



Annual Status Report 2001 and Application for Continuation in 2002

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

1. Research program

Research in organic farming 2000-2005 (DARCOF II)

2. Project title and number

I.7 Soil quality in organic farming: Effects of crop rotations, animal manure and soil compaction (ROMAPAC)

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7. Start of project: 2000
End of project: 2004

8. Annual report/Application for continuation in 2002

A. Objectives and expected achievements (from application)

Aims and objectives

The general objective of the ROMAPAC project is to quantify the effects of some basic management tools upon the quality of organically managed soil. In this context, the project also addresses the existing compaction of subsoil derived from the use of heavy machinery in Danish agriculture. In order to reach this goal and to further differentiate our understanding, we set up the following specific objectives.

- Evaluate whether the widespread occurrence of subsoil compaction in Danish agricultural land generally reduces the production potential and important functions of organically managed soil [WP A1, WP A2 and WP A3]
 - Determine whether mechanical loosening of a compacted soil layer may improve crop performance through better conditions for root growth and other biological processes [WP A1, WP A2 and WP A3]
 - Investigate whether low axle loads and tyre pressures as well as on-land ploughing will reduce compaction and re-compaction of mechanically loosened soil [WP A1 and WP A3]
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- Quantify the effects of crops and animal manure on abiotic and biotic mechanisms involved in the tilling-forming processes [WP B]
- Reveal the relative importance of mechanical disturbance in terms of soil surface traffic on the crop and animal manure effects mentioned above [WP B]
- Investigate soil behaviour in terms of strength and friability as affected by the tilling-forming processes and in turn the management tools involved [WP B]
- Investigate soil porosity as related to its function as a habitat for microorganisms in the framework of the management tools investigated [WP B]
- Evaluate and confirm recent findings on the correlation between descriptive/integrating field methods and differentiating laboratory methods for evaluation of soil tilling [WP B]

Finally, the ROMAPAC project includes as one of its objectives to disseminate the results to consultants and farmers as the practical implications of the achievements is regarded of high importance to a successful development of organic farming [WP A1, WP A2, WP A3, WP B and WP C].

Expected achievements

Organic farming has to rely on an optimal function of all parts of the soil ecosystem. In order to achieve this, it is essential to procure a high level of understanding of soil behaviour and functions. The organic farmer should base his decisions for all management strategies on this knowledge.

Based on the studies in research topic A (WP A1-3), the ROMAPAC project will increase our insight in the effects of compacted subsoil on key aspects of crop growth. First of all, this will include the effects on the crop yields. Moreover, an increased knowledge about the effects on root growth and uptake of plant nutrients is believed to be valuable for development of organic farming. Further, knowledge about the effects of subsoiling may create the basis for general recommendations on how organic farmers should include this tillage procedure in their soil management. Finally, the results may serve as a basis for general recommendations for organic farmers concerning maximum permissible axle loads and tyre pressures.

The studies in research topic B (WP B) are anticipated to increase our knowledge on the basic mechanisms in creation of a tilling optimal to soil behaviour and functions. This knowledge has general value in order to envisage consequences from different management strategies. It further quantifies the relative effects of crop rotations and amendments with organic manures. This has practical implications as it provides an indication of the potentials and problems in specific types of organic farming.

The high impact of intensive tillage and traffic on key topsoil tilling properties that was detected in the former DARCOF-project I.3, in the present project will be studied in close connection to the effects of crops and amendments with manure. It is anticipated that this will yield the opportunity to more specifically interpret the relative effects of the management tools. The practical implications manifest themselves in terms of recommendations for traffic and tillage strategies in organic farming.

B. Project summary (from application)

The ROMAPAC project will address some basic characteristics and functions of soil that are of paramount importance for organic farming. The aim is to improve the understanding of the managed soil ecosystem, and at the same time derive results that are applicable to the practical development of organic farming. The project includes two research topics, labelled A and B. Both topics were also addressed in a former DARCOF project (1996-1999) and the ROMAPAC project is a close follow-up on this. Dissemination of results to consultants and farmers has a high priority in the ROMAPAC project as we consider a higher attention to the compaction aspect included in both research topics essential for the development of organic farming.

