PROJECT FINAL REPORT

Grant Agreement Number: FP7-289328

Project Acronym: CANTOGETHER

Project Title: Crops and Animals TOGETHER

Funding scheme: Large collaborative project

Date of the latest version of Annex I against which the assessment will be made: 2013-10-16

Period covered: **From** 1 January 2012 **to** 31st December 2015

Start date of the project: 1 January 2012 Duration: 48 months

Name, title and organisation of project coordinator:

Name: Dr. Philippe LETERME
Organisation: Institut National de la Recherche Agronomique (INRA)
Tel: (+33) 2 23 48 54 74
E-mail: philippe.leterme@agrocampus-ouest.fr
Project website: http://www.fp7cantogether.eu

TABLE OF CONTENTS

1. Publishable summary

a) An executive summary

One of the major challenges of European agriculture is the environmental impact of animal production. Fostering mixed farming systems (MFS) that combine livestock and crop production could be an efficient strategy to promote a more sustainable production. In this respect, the type of interaction between the three components of MFS (crops, grasslands and animals) was found to be essential. Four types of integration (ICL) were identified, depending of the level of diversity and synergies between crop and livestock enterprises (ICL0: coexistence, ICL1: complementarity, ICL2: on-farm synergy, ICL3: territorial synergy).

This framework was used to design innovative systems through a participatory approach involving stakeholders, technicians and scientists. An ex-ante assessment identified the most promising innovations, which were implemented in a pan-European network of 24 case studies (experimental or commercial farms, local groups of farms) to test their feasibility and contribution to sustainability. Besides biogas plants (6 instances), these innovative options were mainly based on agroecological principles as diversification of crop rotations (8 instances), valorisation of semi-natural spaces such as landscapes elements and grasslands (12 instances) and optimisation of cover crops (3 instances). The importance of organisational aspects was highlighted: local market development appeared in 4 instances, as did forage banks or systems for farmers to directly exchange products (feed, manure) with each other.

These implementations confirmed that it was the physical integration and complementarity between crops and animals (e.g. home-grown feed, recycling of wastes as fertilisers in ICL1 and 2), not just their coexistence (ICL0), which was decisive for generally improving environmental performance of the farm but, unfortunately, also for increasing workload and degrading productivity and economic results. While some farms achieved both satisfactory environmental and economic performances, it was probably because economic considerations, not only technical ones, had been included when the innovative options were designed.

At the district level, collaboration between farms (e.g. exchanging materials such as manure, straw, feed or animals such as heifers in ICL3) generally improved productivity and economic performances, but the potential environmental benefits of cooperation were often restricted by farmers choosing to use the resources made available via cooperation to intensify their operations, rather than diversifying them or reducing inputs. Nonetheless, cooperation led to some environmental benefits by increasing input-use efficiency and reducing environmental impacts of farming when expressed per unit of product produced. Otherwise, territorial cooperation also appeared as a key strategy to enable farms which strongly integrated crops and livestock to recover sufficient profitability.

Regarding the acceptability of the innovations, the main challenges were socioeconomic (economic performance, workload, management complexity). In this regard, biogas plants appeared to facilitate development of MFS by offering a new source of income, optimising waste management and promoting farm autonomy. Otherwise, the innovations tested were not directly transferable from one context to another, and crucial assets for the adoption of an innovation were its adaptability and the ability to implement it step by step on the farm. Comprehensive changes and breakthrough innovations were often thought to be too risky.

Regarding economic policy, the main recommendations for developing MFS addressed potential compensation for economic losses at the farm level by placing a monetary value on the reduced or increased externalities (commodification) as well as facilitation of the conditions for cooperation between farms across a territory.

b) A summary description of project context and objectives

PROJECT CONTEXT

Global demand for food is expected to increase by 70% by 2050 (FAO, 2009a). The increase in demand for animal products driven by growing populations, incomes and diet preferences is stronger than that for most other food items. Global production of meat is projected to more than double from 229 million tonnes in 1999/2001 to 470 million tonnes in 2050, and that of milk to increase from 580 to 1,043 million tonnes (FAO, 2009b). The bulk of the growth in meat and milk production will occur in developing countries, with China, India and Brazil already representing two thirds of current meat production, but the European Union (EU) can and must endeavour to respond to this issue, thus signifying that its agriculture must continue to be productive and competitive.
This demand must be addressed while conserving natural resources (water, soil), non-renewable resources (phosphorus, fossil fuels), and ecosystem services (pollination, natural pest control, soil fertility) - in short, the environment in its larger sense (water, soil, and air quality). It will require designing agricultural systems that use fossil fuels and natural resources (e.g., phosphorus) more efficiently as well as potentially become producers of raw materials for industrial and energy purposes. In addition, these systems will need to be adapted to climate change and help to mitigate it.

If appropriate technologies and policies are applied, agriculture can attenuate its environmental impacts and in the same time can contribute to mitigate climate change. For example, careful recycling of organic waste as fertiliser by integrating crop and animal production makes it possible to minimize losses of nitrogen and other plant nutrients within agro-ecosystems. A diversity of agricultural systems within the same territory is generally an essential asset, as it contributes to the diversity of land and landscape uses and offers greater flexibility. In addition, diversified land use can open up new possibilities for combining food production with biomass production and on-farm production of renewable energy from livestock manure, small biotopes, perennial crops and semi-natural non-cultivated areas.

One of the most promising paths to respond to this challenge is to promote new systems which mix livestock and crops (HERRERO et al., 2010), but unfortunately, it is easy to see that specialization is gaining ground. In 2010, 47% of farms in the EU-28 were specialised in cropping, 27% in livestock, 24% in mixed farming and 2% non-classifiable.
Specialization in animal production is important at the territorial level: at the NUTS3 level, 35 of the total of 975 territorial units concentrate 25% of European animal numbers (animal units) but contain only 13% of its agricultural area. Half of European animal units are located in 114 regions, which contain 31% of its agricultural area.
Concentration of agricultural production in EU countries has been driven by the economic advantages it brings: gains in productivity, economies of scale or economies of agglomeration. Moreover, impacts of these forces on EU agriculture have been enhanced by public policies such as the CAP, environmental policy and WTO agreements. The “common market” aimed to specialise productive agricultural areas according to their comparative advantages, which has resulted in high concentrations of animal production within the EU. Regarding impacts of the current CAP reform (2015-2020), the trend towards more concentration and specialisation is expected to continue. The end of milk quotas should foster concentration of milk production in basins endowed with the main “assets” to produce.
A decoupling policy tends to increase agricultural specialisation by renunciation of less profitable activities. The incidence of decoupling and impacts of single farm payment (with the different implementation schemes available to member states) on the degree of farm specialisation was analysed (Agrosynergie 2013). The key result is that the number of farms in all sectors with the lowest degree of specialisation has decreased significantly. At the EU level, between 2004 and 2009:

- 39% of “mixed cropping” moved to more specialized sectors (specialist cropping)
- 33% of “mixed livestock” moved to more specialized sectors (specialist livestock)

- 34% of "mixed crop-livestock" moved to more specialized sectors, expanding cropping or breeding

At the same time, the number of more specialized farms (specialist field or permanent crops or specialist grazing livestock) has risen by 5%.

So, the question is how to promote new systems which mix livestock and crops. To do so, the EU needs to generate new knowledge about the sustainability of mixed-farming systems, establish pertinent indicators of sustainability to be able to evaluate alternate strategies and negotiate trade-offs, and develop these systems through appropriate implementation processes and public policies. It is in this context that the CANTOGETHER program was funded by the EU and launched in 2012.

OBJECTIVES OF CANTOGETHER

CANTOGETHER designed, evaluated and promoted new mixed crop-livestock systems at farm, district, and landscape levels to optimise energy, carbon and nutrient flows that conserve natural resources and maximise production. The pioneering approach promoted recycling strategies (e.g., transforming livestock waste into fertiliser) based on transfers within each level of organisation.

CANTOGETHER developed and implemented a methodological framework combining models, assessment methods and participatory and experimental approaches. Models incorporated key parameters and processes, including specific ones involved in mixed-farming systems, such as recycling, grass- and legume-based rotations, etc. Design and assessment procedures combined scientific and expert-based knowledge to allow comparison of a wide range of potential solutions. CANTOGETHER brought together data from a network of 24 case studies based on existing field-research platforms and commercial farms across a wide variety of agricultural regions of Europe and different systems (organic, low-input, integrated, etc.), in which some innovative mixed-farming practices and systems were implemented and monitored at farm and/or district levels.

Drawing on these data, CANTOGETHER designed new mixed-farming systems, measured environmental and socio-economic consequences of the most promising innovations, and tested them with socio-economic and biophysical models, following a multi-scale approach from field to landscape levels. For each mixed-farming system selected, CANTOGETHER combined agronomic practices (crop rotations, soil management, etc.) and livestock practices (species selection, feeding, management, etc.) into novel mixed-farming systems ranging from easy-to-adopt combinations of methods to more ambitious solutions involving strategic changes at farm and district levels. These systems ensure high resource-use efficiency (notably of nutrients), reduction in dependence on external inputs (fertilisers, pesticides, concentrated feeds), and acceptable environmental and economic performances.

CANTOGETHER tested the efficacy, practicability and relevance of these innovative systems in agro-ecosystems and farming systems in the main European regions (Atlantic plain, Humid mountains, Continental Europe, Nordic countries and Mediterranean zones) via on-station and on-farm experiments, and performed comparative assessments of their environmental, economic and social sustainability. CANTOGETHER demonstrated their feasibility and produced a complete picture of their positive and negative effects on a variety of economic, social and environmental goals.

By jointly involving researchers and the key actors of farming systems in Europe (farmers, advisors, policy makers and actors of the food-supply chain) in design and assessment, CANTOGETHER facilitated adoption and implementation of these innovative solutions. Moreover, CANTOGETHER produced an e-learning course to present its main results and accelerate their dissemination to the world of education, student audiences and professional training organisations.

