1994. It was divided into two sections, one with unfertilized white clover-ryegrass (organic management) and the other with ryegrass receiving 300 kg N ha^{-1} yr^{-1} (conventional management). The stocking density in 2002 was 7 cattle per hectare, slightly higher than in previous years. Soil compaction was assessed from measurements of bulk density with a high resolution gamma-ray transmission system. The dampening of gamma-rays passing between the tips of two narrow probes is a function of particle density and soil moisture.

Preliminary measurements were conducted in December 2001 along two gradients outside the experimental fields. The two fields were grazed between 1 May and the end of October 2002. In April and in November, bulk density was recorded at 5 cm soil depth along six transects at 1, 5, 10, 20, 40 and 108 m distance from the end of the fields where cattle would enter in the morning, and where the drinking trough was located. Ten measurement points were defined at equal spacing along each transect. Bulk density was recorded in these 60 locations; the measurement positions could not be precisely recovered in November, but were estimated to lie within 1 m of the original position.

Before grazing, bulk density at 5 cm depth was 1.00±0.02 g cm^{-3} (average±S.E.), and ranged from 0.54 to 1.4 g cm^{-3}. The lower end of this range was constituted by two measurements of 0.54 and 0.55 g cm^{-3} which may have been disturbed by cracks in the soil. In November, the corresponding bulk density values averaged 1.09±0.01 g cm^{-3}, and ranged from 0.82 to 1.35 g cm^{-3}. A paired-sample t-test was conducted, excluding the two sampling points with extreme low values in April. The test showed that the average increase in soil bulk density over the grazing season was statistically significant ($P<0.005$; $n = 58$).

Contour maps were prepared for each measurement date (Fig. WP2.5). However, no systematic macro-scale heterogeneity could be observed at the spatial scale used in this experiment.

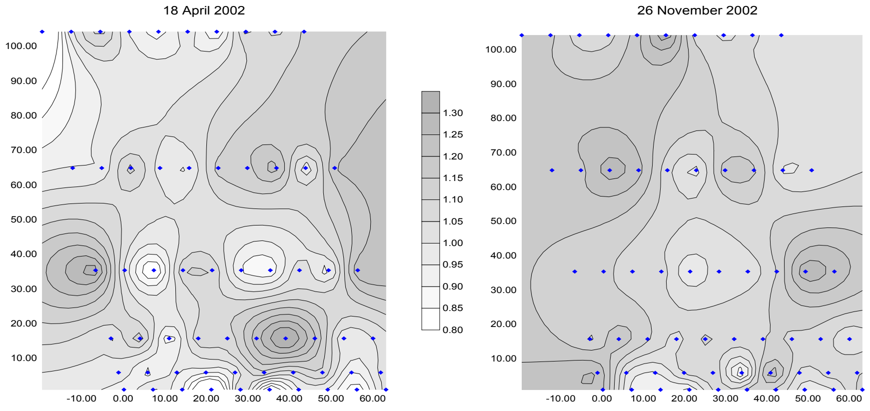
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Fig. WP2.5. Soil compaction at 5 cm depth was recorded in April, prior to the beginning of the grazing season, and in November, three weeks after the grazing season had ended. The measurement positions are indicated by dots.

The observed effect of grazing is in accordance with previous studies. Drewry and Paton (2000) found that a grazed pasture had lower macroporosity, lower air permeability, and lower hydraulic conductivity compared with a ungrazed pasture, while pastures with reduced grazing showed intermediate effects. Depth profiles of soil physical properties have shown that the greatest effects of treading were found in the 0-10 cm depth interval (Singleton et al., 2000).

Spatial distribution of excreta

In June 2002, a section of the summer pasture was mapped for image analysis of pictures taken at defined wave lengths. The filtered image of an area around the drinking trough shows the patchy distribution of photosynthetic activity. It strongly suggests that sward N uptake and growth is closely related to excretal returns of N from the cattle, and that the concentration of N deposits is elevated around the water source.

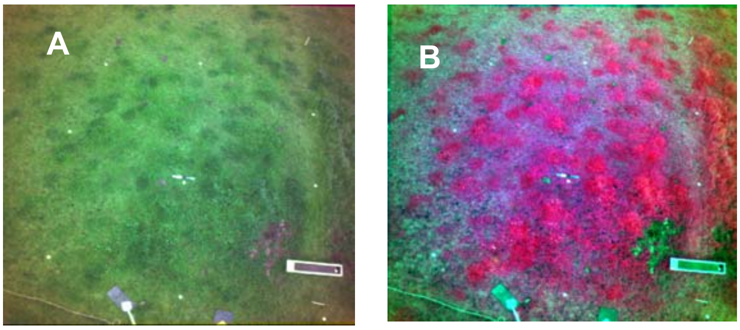

Fig. WP2.6. Digital images taken on 19 June 2002 with the Foulum Image Capture Facility from 13 m height above the pasture. The photos show an unfiltered image (A) of a section of the organic paddock around the drinking trough, as well as a filtered image (B) in which the photosynthetic activity is enhanced by a green filter.

