

Regional Groundwater Protection by Optimised Organic Farming Systems

Acronym (Danish): ØKOVAND

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1. Summary

In Denmark the public gives high priority to being able to use untreated ground water for drinking. There is a growing understanding that clean ground water can only be maintained through active means. A way of regulating land use in vulnerable areas could be to use organic farming. Pesticide use will then stop. However, this does not necessarily mean a stop to nitrate leaching. Probably the loss of nitrate will differ with the type of organic cropping system used and that is the focus of this study.

Our hypothesis is that some of the management steps that characterise organic farming systems can change both the quantity and the quality of the ground water compared with conventional farming. The idea is to focus on the aspects of organic farming systems that presumably will affect the ground water. The total effect of the different management steps on ground water can only be evaluated by the use of a model that integrates the effects from the farming system. This requires that the effects of the organic farm system on the model parameters that are of importance for nitrate leaching are determined.

We especially need knowledge about how the hydraulic parameters are affected by the farming system, and if there are aspects of organic farming systems that generally result in an increased leaching of dissolved organic carbon (DOC) from the plough layer, which can promote a DOC-driven denitrification in the subsoil of leached nitrate. We have identified five management tools that we think would be of particular importance to investigate. These are: (1) the level of application of farmyard manure, (2) the effect of crop rotation and catch crops on the hydraulic properties and denitrification, (3) the effect of N-fixing plants on denitrification, and the effect of tillage systems such as (4) reduced tillage and (5) on-land ploughing on hydraulic properties.

On the basis of these investigations we will be able to recommend systems of organic farming that are better able to reduce nitrate leaching and which will be tested in model scenarios to calculate the leaching from the vadose zone. Further, some of the scenarios will be modelled for a catchment area to see whether the effects will persist in ground water at the regional level.

Regional grundvandsbeskyttelse gennem optimering af økologiske dyrkningssystemer

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Resumé:

I Danmark har det høj prioritet, at vi kan drikke vores grundvand uden rensning. Der er en voksende erkendelse af, at rent grundvand kun kan opretholdes gennem en aktiv indsats. En perspektivrig mulighed for at regulere i forureningsfølsomme områder kan være, at man udlagde større sammenhængende arealer med økologisk jordbrug. Først og fremmest undgår man helt brug af pesticider. For kvælstof mangler der dog en dokumentation, for at man generelt kan undgå nitratudvaskning. Meget tyder på, at tabet af nitrat vil være meget afhængig af det økologiske dyrkningssystem og det er det der er fokus for denne undersøgelse.

Vores hypotese er, at nogle af de driftsforanstaltninger, der kendetegner den økologiske driftsform, vil have en positiv effekt på både kvantiteten og kvaliteten af det grundvand der dannes i forhold til konventionelle driftsformer. Det relevante ligger derfor i at udpege de aspekter af den økologiske dyrkningssystem, der må formodes at påvirke grundvandskvaliteten i positiv retning. En vurdering af den samlede effekt af driftsforanstaltningerne på grundvandet for et givet økologisk dyrkningssystem forudsætter modelberegninger som kan integrere effekten af de forskellige tiltag. Det betyder at vi skal have bestemt effekten af de økologiske dyrkningssystemer på de modelparametre, der er betydende for nitratudvaskningen.

Især mangler der viden om hvordan de hydrauliske parametre påvirkes af dyrkningssystemet samt om der er aspekter i de økologiske dyrkningssystemer der medfører generelt større udvaskning af opløst organisk kulstof (DOC) fra pløjelaget således, at der kan ske en større DOC-dreven denitrifikation i underjorden af udvasket nitrat, hvorved det forsvinder som frit kvælstof. Vi har identificeret 5 driftsforanstaltninger som vi mener især vil have betydning. Mængden af (1) husdyrgødning og et sundt (2) sædskifte med meget efterafgrøder kan have en effekt både på de hydrauliske parametre og denitrifikationen i underjorden, mens (3) N-fikserende planter især menes at påvirke denitrifikation - og jordbearbejdningssystemer med (4) reduceret jordbearbejdning eller (5) on-land pløjning især de hydrauliske parametre.

På grundlag af disse undersøgelser opstilles økologiske sædskifter der i størst mulig omfang tilgodeser grundvandet og der køres modelscenarier, som beregner udvaskningen fra umættet zone. Desuden vil der for nogle af scenarierne blive modelleret for et helt opland for at undersøge om eventuelle effekter i umættet zone også slår igennem i grundvandet på regional niveau.

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3. Introduction

In Denmark the public gives high priority to being able to use untreated ground water for drinking. There is a growing understanding that clean ground water can only be maintained through active means. Therefore, areas with drinking water interest have been appointed and within these areas the counties will firstly look for areas especially vulnerable to nitrate leaching and subsequently for areas especially vulnerable to pesticide leaching. In areas appointed vulnerable, the agricultural practises will be regulated.

Afforestation is one possible way of regulation and is already used today. However, forest often will result in higher evapotranspiration and therefore less percolation to the ground water compared to arable land. Heavy metals can further be more mobile due to a decrease in pH. Further, from an socio-economic point of view it will have some negative consequences with depopulation of larger areas if agriculture is removed.

Another way to regulate land use in these vulnerable areas could be to use organic farming. First of all pesticide use will stop. Further, it is expected that nitrate leaching will be minimal because of the general aim of keeping nutrient cycles as closed as possible and because of the interest in the optimal use of the limited amount of nitrogen in some organic farm systems. However, as stated in FØJO report 10/2001, we still do not have documentation for this. Probably the loss of nitrate will be quite different from different organic cropping systems and will depend on soil type. Consequently, variations in model input in combination with model adjustment will cause the optimal cropping systems with respect to reducing nitrate leaching to vary from area to area on a local and regional level. Also other as-

pects of groundwater quality like heavy metals and organic matter could be of some interest but nitrate leaching will be the focus of this study.

Our hypothesis is that some of the management steps that characterise organic farming systems can change both the **quantity** and the **quality** of the ground water compared with conventional farming. The idea is to focus on the aspects of organic farming systems that presumably will affect the ground water and recommend some realistic cropping systems that can optimise the effect on ground water. Because organic farming is continuously developing, it is important also to look at new possible management steps that might affect the ground water. Therefore we have the following hypotheses of the effects of different organic farming management steps that we would wish to investigate:

Effects on **quantity** of ground water can be

- a. Increased evapotranspiration: Increased use of catch crops will increase the evapotranspiration in autumn and early spring. Further, deeper root systems can result in increased evapotranspiration during dry periods.
- b. Lower evapotranspiration: A general lower fertiliser level can result in smaller leaf area, which can result in less evapotranspiration
- c. Quicker draining of root zone: Less soil compaction and more organic matter in organic farming give a more porous soil and a change in the general water holding capacity. More earthworm burrows and deeper dead root channels give quicker deep drainage in macropores.

Effects on **quality** of ground water can be

- a. Lower nitrate concentrations in water from plough layer: An appropriate use of organic fertiliser and catch crops can give lower concentrations in the percolation water
- b. Higher nitrate concentrations in water from plough layer: An increased use of N-fixing crops in the crop rotation can with inexpedient management increase the risk of leaching pulses of nitrate, as can intensive soil tillage in the autumn, performed to control perennial weeds.
- c. Increased denitrification in subsoils: A large supply of organic matter, the use of N-fixing crops and catch crops that freeze during winter can give large amounts of dissolved organic carbon (DOC) deeper in the soil profile, which can increase the potential for microbial nitrate reduction.
- d. Decreased denitrification in upper soil layers: Suitable crop rotations, a large supply of organic matter and minimised compaction will give better conditions for air exchange and will result in less denitrification in the upper soil layers.
- e. Less preferential flow: Less compaction, on-land ploughing and loosening of the plough pan can reduce risk of preferential flow originating from vertical macropores starting at the plough pan.

The total effect of the different management steps on ground water can only be evaluated by the use of a dynamic model system for water and solute transport and fate in the soil. Daisy/MIKE-SHE (Hansen *et al.*, 1990; Abbott *et al.*, 1986a,b) is such a model system that takes the most important processes for transport and fate into account. But at the same time this requires that the effects of the organic farm system on the model parameters that are of importance for nitrate leaching are determined.

Although most of the management steps mentioned above in the hypothesis can be accounted for in the model, there are several that need to be better addressed. Hansen *et al.* (2000) mention the effect on soil structure and hydraulic properties, and the effect on DOC leaching and denitrification as two of the most important areas where we do not have sufficient knowledge and model input. And although other processes may also need attention, we have chosen to focus on these two topics in the project.

Crop choice, catch crop/green manures and rooting depth are important topics in the BIOMOD project (The Danish Research Centre for Organic Farming) and input from that project will be included in the model simulation planned in this project. Input-output of nitrogen in the systems can for example be manipulated with the number of animals and import of fodder. N-fixing plants are still relatively poorly described in Daisy and any other relevant soil-plant-ecosystem model. However, resourcewise it is not within the scope of this project to build a mechanistic description into DAISY and N-fixing

plants will be handled *ad hoc*, by utilising results from the various grass/clover experiments conducted within project I.4 “Nitrogen management and cropping methods for enhanced bread wheat” (WP1: Utilisation of N in grazed grass-clover pastures, The Danish Research Centre for Organic farming) and the concurrent parameterisation results from the modelling project I.3 “Interactions between nitrogen dynamics, crop production and biodiversity in organic crop rotations analysed by dynamic simulation models” – BIOMOD. The same applies to tillage-induced N mineralisation, where input will be taken from other concurrent projects (The Danish Research Centre for Organic Farming)

4. State of the art

Only a few field investigations have looked at the effect of organic farming on ground water quality (*but see, van der Werff et al., 1995*) and because of the large interaction with management, crop rotation, soil type and climate, these few results are difficult to extrapolate. Therefore, we will use a regional simulation approach using dynamic models, which makes use of current knowledge on the effects of farming practices on ground water. During the project period, we will in the project achieve the most important model input and adjustment necessary for meaningful simulations on a regional level.

4.1 Modelling groundwater quantity and quality

The Daisy model (Hansen *et al.*, 1990, 1991a) is such an agroecosystem model capable of simulating the nitrogen dynamics in agricultural soils and in particular simulating the leaching. Daisy is a 1-dimensional agro-ecosystem model that, in brief, simulates crop production and crop yield, and water, nitrogen and pesticide dynamics in agricultural soil based on information on management practices and weather data (daily values or hourly values), Fig. 1. As indicated in the figure comprises Daisy three main modules, viz. a bioclimate module, a vegetation module and a soil module.