Research topic A is concerned with the effects of subsoil compaction and loosening upon soil conditions and crop performance. It is the aim to elucidate how subsoiling of a compacted soil layer affects the growth of roots and shoots, and eventually crop yields in terms of biomass as well as nutrient uptake. The effects of weed growth will be included in the studies too. It is further intended to evaluate the possibility of avoiding re-compaction of loosened soil by using on-land ploughing and by control-

ling axle loads and tyre pressures of vehicles trafficking the soil. Two existing field trials and three soil types will be included in these studies.

Research topic B is concerned with the topsoil tilth. A stable but yet friable soil is a major concern in order to obtain optimal growing conditions for plants. The soil tilth further determines the living conditions for soil biota. Results from the former DARCOF-project indicated important long-term influence of crop rotation and application of animal manure. Further, the results indicated a pronounced negative influence of tillage and traffic intensity. Generally, therefore, the positive effects on soil fertility from cropping and fertilisation practices are prone to destructive forces from tillage and traffic. In the ROMAPAC project, further studies will be performed to increase our knowledge of the relative importance of each of these basic management tools and their interactions. We address the processes involved in the formation and stabilisation of soil structure. The resulting tilth will be quantified in terms of structural strength/friability and characteristics of soil pores as a habitat for microorganisms. Two field trials and two soil types will be included in these studies.

The investigations in the ROMAPAC project are expected to give organic farming valuable and directly applicable conclusions on the effects of subsoiling compacted land. Another achievement will be a better understanding of the basic mechanisms in creation of a tilth optimal to soil behaviour and functions. This knowledge has general value in order to envisage consequences from different management strategies.

Table 1: Work package list (from application)

No.	Work package title	Participants	Budget (1.000DKr)	Start	End	Deliverable No:
A1	Development of tillage strategies including recompaction evaluation	<u>PS</u> , LJM, (TSM)	468	04/00	12/02	D1, D2, D3
A2	Above-ground crop response to compaction and subsoiling	<u>JEO</u> , PS, LJM	777	08/00	12/04	D4, D5, D6
A3	Soil effects and root response to compaction and subsoiling	<u>LJM</u> , PS, JEO	1435	01/01	12/04	D7, D8
B	Topsoil tilth as affected by crop rotations, animal manure and traffic	<u>PS</u> , SE, KD, LJM	2679	04/00	12/04	D9, D10
C	Project co-ordination and dissemination of results	<u>PS</u> , JEO, LJM, SE, KD	272	04/00	12/04	D11, D12, D13, D14, D15

* Responsible participants are underlined

C. Progress

C.1 Annual description (resume) of main results and conclusions

All workpackages have been active in 2001. Generally, all activities have followed the plan listed in the application. This means that the majority of resources in 2001 has been allocated to the Workpackages A1-A3. The activities in Workpackage B include treatment of field plots for later sampling and measurements. In the context of workpackage C, dissemination of results has taken place through a number of oral presentations (see E.4).

C.2 Fulfilment of tasks and deadlines in individual work packages

(To be completed for each work package)

WP A1: Development of tillage strategies including re-compaction evaluation	Time schedule according to application	Deviations, if any*
Task		
1 Field trial, old plan, all fields		
2 Field trial, new plan, two fields		
Deliverables		
D1 Research objects for DARCOF project IV.3	04/2000	delivered
D2 Research objects for WP A3	04/2001	delivered
D3 DARCOF-report on 1997-2000 years trial results	03/2002	
Milestones		
1 Trial performed by old plan	10/2000	fulfilled
2 On-land plough has been procured and used first time	04/2000	fulfilled
3 The controlled traffic strategy has been implemented	06/2000	fulfilled
4. A DARCOF-report on tillage strategies has been publ.	03/2002	

WP A2: Above-ground crop response to compaction and subsoiling	Time schedule according to application	Deviations, if any*
Task		
1 Subsoiling events		
2 Measurements of above-ground crop response		
Deliverables		
D4 Demonstration of effects for farmers (field-days)	06/2002-2004	
D5 Research objects for WP A3	04/2002	
D6 International scientific paper	10/2004	
Milestones		
1 All subsoiling performed	08/2003	
2 All measurements performed	10/2004	
3 International paper submitted	12/2004	

WP A3: Soil effects and root response to compaction and subsoiling	Time schedule according to application	Deviations, if any*
Task		
1 Root studies at DTS trial, Rugballegaard		
2 Root studies at CRE trial, Foulum and Flakkebjerg		
Deliverables		
D7 Presentation of results at international Conference	06/2003	
D8 International scientific paper	11/2004	
Milestones		
1 Rhizotron studies of roots have been implemented	04/2001	Fulfilled
2 Core sampling completed at Rugballegaard, field B3	06/2001	see C.3
3 Measurements and samplings completed at Rugb. B4	06/2002	
4 Measurements and samplings compl. Foulum and Fl.	06/2003	
5 Presentation of results at ISTRO Conference	06/2003	
6 International scientific paper(s) submitted	12/2004	

WP B: Topsoil tilth as affected by crop rotations, animal manure and traffic	Time schedule according to application	Deviations, if any*
Task		
1 Compaction treatments in subplots, LAM and CRE trial		
2 Field and laboratory measurements, 2002 sampling		
3 Field and laboratory measurements, 2003 sampling		
Deliverables		
D9. Presentation of results at international Conference	06/2003	
D10. International scientific paper(s)	11/2004	
Milestones		
1 Compaction treatments in sub-plots completed	10/2001 and 10/2002	Fulfilled
2 Field measurements and samplings 2002 completed	05/2002	
3 Laboratory measurements for 2002 samplings compl.	01/2003	
4 Field measurements and samplings 2003 completed	05/2003	
5 Presentation of results at ISTRO Conference	06/2003	
6 International scientific paper(s) submitted	12/2004	

WP C: Project coordination and dissemination of results	Time schedule according to application	Deviations, if any*
Task		
1 Production of project manual		
2 Project coordination		
3 Preparation of papers for farmers' magazines		
Deliverables		
D11 Project manual	09/2000	Delivered
D12 1. 2. 3. 4. Annual status report	11/2001 – 11/2004	
D13 Papers in farmers' magazines	no specific date	
D14 Oral presentations at seminars and meetings	no specific date	Delivered
D15 Final status report	10/2004	
Milestones		
1 Project manual completed	10/2000	Fulfilled
2 Annual status reports completed	11/2000 – 11/2004	
3 Final status report completed	10/2004	

* Deviations are to be further discussed at C3

C.3 Discussion on the progress, incl. deviations and achievements in the project as a whole and in the individual work packages

Workpackage A1. Development of tillage strategies including recompaction evaluation

The new scope of the 1997-2000 field trial at Rugballegaard (the risk of recompaction) was put into the plots in the B3 field in 2000 by +/- on-land ploughing and soil compaction with different axle loads (see annual report 2000). The B3 field thus served as a study object for WP A3 in year 2001 (see the description there).

In year 2001, the treatments were performed in the B4 field. This means that this field has been ploughed twice with the differentiated means of ploughing (in April prior to the establishment of an oat crop and again in September prior to sowing a winter wheat crop). The B4 field has experienced differentiated traffic several times in year 2000 (during harvest of grass) and in year 2001 (at harvest of the oat crop). This means, that the trial in B4 is ready for studies by WP A3 from October 2001 and in the growing season of 2002.

WP A1 in 2001 has included work with a report on the 1997-2000 year period of field trials with developing of tillage strategies at Rugballegaard. The report will be ready for printing in early 2002.

Workpackage A2. Above-ground crop response to compaction and subsoiling

A Paraplow implement was used for subsoil loosening to 35-40 cm depth in the CRE plots at Foulum and Flakkebjerg in September 2000 and September/October 2001. It was planned to use an on-land plough for ploughing of the grass-clover fields in the previously loosened plots in order to avoid recompaction. However, by mistake a normal plough was used for this at Foulum in September 2001. Fortunately the soil was comparably dry at the time, and recompaction has probably not been severe. According to the original plan, the subsoil loosening should have taken place in the lupine crop. However, in order to reduce risk of recompaction from tractors and tillage implements in the treated plots, it was decided to apply the treatments to the young grass/clover ley crop about one month after the harvest of the cover crop. Because of this the measuring programme on above-ground crop response is delayed one year (the grass/clover ley is not included in this measuring programme). A visual evaluation of the grass-clover in spring 2001 indicated positive effects of the subsoil loosening.

Workpackage A3. Soil effects and root response to compaction and subsoiling

Penetration resistance was determined early spring at field capacity in the B3 field of the DTS trials at Rugballegaard. Intensive measuring on root growth was performed during the growing season of the winter wheat crop using the mini-rhizotron technique. We recorded root growth on videotape every fortnight from April to late July. The preliminary results show that on-land ploughing in combination with low traffic intensity (i.e., low ground pressure and axle load) minimized recompaction. Early season root growth was most extensive in the treatments with the least recompaction. Later in the season the picture was less clear.

In 2001 the minirhizotron technique was not supplemented by root studies on core samples as originally planned. The soil was simply too dry for core sampling at the time of sampling (middle of July).

Workpackage B. Topsoil tilth as affected by crop rotations, animal manure and traffic

The selected plots of the field trials CRE at Foulum and Flakkebjerg and those of the LAM trial at Foulum (see the Application for details) were compacted wheel by wheel in the spring and again in the autumn. For the LAM trial, an additional treatment with rotovator was included in the trial. Sampling for determination of specific soil quality characteristics (see the Application for details) will take place in these plots (mechanically treated sub-plots as well as control sub-plots) for the first time in the spring of 2002. Some of the plots will receive the treatments also in year 2002 and will then be analyzed in the spring of 2003. The only changes to plans – considering CRE and LAM original treatments – is the that we decided to use the LAM plots receiving slurry as well as straw in stead of using the plots receiving only slurry.

Workpackage C. Project co-ordination and dissemination of results

A project group meeting was held at Research Centre Foulum on 27. March 2001. The meeting had the primary aim of creating a common 'consciousness' among project participants. A project manual had been created prior to the meeting. Plans were made for details in the WP A1-A3 and in WP B. It ought to be mentioned that the project participant Kasia Debosz left her position at the Danish Institute of Agricultural Sciences in early 2001. The duties of Kasia Debosz in the project (WP B) will be undertaken by other project participants.

Dissemination of results and general information about the project has been part of the work undertaken in workpackage C also in 2001 (see E3-E4).

D. Description of plans and future work in the project as a whole and in the work package (Including plans for publication and communication)

The future work in general will follow the plans given in the original project description except that some activities have to be postponed due to changes in some details as mentioned above.

Workpackage A1. Development of tillage strategies including recompaction evaluation

Year 2002 will be the final year of running the DTS field trial at Rugballegaard. This work will include

securing realistic and optimal conditions for all the measurements that will be undertaken by WP A3. Furthermore, the report of the 1996-2000 year trial period will be concluded and published as a DIAS-report (in Danish).

Workpackage A2. Above-ground crop response to compaction and subsoiling

The subsoiling of the next plots in the rotation for the CRE trials at Foulum and Flakkebjerg will take place in the autumn 2002. The measurements of above-ground crop response will be initiated in 2002 in the winter wheat crop in the crop rotation (at the plots subsoiled in the autumn 2000). The measurements will include effects on

- Yields and content of N, P and K in the harvested material
- Total above-ground plant production, including content of N
- Above-ground weed biomass, including content of N
- Weekly measurements of crop spectral reflectance for assessment of light interception and seasonal crop productivity

Workpackage A3. Soil effects and root response to compaction and subsoiling

The measuring programme on root and soil characteristics at the DTS trials at Rugballegaard will be continued and intensified in 2002 by including core sampling for bulk density, for micropenetrometer measurements and for quantification of roots. This is in accordance with the original plan.

Workpackage B. Topsoil tilth as affected by crop rotations, animal manure and traffic

Mechanical disturbance of soil (compaction and for LAM also rotovation) will be applied to the plots at the CRE and LAM trials according to the plan.

In the spring 2002 sampling of soil will take place in plots of both trials and in mechanically pre-treated as well as control plots. The measurements will include water retention, air diffusivity and – permeability, water stable aggregates and clay dispersibility, mechanical characteristics of bulk soil as well as of isolated aggregates, and finally the microbial biomass and hyphal length.

Workpackage C. Project co-ordination and dissemination of results

A project group meeting will be held in early 2002. Dissemination of results and general knowledge will continuously be a task. In 2002, we consider arranging some sort of demonstration of field trial effects at Foulum as well as at Rugballegaard.

E. Project publications

1. Articles in international, scientific journals with review procedures

None so far

2. Presentations at congresses, symposiums etc.

Munkholm, L.J., Schjønning, P., Heckrath, G. & Jørgensen, M.H. 2000. Pløjefri dyrkning: effekter på jordens frugtbarhed. Tidsskrift for Landøkonomi 4/00, 306-309.

Schjønning, P. 2000. Jordens frugtbarhed og kvalitet. Tidsskrift for Landøkonomi 4/00, 290-292.

Schjønning, P., Munkholm, L.J., Elmholt, S., Deboz, K., Mikkelsen, G.H. & Trautner, A. 2000. Den danske dyrkningsjords tilstand og kvalitet – konsekvenser af trafik og jordbearbejdning. Tidsskrift for Landøkonomi 4/00, 293-300.

3. Articles in agricultural journals etc.

Munkholm, L.J. (2001). Fragmentering og smuldringsegenskaber i jord: effekter af vandindhold og dyrkningssystem. Forskningsnytt om Økologisk Lantbruk i Norden 4, 17.

Munkholm, L.J. (2001). Jordens smuldreevne har stor betydning. Økologisk Jordbrug 244, 8.

4. Other presentations at meetings, field days etc.

Munkholm, L.J. 2000. Field demonstration of the Spade analysis. LØJ-seminar, Bygholm Landbrugsskole/Rugballegård, Horsens, 19 September 2000.

Munkholm, L.J. 2000. Oral presentation and field demonstration of the Spade analysis, Kursus for økologisk planteavlskonsulenter Koldkærgård, 5. October 2000.

- Munkholm, L.J. 2001. Jordbehandling med omtanke - Hvordan undgås tryk- og strukturskader? Contribution at the course "Jordbehandling med omtanke". A course for organic farmers held at Landbogården Åbenrå February 7., 2001.
- Munkholm, L.J. 2001. Ødelægges jordens struktur ved intensiv jordbehandling og trafik? Contribution at course for conventional and organic farmers held by Samsø Landboforening March 15., 2001.
- Munkholm, L.J. 2001. Spadeprøve og jordbearbejdning. Contribution at course for organic farmers held by Landbogården Åbenrå at Rugballegaard Research Station June 6., 2001.
- Munkholm, L.J. 2001. Jordløsning på grovsandet jord. Contribution at "Regions-markvandring" a field day held for crop advisors in Ribe County June 12., 2001.
- Munkholm, L.J. 2001. Spadeprøven. Contribution at "Markvandring" a field day held at Foulumgård June 14., 2001.
- Munkholm, L.J. 2001. Jordpakning og jordstruktur. Contribution at a course for lecturers held at Hovborg Kro June 19., 2001.
- Munkholm, L.J. 2001. Spadeprøve og jordbearbejdning. Contribution at field day for advisors and lectures held by The Danish Agricultural Advisory Centre June 26, 2001.
- Munkholm, L.J. 2001. Jordbearbejdning og trafik – effekter på jordstruktur og funktion. Oral presentation at the seminar "Planteavl-efterårskonferencen" held by The Danish Agricultural Advisory Centre October 2nd. 2001.
- Schjønning, P. 2000. Jordstruktur og jordfrugtbarhed. Konsekvenser af almindelig markpraksis i dag. Oral presentation at a seminar organized by LØJ, Bygholm Landbrugsskole/Rugballegård, Horsens, 19. September 2000.
- Schjønning, P. 2000. Jordstruktur, jordbehandling og udbyttevariation. Oral presentation at a course for agricultural advisors, Koldkærgård, 20. September 2000.
- Schjønning, P. 2000. Jordstruktur og mekaniske egenskaber i økologisk jordbrug. Oral presentation at visit from the Royal Veterinary and Agricultural University, 4. October 2000.
- Schjønning, P. 2000. Jordpakning i økologisk jordbrug – hvor tunge maskiner kan vi bruge. Oral presentation at Økokongres 2000, Hotel Pejsegården, Brædstrup, 1. November 2000.
- Schjønning, P. 2000. Skadelig jordpakning og jordens frugtbarhed – generelt og med henblik på pløjefri dyrkning. Oral presentation at a course organized by the Organization for Reduced Tillage in Denmark (FRDK), Scanticon-Comwell, Middelfart, 14. November 2000.
- Schjønning, P. 2001. Jordpakning og jordløsning. Status på forskning og udvikling. Oral presentation at a workshop organized by the The Danish Agricultural Advisory Centre, Skejby, 9. February 2001.
- Schjønning, P. 2001. Bæredygtig jordbearbejdning og trafik i fremtidens jordbrug. Oral presentation at a workshop organized by the Dep. Agricultural Engineering, DIAS, Snaptun Færgesgaard, 22. August 2001.
- Schjønning, P. 2001. Jordpakning, jordbearbejdning og jordfrugtbarhed. Oral presentation at visit from the Royal Veterinary and Agricultural University, 3. October 2001.

F. Scientific education (ph.d. and post doc.), including visiting scientists and visits abroad

Torben S. Madsen (TSM) has initiated a Ph.D. study on the technical aspects of optimization of tillage procedures in organic farming. The ROMAPAC project leader serves as an assistant supervisor for TSM. The Pd.D. project includes aspects of different ploughing systems. Therefore, TSM has been attached to the project group. Part of TSM's studies is carried out in the field trial of WP A1.

G. National and international co-operation

The project coordinates its activities concerning the LAM trials at Foulum with the DARCOF II, Project I.4 NIMAB (project leader Bent T. Christensen).

Another co-operation is concerned with root studies. The root samples collected by the ROMAPAC project are analysed by an automated technique at the Department of Fruit, Vegetable and Food Science within the Danish Institute of Agricultural Sciences (Kristian Thorup-Kristensen and Kai Lønne Nielsen). The project also receive assistance in installing transparent tubes for rhizotron studies in the field. These services are paid for by the ROMAPAC funding.

At the international level, a close link exists to professor Bev Kay at the Department of Land Resource Science, University of Guelph, Ontario, Canada and with Ed Perfect, Department of Geological Sciences, University of Tennessee, USA. The project participant Lars J. Munkholm had a study stay (January-June 2000) at Guelph as a part of his Ph.D. study. Bev Kay and Ed Perfect are experts in soil friability research, and our studies will be based on the most recent advances in this field of science. The studies in subsoil compaction will benefit from an existing co-operation with Johan Arvidsson at the Swedish University of Agricultural Sciences, with Rainer Horn at Chr. Albrechts University at Kiel, Germany and with Jan van den Akker at the Alterra Institute, Wageningen, The Netherlands. Our research will be in line with the suggestions created by a recently completed EU-project on subsoil compaction with these persons as co-ordinators.

The project work will also benefit from a running review work on soil quality carried out by the project leader in cooperation with Bent T. Christensen and Susanne Elmholt, both employed at the Department of Crop Physiology and Soil Science at DIAS. This project includes compilation of a number of texts on soil quality aspects delivered by selected international experts. The review work will be published as a book by CABI Publishing ultimo 2002.