CANTOGETHER therefore should contribute to sustainability and competitiveness of European mixed-farming systems and to increase food security and environmental quality. It also supports public policy and related commercial objectives: reducing fossil energy inputs into agriculture, nitrogen emissions to the environment, and the global environmental impact of European agriculture.

Concretely, to reach this overall objective, CANTOGETHER achieved the following:

1. Identified new combinations of agronomic (crop rotations, soil management, fertilization, etc.), livestock (feeding, waste management) and technological practices (biogas plants) at farm, district and landscape levels that will ultimately allow optimal use of energy, carbon and nutrient flows by rural communities
2. Designed innovative mixed-farming systems for European soil and climate zones and socio-economic contexts using participative approaches and modelling. These systems combine food (animal and plant), feed and energy production (from biomass and animal wastes) with semi-natural non-cultivated areas through diversified land use
3. Tested innovative combinations of agronomic and livestock practices and new mixed-farming systems in different systems at farm and territorial levels using a pan-European case-study network
4. Assessed environmental, economic and social acceptability of the most promising innovative mixed strategies at farm and territorial (district, watershed) levels in different systems across Europe
5. Identified issues related to farm operation, farmer preference, food supply and legislation that are likely to influence their implementation. In particular, it identified key characteristics of the future CAP that could promote development of mixed-farming systems
6. Disseminated innovations to key stakeholders (farmers and extension services, policy-makers, feed industry, milk and meat food chains, consumers, students, nature conservation groups, etc.) through a participatory framework and an e-learning course that will allow them to exchange with researchers and increase their awareness of benefits of mixed-farming systems.

ORGANISATION OF CANTOGETHER

CANTOGETHER was organized into 7 work-packages (WP):
WP1 identified and designed innovative mixed-farming systems satisfying environmental concerns for different European pedo-climatic zones using a participatory modelling approach with farmers and supply-chain stakeholders.
Based on the portfolio of farm-level case studies, WP2 evaluated and validated innovative combinations of agronomic and livestock practices. It verified the feasibility of these combinations and provided useful data for in-depth assessments performed in WP4 and WP5. Fluxes and balances of nutrients were specified, with particular attention to nitrogen, phosphorus and carbon and to natural resources such as water, soil quality and non-renewable energy sources.
At the landscape and district levels, WP3 tested and validated new mixed-farming systems and provided a focal point for testing innovative mixed agronomic and livestock practices on the portfolio of district- and landscape-level case studies. Fluxes of feed, nutrients and carbon at the district level were specified.
WP4 assessed environmental sustainability of innovative mixed-farming systems for a range of agronomic, soil and climate zones. Using existing models and life cycle assessment, WP4 performed an overall evaluation of environmental impacts.
WP5 assessed profitability, gain and socio-economic viability of mixed-farming methods developed across Europe. It identified the acceptability of mixed-farming solutions amongst producers and supply-chain actors. WP5 also analysed existing policies supporting mixed farming and evaluated implications of widespread adoption of mixed-farming systems to provide policy-scenario recommendations to the EU.
WP6 disseminates CANTOGETHER achievements and knowledge to socio-economic stakeholders, especially farmers, farm advisors, rural extension services, other rural actors, policy-makers and the scientific and learning community, to promote innovations in agriculture.

WP7 provided a strong management component that allowed CANTOGETHER to reach its ambitions.

References

AGROSYNERGIE, 2013. Evaluation of the structural effects of direct support. Financed by the European Commission. Final report. Available at:
http://ec.europa.eu/agriculture/evaluation/market-and-income-reports/structural-effects-direct-support-2013_en.htm

FAO (2009a). The state of food insecurity in the world 2009. Economic crisis-impacts and lessons learned (FAO, Rome, 2009)

FAO (2009b). The state of food and agriculture 2009. Livestock in the balance (FAO, Rome, 2009)

HERRERO, M. et al. (2010) Smart investments in sustainable food production: revisiting mixed crop-livestock systems. Science 327, 822-825

c) A description of the main results/foregrounds

WP1: Identify and design innovative mixed farming systems using a participatory approach

A. Methodological results

1. Building a conceptual framework

A conceptual framework based on a three-sphere model (Crops, Grasslands, Animals) was developed to act as a boundary object for the design step and invite thinking innovatively in a "metabolic" approach and an "ecosystemic" approach.
Diversity of crops and grasslands interacting with animals appeared central for designing sustainable farming systems at landscape level, providing and valuing ecosystem services. Within this diversity, we define three types of integrated systems according to their degrees of spatial and temporal coordination: complementarity, local synergy, territorial synergy. Moreover, the options of cooperation and collective structuration between farmers and with other stakeholders of territories to organize and manage this diversity of land use revealed opportunities for smart social innovation
In our conceptual framework, the social system (human societies, economic activities, institutions and social groups) includes a variety of stakeholders, primarily farmers, but also agri-food chains, advisory services (e.g. chambers of agriculture, management consulting centres) and public policy agents, such as those in charge of natural resources. The hypothesis underpinning our participatory design methodology is that farming practices evolve with the social dynamics of coordination and collective learning (e.g. within agri-food chains or farmer collectives), and that synergies can be found through co-building of ideas and knowledge. More specifically, the level of crop-livestock integration is influenced by positive interactions (coordination, exchanges and social networks) or negative interactions (e.g. conflicts over use) between stakeholders. 'Organisational' innovations are thus crucial to make crop-livestock integration effective, to deal with issues such as livestock-farm workload, commercialisation of products, or local governance. We define organisational innovation as all changes in the organisation of work, agri-food chains, information sharing and collective actions implemented to support or regulate land use and management.

2. Use of the conceptual framework for characterizing the types of crop–livestock integration

We identify four types of crop–livestock integration based on the level of diversity and synergies between elements. Type 1: exchange of materials (e.g. grain, forage, straw, waste as organic fertiliser) between specialised farms, regulated by the market, in a rationale of 'coexistence'. Type 2: exchange of materials between crops, grasslands and animals (3 spheres) in a rationale of 'complementarity' at the farm if not territorial level. Crop systems are designed to meet the needs of livestock enterprises (need for concentrates, raw forages and straw) and livestock waste to fertilise arable plots. Type 3: increased temporal and spatial interaction among the 3 spheres in a rationale of 'farm-level synergy': stubble grazing, temporary grasslands in rotations, inter- cropped forages. A high level of diversity in farm components is targeted to enhance regulating services. Type 4: increased temporal and spatial interaction among the 3 spheres in a rationale of 'territory-level synergy': organisation optimises resource allocations, knowledge sharing and cooperation, including work. Types 1 and 2 focus on improving metabolic properties of farming systems, while types 3 and 4 focus on using ecosystem services to regulate pests and increase soil fertility.

3. Use of the conceptual framework for designing integrated crop-livestock systems

The development of integrated crop-livestock systems (ICLS) is a major challenge for greening of agriculture but appears difficult to be implemented at a large scale. A participative method of ICLS design has been developed and implemented.
To design ICLS at farm and territory level, a trajectory of design would be preferable to more instant process. It allows social learnings to be developed and improvements to be found, through iterative

cycles of diagnosis, design, assessment and redesign. During this iterative sequence, the object itself is precised and functions, processes and tradeoffs may be identified.
The method is based on participatory approaches for scenario co-construction and assessment. In a first step, a “light” design method has allowed to define a range of options for better integrating crops and animal in order to reduce environmental impact of specialized agriculture for a large range of case studies across Europe. Then we went more in depth for designing and assessment, either taking into account feedbacks of other workpackages (redesign phase), either in a continuing process of design and assessment (“strong” design).

B. Technical results

Below, we give three examples: (i) options of innovations at European level; (ii) regesign process; (iii) details of the designed system in two different situations (low self-sufficiency farms for organic matter and protein; water shortage in summer for crop farms).

1. Fifteen case studies (CS) across Europe

The participative design method of ICLS has been implemented in fifteen case studies across Europe, representing a large range of production systems (bovine, ovine, pig), challenges, constraints and resources for innovation. Local stakeholders, in first place farmers but also cooperatives, environmental association representatives and managers of natural resources, have been involved in the identification of challenges and existing initiatives of crop-livestock integration, in the design of new options at field, farm and territory level, and then in the qualitative multicriteria assessment of these options.

The adaptation options designed in CS explore metabolic and ecosystemic approaches. We give an overview of these options to identify generic or transversal ideas emerging from these specific cases. Some organisational options have been designed to reduce workload in livestock systems (e.g. investment in a milking robot), add value to farming activities (e.g. producing solar energy on livestock buildings), or benefitting from the landscape quality (e.g. hosting tourists). These are important points but concern all types of systems, either specialised or integrated. Thus, we distinguish between crop–livestock integration options (in metabolic or ecosystemic approaches), and organisational options. Among the diversity of adaptation options designed in CS, few are purely ‘technological’, except biogas production which is cited in six CS. The stakeholders identified mainly sets of practices based on agroecological principles: diversification of crop rotations (eight CS), better use of semi-natural spaces such as landscape elements (four CS) and grasslands (six CS), and optimisation of cover crops (three CS). The importance of organisational aspects is also outlined: local market development appears in four CS, as much as forage banks or structures for exchanging products between farmers directly. Public policies appeared to be a source of support for development of ICLS but less frequently than knowledge-sharing initiatives.
The most frequently mentioned adaptation options (technical or organisational) designed in CS, represent either exploitative or explorative innovation. We observed more exploitative than explorative innovations, probably because stakeholders imagine innovative practices within the limits of their own constraints, and thus deep changes hardly emerge. If individual adaptation options are not significant to change deeply the farming systems, the combination of several options envisioned in many CS in scenarios of crop-livestock integration may lead to a strong reorganisation of land use and farming practices (e.g. CS C14-15). Therefore, we used the typology of crop-livestock integration to classify combinations of options.