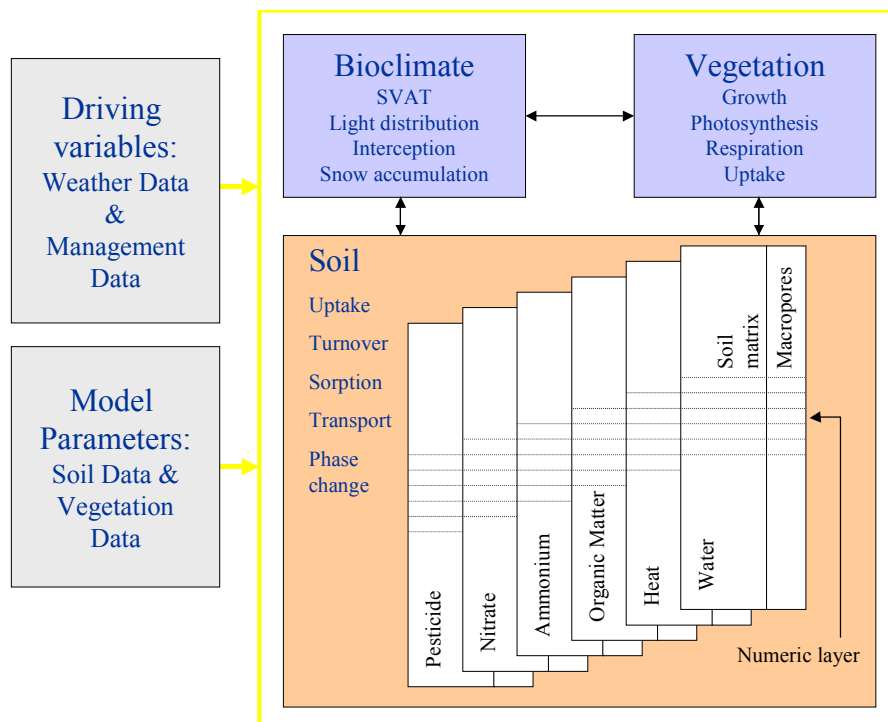


Figure 1. Schematic presentation of the soil-plant-atmosphere model Daisy

The bioclimate module handles the exchange of water, carbon, nitrogen and pesticides with the atmosphere. Water is allocated to the system (bioclimate module) as precipitation (rain or snow) and leaves the system as evapotranspiration, overland flow or infiltration. The soil-vegetation-atmosphere (SVAT)

model calculates the various evaporative fluxes. The bioclimate module interacts with the vegetation module through the vegetation canopy, which may be a composite canopy comprising several plant species. The latter occurs in cases with intercropping.

The vegetation module includes a number of different crop or plant models. The most comprehensive is an adjusted version of the SUCROS (Simple and Universal CROp growth Simulator, van Keulen *et al.*, 1982). The implemented models simulate photosynthesis, assimilate partitioning and plant respiration. Important features of the crop models are the ability to simulate the temporal variation in leaf area index (LAI), rooting depth, root density, dry matter production, and crop nitrogen demand and content because this information is required by other parts of the model.

The soil module of Daisy comprises models for the dynamics of soil water, soil heat, soil organic matter (carbon and nitrogen), ammonium, nitrate and pesticides. The soil profile comprises a number of distinct soil horizons each characterised by a number of soil properties. Soil organic matter, ammonium, nitrate and pesticides may be transformed. The soil organic matter transformation model considers three distinctive types of organic matter; viz. newly added organic matter (AOM), living soil microbial biomass (SMB), and native nonliving soil organic matter (SOM). The model simulates CO₂-evolution, ammonification, and immobilisation of ammonium and nitrate. Furthermore is sorption and nitrification of ammonium and denitrification of nitrate simulated. The transport models can consider transport in the soil matrix as well as in macro pores. At present sorption is considered an instantaneous process, however a model component for simulating sorption kinetics is being developed.

Output from the model is optional and allows for establishing water, ammonium, nitrate, carbon, organic nitrogen, organic matter and pesticide balances. The model can simulate multiple soil columns and intercropping systems, which is useful in simulating processes at larger scales and organic farm rotations, respectively.

Styczen and Storm (1993a,b) and Thorsen *et al.* (2001) linked Daisy with a fully distributed catchment model, MIKE SHE (Abbott *et al.*, 1986a,b) in order to simulate groundwater quality within a hydrological catchment. With a new implementation Daisy can now function as a component in a modelling system like MIKE SHE. The latter linkage is only feasible because the Daisy model software can work in a distributed way, i.e. work with multiple soil columns. Furthermore a GIS interface to Daisy that supports distributed application of Daisy has been developed (www.DHISoftware.com/DAISYGIS).

The Daisy model has been used extensively (e.g. Blicher-Mathiesen *et al.*, 1990; Børgesen *et al.*, 2001; Djurhuus *et al.*, 1999; Hansen *et al.*, 1999; Jensen *et al.*, 1994a,b; Jensen *et al.*, 1996; Magid and Kølster, 1995; Mueller *et al.*, 1996; Petersen *et al.*, 1995; Refsgaard *et al.*, 1999; Styczen and Storm, 1993a,b; Thorsen *et al.*, 2001). The model applications comprise both scientific studies and management related studies aimed at decision support. In addition, the model has been validated in a number of major comparative tests (Vereecken *et al.*, 1991; Hansen *et al.*, 1991a,c; Willigen, 1991; Diekkrüger *et al.*, 1995; Svendsen *et al.*, 1995; Smith *et al.*, 1997; Jensen *et al.*, 1997). Hence, Daisy can be considered a well-tested model.

4.2 Soil structure and hydraulic properties

The existence of continuous macropores in the soil profile has been documented to influence significantly the flow patterns of percolating water (e.g. Van Genuchten *et al.*, 1990; Villholth *et al.*, 1990). Jørgensen & Fredericia (1992) showed that a major part of the ground water infiltration and solute transport might occur through fractures of physical origin. Similarly, Edwards *et al.* (1992) documented that earthworm channels may be preferential pathways for percolating water. Petersen *et al.* (1997a,b) showed in dye studies that the preferential path ways were greatly influenced by soil tillage but only few attempts have been made to quantify these effects, especially with respect to parameters to use in dynamic models.

Crop rotations and manure:

It is generally anticipated that farming systems with application of organic manures and with diversified crop rotations will provide better habitats for soil biota as compared to systems applying synthetic fertilisers to non-diversified crop rotations. Christensen *et al.* (1987) reported that soil management in terms of crop rotation, manuring and soil tillage influenced the populations of earthworms in Danish field trials. Whalen *et al.* (1998) similarly showed that fertilisation with organic manure increased the number and biomass of earthworms as compared to application of inorganic fertilisers. Schjøning *et al.* (2002a) found more microbial biomass in organically than in conventionally managed soil. Although these differences to some extent could be explained by a difference in 'protective pore space', the results clearly indicated that soils receiving no organic manures and grown with monocultures of small grain cereals had a small biomass. A high biological activity in the soil further may be hypothesised to improve root growth. When also considering that diversified crop rotations often include dicotyledonous plants (e.g. clover) with taproots, it may be anticipated that organic farming systems will influence the frequency of persisting, continuous and vertical macropores of importance to water percolation.

Only little work has been done to quantify the effects mentioned above, especially when looking at effects in the subsoil. Schjøning *et al.* (2002b) found dramatic differences in soil pore characteristics of the A-horizon of an organically managed dairy farm soil as compared to a reference soil grown continuously with small grain cereals and receiving no organic manures. The pore system of the former soil might be described as a 'sponge' with a high degree of proliferation of pores in the soil matrix. In contrast the poorly managed soil had a system with 'downpipe' pores and a poor contact between these pores. The study did not address the non-tilled B-horizon and a key question in the context of downward movement of water is how this horizon is affected by the contrasting management.

When addressing the management tools available for influencing the ground water, it is important to be able to differentiate potential manure effects from crop rotation effects. Several investigations have studied farmyard manure effects on soil structure and hydraulic properties (e.g., Mathers and Stewart, 1984; Campbell *et al.*, 1986; Anderson *et al.*, 1990). Some found an increased saturated hydraulic conductivity (Mathers and Stewart, 1984; Anderson *et al.*, 1990) while a few found no effect on hydraulic properties (Campbell *et al.*, 1986). For Danish conditions, Schjøning *et al.* (1994) found a tendency of an increased volume of macropores $> 30 \mu\text{m}$ for soil receiving animal manure than applied with inorganic fertilisers through more than 90 years.

Logsdon *et al.* (1993) and Schjøning *et al.* (2002b) studied the integrated effect of alternative farming systems on infiltration of water. However, infiltration is primarily determined by the topsoil characteristics. Further, both studies addressed the integrated effects of the systems. To our knowledge, no investigations exist of the specific effects of crop rotation on the soil structure and hydraulic properties of the subsoil.

A major issue in the modelling of water transport as affected by organic farming thus is to improve our knowledge of the management effects discussed here.

Tillage:

Schjøning *et al.* (2002a) showed that long-term organically farmed Danish soils exhibited compacted soil layers below ploughing depth to the same extent as did conventionally managed soils. Danish farmers converting to organic management generally use the same tillage and traffic systems as do the conventional farmers. Several investigations have reported a significant densification from ploughing on the soil layer just below the plough depth (e.g., Håkansson *et al.* 1996; Djurhuus & Olesen 2000).

The existence of a dense plough pan may influence air exchange (e.g., Schjøning, 1989) and water movement (Comia, *et al.*, 1994; Ball *et al.*, 1998). Munkholm (2000) and Munkholm *et al.* (2001) clearly demonstrated that a plough pan might force the crop roots to pass the compacted layer only through persistent earthworm channels. Similarly, the high density of the pan may cause percolating water to

prefer the pathway offered by such vertical macropores (Edwards *et al.*, 1992). Munkholm *et al.* (2001) and Nielsen *et al.* (2000) showed that mechanical loosening of a plough pan changed the soil structure and increased root growth significantly. Breaking up the pan also increase the volume of macropores (Schjønning *et al.*, 2002c).

Reduced tillage techniques without the use of the mouldboard plough is another way of influencing the important soil pore system conducting the percolating water. The volume of macropores in the former plough pan has been shown to be increased by conversion to direct drilling or shallow tillage (Ehlers, 1973; Schjønning, 1989; Comia *et al.*, 1994; Schjønning & Rasmussen, 2000). Similarly, the permeability of this layer increases (Douglas & Goss, 1987; Schjønning, 1989; Schjønning & Rasmussen, 2000). Also the continuity of pores across the former ploughing depth will be increased when converting to ploughless tillage (Schjønning & Rasmussen, 2000). On the other hand, reduced cultivation may result in compaction close to the surface (Schjønning 1989). In general, compaction results in a reduced volume of macropores and the hydraulic conductivity will therefore be smaller in the tillage zone in the no-tillage than in conventional tillage soil and greater below the tillage zone.

Due to the direct and significant effects on the soil pore system mentioned above, soil tillage is an important tool with potentials for influencing the percolation of water and thus the ground water quality.

4.3 Denitrification and DOC

An increase in our understanding of the linkage between nitrate in the groundwater and i) the quantity and composition of soluble organic carbon (DOC), and ii) the movement and sorption dynamics in the soil profile can provide an indirect assessment of the potential for denitrification to ultimately remove the nitrate leached from agricultural soils before it reaches the groundwater table (Brye *et al.*, 2000).