The distribution of excretal returns in grazed pastures has been described by different statistical models, such as a negative binomial distribution (Richards and Wolton, 1976) and a stochastic distribution (Hutchings and Kristensen, 1995). These approaches assume that there are no macro-scale heterogeneity in the distribution of the cattle that could affect deposition of urine and faeces within the pasture. White et al. (2001) registered excretions from cattle during 24-h periods five times across a grazing season and found that, during dry weather conditions, the deposition of excreta decreased with distance to the drinking trough or, in other words, the cattle spent more time and deposited a higher proportion of excreta near the water source when the weather was hot and dry. Such a pattern was not observed outside these periods. The concentrated deposition of N indicated by image analysis in this study indicates that soil conditions and the potential for N_2O emission can be very different in the area around the water source, and this spatial heterogeneity was accounted for in the experimental plans for 2003.

Seasonal trends in N_2O emissions

Nitrous oxide fluxes are measured at different times across a grazing season in connection with an ongoing field study located at Rugballegaard, Horsens, which is part of DARCOF Project II.1 ’Organic milk production systems’. In this project, two feeding strategies (with or without supplementary fodder) are compared with respect to milk yield and grazing behaviour.

Grazing takes place in a rotational system where the animals were planned to shift between 8-12 fields every two days in a fixed order, i.e., returning to a given area at 2-4 week intervals. Each 1.3 ha field is split 45%:55% for the groups with and without supplementary fodder, respectively.

Measurements of N_2O emission and soil samples have taken place in a selected field along a transect in each part of the field (high/low feeding intensity). The transects start at the drinking trough. The first sampling took place in late April, before the grazing season. Campaigns were then conducted in May and June and were planned for August and September. Due to severe drought the animals were away from the field between July and mid-September, and therefore no N_2O measurements were conducted in August. Instead a more intensive campaign with broader scope was planned for September, in which N_2O flux measurement points was selected to cover low and high levels of N deposition and soil compaction using the strategy described below, but including both soil density and electrical conductivity as basis for selection of sampling points.

Interaction between pasture age, soil inorganic N and N_2O *emissions*

In early July 2003, a campaign was conducted in which N_2O fluxes, soil inorganic N, pH and electrical conductivity (EC) was described along transects in 1st, 2nd and >10th year pastures at Foulumgaard. First 25 points within each pasture were described with respect to EC as a proxy for soil inorganic N (Smith and Doran, 1996). Based on these measurements, 8 sampling points for N_2O flux measurements and soil sampling were selected to represent the highest and lowest EC values, as well as four samples in between. As exemplified in Fig. WP2.7 only a few high EC values were observed and could easily have been missed if the eight points had been selected at random.

A preliminary data analysis did not reveal significant differences between pasture age with respect to N_2O fluxes. A significant dependency on soil nitrate was indicated, but a more detailed analysis will be conducted during autumn, combining results from this campaign and the seasonal study.

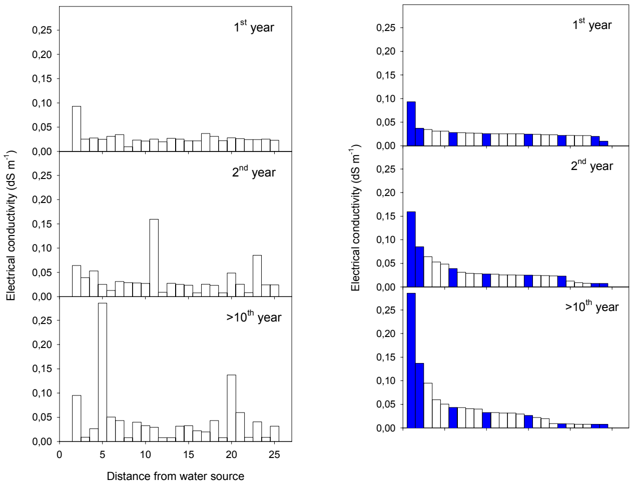

Fig. WP2.7. Electrical conductivity measured along transects in three pastures og different age (left). These measurements were sorted (right) and the colored sampling points used for N_2O flux measurements and soil sampling.

WP3: Modelling of nitrogen exchange between soil and atmosphere.