- Four CS belong to a ‘complementarity’ type, corresponding to enterprises or specialised farms interacting without spatial coordination (each activity is spatially segregated). The integration is oriented to the metabolic approach (e.g. recycling). An example of the complementarity type is CS C16, a commercial pig farm where optimisation of manure management allows nitrogen inputs for crop production to be reduced. The use of local by-products also maintains the fodder supply and benefits the local integration of farming. Cropping and livestock systems coexist and interact through flows of products, but there is no specific management of land use and practices to deliver ecosystem services.

- Four CS belong to a ‘synergy’ type at a farm level, seven at territorial level. The main farm-level issue is self-sufficiency, while the main territorial-level issue is coordination between crop and livestock production (e.g. mixed-use spaces, dual-purpose crops). The synergy type focuses mo
- re on the ecosystemic approach, using diversification of land use and spaces to manage ecosystem services, Examples of the synergy type are CS E7 (farm level) and C2 (territorial level). In CS E7, a high level of self-sufficiency is reached through feeding cover crops and crop residues to animals, which are otherwise fed with grassland hay or by grazing. Grasslands are rotated with crops as much as possible to increase the productivity of both. In CS C2, animal wastes regularly decrease water quality due to nitrate leaching. Their use as a resource for biogas production could decrease environmental impacts. The heat produced by anaerobic fermentation can be used to dehydrate fodder crops such as lucerne, grown locally in rotation with maize. Introducing lucerne increases soil fertility, thereby reducing the amount of manure having to be applied to maize and decreasing water pollution. Lucerne cultivation and management of the biogas plant are undertaken by a farmers’ organisation with pilot farms for experimentation and training of other farmers.

For a deeper understanding of the rationale logic of crop–livestock integration, we present a comparative analysis of four territorial-level CS: E6 in Italy, the merged C14 and C15 in Spain and C4 in the Netherlands. These CS represent three contrasting and illustrative types of crop-livestock integration at the territorial level, each with its own issues and constraints.

The qualitative multicriteria assessment placed workload as the main issue of concern while demonstrating expected benefits of ICLS simultaneously on economic, agronomic, environmental and social criteria. This study raises the conclusion that participatory design of ICLS based on a generic conceptual multilevel and multidomain framework and a methodology to deal with a local context could provide references on new systems to be tested.

2. Redesign phase in some case studies

Case Study C4, Winterswijk

A key point of redesign is home-grown cereals to replace imported concentrates. However, the profit of cereals is too low and price of land too high to grow cereals. Cereals are only attractive in a rotation with high profitable crops like potatoes. Cooperation between arable and dairy farmers offers more options, arable farmers grow cereals for dairy farmers and dairy farmers rent land to arable farmers for potato cultivation.

Case Study C14, Dairy Ebro Basin, Aragón, Spain

A key point of redesign is to organise district-level cooperation between specialised farms with the goal of optimising resource use efficiency as opposed to the goal of increasing production. Three options of change have emerged, each of them having constraints for operationalization:

- **Valorize the manure by means of biogas production** (either collective or individual) to obtain a dry “digestate” of higher value than non-processed manure, to exchange it with arable farmers up to 30 km around the farm. Exchange digestate not by straw, but alfalfa or other feedstuff of higher value. From the previous workshop, it was quite clear that, currently, there are many difficulties in implementing biogas plants in Spain (high initial investments, lack of support of public policies, lack of enough information to farmers…). The farmers did not see clear advantages of this option of change.
- Increase the land/territorial basis of the farm, **lowering stocking rates** (farm level crop-livestock integration), by means of renting (provided that it is not easy to buy land). For some farmers with more labor availability, this is a good option and, in fact, some are increasing land by renting, growing alfalfa in the additional land and diversifying their operations. For other farmers with limited labor availability, to have more land complicates very much the operations, the need of having different kind of machinery, etc. They find it better to exchange materials to manage livestock waste and to have a simpler farming system.
- **Crosses of Holstein Friesian breed x other breeds** (Montbéliarde, Jersey, Swedish Red breeds), to improve longevity, fertility and calving ease. We have so a kind of “extensification” with less productive animals but with lower requirements, higher farm

output/input, eg through reducing milk cow productivity and increase milk quality, or more fat milk content in case of Jersey (better paid). This option of change appeared as well in the Light design workshops, it seems to be a feasible option of change for young farmers of the region, especially when it is linked to the option of direct sale (short circuit) of labelled milk, yogurt or cheesemaking with added value.

3. "Strong design" in the Aveyron River

Co-design and ex-ante assessment of crop-livestock systems at the territory level (watershed - southwestern France)

This territory is composed of highland with intensive livestock systems and of lowland with intensive (mainly irrigated) cropping systems. In the highland, concentrate feed (e.g. oilcakes, raw cereals, cereals processed into complete meal) is the largest import, equaling approximately 110,000 t DM/year from international channels (i.e. South America, China, India). Protein-rich concentrates, such as soybean cakes, are important in the supply chain. Certified non-GMO soybean, in greater demand, comes from India and China. In the lowland there is high potential for locally-produced fodder and concentrates. Supply chain stakeholders look for more stability in supply prices. Self-sufficiency in protein was a particular concern of supply chain stakeholders for livestock systems. Therefore, it was chosen as the central entry of the lowland cropping systems design step.

Thus, we designed alternative cropping systems and their possible spatial distribution in the landscape together with a group of farmers and technical advisors. The resulting options for change in land use and practices were simulated to assess their metabolic functioning, delivered ecosystem services, socioeconomic performance and capacity to respond to local challenges. The most promising option is introduction of alfalfa in current cropping systems. This option reduces the irrigation-water withdrawals up to 50% and represents an opportunity to create a new local supply chain without decreasing socioeconomic performance. Changes in technical practices could be implemented with the support of local supply chains, but require further support of public policies.

Participatory design and integrated assessment of collective crop-livestock organic systems

The study was conducted with a group of organic farmers in Tarn-et-Garonne, a region in southwestern France with highly diversified agricultural landscapes.

Crop-livestock integration promises more sustainable farming systems, but are constrained by organizational and technical issues at farm level. Recently promoted by researchers, locally-adapted territorial crop-livestock systems remain more theoretical due to lack of methods for their design and of application to concrete examples to analyse their benefits and limits. The methodology we have used is characterized by co-building of the question and objectives with farmers and adaptive tools developed along the way with precision of the object of design through iterative sequences of diagnosis, design and assessment. Applied in a group of organic farmers, specialized in crop or livestock production, it allowed identifying potential complementarities between supplies of crop farmers and demand of livestock farmers that nearly allow for self-sufficiency at the collective level. The technical and organizational options for change were selected to satisfy objectives of the different partners. The multi-criteria assessment showed interesting performances of the options for a wide range of criteria and helped refining their possible conditions of implementation. This study shows the crucial role of an adaptive and comprehensive methodology to support the design of innovative sustainable forms of farming systems taking into account real constraints and objectives of farmers.

WP2 Test and validate innovative mixed farming systems on established long running experiments at the farm level

WP2 investigated mixed farming systems **at farm scale.** Mainly productivity, NPC cycling efficiency to reduce losses to the environment, and energy use reliance, are registered to answer to the following research questions:

- Does mixed farming system better close nutrient cycle in current situation than specialized one?
- Are the productivity and NPC cycling improved in farming systems when they implement the new techniques or practices recommended by WP1 (Innovations that enhance mixing)?
- What are the good techniques or practices to promote at cropping system level in mixed farms to reduce NPC losses?
- Are biogas unit encouraged by mixed farming system (Energy efficiency)?

Two commercial farms networks (87 Swiss and 622 French farms), six commercial pilot farms (1 Ireland, 1 Italy, 1 Switzerland, 3 France), and eight experimental farms (1 Germany, 1 Netherlands, 1 Wales UK, 1 Ireland, 4 France) were mobilized to answer to these questions in different socio economical and soil climatic contexts. The different tasks and subtasks run during the project aimed to quantify the gain due to growing crops and rearing animals together within farms to decrease environmental impacts while maintaining or improving farms' productivity. To perform these analyses, it was necessary first to decline the general principle of mixed farming systems, as set up by WP1 Cantogether, in an operational set of technical indicators in connection with the data available at the scale of the studies (networks of commercial farms, selected pilot or experimental farms).
That leads to two outputs in terms of methodology proposed by Cantogether project to quantify what is the level of mixing of a considered farm.

Methodologies proposed to quantify the degree of mixing of a farming system.

For farm network analysis, 3 ways of definition of MFS have been used: (1) the OTEX or FAT99 classification by economic and structural proxies; (2) a running definition ('Birmingham' definition) of integration by considering both the diversity of productions (crops and livestock) and the use of home-grown feed, view as an indicator of the integration between crops and livestock; (3) a measure of autonomy by considering the level of interactions within farming system in terms of feed and fertilizers inputs self-efficiency
For more precise analysis of individual farms, an aggregative scoring method (CADI: **C**rops and **A**nimal **D**iversity and **I**ntegration scoring method), was developed in order to classify farms according to their overall level of mixing of productions within farming systems and to demonstrate the different ways to enhance it. This method integrate 2 scores. The first score reflects the 'diversity' of productions and functions of the agricultural system (feed and food production, renewable energy, ecosystem functions). The second reflects the 'integration' by the intensity of interactions between crops and animal enterprises (e.g. pasture and legumes in rotation with crops, local production of feeds, organic crop fertilization). The development of threshold values for the rating was carried out by the Cantogether partners while observing the values obtained in 20 farms. This rating system has proved to be useful to track the profile of the innovative farming system over time (before and after implementation of techniques) along the two axes

Driving factors for environmental friendly farms of mixed versus specialized farming systems.