Source of DOC:

Compared with nitrate, much less research has focused on quantifying and characterising the leaching of dissolved organic matter (DOM) under field conditions and various management practices, such as tillage, crop choice, and fertilisation. The DOM fraction is considered the most active component of the soil organic matter (McGill *et al.*, 1986) and it provides important energy for microbial communities to drive the transformation processes, including denitrification (Neff & Asner, 2001; Brye *et al.*, 2000). Although DOM as a pool is small, its concentration is replenished by desorption from soil colloids, dissolution from litter, and from root exudates, among others. DOM has been shown to contribute to the mobility of dissolved organic carbon (DOC), organic nitrogen (DON), organic phosphorus (DOP), heavy metals and organic pollutants (Qualls and Haines, 1991; Strobel *et al.*, 2001).

DOC in subsoils is produced in the ploughing layer where it originates from different dynamic turnover processes of applied organic manures, indigenous soil organic matter (ISOM), and crop residues (McTiernan *et al.*, 2001). Productivity of specific organic cropping systems depends on the quantity and quality of the above-mentioned three organic pools. Thus, the amounts of DOC produced and its properties are generally related to the productivity of the system. The quantity and quality of the ISOM depends on the cropping history of the soils and on the parent material for the soil (Christensen and Johnston, 1997). The farming system, the management and the availability of such manures determine the quantity and quality of the organic manures. The quantity and quality of the crop residues is determined by the choice of crops, the management, and the crop rotation.

Mobility of DOC:

The mobility of DOC (including DON and DOP) in the soil profile is strongly affected by sorption to mineral constituents and by the drainage capability of the soil (Jardine *et al.*, 1989; Moore *et al.*, 1997). Hence, during downward migration DOC concentrations decrease. There is poor consensus on the significance of DOC origin on the reactivity and sorption of DOC, whereas it is generally observed that fractionation of DOC takes place down through the column with the more hydrophobic substances being sorbed more strongly than the more hydrophilic fractions (Ludwig *et al.*, 2000; Kaiser *et al.*, 1996;

Moore & Matos, 1999). The extent of sorption is mainly determined by the soil mineral composition, the pH and the ionic composition of the soil solution (Moore *et al.*, 1997). Sorption processes are decisive for the composition, leaching and bioavailability of DOC in subsoils and thus may strongly effect the leaching of DON, DOP and denitrification.

For loamy soils it has been documented that a major part of the groundwater infiltration and solute transport occurs through macropores and fractures of biological or physical origin (e.g., Jørgensen & Fredericia, 1992). Accordingly, it was found that the concentration of nitrate and water soluble carbon (WSC), as well as the number of denitrifying bacteria tended to be higher in the macropore soil than in the matrix soil, with no macropores (Vinther *et al.*, 1999). This indicates that macropore channels are important environments for potential denitrification capacity in subsoils.

Consequently, the source and amount of DOC depends on:

- The management of manures and crop residues
- The crop rotation and crop choice
- The sorption properties of the soil
- The transport properties of the soil (treated in WP 3)
- Microbial degradation of DOM

Hope *et al.* (1994) reported annual DOC exports below rooting depths in the range of 10-100 kg C ha⁻¹ year⁻¹. Recently, however, McTiernan *et al.* (2001) reported DOC exports from grassed grasslands as high as 180 kg C ha⁻¹ in short-term fluxes from undrained soils. There are therefore clear potentials for large losses of DOC from intensively managed crops although these potentials need qualification. The potentials of DON and DOP are largely unknown.

Denitrification:

The quantity of DOC transported below the plough layer or the rooting zone may give important information about the denitrification capacity of the soils. However, the actual denitrification rates needed for model simulations also depend on the characteristics and quality of the organic matter, and hydraulic and physical properties of the soil, such as pore size and structure and permeability.

Denitrification is commonly thought to be insignificant at soil depths below the rooting zone, although denitrifying activity has been observed during anoxic incubation of soil samples from as deep as 20 m (Lind & Eiland, 1989; Yeomans *et al.*, 1992). The denitrifying ability generally decreases with increasing depth and a source of available organic C is generally considered to be the major factor limiting denitrification in subsoils. Where organic C is added, a significant denitrifying potential may be revealed at depths as great as 7 m (McCarty & Bremner, 1992, 1995; Jarvis & Hatch, 1994).

Consequently, it is evident that quantification of DOC and DON as well as determination of origin, composition, sorption and its effects on denitrification is mandatory for subsequent modelling of DOC on the plant-soil level and for simulations of groundwater quality on a cropping system level.

5. Objectives

to determine the effect of different organic farming systems on ground water by model calculations and from this to recommend some organic farming systems that are optimal in relation to the amount of good quality ground water (wp2, wp5 and wp6)

to create the model input and adjustment with regard to the effect of different organic farming systems on the soil hydraulic properties (wp3) and leaching of soluble organic matter and its role for supporting denitrification (wp4)

6. Description of work packages including methods

The project is divided into work packages (WP). Figure 1 shows the causal connections in the project. WP1 co-ordinates the project activities. WP2 includes the activities that define the relevant organic farming systems that we would like to test and the relevant field experiments we want to use as research objects. Further, WP2 gives input on the organic farming systems that we want modelled. WP3 includes measurements of the soil physical properties of importance for transport of water, nitrate and DOC, and for denitrification on the field experiments chosen. Denitrification is determined in relation to DOC and abiotic factors in WP4. The organic farm scenarios defined in WP 2 will be modelled in WP5 on the basis of measurements in WP3 and WP4 with input from the BIOMOD and other ongoing project that improve DAISY's ability to simulate organic farming. Then for a few representative scenarios we upscale the calculation to a regional level to assure that any differences we have on the field scale also will have significance in the ground water (WP6).

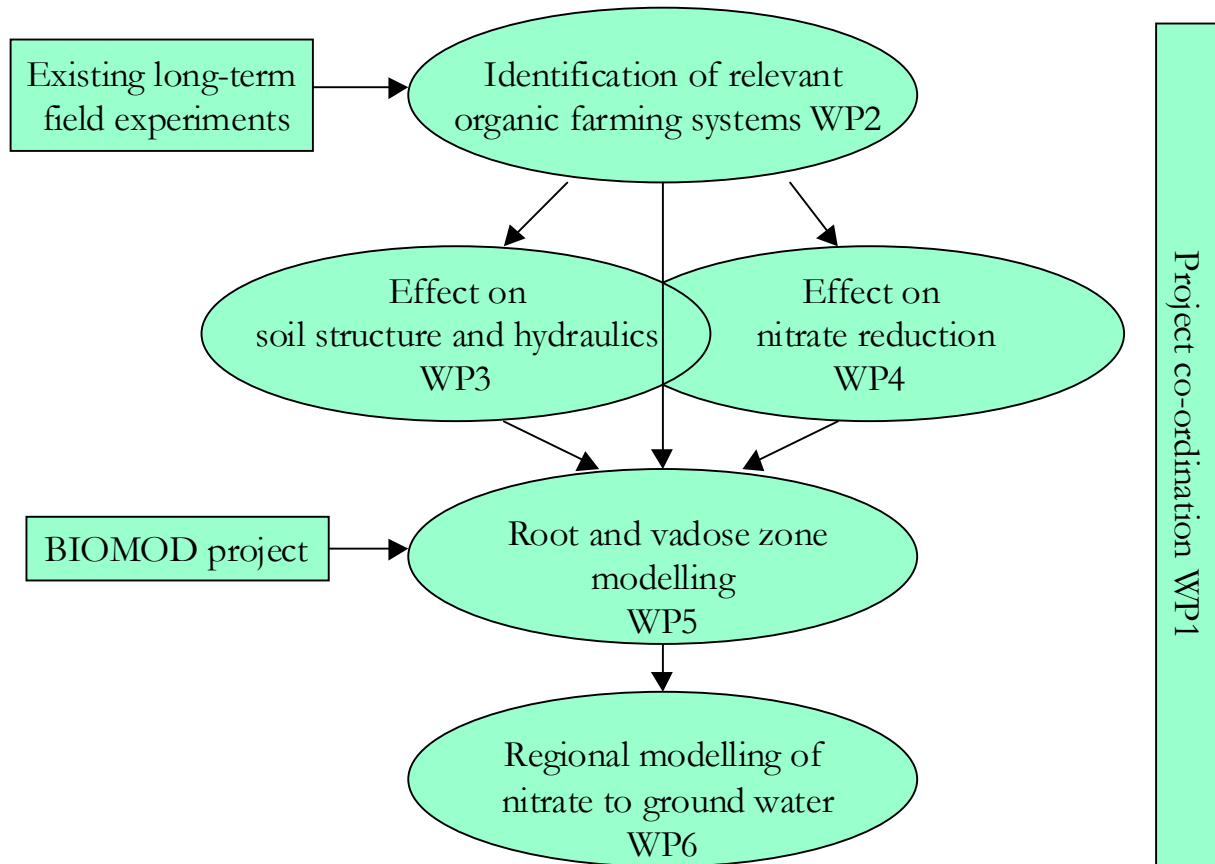


Figure 2. Outline of the project structure.

As mentioned above in the state of art we have isolated some management tools, which require further experimental studies to provide input to the models. These comprise

- 1) Grass/clover effects on DOC and denitrification (in particular when ploughing under the crop)
- 2) Farmyard manure effects on soil structure, hydraulic properties, and DOC and denitrification
- 3) Crop rotation effects on soil structure, hydraulic properties, and DOC and denitrification
- 4) Effects of ploughless tillage on soil structure and hydraulic properties
- 5) Effects of subsoil loosening and on-land ploughing on soil structure and hydraulic properties

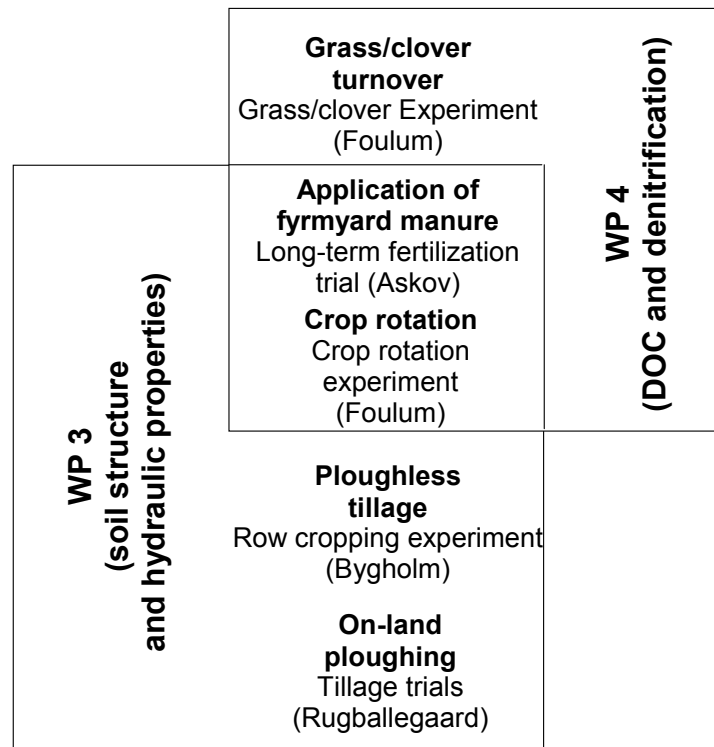


Figure 3. Topic addressed and experiments used in WP3 and WP4

We have tried to detect some long-term field experiments that can fulfil the requirements as study object. It has been necessary to concentrate on loamy soils because of budget constraints and because we expect the effects to be most pronounced on loamy soils. As it appears from Figure 3 each of the five topics will be addressed by measuring and sampling for lab studies in five separate field experiments. The major characteristics of these trials may be described as follows.