An algorithm for dynamic simulation of N_2O emission from agricultural soils was developed and implemented in the FASSET model and used for studying N_2O emission from grasslands under different treatments. Both nitrification and denitrification are included as important sources for N_2O emission in the algorithm. A new model for denitrification, which is based on soil organic matter turnover, mineral nitrogen and soil water responses, was also developed. The algorithm was tested on experimental data of N_2O emission from sites in UK, Finland and Denmark, differing in climatic conditions, soil properties and management of grasslands.

Initially the DNDC model was used to simulate the emissions from these datasets. This model is considered state-of-the-art in simulating NO and N_2O emissions from soils. It has, however, not previously been tested for grasslands. However, the results showed that the model tended to overestimate emissions from grasslands and it could not explain the observed variation in the measured N_2O emission. Better agreement between observed and simulated values was obtained for the new algorithm implemented in the FASSET model. The predicted annual N_2O emissions of the FASSET model were in accordance with the IPCC methodology.

A test of the nitrogen fixation model has been conducted for available datasets in collaboration with the DARCOF II BIOMOD project. The simulated nitrogen fixation of grass-clover pastures is generally in agreement with measured values.

The revised nitrous oxide emission model will further be tested for effect of including spatial heterogeneity in urine deposition from grazing cattle in the model. In addition a collaboration with University of Gent has been initiated with the aim of validating the model against data from measurements of N_2O emission from grasslands in Belgium.

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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	Completed
D1.2 Development of simple method for gross N turnover and gas flux measurements	06/01	Completed
D1.3 Publication on $^{15}N_2$ fixation method	12/01	05/04
D1.4 Publication on $^{15}N_2$ fixation, translocation and gas losses	09/03	05/04
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	Submitted
D1.7 First year data available for WP3	03/02	Completed
D2.1 Report on the relationship between N_2 fixation and leguminous dry matter production	11/01	10/03
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	05/04
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	Completed
D3.1 Revised N_2O and N_2 fixation sub models	02/03	Completed
D3.2 Publication on model work	05/04	
Milestones		
M1.1 Method for $^{15}N_2$ fixation developed	05/01	OK
M1.2 Method for field gross N-turnover and gas measurements developed	06/01	OK
M1.3 $^{15}N_2$ fixation measurements completed	08/02	OK
M1.4 Gross N turnover and gas flux measurements in the field and controlled environment completed.	10/03	OK
M2.1 Experiments on the combined effects of grazing and urine deposits on N_2 fixation in grass/clover completed.	12/01	12/03
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	OK
M3.1 A new N_2O emission sub-model implemented in the whole-farm model FASSET.	02/03	03/04
M3.2 An improved N_2 fixation sub-model implemented in the whole-farm model FASSET.	02/03	03/04
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 significant deviations are expected. Generally, the experimental work has been or will be completed as anticipated. Early changes in priority (see status reports 2001 and 2002) and minor delays in analytical work as well as technical problems have led to some changes in deliverables and milestones, but will not affect the overall output from the project. See also comments with the DIAS budget.

E. Project publications and other products

1. Articles in international, scientific journals with review procedures

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

2. Chatskikh, D., Olesen, J.E., Berntsen, J., Regina, K. & Yamulki, S., 2003. Simulation of N_2O emission from grasslands with the FASSET model. European Journal of Soil Science (ready for submission).

3. Ambus, P. 2003. Relationship between nitrogen cycling and nitrous oxide emission in an organic grass-clover pasture. (ready for submission to Nutr. Cycl. Agroecosys.)

2. Papers presented at congresses, symposiums, etc.

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

2. 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.

3. 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.

4. Eriksen, J. & Vinther, F. P. 2003 Nitrate leaching and N_2-fixation in grasslands of different composition, age and management. 12th N workshop "Controlling N Flows and Losses", 21st - 24th September, University of Exeter, Devon UK

5. Thyme, M. and Ambus, P. 2003 From N_2 fixation to N_2O emission in a grass-clover pasture. Poster presented at 12th N Workshop "Controlling N Flows and Losses", Exeter, UK, 21st – 24th September.*

3. Reports, articles in agricultural journals, etc.

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

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

3. Vinther, F. P. 2003 Symbiotisk N_2 fiksering i kløvergræs http://www.foejo.dk/enyt2/enyt/juni03/nstof.html

4. Vinther, F. P. (2003) Kvælstof fra luften. Klumme til Økologisk Jordbrug, nr. 288.

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

1. 2001 Presentation of experimental site in connection to workshop at Foulum within EU Concerted Action 627 'Carbon Storage in Grasslands', 29 September, Foulum, DK.