The 2 commercial farm networks were analyzed in order to compare the environmental performance of mixed and specialized farms and to analyze the key factors for environmental performance in real conditions
The comparison of mixed and specialized farms showed that there are no clear relationships between the national economic (OTEX) and structural (FAT99) farm classes and the environmental performance of farms. In contrast, the Birmingham classification and the level of measured

autonomy, showed a link between the environmental performance and the degree of mixity of farms. In conclusion, we show that what is decisive for the environmental performance of mixed farms is not the “mixity” in economic or structural terms but the physical integration between crops and animals.
The analysis of the key factors for environmental performance was undertaken "with no prior knowledge" regarding the degree of mixing between animal and plant production on the farms studied. It showed that: regarding the environmental impacts per ha usable agricultural area, the most performing farms were the most extensive farms in terms of stocking density and input use, in Switzerland and France. Regarding the environmental impacts per product unit, it was difficult to draw general conclusions. Depending on the product analyzed (milk, beef or total energy output) different factors were important. Generally, the most performing farms were larger, high-productive farms. Regarding the aggregated results per area and product unit, the most efficient farms were those that managed more effectively their inputs, had a greater feed autonomy and recycled animal waste.
So the decisive factors for a high environmental performance depend on the functional unit for the environmental impacts. For low impacts per area unit, the intensity of a farm is most important: the more extensive a farm is, the lower its impacts per agricultural area. For the impacts per production unit, it is rather a high productivity/ animal (l milk, or kg beef) which is important, even though the trends are less clear. The analyses also showed that it is possible to achieve a high environmental performance both per area and production unit. But, only a small number of farms reached this goal, observation which reveals the difficulty of combining both aspects. Farms which performed well in both functional units were generally very efficient farms with an optimal, site-specific combination of plant and animal production and a high degree of integration.

Are the new techniques or practices proposed by light design efficient to improve productivity and decrease environmental impacts of MFS?

Cantogether is betting that the complementary between productions can make agricultural production more sustainable. This hypothesis is tested on a sample of nine innovative farms located in Europe in different soil and climatic contexts (649-1385 mm rain / year, average temperature of 9-15 ° C, sandy or loamy soils, altitude 15-550 m). They are experimental units (x) or farmers in real economic conditions (e), and implement different productions: milking cattle (Mirecourt (x), Derval (x), Coopedom (e) FR, De Marke (x) NL, Ty Gwyn (x) GB, Solohead (x) (e) IR, San Giuliano (e) IT), beef cattle (Thorigné (x) FR, Lindhof (x) G) or monogastric (pigs farm in Midi Py. (e) FR, pigs and hens at Lindhof (e) G). They implement different innovative techniques related to mixed farming system opportunities: i) the management of surfaces with low levels of inputs through original crop choices (types of rotation, variety selection, pure legume or in combination, catch crops) ii) a local animal feed (production of grain legumes or ensiled mixtures, using alfalfa as hay or dehydrated concentrate, cereals home consumed), iii) the valuation of manure as fertilizer (separation, dehydration, composting, spot application) or as a source of energy (biogas).

For each case study, the farm performance is described with and without the innovation implemented, called respectively innovated and baseline farm situation. By putting into practice those new techniques which are often influencing work organization, it was expected to improve the different aspects of sustainability. Farms Nitrogen emissions (NO3, NH3, N2O, NO), phosphorus, carbon (CO2 and CH4) losses, were estimated according to a common methodology. The level of productivity and environmental risk are then discussed with the evolution of CADI score.

In baseline situation, farms covered a wide range of intensification level, from organic to high productive farming systems (3,2-11,7 TDM/Ha, 0,98-4,57 LSU/Ha). NPC fluxes and losses display also significant ranges: farm gate balance excess (49-359 kg N/ha, 0-36 kg P/ha), nitrogen losses (leaching 26-135 kg N/ha, ammonia losses 12-122 kg N/ha) and carbon (methane 2.9-19.4 t eq. CO_2/Ha, direct energy carbon dioxide 0,2-1,6 t eq. CO_2/ha). While implementing new practices and techniques recommended by WP1, farms increased the level of diversification and integration of farming systems (on average, Cadis score is 15 % higher in innovative situations than in baseline).

For the 9 farms that documented baseline and innovative situations, primary production of agriculture area was rather stable (-1% tDM/Ha produced for innovative situations), but this production was more sustainable as it required less mineral fertilizer (minus 42% N mineral fertilizer and minus 84 % P used per TDM produced in innovative situations). In terms of protein provided per hectare, results are variable (4 farms increase it while 3 decrease it). In addition, 4 farms developed a production of renewable energy.
Direct emissions per hectare of agriculture area were lower for nitrogen losses: nitrate leaching risk decreased (5 farms have reduced more than 7% the risk of leaching on AA) when nitrogen fluxes to atmospheres (NH_3, NO, N20) stayed at the same leval in average but variable (no major change for 4 farms, 3 farms decreased emissions and 2% increased). For climate warming potential, the direct emissions per hectare of AA (CH_4, CO_2 direct energy, N_20) were decreased for 7 farms but regarding per unit of product (protein outputs), the emissions were lowered only in 4. Moreover, the sink of Carbone is reduced in innovative situation as permanent grassland proportion in agriculture area is lowered in 5 farms.

Are biogas unit an efficient way to promote the MFS?

A specific work on energy efficiency has been done on farms which are recycling livestock wastes and crops or crop residues in an anaerobic digester (AD). The interest of biogas unit process to support mixed farming system were studied in four socio economic context (i.e. level of subsidies for green energy investments and price of renewable energy in France, Italy, Netherlands and Switzerland) and within diverse farming systems: number of cows from 42 (CH) to 290 (IT); agriculture area from 34.4 ha (CH) up to 200 ha (FR); livestock density (0.65 to 1.9 dairy cows / ha). The farms presented similarities (four case studies producing milk; AD filled with liquid continuous mesophilic system and a combined heat and power (CHP) unit to valorise biogas production), but also some differences in farm type (one farm with fattening pig; one experimental farm when the other are commercial farms) and in terms of AD unit (manure represented from 12 to 100% of dry matter entering AD, size of AD going from 36 to 250 kWe). Energetic efficiency varied between the farms, FR and NL sites produced the best quality of biogas with 63% of methane. Electricity production were more important for bigger unit (in our case, IT, FR and CH2 sites produced respectively 847, 934 and 913 kWh/t dry matter (DM) entering AD, whereas smaller units in NL and CH1 farms produce respectively 382 and 447 kWh/t DM). They also valorised the heat produced by the CHP in different way: digester heating (all farms), wood drying (2 farms), grain drying and fodder drying (FR), digestate drying (IT), heating houses and onions drying (CH1).
Through those diversified situations, it is shown that biogas is useful to promote MFS as:

- It creates a new activity on farm that can generate more work force (employment when AD is big size) thanks to new incomes (heat, electricity, biomethane, dried digestate valorized as an organic fertilizer).
- It reduces the reliance to mineral fertilizer inputs: during fermentation organic nitrogen of manure changes its form into ammoniacal nitrogen form that is integrated more easily by the plant.
- It facilitates the work for manure application: digestate is easier to spread on land with a more standardized product than slurry or solid manure.
- It is an opportunity to improve quality of feed (poor quality of fodder harvested can be orientated to AD whereas good quality is saved for animals feeding, the heat of AD is used to dried fodder that preserves its quality),
- It helps for environmental targets in MFS: AD decreases greenhouse gas emissions by covering manure during the process (usually non covered before) and of course, by producing renewable energy, it reduces the use of nonrenewable one.

WP3: Test and validate innovative mixed farming system at the district and landscape level

WP3 has focused on analysing, testing and implementing (technical) performances of existing and new mixed farming systems at a landscape or district level by using case studies to collect data, study the flows of feed, energy, nutrients and carbon at the district level and to get reliable information about the experiences of farmers and other stakeholders in different regions of Europe.

The main message from the work done in WP3 is that at farm level it is generally spoken for specialised farms not attractive to become a mixed farm, because of extra labour pressure, machinery costs and complexity of the farm. Better option is to collaborate with a neighbouring farm and exchange materials (manure, straw, feed) or animals (heifers in the Swiss case). Farmers then can benefit from the advantages of specialisation and from the cooperation (in different forms studied in case studies) to make better use of local resources and on the other hand to use products or space to become or stay more intensive (or better meet environmental regulations). At ha level the potential environmental benefits are lost by this intensification, but at product level (per kg milk/meat) these benefits are gained.

Going more into details:

- A farming system approach was used to describe, analyse and assess the following strategies to recouple crop and livestock production at the district scale: (1) Local exchange of materials among farms; (2) Provision of high quality forages through a cooperative dehydration facility; (3) Land sharing between dairy and arable farms; and (4) Animal exchanges between lowland and highland regions. A selection of non-cooperating baseline farms (specialised and, where available, mixed) were compared with specialised or mixed cooperating farms in each district using data on farming practices and organisation, input use, feeding strategies, fertilising strategies, land use, nutrient recycling, and agronomic and economic performance. The data were collected via farmer interviews. The results indicate that the potential ecological benefits of cooperation are restricted by farmers choosing to use the resources made available via cooperation to intensify their operations as opposed to diversifying them. An increase in the number of milking cows per hectare on dairy farms and increased cropping intensity on arable farms precluded certain benefits, such as lower external input use and improved district-level nutrient autonomy from being realised. In most cases, cooperating farms exhibited higher input use than specialised farms. Cooperation via improved forage provision or animal exchanges resulted in improved productivity, increased land use diversity and lower N surplus per unit of agricultural output compared to non-cooperating farms. Cooperation via material exchange resulted in increased productivity. The findings suggest that if district-level cooperation between farms is organised with the goal of optimising resource use efficiency as opposed to the goal of increasing production then it has potential as a blueprint for sustainable intensification as it can simultaneously raise yields (and income), increase input use efficiency and reduce the potential for negative environmental impact.
- The results showed that crop-livestock integration at regional level does not necessarily lead to environmental benefits. Instead the cooperating farms have often more intensive farming practices than non-cooperating specialised farms e.g. in terms of stocking rate or milking cow per ha, input use and N balance. Therefore, the benefits of integration were restricted by farmers choosing to use cooperation as a means to overcome environmental regulations and intensify their operations (since it provides a way to handle the large N excess that accompanies intensification) as opposed to diversifying them. It is not yet clear whether cooperation helped farmers to intensify their system, or is required to sustain already intensive systems.
- Collaborative dairy production between lowland farms and mountain farms in Switzerland is identified as a suitable production system for disadvantaged regions not only in an economic but also in an environmental context. However, in a rather complex production system like dairy production, the comparative advantage does not cover possible side effects that a

division of labour could cause. In the Swiss case study, changes in both meat and crop production were induced by the collaboration, and contributed either in a positive or negative way to the environmental and economic impact of the dairy production systems. In general, the collaborative production reduced the environmental impact on a supra-regional level.

