

# **Improving barley yields in organic stockless farming systems through innovations in green manure management**

## **Project description PART 1:**

### **1. Objectives**

#### **Main objective**

Improved yields of feed barley on stockless farms converted to organic production

#### **Sub objective 1**

Investigate the possibility of improving the N cycling and reduce the N loss to the environment, in organic barley – green manure rotations by use of the green manure crops for biogas production.

#### **Sub objective 2**

Investigate key feed quality parameters of barley as influenced by different green manure/biogas strategies in organic stockless systems.

#### **Sub objective 3**

Investigate the short-term effects of green manure and biogas slurry on soil structure and earthworms.

#### **Sub objective 4**

Improve a computer-based nutrient plan programme to increase its applicability as decision making tool for N management in organic barley production.

## **2. Frontiers of knowledge and technology, Introduction**

It is an important aim in Norwegian agricultural policy to be self-sufficient in carbohydrate feedstuffs, be it in organic or conventional production. Due to increased demand for organic dairy, pork and poultry products in Norway, the demand for organic concentrate feed is currently exceeding domestic supply. In order to reduce import, more organic feed grain is therefore needed (see more under PART 2, item 11).

On organic farms with animal production, clover–grass swards provides feed for the animals, but it also has other important functions such as to maintain soil organic matter (SOM) content, to improve soil structure, and to supply biologically fixed nitrogen for crops in the rotation. Perennial legume-grass mixtures are best in this respect because of the more developed root-system compared to annual crops. Manure obviously contributes to the recycling of the plant nutrients and organic matter to soil.

The main cereal cropping areas – having the most appropriate climate, machinery equipment and infrastructure for cereal production – are in south-eastern and central Norway, where the production is dominated by stockless arable farming. A decline in soil structure quality, content of soil organic matter and nitrogen is observed in conventional stockless arable systems (Christensen 1990; Uhlen 1991; Riley & Bakkegard 2006; Riley et al. in prep.) In a comparative trial, Riley et al. (in prep.) observed that such farming systems had higher soil bulk density and larger mean aggregate size than other farming systems, and lower levels of plant available water as well as lower aggregate stability. The development of the leaf area of

cereals is directly dependent on the amount of N in the shoot. In barley the period for the development of the leaf area is shorter than for other cereals. Insufficient N supply very early in the growth period has more severe consequences for the photosynthetic ability of the crop. In addition, barley is very sensitive to poor soil structure (Løes 2002; Abrahamsen 2006). Due to problems with low and fluctuating barley yield levels in organic stockless farming, many organic farmers choose to produce oats instead of barley (Abrahamsen 2006). The Norwegian feed industry states that both barley and oats are required in order to produce enough organic feed concentrates of appropriate quality<sup>1</sup>. To ease the conversion into and increase the production level of organic barley, agronomic measures have to be taken to improve soil structure and N availability in early developmental stages of the barley crop.

### **Green manure**

In organic stockless farming the legume-grass sward is replaced by green manure crops. Their positive effect on the yields of subsequent cereal crops is well documented (Schmidt et al. 1999; Breland 1996a; Wivstad et al. 1996; Kumar & Goh 2002; Løes et al. 2007). Both whole season green manure crops and subcrops of clover sown under the cereal are used. Green manure crops are usually grown on one third to one half of the arable land (Ögren 1998), and they are commonly grown as set-aside; managed by repeatedly mowing, leaving as green mulch on the stubble several times during the growing season (Stopes et al. 1996; Cormack et al. 2003). Repeatedly mowing is done mainly to control perennial weeds. The common practice in Norway is to mow 3-4 times during the growing season, and leave the herbage on the stubble after each cut (Frøseth 2006).

Green manure preceding barley may increase yields through i) improved nitrogen (N) supply by biological N fixation by legumes, ii) improved soil structure, iii) suppression of diseases and weeds, iv) release of growth-promoting substances and v) increased mycorrhizal activity (Janzen & Schaalje 1992). Use of green manure crops with deep root systems may also improve N supply to subsequent shallow-rooted crops by lifting leached N from deeper soil layers (Thorup-Kristensen 2006).

### **Improved N cycling**

However, due to the large N concentrations in a green manure crop, N from green manure is at risk of being lost from the cropping system (Breland 1996 a, b; Askegaard et al. 2005), and the practice of leaving the herbage as mulch after repeated mowing increases this risk (Larsson et al. 1998) both through gaseous emissions ( $\text{NH}_3$ ,  $\text{N}_2\text{O}$  and  $\text{NO}$ ), and surface runoff or leaching of  $\text{NO}_3^-$  and soluble organic N. High risk of N losses is a hazard for the environment and a reduction of the fertilizer value. Therefore it is not compatible with a sustainable development of organic farming. The N recovery in subsequent crops is measured to be between 6 and 53 % of the residue N (Ladd et al. 1983; Ladd & Amato 1986; Müller & Sundman 1988; Janzen et al. 1990; Wivstad et al. 1996; Mayer et al. 2003). It is, however, not known how large part of the N that is lost through leaching or gaseous emissions and how large part that is built into soil organic matter and available for subsequent crops. Fast N mineralisation from green manure may occur even in cold soil, and this is important for optimizing green manure management, but it is not included in current modelling approaches and our general understanding.

In two Scandinavian field studies, little difference was found on the N effect of green manure on succeeding crops when the harvested herbage was left or removed in the field (Solberg 1995; Wivstad 1997). This may indicate that the N utilization of mowed plant material as mulch in another vegetable field may be more efficient and sustainable than leaving the green manure herbage on the stubble (Riley et al. 2003). The practice of green mulching has become common in organic agriculture on areas with horticultural crops (Larsson et al. 1998; Riley et al. 2003). In organic stockless cereal production there are no opportunities for such use. An

alternative could be the conservation during the winter as hay, silage, compost, or using other processes, for early incorporation in the spring before sowing the barley crop (NB: in Norway barley is grown only as a spring cereal). Wivstad (1997) found that addition of ensiled green manure would have smaller effect on a succeeding crop than fresh or dried herbage, but would contribute more to soil organic N. One interesting method could be to use the harvested green manure for biogas production, and then use the slurry from anaerobically digested green manure foliage as manure for barley.

### **Improved farm N cycling from anaerobic digestion of green manure foliage**

Application of biogas slurry from anaerobically digested green manure foliage may seem a promising option for improved yields and N recovery in organic stockless farming instead of mulching *in situ* or ploughing under the green manure as is current practice (Hansson & Christensson 2005; Svensson 2005). The green manure is collected, thus the risk of ammonia loss and N leaching from the mulch is reduced. Also, the N leaching from the field during winter is reduced (Björnsson et al. 2001). In the biogas reactor the easily degradable organic matter is used for methane (CH<sub>4</sub>) production, which can be used for heating or fuel, while organic N compounds are mineralised. If properly managed, the resulting biogas slurry can be a valuable fertilizer, and the application timed with the crop nutrient requirements in the subsequent season (Elfstrand 2007). Due to the low carbon content, denitrification is expected to be lower from biogas slurry than from fresh undigested biomass (Hansson & Christensson 2005; Möller et al. 2006).

In Norway there are only a few biogas reactors, and these are mostly centralized biogas plants that digest sewage effluents and household waste; only two biogas reactors digest animal manure. In other countries, farm-based biogas reactors are much more widespread, for example in Sweden, Denmark and Germany.

In general there are few biogas reactors that digest crop residues, and there is little in the literature on the fertilizer value of biogas slurry from anaerobically digested green manure (Hansson & Christensson 2005), as most of the attention has been on the biogas (methane) production. Increased yields of beetroot and wheat, as well as increased N yield and N use efficiency were reported when green manure in an organic farming system was digested in a biogas reactor and applied as fertilizer for the subsequent crop compared with the general practice (Hansson & Christensson 2005; Gunnarsson et al. 2006). The content of ammonium in biogas slurry is relatively high; thus the risk of ammonium-N losses when biogas slurry is applied is high. Because earthworms are sensitive to high ammonium concentrations (Curry 1976), the effect on earthworms should be evaluated.

Temperature and substrate influence the anaerobic digestion process, and the economically interesting factors being the methane yield and the resulting biogas slurry.

Depending on the yield of the grass-clover ley or green manure, the methane yield from anaerobic digestion can range from 600 to 1000 m<sup>3</sup> per hectare. The profitability of farm-scale biogas systems depends on several factors: investment and operational costs, biogas utilisation and price (Morken et al. 2005), and not at least the value of the biogas slurry as fertilizer. In organic farming fertilizer generally has a high value because it often is the factor limiting crop yields. Organic farmers are frequent among those having newly established, farm-scale digesters in Sweden. Therefore Lantz et al. (2007) conclude that: "It is thus likely that organic farmers could function as prime movers in the wider implementation of the biogas system in Sweden, especially for biogas systems based on ley crops".

### **Feed quality of organic barley**

Feed concentrate of barley is mainly an energy source for ruminants, pigs and poultry. In addition it is a source of protein. The content of digestible energy (DE) in the grain is best explained by hectolitre weight and starch content (Taugbøl et al. 2007; Brand & Swart 1999).

Well-filled grain is heavier and contains more starch and less fibre, and thus has higher energy content. A measure for grain weight is 1000-kernel weight, however hectolitre weight is the international quality measure in the grain trade. Hay and Walker (1994) state that individual grain weight can be increased, reduced or unaffected by N fertilization. Eltun (1996) found higher individual grain weight in organic oats, lower in organic spring wheat and no difference in organic barley as compared to grown conventionally. There is little in the literature regarding how much the hectolitre weight and energy content are affected by different organic farming systems, including stockless arable farming with green manure. Little is reported in the literature on protein content in barley grown in organic farming systems.

### **Soil structure and earthworms**

Soil structure is important for the development of the barley crop, both to create good conditions for root growth and for turnover of soil organic matter. Many authors have observed a positive effect of green manure on soil structure (MacRae & Mehuys 1985; Latif et al. 1992; Breland 1995). The positive effects on soil structure are caused by root growth and increased food supply for soil organisms. One year of green manure is however not much, and it has so far not been investigated how large improvements in soil structure are that can be achieved in stockless systems under Norwegian conditions.

Because earthworm activity is important to improve and maintain soil structure and aggregate stability (Edwards & Lofty 1977; Marinissen 1994), the effects of green manure management on earthworm activity is important to measure.

Pommeresche et al (2006) found that one year of grass-clover leys in a four year cereal crop rotation, resulted in high numbers and biomass of earthworms, comparable with that found in grassland forage producing systems. In this study the green manure leys were mowed and mulched *in situ* several times. This finding supports the idea that one intensive year of “feeding” the soil, can increase soil structure and soil nutrient status. However, the effect on earthworms or other soil organisms when green manures are removed and subsequently returned as biogas slurry instead of being mulched is not known. It is reasonable to expect that it will not be as positive, since there will be less food available for the soil organisms when biogas slurry is applied as compared to when the green manure is mulched.

Short-term effects on soil structure can be difficult to assess by traditional soil physical methods, but can be visually assessed (Ball et al. 2007). Several methods have been developed for visual soil assessment (Boizard et al. 2005), also for Scandinavian conditions (Gustafson-Bjuréus & Karlsson 2002; Berglund 2003; Kolsrud et al. 2005).

### **Nutrient planning program**

Suitable tools or schemes are lacking in terms of assisting farmers in the complex within N management considerations. The most commonly used Norwegian program for fertilization planning (Skifteplan) is currently under extensive revision (working title GJØK) in a ongoing SLF project “Gjødslingsplanleggingsverktøy tilpasset økologisk drift”. This revised version is especially designed for organic farming. In relevance to objectives in this project the model will operate with important N dynamic processes incorporated (Fystro et al., 2005). This includes weather conditions as driving variables, dynamics of organic C and N pools, estimates of plant available N and N losses, and dry matter yield responses as related to N concentrations in plant materials. To obtain improved yields quality of feed barley on organic stockless farms, and still ensure effective and environmental friendly production systems, detailed knowledge is needed on the plant and soil N processes.

### **3. Research tasks (Forskningsoppgaver)**

Organic waste from households and industry may also be used to improve the nutrient supply of cereal production in stockless systems. However, on the larger scale, their use can supplement, but not replace the use of green manure in the rotation. There is a need for more specific knowledge in green manure management adapted to Norwegian conditions. This work will focus on the potential to improve cereal yields through a better management of green manure on stockless farms and the corresponding environmental challenges.

Insufficient N supply often limits barley yields in organic farming systems, while green manure may increase the N pollution. There is the potential that digestion of harvested green manure may facilitate its use as a N source, but it may also have some environmental and agronomic drawbacks. Therefore the main research task will be to investigate how green manure management (with or without production of biogas) can be improved in order to optimize the N cycling and utilization. Since cereal quality is essential for the value of the feed concentrate, we want also to investigate how the various green manure treatments are affecting key grain quality parameters. Due to the difficulties in maintaining a high soil organic matter (SOM) content and a good soil structure in cereal monoculture, and their importance for barley in organic systems, attention will be given to these aspects.

#### ***Tasks related to sub objective 1 - Improved productivity and N cycling***

To investigate the possibility of improving the N cycling and utilization of N we focus on yield response, N uptake in barley, changes in the level of mineral N in the soil, and (model simulated) N losses and N balances related to selected green manure strategies in whole year green manure. Because subcropping is intensively studied in project “Repeated subcropping as a strategy for commercial organic grain production” (funded by the Research Council of Norway), and the risk of N pollution is larger with whole year green manure, we choose in the present project to focus on whole year green manure.

#### **Hypotheses**

- 1.1 N losses from the field are less when green manure herbage is removed than if it is mulched in the season preceding the barley crop
- 1.2 Higher N fixation and lower N losses are achieved when two out of three green manure harvests are removed, than if all three green manure harvests are mulched, but barley yields the subsequent year will remain the same.
- 1.3 Fast N mineralisation from green manure may occur even in cold soil
- 1.4 Green manure herbage that is collected from the field, anaerobically digested for biogas production, and applied as biogas slurry in the subsequent growing season will reduce N losses, increase soil mineral N availability in the spring, and increase barley N uptake and yield compared with when the green manure is repeatedly mulched the preceding season.
- 1.5 Temperatures and substrates used during fermentation of green manure herbage will affect the nutritional effect of biogas slurry

#### ***Tasks related to sub objective 2 – Feed quality***

To study key feed quality parameters in barley with regard to energy and protein content as affected by different green manure management strategies and locations.

#### **Hypothesis**

- 2.1 N supply synchronized to the high demand during phases of rapid growth will result in a higher feed quality of barley

### ***Tasks related to sub objective 3 – Soil structure and earthworms***

The most suitable assessment methods to identify soil structural changes that may effect barley growth will be selected and used to study the impact of green manure on soil that have been under intensive arable conventional cropping. We will also implement the results of the work done by Kolsrud et al. (2005) on assesement of soil structure on organic farms with cereals. Because earthworm activity is important to improve and maintain soil structure and aggregate stability (Edwards & Lofty 1977; Marinissen 1994), the effects of green manure management on earthworm activity will also be determined.

### **Hypotheses**

- 3.1 Beneficial effects on soil structure and earthworm population are greater when the green manure herbage is mulched than if removed.
- 3.2 Return in the subsequent growing season of biogas slurry produced on removed green manure herbage does not benefit soil structure and earthworm population.

### ***Task related to sub objective 4 - Nutrient plan programme***

The gained knowledge on possibilities for improved yields and quality of feed barley on organic stockless farms will be utilized to make adjustments in the GJØK model for nutrient management decisions where farmers and advisors are intended users. The present project will supply the knowledge gained in the project: “Baking quality of Norwegian organic wheat” (application to NFR in this similar round).

**Hypothesis 4.1 :** A simplified model adapted for practical nutrient planning can predict both the N supply from various green manure and biogas slurry regimes, and the yield and feed quality response to N availability in organic stockless barley production.

## **4. Research approach, methods**

Since the field trials will serve all research tasks they are mentioned first

### **Field trials**

Four year field trials with one year whole-year green manure will be used to work out the research tasks. A green manure mixture of clover and grass will be undersown (GMU) in barley in the season preceding the green manure. The consecutive year green manure will be ploughed in spring, and barley will be sown. The following green manure treatments will be included; chopped and left as green mulch on stubble, removed, partly removed, fertilizing with biogas slurry, controls.

Nitrogen will be tracked through the green manure period, and in the subsequent barley year. The effects on earthworms will be assessed in autumn after green manure and the subsequent barley year, and soil structure in the barley year.

The trials will be placed on four locations on soils where cereals have been the dominant crop. The locations are the Norwegian Institute for Agricultural and Environmental Research (Bioforsk) at Kvithamar in central Norway 2 fields (silty clay loam and sandy loam) and Apelsvoll in central southeastern Norway (loam) and at the University of Life Sciences (UMB) silty clay.

### **WP 1.1 Improved productivity and N cycling**

The N-dynamics (microbial decomposition of organic matter, plant N uptake, leaching and denitrification losses) will be estimated by means of the Soil Plant Nitrogen model SPN and the EU-Rotate model. SPN is a mechanistic model simulating the combined plant (KONOR, bleken 2001 ) and soil microbial responses (SOIL\_NO, Vold et al 1999) to weather conditions

on a one-day time step. This model is comparable to other internationally known models as DAISY (Hansen 1990) or Apsym (NcCown 1996), but developed and tested under Norwegian conditions (Vatn et al. 2006). SPN it is presently used in a NFR funded project on the effect of climate change (Ecology and economy of agriculture in a changing climate, Bakken et al. 2004, Bleken and Bakken 2004). It has also been recently successfully adapted to silage maize in Northern Germany (Bleken et al. 2007), which demonstrates that the model has a potential for performing well under a wide range of conditions and crops. In particular the algorithms and parameters for the leaf area development have been developed for barley cultivars grown under Norwegian conditions. This is a highly important aspect of the model, since the leaf area development, and thus the potential photosynthetic activity, is proportional to the amount of nitrogen present in the shoot.

Also the EU-Rotate model which has recently been developed in an EU (FP5) project will be used. This model has special focus on simulating rotation effects, root growth effects, and effects of green manures in organic rotations, but less focus on precise crop growth simulation. Data from the project will be used in the work on improving specific aspects of this model, especially on mineralization effects of longer term green manures with repeated mulching and continuous litter loss, and on N mineralization at low soil temperatures which is of especial importance under Scandinavian conditions.

Specifically chosen control plots will be used for the initialization and partial calibration of the microbial processes in the soil. The incubation trials will provide knowledge for characterization of the added organic matter (green manure pre-crop, green manure mulch and biogas slurry). Further, soil taken from the field plots at incorporation time, and incorporated under outdoor temperature conditions. This will give more precise information about the effect of green manure management regimes on mineralization and on mineralization under the realistic cold soil conditions. Such data will be very valuable both for improving the models, and for making realistic simulations of the specific management systems tested in this experiment.

Information from the incubation trials will be used in the models, and the remaining treatments of the field trials (other than the control) will be used for the validation of the model.

In the studies of the decomposition of the added biomass in the incubation trials, ad hoc submodels, based on both SPN and EU-Rotate will be used.

The most important direct measurements will be:

- Content and concentrations of N in the harvests of green manure and biogas slurry
- Yields and N uptake in barley the subsequent year through the growing season
- Soil mineral N ( $\text{NO}_3\text{-N}$  and  $\text{NH}_4\text{-N}$ ) will be determined in relevant depths depending of soil layers and root growth of each field at selected occasions

SPN and EU-Rotate will be used to estimate the extent of processes that are not directly measured ( $\text{N}_2\text{O}$  and N-leaching), to interpolate between measured points (e.g., regarding mineral-N in soil and uptake in plants), and to simulate combinations of climate and soil conditions not covered in the field experiments. The model can then be used to make more general hypothesis. The use of the models will be necessary in order to analyse the results and to draw general conclusions out of them.

### **WP 1.2. Anaerobically digested green manure residues as fertilizer**

We will study the fertilising effect of green manure herbage anaerobically digested in a biogas reactor. Factors affecting the anaerobic digestion process (high N vs. low N green manure substrate; high mesophilic vs. low mesophilic conditions) will be tested in laboratory-scale

experiments to evaluate the effect on plant nutrient content in the resulting biogas slurry. In the first phase of the project, pot experiments with barley fertilised with biogas slurry from the laboratory-scale experiment will be carried out in a growth chamber to assess biomass yield and plant nutrient content of the barley. Thorough chemical analyses of the biogas slurry will be carried out, with emphasis on N compounds and S. In addition, the methane (CH<sub>4</sub>) production in the laboratory-scale and small-scale biogas reactors will be measured. In the field block experiments, biogas slurry based on green manure digested in a small-scale reactor will be applied to the “biogas slurry” treatment in amounts equivalent to the green manure that was removed the preceding season. Soil and crop parameters will be recorded in the field as for the other treatments.

## **WP 2. Feed quality**

This WP will include studies of key feed quality parameters of barley grain grown in the block experiments. Emphasis will be on energy and protein content. The first factor is location (different soil types and climate / weather), which is likely to influence barley grain energy and protein content. The second factor is green manure treatment, which will affect N supply and availability, and correspondingly barley N uptake and protein content as well as grain filling and energy content. Parameters to analyse are: hectolitre weight, starch content, crude protein and ash content. Neutral detergent fibre (NDF) and 1000-kernel weight will be analysed if yield or hectolitre weight are very variable.

## **WP 3. Soil structure and earthworms**

### ***Soil structure***

In the year with barley subsequent the green manure, soil structure will be visually assessed mainly following the methods of Shepherd (2000), Shepherd et. al. (2002) and Gustafson-Bjuréus & Karlsson (2002). These methods will be slightly modified and adapted to Norwegian cereal growing farms. The visual assessments will be combined with aggregate stability and aggregate size registrations.

### ***Earthworm activity***

Earthworm data will be sampled at Kvithamar, in each of two soil types, from four treatments (1-4) and four replicates. Samples will be taken from established green manure (autumn 2009 and 2010) and the barley the year after (2010 and 2011). Earthworms will be hand-sorted from one soil block (30 cm x 30 cm x 25 cm depth) in each replicate and treatment. Mustard water will be pored into the hole of the soil block to search for deep-burrowing large earthworms, which may be underrepresented using the former method. The density of juvenile and adult worms and the dead, fresh biomass will be measured. The identification of species will be according to (Sims & Gerard 1999).

## **WP 4. Nutrient plan programme**

Important knowledge gained in this project will be implemented in the planning tool GJØK designed for farmers and advisers as intended users. This model will be improved according to the revealed needs for management decisions important to obtain improved yields and quality in organic barley productions, and in accordance to basic principles of organic farming (as acceptable N losses). Interactions between yield and quality responses to the complex of plant N supply will be looked into. Processes that includes soil structure are not yet implemented, and a model development will be considered within this project. Existing and gained knowledge within the WPs in this project will be used. Calibration and adjustments of the model will be performed on the basis of results from the diverse studies outlined, the SPN simulations also important for GJØK improvements. Selected field data results (treatments within years) will be used as independent data sets for a proper test (hypotheses 4.1) on the



prediction potential of the present being GJØK model. Possible identified needs for adjustment will be performed.

## **5. Project organisation and management**

The planned project is a collaboration between Bioforsk and the Norwegian University of Life Sciences (UMB) and is managed by Bioforsk Organic Food and Farming Division (BOFF). Project leader will be Dr Sissel Hansen (BOFF).

**WP 1.1** will be lead by Dr Sissel Hansen and carried out in close cooperation with the Department of Plant and Environmental Sciences (IPM) at UMB (responsible: Dr Marina A Bleken), Bioforsk Grassland and Landscape Division (responsible: Dr Anne Kjersti Bakken), Bioforsk Arable Crops Division (BACD, responsible: Dr Ragnar Eltun), researcher Randi B Frøseth (BOFF) and Prof. Kristian Thorup-Kristensen (Head of research unit, Horticulture Research Centre Aarslev, Faculty of Agricultural Sciences, Aarhus University).

**WP 1.2** will be administered by researcher Jon Magne Holten (BOFF). Responsible research scientist will be Dr Tormod Briseid (Bioforsk Soil and Environment). This WP will be carried out in close cooperation with Department of Biotechnology at Lund University (Prof. Bo Mattiasson) and Agellus Miljökonsulter (responsible: Kjell Christensson), Sweden.

**WP 2** will be lead by researcher Jon Magne Holten (BOFF) and carried out in close co-operation with the Norwegian feed industry.

**WP 3** will be lead by Dr Sissel Hansen and carried out in close cooperation with Bioforsk Arable Crops Division (responsible for soil structure assessments: Prof. Hugh Riley) and responsible for earthworm registrations researcher Reidun Pommeresche (BOFF).

**WP 4** will be lead by Dr. Gustav Fystro (BACD).

In addition to the scientists involved in carrying out the research, there will be a reference group consisting of representatives from the Norwegian feed industry, persons in the organic agriculture extension service working on cereal farming and soil fertility, and organic cereal growers growing green manure.

Bioforsk is a national R&D institute under the Norwegian Ministry of Agriculture and Food. The main areas of competence are linked to food quality and safety, agriculture and rural development, environmental protection and natural resources management. Bioforsk has a staff of about 500, with an annual turnover of some €40 million. Bioforsk encompasses a wide range of competence within natural sciences, with long traditions in field- and laboratory-based experimental studies.

Bioforsk Organic Food and Farming Division (BOFF) coordinates Bioforsk's many projects regarding organic agriculture. BOFF is also the main link to organic research internationally and to organisations involved in the development of organic agriculture world-wide.

The Department of Plant and Environmental Sciences (IPM) at the Norwegian University of Life Sciences (UMB) has a strong interdisciplinary group of researchers involved in dynamic modelling of soil and plant processes. This group is has developed and is continuously improving the SPN model. IPM has also a tradition in research and teaching of organic farming, also at PhD-level.

## **6. International co-operation**

Through the cooperation with Prof. Kristian Thorup-Kristensen, DK, this work will be connected to the projects VegQure (<http://www.veggure.elr.dk/>) and "Effect of crop management practices on the sustainability and environmental impact of organic and low input food production systems" [http://www.qlif.org/qlifnews/feb\\_07/keynote7.html](http://www qlif.org/qlifnews/feb_07/keynote7.html). This project is a part of QualityLowInputFood (QLIF), which is an integrated project funded by the European Commission. For many years Prof. Thorup-Kristensen has worked with N-dynamics in green manure and on how to increase N-efficiency in organic farming systems. In the present

project he will participate in detail planning of experiments and model N-dynamics in the green manure systems. He will further use the data from this project to validate his models.

The Swedish group that works on biogas in Lund (Dept. of Biotechnology, Lund University and Agellus Miljökonsulter) will provide competence on biogas technology and the production and application of biogas slurry in organic agriculture. This group has been developing technology for biogas production from crop residues that can be reliable and profitable at farm scale. They also have worked on the integration of farm based biogas systems in stockless conventional and organic farming to increase the recycling of nutrients.

## 7. Progress plan - milestones

Activities	2008				2009				2010				2011			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Detailed planning with all partners and reference group	x	x														
Field trials running		x	x			x	x			x	x			x	x	
Incubation studies green manure herbage			x	x												
Modelling N-dynamics	x	x		x	x			x	x			x	x	x	x	x
Pot trials green manure/biogas slurry		x	x													
Feed quality assessments											x				x	
Soil structure assessments											x				x	
Earthworms registrations											x				x	
Annual project meeting	x				x				x				x			
Planning and implementations to GJØK	x						x	x	x	x	x	x	x	x	x	X
Publishing					x			x	x			x	x	x	x	X

## 8. Costs incurred by each research performing partner (in NOK 1000)

Executive partner	Payroll and indirect expenses	Equipment	Other operating expenses	Total
Bioforsk	3972		1067	5039
UMB	530			530
Aarhus University	400			400
Dept. of Biotech, LU	115			115
Agellus Environ. Consultants	115		60	175

## 9. Financial contribution by partner (in NOK 1000)

	2008	2009	2010	2011	Total
FK Agri *	60	60	60	60	240
Norgesfôr/Unikorn AS	20	20	20	20	80
Fiskå Mølle	20	20	20	20	80
Norwegian Research Council	527	761	811	830	2929

Fondet for forskningsavgift på landbruksprodukter	264	381	405	415	1465
Forskningsmidler over jordbruksavtalen	264	381	405	415	1465
Total	1155	1623	1721	1760	6259

\* to be clarified after the application deadline.

## **PART 2: Exploitation of results**

### **9. Relevance for knowledge-building areas**

The project is directed towards a call for proposals regarding competitive primary production and is aiming at feed concentrates producers which produce is of significant importance for the meat and dairy sector.

The project's most important contribution is reducing a major obstacle for stockless cereal growers to convert to and remain in organic cereal production, namely crop nutrient supply through green manure management and biogas slurry application

The methodology and results from the research project will be of great importance for research based teaching at the Norwegian University of Life Sciences (UMB). Marina Bleken is responsible for that as lecturer in agroecology at UMB. The direct link to students will ensure that new knowledge is effectively communicated, and that new methods will be implemented. Master students as well as a PhD student will be involved in the project and make use of the available field trial facility at Vollebekk experimental farm at UMB. The build-up of new competence within farm-scale biogas systems based on crop residues, and the laboratory biogas trials, can also be incorporated in teaching at UMB. Cooperation with the Swedish group at Lund University on biogas and AGRSCI in Denmark is an added value of the project.

### **10. Importance to Norwegian industry**

Increased consumer demand for organic products, in particular organic dairy, pork and poultry products, has spurred domestic demand for organic feed concentrates, which is currently exceeding supply (FK Agri, pers. comm., 2007<sup>1</sup>). In May 2007, FK Agri imported 6 000 tonnes of organic cereals at a high price, mainly from Argentina, for organic feed concentrates production. If domestic production of organic cereals does not increase, this shortage and the corresponding import of organic cereals will persist for many years. This will reduce the credibility of organic food (e.g. Nationen, 23 April 2007; VG, 7 May 2007<sup>2</sup>), as well as reduce the domestic market for Norwegian cereals in general. However, conversion to organic farming in the major cereal growing areas is limited because farmers do not expect to meet their production goals.

<sup>1</sup> Aslak Hauge, FK Agri, pers. comm., 2007.

<sup>2</sup> - Må importere økokraftfôr. Nationen, 23 April 2007.

Source: <http://www.nationen.no/landbruk/article2731325.ece>

- Miljøkrise for økologisk mat. Verdens Gang, 7 May 2007.

Source: <http://matportalen.no/Saker/1178521004.58>

The potential for added value due to the results of the project is high because improved green manure management strategies can increase organic feed grain yields and the adoption of organic stockless arable farming.

The current Norwegian coalition government's position paper, the so-called "Soria Moria declaration", states the aim of achieving 15 % organic production and consumption by the year 2015.

Furthermore, the potential for adoption of farm-scale biogas systems in organic as well as conventional agriculture is high in a medium to long-term perspective.

## **11. Relevance for call for proposals and programmes**

Relevance for call for proposals:

*Competitive primary production – Organic production and sales.*

This project is aiming for higher production volume of organic feed grain to supply the increasing organic feed market, and subsequently to meet the increasing domestic demand for organic animal dairy and meat products. The project is doing so by enabling organic farmers to increase their organic cereal production, and meeting their production goals.

Furthermore, the project is relevant for the RENERGI programme, as biogas production is a renewable energy source. It also has relevance for the NORKLIMA programme as farm biogas systems has a potential of reducing the emissions of greenhouse gases like N<sub>2</sub>O.

## **12. Environmental impact**

Better knowledge on the N-dynamics of green manure systems is an important tool to create methods that increase N-utilisation and reduce potential N losses and pollution of watercourses and the atmosphere. Since whole year green manure production is a common practise on stockless organic farms, such improvements are crucial for the sustainability of stockless organic farming systems.

## **13. Information and dissemination of results**

Preliminary titles of some of planned papers in international scientific journals:

- Effects of various green manure management strategies on N cycling and efficiency on stockless organic farms.
- Effects of temperature and substrate on the fertilizing effect of anaerobically digested green manures.
- Effects of various green manure management strategies on yield and quality of organic feed barley.
- Short-term effects of green manure and biogas slurry on earthworm populations and soil structure.

*Presentations and posters at international conferences and workshops:*

*Target group:* International scientists.

*Relevant workshops and conferences:* 'Quality Low Input Food' conferences in 2009.

*Relevant results exploited by end-users.*

*Target group:* The extension service, farmers and feed industry.

- Presentations at relevant national congresses

- Papers in relevant periodicals
- Web page with regular updates on activities and results
- Interactive meetings with feed industry, farmers, extension service and researchers in the beginning of the project period as reference partners.
- The project team including the active project partners will assist in disseminating the project results among farmers.
- The results of the project will be implemented in GJØK and will through this directly influence the planning of fertilization and crop management on organic farms

## References

- Abrahamsen, S. 2006, "Erfaringer fra praktisk økologisk byggdyrking" Bioforsk FOKUS vol. 1 no. 3, pp 66-67. (In Norwegian)
- Askegaard, M., Olesen, J. E., & Kristensen, K. 2005, "Nitrate leaching from organic arable crop rotations: effects of location, manure and catch crop", *Soil Use and Management*, vol. 21, no. 2, pp. 181-188.
- Bakken, L.R., Bleken, M.A., Haugen, L.E., Lundekvam, H. and Rørstad, P.K. 2004, *Impacts of global change on agroecosystems, preliminary analyses for Southeast Norway: General summary*. EACC report, NLH report 1/2004, pp. 19. [http://www.umb.no/forskning/mildri/publikasjoner/eacc\\_report1.pdf](http://www.umb.no/forskning/mildri/publikasjoner/eacc_report1.pdf)
- Ball, B. C., Watson, C. A., & Baddeley, J. A. 2007, "Soil physical fertility, soil structure and rooting conditions after ploughing organically managed grass/clover swards", *Soil Use and Management*, vol. 23, no. 1, pp. 20-27.
- Berglund, K., Berglund, Ö., & Gustafson, B. A. 2003, "Soil Structure Index – a method to evaluate the physical status of the soil and the effect of the farming system on soil structure.", in *Proceedings of the Nordic Association of Agricultural Scientists 22nd Congress, July 1-4 2003, Turku, Finland, Nordic agriculture in Global Perspectiv*, SLU, p. 394.
- Björnsson, L., Batstone, D., Christensson, K., & Mattiasson, B. "Agrigas - biogas production from crop residues", W. Verstraete & L. van Velsen, eds., Antwerpen, pp. 561-567.
- Bleken, M.A. 2001, *KONOR: A Modell for Simulation of Cereal Growth. Documentation*. Agricultural University of Norway, report 2/2001, 33 pp. ISBN: 2-483-0011-0, ISSN: 1500-3469. [http://www.umb.no/forskning/mildri/publikasjoner/konor\\_doc.pdf](http://www.umb.no/forskning/mildri/publikasjoner/konor_doc.pdf)
- Bleken, M.A. and Bakken, L.R. 2004, *Impacts of global change on agroecosystems, preliminary analyses for Southeast Norway: Plant growth and soil N analysis*. EACC report, NLH report 6/2004, pp.24. [http://www.umb.no/forskning/mildri/publikasjoner/eacc\\_report6.pdf](http://www.umb.no/forskning/mildri/publikasjoner/eacc_report6.pdf)
- Bleken MA, Herrmann A, Haugen LH, Bakken LR and Taube F. (2007). SPN: a model for studying the soil-plant N cycle and N losses of silage maize production. Poster presented at the 15th N workshop, Lleida, 27-30 May 2007. Short article in *Proceedings* (in press).
- Boizard, H., Batey, T., McKenzie, D. C., Richard, G., Ball, B., Bradley, I., Cattle, S., Hasinger, G., Munkholm, L., Murphy, B., Nievergelt, J., Peigné, J., & Shepherd, G. 2007, *Field meeting "Visual soil structure assessment" held at the INRA research station, Estrés-Mons, France 25-17 May 2005*, INRA.
- Brand, T. S. & Swart, C. J. 1999, "Relationship between various physical and chemical measurements on barley grain and its nutritive value measured by in sacco and in vitro methods", *Journal of Applied Animal Research*, vol. 15, no. 2, pp. 153-163.
- Breland, T. A. 1995, "Green manuring with clover and ryegrass catch crops undersown in spring wheat: effects on soil structure", *Soil Use and Management*, vol. 11, pp. 163-167.
- Breland, T. A. 1996a, "Green manuring with clover and ryegrass catch crops undersown in small grains: Crop development and yields", *Acta Agriculturae Scandinavica Section B-Soil and Plant Science*, vol. 46, no. 1, pp. 30-40.
- Breland, T. A. 1996b, "Green manuring with clover and ryegrass catch crops undersown in small grains: Effects on soil mineral nitrogen in field and laboratory experiments", *Acta Agriculturae Scandinavica Section B-Soil and Plant Science*, vol. 46, no. 3, pp. 178-185.
- Christensen, B.T., 1990. Long-term changes in soil organic matter of three experiments: effect of fertilization, straw incorporation and crop rotation. In "Decomposition and Soil Organic Matter", Nordic Assoc. Agric. Scientists Seminar Report no. 57, 123-128.
- Cormack, W. F., Shepherd, M., & Wilson, D. W. 2003, "Legume species and management for stockless organic farming", *Biological Agriculture and Horticulture*, vol. 21, no. 4, pp. 383-398.
- Curry, J. P. 1976, "Some effects of animal manures on earthworms in grassland", *Pedobiologia*, vol. 16, pp. 425-438.
- Edwards, C. A. & Lofty, J. R. 1977, *Biology of earthworms*, 2.edition edn.
- Elfstrand, S. 2007, *Impact of Green Manure on Soil Organisms With Emphasis on Microbial Community Composition and Function*, PhD, Faculty of Natural Resources and Agricultural Sciences, Department of Soil Sciences, Swedish University of Agricultural Sciences.

- Eltun, R. 1996, "The Apelsvoll cropping system experiment III. Yield and grain quality of cereals.", *Norwegian Journal of Agricultural Sciences*, vol. 10, no. 1, pp. 7-21.
- Frøseth, R. B. 2006, "Økologisk kornproduksjon: Næringsforsyning – helårs grønngjødsling". *Bioforsk TEMA* vol. 1, no. 31 (In Norwegian)
- Fystro, G, Abrahamsen S., Lunnan, T. 2005. "Utvikling av nye metodar for gjødslingsplanlegging". *Grønn kunnskap* vol. 9 no. 2, 52p (In Norwegian)
- Gustafson-Bjuréus, A. & Karlsson J. 2002, Markstrukturindex - utvärdering av en metod att bedöma odlingssystemets uthållighet och jordarnas fysikaliska status. Avdelningsmeddelande 02:2, Inst. för markvetenskap, avd. för lantbrukets hydroteknik, Swedish University of Agricultural Sciences (SLU), 167p.
- Gunnarsson, A., Gertsson, U., & Bohn, L. 2006, "Anaerobically digested crop material for improved nitrogen efficiency in a crop rotation with beetroot (*Beta vulgaris* var. *conditiva* Alef)", F. Tei, M. Benincasa, & M. Guiducci, eds., International Society for Horticultural Science, Perugia, Italy .
- Hansen, S., Jensen H.E., Nielsen N.E. and Svendsen K. 1990. *DAISY – Soil Plant Atmosphere System Model*. Np0-forskning fra Miljøstyrelsen nr. A10 1990, pp270. ISBN 87-503-8790-1
- Hansson, A. & Christensson, K. 2005, *Biogas energises organic farming (in Swedish)*, Swedish Board of Agriculture (Jordbruksverket), 22p
- Hay, R. K. & Walker, A. J. 1989. *An introduction to the plant physiology of crop yield*. Longman Scientific & Technical. New York. 292p
- Janzen, H. H. & Schaalje. B. 1992, "Barley response to nitrogen and non-nutritional benefits of legume green manure", *Plant and Soil*, vol. 142, no. 1, pp. 19-30.
- Janzen, H. H., Bole, J. B., Biederbeck, V. O., & Slinkard, A. E. 1990, "Fate of N applied as green manure or ammonium fertilizer to soil subsequently cropped with spring wheat at three sites in Western Canada", *Canadian Journal of Soil Science*, vol. 70, no. 3, pp. 313-323.
- Kolsrud, E., Næss, A. & Haugerud, Ø. 2005. "Jordstruktur i økologisk planteproduksjon - god økonomi = god økologi". Rapport nr.2. Fylkesmannen i Buskerud, Drammen. 40s. (In Norwegian)
- Kumar, K. & Goh, K. M. 2002, "Management practices of antecedent leguminous and non-leguminous crop residues in relation to winter wheat yields, nitrogen uptake, soil nitrogen mineralization and simple nitrogen balance", *European Journal of Agronomy*, vol. 16, no. 4, pp. 295-308.
- Ladd, J. N. & Amato, M. 1986, "The fate of nitrogen from legume and fertilizer sources in soils successively cropped with wheat under field conditions", *Soil Biology and Biochemistry*, vol. 18, no. 4, pp. 417-425.
- Ladd, J. N., Amato, M., Jackson, R. B., & Butler, J. H. A. 1983, "Utilization by wheat crops of nitrogen from legume residues decomposing in soils in the field", *Soil Biology and Biochemistry*, vol. 15, no. 3, pp. 231-238.
- Lantz, M., Svensson, M., Björnsson, L., & Borjesson, P. 2007, "The prospects for an expansion of biogas systems in Sweden - Incentives, barriers and potentials", *Energy Policy*, vol. 35, no. 3, pp. 1830-1843.
- Larsson, L., Ferm, M., Kasimir-Klemedtsson, A., & Klemedtsson, L. 1998, "Ammonia and nitrous oxide emissions from grass and alfalfa mulches", *Nutrient Cycling in Agroecosystems*, vol. 51, no. 1, pp. 41-46.
- Latif, M. A., Mehuys, G. R., MacKenzie, A. F., Alli, I., & Faris, M. A. 1992, "Effects of legumes on soil physical quality in a maize crop", *Plant and Soil*, vol. 140, no. 1, pp. 15-23.
- Løes, A-K. 2002. "Bygg og vårhvete – forskjeller og fellestrekk i næringskonsentrasjoner i plantevevet", *Forskningsnytt*, no. 2, pp. 9-11.
- Løes, A.-K., Henriksen, T. M., & Eltun, R. 2007, "N supply in stockless organic cereal production under northern temperate conditions. Undersown legumes, or whole-season green manure?", U. Niggli et al., eds., pp. 226-230.
- MacRae, R. J. & Mehuys, G. R. 1985, "The effect of green manuring on the physical properties of temperate soils", *Advances in Soil Science*, vol. 3, pp. 71-94.
- Marinissen, J. C. Y. 1994, "Earthworm populations and stability of soil-structure in a silt loam soil of a reclaimed polder in the Netherlands", *Agriculture, Ecosystems & Environment*, vol. 51, no. 1-2, pp. 75-87.
- Mayer, J., Buegger, F., Jensen, E. S., Schlöter, M., & Heß, J. 2003, "Residual nitrogen contribution from grain legumes to succeeding wheat and rape and related microbial processes", *Plant and Soil*, vol. 255, pp. 541-554.
- Mccown, R.L., Hammer, G.L., Hargreaves, J.N.G., Holzworth, D.P. and Freebairn, D.M. 1996, "Apsim: a Novel Software System for Model Development, Model Testing and Simulation in Agricultural Systems Research", *Agricultural Systems* 50, 255-271.
- Morken, J., Sørby, B., Sørby, I., Bikeland, K. & Sakshaug, S. 2005, "Bruk av bioenergi I landbruket. Er det lønnsomt å bygge gårdsbiogassanlegg, og hvilke fordeler kan bonden og samfunnet oppnå? *Grønn kunnskap*, vol 9, no. 121, pp. 30 p (In Norwegian)
- Möller, K., Stinner, W., & Leithold, G. 2006, "Biogas in organic agriculture: Effects on yields, nutrient uptake and environmental parameters of the cropping system", Odense, Denmark.
- Müller, M. M. & Sundman, V. 1988, "The fate of nitrogen (N-15) released from different plant materials during decomposition under field conditions", *Plant and Soil*, vol. 105, no. 1, pp. 133-139.
- Pommeresche, R., Hansen, S., Eltun, R., & Korsæth, A. 2006, "Long-term effects of cropping systems on the earthworm populations in a loam soil in southeast Norway," in *Proceedings of ISTRO 17th Triennial Conference*

28 Aug- 3 sept 2006, *Sustainability - its Impact on Soil Management and Environment*, R. Horn, ed., International Soil Tillage Research Organisation, ISTRO, Kiel, pp. 676-681.

Riley, H. & Bakkegard, M. 2006, "Declines of soil organic matter content under arable cropping in southeast Norway", *Acta Agric. Scand. Section B*, vol. 56, no. 3, pp. 217-223.

Riley, H., Loes, A. K., Hansen, S., & Dragland, S. 2003, "Yield responses and nutrient utilization with the use of chopped grass and clover material as surface mulches in an organic vegetable growing system", *Biological Agriculture & Horticulture*, vol. 21, no. 1, pp. 63-90.

Riley, H., Pommeresche, R., Eltun, R., Hansen, S., & Korsæth, A. 2007, "Soil structure, organic matter, earthworm activity and nutrient status in a comparison of cropping systems with contrasting tillage, rotations, fertilizer levels and manure use", *Agriculture, Ecosystems and Environment*.

Schmidt, H., Philipps, L., Welsh, J. P., & von Fragstein, P. 1999, "Legume breaks in stockless organic farming rotations: Nitrogen accumulation and influence on the following crops", *Biological Agriculture and Horticulture*, vol. 17, no. 2, pp. 159-170.

Shepherd, G. 2000, *Visual soil Assessment. Volume 1. Field guide for cropping and pastoral grazing on flat to rolling country*. Horizons.mw & Landcare Research, Palmerstone North. 84p

Shepherd, T. G., Sparling, G.P., Todd, M.D, 2002, Visual Soil Assessment: Can we see what we measure? Proc. Soil Quality and Sustainable Land Management Conference, Landcare Research, Palmerston North, New Zealand, pp. 117-122.

Sims, R. W. & Gerard, B. M. 1999, *Earthworms. Notes for the identification of British species*, 31 edn, The Linnean Society of London, London.

Solberg, S. Ø. 1995, "Nitrogen mineralization and after-year effects of green manure on certain soils in Southeast Norway", *Norsk Landbruksforskning*, vol. 9, pp. 117-132.

Stopes, C., Millington, S., & Woodward, L. 1996, "Dry matter and nitrogen accumulation by three leguminous green manure species and the yield of a following wheat crop in an organic production system", *Agriculture Ecosystems and Environment*, vol. 57, no. 2-3, pp. 189-196.

Svensson, M. 2005, *The Technology and Economy of Farm-Scale, High-Solids Anaerobic Digestion of Plant Biomass*, PhD, Department of Biotechnology, University of Lund.

Taugbøl, O., Abrahamsen, U., Anker-Nilssen, K., Hetland, et al. 2007, "Bruk av norske kraftfôrråvarer til husdyr". *Bioforsk FOKUS*, vol. 2, no. 1, pp. 90-91. (In Norwegian)

Thorup-Kristensen, K. 2006, "Effect of deep and shallow root systems on the dynamics of soil inorganic N during 3-year crop rotations", *Plant and Soil*, vol. 288, no. 1-2, pp. 233-248.

Uhlen, G. 1991, "Long-term effects of fertilizers, manure, straw and crop rotation on total-N and total-C in soil", *Acta Agriculturae Scandinavica*, vol. 41, pp. 119-127.

Vatn, A., Bakken, L.R., Bleken, M.A., Baadshaug, O.H., Fykse, H., Haugen, L.E., Lundekvam, H., Morken, J., Romstad, E., Rørstad, P.K., Skjelvåg, A.O. and Sogn, T. 2006, "A methodology for integrated economic and environmental analysis of pollution from agriculture", *Agricultural Systems* 88(2-3): 270-293.

Vold, A., Breland, T.A., Sørensen, J. 1999, "Multiresponse estimation of parameter values in a model of soil carbon and nitrogen dynamics", *Journal of Agricultural, Biological, and Environmental Statistics* 4:290.

Wivstad, M. 1997, *Green-manure crops as a source of nitrogen in cropping systems* Doctoral thesis, Swedish University of Agricultural Sciences.

Wivstad, M., Salomonsson, L., & Salomonsson, A. C. 1996, "Effects of green manure, organic fertilizers and urea on yield and grain quality of spring wheat", *Acta Agriculturae Scandinavica Section B-Soil and Plant Science*, vol. 46, no. 3, pp. 169-177.

Ögren, E., Båth, B., & Ramert, B. 1998, "First and second year nitrogen effects of autumn and spring-incorporated green-manure crops in field vegetable production", *Swedish Journal of Agricultural Research*, vol. 28, no. 3, pp. 137-146.