- ◆ The Grass/clover Experiment (GCE) was initiated in 1997 and is concerned with studies of the nitrogen dynamics and leaching as affected by different strategies for ploughing under the grass/clover crop. The trial is located at Research Centre Foulum on a loamy sand soil.
- ◆ The long-term fertilisation trial (LTF) at Askov (sandy loam) includes a number of different fertilisation strategies and has been running since 1895. In this context, we aim at studying two treatments, - one having received plant nutrients only as farm yard manure (slurry) and the other only as commercial NPK dressings.
- ◆ The Crop Rotation Experiment (CRE) includes a number of different crop rotations with and without the application of animal manure and catch crops. The experiment was started in 1997 and is located at (among others) Research Centre Foulum (loamy sand soil). We intend to address two rotations with rather different degrees of 'green cover' during the year. The 'poor' rotation comprise the crops spring barley, spring oats, spring wheat and lupine with no catch crops and no animal manure applications. The versatile rotation comprise the crops spring barley undersown with a grass/clover mixture, grass/clover mixture for green manure, winter wheat with undersown catch crop of ryegrass, lupine with undersown catch crop of ryegrass.
- ◆ The Row Cropping Experiment (RCE) was initiated in 1997 on loamy sand at Research Centre Bygholm. The field trial includes a number of tillage strategies. We intend to study the direct drilled plots with conventional mouldboard ploughing as a reference.
- ◆ The tillage trials at Rugballegaard (TTR) were initiated in 1997. We intend to study only one of the five fields included in this comprehensive trial. In this field (labelled B4), some plots were subsoiled to 35-40 cm depth in 1997 and again in 1998. Since then the tillage has been differentiated leaving the potential of studying on-land versus traditional ploughing on these formerly subsoiled plots. Reference plots are provided by traditionally ploughed soil that has never been subsoiled.

WP 3 and 4 will attempt to use identical soil samples for the studies at the long-term fertilisation experiment (Askov) and at the crop rotation experiment at Foulum.

Table 1: Workpackage list

WP No	WP title	Responsible participant	Budget (in kkr)	Start	End	Deliverable, No
1	Project co-ordination	OHJ	135	2002/02	2005/07	D1(1-4)
2	Identification of relevant organic farm systems	JEO	60	2002/03	2005/07	D2.(1-2)
3	Effect of organic farm systems on soil structure and hydraulic parameters	PS	698	2002/09	2004/12	D3.(1-5)
4	Effect of organic farming systems on DOC mobilisation and DOC-assisted denitrification	FPV	1255	2002/02	2004/12	D4.1-4 13 i alt
5	Root and vadose zone modelling	SH	612	2002/06	2005/07	D5.1-2 3 i alt
6	Regional modelling of nitrate to ground water	MS	240	2004/01	2005/07	D6.1
Total			3000			

Table 2: Description of workpackages

WP1: Project co-ordination	
Workpackage number:	1
Start date or starting event:	2002/02
Responsible person:	Ole Hørbye Jacobsen
Contributing persons:	
Person-months:	2
Objectives:	
To assure co-ordination between the subprojects	
Description of work:	
The research in the different subprojects are based in different fields of agricultural and hydrological science but are still very dependent on deliverables from other subprojects. Project co-ordination will involve assuring good interaction between subprojects and that the flow of data in the project is effective. Project co-ordination also involves preparing annual reports of progress and the final report from the project.	
Deliverables:	
D1.1. First annual report 2002	
D1.2. Second annual report 2003	
D1.3. Third annual report 2004	
D1.4. Report with optimal organic farming systems (See M2.3 and 5.5)	
D1.5. Final report 2005	
Milestones:	
M1.1 First annual report completed (2002/10)	
M1.2 Second annual report completed (2003/10)	
M1.3 Third annual report completed (2004/10)	
M1.4 Final report completed (2005/07)	
WP2: Identification of relevant organic farm systems	
Workpackage number:	2
Start date or starting event:	2002/02
Responsible person:	Jørgen E. Olesen
Contributing persons:	All project members
Person-months:	1
Objectives:	
1. To set up preliminary organic farming systems to test and identify experiments with the relevant management tools	
2. To set up the final organic farm systems for the model scenarios	
Description of work:	
We will define the preliminary farming systems by using the crop rotations systems suggested in Hansen <i>et al.</i> (2000). From our hypothesis on how the ground water is affected we have isolated what we	

think is the most important management tools that influences nitrate leaching. By combining this we will finally decide which experimental systems we will use for our process studies. In defining the relevant crop rotations and related management practices special consideration will be given to methods for application of manure, establishment of catch crop and control of weeds, incl. perennial weeds.

After the results from the process studies appear we will – if necessary - adjust the model farm systems. On the basis of the model simulations we will come up with a number of crop rotations and farming systems that have low risk of contaminating the ground water

Deliverables:

- D2.1 Suggestions of organic farming systems and crop rotation to test in the project
- D2.2 Description of agricultural practices in the farming systems for use in simulations
- D2.3 List with optimal organic farming systems

Milestones:

- M2.1 Agreement on farming systems to test (2002/06)
- M2.2 Agreement on agricultural description for model simulations (2003/12)
- M2.3 Report with optimal organic farming systems (See M1.4 and M5.5) (2005/07)

WP3: Effect of organic farm systems on soil structure and hydraulic parameters

Workpackage number:	3
Start date or starting event:	2002/09
Responsible person:	Per Schjønning
Contributing persons:	OHJ
Person-months:	Scientific: 7 Technicians: 7

Objectives:

To quantify the effect of soil management on soil structure and hydraulic properties

Description of work:

WP3 will use the four field trials labelled LTF, CRE, RCE and TTR (see above) for identification of effects of continuously farmyard manure applications, crop rotation, ploughless tillage, and subsoil loosening on soil structure and hydraulic properties of further importance for transport of water and thus NO₃ and DOC to the groundwater. Most of the work will be concentrated on the manure and crop rotation experiments and only few samples on the tillage plots.

Soil will be sampled in the field in undisturbed cores either 100 cm³ (61 mm Ø and 34 mm height) or 6800 cm³ (200 mm Ø and 200 mm height). Sampling will cover the soil profile from the very top to the bottom of the root zone. We will especially focus on the properties of the pores in the plough layer, across the plough pan and the B-horizon.

When sampling the cores in the field, the soil profile will be visually described with the procedure suggested by Munkholm (2000) in order to detect macroscopic structural features and root growth.

At the laboratory, the small samples will be saturated with water and drained to pre-selected matric potentials in order to estimate the water retention curve and the pore size distribution. Bulk soil air diffusion and permeability will be measured at a number of matric potentials. These measurements will enable a detailed characterisation of the porosity, tortuosity and pore connectivity - all of importance for water and air transport in the soil. Some of these samples will further be used in incubation

experiments to measure denitrification.

The large soil cores will be used for measuring saturated hydraulic conductivity by the constant head method and near-saturated hydraulic conductivity at steady state using a drip infiltrometer. Due to the large cores used for the purpose, this will give information of macropores of importance for leaching of dissolved material in situations with a high precipitation in the field.

For the use of these results in regional models we need to know how to take the effects of different managements tools into account for other soil types than the ones actually tested. The effect of the different management tools may effect the hydraulic functions in different ways and wp3 will give suggestions on how these functions can be scaled to soil types with slightly different clay content

Deliverables:

D3.1 Effect of management tools on porosity, retention curves, saturated and unsaturated hydraulic conductivities

D3.2 Effect of management tools on tortuosity and pore connectivity

D3.3 Semi-quantitative description of depth and distribution of roots and macropores in the field trials

D3.4 Soil physical characterised soil samples for the denitrification incubation experiments

D3.5 Suggestions on how to extrapolate parameter effects to other soil types

Milestones:

M3.1 Sampling in the field trials finished (2003/04)

M3.2 Data of hydraulic properties and pore characterisation parameters delivered to modellers (2003/12)

M3.3 Soil samples for the denitrification incubation delivered (2003/08)

M3.4 Agreement on how to extrapolate parameter effects to other soil types (2004/03)

WP4: Effect of organic farming systems on DOC mobilisation and DOC-assisted denitrification

Workpackage number:	4
Start date or starting event:	2002/02
Responsible person:	Finn P. Vinter
Contributing persons:	HCBH, PS, HHJ
Person-months:	Scientific: 9 Technicians: 15.5 (HCBH and HHJ are contributing with their own salary)

Objectives:

1. To quantify the origin and amount of DOC entering soil layers below the A-horizon
2. To characterise the quality and sorption/mobility properties of DOC
3. To establish relationships between DOC and denitrification for model input

Description of work:

WP 4.1 Quantification of amount and export of DOM from different soil layers

In order to evaluate the contribution from grassland to DOM export, DOM will be quantified in the Grass-Clover Experiment (GCE; see above) with the focus on determining the effects of i) application of slurry on the leaching of dissolved organic matter from established swards of grass-clover and pure stand ryegrass, and ii) the effects of ploughing under grass-clover and pure stand ryegrass.

In this experiment, existing ceramic suction cups are located in 100 cm depth. Additional Teflon suction cups will be installed to be able to sample the soil solution in different depths (30 and 60 cm) through the soil profile.

Further, DOC will be measured on some samples from suction cups in 100 cm depth in the long-term fertiliser experiment (LTF) and the crop rotation experiment (CRE).

Concern has been expressed that solutions extracted by ceramic suction cups may exhibit significant changes in composition due to sorption processes in the suction cup itself. However, comparing the chemical composition of soil water percolated through newly installed ceramic suction cups with old, over 3 years field-equilibrated suction cups with respect to quantitative and qualitative changes of DOC, Guggenberger & Zech (1992) found that field-equilibrated suction cups alter DOC neither in concentration nor in composition. Such effects are not expected with new Teflon cups.

DOC in water samples from the suction cups will after filtration through a 0.4 µm filter be determined using a Shimadzu total organic carbon analyser (TOC-5050).

WP 4.2 Origin, composition, and mobility of DOM from grass-clover mixtures

The contribution of clovers and grasses in the mixtures to DOM export and the origin and composition of the DOM from grass-clover mixtures will be evaluated in a controlled experiment using tracers (¹⁵N and ¹⁴C). The use of tracers enables us to determine where the DOM originates, what is its composition, and how mobile is it in the soil profile. These studies will complement the field measurements (WP 4.1) by using the same grassland leys but achieving a higher degree of understanding of the origin and mobility of DOM.

This will be achieved by using column studies and using isotopic cross-labelling of individual plants and tracing methodology. These columns will be taken to a depth of 20, 40 and 60 cm in the existing grass/clover leys of the GCE at Foulum and transferred to controlled conditions for isotopic cross-labelling. Small undisturbed cores taken next to the columns to determine water retention and soil density. The methodology used for isotopic labelling will be by short-term emergence of single leaves into ¹⁵N- and ¹⁴C-enriched solutions, which has been shown to be able to give appropriate labelling levels (Høgh-Jensen and Schjoerring, 2001; Neergaard, 2000). These columns will be managed under specific leaching conditions that enable collection of leachates. These leachates will be analysed and subsequently used for sorption studies (WP 4.3). After finalising the leaching studies, the columns will be sliced to determine isotopic distribution, which will enable mass balance calculations. Following slicing the soil will be analysed for total N and total C.

DOC will be determined by combustion and reactive groups will be determined by titration. The elemental composition determined using a C- and N-analyser, ¹⁵N by using a mass spectrometer, and ¹⁴C by using a scintillation counter.

WP 4.3 Sorption of DOM from different sources

DOM may be exported in different quantities and qualities from the individual soil layer. However, the sorping capabilities of the soils may influence the amount and also the composition of the DOM actually exported. The studies in this subproject lead to quantification of the sorption parameters, which are necessary for the DOC modelling module in DAISY. Furthermore the experiments will be used to verify if the observed concentration and composition of DOC vs. profile depth can be explained as a result of DOC sorption. The experiments comprise:

1. Sampling and isolation of DOC from A horizons from grass-clover leys and from column studies (WP 4.1 and WP 4.2) (Raulund-Rasmussen et al., 1998).
2. Composition and characterisation of the isolated DOCs (Strobel et al., 2001)
3. Application of the isolated DOC to batch sorption experiments using subsoils from the Grass-Clover Experiment. Soil samples are collected at 10 cm intervals from the bottom of the A-horizon to the top of the C-horizon. The variables in the sorption experiments are DOC concentration and

properties of the soil sample (mineralogy, specific surface area, C content) while pH and ionic composition is held constant. Fractionation of DOC during sorption will be investigated.

4. Establishment of a simple model for DOC sorption and comparison with observations from part WP4.2.

DOC will be determined by combustion, the elemental composition determined using an C, N and P analyser, and the molecular fingerprint obtained by FT-IR spectroscopy. Reactive groups of the two DOC isolates will be determined by titration.

WP 4.4 Effects of DOC on denitrification

Soil physical factors, such as pore size and distribution, play an important role for the oxygen status in the soil, and consequently for the denitrification process (Castle et al., 1998; Simek et al., 2000), which besides nitrate and carbon sources need anaerobic conditions. In the natural environment all these factors act simultaneously, and to estimate denitrification under 'real life' conditions measurements will therefore primarily be carried out on intact soil samples, where also a number of soil physical characters will be measured (WP 3). To give additional information about the effects of a single factor, namely DOC, measurements of potential denitrification as a function crop history, fertilisation and soil depth. Measurements will be carried out in the three field trials labelled GCE, LTF and CRE.

'Actual' denitrification

In short, soil will be sampled in the field in 100-cm³ steel cylinders (61 mm Ø and 34 mm height) covering the soil profile from the very top to the bottom of the root zone. In the laboratory, the samples will be adjusted to pre-selected water potentials using a solution of known concentrations of DOC (leachate from WP 4.1) and NO₃. Bulk soil air diffusion and permeability will be measured, and afterwards the samples will be transferred to containers for denitrification measurements using the acetylene inhibition method. Repeating this with different water potentials and DOC-concentrations will enable us to estimate the effect of DOC on denitrification under the influence of soil physical characters (porosity, volumetric water content, water filled pore space), soil depth, cropping and fertilisation strategies.

Potential denitrification

Soil samples from the entire root zone are taken in 10-15 cm increments, and analysed for DOC and NO₃. Potential denitrification is measured on soil slurries under anaerobic conditions (headspace gas exchanged with nitrogen) using the acetylene inhibition method. Soil slurries are prepared by mixing soil and solution of nitrate (excess amount), which will give potential denitrification rates, where only DOC will be the variable under study.

Deliverables:

- D4.1-1 Field record of the time dependent profile DOC (including DON) concentrations under conditions of high carbon and nitrogen turnover
- D4.1-2 DOM isolates for further characterisation in WP 4.2 and for use in sorption work in WP 4.3
- D4.1-3 Dataset for calibration of DOC modelling by DAISY
- D4.2-1 Determination of origin of DOM in grass-clover mixtures
- D4.2-2 Determination of the composition of DOM originating from specific species
- D4.2-3 Determination of the contribution of single species to the mobile part of the DOM
- D4.2-4 DOM pulse as related to precipitation intensity
- D4.3-1 Quantitative measures of DOC bonding according to soil composition, DOC composition and DOC concentration
- D4.3-2 Selective sorption of specific DOC fractions during sorption
- D4.3-3 Input parameters to DAISY modelling of DOC dynamics
- D4.4-1 Determination of soil physical characteristics on intact soil cores for denitrification measurements
- D4.4-2 Dataset from measurements on intact soil cores for calibration of Daisy denitrification sub-module
- D4.4-3 Influence of DOC on potential denitrification as a function of crop type, organic fertiliser input

and soil depth

Milestones:

- M4.1-1 Teflon suction cups installed (2002/09)
- M4.1-2 Sampling from suction cups and analysis of DOC finalised (2004/04)
- M4.2-1 Soil column studies about origin of DOM in grass-clover mixtures completed (2003/05)
- M4.2-2 Dataset for calibration of DOC modelling by DAISY delivered (2003/12)
- M4.3-1 Studies on DOM sorption and composition completed (2003/08)
- M4.3-2 Sorption parameters for calibration of DOC modelling by DAISY delivered (2003/09)
- M4.4-1 Studies on relationships between DOC, soil physical characters and denitrification completed (2003/12)
- M4.4-2 Dataset for calibration of denitrification sub-module in DAISY delivered (2003/12)
- M4.4-3 Studies on the influence of DOC on potential denitrification as a function of crop type, organic fertiliser input and soil depth completed (2003/12)

WP5: Root and vadose zone modelling

Workpackage number: **5**
 Start date or starting event: **2002/06**
 Responsible person: **Søren Hansen**
 Contributing persons: **LSJ, modeller**
 Person-months: **12**

Objectives:

1. To model production, turnover adsorption and leaching of DOC/DON, in particular the influence of grass-clover leys and animal manure input on the temporal dynamics of DOC/DON down through the root zone profile.
2. To model the influence of organic farming scenarios (WP2) on the temporal quantity and quality of root zone percolate feeding into the groundwater reservoir.

Description of work:

WP5.1 Development of a new module for formation, turnover and transport of DOC/DON:

The new DOC/DON module is based on the following assumptions. DOC/DON is considered to be a part of a general DOM (Dissolved Organic Matter) component. The new DOM component interacts strongly with the existing mobilization-immobilization turnover (MIT) model as a new pool. DOM is assumed to be formed as consequence of the general turnover of organic matter. DOM may also be allocated to the system as part of applications of organic fertilisers. DOM may be decomposed as a part of the organic matter turnover. In these respects DOM resample the AOM-pools (Added Organic Matter) of the MIT-model. However, the new DOM pool differs from the existing MIT-model pools in respect to the following properties: the C/N ratio is variable, DOM may be transported by convective-dispersive flow and by preferential flow and DOM may be sorbed. Implementation and verification of the new DOC/DON will be a major part of WP5.1.

Calibration of the new DOC/DON module is based on results from WP4.

WP5.2 Scenario simulations and analyses

Based on the outcome of WP2, regarding the crop rotations systems to be studied, these will be set up for scenario analyses, according to the described agricultural practices in the farming systems. It is expected that the simulations will include a large proportion of catch crops, annual green manures, and grazed, perennial pastures. To make the model simulations of general predictive value, parameterisation of organic matter inputs, such as crop residues of a grass-clover sward, will be based on measurable properties to as great an extent as possible. However, often we do not know the critical and measurable parameters for proper prediction of N mineralisation and subsequent crop utilisation under organic field conditions and the inputs of organic matter and N are not well defined in time or space. Thus, parameterisation of all these situations will largely be based on:

- ◆ inclusion of the data from WP3, WP4 and parameterisation of DOC/DON from WP5.1
- ◆ *ad hoc* calibrations of the crop module for grass-clover leys based on existing available data and knowledge
- ◆ parameterisation results from the BIOMOD project, which includes both in depth calibration of the soil organic matter module and whole-model calibration and validation on experimental field data.

It is not within the scope and resources of this project to complete an extensive calibrations of a grass-clover intercropping module for Daisy, and the *ad hoc simulation* carried out here (i) can be seen more as a first preliminary step towards describing the dynamic nature of grass-clover ley intercompetition and development.

For ii) this includes data on dairy crop rotations with grazed grass/clover pastures (nutrient cycling experiment, NCE, and grass-clover experiment, GCE) in dairy crop rotations at Foulum during several periods Eriksen et al., 1999; Eriksen & Søegaard, 2000, Eriksen 2001; as well as a current DARCOF project: *I.4 Nitrogen management and cropping methods for enhanced bread wheat, WP1: Utilization of N in grazed grass-clover pastures* (Eriksen, pers. comm.). Furthermore the BIOMOD whole model calibration includes vegetable crop rotations using data from Årslev from the period 1996 to 1998 (Thorup-Kristensen, 1999).

The whole model calibration and validation of the BIOMOD project is expected completed in mid 2003 and the results will thus be available in time for utilisation within the current work-package.

The scenarios will be evaluated with respect to the effect of each of the important management tools and with respect to how optimised organic farming system compare to existing farming systems.

Deliverables:

D5.1-1 Operational DOC module in DAISY

D5.2-1 Scenario simulations of the suggested organic farming systems and standard conventional systems

D5.2-2. Input data for regional groundwater simulations

Milestones:

M5.1-1 DOC module ready (2003/12)

M5.2-1 Agreement on agricultural description (2003/12)

M5.2-2 Scenario simulation finished (2004/10)

M5.2-3 Input data delivered to WP6 (2004/10)

M5.2-4 Report with optimal organic farming systems (See M1.3 and M2.3) (2005/06)

WP6. Regional modelling of nitrate to ground water

Workpackage number:	6
Start date or starting event:	2003/10
Responsible person:	Merete Styczen
Contributing persons:	Morten Haastrup, MIKE SHE- modeller and programmer
Person-months:	3

Objectives:

1. To upscale results of Daisy-simulations of leaching to Odense stream catchment.
2. To perform minor relevant model modifications to improve the solute transport simulations

Description of work:

Odense stream catchment includes parts designated as nitrate sensitive groundwater areas. The catchment has been used for nitrate simulations earlier in an exercise related to uncertainty estimation. However, the groundwater model was not based on the best existing information. Other parameterisations of the groundwater model exist for the same catchment (all of them in the MIKE SHE modelling system), either one earlier prepared by DHI or the Denmark model for Funen, prepared by GEUS (DHI has access to this model). The possibilities will be reviewed and the groundwater model selected and parameterised specifically to nitrate modelling. In the groundwater zone, this specifically concerns the parameterisation of identified reduced layers. If at all possible, this work will be done in co-operation with a PhD expected to concentrate on the same area (co-operation between GEUS and KVL).

Agreement has to be reached with the other partners concerning the agricultural description to be used for the present situation and for the scenario-situation, assuming more ecological agriculture in a sensitive area.

Minor code changes will be carried out as required.

The existing situation and the scenario-situation has to be simulated. Work package 5 deliver input calculated for the unsaturated zone. The calculated nitrate load will be run through the groundwater model, and the distribution of concentrations in the groundwater will be compared for the different scenarios. The simulations will be reported.

Deliverables:

D6.1. Report describing the results of the upscaling exercise

Milestones:

- M6.1. Agreement on choice of groundwater model (2002/10)
- M6.2. Agreement on agricultural description (2003/12)
- M6.3. Report describing the results of the upscaling exercise (2005/07)

5. Implementation and time schedule

Table 3: Deliverables list

Deliverable, No	Deliverable title	Delivery date	Meeting ¹	Nature
D1.1	First annual report 2002	2002/10	x	Re
D1.2	Second annual report 2003	2003/10	x	Re
D1.3	Third annual report 2003	2004/10	x	Re
D1.4	Report with optimal organic farming systems	2005/07		Re
D1.5	Final Report	2005/07	x	Re
D2.1	Suggestions of organic farming systems and crop rotation to test in the project	2002/06		O
D2.2	Description of agricultural practices in the farming systems for use in simulations	2003/12		O
D3.1	Effect of management tools on porosity, retention curves, saturated and unsaturated hydraulic conductivities	2003/12		Pu
D3.2	Effect of management tools on tortuosity and pore connectivity	2003/12		Pu
D3.3	Semi-quantitative description of depth and distribution of roots and macropores in the field trials	2003/05		O
D3.4	Soil physical characterised soil samples for the denitrification incubation experiments	2003/08		O
D3.5	Suggestions on how to extrapolate parameter effects to other soil types	2004/04		O
D4.1-1	Field record of the time dependent profile DOC (including DON) concentrations under conditions of high carbon and nitrogen turnover	2003/12		O
D4.1-2	DOM isolates for further characterisation in WP 4.2 and for use in sorption work in WP 4.3	2003/05		O
D4.1-3	Data set for calibration of DOC modelling by DAISY	2003/12		O
D4.2-1	Determination of origin of DOM in grass-clover mixtures	2003/07		O
D4.2-2	Determination of the composition of DOM originating from specific species	2003/12		Pu
D4.2-3	Determination of the contribution of single species to the mobile part of the DOM	2003/07		O
D4.2-4	DOM pulse as related to precipitation intensity	2003/07		O
D4.3-1	Quantitative measures of DOC bonding according to soil composition, DOC composition and DOC concentration	2003/12		Pu
D4.3-2	Selective sorption of specific DOC fractions during sorption	2003/07		O
D4.3-3	Input parameters to DAISY modelling of DOC dynamics	2003/12		O
D4.4-1	Determination of soil physical characteristics on intact soil cores for denitrification measurements	2003/06		O
D4.4-2	Dataset from measurements on intact soil cores for calibration of Daisy denitrification sub-module	2003/12		O
D4.4-3	Influence of DOC on potential denitrification as a function of crop type, organic fertiliser input and soil depth	2003/12		Pu
D5.1-1	Operational DOC module in DAISY	2004/01		O
D5.2-1	Scenario simulations of the suggested organic farming systems and standard conventional systems	2004/09		O
D5.2-2	Input data for regional groundwater simulations	2004/09		O
D6.1	Report describing the results of the upscaling exercise	2005/07		Re

¹Plenum project group meetings will be held in connection with the preparation of each annual report.
Pu = international publication, Re = reports, O = others

Table 4: Timetable

TITLE	Quarter	2002				2003				2004				2005			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	WP1: Project co-ordination																
M1.1	Project co-ordination	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
M1.2	First annual report completed (2002/10)																
M1.3	Second annual report completed (2003/10)																
M1.4	Third annual report completed (2004/10)																
M1.4	Final report completed (2005/12)																x
2	WP2: Identification of relevant organic farm systems																
3	Define organic farming systems and crop rotation to test in the project	x	x														
M2.1	Description of agricultural practices in the farming systems for use in simulations							x									
M2.2	Agreement on farming systems to test		x														
M2.3	Agreement on agricultural description for model simulations																
M2.3	Report with optimal organic farming systems (See M6.5)																x
4	WP3 Effect of organic farm systems on soil structure and hydraulic parameters																
5	Sampling in the field trial				x			x									
6	Measurement of soil physical properties in the lab.					x		x	x	x							
M3.1	Data handling								x	x							
M3.2	Sampling in the field trials finished								x								
M3.3	Data of hydraulic properties and pore characterisation parameters delivered to modellers																
M3.4	Soil samples for the denitrification incubation delivered																
M3.4	Agreement on how to extrapolate parameter effects to other soil types																
7	WP4. Effect of organic farming systems on DOC mobilisation and DOC-assisted denitrification																
8	Installing suction cups				x												
9	Sampling pore water				x	x		x	x	x							
10	Column experiment					x		x	x	x							
11	DOC characterisation and sorption					x		x	x	x							
M4.1-1	Denitrification experiments								x	x	x						
M4.1-2	Teflon suction cups installed				x												
M4.2-1	Sampling from suction cups and analysis of DOC finalised								x								
M4.2-2	Soil column studies about origin of DOM in grass-clover mixtures completed								x								
M4.3-1	Dataset for calibration of DOC modelling by DAISY delivered																
M4.3-2	Studies on DOM sorption and composition completed																
M4.4-1	Sorption parameters for calibration of DOC modelling by DAISY delivered																
M4.4-2	Studies on relationships between DOC, soil physical characters and denitrification completed																x
M4.4-3	Dataset for calibration of denitrification sub-module in DAISY delivered																x
M4.4-3	Studies on the influence of DOC on potential denitrification as a function of crop type, organic fertiliser input and soil depth completed																x

Regional Groundwater Protection by Optimised Organic Farming Systems

	WP5 Root and vadose zone modelling				
12	DOC module	x	x	x	
13	Scenario simulations				
M5.1-1	DOC module ready				x x x
M5.2-1	Agreement on agricultural description				x
M5.2-2	Scenario simulation finished				x
M5.2-3	Input data delivered to WP6				x
M5.2-4	Report with optimal organic farming systems (See M2.3)				x
	WP6. Regional groundwater modelling				
14	Regional groundwater modelling				x x x
M6.1	Agreement on choice of groundwater model				x
M6.2	Agreement on agricultural description				x
M6.3	Report describing the results of the upscaling exercise				x

7. Collaborative partners

There will be collaboration with several research groups and projects on a national basis.

We will intensively be using the experimental area described in DARCOF project VII.11. The two projects will work in close collaboration experimentally and in the interpretation of data. The experiment is now used in DARCOF project I.4 “Nitrogen management and cropping methods for enhanced bread wheat” and the experiment is labelled the “Grass-clover experiment” (GCE). (Contact: Jørgen Eriksen, DIAS)

We have access to the long-term crop rotation experiment that is financed by DARCOF project II-23 “Experimental units for research in organic farming systems” (EXUNIT) (Contact: Jørgen E. Olesen, DIAS)

Effects of long-term effect of manure application are studied in the long-term fertiliser experiments in Askov (Contact: Bent T. Christensen, DIAS)

Effects of reduced tillage are studied in the “The Row Cropping Experiment” in Bygholm (Contact: Per Schjønning, DIAS)

In DARCOF project ROMAPAC effects of different tillage systems are evaluated with respect to soil quality. We will get basic data on soil physics from that project and access to the experiment and do sampling in the subsoil (Contact: Per Schjønning, DIAS)

Several of the participants in this project are involved the DARCOF project “Interaction between nitrogen dynamics, crop production and biodiversity in organic rotations analysed by dynamic simulation models” - BIOMOD (LSJ, SH, JEO, FPV) and we will make use of the improvements of Daisy and data input to simulate organic farming systems.

Co-operation with the Geological Survey of Denmark and Greenland, GEUS in connection to a Ph.D. study in nitrate leaching modelling at catchment scale.

There is a co-operation between SH, LSJ, HHJ and Dr. Torsten Müller at the Department of Soil Biology and Plant Nutrition, Faculty of Agriculture, International Rural Development and Environmental, Witzhausen at University of Kassel about modelling of how organic farming systems affect N dynamics, crop growth and environment.

HHJ is a participant in Cost Action: Carbon Storage in European Grasslands.

8. Budget (in kkr)

DIAS	2002	2003	2004	2005	Total
Months (scientific)	4.5	9	2.5	3	
Months (technical)	4.4	8.7	3.2	0.3	
Salary (scientific)	195	410	121	156	
Salary (technical)	106	224	86	7	
Operation – equipment					
Operation – other	51	69	24	9	
Overhead	70	141	46	35	
Total	422	844	277	207	1750

Regional Groundwater Protection by Optimised Organic Farming Systems

RVAU	2002	2003	2004	2005	Total
Months (scientific)	6	1	4	1	
Months (technical)	1.5	1			
Salary (scientific)	240	40	160	40	
Salary (technical)	36	24			
Operation – equipment	5				
Operation - other	27	44	10	7	
Overhead	62	22	34	9	
Total	370	130	204	56	760

RVAU	2002	2003	2004	2005	Total
Months (scientific)					
Months (technical)	2	2	1		
Salary (scientific)					
Salary (technical)	48	48	24		
Operation – equipment					
Operation - other	29	43	17		
Overhead	15	18	8		
Total	92	109	49		250

DHI	2002	2003	2004	2005	Total
Months (scientific)			1.5	1.5	
Months (technical)					
Salary (scientific)			80	80	
Salary (technical)					
Operation – equipment					
Operation – other			20	20	240

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Appendix: CV's of central persons, and description of role, qualifications, capacity and experience of each participant.

CURRICULUM VITAE

Ole Hørbye Jacobsen

Personal data:

Born: 09.05.1961

Degrees:

1991: Ph.D. (Soil Physics), Royal Veterinary and Agricultural University, Copenhagen.

1986: M.Sc. (Horticultural Science, cand. hort.), Royal Veterinary and Agricultural University, Copenhagen.

Professional Positions:

1998-: Research leader of Research Group of Soil Physics and Chemistry. Danish Institute of Agricultural Sciences, Department of Crop Physiology and Soil Science, Research Centre Foulum, Tjele.

1994-98: Senior Scientist at Danish Institute of Plant and Soil Science, Research Centre Foulum.

1991: Visiting Scientist at U.S. Salinity Laboratory, Riverside, California (4 month).

1987-94: Research Associate at Danish Institute of Plant and Soil Science, Højer Experimental Station, Jyndevad Experimental Station and Research Centre Foulum.

Research Activities:

Participating and project leader in several joint projects concerning water, solute and colloid transport – mainly nitrate, phosphorus and pesticides and especially in heterogeneous soils.

Other Professional Involvements:

Associate Editor of Journal of Environmental Quality, External examiner at the Technical University of Denmark, Ph.D. supervisor.

Selected Peer-Reviewed Publications: (Author or coauthor on 24 peer-reviewed papers, 18 reports and articles in popular journals, and 26 conference presentations)

Jacobsen, O.H. & P. Schjønning. 1993. Field evaluation of time domain reflectometry for soil water measurements. *Journal of Hydrology* 151, 159-172.

Jacobsen O.H, P. Moldrup, C. Larsen, L. Konnerup & L.W. Petersen. 1997. Particle transport in macropores of undisturbed soil columns. *Journal of Hydrology* 196, 185-203

Djurhuus, J., S. Hansen, K. Schelde & O.H. Jacobsen. 1999. Modelling mean nitrate leaching from spatially variable fields using effective hydraulic parameters. *Geoderma* 87:261-279.

Sommer, S.G. & O.H. Jacobsen 1999. Infiltration of slurry liquid and volatilization of ammonia from surface applied pig slurry as affected by soil water content. *Jour. Agric. Sci., Cambridge* 132:297-303.

Laubel, A., O.H. Jacobsen, B. Kronvang, R. Grant & H.E. Andersen. 1999. Subsurface drainage loss of particles and phosphorus from field plot experiments and a tile-drained catchment. *Jour. Environ. Qual.* 28:576-584.

CURRICULUM VITAE

Søren Hansen

Date of Birth April 20, 1951

Nationality Danish

Education Technical University of Denmark, 1976, M.Sc., Specialization: Hydrology

Employment Record

<i>Year</i>	<i>Organisation</i>	<i>Position</i>
1977-date	Royal Veterinary and Agricultural University (KVL)	Associate Professor, Department of Agricultural Sciences (AGSCI), Laboratory for Agrohydrology and Bioclimatology, 1993-date. Research Assistant, Danish Informatics Network in Agricultural Sciences, 1991-1992. Assistant Professor, AGSCI, 1987-1991 Research Assistant, AGSCI, 1977-1986

Research Interests

Transport processes in the soil-vegetation-atmosphere system. Agro-ecological modelling.

Key Personal Assignments and Experience

Member of editorial board of Applied Soil Ecology.

Member of evaluation boards at PhD defenses at the Royal Veterinary and Agricultural University, University of Copenhagen, University of Roskilde, and Swedish University of Agricultural Sciences.

External examiner at University of Copenhagen, University of Aalborg, Technical University of Denmark

Curriculum development at Post Graduate Institute of Agriculture, Sri Lanka. UNDP project.

Some recent Publications

Djurhuus, J., Hansen, S., Schelde, K., and Jacobsen, O.H. (1999) Modelling the mean nitrate leaching from spatial variable fields using effective parameters. *Geoderma* 87, 261-279.

Hansen, S., M. Thorsen, E.J. Pebsma, S. Kleeschulte and H. Svendsen (1999) Uncertainty associated with the simulation of regional nitrate leaching. A case study. *Soil Use and Management* 15, 167-175.

Abrahamsen, P., and Hansen, S. (2000) Daisy: An Open Soil-Crop-Atmosphere System Model. *Environ. Model. Software* 15, 313-330

Thorsen, M., J.C. Refsgaard, S. Hansen, E. Pebesma, J.B. Jensen and S. Kleeschulte (2001) Assessment of uncertainty in simulation of nitrate leaching to aquifers at catchment scale. *J. Hydrology* 242, 210-227.

Hansen, S., Thirup, C., Refsgaard, J.C. and Jensen, L.S. (2001) Modelling of nitrate leaching at different scales - application of the *Daisy*. In: Shaffer, M., Liwang, M and Hansen, S. (Eds.) *Modeling Carbon and Nitrogen Dynamics for Soil Management*. Lewis Publishers, Boca Raton, 511-547

CURRICULUM VITAE

Per Schjønning

Born on the 22nd October, 1953. M.Sc. in soil science from the Royal Veterinary and Agricultural University in Copenhagen, 1980. Senior scientist in the research group 'Soil Physics and Chemistry' within the Department of Crop Physiology and Soil Science (DCPSS) at the Danish Institute of Agricultural Sciences (DIAS).

Major Fields

Main research activities are concerned with effects of soil management on soil physical characteristics. Several projects have addressed soil quality in terms of erodibility, compactability, aggregate stability etc. Tillage and traffic effects on soil physical properties have been investigated in a number of projects. Involved in projects with multidisciplinary approaches for understanding the effects of soil physical properties on biological processes.

Specific tasks and relations

Danish representative in the Council of the European Society for Soil Conservation (ESSC) and in this context responsible for ESSC task force on 'Soil Quality'. Currently serving as head of an editorial group preparing a book on soil quality entitled 'Managing Soil Quality – Challenges in Modern Agriculture) to be published worldwide by CABI Publishing ultimo 2002. Serving as a referee for the journals 'Soil & Tillage Research' and 'Swedish Journal of Agricultural Research'. Currently (November 2001) serving as an assistant supervisor for two Ph.D.-students and one M.Sc.-student.

Publications

Author and co-author of 49 refereed papers, of which 13 in a national (Danish) journal, and 36 in international journals. Senior- or single author of 23 of these papers. A further 30 papers have been presented at international conferences with Proceedings.

Selected recent papers

- Schjønning, P., Munkholm, L.J., Moldrup, P. & Jacobsen, O.H. 2002. Modelling soil pore characteristics from measurements of air exchange: the long-term effects of fertilization and crop rotation. *European Journal of Soil Science* (accepted).
- Ball, B.C. & Schjønning, P. 2002. Air permeability. In: J.H. Dane and G.C. Topp (eds.) *Methods of Soil Analysis, Part 4, Physical Methods*, pp. 0000-0000. 3rd ed., *Agronomy Monograph, ASA and SSSA*, Madison, WI (in press).
- Schjønning, P., Elmholt, S., Munkholm, L.J. & Deboz, K. 2002. Soil quality aspects of humid sandy loams as influenced by organic and conventional long-term management. *Agriculture, Ecosystems & Environment* (in press).
- Schjønning, P. & Rasmussen, K.J. 2000. Soil strength and soil pore characteristics for direct-drilled and ploughed soils. *Soil & Tillage Research*, 57, 69-82.
- Schjønning, P., Thomsen, I.K., Møberg, J.P., de Jonge, H., Kristensen, K. & Christensen, B.T. 1999. Turnover of organic matter in differently textured soils. I. Physical characteristics of structurally disturbed and intact soils. *Geoderma*, 89, 177-198.

CURRICULUM VITAE

Finn Pilgaard Vinther

Date of birth: 04.09.52
Address: Danish Institute of Plant and Soil Science, Dept. of Crop Physiology and Soil Science, Research Centre Foulum, P.O.Box 50, DK-8830 Tjele, Denmark
Tel: +45 89 99 18 61
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Education:

01.09.79: Cand. agro. (M.Sc.)
01.10.93: Senior scientist (Dr.), Microbial ecology

Occupations:

1979 – 1982: Department of Microbiology and Microbial Ecology, The Royal Veterinary and Agricultural University, Copenhagen.
1982 – 1986: Danish Institute of Seed Pathology for Developing Countries (DANIDA), Copenhagen.
1986 – 1987: Center for Terrestrial Ecology, Danish Environmental Agency, Copenhagen.
1987 – 1993: Department of Soil Biology and Chemistry, Danish Institute of Plant and Soil Science, Copenhagen.
1994 – 2000: Head of Research Group of Microbial Ecology, Department of Soil Science, Danish Inst. of Plant and Soil Science, Research Centre Foulum, Tjele.
2000 - Research Group of Organic Matter and Microbial Ecology, Department of Soil Science, Danish Inst. of Plant and Soil Science, Research Centre Foulum, Tjele.

I have worked with different aspects of microbial ecology in agricultural soils, including soil layers below the root zone. The research has primarily involved studies on the exchange of gases between soil and atmosphere, with emphasis symbiotic N₂ fixation in grass-clover pastures, the influence of biotic and abiotic factors on nitrification and denitrification, and emission of the greenhouse gases methane (CH₄) and nitrous oxide (N₂O). FPV has published 29 papers in international journals; 30 contributions in proceedings, and 38 publications as reports, book chapters or in Danish journals.

Selected Publications:

- Hansen, J. P. & Vinther, F. P. (2001) Spatial variability of symbiotic N₂ fixation in grass-white clover pastures estimated by the ¹⁵N enriched method and the natural ¹⁵N abundance method. *Plant and Soil* **230**, 257-266.
- Vinther, F. P. & Jensen, E. S (2000) Estimating legume N₂ fixation in a grass-clover mixture of grazed organic cropping systems using two ¹⁵N methods. *Agriculture, Ecosystems & Environment* **78**, 139-147.
- Maag, M. & Vinther, F. P. (1999) Carbon dioxide and nitrous oxide production in slurry amended soils under varying temperature and water contents. *Soil Science Society of America Journal* **63**, 858-865.
- Vinther, F.P., Eiland, F., Lind, A.-M. & Elsgaard, L. (1999) Microbial biomass and denitrification related to macropores in agricultural and forest soils. *Soil Biology and Biochemistry* **31**, 603-611.
- Maag, M. & Vinther, F. P. (1996). Nitrous oxide emission by nitrification and denitrification in different soil types and at different soil moisture contents and temperatures. *Applied Soil Ecology* **4**, 5-14.

CURRICULUM VITAE

Lars Stoumann Jensen

- Born:** 27 July 1960
- Education:** 1990 M.Sc. in agriculture from The Royal Vet. and Agricultural Univ. (KVL)
1994 Ph.D. degree in Plant Nutrition and Soil Fertility
- Employment:** 1995-1996 Research Fellow at KVL, 1996-1999 Assistant Professor and
1999- Associate Professor at Plant Nutrition and Soil Fertility Laboratory, KVL
- Research abroad:** 1992-1993 Visiting scientist working with Dr. Kevin R. Tate and Dr. Des J. Ross at Manaaki Whenua Landcare Research, Lower Hutt, New Zealand
- Research projects:** 1994-1996: *Temporal variation of nitrogen turnover in soil microbial biomass and soil organic matter fractions - effect of abiotic factors*, Danish Root Zone Centre, SMPI (project participant)
1996-1999: Subproject of *Nitrogen Fixation, Recycling and Leaching in Organic Cropping Systems (NICLEOS)*, Danish Research Centre for Organic Farming (project participant)
1999-2001: *Biomass export for energy purposes - consequences for soil fertility in agriculture and forestry*. Ministry of Energy and Environment (project leader)
1999-2002: *Temporal mineralization patterns of residual N*. Ministry of Agriculture, Fisheries and Food (project leader)
2000-2003: *Characterisation of plant residue quality for prediction of decomposition and nitrogen release in agricultural soils* Nordic Council of Ministers. (project leader)
2000-2003: *Development of organic vegetable cultivation methods, and the use of catch crops to improve the production and protect the environment - VEGCATCH* (Danish Research Centre for Organic Farming II, project leader)
2000-2003: *Interactions between nitrogen dynamics, crop production and biodiversity in organic crop rotations analysed by dynamic simulation models - BIOMOD* Danish Research Centre for Organic Farming II (project leader)
2001-2003: *Effect of plant residue quality on gross N mineralization-immobilization turnover in soils*. Marie Curie Fellowship, EU Commission (project leader)
2001-2004: *Modelling the decomposition of plant litter and organic residues in soil: Applying new concepts of mechanisms and nutrient dynamics* KVL Ph.D.-fellowship (supervisor)
- Research interests:** Decomposition of organic residues, nitrogen mineralisation, soil microbial biomass, use of stable isotopes as tracers and the integration of experimental work and simulation modelling.

Selected Publications:

- Jensen L.S., Mueller T., Nielsen N.E., Hansen S., Crocker G.J., Grace P.R., Klir J., Körschens M. and Poulton P.R. (1997) Simulating soil organic matter trends in long-term experiments with the soil-plant-atmosphere model DAISY. *Geoderma* 81, 5-28
- Mueller T., Magid J., Jensen L. S. and Nielsen N. E. (1998) Soil C and N turnover after incorporation of chopped maize, barley straw and bluegrass in the field: Evaluation of the DAISY soil-organic-matter submodule. *Ecological Modelling* 111, 1-15.
- Eriksen J. and Jensen L.S. (2001) Soil respiration, nitrogen mineralization and uptake in barley following cultivation of grazed grasslands *Biol Fertil Soils* 33:139 –145 Reprint here
- de Neergaard A., Huggard-Nielsen H., Jensen L. S., and Magid J. (2001) Decomposition of white clover (*Trifolium repens*) and ryegrass (*Lolium perenne*) components: C and N dynamics simulated with the DAISY soil organic matter submodel. *European Journal of Agronomy*. In press
- Jensen L.S., Mueller T, Bruun S. and Hansen S. (2001) Application of the Daisy model for short and long-term simulation of soil carbon and nitrogen dynamics. In: *Modelling Carbon and Nitrogen Dynamics for Soil Management* (Edited by M. Shaffer, L. Ma

CURRICULUM VITAE

Hans Christian Bruun Hansen

Personal data:

Born: 12.04.1959

Degrees:

1991: Ph.D. (Soil Chemistry), Royal Veterinary and Agricultural University, Copenhagen.

1987: M.Sc. (Silvicultural Science, cand. hort.), Royal Veterinary and Agricultural University, Copenhagen.

Professional Positions:

1999-: Professor of Environmental Soil Chemistry, Chemistry Department, Royal Veterinary & Agricultural University, Copenhagen

1994-99: Associate professor, Soil Chemistry, Chemistry Department, Royal Veterinary & Agricultural University, Copenhagen

1990-94: Assistant professor, Soil Chemistry, Chemistry Department, Royal Veterinary & Agricultural University, Copenhagen

1987-90: Ph.d. scholar, Chemistry Department, Royal Veterinary & Agricultural University, Copenhagen

Research Activities:

Current research activities comprise four main areas: i) Abiotic iron(II)-facilitate degradation of organic pollutants, ii) metal ion speciation, reactivity and mobility, iii) DOC sorption to soil materials and DOC facilitated desorption and dissolution processes, iv) kinetics of pollutant sorption and desorption in soils and v) environmental chemistry of natural toxins. Received 11 personal awards. Participated in 16 larger successful research applications.

Other Professional Involvements:

Teaching in a different courses spanning from basic chemistry, to soil chemistry and environmental chemistry, and covering bachelor to ph.d. levels. Supervision of 25 bachelor projects, more than 30 master theses and 9 ph.d. theses. Examiner at the Technical University of Denmark, Copenhagen University and Danish Pharmaceutical University. Referee at more than 10 journals. Member of many councils and committees.

Selected Peer-Reviewed Publications: (Author or coauthor on 53 peer-reviewed papers, 7 textbook contributions, and 44 conference presentations)

Strobel, B.W.; Hansen, H.C.B.; Borggaard, O.K.; Andersen, M.K. & Raulund Rasmussen, K. (2001) Composition and reactivity of DOC in forest floor solutions in relation to tree species and soil type. *Biogeochemistry* **56**, 1 - 26

Poulsen, I.F. & Hansen, H.C.B. (2000) Soil sorption of nickel in the presence of citrate or arginine. *Water, Air and Soil Pollut.* **120**, 249 - 259.

Jensen, M.B.; Jørgensen, P.R.; Hansen, H.C.B. & Nielsen, N.E. (1998) Biopore mediated subsurface transport of dissolved orthophosphate. *J. Environ. Qual.*, **27**, 1130 - 1137.

Rasmussen, L.H.; Ernstsén, V.; Hansen, H.C.B. (2001) Redoximorphic macropore environments in an Agradalf. *Nordic Hydrology* (accepted).

Hansen, H.C.B.; Hansen, P.E. & Magid, J. (1999) Empirical modelling of the kinetics of phosphate sorption to macropore materials in structured subsoils *Eur. J. Soil Sci.*, **50**, 317 - 327.

CURRICULUM VITAE

Henning Høgh Jensen, cand. agro., Ph.D.

Address: Organic Farming Unit, Dept. of Agricultural Sciences, KVL
Agrovej 10, DK-2630 Taastrup.
Phone 3528 3391, e-mail hhj@kvl.dk.

Date of birth: 15 April 1957. Denmark.

Professional record:

- 2000- : Associate Professor at the Department of Agricultural Sciences, Royal Veterinary and Agricultural University, Copenhagen,
97-2000: Research Assistant Professor at Plant Nutrition Laboratory, Department of Agricultural Sciences, Royal Veterinary and Agricultural University, Copenhagen
93-97: Ph.D. project at the Plant Nutrition Laboratory, Department of Agricultural Sciences, Royal Veterinary and Agricultural University, Copenhagen.

Research activities:

My research is focused on developing an understanding of the nutrient and matter dynamics (NRM) in intercropped systems with particular emphasis on low input systems in general and organic farming systems in particular. Of particular interest are competition and facilitation processes in order to obtain complementarity in intercropped systems. The research takes place in temperate and tropical ecological zones under the use of a variety of methodologies, ranging from plant physiological studies to field experiments and dynamic simulations

The activities focus mainly on the nitrogen dynamics in crop mixtures of different kind, including aspects of rhizodeposition of N, N₂-fixation, N-transfer. Also the use of sparingly soluble sources of potassium and phosphorus are included.

Selected publications:

- Høgh-Jensen H., Fabricius V. and Schjoerring J. K. (2001) Regrowth and Nutrient Composition of Different Plant Organs in Grass-clover Canopies as Affected by Phosphorus and Potassium Availability. *Annals of Botany* 88, 153-162.
Høgh-Jensen H. and Schjoerring J. K. (2001) Rhizodeposition of nitrogen by red clover, white clover and ryegrass leys. *Soil Biology & Biochemistry* 33, 439-448.
Høgh-Jensen H. and Schjoerring J. K. (2000) Below-ground nitrogen transfer between different grassland species: Direct quantification by ¹⁵N leaf feeding compared with indirect dilution of soil ¹⁵N. *Plant and Soil* 227, 171-183.
Hansen B., Kristensen E.S., Grant R., Høgh-Jensen H., Simmelsgaard S.E. and Olesen J.E. (2000) Nitrogen leaching from conventional versus organic farming systems – a systems modelling approach. *European Journal of Agronomy* 13, 65-82.
Eriksen J. and Høgh-Jensen H. (1998) Variation in the natural abundance of ¹⁵N in ryegrass/white clover shoot material as influenced by cattle grazing. *Plant and Soil* 205, 67-76.

CURRICULUM VITAE

Merete E. Styczen

Personal data: Born: 30.04. 1958

Degrees:

1988: Ph.D (Soil Science), Royal Veterinary and Agricultural University, Copenhagen

1981: M.Sc. (cand. agro., specialised in Soil Science, Chemistry and Agronomy), Royal Veterinary and Agricultural University, Copenhagen

Professional Positions:

1988-: DHI Water and Environment. Responsible for a) assessment and modelling of agricultural systems with regard to leaching of nitrate and pesticides; b) development of soil erosion models and soil physical aspects within hydrological modelling, c) coordination of research and development in the field of agro-technology.

1985-88: Consultancies: DHI Water and Environment, Advisor on soil erosion modelling for watersheds; b) I. Krüger, Consulting Engineers: External Consultant in agricultural development projects, c) Danida: External consultant in erosion and agroforestry.

1985-88 Ph.D. student, Royal Veterinary and Agricultural University.

1982-85 FAO, Associate expert in Kenya and Ethiopia.

Research Activities:

Participating and project leader in several projects concerning water, nitrate, pesticide, phosphorus transport and erosion.

Other Professional Involvements:

External examiner at the Royal Veterinary and Agricultural University, Visiting Research Scientist at Asian Institute of Technology, board member of GEUS and GRAS.

Selected Publications:

Styczen, M. and Storm B. (1983): Modelling of N-movements on catchment scale – a tool for analysis and decision making. 1. Model description. *Fertilizer Research*, 36: 1-6.

Styczen, M. and Storm B. (1983): Modelling of N-movements on catchment scale – a tool for analysis and decision making. 2. A case study. *Fertilizer Research*, 36: 7-17.

Styczen, M. (1984): Regional simulations as a basis for the assessment of National Nutrient Emissions at Various Input Scenarios. *Proc. Scenario Studies for the Rural Environment*, Wageningen, 12-15 Sept. 1994.

Thorsen, M., Feyen, J. and Styczen, M (1996): Agrochemical Modelling. In Abbott, M. and Refsgaard, J.C. (Ed): Distributed Hydrological Modelling. *Water Science and Technology Library*, Vol 33. Kluwer Academic Publishers, Dordrecht, The Netherlands, 121 – 141.

Styczen, M., Butts, M.B., and Refsgaard, J.C. (2001): Scale considerations for watershed modelling of non-point pollution. In: (Eds: Foster, W., and Gromiec, M.) "Applied Non-Point Source Pollution Models in Agricultural Watersheds" to be published in the "Developments in Environmental Modeling Series" from Elsevier Science Limited. Submitted.