- The results of pig slurry and grain exchange between pig and arable farmers in Ireland showed that applying pig manure to tillage land can, on paper, seem to be an ideal solution to the problems that pig farmers face. The data analysis shows positive aspects related to the use of pig manure on tillage land in the region. The data demonstrated that on farms where pig manure was used in conjunction with mineral fertiliser the amount of mineral fertiliser that had to be imported onto the farm was reduced. This offsets the cost of fertiliser associated with growing crops and also reduces the farmer's exposure to price volatility. On the cooperating pig farms 35% of the concentrates were replaced by grain from the cooperating arable farms. However, in practice, there are a number of factors that will make tillage farmers reluctant to use pig manure. One of the main concerns that tillage farmers have is concerned with the restrictions imposed by the Nitrates Regulations SI 31 of 2014. The implication of these regulations for those that use pig manure is that they have to reduce accordingly the amount of mineral fertiliser they import onto the farm. In theory this appears like a more economical method of getting N and P onto crops as pig manure is generally given to tillage farmers for free or for a small fee but there is a large variability associated with the nutrient content of pig manure.
- In Spain in the Ebro River basin dairy and tillage farms arrangements were studied whereby dairy farms exchange manure with tillage farms in return for straw for use as animal bedding and feeding. The results indicate that the potential ecological benefits of cooperation are restricted by farmers' choice to use the resources made available via cooperation to intensify their operations as opposed to diversifying them. An increase in the number of milking cows per hectare on dairy farms and increased cropping intensity on arable farms precluded benefits, such as lower external input use and improved district-level nutrient autonomy. It was found that in this region, when compared to non-cooperating specialised dairy farms, cooperating dairy farms had lower land use diversity, shorter crop rotations and fewer species in the rotation, less area alternating spring and winter crops and greater area with two or more subsequent cereals. These results provide further evidence of the higher intensity of farming taking place on cooperating dairy farms relative to non-cooperating specialised dairy farms.
- To facilitate the exchange of slurry, feed and animals between farms an online brokering system was developed to find partners for collaboration (in the Swiss case for animal exchange, and for pig manure exchange in the Irish case). This system is a helpful tool. In Switzerland, lowland and mountain farmers are connected for young stock rearing, in Ireland arable farmers and pig farmers for exchange of pig manure. The brokering system will be hosted by Teagasc (Ireland) and AGFF (Switzerland).
- In Spain, transhumance by herding compared to transport by lorry or train revealed economic advantages and similar or even better animal welfare, in terms of farmers' perception. No significant differences in greenhouse gas emissions (in terms of CO2 eq.) were observed in herding/walking vs. lorry transport and depended on the flock size, selected drove roads and characteristics of plants grazed along the drove road vs. on farm. Total costs per trip increases up to 190% in lorry transport vs. herding/walking. The difference was higher in larger flocks. The most important cost in herding was labor. Walking/herding transhumance offers high ecological sustainability, including high potential connectivity to the Natura 2000 Network.
- To improve local forage provision with high quality feed, dehydration of forages is a potential option. However the cost of dehydration is high just like the greenhouse gas emissions. Replacing fossil fuels in the dehydration of forage was studied to increase farm economic and material self-sufficiency at the local scale. To assess the benefits and impacts of different fuels, forage dehydration using coal or biofuel are studied. Also the ability of farms to supply themselves with energy, residues and crops from agricultural areas were studied, using a variety of biomass crops: perennial crops (*Miscanthus* and switchgrass), annual crops (fescue) and agricultural residues (straws), as well as a local wood supply chain. The type of biofuels best suited for a particular situation depends on motivations, available

equipment and needs. When using biofuels and residues, multiple-fuel furnaces are better suited. In this study, biofuels reduced dependence on fossil energy by 94% (switchgrass) to 98% (*Miscanthus*, wood, straw), thus improving local self-sufficiency. In terms of GHG emissions, biofuels reduced the impact of dehydration (since emissions from biofuel combustion were excluded). Biofuels are currently more expensive than coal for dehydration. A retail price of coal of 130 €/t would benefit biofuel use. However, expected increases in coal prices each year and decreases in the European CO_2 emission allowance indicate a future advantage for *Miscanthus* and wood chips over a longer period.

- In the context of mixed farming systems, land sharing refers to cooperation between productive and ecological areas, and/or between livestock farms and arable farms. Land sharing may have an impact on soil and water quality, landscape and biodiversity. Changes in soil organic carbon (SOC) are a major indicator by which these impacts may be assessed. However, not much was known about possible effects on SOC due to land sharing at the farm or regional level. Therefore, a farming system approach was used to evaluate the impact of land sharing on SOC at mixed farms, compared to specialised arable or livestock farms. This was studied in three case studies. Results indicate that in intensive arable systems on soils low in SOC, the amount of C-input from crop residues and/or manure is the driving force for increasing SOC rather than the specialist (cereal-based) or mixed character of the farming system. However, the calculations also showed that this contribution may be higher in mixed arable systems than in specialised arable systems. At soils high in SOC, specialised (potato-based) arable systems lead to significant carbon loss over time. In contrast, the specialised dairy farms as well as the mixed dairy farms increased SOC. Concerning the latter, mixed systems with cereal cultivation to stimulate biodiversity provided more carbon than mixed systems with measures to reduce mineral losses to ground- and surface waters. However, results of the calculations for the Lieue de Grève farms show that highest gain in carbon was obtained by the specialist (grass-based) dairy system at moderate production level.
- Intensive dairy farms that undertake practices to maintain landscape quality and improve water quality can be regarded as a specific type of MFS. The technical results of the case studies in Winterswijk (NL) and the Lieue de Grève catchment (FR) are promising. Adjusting the management of intensive dairy farms to maintain nature values and abiotic ecosystem boundaries of the regional landscape resulted in a wide range of practices. Some of these practices were economically viable, while others were not. Payments for specific ecosystem services, regionally devised by stakeholders, could stimulate farmers to implement these practices.

WP4: Environmental assessment

Objectives of the work package WP4 were to:

Develop a scientifically coherent methodological framework of environmental assessment both at farm and territory level able to assess the environmental impact of diversification strategies with focus on animal production.

For direct emissions from animals, a tool was developed by project partner SIK/SP. For the calculation of nitrogen cycles on field level, the SPACSYS from project partner Rothamsted was chosen. As SPACSYS did not cover ammonia losses, those were calculated in a separate module developed by FDEA-ART in the case of mineral fertilisers, or in the tool of SIK/SP in the case of organic fertilisers. Concerning erosion losses, it was decided to use RUSLE2, however during the project it turned out that data of sufficient quality was lacking, thus USLE was implemented as an alternative. Heavy metal emission, a biodiversity assessment as well as background inventories for inputs are based on the SALCA methodology developed by FDEA-ART. Based on this methodology, a data collection sheet (DWP4) and calculation tools (CanTools) were developed.
At district level, DWP4 and CanTools were applied to one of the case studies (Swiss Mountains and Lowlands). The LCA for the other two case studies (Coopédom and Lieue de Grève) was based on the especially developed INRA LCA sheet, as the data required for DWP4 and CanTools were not available for those case studies. In addition, all three case studies were analysed with SALCA Biodiversity. Case study Lieue de Grève was also analysed using the CASIMOD'N model, predicting the environmental impacts on catchment level.

Apply the developed methodology for a selection of case studies consisting of the most promising diversification strategies as defined in the WP1, 2 and 3.

> On farm level, the described methodologies were used for the calculation of all selected case studies, namely
- E6 San Giuliano: A conventional commercial dairy farm in the North of Italy.
- E5 Ty Gwyn: An organic experimental dairy farm in Wales, UK
- C7 Västra Götaland: A modelled conventional pig farm (modelled) in the South East of Sweden.
- E4 De Marke: A conventional experimental dairy farm in the East of the Netherlands.
- C16 Midi-Pyrenées: A conventional commercial pig farm in the South West of France.

By performing life cycle assessment (LCA) we have focused on the differences in the environmental impacts of the different scenarios defined for each case study farm with respect to the particular baseline scenario. The innovation strategies consisted of i) a shift to low-input farming, ii) the introduction of energy production, iii) the transition to on-farm concentrated feed production, and iv) the improvement of the nutrient efficiency. In three of the case studies the innovation step was followed by a refinement step. The analyses were restricted to the comparison of the scenarios within the case studies expressing the LCA results relatively to the baseline. As agriculture has to fulfil different functions we assessed the environmental impacts of the scenarios with regard to the function of preservation of livelihood and the productive function.

The results showed different levels of target achievement:

- First, four out of five case studies had a better environmental performance in the innovation scenario with respect to the livelihood preservation showing that the applied strategies are promising options.
- Second, in some cases the judgement was even that the performance was very favourable. However, with two exceptions there were contrasting results regarding the productive function, hence a trade-off meaning that the strategies need overworking or where this would only lead to a relocation of the environmental impacts decisions by politics or society must be taken on which function has to be favoured.
- Third, the refinement steps did not result in distinct further reductions of the environmental burden.

We concluded that the desirable environmental effects can only be achieved, if the innovation is carried out consequently implying a major change of the farming system. The sample size is small, only allowing the identification of the strengths and weaknesses for the specific case but not generally valid insights. Furthermore, for a superordinate appraisal of the results the global consequences (shift of production, pressure on crop land, etc.) should be taken into account. Yet, from a methodological aspect, applying life cycle thinking to the research question proved to be a very sensible choice to prevent measures that did not take into consideration further effects on the farm performance. However, this is restricted to the environmental pillar of sustainability and does not include the many aspects of the framework of a farm (e.g. market opportunities, regulations, financial and labour situation, and preferences), which in sum calls for an individual (environmental) optimisation for each farm.

> On regional/territory level, three case studies were analysed, namely:

- Coopédom: A farm cooperative in Brittany, France. This cooperative operates a centralised furnace in order to dehydrate fodder for its over 700 members. The baseline scenario was defined as a situation where farms do not dehydrate fodder at the centralised furnace and thus do not grow lucerne. In the innovation scenario 1, farms grow lucerne instead of pasture and dehydrate it at the centralised furnace. This furnace is fuelled mainly by coal. In the innovation scenario 2, farms grow Lucerne and miscanthus instead of pasture. Miscanthus is used to partially substitute coal as a fuel for the furnace. All studied farm types are dairy farms.
- Lieue de Grève: A catchment in Brittany, France. The studied farms from the catchment are dairy farms. The baseline consists of data from farms, as collected in 2007. The innovative scenario was modelled to limit stocking density to 1.4 livestock units / ha of grassland and net N input from fertilisers and feed to 100 kg N / ha agricultural area (including cropping area), while milk production per ha was kept constant.
- Swiss Mountains and Lowlands: Dairy farms from a lowland canton (Thurgau) and a mountain canton (Grisons) in the eastern part of Switzerland. The baseline consisted of farms from both regions that produce milk and rear their own young stock for restocking. A part of the farms were mixed, while others were specialised dairy farms. In the innovation scenario, the lowland farms outsource the young stock to a mountain farm, and the mountain farm specialised in keeping the young stock and give up milking.

At the district level, we have estimated how environmental impacts of agricultural regions composed of multiple farms would change after adoption of innovative farming practices to increase interactions between crops and animals. Environmental impacts tended to decrease per ha and per kg of milk.

- Coopédom's innovation slightly reduced most impacts but increased the amount of land necessary to produce milk.
- Lieue de Grève's innovation decreased impacts of the region's surface area and the milk it produced. The model CASIMOD'N simulated a decrease in N_2, N_2O, NH_3 and NO_3 emissions within the Lieue de Grève catchment under the innovative scenario.
- The Swiss innovation decreased impacts of the network of farms from both regions.

These innovations also had social and economic effects that need to be considered in a wider assessment. Because innovations potentially effective for decreasing a region's environmental impacts depend greatly on the region's impacts of importance, agricultural systems, and climate and geography, we recommend development of an assessment framework that could be applied to a given region.

To contribute in an iterative way to the development of diversification strategies (design and redesign with WP1) and to the overall sustainability assessment (with WP5)

WP4 contributed to the design and redesign of innovative strategies (see above WP1 report) and to overall sustainability assessment (see below WP5 report)

.

WP5: Socio-economic viability of mixed farming systems

What is a mixed farming system? – Developing a definition for the Cantogether project

The general trend within agriculture across the EU has been one of specialisation, with increased polarity between cropping and livestock farms. However, mixed farms are perceived to offer improved sustainability compared to their specialised counterparts (Ryschawy et al., 2012), but how do you define a mixed farm and how do they perform financially? Utilising EU and Swiss Farm Economic data Network (FADN) data, (comprising a sample of 243,806 holdings from 2007-2009), a new farm type and farm system typology was developed to compare the characteristics and relative profitability of mixed and specialised farms in Europe.

As an initial step, all FADN farms were re-classified into farm types according to their main economic enterprise (e.g. fieldcropping, horticulture and permanent crops, dairy, beef and small ruminants, pigs and poultry. Secondly, within each farm type, every farm holding was then classified into a farm system, according to their land use, livestock and proportion of non-forage feed sourced as home grown feed; allowing a contrast in systems for analysis:

· Specialist Cropping (SC) – cropping farms with no livestock
· Specialist Grass (SG) – pasture based livestock farms
· Fodder Cropping (FC) – farms with livestock and forage crops e.g. maize
· Mixed Output (MO) – livestock and cropping farms - no use of home grown arable feeds
· Semi-Integrated (SI) – livestock and cropping farms - some use of arable home grown feeds
· Fully-Integrated (FI) – livestock and cropping farms - high use of arable home grown feeds

Therefore each farm within the combined EU-FADN and Swiss farm economic database were classified by their primary economic output and their farming system based upon land use and level of home grown feed; allowing a comparison for each primary economic input between diversified (MO, SI, FI) and specialized (SC, SG, FC) farms and between diversified farms showing an increasing degree of integration of crops and livestock (from MO to SI and finally to FI).

Economic performance of mixed farming systems

Using the classification system described above, a large number of FADN and calculated variables were produced for each holding and this formed part of an analysis undertaken at three levels, comprising European and selected national and NUTS2 regional levels. Overall, the results appear to demonstrate that in many cases the specialised (Specialised Grass (SG), Fodder Cropping (FC)) and mixed output (MO) farms achieved higher output through greater use of external inputs and ultimately were more profitable. However, when analysed at national or regional level the conclusions were not always so clear. Despite lower output, the fully integrated (FI) systems often achieved similar profitability to the more intensive systems (e.g. dairying in mid-Sweden; beef & small ruminants in central France showed no statistical difference in farm net income between the systems).

Whilst there is often a negative perception of the economics of integrated farming, many of the analyses indicate that profitability can be at a similar level to specialist systems. However, encouraging more intensive specialised farms to convert to more integrated farming could be problematic as existing commitments to specialised capital infrastructure would prevent many farms from adjusting to lower output, lower external input systems without a severe financial penalty. Another issue appears to be that productivity is lower on the more integrated systems with lower milk and wheat yields, though in theory this should not be assumed as the internal transfer of nutrients within the farm, in addition to any external inputs should result in similar yields.

In terms of environmental indicators, it was clear from almost every comparison that the FI farms had significantly lower expenditure on external inputs of feed, fertiliser and crop protection products, combined with high cropping diversity and lower livestock stocking densities. However, despite these positive environmental indicators, the FI holdings usually received lower or similar total subsidy payments, and agri-environmental payments were no different to the more intensive systems.

Overall, the results appear to demonstrate that the FI holdings usually have lower inputs and outputs, high crop diversity and lower levels of stocking, but this often resulted in lower profitability compared to the less integrated and diversified systems. However, for some analyses there was no difference in the profitability of specialist and FI systems, and FI systems appear to offer significant advantages in sustainability through lower external inputs as a means of minimising farming intensity, and also in reducing input and output price exposure to volatility on smaller and family farms.

Sustainability assessment of Spanish sheep and Welsh beef mixed crop-livestock farming using the MESMIS framework

Farm sustainability was evaluated using the MESMIS framework. It relies on a systemic approach by the definition of five basic sustainability attributes: (a) Productivity (capacity to provide the required level of goods and services); (b) Stability (the ability of the system to cope with change); (c) Adaptability (the ability to find new levels of balance or to continue offering benefits to long-term changes in the environment); (d) Equity (the ability to distribute both intra - and intergenerational benefits and costs fairly); (e) Self-reliance (the ability to regulate and control interactions with the outside). The two case studies assessed included a Spanish consisting of meat sheep farming systems associated to cash crops (mainly cereals) and a Welsh (UK) producer group consisting of beef farming systems (and sheep) associated with crops (mostly fodder crops and 40% of farms with cultivated cereals).
From the analysis, four “types” of farms were identified for each of the case study based on the emphasis placed by the farmers on each of the five sustainability attributes described above. For The Spanish farmers these were: Group 1 – more self-sufficiency and stability; Group 2 – best productivity and worst equity and adaptability; Group 3 – less sustainable and Group 4 – best equity and high adaptability. For the Welsh farmers the four groups were: Group 1 – highest equity; Group 2 – best productivity; Group 3 – least self-sufficient and Group 4 – least stability and adaptability.
Mixed sheep farms (Spain) belonged mainly to group 1 (higher levels of self-sufficiency) and were more evenly spread across groups 2, 3 and 4. In terms of sustainability pillars, the social and economic sustainability was lower than environmental sustainability.
Mixed beef farming systems (Wales) were relatively evenly spread between the four groups but obtained slightly higher scores in equity and productivity than in the other sustainability attributes. These farms scored lower for social than economic and environmental sustainability, though the range for environmental sustainability was relatively large.

To conclude, we can say that mixed farming systems are generally more environmentally and economically than socially sustainable. However to achieve higher social did not involve in all the cases lower economic or environmental sustainability (e.g. Group 1 farmers in Wales).

The acceptance of innovative mixed farming solutions by producers and supply chains

Stakeholder workshops were conducted in Wales, Spain and Switzerland to discuss the acceptability and transferability of a number of innovative mixed farming systems case studies (Celtica, San Guiliano, Oviaragon and Swiss Mountain and Lowland) from the Cantogether Project. The workshop participants included producers and other supply chain members and experts. The mixed farming system case studies were evaluated in the theoretical framework of innovation adoption (Botha, N. and K. Atkins (2005) and Rogers (1962)) and looking specifically at the technical feasibility of the innovation (including adaptability and relative advantage/disadvantage), the economic viability, the social acceptability (including in relation to cultural norms and the achievement of goals) and additionally any policy related barriers.

The workshop discussions indicated that innovative mixed farming systems which require high capital investment and are perceived to divert valuable nutrient resources from the farming system, such as the San Giuliano case study, are not acceptable to relatively small individual dairy, and mixed livestock/cropping farms. The potential for these systems appears to lie with intensive livestock systems that have little land for disposing of excess manure and slurry. Even if Government support existing to assist with the establishment of biogas plants individual farmers are unlikely to use them due to the difficulties associated with fuelling them. Establishing co-operative biogas plants could be a way of overcoming this, however there are regulations in place in some countries restricting the movement of manure and slurry which would be a barrier to this.

The Swiss case study where animals are reared or finished on specialised units to free up land and resources on the home farm was much more acceptable to the workshop participants in Wale and Spain and similar practices were common in both countries. Certain practices such as the selling of dairy heifers to the rearing unit rather than rearing on a contract basis was viewed as quite novel by the Welsh participants and seen to have possible benefits in terms of TB management. Whether innovative systems such as the Swiss case study actually result in increased in mixed farming remains to be seen however and the Deliverable D3.7 - an in depth feasibility study of the Swiss case study, indicated that rather than diversifying and growing crops to become more self-sufficient in feed and nutrient efficient, farmers actually intensified the dairy system on the land freed up through collaborating with specialised upland heifer rearing units

The conclusion from the Welsh discussion of the Oviaragon case study is that some innovative mixed farming systems are just clearly not applicable to other pedo-climatic regions, in this instance agro-forestry in Wales. The benefits derived from such a system in Spain such as shelter for livestock from the sun and conservation of soil moisture under the trees on which to grow pasture, among other benefits, are simply not relevant in Wales. The costs of implementing such a system would far outweigh the benefits. What was interesting in the Welsh workshop was that the participants took the principles of the stratified agro-forestry system and discussed a very innovative system involving grazing livestock underneath solar parks.

Some mixed farming practices, such as the diverse, mixed farm system described in the Celtica case study are relatively transferable and were actually viewed as traditional farming practices in the Aragon region in Spain. Even so, there were still some aspects of the Celtica case study, such as the direct marketing of products, which were relatively novel for the Spanish group and were discussed as a way of perhaps improving the future economic viability of what is currently a declining farm system.

In conclusion, whilst it is clear that many of the innovative mixed farming system case studies presented are not directly transferable or acceptable in other pedo-climatic regions in Europe due to some technical, biophysical, economic, social and policy reasons, their discussion and analysis by stakeholders in other regions shows that there is potential to adapt these systems or extract certain aspects that may improve the sustainability of farming systems in those regions.

An integrated assessment to identify tradeoffs and win win innovative mixed farming strategies.

A trade-off analysis between environmental and economic performance was conducted for four case studies, three at farm level (San Giuliano, Ty Gwyn and DeMarke) and one at the territorial level (Swiss Mountain and Lowland). Environmental indicators used included Global Warming Potential (GWP), non-renewable energy use (NRE), eutrophication potential of N and P, terrestrial ecotoxicity and biodiversity. The financial indicator used was net margin per annual work unit.

San Giuliano represented a strategy based on waste recycling. The main goals in terms of environment (global warming potential, non-renewable energy) were achieved without economic trade-off. The implementation of a biogas plant with thoughtful treatment of the residues represents in the context of San Giuliano a win-win situation - it is a confirmation that the valorisation of waste products can be a very valuable option to the sustainability of a milk production system.

Ty Gwyn represented a strategy based on extensification. Expressed per ha UAA (as functional unit), it is not surprising that the environmental goals were achieved – but of course at the cost of more land use, especially for growing cereal concentrates. However, there was an evident conflict between environment and economics. Indeed, the purchase costs of feeds were almost eliminated, but they did not compensate for the drastic drop of the milk production and sales, especially considering that the contractor costs increased due to the greater cultivation area. If the environmental analysis was made per product unit, the outcome would have be significantly less positive –a lose-lose situation in fact. Ty Gwyn is confirmation that an extreme extensification strategy is rarely a valuable sustainable option.

De Marke represents a strategy based on new feeding fundaments. The innovation succeeded from an environmental point of view, especially for global warming potential, without environmental drawbacks.
Like Ty Gwyn, there was a clear conflict of objectives between environment and economy. This was mainly due to the unsuccessful new feeding strategy where the costs of the purchased feed increased and the production and sales of milk diminished. Moreover, there were increased contractor and cost crops.

From an environmental point of view, Swiss Mountain and Lowland collaboration was without relevant consequences, and even brought certain advantages, especially regarding the use of nutrients and energy resources. From an economic point of view, the net margin, from an initial negative value, strongly increased due to significantly lower labour costs. The livestock sales and the lower concentrate feed costs despite higher livestock purchases due to the transfer between the farms are further factors contributing to this positive economic effect. In summary, the Swiss Network Case Study illustrated the positive sustainability improvement that the exploitation of synergies between farmers in different localities can be achieved.

Based on these four case studies, no general conclusions can be drawn, however it is interesting to note that it is possible to have win-win situations (San Giuliano, Swiss Mountains). One possible explanation for this is perhaps that economic consideration were already taken into account when these case studies were conceived (e.g. new income stream for San Giuliano, application of the Ricardo principle of comparative cost advantages in the Swiss case), whereas the case studies Ty Gwyn and De Marke were firstly motivated by agronomic considerations of feeding strategies and intensification level. Much more analysis of this type would be necessary in order to support such a hypothesis.

d) The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results

POTENTIAL IMPACT

A- Alleviate environmental problems in crop and livestock production

Minimising reliance on external inputs (feed, energy, manure and mineral fertilisers)

The synergy form of integration, which requires social coordination among farmers, development of adequate spatiotemporal integration between crops, grasslands and animals promotes soil fertility, erosion control and field-level biological regulation services.
The proper recycling of nutrients on a farm reduces emissions per hectare and this way of progress is possible in both intensive and extensive farms. Improvements are observed both on water quality (less risk for high nitrate concentration in water resources) and on climate change (less greenhouse gases emissions per hectare of agriculture area). Renewable energy are also development opportunities for MFS. The investment in a biogas unit is source of new income (return on investment is nevertheless context dependent) and employment. That can also reinforce sustainability of the farming system with improvement of feed quality (heat valorized to dry) and valorization of co product (intercrops, slurry, straw of beddings as inputs for anaerobic digestate). The double environmental performance per unit of product and per unit of agricultural area, was studied at the level of farm networks in terms of recycling efficiency of nutrients and energy efficiency. We have showed that more autonomous farms in fertilizers and feed concentrates are more represented in the farms showing the best environmental results (i.e acidification, eutrophication, global warming).

At the district level, the potential ecological benefits of cooperation are restricted by farmers choosing to use the resources made available via cooperation to intensify their operations as opposed to diversifying them. An increase in the number of milking cows per hectare on dairy farms and increased cropping intensity on arable farms precluded certain benefits, such as lower external input use and improved district-level nutrient autonomy from being realised. In most cases, cooperating farms exhibited higher input use than specialised farms. Cooperation via improved forage provision or animal exchanges resulted in improved productivity, increased land use diversity and lower N surplus per unit of agricultural output compared to non-cooperating farms. Cooperation via material exchange resulted in increased productivity. The findings suggest that if district-level cooperation between specialised farms is organised with the goal of optimising resource use efficiency as opposed to the goal of increasing production then it has potential as a blueprint for sustainable intensification as it can simultaneously raise yields (and income), increase input use efficiency and reduce the potential for negative environmental impact.

The economic analysis conducted at the EU level in Cantogether demonstrated that in many cases the specialised grass (SG), fodder cropping (FC) and mixed output (MO) farms achieved higher output through greater use of external inputs and ultimately were more profitable than the diversified farms with a more or less large integration of crops and livestock.
However, when analysed at national or regional level the conclusions were not always so clear and cases were identified where the fully integrated (FI) systems achieved similar profitability to the more intensive systems (e.g. dairying in mid-Sweden; beef & small ruminants in central France). The economic analysis of the case studies as part of the integrated assessment process indicated that in some instances (e.g. San Giuliano biogas and Swiss mountain and lowland collaboration for dairy rearing) the integration results in win-win situations in terms of both economic and environmental performance. However the good economic performance relied to a certain extent on the labour resources that were freed up as a result of the mixed farming innovation to generate an alternative, often off farm income streams. This has implications in terms of farmer/farming family skills and training to be able to take up off farm employment and is also very dependent on the locality of the farm in terms of available employment opportunities.

Unfortunately, other mixed farming case studies exhibited a conflict between environmental and economic performance (e.g. Ty Gwyn and DeMarke), usually as a result of reduced output per ha.

Agriculture is a multifunctional activity, whose most important ones are the production of goods and the preservation of a sound agricultural area. The LCA methodology allowed to clearly distinguishing between these two functions by the appropriate choice of the functional unit chosen for the assessment. Depending on the function considered, a given strategy can be assessed as being more or less adequate. Considering the issues dealt with in CANTOGETHER, especially in connection with excessive nutrient losses leading to local and regional environmental problems, the innovations proposed were first assessed according to their capacity at alleviating the environmental problems on an area basis. In this respect, strategies having a high extensification component proved in general to be favorable independently from the question whether they are more or less mixed. This is illustrated by different case studies, as Ty Gwyn and Västra Götaland at farm level or Lieue de Grève at territory level. In summary, when applying an extensification strategy such low-input organic farming system or reduced fertilizing input, of course, less environmental impacts per cultivated area are obtained. But this is often achieved at the expense of productivity. If this trade-off cannot be overcome by augmenting the food and feed output while keeping the inputs at low level, this strategy is not convincing at global scale. An exception can be seen if there is suitable and available arable land currently out of production, for example due to set-aside policy (like in the Swedish case study). If not, it would be a shift in the global equilibrium resulting in a lack of that crop area in another part of the world. Such an approach is only justified in very specific conditions, for example when the environmental impact is not any more bearable at regional level (like in the Brittany case study. In the Cantogether case studies, often the step from a specialised farm towards a more mixed farm goes hand in hand with an extensification. This makes it difficult to attribute the possible environmental benefits to either the extensification or the improved diversification of the farm, and thus a final conclusion whether mixed systems are beneficial per se from an environmental point of view cannot be drawn only on this basis.