2. 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 Frilutfsgaard, DK.*

3. 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.*

4. 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.*

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

6. 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.*

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

9. Petersen, S.O. 2003. Greenhouse gas emissions from animal manure. Invited presentation at joint Carboeurope-Greengrass concerted action: Synthesis of the European Greenhouse Gas Budget, 4-5 September, Clermont-Ferrand, France.

10. Petersen, S.O, Stamatiadis, S., Christofides, C.; Yamulki, S. and Bol, R. 2003. Urea concentration affects short-term N turnover and N_2O production in grassland soil. Poster presented at 12th N Workshop in North Wyke, 21-23 September, UK.

11. Ambus, P. 2003. Short term C-dynamic in urine affected grass-clover pasture: a 13C pulse labelling study. Invited presentation at the COST-627 action Carbon sequestration opportunities in European grasslands: mitigation scenarios at plot, farm and regional scales, 7-8 September, Clermont-Ferrand, France.

12. Thyme, M. 2002 Produktion af lattergas (N_2O) i kløvergræs. Half-yearly seminar in SOAR (Research School for Organic Agriculture and Food Systems), 29 November, Risø, 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.
11. Dr. Kristiina Regina, MTT, Finland
12. PhD student Daan Beheydt, ISOFYS Laboratory, Gent University, Belgium

H. Critical reflection on the project

As discussed in mid-term report 2002, it was decided to put more effort into a generalization of the experimentation in the project, e.g. by including comparisons with conventional systems. The reason for this was partly due to issues raised during the DARCOF-project meetings in 2002 and the international mid-term evaluation, but also to achieve a more intimate co-operation with ongoing EU-funded activities within this research field. For this reason it is thus evident that some activities are diverging from the initial project objectives, examplified by the inclusion of C-dynamic studies (WP1.1) and conventional systems (WP2.3).

During the autumn 2002 it was discovered that nitrous oxide analyses at DIAS had been affected by interference from CO_2 for an extended period due to an inability of the GC column to separate the two compounds. An effort has been made to correct measurements in arable systems, but in the pasture system with highly dynamic patterns of both N_2O and CO_2 fluxes it was considered impossible to use this approach. Consequently the results from 2002 focus on the characterization of spatial variability of soil conditions and excretal returns (WP2.3). New field studies are conducted in 2003 to obtain N_2O flux measurements in high- and low-intensity grazed systems, but the description of relationships between N_2O and soil characteristics is also emphasized. Due to the extreme heterogeneity of the pasture system it is likely that estimates of field scale N_2O emissions have to be based on mechanistic modelling that can simulate the depositions of N during grazing.

8. Budget

A. Account for any change in budgets

No changes in overall budget.

B. Budget for the whole project (1.000 DKK)

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Man-months					
Scientific personnel	24	14	6		44
Technical personnel	16	8	1		25

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Salaries					
Scientific personnel	1005	623	274		1902
Technical personnel	408	217	27		652
Other operational costs	261	75	11		347
Equipment	70				70
Others (travel)	28	20	31		79
Direct costs	1772	935	343		3050
Indirect costs (20% of direct costs)	355	187	69		610
Total	2126	1122	412		3660

Comments:

See comments in DIAS-budget

9. Signatures and stamps

Name	Institute	Date	Signature
Head of project			

Appendix I. Detailed budget

A. Budget for each participating institute (1.000 DKr)

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

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Man-months					
Scientific personnel	14	10	4[1,2]		28
Technical personnel	10	5			15

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Salaries					
Scientific personnel	581	443[1]	181[1,2]		1205
Technical personnel	259	139			398
Other operational costs	156	38[2]	6		200
Equipment					
Others (travel)	12	6	17		35
Direct costs	1008	626	204		1838
Indirect costs (20% of direct costs)	202	125	41		368
Total	1210	751	245		2206

Comments:

1) Due to a slight delay in the experimental work, one scientific month is transferred from 2003 to 2004 in WP3 (modelling)

2) Due to less expensive sample analysis than expected, operational cost are converted to one scientific month and transferred from 2003 to 2004 in WP2.1 & 2.2 (N_2 fixation)

Name of Institute: **Risø National Laboratory**

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

Year:	Consumption before 2003	Expected consumption 2003	2004	2005	Total
Salaries					
Scientific personnel	424	180	93		697
Technical personnel	149	78	27		254
Other operational costs	105	37	5		147
Equipment	70				70
Others (travel)	16	14	14		44
Direct costs	763	309	139		1211
Indirect costs (20% of direct costs)	153	62	28		243
Total	916	371	167		1454

Comments: