Sustainable Organic and Low-input Dairying (SOLID)

Sprawozdania

Informacje na temat projektu

SOLID

Identyfikator umowy o grant: 266367

Projekt został zamknięty

Data rozpoczęcia
1 Kwietnia 2011

Data zakończenia
31 Marca 2016

Finansowanie w ramach
Specific Programme "Cooperation": Food, Agriculture and Biotechnology

Koszt całkowity
€ 7 754 042,49

Wkład UE
€ 5 955 858,00

Koordynowany przez
ABERYSTWYTH UNIVERSITY
United Kingdom

Final Report Summary - SOLID (Sustainable Organic and Low-input Dairying (SOLID))

Executive Summary:
The SOLID (Sustainable Organic and Low Input Dairying) project considered organic and low-input cow and small ruminant (sheep and goat) systems with partner organisations representing the wide geographical and farm system diversity across Europe. The objective was to support developments and innovations in these dairy systems to optimise competitiveness for a sustainable and profitable dairy industry in Europe, whilst also (i) maximising the potential of these systems to deliver environmental goods and enhance biodiversity and (ii) optimising economic, agronomic and nutritional advantages for innovative and sustainable organic and low input dairy systems and supply chains.

A farmer-led participatory approach was adopted to address key challenges to organic and low-input dairy farming including feeding and forage, natural resources use, environmental and animal management. Close collaboration between famers and researchers allowed better formulation of specific research questions and identification of suitable methods to address them. Participatory research based on close collaboration and exchange between farmers and researchers can help develop context specific solutions to increase sustainability and competitiveness of low-input and organic milk production.
Given the diversity of low input and organic dairy cow systems throughout Europe, results suggest that within well managed herds, breeds perceived as being better adapted to low-input and organic systems did not necessarily show clear and substantial advantages over conventional breeds. A large dairy goat study involving two indigenous and imported breed noted system-specific limitations (productivity, animal welfare) and breed-specific advantages, especially in terms of milk quality, which are important to future dairy goat breeding programmes.
Nutrition studies demonstrated the potential for a range of novel and local feed sources to contribute as important sources of energy and/or protein in the future. It was noted that the “maintenance” energy requirements of cow’s increases with high forage diets and this should be considered in feed evaluation systems. A decision support tool was developed to assist farmers to evaluate the balance of feed supply and herd requirements on dairy cow farms.
An environmental tool box to support organic and low input dairy production was developed and concluded it is important to include carbon-sequestration in grasslands and biodiversity to help further underpin the environmental strengths of low input and organic dairy production systems.
Supply chain and consumer studies helped to further understand which types of innovative production strategies are acceptable to stakeholders. Alternative protein sources to soya were a priority for farmers but was not understood or valued by consumers. Studies suggested that to avoid bottlenecks in innovation uptake within dairy supply chains then increased collaboration and information-sharing activities along the chain is important.
Data from the European Farm Accountancy Data Network (FADN) was used to establish a definition of “low-input” (LI) dairy production based on an indicator that relates external inputs used, relative to grazing livestock units on a farm. In general, over EU member states, LI, compared to high input (HI) dairy farms are smaller, less specialised, have a larger share of forage and grassland in their utilized agricultural area, and lower maize. They also have more family labour, a lower productivity and a lower production density.
Tailor-made farm planning is required to maximise competitiveness of an individual farm, building on the unique combination of farmer and entrepreneur to make smart-decisions whether this is related to farm management practices and/or most appropriate routes to adding value along the supply chain.
Organic and low-input dairy cow and goat production systems are competitive but for future sustainability attention must focus of continuous improvement in farm management with close attention to welfare and the production of high quality milk. More effective and shorter supply chains will also help to improve the collaboration, competitiveness and sustainable of these dairy systems.

Project Context and Objectives:
WP1: Innovation through stakeholder engagement and participatory research

The main aim of this work package was to facilitate innovation by actively involving stakeholders (i.e. organic and low-input dairy farmers, farmer groups and farm advisors) and researchers in a participatory approach. The emphasis was on engaging farmers to identify research needs to address innovative solutions at farm level with regards to production, health and welfare issues. The development, implementation and analysis was undertaken in close collaboration with researchers. The work consisted of five key activities: co-ordination to develop a time table for stakeholder interaction and to ensure that SMEs partners of the project and the farmer members of these organisations were not overburdened with requests for data from the whole project; identifying topics where farmers mentioned knowledge or innovation needs; developing appropriate research approaches and experimental procedures to test innovative solutions for topics identified and carry out between one and five projects per country and reporting on the lessons learned and communicate the outcomes to farmers, consultants and researchers (see also SOLID Deliverable 1.5).

Identification of innovation needs and specific research topics

To identity research priorities, sustainability assessments were carried out on more than 100 (organic/low-input) dairy cow or dairy goat farms in nine countries across Europe using an adapted version of the public goods tool developed by the Organic Research Centre (Gerrard et al., 2011; Marchand et al., 2014). This was intended to ‘set the scene’ and consider sustainability in its broadest sense when identifying suitable topics for participatory research. Farms were chosen by the SME partner (either low-input or organic) to reflect the range in terms of size, intensity/level of input use, breeds, products, marketing channels and geographical area in the respective country/region, and some illustrative case studies were presented on the SOLID website.

The results illustrate indeed the great diversity of low-input or and organic dairy farms that exist across the nine countries and highlight the need to look for targeted rather than general solutions. Cow farms varied from less than 20 ha (Austria and Italy) to more than 400 ha (Denmark, UK), with herd sizes ranging from nine (Finland) to over 300 cows (Italy, Denmark, UK) and milk yields ranging from less than 2500 kg/cow (Austria and Romania) to more than 8000 l/cow (Denmark). There was landless low-input dairy goat farming in Spain and Flanders, but also grazing on more than 300 ha of common land in Spain and Greece with herd sizes between 22 goats (Spain) and 1150 (Belgium) and milk yields between 117 and 900 l/year. The “classical” indicators of environmental sustainability (management of soil, water and nutrients, energy and carbon) showed considerable variation, indicating that there is the capability for poorer performing farms to improve. Data from the sustainability assessment were used to further investigate the environmental impact of low-input or organic dairy farming systems in WP 4 (e.g. SOLID Deliverable 4.2) and also informed aspects of the modelling work in WP6.

The results from the sustainability assessments were presented at 12 meetings, attended by 161 dairy producers in the nine countries and SME staff with researchers acting as facilitators of the discussions to identify research priorities. The farmers welcomed the opportunity to participate and express their views about research needs specifically providing knowledge for organic/low input production. Most farmers’ own perception of sustainability included economic sustainability but the assessment encouraged thinking also about social and environmental aspects which provided a good basis for the following discussions. The research needs identified can be summarized under a number of headings that correspond to the Work Packages of the SOLID: topics on animal feeding and forage production were central to many farmers and related to the work in WP3; questions about natural resource management linked to WP4; animal management and animal health linked also to WP2 but the work in the participatory studies focused more on various strategies that farmers use to improve health, whereas WP2 had greater emphasis on breed choice. The farmers also indicated that research in product differentiation and marketing was important and this was covered in WP5. The fact that farmers identified such as broad range of topics indicates a lack of knowledge and confidence regarding low-input and organic farming strategies. For further details of the sustainability assessments and identification of research topics see SOLID Deliverable 1.1 for details.

Setting up the projects and developing the appropriate research method for each study

In the next stage we narrowed down the topics, because the number of projects in each country was limited. Identifying the 'right' research question is important for any research and this is equally true for participatory studies. The farmers' experience on what treatments they could implement and what indicators can be monitored on farms was brought together with the researchers' knowledge of existing research, experimental design, data analysis and statistics. This process led to some adjustments of the topics initially suggested by the farmers.

The choice of specific method depended on the topic and involved one or a combination of several of the following approaches:
– Farm case studies were based on monitoring certain aspects on a single farm, using a variety of data collection methods, both quantitative and qualitative. In comparative case studies, this approach was extended to several farms and observations were compared.
– On-farm trials introduced a specific treatment (e.g. use of new feed resources) compared with a control group or with performance prior to the treatment being introduced.
– Group discussion involved a facilitated exchange among participating farmers with the aim to improve practice (i.e. Farmer Field Schools, Stable Schools, field labs).

Outcomes of the participatory research

In total 18 participatory projects were carried out in eight countries with final choice covering a wide range of topics reflecting farmers' priorities and suitability for a participatory project. The topics can be grouped into the following main themes:
• Forage production and feeding
o Enhancing on-farm forage protein production (FI)
o Assessing the effects of inclusion of Camelina meal and grape marc on dairy cows' performances. (RO)
o Mob Grazing for Dairy Farm Productivity (UK)
o Performance of Diverse Swards on Commercial Dairy Farms (UK)
• Strategies for animal health management
o Reducing antibiotic use for mastitis control in organic dairy farms (UK)
o Use of herbs in pastures for dairy cows (DK)
o A farm case study of rearing calves on milking cows; Dairy calves suckling milking cows during the first part of their lives (UK, DK)
o Iodine concentrations in milk of organic dairy farms (UK)
• Studies with small ruminants
o Use vegetable and citrus by-products for milking goats (ES)

o Impact of goats grazing on irrigated pasture on milk yield and quality (GR)
• Natural resources use and environmental impact
o Biodiversity on dairy farms of Sennerei Hatzenstädt – assessing the current status and future scenarios (AT)
o Climate friendly organic milk production (IT)
o Soil Health and Grassland Productivity (UK)
o Farmer field schools on climate friendly farming (DK)

Forage production, utilisation and feeding (see SOLID Deliverable 1.2)

Finnish projects investigating how to increase protein supply from forage found that topping of grass/red clover mixtures before cutting did not have a positive impact on the proportion of clover and protein content, whereas slurry application in the autumn did increase crude protein in the first silage cut of the following year. One of the UK case studies illustrated the potential of bio-diverse pastures with several different legumes and grasses to serve as a sufficiently productive alternative to conventional pastures (i.e. grass/clover pastures). It also found additional benefits for soil organic matter through the use of rotational (mob) grazing systems with high stocking density and longer recovery periods on the case study farm. Future research related to forage production should focus on suitability of more bio-diverse mixtures for different soil types, their feed value (including protein) as well as impact on soil fertility, other ecosystem services, and animal productivity and health. On-farm trials in Romania conducted after screening of novel forages in WP3 showed that industry by-products (camelina meal and grape marc) can be used as replacements for other energy and protein components in dairy cow rations on low-input farms and also have a positive influence on polyunsaturated fatty acids profile in the milk. The comparative case studies of the impact of dietary mineral supplementation on milk iodine concentrations in the UK revealed that use of iodised teat disinfectant influences the iodine concentration in milk, which therefore does not serve as a robust indicator of dietary iodine deficiencies. Some very specific suggestions for research needs, such as equipment and energy needs for drying forage (Austria), using various plant species (including for browsing) and identifying drought resistant plants and varieties (Italy, Romania, Spain, UK) could not be further investigated in participatory projects.

Animal management and animal health (see SOLID Deliverable 1.3)

Animal health and welfare scored well in the sustainability assessment and much research has been done, but the farmers still expressed a need for further research on this topic. The results show that organic and low-input farmers apply a number of different strategies to improve animal health and welfare and through this explicitly reduce antibiotic use. In comparative Danish case studies the farmers, who had started growing herbs in pastures several years ago, expressed a strong belief that this was beneficial for animal health and welfare although the case studies could not confirm this empirically. They continually experimented and developed their systems, for example by growing herbs in strips rather than across the whole pasture. Two case studies in the UK and in Denmark that leave calves suckling with milking cows found healthier calves that learn from their mothers and have improved weight gains, but also less milk in the tank. This emphasises the importance of sharing good practice in developing farm-specific calf rearing systems based on natural suckling. A UK discussion group for reducing antibiotic use began with mutual advice among the farmers on health promoting strategies. This was followed by on-farm trials on four farms that could demonstrate a significant impact of keeping SCC levels low after calving by treating cows with a mint-based udder cream. The farmers became more confident in aiming for further reductions in antibiotic use. All these studies cannot claim to conclusively show long-term health benefits, but emphasise the relevance of knowledge and experience sharing regarding various strategies adopted by the farmers that are supportive to the animals' wellbeing.

The choice of cow breeds and animals best suited to low input and/or organic systems was also raised as a research topic in several countries, but this was not chosen for on-farm experiments because the suitability of breeds for organic and low-input systems was investigated in experiments in WP2.

Studies with small ruminants (see SOLID Deliverable 1.4)

Dairy goat farmers in Spain and Greece identified two main areas of research needs related to feed supply strategies and genetic resources and their impact on productivity of milking goats. On-farm research with lactating goats in Southern Spain conducted after screening of feed sources in WP3 helped to develop good practises in the use of by-products, which can provide a range of nutrient resources replacing more traditional feeds used by low-input farmers. Ensiling was found to represent a valid strategy to maintain the nutritive value and ensure continuous supply of the by-products throughout the year. Specifically, silages made with tomato and olive by-products could replace medium quality forage (i.e. oat hay) in dairy goat feeding without compromising milk yield, provided that the farm is within a 50 km radius from the site of production of the by-product. Testing of environmental benefits using an LCA approach suggested a potential for overall GHG reductions arising from N2O emissions (from feed production stages) and enteric CH4 (in the case of tomato wastes) without productivity being compromised. The Greek study showed the potential of using irrigated sown pasture as an additional feeding strategy in semi-intensive dairy goat production in Greece by providing data regarding pasture management and dairy goat performance (milk yield and milk quality). The question of genetics of dairy goats in Greece was also studied as part of WP2.

Natural Resource Management (see also SOLID Deliverable 1.5)

The Austrian project demonstrates how an organic mountain dairy farming system can contribute to maintaining biodiversity. The study confirmed that assessment can raise awareness and that the attitude of farmers towards biodiversity and farm management is crucial for supporting and maintaining on-farm biodiversity alongside agri-environmental schemes. The Italian case study of soya replacement using home-grown pulses as concentrate feed found lower milk production leading to lower profitability and because of that also increased environmental impact per unit of fat and protein corrected milk (FPCM) produced. The work links to questions of environmental impact addressed in WP4 and modelling of strategies for using home-grown protein sources in WP6. Farmers in the UK wanted a better understanding of the soil to diagnose potential problems with declining productivity under organic conditions. Results of a survey followed by comparative case studies showed that farmers' assessment of soil structure tends to match the scientific assessment. The results strengthened the farmers' confidence in using visual tools and trusting their own judgement in discovering soil problem. This will need to be followed with further work on identifying remedial strategies that the farmers can put into place.

Farmers were also interested in questions related to product differentiation and how to improve communication with consumers about the value of their products. No specific project was conducted in this area, but results of the Austrian and Italian projects could support using specific claims in selling directly to the public. Other ideas suggested included the connections with agro-tourism, increasing the offered product range or developing an ‘a la carte’ strategy and targeting high-end restaurants for different types of flavoured goat cheeses. The work of WP5 is also relevant in this context.

Conclusions

The participatory methods have contributed to developing knowledge about sustainable Organic and Low-input dairying. Farmers are active contributors to agricultural innovation by trying out many things informally. Close collaboration between farmers and researchers as practised in the 18 participatory projects that were conducted has shown that such experiments can play a significant role in developing the knowledge about sustainable low-input and organic agriculture. Our approach encouraged to farmers to go beyond their day to day farming activities and identify sustainability challenges, formulate research questions, help carry out trials, analyse data and disseminate the results.

There is a need consider the economic impact and be aware of the diversity of systems and context when developing strategies to improve overall sustainability of organic and low-input farming. The sustainability assessment of more than 100 farms in nine countries illustrated this diversity among organic and low-input dairy cow and goat farms in terms of size and intensity. We also found variability in interest in the sustainability assessed, with financial sustainability being very important to most farmers.

Forage production and utilisation and the role of home-grown protein sources are of crucial importance to low-input and organic milk producers. Nine of the 18 studies contained elements related to forage production and feeding. We found several but not all proposed strategies to have a positive impact on animal productivity and economics. Positive impacts were found related to bio-diverse mixtures, application of slurry to increase forage protein content and irrigated pasture, preserving (i.e. through ensiling) and using several regionally available by-products. The results of studies using herbs in pasture, different grazing strategies, replacing soya protein with home-grown feeds and topping to increase clover content of ley were not conclusive regarding productivity and economics but some found other benefits.

It appears relevant to include ‘low inputs of antibiotics’ as an important criterion when defining ‘low input milk production’. The projects investigated a number of strategies that farmers use to improve animal health and welfare and through this, explicitly reduce antibiotic use. Examples included the use of herbs in leys, letting calves suckle their mothers, the use of external mint-based udder treatments and farmer discussion groups. The results cannot claim to be conclusive in terms of improved animal health and welfare, but illustrate a variety of strategies that can become part of a ‘tool box’ to help farmers to become more confident in reducing antibiotic use.

Participatory research can play a significant role in developing practical solutions by generating context specific new knowledge as well as involving farmers’ mutual inspiration and knowledge exchange. Engaging with the participatory research projects was seen as positive by both the farmers and the scientists. Farmers and scientists worked closely together from identifying the questions and the initial design through to data gathering, analysis and follow-up actions. Farmers were actively involved in identifying problems, contributing their experience and knowledge and in carrying out research and evaluating the results. The farmers became more aware of research and more confident in using the results. The researcher involvement facilitated systematic data collection and analysis. Several on-farm trial projects use of statistical methods for analysis and publication of the results is envisaged. The researchers thus contributed to the wider dissemination of the findings which extended beyond what was interesting for the participating farmers (see for example Padel et al., 2015).

WP2: Adapted breeds for productivity, quality, health and welfare in organic and low input dairy systems

Within the studies described below, evidence for differences between conventional and alternative dairy cattle and goat genotypes was examined in terms of metabolic balance, fertility, health and product quality. This, and the identification of indicators for 'adaptation', has the potential to have a significant impact on the future direction of breeding programmes for organic and low input production systems, with a subsequent improvement in the overall competitiveness of these systems. In achieving these goals, the supply and affordability of milk and milk products from organic and low input systems will be increased. Furthermore, the impact of developing specific risk-based improvement strategies for animal health and welfare in organic and low input dairy systems will contribute to the competitiveness of the sector, address societal expectations, and provide information for future programmes aimed at the development of sustainable organic and low input dairy production.

Although dairy systems are generally termed 'low input' if the use of external supplementary feed sources is limited to some extent, these low input systems are actually extremely diverse across Europe, both in terms of availability of production factors and in management strategies. These low input and organic systems require dairy livestock which are adapted to the specific conditions within individual systems, while the diversity of the systems means that different breeding approaches may be required to secure appropriate livestock. In the light of the absence of a dairy genotype which may be generally adapted to all different types of organic and low input dairy systems, actors within the sector in Europe have identified a number of possible 'alternative' strategies, such as crossbreeding and selection for robustness and lifetime performance to overcome the limitations of conventional genotypes within low input or organic systems. Robust scientific evidence in support of these 'bottom up' approaches is absent. The work conducted in the course of the project therefore aimed at characterising the degree of adaptation to low input environments of dairy cattle and dairy goat genotypes, which had been selected using very different approaches, in different geographical locations and within different production systems.

Dairy Cattle Studies

The dairy cattle studies compared the response to concentrate supplementation (including a challenge diet with reduced concentrate supplementation and a control diet) of widely used 'conventional' breeds and breeds that were perceived to be 'adapted' to low input systems. The diversity of low input and organic systems is reflected in the very different concentrate inputs adopted across the three geographical regions studied, Western Europe (UK), Austrian Mountain and Northern Europe (FI). Both total feed intake and milk output were lower with the low input diets than with the control diets, with the level of production being distinctly different across the three regions. Feed intake and energy corrected milk yield were different between genotypes for one region only, while milk fat content was higher for the alternative breed in all regions and milk protein in two out of three regions. No consistent patterns were observed among genotypes for body weight and body condition score, their change throughout lactation, and time of nadir.

There were indications of improved health traits with the alternative genotypes in two regions, while across all regions fertility was unaffected by genotype or dietary treatment. In the absence of consistent interactions between genotype and dietary treatment, both the conventional and alternative genotypes appear to have responded in a similar manner to a feed challenge. However, there is some evidence from blood and milk biomarkers that the different genotypes respond differently at the metabolic level to the system-specific reduction in energy supply. The somewhat inconsistent trends and significant effects for some fertility and health traits should be addressed both in future studies and in the development of breeding programmes for low input and organic dairy systems. See SOLID Deliverable 2.5 for further details.

A potential advantage of certain genotypes may comprise of, among others, a greater efficiency of utilization of feed energy. Therefore, information was collected and analysed on the energetic efficiency of a conventional (Holstein Friesian, HF) and of alternative genotypes (Norwegian, F1 Jersey x HF, F1 Norwegian x HF). The results indicate that no significant differences exist between these genotypes in terms of energy digestibility, metabolizability of gross energy, energy used for maintenance and for lactation. It is therefore concluded that cow groups evaluated herein have no significant effects on energy expenditure or energetic efficiency. However, the maintenance energy requirement is not a constant as adopted in the majority of energy rationing systems across the world, but is likely to increase with increasing feed intake. See SOLID Deliverable 2.4 for further details.

Goat Studies

Due to the absence of scientific information on the phenotypic and genotypic characteristics of dairy goats in low input systems in Southern Europe, the work conducted on goats had a somewhat different focus compared to the studies on cows. The data collected during the course of this project fills a critical knowledge gap in terms of providing basic information on the productivity, reproductive performance, health, welfare and milk quality within low input Southern European dairy goat production systems. The information collected includes much needed data, such as the reduction in productivity due to internal parasites.

Distinct differences were identified between the different dairy goat breeds studied herein. One exotic breed appears to be well adapted to the specific requirements of Southern European low input systems. Differences in the frequencies of alleles associated with productivity and milk quality are highly relevant for the design and implementation of breeding programmes. The information from genotyping points to a superiority of the autochthonous breeds over internationally used high-yielding breeds in terms of milk quality. See SOLID Deliverable 2.5 for further details.

Animal Welfare Studies

Animal welfare in organic and low-input dairy cow systems is commonly expected to achieve at least satisfactory levels. This assumption is based on the regulations regarding housing and management of the animals and/or the access to pasture. The aim of the work directed towards welfare of dairy cows within this study was therefore to evaluate the welfare state of the dairy cows in three regionally different low-input and/or organic dairy systems throughout Europe (Northern Ireland, Spain and Romania), using a state-of-the-art assessment scheme WelfareQuality®. Half of the 30 farms assessed were graded 'Acceptable', 43 % achieved an 'Enhanced' welfare state and one farm was classified 'Excellent'; one farm was 'Not classified'. In five out of the 12 criteria, the average score indicated the occurrence of welfare problems in at least one country. Across the production systems investigated, the presence of injuries in the cows may be regarded as a general welfare problem. Furthermore, 'Comfort around resting' and 'Absence of pain induced by management procedures' were identified as unsatisfactory in at least two countries. 'Thermal comfort', 'Ease of movement', 'Absence of disease' as well as most of the criteria related to 'Appropriate behaviour' may be considered at least acceptable. Variation between farms shows that on one hand, farms could benefit from intervention studies and, on the other hand, that good and even excellent results may be achieved in organic and low-input dairy systems. See SOLID Deliverable 2.1 for further details.

Based on a risk analysis and the scores that farms achieved in the welfare assessment, weak points and strengths of the organic and low-input farms were defined. Improvement strategies based on the risk-factor analysis and additionally an evidence-based approach point at key intervention measures such as changes in feeding management, adaptation of the resting area or use of best practice for disbudding of calves. See SOLID Deliverable 2.2 for further details.

Conclusions

The results from the studies conducted within this WP contribute to improving the overall sustainability of organic and low input dairy production systems by supporting breed choice and the further development of dairy cattle and goat genotypes used in these systems. Furthermore, the risks identified in terms of reduced welfare in dairy cows need to be addressed by appropriate improvement strategies in order to maintain and develop respective advantages which organic and low input dairy systems may have.

WP3: Forages for productivity, quality, animal health and welfare in organic and low input dairy systems

The overall objective of this work was to improve the competitiveness of organic and conventional low input dairy production systems by improving the health and welfare, the productivity and product quality of livestock in low input and organic systems through improving the supply of forage. We accomplished this by improving the supply of nutrients from forages and by products through the use of novel feeds; increasing the understanding of the efficiency with which high forage diets are utilised by dairy cattle and reducing risk and finally providing a decision support systems for forage management and feeding.

Development of novel and underutilized feed resources including by-products from processing of renewable raw materials

The amount and quality of feeds offered to animals have significant effects on feed intake and milk production, which largely dictates the economics of production. In addition they may also influence milk quality and the health of the animals. We first conducted a literature survey of novel feeds (SOLID

Deliverable 3.1) and then continued with laboratory and in vitro analyses with a wide variety of novel feeds, with some of them finally tested in on-farm trials (SOLID Deliverable 3.2). The literature review demonstrated the potential of a range of by-products and underutilized sources as animal feeds and highlighted the need for additional information concerning certain by-product feeds that should be obtained through a strong farmer and stakeholder interaction.

The in vitro and in vivo assessments as well as on-farm trials were conducted by different partners across different regions of Europe (LUKE (Finland), ICDBNA (Romania) CSIC (Spain) and ORC (UK)). The experimental work addressed the need to alleviate the deficit of protein crops in Europe, feeds from emerging industries in Eastern European countries, biofuel crops across Europe and wood industry in Northern Europe, by-products from food processing industries in Southern and Western Europe and agroforestry systems based on UK experience.

The main conclusions of the work conducted are:

• Grain legumes and rapeseed have potential to replace soya bean based protein supplements in dairy cow feeding, but mainly economic reasons restrict their wider use.

• Wood based hemicellulose extracts are currently not available in the global feed market and agroforestry is used only to a limited extent and despite benefits being identified for both approaches, wider use of them would require large changes to the current circumstances.

• The agro-industry sector in Southern Europe provides a range of valuable by-products with potential to be used as feed for small ruminants. However, the high moisture content represents the main limitation for the successful and wide use of some by-products by the feeding industry. Ensiling represents a promising option: silages made with tomato and olive by-products may replace medium quality forage (i.e. oat hay) in dairy goat farms provided that the farm is within 50 km from the site of production of the by-product. Such strategies could be applied to a number of potential different fruit or vegetable by-products in the future.

• Oil industry derived by-products tested in Eastern Europe showed, in general, a higher content of oil and crude fibre, at the expense of crude protein content. Camelina meal could replace the classical sunflower meal in diets for low-input dairy cows (low production level) without noticeable adverse effects on milk yield.

• Grape marc could partly replace cereals, as a temporary substitute (e.g. in case of feeds shortages) in diets for dairy cows within low-input systems, at dietary levels up to 3 kg/d and replacement ratios that allow meeting the feeding requirements for net energy and intestinally digestible protein, without significant negative effects on milk yield and quality.

Overall, the range of potential novel and underutilized feeds is large. The current results can be used to assist in exploiting the potential of different feed resources and in ration formulation. Improved supply of feeds may be particularly favourable in situations when the basal feed supply is reduced due to, e.g. adverse weather conditions. The economic effects of use of novel feeds is highly dependent on the pricing of the feeds but may in many cases be expected to be positive. Widening the type of on-farm produced feeds may also have beneficial effects beyond simply feed supply such as improved crop rotation, self-medication, microclimate or other ecosystem services. In some cases, use of novel feeds may also include risks, e.g. to animal health (anti-nutritional factors), milk quality or consumer acceptability, and these factors must be kept in mind when innovative animal production solutions are developed.

Assessment of an agroforestry system in terms of feed supply and multifunctionality

This work was based on two agroforestry systems in the UK, where the other one was already established (SOLID Deliverable 3.2 Part1) and the other one covered the starting phase of a new agroforestry system (SOLID Deliverable 3.2 Part2). The main conclusions of the work were:

• Agroforestry has been identified as a 'win-win' multifunctional land use approach that balances the production of commodities with non-commodity outputs such as environmental protection and cultural and landscape amenities.

• Designing a new system must consider the desired outputs (food, fuel, fibre), site conditions and climate, species properties (canopy size, root characteristics, shading tolerance etc.), species interactions, agronomic factors as well as government regulations.

• Controlling competition from weeds and grasses is essential for promoting better tree establishment.

• Tree fodder may offer nutritional benefits to livestock, although values vary depending on tree and animal species, as well as seasonal and bio-geographical factors. Fencing is essential to protect the trees from livestock and control the impact of browsing.

• Providing shelter for livestock during the winter months can lead to better survival rates, increased milk production and significant savings in feed costs. The provision of shade in hot summers is an important factor for animal welfare.

To derive estimates of energy utilization by dairy cows on high forage diets

This analysis used a unique animal data base maintained by AFBI in which measurements of energy intake, and outputs (in faeces, urine, methane and milk), heat production and energy retention in body tissue have been measured on over 1000 dairy cows using calorimeter chambers. This dataset includes comparisons of forages of different qualities and type, and critically, data from cows offered diets containing very different forage proportions (from 100% forage to diets containing in excess of 80% concentrates).

The results from work in WP2 revealed that cows of adapted breeds (e.g. Norwegian Red and crossbred cows) have similar maintenance energy requirements as Holstein cows, and utilise energy for lactation with a similar efficiency as Holstein cows. Thus existing rationing systems are appropriate for a range of dairy cow breeds.

However, the results demonstrated that dairy cows managed under low input or organic farming regimes may require more feed energy for maintenance of their basal body activity than those managed within higher concentrate input systems. Cows offered high forage diets may require more time and a greater effort to eat, ruminate and digest these bulky forage based diets. This issue has not been considered within energy feeding systems for dairy cows in many European countries. Thus many existing systems may underestimate the feed requirements of dairy cows managed within low concentrate input systems. In order to improve the economic and environmental sustainability of dairy farming in Europe, there is an urgent need to upgrade current energy rationing systems for low input and organic dairy farming, taking account of the findings of the current work (see SOLID Deliverable 3.4).

Development of a decision support model for optimum management of forages and by products in organic and low input systems

The SOLID-DSS is a decision support system (DSS), which helps to optimize the management of feed resources and feed supply systems within organic and low input dairy systems in Europe to minimize the risk of feed shortages. The model serves both organic and low input farms as long as they depend mainly on on-farm produced forages. Restrictions concerning external feeds for organic farms resulting from the EU directives are included in the DSS.
On basis of integrated European wide weather database (1997-2007), the annual site and farm specific yield calculations of arable grain and forage crops and permanent grassland forage yields for conservation and grazing can be assessed. This helps to provide a risk assessment of potential annual forage.

The SOLID-DSS is structured around two main models:
1. Crop and Grassland Model within the SOLID-DSS (Crop.js) based on: The crop and crop rotation model which is based on MONICA (http://monica.agrosystem-models.com/). The grassland model which is based on the Sustainable Grazing Systems SGS Pasture Model (http://imj.com.au/sgs/. This allows for a site and annual weather specific yield calculation of crops within three to five year crop rotations and of permanent grassland (harvested and grassed) using a European wide weather data base implemented in the DSS.
2. Dairy model (dairy.js)
It is built as an open-source JavaScript library built to simulate dairy cows and young stock, their growth, requirements and diets. The implemented modules allow for simulating herd structure, milk yield and solids, energy and protein requirements (expressed in different European systems), feed evaluation (expressed in different European systems), dry matter intake (fill value based), growth and mobilization, cow grouping and diets.

Because of necessary simplifications (limited crop spectrum, only one mean soil type per farm, limited to non-groundwater influenced soils, simplified cutting and grazing regime, no grazing for dry cows) and limitations of the model outputs of non-site-specific calibrated plant-soil simulation models in absolute terms can only be used restrictedly under real farm conditions. Nevertheless the SOLID-DSS provides a deeper understanding of the complex relationships and dependencies of sustainable organic and low input dairy systems and is well suited for agricultural extension, training and teaching. An additional benefit of this work is that the whole SOLID-DSS is programmed in well-documented open-source code and is available for modellers to be used e.g. in future projects (See SOLID Deliverable 3.5 for details).

WP4: Environmental assessment: For improvements and communication in organic and low input dairy systems

This work had three overarching goals: 1) To develop the necessary methodology for a comprehensive assessment of environmental sustainability in a dairy chain taking appropriately into account the peculiarities of low input and organic systems; 2) To develop a decision support tool to enhance environmental sustainability on practical dairy farms; and 3) To assess the environmental performance of organic and low input systems compared with conventional intensive dairy production systems.
Furthermore, it was decided that the concepts behind the assessment should be based on the life cycle approach, where all environmental impacts from manufacturing of inputs to the farm in addition to all

emissions taken place at the farm are combined and put in relation to the amount of milk produced.

Development of the assessment framework

The LCA approach has been supported by the EU for several years through its integrated product policy, which aims to relate the environmental impact to the individual products in order to allow for informed choices among all parties in a product chain, when using/consuming different products. In the last few years the Commission have reinforced such initiatives by establishing the Product Environmental Footprint (PEF) initiative as part of supporting the single market to include environmental issues. In this initiative the Commission work with industries and scientists to establish commonly agreed methodologies to make an environmental assessment, which ultimately are those to be used when claiming environmental performance in relation to the single market. Food is part of these initiatives and there is a pilot established dairy products. When this pilot is finished, the results should provide mandatory ways to claim environmental impact of dairy products. This holds for which types of environmental impacts should be included in an assessment as well as methodology on how to calculate them.

Our work has been matching the above mentioned initiatives. Two aspects are in particular important in a proper evaluation of organic and low-input dairy farming. This is how to account for impact on biodiversity and how to account for differences in soil carbon sequestration in the assessment of emissions of greenhouse gasses. In the work with the PEF these aspects are also recognized as dimensions for which there is a need for better assessment methodologies.

Inclusion of soil carbon changes in LCA

As regards soil carbon sequestration a conceptual model has been developed and published (Petersen et al., 2013) which is suitable for use in LCA work. The key feature of this model is that it is generic, based on carbon in crop residues that enters the soil, takes into account the subsequent release of carbon from soil the following years, and furthermore the subsequent deposition of carbon in oceans following the Bern carbon cycle. Thus it is possible to estimate the global warming impact of a specific amount of carbon put in the soil over a 100 year perspective (similar to the way the impact of other greenhouse gasses are calculated) and the impact can be directly added to the other contributors to the global warming impact.

For practical planning purposes we have published, how the methodology works for different types of cattle feed (Mogensen et al., 2014). In this paper default numbers are given on how much carbon that can be expected for different crops as well as the contribution of carbon from adding manure, which is very central in particular in organic and low-input systems. For example, it was shown that 1 ha of maize for silage was related to a release of carbon corresponding to a global warming potential of 900 kg CO2 per year and if supplemented with manure, of an additional 270 kg CO2 per year, whereas a grazed clover grass field was related to a sequestration corresponding to a global warming potential of 700 kg CO2 per year. The difference could therefore amount to 1600 kg CO2 per ha per year depending on the type of crop used.

At the same time we have worked with an existing farm model that can be used for practical assessment of the environmental performance of specific farms based on easily available farm data (SOLID Deliverable

4.2). We have used this model to investigate the carbon foot print of milk from 34 organic farms from 6 countries in Europe (UK, Denmark, Finland, Belgium, Italy, and Austria). The farms were chosen to represent very different farming practise. The average carbon footprint was 1.3 per kg milk delivered from farm gate with a considerable variation among farms but only little variation between countries, illustrating that the actual farming practise has a considerable influence on the carbon footprint. The overall standard deviation per kg milk was 0.2.

Of the total average GHG emissions, enteric fermentation by dairy cows contributed 33% and young stock contributed 12 %. N2O emissions from housing and crop cultivation accounted for 22%, farm capital goods for 9 % and manure management for 6% of the total emissions. Electricity and fuels were both contributing 5 %, and imported feeds contributed 3 % of total GHG emissions.
As a second step we estimated the carbon footprint for 23 organic dairy farms from the UK, Denmark and Finland with and without including soil carbon sequestration in the assessment. As a reference we used a typical conventional intensive dairy production represented by a mixed Danish dairy system. The results show that for all the organic farms, the carbon footprint is reduced when soil carbon sequestration is included in the calculations. The carbon footprint of conventional milk was not significantly affected. The main reason is that organic farms generally have a higher share of grassland relative to cereals/maize on their farms. The grasslands increase the carbon pool in the soil, whilst maize reduces it. Since a higher level of soil carbon is one of the main features of organic farming, it is crucial to include sequestration for accurate carbon footprint calculations.

Inclusion of biodiversity in LCA

It is well documented in literature that biodiversity is typically higher on fields that are grown organically compared to conventionally cultivated fields. The empirical basis and concept for including this in an LCA assessment is missing, however, it is acknowledged that this is an important aspect that should be included. Presently in the PEF, what it is included is the pressure on biodiversity from other emissions, whereas the impact of cultivation method on biodiversity per se is not included.

In this project, we have revisited biodiversity data from the EU funded BioBio project (http://www.biobio-indicator.org/) where data on plant species on organic and conventionally fields with different crops were collected in seven European countries. We have used the data from six countries placed in the biome 'Temperate Deciduous Forest', that represent a major part of the North, West and Central European agricultural landscape, to analyse number of plant species in different crops and compare with the number of plant species that are present in semi-natural vegetation. Based on these data we could calculate the relative number of plant species depending on type of crop and whether the crop was grown organically or not in comparison to the natural vegetation. Thus we distinguished between pastures (monocotyledons or mixed), arable land and hedges as well as management practices (organic, less-intensive or intensive conventional production systems).

The indicator (already defined in literature) is called Potential Disappeared Fraction (PDF). The potential disappeared fraction of plant species in for example a conventional cereal field is approximately 0.70 or 70%, whereas in an organic cereal field it is only approximately 0.20 or 20%. In conventional grasslands the loss of species is only approximately 0.10 or 10%, whereas in organic grasslands you actually find a higher number of plant species than in the natural vegetation (semi-natural forest); here the loss is approximately -0.30 meaning that you actually gain 30% more plant species compared to natural vegetation. It is acknowledged that number of plant species is not a comprehensive indicator of biodiversity but this indicator is sensitive to field management options as opposed to indicators based on insects, birds and mammals which are more dependent on the landscape features.

The PDF indicator was used as an indicator of Biodiversity Damage Potential on the previously mentioned 23 organic farms in UK, Denmark and Finland, and expressed per kg of milk produced, like the other indicators. In many cases the organic farms had negative Biodiversity Damage Potential, which means that the production system in fact resulted in an overall increase in biodiversity compared to semi-natural vegetation. In comparison, the average Danish conventional milk production has a Biodiversity Damage Potential of approximately 0.40 per litre of milk. It was also shown, that there was a tendency for a trade-off between the carbon footprint and the impact on biodiversity – in that farms with lower carbon foot print had more damage to biodiversity.

Comparison of different production systems

In order to assess the possible environmental benefits of organic and low-input dairy farming compared to conventional farming practises we defined three very different basic systems and modelled the environmental impact (SOLID Deliverable 4.3). The three basic systems, which we assume represent a major part of the EU dairy production, were lowland grassland based systems, lowland integrated crop-livestock systems, and mountainous systems. The grassland based systems were represented by typical UK organic and conventional systems, the mixed dairy systems by typical Danish organic and conventional systems, and the mountainous systems by typical Austrian organic, low-input, and conventional systems. Input, output as well as internal farm turn-over of the different farm types was modelled as a basis for the environmental assessment.

Looking across all systems considered, the amount of bought-in concentrate showed major differences varying from 258 kg to 2437 kg per ha, while the fertilizer input ranged from 0 to 134 kg N per ha. From an overall point of view, all mountainous systems and the grassland based organic systems could be considered as low input, whereas the mixed systems and the grassland based conventional can be considered medium or high input systems. Considering the on-farm forage production, a main difference is a lower yield in cereal crops in organic compared to conventional systems.

A particular issue when comparing organic and conventional dairy systems is the use of pesticides in conventional production. While in principle this is accounted for in the PEF by calculating impact on eco-toxicity, there is only very limited material available to get good estimates of the impact of different pesticides on eco-toxicity. This is due to methodological challenges, such as the fate and uncertainty of the toxicity impacts compared to other impact categories or the lack of data or characterization factors for potentially key pollutants. Therefore, in this project we provided 20 new characterization factors (CFs) for fresh water toxicity potentials of pesticide active ingredients used in the production of the livestock feeds; barley, maize, grass, soybean, and wheat. The USEtox 2.0 model was selected as a characterization model since it was developed in scientific consensus, to better represent application practice for characterization of toxic impacts of chemicals and pesticides in LCA. The new CFs, are expressed as comparative toxic units (CTU) or comparative damage units (CDU) and calculated at midpoint and endpoint level respectively.

Our analyses showed no major differences in contribution to global warming between organic and conventional milk produced in mixed dairy and mountainous systems, whereas the organic milk had a lower global warming impact than conventional in the grassland-based system. This was mainly due to a lower impact of legumes in the home-grown feed than of fertilized grasses. In general the organic milk had lower mineral and energy use (75%) and a lower impact on marine eutrophication (40%). Eco-toxicity related to organic milk was more than 1 order of magnitude lower than for conventional milk and where the biodiversity damage in conventional milk production was in the range of 0.5 PDF, it was close to zero in the mixed organic system and in the range of −0.5 in the grassland and mountainous organic systems. However, the land requirement for the organic milk was considerably larger than that of the conventional milk per unit of milk produced.

In conclusion our results show that the carbon footprint of organic milk varies among farms, shows no clear differences between countries, and is comparable to the carbon footprint of milk produced by typical, conventionally managed dairy farms. Organic farms generally have higher soil carbon sequestration, due to a higher proportion of grassland and greater use of manures, instead of synthetic fertilisers. Likewise, organically managed fields generally have higher biodiversity compared to conventional fields. These two factors - soil carbon and biodiversity - are not normally included in the environmental LCA of milk, resulting in a biased comparison of organic and conventional milk.

Optimizing environmental impacts

A main challenge when working with practical farm data is to estimate the consequences of a change (an improvement option) due to the interactions between different farm components. Thus, an improvement in one aspect may lead to unforeseen impacts in other parts of the farm production chain. In order overcome this, a Bayesian belief network model was developed. The previous LCA model for carbon foot print was adapted to also account for marine eutrophication. Secondly this was built into a Bayesian belief network, which is operated by Hugin researcher software. In addition the model was fed with expert knowledge on the likelihood of achieving an environmental gain by up to 19 management options. The input to the model is the farm specific data which was also used for the carbon footprint model and the considered management options. Based on the deterministic model built in the networks and the likelihood of achieving a better environmental performance the model can optimize according to 4 management options at a time.

The model work per se is accomplished as a research model that can be used for identifying most relevant improvement options for different farm types and there is comprehensive description of the principles and practical use of the model. The model is, however, yet not available for use as an internet application. This is expected to be achieved later in 2016.

WP5: Competitiveness of organic and low input dairy sector: Supply chain and consumer analyses

This work had three main aims: 1) to identify the broad range of expectations for innovation in management practices and adapted breeds along the whole low-input and organic dairy farming supply chain (fork to farm); 2) assess the acceptability of novel strategies (developed in WP1, 2 and 3) along the whole supply chain given the differing expectations (with special consideration to consumer acceptance and preferences, and the sustainability of supply chain management practices) and 3) identify optimal strategies to enhance collaborative behaviours in low-input and organic dairy supply chains.

Identification of expectations along the supply chain

The expectations and objectives of low input and organic dairy supply chain members (producers, milk buying groups, processors, retailers and consumers) were identified by means of focus groups (3 focus groups consisting of 8-12 participants from a range of low input and organic supply chains) in participating countries (UK, IT, FI, BE). The Q Methodology (Eden et al., 2008) was used to compare the viewpoints of the different participants. This methodology highlights common ground and divergence in the expectations that organic and low input dairying can deliver and is used to understand the points of view of a specific part of the population and is not intended to lead to conclusions about the population as a whole.

There was consensus across all participants within a supply chain in a country and across countries as to which innovations were deemed to be unacceptable in organic (from an ethical and/or regulatory perspective) and low-input dairy systems. These included:
• Improve forage quality and yields in low-input dairy systems by GM plant breeding techniques.
• Develop designer dairy food from transgenic animals.
• Acceleration of genetic selection including recombination in vitro.
• Innovations to speed up calf development from birth to maturity so that they can breed earlier.
• Innovation in indoor (100% housed) dairy systems to improve animal welfare.
With the exception of “Innovation in indoor (100% housed) dairy systems to improve animal welfare” in Finland (which consumers liked and processors and retailers disliked), there were no major conflicts within country specific supply chains over which innovations were acceptable or not. There were however differences in where different supply chain members priorities lay. Consumers tended to load more on Factors where the main theme was high animal welfare, this was a pattern observed across countries too. Producers and retailers/processors on the other hand tended to load more on factors related to feed efficiency, feed quality and efficiency of production. Innovations to improve animal welfare, however, were still also important to this group. Italy was unique in having a group of supply chain members loading on a supply chain efficiency factor (see SOLID Deliverable 5.1).

Assessing the acceptability of novel production strategies

The results of the work above and of other relevant SOLID work resulted in a list of innovative production strategies that represented a sort of “wish-list” of potential innovations in management practices and adapted breeds along the whole low-input and organic dairy farming supply chain generated in the SOLID project.

In order to test in a more quantitative manner which of those was most acceptable along the organic and low-input dairy supply chain, we reduced that list to just three main novel production strategies. Extensive brainstorming and consultations among the partners and the stakeholder platform of the SOLD

project led to the choice of the following three novel production strategies, which were the focus of all subsequent analyses in WP5. These were:
• Agroforestry
• Alternative Protein Source (with lupin or other soy-substitutes)
• Prolonged Maternal Feeding

The Supply Chain survey

In order to measure the acceptance of the proposed novel strategies we applied a modified version of the Technology Acceptance Model (TAM) developed by Davis (1989). A survey was administered to a convenience sample of more than 1500 members of the organic and low-input dairy supply-chain members in 6 countries. In total, 223 respondents completed the survey. The majority of respondents were Dairy Farmers (72%), the other groups were considerably less well represented (Dairy Farmer and Processors: 14%; Dairy processor/Milk buying group: 8%; Compound feed producer/distributor: 6%).

The analysis of the acceptance does not show many differences among the different supply chain members. Over 50% of each supply-chain level ranked first the alternative protein source production strategy confirming the results analysed by country. Our results allow us to make some theoretical and practical contributions. This was the first attempt to apply and test the extended TAM model in the dairy sector. Our study confirms the validity of general TAM framework in explaining technology adoption intentions (and decisions), but also demonstrates that, in the context of novel production strategies aimed at the organic and low-input dairy sector, the individual’s belief is strongly influenced by those of others, specifically leading companies, peers and other significant influencers. Further research is needed to validate our findings in other contexts, but we believe that the results of our study have theoretical implications that go beyond the specific case under observation.

Our findings also have relevant practical implications for dairy farmers, compound feed producers and retailers, dairy processors, researchers, and advisers. Farmers’ perceptions of what other relevant people want them to do, strongly influences what farmers’ perceive as useful to adopt, particularly if they are uncertain about the impact of certain innovations on their farms. Pioneers are always taking the risk for all the followers, and this may turn out very costly in dairy farming, where a large portion of the farm capital is invested in the livestock. The fact that the most preferred strategy - across all countries and roles in the dairy supply chain - was soy substitution by Alternative Protein Source, may derive from the large influence of others opinions on each individual (subjective norms). Many farmers affirm that they have already adopted this strategy, indicating that this innovation is potentially already better embedded in the sector. Others feel more confident in being followers of a tested strategy. In other words, individual farmers consider it more useful and are more likely to adopt those innovations, those novel production strategies that receive broader consensus among their peers, their advisers and the society in general.

Finally, the finding that those farmers who are better in sharing information along the supply chain are those whose opinions are less impacted by the opinions of others may help understanding the role of increased collaboration within the supply chain to speed up the adoption of novel technologies and strategies, especially those which appear less ‘mainstream’ in the eyes of the prospect adopters.

Sustainable production strategies, especially those applied in organic farming, need strong collaboration throughout the whole supply chain: input producers need to recognise the (novel) needs of their farming customers, while processors, distributors and finally consumers need to perceive the higher value produced by means of these more sustainable practices. In the past, organic farming, itself seen as innovation, has been an example on how sharing information and knowledge can become viral, even against strong corporate interests in the chemical input industry and against mainstream knowledge-based supply chains that were not favourable (and in many instances still are) to its diffusion (universities, research centres, advisory and extension agencies).

In the organic and low-input dairy supply chain lack of home-grown or local feed is among the greatest barriers to a real sustainable and safe development. Given an alternative protein source strategy is prone to have implications on farm productivity, profitability as well as in milk quality, the success of this strategy hinges upon an increased collaboration among the various supply chain actors. Prolonged maternal feeding cannot be applied successfully without an increased level of information from farm to fork. Without consumer recognition of higher welfare standards, the payoffs of that strategy are clearly negative. Finally, it is likely that agroforestry, as a sustainable alternative feed/increased welfare strategy, needs wider societal recognition, since the public goods (biodiversity, reforestation, etc.) produced cannot all be borne by the consumer. Indeed, our findings should encourage policymakers to consider the important role of supply chain management practices, including collaboration, to enhance the sustainability of dairy organic and low input farming systems. Furthermore, information, in order to be shared within a supply chain, needs to be freely accessible by all interested parties. Since providing information and knowledge is costly, increased public efforts in the direction of increased free access to information resources as well as increased provision of information, advisory and extension services are paramount to the adoption of sustainable production strategies in the dairy supply chain. Finally, managers and policy makers are not restricted to apply our results only within the narrow boundaries of the organic and low input dairy segment.
In the future, the role of information sharing practices is likely to become increasingly crucial not only to achieve higher levels of sustainability but also to defend the profitability of all supply chains, even outside the agro-food sector (SOLID Deliverable D5.2).

The Consumer survey

After having defined the novel production strategies to be used for testing, a survey was administered to 6969 consumers in 6 countries. 5497 valid survey responses were collected in six EU countries: AT (905), IT (985), BE (901), DK (893), UK (909) and FI (904). Female respondents represent 58.4% of the sample. Our model stems from an extended version of the Theory of Planned Behaviour model, focusing on attitude formation and its direct relationship with beliefs such as perceived risk and benefits of a novel production strategy (see SOLID Deliverable 5.3). Willingness-to-pay estimates related to the three novel production strategies assessed were derived using advanced discrete choice econometric methods. The production strategy ‘Prolonged Maternal Feeding’ is ranked first by 42.1% of respondents and second by 31.8%, summing up to 73.7%. ‘Agroforestry’ was slightly less favoured: though ranked first by only just a third of respondent (33.3%), was ranked second by another 38.2%, summing up to 71.5%. Although country differences exist, ‘Alternative Protein Source’ was the least preferred strategy by the consumer: only 24.6% ranked it first.

These results are diverging with those previously reported concerning dairy supply-chain members, who by and large preferred the ‘Alternative Protein Source’ strategy. In terms of “Purchase Intention”, consumers in all countries rated – on average - dairy food produced by Agroforestry higher than food produced by Prolonged Maternal Feeding, while dairy food produced by Alternative Protein Source has substantially lower average rating. All differences are statistically significant.

Identifying optimal Supply Chain Management (SCM) strategies to improve competitiveness and adapt the production systems to geographic diversity

On the basis of the results of previous tasks and other SOLID preliminary results, an international Future Dairying Workshop was organized in Vantaa, Finland, 20-21 May 2014.
The workshop was designed with the aim of generating participatory interaction targeted at identifying the challenges of adapting the organic and low input production systems in different geographic and cultural environments using future research methodology.

The future workshop approach was structured in three phases: 1. Critique phase, 2. Visioning phase and 3. Operationalization and Implementation phase. The participants were split into three operational working groups from homogenous areas with similar characteristics from a geographic and climate perspective or from the market viewpoint – these were Nordic, Eastern Europe and Western Europe. Each group consisted of three to four participants and they were selected from different geographic areas, representing different levels of the milk supply chain and from different production systems (organic, low input, conventional).

In the first day of the workshop, during the critique step, participants identified expected challenges in the near future in the organic and low input milk supply chains and then the visioning step aimed at finding solution to these challenges. Previous tasks of the SOLID project and extensive brainstorming and consultations among the project partners and the stakeholders’ platform led to the choice of the following three novel production strategies: agroforestry, alternative protein sources with lupin and other soya substitutes and prolonged maternal feeding. These production strategies were presented to the workshop participants in a general format in terms of strengths and weaknesses, threats and opportunities. During the workshop participants discussed how they would see the potential of these production strategies to solve identified challenges. In addition, in the visioning phase participants were engaged in creative imagination of an ideal future state for organic and low input dairying and creation of new optimal strategies.

The theme of the second day of the workshop was to discuss the transferability of practices between different regional contexts. The method of storytelling was used when individual stories of the specific geographical group were constructed. The collective group story was then revealed to the other groups to identify the underlying strands that defined the problem in that geographic location and to discuss the transferability of the identified optimal strategies.

The “Critique phase” yielded two universal themes across all the groups - profitability of the farm and feeding strategies. The Nordic group identified a total of eight challenges, of which three were at farm level, two at policy level and three linked to consumers and markets. During the discussion on profitability, high investment cost for farms in the cold Northern climate as well as other challenges that affected profitability were mentioned, such as the upcoming abolition of milk quotas and milk price fluctuations. Three of the challenges were more consumer or market oriented. Competition with other beverages was seen as a problem, due to the low pricing of alternative beverages and consumer trends towards more consumption of soft drinks. One market challenge was directly addressed at dairy processors, as there was criticism that there were too few organic products available for consumers. The Central and Eastern Europe groups identified a total of 12 challenges, which were mostly linked to consumers and markets. Again, at farm level, low farm profitability was seen as one of the main challenges because of the high cost of production and low price of organic milk products. Price and availability of EU/home-grown protein feed were also highlighted. In addition, the required investments in new technology were mentioned as too costly for farms. One market-related problem was also the low price of male dairy calves. In the Western Europe group, a total of ten challenges were identified, of which most were at farm level. Again, following the identified challenges in the previous groups, farm profitability was linked to the discussion about farm-level cost reduction, milk price and farm-level risks. Protein alternatives to soya were also mentioned in this group. Extensive discussion was also targeted at the health and welfare of the cows and better grass-based feeding strategies. Regarding feeding strategies, the discussion covered themes such as better grassland utilization, pasture improvement, feed efficiency, and self-sufficiency in feeding and reliable forage production. This group also identified some farm management issues such as ease of farm management. The discussion about best practices was linked to self-sufficiency of protein feeds as well as the large variation in performances at farm level. Challenges regarding milk quality were considered and linked with the discussion concerning contamination of milk and use of antibiotics and milk quality, specifically fatty acids and milk constitution.

Of the three SOLID novel production strategies, the most discussed and voted on was alternative protein sources for feed. Various optimal strategies are needed in the organic and low input supply chains to cultivate more home-grown proteins, starting with improved knowledge and technology transfers between extension services, advice, dairy farmers, breeding companies and research. In addition, independent knowledge centres for novel feeds (e.g. cotton seeds, lupins and algae) were seen as necessary to encourage farmers to produce protein feeds in different geographic regions. A key issue is to develop and share knowledge between different regions about new sources of protein feeds as well as more intensive use of by-products.

With respect to transferability of practices, the final stories of the groups highlighted a number of possible strategies in detail. Many of the participants suggested innovative strategies to ensure profitability of organic milking by increasing transparency in the supply chain. Two of the innovations were linked to showing the price structure to consumers using so-called transparency indicators. These indicators would allow the consumer to observe if the producer was receiving a fair share of the price of the product. The other strategy for securing the level of profitability for farms would be to set a minimum price in the supply chain. This would require much collaborative action from the milk supply chain to achieve agreement on the level of the minimum price.

At farm level, the production costs were stated as being too high due to high capital and technological investment costs. One solution to reduce the production costs suggested by the participants was a shift

towards more grass-based systems. Improving competitiveness is not the only farm-level challenge. In highly differentiated products such as organic products, competitiveness can only be achieved through better knowledge of consumers' needs and expectations and satisfying them. In the workshop, better communication of the value added properties of organic milk was seen as supporting this view. At processing level, more pressure should be targeted at innovative branding strategies. More research funding should be targeted at the development of quality-enhanced milk such as high levels of omega-3 fatty acids or products containing various minerals.
Even though the participants were mainly representatives of farmers, quite a few issues highlighted were linked to consumers, markets and policy choices. To create better future prospects for organic milk, a variety of supply chain strategies were identified, e.g. adding more valued added properties to organic milk. The participants said that consumers should be informed more about the health benefits of organic milk and the effects of grass-feeding on milk quality, and take into account a broader view of social sustainability issues.

One suggested innovation to deliver these properties straight to the final customer was to organize the delivery of the organic milk using vending machines for organic raw milk. One innovative solution to avoid waste is to reuse milk that is becoming out of date to make special cheese. Overall, it was argued that organic milk still needs more informative advertising campaigns, better transparency by allowing consumers to check the steps of the organic milk chain, and communication of the core values of the organic milk production to consumers. Communication to consumers and better knowledge transfer systems would also be more easily transferable from region to region.

Policy recommendations from SOLID

The following list of recommendations, based on results WP5 and other SOLID work, have been issued as part of SOLID Deliverable 5.5:
1: Extend the use of home-grown and local feed.
2: Multi-species diverse pastures may help combining competitiveness and environmental benefits of grassland-based forage.
3: Novel, alternative feeds should be introduced taking care of both consumer and producer advantages.
4: Breeding strategies tailored for low-input and organic dairy systems should be further pursuit to overcome the limits of high yielding breeds.
5: Dairy supply-chain strategies should aim at reducing (increasing) health-related perceived risks (benefits) if they wish to increase consumer confidence and willingness-to pay.
6: Extension and dissemination policies in the dairy sector are crucial to maintain its competitiveness and increase its sustainability, given the overall reduction of monetary subsidies.
7: Innovation uptake by risk-averse dairy farmer can only be boosted if dissemination focuses on the usefulness of innovative production strategies.

WP6: Socio-economic evaluation of novel strategies in organic and low input farming

The central research questions in this work were whether organic and low input farming is economically competitive and whether novel strategies and policy actions can improve competitiveness. To answer these questions, a range of quantitative research methods (e.g. modelling) were used. To allow quantitative approaches, one necessary pre-condition was to obtain a workable definition of low-input dairy farming, similar to that already existing for organic. Such a definition must then, with existing data (FADN) and modelling techniques (e.g. ORGPLAN, DREMFIA, CAPRI), be able to be used to evaluate competitiveness, farm planning and policy impact. Another major objective in WP6 was to provide evidence for policy recommendations.

Exploring farm characteristics and competitiveness

The first task was to develop a workable definition for low input (LI) dairy farming. Contrary to organic farming which relies on a precise set of regulations, a literature review on LI farming only yielded fuzzy notions of farming systems that are less reliant on external inputs, such as concentrates and pesticides, and as such also cause less environmental burden and provide more nature value. As some existing approaches consider absolute values of input or output intensity, they rather isolate low-input as marginal production systems and hamper honest competitiveness estimations. Therefor SOLID introduced a quartile-based discrimination focussed on an indicator expressing the use of external inputs per grazing livestock unit.

The results show, in general, over EU member states, that LI dairy farms, compared to their high input (HI) counterpart are smaller, are less specialised, have a larger share of forage and grassland in their utilized agricultural area and a lower share of maize. They also have more family labour, lower productivity and a lower production density. Although LI and organic (ORG) have low external input use in common, ORG farming cannot be assigned as similar to LI in all aspects, nor could LI be seen as an organic farming system without the organic regulations.

The same quartiles-based method was used to analyse the economic performance of LI and HI as outer quartiles, compared to medium intensity (MI) as inner quartiles (x2) and to ORG. Results obtained from the accountancy years 2007-2008 indicates that LI, despite the much lower productivity, is not that much economically worse than HI. On the contrary, when external input prices are high or milk prices low, then LI in many countries outperforms HI. The picture of structural and economic differentiation, however, is very different from one country to another. In Finland for example HI is economically less competitive than LI, UK has competitive ORG dairy farming, and in Belgium neither LI nor HI are most competitive, and the better performance of the farms in between (MI) indicates that using too much or too little input is not optimal.

Context specificity

As profitability results are sensitive to calculation methods and the economic market context, and as these findings are fundamental for further policy and planning advice, economic analysis was also conducted over a longer period (2004-2012) to validate and valorise earlier findings on the characteristics and economic competitiveness of the LI and ORG farms. We conclude that LI characteristics and starting points for competitiveness are very country- and context-specific. This calls for tailor-made policy measurements and farm development strategies instead of generic recommendations.

Context-specificity calls for farm and farmer centred diagnostic and planning approaches. One dominant diagnostic task is to obtain a complete picture of sustainability. A RAT, rapid assessment tool (SOLID Deliverable 1.1) has been developed to identify aspects of the farming system to be improved in order to improved competitiveness. For farm-centred planning, participatory approaches for planning, innovating and follow-up seem of high value. In addition to the participatory work of SOLID described in WP1, we also conducted participatory modelling, in which new farm plans were conceived and fine-tuned in close collaboration between modeller, advisor and farmer.

Novel Strategies (NS)

The novel strategies (NS) for improvement evaluated in WP6 are firstly science-driven (explored from literature and from the various multidisciplinary outputs from the other SOLID work packages) and secondly data-driven (derived from productive efficiency methods).

Given the above described context specificity, a successful NS adoption not only depends on intrinsic attributes, but also on the farm-specific factor endowments, the farmer's decision behaviour and the decision environment. In SOLID, various methods have been used to delimitate potential strategies: economic analysis of FADN data, the participatory processes of assessment, on-farm experimenting and modelling, agronomic sciences, a consumer survey and creative recombination through farm modelling. The interactive information between farmers, stakeholders and scientist needs a practical methodology to come to design, description and pragmatic information flows at farm, sector and policy level

Explorative theoretical, conceptual and methodological work in SOLID revealed that, basically, strategy design does not differ between traditional and LI and ORG farms, but that designing strategies for those farms suffers from lack of data. The main finding is that the information flow needs to be more interactive instead of linear. Although the SOLID project is highly interdisciplinary and participatory, important gaps are still observed between strategy providers, the final decision maker and the decision making support through modelling. The conceptual considerations led to some methodological foci and priority was given to evaluating home-grown proteins as a novel strategy and typical farms as a communicative instrument.

Typical farms were considered in terms of improving their operational effectiveness. Firstly, we defined typical farms to extend the competitiveness analysis from a mere profitability analysis to market price resilience analysis. The typical farms were constructed from a set of median farms and proved to be a good instrument for communication between modellers. Secondly, efficiency analysis reveals sources of competitiveness between LI and HI farming types and within LI farms. Indeed both groups show efficient and non-efficient farms, which encourages to explore improvement margins. Thirdly, on-farm observations using a participatory approach and a quick scan sustainability measurement tool showed some promising novel strategies when applied to the typical farms. Based on this and the outcomes of work in WP5, the home-grown protein strategy was the one taken forward for further analysis in WP6.

Modelling farm strategies' impacts at various levels farm, national, EU)

With the context specificity in mind, the first step was to mine the opportunities and threats on individual farms to adopt a new strategy. We developed a participatory modelling process that, in close interaction between adviser, researcher (modeller) and farmer, guarantees tailor-made strategies. The participatory farm model (PAFAMO) is used in an interactive way to ensure the co-production of insights from researchers, adviser and farmer on the farming system and objectives. The participatory modelling case focussed on home-grown proteins. The integrated approach helped to detect weaknesses and possibilities for each farm, in particular its factor endowments. Possible adoption of home-grown protein mainly depends on farmers' attitude, opportunity costs and greening subsidies.

Still at farm level, but now with a budgeting model (ORGPLAN) instead of a normative model, simulations in UK and Belgium revealed that incorporating home-grown protein in the cropping plan and feed ration is economically feasible for typical farms. This feasibility stands in particular when attention is paid to the protein contribution from forage clover grass in the ration which then reduces the need for supplementing with home-grown pulses. The simulations are based on a 'forage first' approach, this means that the ration planning was modified to an annual approach so that assumed protein utilisation from grazed and conserved forages was maximised first, followed by a calculation of the needed protein supplementation through home-grown pulses (in this case beans). Greatest increases in whole farm gross margin values were seen in farm management scenarios where high forage intakes are assumed.

Sector-level simulations in Finland confirm findings on feasibility of home-grown proteins, here grass-clover, but also showed high impact of generic policy measures such as manure regulations or fertiliser taxes. The objective was to evaluate challenges and appropriate policy measures of increasing home grown protein. Premium payments per hectare, nitrogen fertiliser taxes, reduced costs, and higher yield levels were implemented. The results showed that promoting yields of clover-grass mixes and introduction of nitrogen tax are the most robust measures in promoting clover-grass, while premium payments and modest cost reductions has relatively less effect. Further increase of the total grass forage area in the case of Finland is hard because of the fact that manure spreading is rather modest on clover-grass area, and this increases the logistic and other costs of manure spreading. Even if clover-grass or similar low input feeds (based on nitrogen fixation) are likely to reduce energy and fertiliser, the potential of such options is limited in conventional dairy production.

The various model simulations confirm this need to be cautious in seeking generic approaches that apply everywhere. This is also supported by the work on participatory farm planning and innovation, clearly showing the need for exploring the farm's uniqueness. EU-wide simulations of, for example fertiliser taxes need to be interpreted with high caution, given the variability in LI and ORG farming.

Farm planning and policy recommendations

Towards farm development, we recommend to re-consider the holistic basic farm strategic decision about allocating land, labour and capital, with decisions about forage cropping, grassland management, breeds, production capacity. When aiming at valorising the environmental or nature value from LI and ORG, processing and marketing questions will add to the intrinsic production questions. Farm planning needs to cope with personal characteristics and context-specific conditions. Coming back to politics, this means that inciting these tailor-made farm planning activities is preferred to generic policy measures. Support could be aimed at facilitating specific farm planning that stems from the unique combination of an entrepreneur in his decision making context, considering the utilisation of forage as well as different routes to adding value along the supply chains including also the growing market for organic milk.

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Project Results:
WP1: Innovation through stakeholder engagement and participatory research

The main aim of this work package was to facilitate innovation by actively involving stakeholders (i.e. organic and low-input dairy farmers, farmer groups and farm advisors) and researchers in a participatory approach. The emphasis was on engaging farmers to identify research needs to address innovative solutions at farm level with regards to production, health and welfare issues. The development, implementation and analysis was undertaken in close collaboration with researchers. The work consisted of five key activities: co-ordination to develop a time table for stakeholder interaction and to ensure that SMEs partners of the project and the farmer members of these organisations were not overburdened with requests for data from the whole project; identifying topics where farmers mentioned knowledge or innovation needs; developing appropriate research approaches and experimental procedures to test innovative solutions for topics identified and carry out between one and five projects per country and reporting on the lessons learned and communicate the outcomes to farmers, consultants and researchers (see also SOLID Deliverable 1.5).

Identification of innovation needs and specific research topics

To identity research priorities, sustainability assessments were carried out on more than 100 (organic/low-input) dairy cow or dairy goat farms in nine countries across Europe using an adapted version of the public goods tool developed by the Organic Research Centre (Gerrard et al., 2011; Marchand et al., 2014). This was intended to ‘set the scene’ and consider sustainability in its broadest sense when identifying suitable topics for participatory research. Farms were chosen by the SME partner (either low-input or organic) to reflect the range in terms of size, intensity/level of input use, breeds, products, marketing channels and geographical area in the respective country/region, and some illustrative case studies were presented on the SOLID website.

The results illustrate indeed the great diversity of low-input or and organic dairy farms that exist across the nine countries and highlight the need to look for targeted rather than general solutions. Cow farms varied from less than 20 ha (Austria and Italy) to more than 400 ha (Denmark, UK), with herd sizes ranging from nine (Finland) to over 300 cows (Italy, Denmark, UK) and milk yields ranging from less than 2500 kg/cow (Austria and Romania) to more than 8000 l/cow (Denmark). There was landless low-input dairy goat farming in Spain and Flanders, but also grazing on more than 300 ha of common land in Spain and Greece with herd sizes between 22 goats (Spain) and 1150 (Belgium) and milk yields between 117 and 900 l/year. The "classical" indicators of environmental sustainability (management of soil, water and nutrients, energy and carbon) showed considerable variation, indicating that there is the capability for poorer performing farms to improve. Data from the sustainability assessment were used to further investigate the environmental impact of low-input or organic dairy farming systems in WP 4 (e.g. SOLID Deliverable 4.2) and also informed aspects of the modelling work in WP6.

The results from the sustainability assessments were presented at 12 meetings, attended by 161 dairy producers in the nine countries and SME staff with researchers acting as facilitators of the discussions to identify research priorities. The farmers welcomed the opportunity to participate and express their views about research needs specifically providing knowledge for organic/low input production. Most farmers' own perception of sustainability included economic sustainability but the assessment encouraged thinking also about social and environmental aspects which provided a good basis for the following discussions. The research needs identified can be summarized under a number of headings that correspond to the Work Packages of the SOLID: topics on animal feeding and forage production were central to many farmers and related to the work in WP3; questions about natural resource management linked to WP4; animal management and animal health linked also to WP2 but the work in the participatory studies focused more on various strategies that farmers use to improve health, whereas WP2 had greater emphasis on breed choice. The farmers also indicated that research in product differentiation and marketing was important and this was covered in WP5. The fact that farmers identified such as broad range of topics indicates a lack of knowledge and confidence regarding low-input and organic farming strategies. For further details of the sustainability assessments and identification of research topics see SOLID Deliverable 1.1 for details.

Setting up the projects and developing the appropriate research method for each study

In the next stage we narrowed down the topics, because the number of projects in each country was limited. Identifying the 'right' research question is important for any research and this is equally true for participatory studies. The farmers' experience on what treatments they could implement and what indicators can be monitored on farms was brought together with the researchers' knowledge of existing research, experimental design, data analysis and statistics. This process led to some adjustments of the topics initially suggested by the farmers.

The choice of specific method depended on the topic and involved one or a combination of several of the following approaches:

– Farm case studies were based on monitoring certain aspects on a single farm, using a variety of data

collection methods, both quantitative and qualitative. In comparative case studies, this approach was extended to several farms and observations were compared.
– On-farm trials introduced a specific treatment (e.g. use of new feed resources) compared with a control group or with performance prior to the treatment being introduced.
– Group discussion involved a facilitated exchange among participating farmers with the aim to improve practice (i.e. Farmer Field Schools, Stable Schools, field labs).

Outcomes of the participatory research

In total 18 participatory projects were carried out in eight countries with final choice covering a wide range of topics reflecting farmers' priorities and suitability for a participatory project. The topics can be grouped into the following main themes:
• Forage production and feeding
o Enhancing on-farm forage protein production (FI)
o Assessing the effects of inclusion of Camelina meal and grape marc on dairy cows' performances. (RO)
o Mob Grazing for Dairy Farm Productivity (UK)
o Performance of Diverse Swards on Commercial Dairy Farms (UK)
• Strategies for animal health management
o Reducing antibiotic use for mastitis control in organic dairy farms (UK)
o Use of herbs in pastures for dairy cows (DK)
o A farm case study of rearing calves on milking cows; Dairy calves suckling milking cows during the first part of their lives (UK, DK)
o Iodine concentrations in milk of organic dairy farms (UK)
• Studies with small ruminants
o Use vegetable and citrus by-products for milking goats (ES)
o Impact of goats grazing on irrigated pasture on milk yield and quality (GR)
• Natural resources use and environmental impact
o Biodiversity on dairy farms of Sennerei Hatzenstädt – assessing the current status and future scenarios (AT)
o Climate friendly organic milk production (IT)
o Soil Health and Grassland Productivity (UK)
o Farmer field schools on climate friendly farming (DK)

Forage production, utilisation and feeding (see SOLID Deliverable 1.2)

Finnish projects investigating how to increase protein supply from forage found that topping of grass/red clover mixtures before cutting did not have a positive impact on the proportion of clover and protein content, whereas slurry application in the autumn did increase crude protein in the first silage cut of the following year. One of the UK case studies illustrated the potential of bio-diverse pastures with several different legumes and grasses to serve as a sufficiently productive alternative to conventional pastures (i.e. grass/clover pastures). It also found additional benefits for soil organic matter through the use of rotational (mob) grazing systems with high stocking density and longer recovery periods on the case study farm. Future research related to forage production should focus on suitability of more bio-diverse mixtures for different soil types, their feed value (including protein) as well as impact on soil fertility, other ecosystem services, and animal productivity and health. On-farm trials in Romania conducted after screening of novel forages in WP3 showed that industry by-products (camelina meal and grape marc) can be used as replacements for other energy and protein components in dairy cow rations on low-input farms and also have a positive influence on polyunsaturated fatty acids profile in the milk. The comparative case studies of the impact of dietary mineral supplementation on milk iodine concentrations in the UK revealed that use of iodised teat disinfectant influences the iodine concentration in milk, which therefore does not serve as a robust indicator of dietary iodine deficiencies. Some very specific suggestions for research needs, such as equipment and energy needs for drying forage (Austria), using various plant species (including for browsing) and identifying drought resistant plants and varieties (Italy, Romania, Spain, UK) could not be further investigated in participatory projects.

Animal management and animal health (see SOLID Deliverable 1.3)

Animal health and welfare scored well in the sustainability assessment and much research has been done, but the farmers still expressed a need for further research on this topic. The results show that organic and low-input farmers apply a number of different strategies to improve animal health and welfare and through this explicitly reduce antibiotic use. In comparative Danish case studies the farmers, who had started growing herbs in pastures several years ago, expressed a strong belief that this was beneficial for animal health and welfare although the case studies could not confirm this empirically. They continually experimented and developed their systems, for example by growing herbs in strips rather than across the whole pasture. Two case studies in the UK and in Denmark that leave calves suckling with milking cows found healthier calves that learn from their mothers and have improved weight gains, but also less milk in the tank. This emphasises the importance of sharing good practice in developing farm-specific calf rearing systems based on natural suckling. A UK discussion group for reducing antibiotic use began with mutual advice among the farmers on health promoting strategies. This was followed by on-farm trials on four farms that could demonstrate a significant impact of keeping SCC levels low after calving by treating cows with a mint-based udder cream. The farmers became more confident in aiming for further reductions in antibiotic use. All these studies cannot claim to conclusively show long-term health benefits, but emphasise the relevance of knowledge and experience sharing regarding various strategies adopted by the farmers that are supportive to the animals' wellbeing.
The choice of cow breeds and animals best suited to low input and/or organic systems was also raised as a research topic in several countries, but this was not chosen for on-farm experiments because the suitability of breeds for organic and low-input systems was investigated in experiments in WP2.

Studies with small ruminants (see SOLID Deliverable 1.4)

Dairy goat farmers in Spain and Greece identified two main areas of research needs related to feed supply strategies and genetic resources and their impact on productivity of milking goats. On-farm research with lactating goats in Southern Spain conducted after screening of feed sources in WP3 helped to develop good practises in the use of by-products, which can provide a range of nutrient resources replacing more traditional feeds used by low-input farmers. Ensiling was found to represent a valid strategy to maintain the nutritive value and ensure continuous supply of the by-products throughout the year. Specifically, silages made with tomato and olive by-products could replace medium quality forage (i.e. oat hay) in dairy goat feeding without compromising milk yield, provided that the farm is within a 50 km radius from the site of production of the by-product. Testing of environmental benefits using an LCA approach suggested a potential for overall GHG reductions arising from N2O emissions (from feed production stages) and enteric CH4 (in the case of tomato wastes) without productivity being compromised. The Greek study showed the potential of using irrigated sown pasture as an additional feeding strategy in semi-intensive dairy goat production in Greece by providing data regarding pasture management and dairy goat performance (milk yield and milk quality). The question of genetics of dairy goats in Greece was also studied as part of WP2.

Natural Resource Management (see also SOLID Deliverable 1.5)

The Austrian project demonstrates how an organic mountain dairy farming system can contribute to maintaining biodiversity. The study confirmed that assessment can raise awareness and that the attitude of farmers towards biodiversity and farm management is crucial for supporting and maintaining on-farm biodiversity alongside agri-environmental schemes. The Italian case study of soya replacement using home-grown pulses as concentrate feed found lower milk production leading to lower profitability and because of that also increased environmental impact per unit of fat and protein corrected milk (FPCM) produced. The work links to questions of environmental impact addressed in WP4 and modelling of strategies for using home-grown protein sources in WP6. Farmers in the UK wanted a better understanding of the soil to diagnose potential problems with declining productivity under organic conditions. Results of a survey followed by comparative case studies showed that farmers' assessment of soil structure tends to match the scientific assessment. The results strengthened the farmers' confidence in using visual tools and trusting their own judgement in discovering soil problem. This will need to be followed with further work on identifying remedial strategies that the farmers can put into place.
Farmers were also interested in questions related to product differentiation and how to improve communication with consumers about the value of their products. No specific project was conducted in this area, but results of the Austrian and Italian projects could support using specific claims in selling directly to the public. Other ideas suggested included the connections with agro-tourism, increasing the offered product range or developing an 'a la carte' strategy and targeting high-end restaurants for different types of flavoured goat cheeses. The work of WP5 is also relevant in this context.

Conclusions

The participatory methods have contributed to developing knowledge about sustainable Organic and Low-input dairying. Farmers are active contributors to agricultural innovation by trying out many things informally. Close collaboration between farmers and researchers as practised in the 18 participatory projects that were conducted has shown that such experiments can play a significant role in developing the knowledge about sustainable low-input and organic agriculture. Our approach encouraged to farmers to go beyond their day to day farming activities and identify sustainability challenges, formulate research questions, help carry out trials, analyse data and disseminate the results.
There is a need consider the economic impact and be aware of the diversity of systems and context when developing strategies to improve overall sustainability of organic and low-input farming. The sustainability assessment of more than 100 farms in nine countries illustrated this diversity among organic and low-input dairy cow and goat farms in terms of size and intensity. We also found variability in interest in the sustainability assessed, with financial sustainability being very important to most farmers.
Forage production and utilisation and the role of home-grown protein sources are of crucial importance to

low-input and organic milk producers. Nine of the 18 studies contained elements related to forage production and feeding. We found several but not all proposed strategies to have a positive impact on animal productivity and economics. Positive impacts were found related to bio-diverse mixtures, application of slurry to increase forage protein content and irrigated pasture, preserving (i.e. through ensiling) and using several regionally available by-products. The results of studies using herbs in pasture, different grazing strategies, replacing soya protein with home-grown feeds and topping to increase clover content of ley were not conclusive regarding productivity and economics but some found other benefits.
It appears relevant to include 'low inputs of antibiotics' as an important criterion when defining 'low input milk production'. The projects investigated a number of strategies that farmers use to improve animal health and welfare and through this, explicitly reduce antibiotic use. Examples included the use of herbs in leys, letting calves suckle their mothers, the use of external mint-based udder treatments and farmer discussion groups. The results cannot claim to be conclusive in terms of improved animal health and welfare, but illustrate a variety of strategies that can become part of a 'tool box' to help farmers to become more confident in reducing antibiotic use.
Participatory research can play a significant role in developing practical solutions by generating context specific new knowledge as well as involving farmers' mutual inspiration and knowledge exchange. Engaging with the participatory research projects was seen as positive by both the farmers and the scientists. Farmers and scientists worked closely together from identifying the questions and the initial design through to data gathering, analysis and follow-up actions. Farmers were actively involved in identifying problems, contributing their experience and knowledge and in carrying out research and evaluating the results. The farmers became more aware of research and more confident in using the results. The researcher involvement facilitated systematic data collection and analysis. Several on-farm trial projects use of statistical methods for analysis and publication of the results is envisaged. The researchers thus contributed to the wider dissemination of the findings which extended beyond what was interesting for the participating farmers (see for example Padel et al., 2015).

WP2: Adapted breeds for productivity, quality, health and welfare in organic and low input dairy systems

Within the studies described below, evidence for differences between conventional and alternative dairy cattle and goat genotypes was examined in terms of metabolic balance, fertility, health and product quality. This, and the identification of indicators for 'adaptation', has the potential to have a significant impact on the future direction of breeding programmes for organic and low input production systems, with a subsequent improvement in the overall competitiveness of these systems. In achieving these goals, the supply and affordability of milk and milk products from organic and low input systems will be increased. Furthermore, the impact of developing specific risk-based improvement strategies for animal health and welfare in organic and low input dairy systems will contribute to the competitiveness of the sector, address societal expectations, and provide information for future programmes aimed at the development of sustainable organic and low input dairy production.
Although dairy systems are generally termed 'low input' if the use of external supplementary feed sources is limited to some extent, these low input systems are actually extremely diverse across Europe, both in terms of availability of production factors and in management strategies. These low input and organic systems require dairy livestock which are adapted to the specific conditions within individual systems, while the diversity of the systems means that different breeding approaches may be required to secure appropriate livestock. In the light of the absence of a dairy genotype which may be generally adapted to all

different types of organic and low input dairy systems, actors within the sector in Europe have identified a number of possible ‘alternative’ strategies, such as crossbreeding and selection for robustness and lifetime performance to overcome the limitations of conventional genotypes within low input or organic systems. Robust scientific evidence in support of these ‘bottom up’ approaches is absent. The work conducted in the course of the project therefore aimed at characterising the degree of adaptation to low input environments of dairy cattle and dairy goat genotypes, which had been selected using very different approaches, in different geographical locations and within different production systems.

Dairy Cattle Studies

The dairy cattle studies compared the response to concentrate supplementation (including a challenge diet with reduced concentrate supplementation and a control diet) of widely used ‘conventional’ breeds and breeds that were perceived to be ‘adapted’ to low input systems. The diversity of low input and organic systems is reflected in the very different concentrate inputs adopted across the three geographical regions studied, Western Europe (UK), Austrian Mountain and Northern Europe (FI). Both total feed intake and milk output were lower with the low input diets than with the control diets, with the level of production being distinctly different across the three regions. Feed intake and energy corrected milk yield were different between genotypes for one region only, while milk fat content was higher for the alternative breed in all regions and milk protein in two out of three regions. No consistent patterns were observed among genotypes for body weight and body condition score, their change throughout lactation, and time of nadir. There were indications of improved health traits with the alternative genotypes in two regions, while across all regions fertility was unaffected by genotype or dietary treatment. In the absence of consistent interactions between genotype and dietary treatment, both the conventional and alternative genotypes appear to have responded in a similar manner to a feed challenge. However, there is some evidence from blood and milk biomarkers that the different genotypes respond differently at the metabolic level to the system-specific reduction in energy supply. The somewhat inconsistent trends and significant effects for some fertility and health traits should be addressed both in future studies and in the development of breeding programmes for low input and organic dairy systems. See SOLID Deliverable 2.5 for further details.
A potential advantage of certain genotypes may comprise of, among others, a greater efficiency of utilization of feed energy. Therefore, information was collected and analysed on the energetic efficiency of a conventional (Holstein Friesian, HF) and of alternative genotypes (Norwegian, F1 Jersey x HF, F1 Norwegian x HF). The results indicate that no significant differences exist between these genotypes in terms of energy digestibility, metabolizability of gross energy, energy used for maintenance and for lactation. It is therefore concluded that cow groups evaluated herein have no significant effects on energy expenditure or energetic efficiency. However, the maintenance energy requirement is not a constant as adopted in the majority of energy rationing systems across the world, but is likely to increase with increasing feed intake. See SOLID Deliverable 2.4 for further details.

Goat Studies

Due to the absence of scientific information on the phenotypic and genotypic characteristics of dairy goats in low input systems in Southern Europe, the work conducted on goats had a somewhat different focus compared to the studies on cows. The data collected during the course of this project fills a critical

knowledge gap in terms of providing basic information on the productivity, reproductive performance, health, welfare and milk quality within low input Southern European dairy goat production systems. The information collected includes much needed data, such as the reduction in productivity due to internal parasites.
Distinct differences were identified between the different dairy goat breeds studied herein. One exotic breed appears to be well adapted to the specific requirements of Southern European low input systems. Differences in the frequencies of alleles associated with productivity and milk quality are highly relevant for the design and implementation of breeding programmes. The information from genotyping points to a superiority of the autochthonous breeds over internationally used high-yielding breeds in terms of milk quality. See SOLID Deliverable 2.5 for further details.

Animal Welfare Studies

Animal welfare in organic and low-input dairy cow systems is commonly expected to achieve at least satisfactory levels. This assumption is based on the regulations regarding housing and management of the animals and/or the access to pasture. The aim of the work directed towards welfare of dairy cows within this study was therefore to evaluate the welfare state of the dairy cows in three regionally different low-input and/or organic dairy systems throughout Europe (Northern Ireland, Spain and Romania), using a state-of-the-art assessment scheme WelfareQuality®. Half of the 30 farms assessed were graded ‘Acceptable’, 43 % achieved an ‘Enhanced’ welfare state and one farm was classified ‘Excellent’; one farm was ‘Not classified’. In five out of the 12 criteria, the average score indicated the occurrence of welfare problems in at least one country. Across the production systems investigated, the presence of injuries in the cows may be regarded as a general welfare problem. Furthermore, ‘Comfort around resting’ and ‘Absence of pain induced by management procedures’ were identified as unsatisfactory in at least two countries. ‘Thermal comfort’, ‘Ease of movement’, ‘Absence of disease’ as well as most of the criteria related to ‘Appropriate behaviour’ may be considered at least acceptable. Variation between farms shows that on one hand, farms could benefit from intervention studies and, on the other hand, that good and even excellent results may be achieved in organic and low-input dairy systems. See SOLID Deliverable 2.1 for further details.
Based on a risk analysis and the scores that farms achieved in the welfare assessment, weak points and strengths of the organic and low-input farms were defined. Improvement strategies based on the risk-factor analysis and additionally an evidence-based approach point at key intervention measures such as changes in feeding management, adaptation of the resting area or use of best practice for disbudding of calves. See SOLID Deliverable 2.2 for further details.

Conclusions

The results from the studies conducted within this WP contribute to improving the overall sustainability of organic and low input dairy production systems by supporting breed choice and the further development of dairy cattle and goat genotypes used in these systems. Furthermore, the risks identified in terms of reduced welfare in dairy cows need to be addressed by appropriate improvement strategies in order to maintain and develop respective advantages which organic and low input dairy systems may have.

WP3: Forages for productivity, quality, animal health and welfare in organic and low input dairy systems

The overall objective of this work was to improve the competitiveness of organic and conventional low input dairy production systems by improving the health and welfare, the productivity and product quality of livestock in low input and organic systems through improving the supply of forage. We accomplished this by improving the supply of nutrients from forages and by products through the use of novel feeds; increasing the understanding of the efficiency with which high forage diets are utilised by dairy cattle and reducing risk and finally providing a decision support systems for forage management and feeding.

Development of novel and underutilized feed resources including by-products from processing of renewable raw materials

The amount and quality of feeds offered to animals have significant effects on feed intake and milk production, which largely dictates the economics of production. In addition they may also influence milk quality and the health of the animals. We first conducted a literature survey of novel feeds (SOLID Deliverable 3.1) and then continued with laboratory and in vitro analyses with a wide variety of novel feeds, with some of them finally tested in on-farm trials (SOLID Deliverable 3.2). The literature review demonstrated the potential of a range of by-products and underutilized sources as animal feeds and highlighted the need for additional information concerning certain by-product feeds that should be obtained through a strong farmer and stakeholder interaction.
The in vitro and in vivo assessments as well as on-farm trials were conducted by different partners across different regions of Europe (LUKE (Finland), ICDBNA (Romania) CSIC (Spain) and ORC (UK)). The experimental work addressed the need to alleviate the deficit of protein crops in Europe, feeds from emerging industries in Eastern European countries, biofuel crops across Europe and wood industry in Northern Europe, by-products from food processing industries in Southern and Western Europe and agroforestry systems based on UK experience.
The main conclusions of the work conducted are:

- Grain legumes and rapeseed have potential to replace soya bean based protein supplements in dairy cow feeding, but mainly economic reasons restrict their wider use.
- Wood based hemicellulose extracts are currently not available in the global feed market and agroforestry is used only to a limited extent and despite benefits being identified for both approaches, wider use of them would require large changes to the current circumstances.
- The agro-industry sector in Southern Europe provides a range of valuable by-products with potential to be used as feed for small ruminants. However, the high moisture content represents the main limitation for the successful and wide use of some by-products by the feeding industry. Ensiling represents a promising option: silages made with tomato and olive by-products may replace medium quality forage (i.e. oat hay) in dairy goat farms provided that the farm is within 50 km from the site of production of the by-product. Such strategies could be applied to a number of potential different fruit or vegetable by-products in the future.
- Oil industry derived by-products tested in Eastern Europe showed, in general, a higher content of oil and crude fibre, at the expense of crude protein content. Camelina meal could replace the classical sunflower meal in diets for low-input dairy cows (low production level) without noticeable adverse effects on milk yield.
- Grape marc could partly replace cereals, as a temporary substitute (e.g. in case of feeds shortages) in diets for dairy cows within low-input systems, at dietary levels up to 3 kg/d and replacement ratios that allow meeting the feeding requirements for net energy and intestinally digestible protein, without significant

negative effects on milk yield and quality.
Overall, the range of potential novel and underutilized feeds is large. The current results can be used to assist in exploiting the potential of different feed resources and in ration formulation. Improved supply of feeds may be particularly favourable in situations when the basal feed supply is reduced due to, e.g. adverse weather conditions. The economic effects of use of novel feeds is highly dependent on the pricing of the feeds but may in many cases be expected to be positive. Widening the type of on-farm produced feeds may also have beneficial effects beyond simply feed supply such as improved crop rotation, self-medication, microclimate or other ecosystem services. In some cases, use of novel feeds may also include risks, e.g. to animal health (anti-nutritional factors), milk quality or consumer acceptability, and these factors must be kept in mind when innovative animal production solutions are developed.

Assessment of an agroforestry system in terms of feed supply and multifunctionality

This work was based on two agroforestry systems in the UK, where the other one was already established (SOLID Deliverable 3.2 Part1) and the other one covered the starting phase of a new agroforestry system (SOLID Deliverable 3.2 Part2). The main conclusions of the work were:
• Agroforestry has been identified as a 'win-win' multifunctional land use approach that balances the production of commodities with non-commodity outputs such as environmental protection and cultural and landscape amenities.
• Designing a new system must consider the desired outputs (food, fuel, fibre), site conditions and climate, species properties (canopy size, root characteristics, shading tolerance etc.), species interactions, agronomic factors as well as government regulations.
• Controlling competition from weeds and grasses is essential for promoting better tree establishment.
• Tree fodder may offer nutritional benefits to livestock, although values vary depending on tree and animal species, as well as seasonal and bio-geographical factors. Fencing is essential to protect the trees from livestock and control the impact of browsing.
• Providing shelter for livestock during the winter months can lead to better survival rates, increased milk production and significant savings in feed costs. The provision of shade in hot summers is an important factor for animal welfare.

To derive estimates of energy utilization by dairy cows on high forage diets

This analysis used a unique animal data base maintained by AFBI in which measurements of energy intake, and outputs (in faeces, urine, methane and milk), heat production and energy retention in body tissue have been measured on over 1000 dairy cows using calorimeter chambers. This dataset includes comparisons of forages of different qualities and type, and critically, data from cows offered diets containing very different forage proportions (from 100% forage to diets containing in excess of 80% concentrates).
The results from work in WP2 revealed that cows of adapted breeds (e.g. Norwegian Red and crossbred cows) have similar maintenance energy requirements as Holstein cows, and utilise energy for lactation with a similar efficiency as Holstein cows. Thus existing rationing systems are appropriate for a range of dairy cow breeds.
However, the results demonstrated that dairy cows managed under low input or organic farming regimes may require more feed energy for maintenance of their basal body activity than those managed within

higher concentrate input systems. Cows offered high forage diets may require more time and a greater effort to eat, ruminate and digest these bulky forage based diets. This issue has not been considered within energy feeding systems for dairy cows in many European countries. Thus many existing systems may underestimate the feed requirements of dairy cows managed within low concentrate input systems. In order to improve the economic and environmental sustainability of dairy farming in Europe, there is an urgent need to upgrade current energy rationing systems for low input and organic dairy farming, taking account of the findings of the current work (see SOLID Deliverable 3.4).

Development of a decision support model for optimum management of forages and by products in organic and low input systems

The SOLID-DSS is a decision support system (DSS), which helps to optimize the management of feed resources and feed supply systems within organic and low input dairy systems in Europe to minimize the risk of feed shortages. The model serves both organic and low input farms as long as they depend mainly on on-farm produced forages. Restrictions concerning external feeds for organic farms resulting from the EU directives are included in the DSS.
On basis of integrated European wide weather database (1997-2007), the annual site and farm specific yield calculations of arable grain and forage crops and permanent grassland forage yields for conservation and grazing can be assessed. This helps to provide a risk assessment of potential annual forage.
The SOLID-DSS is structured around two main models:
1. Crop and Grassland Model within the SOLID-DSS (Crop.js) based on: The crop and crop rotation model which is based on MONICA (http://monica.agrosystem-models.com/). The grassland model which is based on the Sustainable Grazing Systems SGS Pasture Model (http://imj.com.au/sgs/. This allows for a site and annual weather specific yield calculation of crops within three to five year crop rotations and of permanent grassland (harvested and grassed) using a European wide weather data base implemented in the DSS.
2. Dairy model (dairy.js)
It is built as an open-source JavaScript library built to simulate dairy cows and young stock, their growth, requirements and diets. The implemented modules allow for simulating herd structure, milk yield and solids, energy and protein requirements (expressed in different European systems), feed evaluation (expressed in different European systems), dry matter intake (fill value based), growth and mobilization, cow grouping and diets.
Because of necessary simplifications (limited crop spectrum, only one mean soil type per farm, limited to non-groundwater influenced soils, simplified cutting and grazing regime, no grazing for dry cows) and limitations of the model outputs of non-site-specific calibrated plant-soil simulation models in absolute terms can only be used restrictedly under real farm conditions. Nevertheless the SOLID-DSS provides a deeper understanding of the complex relationships and dependencies of sustainable organic and low input dairy systems and is well suited for agricultural extension, training and teaching. An additional benefit of this work is that the whole SOLID-DSS is programmed in well-documented open-source code and is available for modellers to be used e.g. in future projects (See SOLID Deliverable 3.5 for details).

WP4: Environmental assessment: For improvements and communication in organic and low input dairy systems

This work had three overarching goals: 1) To develop the necessary methodology for a comprehensive assessment of environmental sustainability in a dairy chain taking appropriately into account the peculiarities of low input and organic systems; 2) To develop a decision support tool to enhance environmental sustainability on practical dairy farms; and 3) To assess the environmental performance of organic and low input systems compared with conventional intensive dairy production systems. Furthermore, it was decided that the concepts behind the assessment should be based on the life cycle approach, where all environmental impacts from manufacturing of inputs to the farm in addition to all emissions taken place at the farm are combined and put in relation to the amount of milk produced.

Development of the assessment framework

The LCA approach has been supported by the EU for several years through its integrated product policy, which aims to relate the environmental impact to the individual products in order to allow for informed choices among all parties in a product chain, when using/consuming different products. In the last few years the Commission have reinforced such initiatives by establishing the Product Environmental Footprint (PEF) initiative as part of supporting the single market to include environmental issues. In this initiative the Commission work with industries and scientists to establish commonly agreed methodologies to make an environmental assessment, which ultimately are those to be used when claiming environmental performance in relation to the single market. Food is part of these initiatives and there is a pilot established dairy products. When this pilot is finished, the results should provide mandatory ways to claim environmental impact of dairy products. This holds for which types of environmental impacts should be included in an assessment as well as methodology on how to calculate them.
Our work has been matching the above mentioned initiatives. Two aspects are in particular important in a proper evaluation of organic and low-input dairy farming. This is how to account for impact on biodiversity and how to account for differences in soil carbon sequestration in the assessment of emissions of greenhouse gasses. In the work with the PEF these aspects are also recognized as dimensions for which there is a need for better assessment methodologies.

Inclusion of soil carbon changes in LCA

As regards soil carbon sequestration a conceptual model has been developed and published (Petersen et al., 2013) which is suitable for use in LCA work. The key feature of this model is that it is generic, based on carbon in crop residues that enters the soil, takes into account the subsequent release of carbon from soil the following years, and furthermore the subsequent deposition of carbon in oceans following the Bern carbon cycle. Thus it is possible to estimate the global warming impact of a specific amount of carbon put in the soil over a 100 year perspective (similar to the way the impact of other greenhouse gasses are calculated) and the impact can be directly added to the other contributors to the global warming impact. For practical planning purposes we have published, how the methodology works for different types of cattle feed (Mogensen et al., 2014). In this paper default numbers are given on how much carbon that can be expected for different crops as well as the contribution of carbon from adding manure, which is very central in particular in organic and low-input systems. For example, it was shown that 1 ha of maize for silage was related to a release of carbon corresponding to a global warming potential of 900 kg CO2 per year and if supplemented with manure, of an additional 270 kg CO2 per year, whereas a grazed clover grass field was related to a sequestration corresponding to a global warming potential of 700 kg CO2 per

year. The difference could therefore amount to 1600 kg CO_2 per ha per year depending on the type of crop used.
At the same time we have worked with an existing farm model that can be used for practical assessment of the environmental performance of specific farms based on easily available farm data (SOLID Deliverable 4.2). We have used this model to investigate the carbon foot print of milk from 34 organic farms from 6 countries in Europe (UK, Denmark, Finland, Belgium, Italy, and Austria). The farms were chosen to represent very different farming practise. The average carbon footprint was 1.3 per kg milk delivered from farm gate with a considerable variation among farms but only little variation between countries, illustrating that the actual farming practise has a considerable influence on the carbon footprint. The overall standard deviation per kg milk was 0.2.
Of the total average GHG emissions, enteric fermentation by dairy cows contributed 33% and young stock contributed 12 %. N_2O emissions from housing and crop cultivation accounted for 22%, farm capital goods for 9 % and manure management for 6% of the total emissions. Electricity and fuels were both contributing 5 %, and imported feeds contributed 3 % of total GHG emissions.
As a second step we estimated the carbon footprint for 23 organic dairy farms from the UK, Denmark and Finland with and without including soil carbon sequestration in the assessment. As a reference we used a typical conventional intensive dairy production represented by a mixed Danish dairy system. The results show that for all the organic farms, the carbon footprint is reduced when soil carbon sequestration is included in the calculations. The carbon footprint of conventional milk was not significantly affected. The main reason is that organic farms generally have a higher share of grassland relative to cereals/maize on their farms. The grasslands increase the carbon pool in the soil, whilst maize reduces it. Since a higher level of soil carbon is one of the main features of organic farming, it is crucial to include sequestration for accurate carbon footprint calculations.

Inclusion of biodiversity in LCA

It is well documented in literature that biodiversity is typically higher on fields that are grown organically compared to conventionally cultivated fields. The empirical basis and concept for including this in an LCA assessment is missing, however, it is acknowledged that this is an important aspect that should be included. Presently in the PEF, what it is included is the pressure on biodiversity from other emissions, whereas the impact of cultivation method on biodiversity per se is not included.
In this project, we have revisited biodiversity data from the EU funded BioBio project (http://www.biobio-indicator.org/) where data on plant species on organic and conventionally fields with different crops were collected in seven European countries. We have used the data from six countries placed in the biome 'Temperate Deciduous Forest', that represent a major part of the North, West and Central European agricultural landscape, to analyse number of plant species in different crops and compare with the number of plant species that are present in semi-natural vegetation. Based on these data we could calculate the relative number of plant species depending on type of crop and whether the crop was grown organically or not in comparison to the natural vegetation. Thus we distinguished between pastures (monocotyledons or mixed), arable land and hedges as well as management practices (organic, less-intensive or intensive conventional production systems).
The indicator (already defined in literature) is called Potential Disappeared Fraction (PDF). The potential disappeared fraction of plant species in for example a conventional cereal field is approximately 0.70 or 70%, whereas in an organic cereal field it is only approximately 0.20 or 20%. In conventional grasslands

the loss of species is only approximately 0.10 or 10%, whereas in organic grasslands you actually find a higher number of plant species than in the natural vegetation (semi-natural forest); here the loss is approximately -0.30 meaning that you actually gain 30% more plant species compared to natural vegetation. It is acknowledged that number of plant species is not a comprehensive indicator of biodiversity but this indicator is sensitive to field management options as opposed to indicators based on insects, birds and mammals which are more dependent on the landscape features.
The PDF indicator was used as an indicator of Biodiversity Damage Potential on the previously mentioned 23 organic farms in UK, Denmark and Finland, and expressed per kg of milk produced, like the other indicators. In many cases the organic farms had negative Biodiversity Damage Potential, which means that the production system in fact resulted in an overall increase in biodiversity compared to semi-natural vegetation. In comparison, the average Danish conventional milk production has a Biodiversity Damage Potential of approximately 0.40 per litre of milk. It was also shown, that there was a tendency for a trade-off between the carbon footprint and the impact on biodiversity – in that farms with lower carbon foot print had more damage to biodiversity.

Comparison of different production systems

In order to assess the possible environmental benefits of organic and low-input dairy farming compared to conventional farming practises we defined three very different basic systems and modelled the environmental impact (SOLID Deliverable 4.3). The three basic systems, which we assume represent a major part of the EU dairy production, were lowland grassland based systems, lowland integrated crop-livestock systems, and mountainous systems. The grassland based systems were represented by typical UK organic and conventional systems, the mixed dairy systems by typical Danish organic and conventional systems, and the mountainous systems by typical Austrian organic, low-input, and conventional systems. Input, output as well as internal farm turn-over of the different farm types was modelled as a basis for the environmental assessment.
Looking across all systems considered, the amount of bought-in concentrate showed major differences varying from 258 kg to 2437 kg per ha, while the fertilizer input ranged from 0 to 134 kg N per ha. From an overall point of view, all mountainous systems and the grassland based organic systems could be considered as low input, whereas the mixed systems and the grassland based conventional can be considered medium or high input systems. Considering the on-farm forage production, a main difference is a lower yield in cereal crops in organic compared to conventional systems.
A particular issue when comparing organic and conventional dairy systems is the use of pesticides in conventional production. While in principle this is accounted for in the PEF by calculating impact on eco-toxicity, there is only very limited material available to get good estimates of the impact of different pesticides on eco-toxicity. This is due to methodological challenges, such as the fate and uncertainty of the toxicity impacts compared to other impact categories or the lack of data or characterization factors for potentially key pollutants. Therefore, in this project we provided 20 new characterization factors (CFs) for fresh water toxicity potentials of pesticide active ingredients used in the production of the livestock feeds; barley, maize, grass, soybean, and wheat. The USEtox 2.0 model was selected as a characterization model since it was developed in scientific consensus, to better represent application practice for characterization of toxic impacts of chemicals and pesticides in LCA. The new CFs, are expressed as comparative toxic units (CTU) or comparative damage units (CDU) and calculated at midpoint and endpoint level respectively.

Our analyses showed no major differences in contribution to global warming between organic and conventional milk produced in mixed dairy and mountainous systems, whereas the organic milk had a lower global warming impact than conventional in the grassland-based system. This was mainly due to a lower impact of legumes in the home-grown feed than of fertilized grasses. In general the organic milk had lower mineral and energy use (75%) and a lower impact on marine eutrophication (40%). Eco-toxicity related to organic milk was more than 1 order of magnitude lower than for conventional milk and where the biodiversity damage in conventional milk production was in the range of 0.5 PDF, it was close to zero in the mixed organic system and in the range of −0.5 in the grassland and mountainous organic systems. However, the land requirement for the organic milk was considerably larger than that of the conventional milk per unit of milk produced.
In conclusion our results show that the carbon footprint of organic milk varies among farms, shows no clear differences between countries, and is comparable to the carbon footprint of milk produced by typical, conventionally managed dairy farms. Organic farms generally have higher soil carbon sequestration, due to a higher proportion of grassland and greater use of manures, instead of synthetic fertilisers. Likewise, organically managed fields generally have higher biodiversity compared to conventional fields. These two factors - soil carbon and biodiversity - are not normally included in the environmental LCA of milk, resulting in a biased comparison of organic and conventional milk.

Optimizing environmental impacts

A main challenge when working with practical farm data is to estimate the consequences of a change (an improvement option) due to the interactions between different farm components. Thus, an improvement in one aspect may lead to unforeseen impacts in other parts of the farm production chain. In order overcome this, a Bayesian belief network model was developed. The previous LCA model for carbon foot print was adapted to also account for marine eutrophication. Secondly this was built into a Bayesian belief network, which is operated by Hugin researcher software. In addition the model was fed with expert knowledge on the likelihood of achieving an environmental gain by up to 19 management options. The input to the model is the farm specific data which was also used for the carbon footprint model and the considered management options. Based on the deterministic model built in the networks and the likelihood of achieving a better environmental performance the model can optimize according to 4 management options at a time.
The model work per se is accomplished as a research model that can be used for identifying most relevant improvement options for different farm types and there is comprehensive description of the principles and practical use of the model. The model is, however, yet not available for use as an internet application. This is expected to be achieved later in 2016.

WP5: Competitiveness of organic and low input dairy sector: Supply chain and consumer analyses

This work had three main aims: 1) to identify the broad range of expectations for innovation in management practices and adapted breeds along the whole low-input and organic dairy farming supply chain (fork to farm); 2) assess the acceptability of novel strategies (developed in WP1, 2 and 3) along the whole supply chain given the differing expectations (with special consideration to consumer acceptance and preferences, and the sustainability of supply chain management practices) and 3) identify optimal strategies to enhance collaborative behaviours in low-input and organic dairy supply chains.

Identification of expectations along the supply chain

The expectations and objectives of low input and organic dairy supply chain members (producers, milk buying groups, processors, retailers and consumers) were identified by means of focus groups (3 focus groups consisting of 8-12 participants from a range of low input and organic supply chains) in participating countries (UK, IT, FI, BE). The Q Methodology (Eden et al., 2008) was used to compare the viewpoints of the different participants. This methodology highlights common ground and divergence in the expectations that organic and low input dairying can deliver and is used to understand the points of view of a specific part of the population and is not intended to lead to conclusions about the population as a whole.
There was consensus across all participants within a supply chain in a country and across countries as to which innovations were deemed to be unacceptable in organic (from an ethical and/or regulatory perspective) and low-input dairy systems. These included:

• Improve forage quality and yields in low-input dairy systems by GM plant breeding techniques.
• Develop designer dairy food from transgenic animals.
• Acceleration of genetic selection including recombination in vitro.
• Innovations to speed up calf development from birth to maturity so that they can breed earlier.
• Innovation in indoor (100% housed) dairy systems to improve animal welfare.

With the exception of “Innovation in indoor (100% housed) dairy systems to improve animal welfare” in Finland (which consumers liked and processors and retailers disliked), there were no major conflicts within country specific supply chains over which innovations were acceptable or not. There were however differences in where different supply chain members priorities lay. Consumers tended to load more on Factors where the main theme was high animal welfare, this was a pattern observed across countries too. Producers and retailers/processors on the other hand tended to load more on factors related to feed efficiency, feed quality and efficiency of production. Innovations to improve animal welfare, however, were still also important to this group. Italy was unique in having a group of supply chain members loading on a supply chain efficiency factor (see SOLID Deliverable 5.1).

Assessing the acceptability of novel production strategies

The results of the work above and of other relevant SOLID work resulted in a list of innovative production strategies that represented a sort of “wish-list” of potential innovations in management practices and adapted breeds along the whole low-input and organic dairy farming supply chain generated in the SOLID project.
In order to test in a more quantitative manner which of those was most acceptable along the organic and low-input dairy supply chain, we reduced that list to just three main novel production strategies.
Extensive brainstorming and consultations among the partners and the stakeholder platform of the SOLD project led to the choice of the following three novel production strategies, which were the focus of all subsequent analyses in WP5. These were:

• Agroforestry
• Alternative Protein Source (with lupin or other soy-substitutes)
• Prolonged Maternal Feeding

The Supply Chain survey

In order to measure the acceptance of the proposed novel strategies we applied a modified version of the Technology Acceptance Model (TAM) developed by Davis (1989). A survey was administered to a convenience sample of more than 1500 members of the organic and low-input dairy supply-chain members in 6 countries. In total, 223 respondents completed the survey. The majority of respondents were Dairy Farmers (72%), the other groups were considerably less well represented (Dairy Farmer and Processors: 14%; Dairy processor/Milk buying group: 8%; Compound feed producer/distributor: 6%).
The analysis of the acceptance does not show many differences among the different supply chain members. Over 50% of each supply-chain level ranked first the alternative protein source production strategy confirming the results analysed by country. Our results allow us to make some theoretical and practical contributions. This was the first attempt to apply and test the extended TAM model in the dairy sector. Our study confirms the validity of general TAM framework in explaining technology adoption intentions (and decisions), but also demonstrates that, in the context of novel production strategies aimed at the organic and low-input dairy sector, the individual's belief is strongly influenced by those of others, specifically leading companies, peers and other significant influencers. Further research is needed to validate our findings in other contexts, but we believe that the results of our study have theoretical implications that go beyond the specific case under observation.
Our findings also have relevant practical implications for dairy farmers, compound feed producers and retailers, dairy processors, researchers, and advisers. Farmers' perceptions of what other relevant people want them to do, strongly influences what farmers' perceive as useful to adopt, particularly if they are uncertain about the impact of certain innovations on their farms. Pioneers are always taking the risk for all the followers, and this may turn out very costly in dairy farming, where a large portion of the farm capital is invested in the livestock. The fact that the most preferred strategy - across all countries and roles in the dairy supply chain - was soy substitution by Alternative Protein Source, may derive from the large influence of others opinions on each individual (subjective norms). Many farmers affirm that they have already adopted this strategy, indicating that this innovation is potentially already better embedded in the sector. Others feel more confident in being followers of a tested strategy. In other words, individual farmers consider it more useful and are more likely to adopt those innovations, those novel production strategies that receive broader consensus among their peers, their advisers and the society in general.
Finally, the finding that those farmers who are better in sharing information along the supply chain are those whose opinions are less impacted by the opinions of others may help understanding the role of increased collaboration within the supply chain to speed up the adoption of novel technologies and strategies, especially those which appear less 'mainstream' in the eyes of the prospect adopters. Sustainable production strategies, especially those applied in organic farming, need strong collaboration throughout the whole supply chain: input producers need to recognise the (novel) needs of their farming customers, while processors, distributors and finally consumers need to perceive the higher value produced by means of these more sustainable practices. In the past, organic farming, itself seen as innovation, has been an example on how sharing information and knowledge can become viral, even against strong corporate interests in the chemical input industry and against mainstream knowledge-based supply chains that were not favourable (and in many instances still are) to its diffusion (universities, research centres, advisory and extension agencies).
In the organic and low-input dairy supply chain lack of home-grown or local feed is among the greatest barriers to a real sustainable and safe development. Given an alternative protein source strategy is prone to have implications on farm productivity, profitability as well as in milk quality, the success of this strategy

hinges upon an increased collaboration among the various supply chain actors. Prolonged maternal feeding cannot be applied successfully without an increased level of information from farm to fork. Without consumer recognition of higher welfare standards, the payoffs of that strategy are clearly negative. Finally, it is likely that agroforestry, as a sustainable alternative feed/increased welfare strategy, needs wider societal recognition, since the public goods (biodiversity, reforestation, etc.) produced cannot all be borne by the consumer. Indeed, our findings should encourage policymakers to consider the important role of supply chain management practices, including collaboration, to enhance the sustainability of dairy organic and low input farming systems. Furthermore, information, in order to be shared within a supply chain, needs to be freely accessible by all interested parties. Since providing information and knowledge is costly, increased public efforts in the direction of increased free access to information resources as well as increased provision of information, advisory and extension services are paramount to the adoption of sustainable production strategies in the dairy supply chain. Finally, managers and policy makers are not restricted to apply our results only within the narrow boundaries of the organic and low input dairy segment.

In the future, the role of information sharing practices is likely to become increasingly crucial not only to achieve higher levels of sustainability but also to defend the profitability of all supply chains, even outside the agro-food sector (SOLID Deliverable D5.2).

The Consumer survey

After having defined the novel production strategies to be used for testing, a survey was administered to 6969 consumers in 6 countries. 5497 valid survey responses were collected in six EU countries: AT (905), IT (985), BE (901), DK (893), UK (909) and FI (904). Female respondents represent 58.4% of the sample. Our model stems from an extended version of the Theory of Planned Behaviour model, focusing on attitude formation and its direct relationship with beliefs such as perceived risk and benefits of a novel production strategy (see SOLID Deliverable 5.3). Willingness-to-pay estimates related to the three novel production strategies assessed were derived using advanced discrete choice econometric methods. The production strategy ‘Prolonged Maternal Feeding’ is ranked first by 42.1% of respondents and second by 31.8%, summing up to 73.7%. ‘Agroforestry’ was slightly less favoured: though ranked first by only just a third of respondent (33.3%), was ranked second by another 38.2%, summing up to 71.5%. Although country differences exist, ‘Alternative Protein Source’ was the least preferred strategy by the consumer: only 24.6% ranked it first.

These results are diverging with those previously reported concerning dairy supply-chain members, who by and large preferred the ‘Alternative Protein Source’ strategy. In terms of “Purchase Intention”, consumers in all countries rated – on average - dairy food produced by Agroforestry higher than food produced by Prolonged Maternal Feeding, while dairy food produced by Alternative Protein Source has substantially lower average rating. All differences are statistically significant.

Identifying optimal Supply Chain Management (SCM) strategies to improve competitiveness and adapt the production systems to geographic diversity

On the basis of the results of previous tasks and other SOLID preliminary results, an international Future Dairying Workshop was organized in Vantaa, Finland, 20-21 May 2014.

The workshop was designed with the aim of generating participatory interaction targeted at identifying the

challenges of adapting the organic and low input production systems in different geographic and cultural environments using future research methodology.
The future workshop approach was structured in three phases: 1. Critique phase, 2. Visioning phase and 3. Operationalization and Implementation phase. The participants were split into three operational working groups from homogenous areas with similar characteristics from a geographic and climate perspective or from the market viewpoint – these were Nordic, Eastern Europe and Western Europe. Each group consisted of three to four participants and they were selected from different geographic areas, representing different levels of the milk supply chain and from different production systems (organic, low input, conventional).
In the first day of the workshop, during the critique step, participants identified expected challenges in the near future in the organic and low input milk supply chains and then the visioning step aimed at finding solution to these challenges. Previous tasks of the SOLID project and extensive brainstorming and consultations among the project partners and the stakeholders' platform led to the choice of the following three novel production strategies: agroforestry, alternative protein sources with lupin and other soya substitutes and prolonged maternal feeding. These production strategies were presented to the workshop participants in a general format in terms of strengths and weaknesses, threats and opportunities. During the workshop participants discussed how they would see the potential of these production strategies to solve identified challenges. In addition, in the visioning phase participants were engaged in creative imagination of an ideal future state for organic and low input dairying and creation of new optimal strategies.
The theme of the second day of the workshop was to discuss the transferability of practices between different regional contexts. The method of storytelling was used when individual stories of the specific geographical group were constructed. The collective group story was then revealed to the other groups to identify the underlying strands that defined the problem in that geographic location and to discuss the transferability of the identified optimal strategies.
The "Critique phase" yielded two universal themes across all the groups - profitability of the farm and feeding strategies. The Nordic group identified a total of eight challenges, of which three were at farm level, two at policy level and three linked to consumers and markets. During the discussion on profitability, high investment cost for farms in the cold Northern climate as well as other challenges that affected profitability were mentioned, such as the upcoming abolition of milk quotas and milk price fluctuations. Three of the challenges were more consumer or market oriented. Competition with other beverages was seen as a problem, due to the low pricing of alternative beverages and consumer trends towards more consumption of soft drinks. One market challenge was directly addressed at dairy processors, as there was criticism that there were too few organic products available for consumers. The Central and Eastern Europe groups identified a total of 12 challenges, which were mostly linked to consumers and markets. Again, at farm level, low farm profitability was seen as one of the main challenges because of the high cost of production and low price of organic milk products. Price and availability of EU/home-grown protein feed were also highlighted. In addition, the required investments in new technology were mentioned as too costly for farms. One market-related problem was also the low price of male dairy calves. In the Western Europe group, a total of ten challenges were identified, of which most were at farm level. Again, following the identified challenges in the previous groups, farm profitability was linked to the discussion about farm-level cost reduction, milk price and farm-level risks. Protein alternatives to soya were also mentioned in this group. Extensive discussion was also targeted at the health and welfare of the cows and better grass-based feeding strategies. Regarding feeding strategies, the discussion covered themes such as better

grassland utilization, pasture improvement, feed efficiency, and self-sufficiency in feeding and reliable forage production. This group also identified some farm management issues such as ease of farm management. The discussion about best practices was linked to self-sufficiency of protein feeds as well as the large variation in performances at farm level. Challenges regarding milk quality were considered and linked with the discussion concerning contamination of milk and use of antibiotics and milk quality, specifically fatty acids and milk constitution.

Of the three SOLID novel production strategies, the most discussed and voted on was alternative protein sources for feed. Various optimal strategies are needed in the organic and low input supply chains to cultivate more home-grown proteins, starting with improved knowledge and technology transfers between extension services, advice, dairy farmers, breeding companies and research. In addition, independent knowledge centres for novel feeds (e.g. cotton seeds, lupins and algae) were seen as necessary to encourage farmers to produce protein feeds in different geographic regions. A key issue is to develop and share knowledge between different regions about new sources of protein feeds as well as more intensive use of by-products.

With respect to transferability of practices, the final stories of the groups highlighted a number of possible strategies in detail. Many of the participants suggested innovative strategies to ensure profitability of organic milking by increasing transparency in the supply chain. Two of the innovations were linked to showing the price structure to consumers using so-called transparency indicators. These indicators would allow the consumer to observe if the producer was receiving a fair share of the price of the product. The other strategy for securing the level of profitability for farms would be to set a minimum price in the supply chain. This would require much collaborative action from the milk supply chain to achieve agreement on the level of the minimum price.

At farm level, the production costs were stated as being too high due to high capital and technological investment costs. One solution to reduce the production costs suggested by the participants was a shift towards more grass-based systems. Improving competitiveness is not the only farm-level challenge. In highly differentiated products such as organic products, competitiveness can only be achieved through better knowledge of consumers’ needs and expectations and satisfying them. In the workshop, better communication of the value added properties of organic milk was seen as supporting this view. At processing level, more pressure should be targeted at innovative branding strategies. More research funding should be targeted at the development of quality-enhanced milk such as high levels of omega-3 fatty acids or products containing various minerals.

Even though the participants were mainly representatives of farmers, quite a few issues highlighted were linked to consumers, markets and policy choices. To create better future prospects for organic milk, a variety of supply chain strategies were identified, e.g. adding more valued added properties to organic milk. The participants said that consumers should be informed more about the health benefits of organic milk and the effects of grass-feeding on milk quality, and take into account a broader view of social sustainability issues.

One suggested innovation to deliver these properties straight to the final customer was to organize the delivery of the organic milk using vending machines for organic raw milk. One innovative solution to avoid waste is to reuse milk that is becoming out of date to make special cheese. Overall, it was argued that organic milk still needs more informative advertising campaigns, better transparency by allowing consumers to check the steps of the organic milk chain, and communication of the core values of the organic milk production to consumers. Communication to consumers and better knowledge transfer systems would also be more easily transferable from region to region.

Policy recommendations from SOLID

The following list of recommendations, based on results WP5 and other SOLID work, have been issued as part of SOLID Deliverable 5.5:
1: Extend the use of home-grown and local feed.
2: Multi-species diverse pastures may help combining competitiveness and environmental benefits of grassland-based forage.
3: Novel, alternative feeds should be introduced taking care of both consumer and producer advantages.
4: Breeding strategies tailored for low-input and organic dairy systems should be further pursuit to overcome the limits of high yielding breeds.
5: Dairy supply-chain strategies should aim at reducing (increasing) health-related perceived risks (benefits) if they wish to increase consumer confidence and willingness-to pay.
6: Extension and dissemination policies in the dairy sector are crucial to maintain its competitiveness and increase its sustainability, given the overall reduction of monetary subsidies.
7: Innovation uptake by risk-averse dairy farmer can only be boosted if dissemination focuses on the usefulness of innovative production strategies.

WP6: Socio-economic evaluation of novel strategies in organic and low input farming

The central research questions in this work were whether organic and low input farming is economically competitive and whether novel strategies and policy actions can improve competitiveness. To answer these questions, a range of quantitative research methods (e.g. modelling) were used. To allow quantitative approaches, one necessary pre-condition was to obtain a workable definition of low-input dairy farming, similar to that already existing for organic. Such a definition must then, with existing data (FADN) and modelling techniques (e.g. ORGPLAN, DREMFIA, CAPRI), be able to be used to evaluate competitiveness, farm planning and policy impact. Another major objective in WP6 was to provide evidence for policy recommendations.

Exploring farm characteristics and competitiveness

The first task was to develop a workable definition for low input (LI) dairy farming. Contrary to organic farming which relies on a precise set of regulations, a literature review on LI farming only yielded fuzzy notions of farming systems that are less reliant on external inputs, such as concentrates and pesticides, and as such also cause less environmental burden and provide more nature value. As some existing approaches consider absolute values of input or output intensity, they rather isolate low-input as marginal production systems and hamper honest competitiveness estimations. Therefor SOLID introduced a quartile-based discrimination focussed on an indicator expressing the use of external inputs per grazing livestock unit.
The results show, in general, over EU member states, that LI dairy farms, compared to their high input (HI) counterpart are smaller, are less specialised, have a larger share of forage and grassland in their utilized agricultural area and a lower share of maize. They also have more family labour, lower productivity and a lower production density. Although LI and organic (ORG) have low external input use in common, ORG farming cannot be assigned as similar to LI in all aspects, nor could LI be seen as an organic farming

system without the organic regulations.

The same quartiles-based method was used to analyse the economic performance of LI and HI as outer quartiles, compared to medium intensity (MI) as inner quartiles (x2) and to ORG. Results obtained from the accountancy years 2007-2008 indicates that LI, despite the much lower productivity, is not that much economically worse than HI. On the contrary, when external input prices are high or milk prices low, then LI in many countries outperforms HI. The picture of structural and economic differentiation, however, is very different from one country to another. In Finland for example HI is economically less competitive than LI, UK has competitive ORG dairy farming, and in Belgium neither LI nor HI are most competitive, and the better performance of the farms in between (MI) indicates that using too much or too little input is not optimal.

Context specificity

As profitability results are sensitive to calculation methods and the economic market context, and as these findings are fundamental for further policy and planning advice, economic analysis was also conducted over a longer period (2004-2012) to validate and valorise earlier findings on the characteristics and economic competitiveness of the LI and ORG farms. We conclude that LI characteristics and starting points for competitiveness are very country- and context-specific. This calls for tailor-made policy measurements and farm development strategies instead of generic recommendations.
Context-specificity calls for farm and farmer centred diagnostic and planning approaches. One dominant diagnostic task is to obtain a complete picture of sustainability. A RAT, rapid assessment tool (SOLID Deliverable 1.1) has been developed to identify aspects of the farming system to be improved in order to improved competitiveness. For farm-centred planning, participatory approaches for planning, innovating and follow-up seem of high value. In addition to the participatory work of SOLID described in WP1, we also conducted participatory modelling, in which new farm plans were conceived and fine-tuned in close collaboration between modeller, advisor and farmer.

Novel Strategies (NS)

The novel strategies (NS) for improvement evaluated in WP6 are firstly science-driven (explored from literature and from the various multidisciplinary outputs from the other SOLID work packages) and secondly data-driven (derived from productive efficiency methods).
Given the above described context specificity, a successful NS adoption not only depends on intrinsic attributes, but also on the farm-specific factor endowments, the farmer's decision behaviour and the decision environment. In SOLID, various methods have been used to delimitate potential strategies: economic analysis of FADN data, the participatory processes of assessment, on-farm experimenting and modelling, agronomic sciences, a consumer survey and creative recombination through farm modelling. The interactive information between farmers, stakeholders and scientist needs a practical methodology to come to design, description and pragmatic information flows at farm, sector and policy level
Explorative theoretical, conceptual and methodological work in SOLID revealed that, basically, strategy design does not differ between traditional and LI and ORG farms, but that designing strategies for those farms suffers from lack of data. The main finding is that the information flow needs to be more interactive instead of linear. Although the SOLID project is highly interdisciplinary and participatory, important gaps

are still observed between strategy providers, the final decision maker and the decision making support through modelling. The conceptual considerations led to some methodological foci and priority was given to evaluating home-grown proteins as a novel strategy and typical farms as a communicative instrument. Typical farms were considered in terms of improving their operational effectiveness. Firstly, we defined typical farms to extend the competitiveness analysis from a mere profitability analysis to market price resilience analysis. The typical farms were constructed from a set of median farms and proved to be a good instrument for communication between modellers. Secondly, efficiency analysis reveals sources of competitiveness between LI and HI farming types and within LI farms. Indeed both groups show efficient and non-efficient farms, which encourages to explore improvement margins. Thirdly, on-farm observations using a participatory approach and a quick scan sustainability measurement tool showed some promising novel strategies when applied to the typical farms. Based on this and the outcomes of work in WP5, the home-grown protein strategy was the one taken forward for further analysis in WP6.

Modelling farm strategies' impacts at various levels farm, national, EU)

With the context specificity in mind, the first step was to mine the opportunities and threats on individual farms to adopt a new strategy. We developed a participatory modelling process that, in close interaction between adviser, researcher (modeller) and farmer, guarantees tailor-made strategies. The participatory farm model (PAFAMO) is used in an interactive way to ensure the co-production of insights from researchers, adviser and farmer on the farming system and objectives. The participatory modelling case focussed on home-grown proteins. The integrated approach helped to detect weaknesses and possibilities for each farm, in particular its factor endowments. Possible adoption of home-grown protein mainly depends on farmers' attitude, opportunity costs and greening subsidies.
Still at farm level, but now with a budgeting model (ORGPLAN) instead of a normative model, simulations in UK and Belgium revealed that incorporating home-grown protein in the cropping plan and feed ration is economically feasible for typical farms. This feasibility stands in particular when attention is paid to the protein contribution from forage clover grass in the ration which then reduces the need for supplementing with home-grown pulses. The simulations are based on a 'forage first' approach, this means that the ration planning was modified to an annual approach so that assumed protein utilisation from grazed and conserved forages was maximised first, followed by a calculation of the needed protein supplementation through home-grown pulses (in this case beans). Greatest increases in whole farm gross margin values were seen in farm management scenarios where high forage intakes are assumed.
Sector-level simulations in Finland confirm findings on feasibility of home-grown proteins, here grass-clover, but also showed high impact of generic policy measures such as manure regulations or fertiliser taxes. The objective was to evaluate challenges and appropriate policy measures of increasing home grown protein. Premium payments per hectare, nitrogen fertiliser taxes, reduced costs, and higher yield levels were implemented. The results showed that promoting yields of clover-grass mixes and introduction of nitrogen tax are the most robust measures in promoting clover-grass, while premium payments and modest cost reductions has relatively less effect. Further increase of the total grass forage area in the case of Finland is hard because of the fact that manure spreading is rather modest on clover-grass area, and this increases the logistic and other costs of manure spreading. Even if clover-grass or similar low input feeds (based on nitrogen fixation) are likely to reduce energy and fertiliser, the potential of such options is limited in conventional dairy production.
The various model simulations confirm this need to be cautious in seeking generic approaches that apply

everywhere. This is also supported by the work on participatory farm planning and innovation, clearly showing the need for exploring the farm's uniqueness. EU-wide simulations of, for example fertiliser taxes need to be interpreted with high caution, given the variability in LI and ORG farming.

Farm planning and policy recommendations

Towards farm development, we recommend to re-consider the holistic basic farm strategic decision about allocating land, labour and capital, with decisions about forage cropping, grassland management, breeds, production capacity. When aiming at valorising the environmental or nature value from LI and ORG, processing and marketing questions will add to the intrinsic production questions. Farm planning needs to cope with personal characteristics and context-specific conditions. Coming back to politics, this means that inciting these tailor-made farm planning activities is preferred to generic policy measures. Support could be aimed at facilitating specific farm planning that stems from the unique combination of an entrepreneur in his decision making context, considering the utilisation of forage as well as different routes to adding value along the supply chains including also the growing market for organic milk.

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Potential Impact:
WP1: Innovation through stakeholder engagement and participatory research

With such as wide range of activities conducted as part of WP1 there is considerable potential for impact arising from the activities and results. Participatory research based on close collaboration and exchange between farmers and researchers can help develop context specific solutions to increase sustainability and competitiveness of low-input and organic milk production. The impact and dissemination of activities

of WP1 are listed.
- The farmer workshops to discuss the results of sustainability assessment and identify research priorities (SOLID Deliverable 1.1) were attended by more than 150 farmers as well as by staff of the SOLID SME partners and by other interested parties in nine countries.
- In total 18 participatory studies were carried out, directly involving more than 100 farmers in eight countries. The final reports of these studies can be downloaded from the SOLID website and the SOLID knowledge platform.
- There was continuous collaboration between researchers and SME partners throughout the project in eight countries with researchers contributing information about the SOLID project activities in technical newsletters, farmers' magazines and by attending events.
- We held a workshop for Nordic researchers in Helsinki in 2013 introducing the concept of participatory research attended by 50 scientists.
- We held a specific workshop to discuss the participatory research approaches at the 2014 IFOAM World Congress in Turkey, which was attended by approximately 100 scientist and organic sector stakeholders.
- One E-learning module on how to conduct participatory research aimed at farmers and researchers has been developed and is available at http://farmadvice.solidairy.eu/.
- The results of the participatory projects were presented in three separate deliverable reports summarising conclusions and recommendations related forage production and utilisation and feeding of dairy cows (Deliverable 1.2) animal health management (Deliverable 1.3) and management of small ruminants (Deliverable 1.4).
- The final deliverable of WP1 was a Farmer Handbook of SOLID with 12 technical notes (Deliverable 1.5) which included results of some of the participatory research projects as well as other outcomes of the SOLID project. The technical notes are shared on the SOLID knowledge platform (http://farmadvice.solidairy.eu/) and will be promoted via other media, e.g. the website www.agricology.co.uk (an on-line platform for practical sustainable farming) and by the SME partners.
- Presentations related to WP1 activities were given at the following national and international events: IFOAM animal conference in Germany in 2012; ISOFAR/IFOAM World Congress in 2014 (several papers); British Grassland Society Conference in 2013; Joint Conference of British Ecological Society and Association of Applied Biologist on rethinking agricultural systems in 2013; OECD/USDA/IRCOFS Conference on Innovation in Organic Agriculture in 2014 (Padel et al., 2015), a Finnish conference on organic farming in 2014 and the British Society of Animal Science in 2015.
- Results arising from WP1 activities were presented at the four regional workshops in the final year of the project in 2015 in Greece, Romania, Finland and finally in the UK (Jan 2016) and were also included in the presentations at the final SOLID conference in Brussels, May 2016.

WP2: Adapted breeds for productivity, quality, health and welfare in organic and low input dairy systems

The results from the studies conducted within this WP offer important contributions to an overall improvement of the sustainability of organic and low input dairy production systems in terms of breed choice and the further development of dairy cattle and goat genotypes adapted to these systems. This includes productive, reproductive, economic and milk quality aspects. Concerning animal health and welfare, the risks identified in terms of reduced welfare in dairy cows need to be addressed by appropriate improvement strategies in order to secure the development of sustainable organic and low input dairy systems. Apart from the productivity perspective, the animal health and welfare status addresses a focal point of societal expectations towards organic and low input dairy production.

With publication activities still ongoing, the results produced within this WP so far led to 14 journal articles, more than 50 conference papers and contributions to 6 scientific seminars. While these publications mainly address the scientific community, different dissemination activities were aimed at reaching a stakeholder community of farmers, advisors and the industry as a whole. In order to reach out to this auditorium, more than 40 press articles and articles in farmers' magazines were produced, together with presentations at farmers' meetings, regional workshops, etc.

In an attempt to use other approaches for dissemination, strong contributions to the specific dissemination-WP7 were developed by the WP2 team. Among others, an e-learning tool was developed from which users with a certain a priori-knowledge on dairy production systems should learn about the specific need for genotypes suitable for organic and low input dairy production systems and the scientific background of breeding for these systems. The e-learning course shall enable them to identify important traits and breeding goals for low input and organic dairy systems.
A different format was used in a contribution to a farmers handbook produced within WP1, for which a technical leaflet "Breeding cows suitable for low-input and organic dairy systems" was compiled. The addressees of this leaflet are dairy farmers, their advisors, industry staff, teachers and other groups interested in the issue of breeding for organic and low input dairy systems. This contribution shall foster an understanding of the characteristics of genotypes appropriate for such systems and the advantages that cattle breeds may actually possess which are perceived by the industry as being "adapted". An important element of the leaflet is a critical reflection of the potential use which organic and low input breeders can make of breeding animals from "conventional" breeding programmes. Crossbreeding approaches are also included and add to the list of options low input and organic dairy producers have.

WP3: Forages for productivity, quality, animal health and welfare in organic and low input dairy systems

The results from Tasks 1-4 have been disseminated widely through various channels including scientific publications (4), congresses and other meetings (10) and several professional articles. The information created has also contributed to SOLID Farmers leaflets (4 titles in Deliverable 1.5) and an e-learning module as well as other material on SOLID website (Deliverable 7.6).

The awareness of novel feeding systems such as alternatives to soya bean based feeds as protein supplements, use of by-product feeds and multifunctionality of agroforestry systems has increased. One good example is demonstrations of fruit and vegetable by-product use in Southern European conditions. Time will show how large the magnitude of adoption of the new feeding systems will be over years.

The analysis of a large and detailed dataset of dairy cow energy utilization showed that the maintenance energy requirements of the cows increases with high forage diets. Although the magnitude of this effect was not very large and cows are typically fed ad libitum, this effect should be taken into account in feed evaluation and ration formulation systems in the future.

The decision support model to evaluate the balance of feed supply and herd requirements on a dairy fam based on crop rotation and herd structure is useful in demonstrating how complex a system a dairy farm is and in highlighting the effects of management decisions and weather conditions on the balance of feed supply and demand. This is particularly critical on organic and low input farms as they heavily rely on on-farm produced forages. The model is available at: https://zalf-lse.github.io/solid-dss/ and is well suited for agricultural extension, training and teaching. An additional benefit of this work is that the whole SOLID-DSS is programmed in well documented open-source code and is available for modellers to be used e.g. in future projects.

WP4: Environmental assessment: For improvements and communication in organic and low input dairy systems

At the European level, meat and dairy products are estimated to be responsible for a major part of the environmental impacts of overall human consumption. Organic and low-input dairy systems are perceived to contribute to environmental and other societal benefits but a comprehensive assessment does not yet exist. A number of initiatives are taking place at the European level, which dairy farming has to relate to. The EU climate and energy package 2013-2020 demands a reduction of GHG emissions by 20% (from 1990-2020), and it is foreseen that the non-quota sectors (like agriculture) should be included in achieving this reduction. It is mentioned that methods to increase the capacity to preserve and to sequester carbon should be considered in agriculture. Likewise the EU Biodiversity strategy 2020 (EC 2011) asks for initiatives to halting the loss of biodiversity. Depending on the farming system, dairy systems may be adapted to perform on these parameters, but it is unclear to what extent organic and low input systems perform in reality.

At the same time The Commission - as part of its policy of 'Building the Single Market for Green Products' - has launched the Product Environmental Footprint (PEF) initiative (EC, 2013). The initiative sets rules about the environmental impacts to be included in an assessment, but it is also recognized that for some impacts the methodology are not fully developed to allow for being included in the assessment. This holds for biodiversity, eco-toxicity, and for a method to include soil organic carbon stock changes in the calculation of global warming impacts. These aspects are recognized as being important and they may have particular relevance in organic and low input dairying.

It is a main achievement in SOLID that methods were developed to estimate and characterize these potential impacts (Petersen et al., 2013; Mogensen et al., 2014), thus allowing these aspects to be included in the assessment. This will result in more comprehensive and less biased results in the assessment of the environmental impact of milk from different production systems. For example, we demonstrated that the carbon footprint of organic milk is reduced when soil carbon sequestration is appropriately accounted for in the assessment, whereas this will typically not be the case for conventional milk. Also we demonstrated that a higher proportion of grass in the cows' feed ration increases soil carbon sequestration and can also increase biodiversity, depending on the duration of the grassland and the structural characteristics of the grass sward.

In particular the results regarding biodiversity have attracted attention in relation to the PEF work, where it has been suggested to be tested in the red meat pilot. As regards the method to include soil carbon in the assessment, there has significant interest in the scientific community. Also the publication of carbon footprint from many real farms across Europe and the elucidation of its interaction with soil carbon and biodiversity (Hietala et al 2015) form a solid base on which to consider real improvement options.

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WP5: Competitiveness of organic and low input dairy sector: Supply chain and consumer analyses

The activities in WP5 have provided the following potential impacts and dissemination activities that contribute to improving the overall competitiveness of organic and low input dairy supply chains.
• Identification of which types of innovation are acceptable in low input and organic dairy supply chains highlighting the potential for focus on the development of the use of home grown proteins in particular in organic and low input dairying.
• A better understanding of:
o the factors that influence the acceptance of innovative production strategies at dairy farm and processor level, especially perceived usefulness;
o the importance of pioneers since individual's belief on the usefulness of an innovation is strongly influenced by those of others, specifically leading companies, peers and other significant influencers;
o the importance of supply chain collaboration and information sharing to enhance the sustainability of dairy organic and low input farming systems;
o consumer attitudes, intentions and stated willingness-to-pay for the novel production strategies developed by the SOLID project;
o and the substantial differences in the acceptance of innovative production strategies by stakeholders at different stages of the supply-chain.
• Providing guidance for members of the dairy supply chain, researchers and policy makers:
o on identified challenges in organic and low input farming;
o on suggested optimal supply chain strategies to overcome these challenges;
o on which novel production strategies to pursue to improve the sustainability of organic and low input dairying. Specifically, protein sources alternative to soya have been among the top research priorities for farmers and, partly, processors and have been among relevant topics in both FP7 & Horizon 2020 work programmes. However, the priority is not fully understood (and, in any case, valued) by consumers;
o on ensuring that bottlenecks in innovation uptake within the dairy supply chain do not occur, by increasing collaboration and information-sharing activities along the chain and
o on which priorities research funding for organic and low-input dairying should be directed and targeted in the future.
• Researchers working in WP5 have published five peer reviewed journal articles (with another in press) and given workshop presentations at six scientific and farmer conferences/workshops.

WP6: Socio-economic evaluation of novel strategies in organic and low input farming

The SOLID project made various aspects of competitiveness of low input and organic dairy farming more concrete. First of all, the fuzzy notion of low input itself became more tangible through the development of a working definition of what low input using FADN data. By doing this, for the first time it was also possible to systematically compare low input and organic dairy systems. Secondly, the rapid sustainability exercise (RAT) conducted in WP1 and utilised in WP6, made the complex notion of sustainability more accessible. Thirdly, and last but not least, evidence is given for farm planning and policy making, not in the sense of supplying concrete levels of constraints, thresholds or subsidies/taxes, but in a loud-and-clear avocation for facilitating farmers' initiatives instead of regulating them.

The potential impact is that governments or important players might perceive low input and organic dairying not as mere poor branches in the sector only to be supported for better ecological performance, but as possible viable alternatives to traditional intensive agricultural systems. The SOLID WP6 evidence will also help to recognize that both for policy making as for farm planning, there is no one-fits-all solution; instead tailor-made solutions must be encouraged. Merging the WP6 evidence with the participatory experiences of WP1 calls for recognizing the role of the individual farmer and for facilitating his initiatives instead of imposing them by generic regulations. An important outcome is that there is a clear need for the farmer to be in the driving seat for innovation design, testing and uptake.

From these insights, we aimed at dissemination of results through various forum including Eurochoices to launch the facilitating policy ideas, a Profitability Note in the Farmers' Handbook (Deliverable 1.5) to encourage farmers thinking about new profitable avenues and the e-learning for stimulating economic reasoning (Deliverable 7.6). Various scientific papers are under construction.

WP7: Knowledge exchange, training and dissemination

WP7 has used a variety of channels to disseminate the results and outputs from the SOLID project. In the following, a short overview of these activities is given.

Basic communication
A flyer presenting the project was issued early on in the project period – as was a basic webpage.

Meetings, workshops and conferences

SOLID scientific symposiums and presentations were held at the EAAP annual meetings in Stavanger, Norway August 2011, in Bratislava, Slovak Republic, August 2012, in Nantes in August 2013 and in Copenhagen, Denmark August 2014. Presentations from these meetings can be found http://www.solidairy.eu/index.php/dissemination-activities/presentations-at-the-eaap-annual-meeting-bratislava-slovak-rep-2012/.

The SOLID project had 11 oral presentations and/or posters at the IFOAM Organic World Congress in Istanbul in 2014.

Four regional workshops have been held during the project: In Greece (September 2015), Romania (October 2015), Finland (October 2015) and the United Kingdom (January 2016). A final conference aimed at policy makers was held in Brussels in March 2016. The presentations and proceedings from all the workshops are available on the project website www.solidairy.eu. Furthermore, a workshop was held in Brussels in January 2016 on future research and implementation strategies (See Deliverable 7.5 for summaries).

Newsletters

Internal (Solid Insider) and external (SOLID News) newsletters have been sent out twice a year throughout the 5 year project. The external newsletters have 8-1200 subscribers.

Web activities

The webpage www.solidairy.eu has been continuously developed and has been visited by more than 4000 unique visitors during the project period. A new website targeting the end-users has been created: http://farmadvice.solidairy.eu/ . The new website is structured along the lines of the "Farmers Handbook" developed in WP1 with subpages on the same themes: Agroforestry, Forage for cows, Cows´ energy need, Homegrown protein, Minerals for cows, By-products for goats/sheep, Animal health & welfare, Breeding cows, Breeding goats, Carbon footprint, How to make a living, Improving biodiversity, Consumer preferences, Policy: how to get there? The menu will also integrate the e-Learning materials developed as well as the SOLID Decision Support System (DSS) in English, German and French to provide usage of the tool by English, German and French speaking EU farmers.

E-learning tools

E-learning tools have been developed in close corporation with the WPs and are available at http://farmadvice.solidairy.eu/.
The e-learning material consists of 5 courses:
1. Participatory research in organic and low-input farming systems
2. Life cycle assessment (LCA) of dairy chains
3. Dairy cattle genotypes for low-input and organic farming systems
4. Novel and Underutilized Feeds for Low input and Organic Dairy Farms
5. Profit in Low Input and Organic Dairying
Partners produced technical material which were then converted into interactive format. This material was then reviewed (including regional meetings) and modified.

Fact sheets and technical notes

There has been close corporation between WP7 and the other WPs, especially with WP1 focusing on participatory research. In this teamwork between WPs, fact sheets on the case farms that were analyzed with the rapid sustainability assessment tool in WP1 were developed and are available for from the webpage http://www.solidairy.eu/index.php/case-farms/. Also the fact sheets and technical notes derived from the Farmers Handbook developed in WP1 (Deliverable 1.5) is a result of teamwork between the WPs and are presented on the new web platform http://farmadvice.solidairy.eu/.

Stakeholder involvement

Stakeholder involvement has been assured as the Stakeholder Platform group have attended all general assemblies and have given oral and written feedback on how they saw the relevance and scoping for end users of the work in each WP.

Other dissemination activities

Each work package has carried out a broad variety of communication activities themselves, and publications and media clippings from both scientific, national, regional and local media (broadcasting, web and print media) are gathered on the www.solidairy.eu website and in the Organic Eprints archive for scientific papers and grey papers.

List of Websites:
Public SOLID project web address: http://www.solidairy.eu/
Public SOLID farmer and advisory web address: http://farmadvice.solidairy.eu/

For further information about the SOLID project please contact Dr Phillipa Nicholas-Davies, SOLID Project Manager, Institute of Biological, Environmental and Rural Sciences, Aberystwyth University, Aberystwyth, SY23 3EE, Wales, UK, email:pkn@aber.ac.uk

Powiązane dokumenty

final1-solid-participants.pdf

Ostatnia aktualizacja: 15 Listopada 2016

Permalink: https://cordis.europa.eu/project/id/266367/reporting/pl