Another important insight is that from an environmental perspective only distinct steps in innovation will produce a clear improvement. This may seem at first sight to be trivial. However, the analysis of the case studies De Marke and San Giuliano at farm level and Coopedom at territory level shows that an innovation such as the installation of a biogas and CHP unit or growing lucerne to replace imported feeds can only be successful if it is carried out by exploring all possible benefits and not in some minimal way.

Finally, case studies founded in a better integration of the processes, at farm level thanks to a biogas plant in order to cope with manure surpluses (e.g. San Giuliano Case Study) or at territory level by fostering the collaboration between farmers of different regions (e.g. Swiss Mountains and Lowlands case study) appeared to be rather successful from an environmental point of view. In other words, when mixed farming has an integrative character, it seems to be more appropriate in order to alleviate environmental impacts than when it has first an extensification character.

Prepare for a greenhouse gas mitigation role of agriculture

The direct emissions of GHG per hectare of AA were decreased for innovative options in 7 farms (on 9) but regarding per unit of product only in 4. Moreover, the sink of carbone is reduced in innovative situation as permanent grassland proportion in agriculture area is lowered in 5 farms. If we prefer the function of occupancy and maintenance of space, it makes sense to express impacts per unit area. In these circumstances, we find that the MFS are generally virtuous. However, if we favor the production function of agriculture and we expressed impacts per unit of product, we see that MFS does not provide a valuable solution in all cases and should therefore be to refine the definition of innovations implemented. In this regard, the development of biogas units can be a determining factor by the consumption of fossil energy it avoids.
Environmental policies are frequently defined by type of impact, mainly for simplicity. Work in Cantogether has shown that it is necessary to combine the different dimensions of environmental problem: climate change but also air quality and water.

To improve local forage provision with high quality feed, dehydration of forages is a potential option (sub-task 3.3.2; D3.4). However the cost of dehydration is high just like the greenhouse gas emissions from the use of fossil fuels. The use of biofuels reduced dependence on fossil energy by 94% (switchgrass) to 98% (Miscanthus, wood, straw), thus improving local self-sufficiency. In terms of GHG emissions, biofuels reduced the impact of dehydration (since emissions from biofuel combustion were excluded). Biofuels are currently more expensive than coal for dehydration.

Boost the role of mixed farming in landscape protection

Intensive dairy farms that undertake practices to maintain landscape quality and improve water quality can be regarded as a specific type of MFS. The technical results of the case studies in Winterswijk (NL) and the Lieue de Grève catchment (FR) are promising. Adjusting the management of intensive dairy farms to maintain nature values and abiotic ecosystem boundaries of the regional landscape resulted in a wide range of practices. Some of these practices were economically viable, while others were not. Payments for specific ecosystem services, regionally devised by stakeholders, could stimulate farmers to implement these practices.

B- Reinforcing agriculture competitiveness

Societal impact

Although crop–livestock farms seem theoretically ideal to improve the sustainability of agriculture, their number is declining across Europe. Indeed, beside expected benefits (less pressure on the environment, social learning and collective empowerment…..), there are several limitation related to workload. In addition, limitations to crop–livestock integration beyond the farm level include cognitive and social aspects such as difficulties in finding long-term agreements between farmers.
Economic limitations are linked to the cost of transporting products between farms. Nevertheless, there were case studies with promising results, like for instance San Giuliano, where productivity was not affected by the implementation of the innovation. Such case studies can be used as an inspiration for others.
Generally, at farm level specialised farms were not attractive to become a mixed farm, because of extra labour pressure, machinery costs and complexity of the farm. Better option is to collaborate with a neighbouring farm and exchange materials (manure, straw, feed) or animals (Swiss case). Farmers then can benefit from the advantages of specialisation and from the cooperation (in different forms studied in case studies) to make better use of local resources and on the other hand to use products or space to become or stay more intensive (or better meet environmental regulations). At ha level the potential environmental benefits are lost by this intensification, but at product level (per kg milk/meat) these benefits are gained.

The study of the acceptability of innovations indicated that whilst the concept of some of the innovative mixed farming systems was reacted to positively, on a local or regional level there were often many perceived barriers to actually implementing the system. For example the idea of moving young animals to specialist rearing units to free up resources on the home farm (as was the case in the Swiss case study) was thought to be a good idea in both Wales and Spain but barriers to implementation in these countries included the risk of transmitting disease (Bovine Tuberculosis is a big problem in both these countries but not in Switzerland). In the Swiss Mountains and Lowlands Case Study, some economic and social consequences were observed for some actors – including the employment issue when transferring activities form a farm to another one. Such systems require, if one wants to implement them, a collective decision-making process about which ones are acceptable and if compensation actions are required.

One of the key findings of the acceptability work was that in order to increase the uptake of innovative mixed farming systems, farmers must be provided with the support and advice needed to adapt the system to their own needs and circumstances. This is a particularly important issue when disseminating the results of the Cantogether project.

Finally, innovations for which a positive message can be made to the farmer regarding his impact on the environment together with the feeling of modernity contribute to an appreciation of the profession, as it could be observed in the direct contacts with the farmers participating in the case studies Lieue de Grève and San Giuliano.

Transferring knowledge in practical applications for farmers and service providers

Designing Territorial CLS adapted to local or global challenges requires accounting for the complexity of constraints that arise on concerned farms and in territories. As it was shown that the relevant forms of integration (farm or landscape level, complementarity or synergy between crop and livestock, place of grasslands…….) to be implemented depend on the nature, area and spatial configuration of crops, grasslands and animals in farms and landscapes, a generic method has been developed that can be easily implemented by local stakeholders to find adaptations well-tailored for their own conditions. This method (method for designing, criteria for assessment) could help to reduce complexity and uncertainty. The participatory modelling approach engages participants in a greater understanding of the trade-offs between resources needed and the impacts of extraction of those resources. It helps to bring credible transparency to individual and institutional beliefs.
The conceptual framework can be used as an intermediary object for the characterization and the participatory design of territorial CLS while also considering changes induced at the farm level. It helps to stimulate and to structure analysis of the issues, to develop a portfolio of proposed options of change, and to combine them for designing a whole territorial CLS. Overall, this design process aims to support interactions between stakeholders to foster collective decisions and governance within a social-ecological system. Further research would be necessary to perform and evaluate design processes with stakeholders. The analysis of the constitution of stakeholders' groups, the meaning of their involvement, and the type of territorial CLS they imagine would provide a rich picture of possible futures for diversified and resilient agricultural systems.
This method is designed to support both (i) specification of the problem, i.e. analysis of land use in current CLS and the associated key metabolic and ecosystem services issues, and (ii) design of territorial CLS taking into account their ecological and social dimensions. It has been used successfully in 15 European case studies to support the collective design of crop-livestock systems at farm and territory levels. The representation of the studied area landscape, agronomic potentials and typical farming systems helped stakeholders in defining functional complementarities between the different components. Stakeholders discussed the most important element to represent and characterized the drivers of change and acceptable degrees of change in the different parts of the system. These discussions allowed expression of different points of view of stakeholders and identification of opportunities for change.

The works of the project Cantogether were valued during the project actively in the Joint Technology Network SPYCE (Polyculture Breeding Systems) in France. The definitions worked around the diversity of farming systems across farms and territories and indicators developed in Cantogether were able to be shared by a larger number of partners in research and development.

One of the tools developed in CANTOGETHER for farmers is the brokering system: a contact platform in which it will be possible to link producers and consumers of certain kinds of goods/services. In Switzerland the system focus on young stock rearing and summer pasture grazing. The Swiss tool is hosted by AGFF, a private association of 3000 farmers which facilitates the uptake of research findings by farmers. On line websites and leaflets are available in German, French and Italian. The Swiss tool will be online at the end of March 2016 and presented on the AGFF general member assembly on April 5th 2016.
The brokering tool for Ireland links pig farmers looking for room for manure export to arable farms and arable farmers looking to sell their grain as feed for pig farms. Also the Irish tool is already working, but appointments about hosting and future support are not yet finished. Stakeholders and farmers found the platforms very interesting, and are looking forward on their official implementation in both case studies. The brokering tool is programmed with open source code, so that it can also be adapted to other regions, for other objectives etc.

To judge the possibility of extrapolating the results and to transfer certain innovations, methodological precautions must be taken in particular regarding the risks of confusion between soil and climate effects and types of production systems. In Oviaragon for example the less sustainable farms were those that were more mixed with a high % of crops fed to livestock, however, these farms also tended to have the lowest availability of irrigated land, resulting in poorer economic performance. Similarly, at the European level, productivity was often found to be lower on the more integrated systems with lower milk and wheat yields: a partial explanation could be that the fully integrated farms represented a group at the margin of good cropping land and also that the fully integrated sample was likely to include a higher proportion of organic farms with restricted inputs.

C - Implementation of EU policies and initiatives

In Winterswijk NL, a region with 65% of the land used for grassland and 22% for silage maize, dairy farmers were stimulated in a pilot to grow grains for provision of own concentrates. Most participating farmers were enthusiast about the results of the pilot. It was expected that growing grain could become part of the greening of the new ecological focus areas (EFA) of the CAP. However, only arable farms (> 30 ha) have to convert 5% of their agriculture land in EFA. Dairy farms are already ‘green’ when they consist of at least 75 % grassland. Next to that, in the Netherlands most dairy farmers apply for derogation **(**a measure that results from the Nitrates Directive).The derogation demands a minimum of 80% grassland. The results of these new policies imply for this region that the expanding opportunities for growing grain on dairy farms observed in last years has already stopped. The Winterswijk region will be dominated again by grass and maize.

Despite the positive environmental indicators found in the fully integrated systems, the FI holdings usually received lower or similar total subsidy payments, and agri-environmental payments were no different to the more intensive systems. These findings are probably due to the historical nature of most subsidy payments that were previously linked to livestock headage payments, now converted to the single farm payment (SFP) system. However, this means that the farms with the most intensive systems are usually the recipients of the highest subsidies, despite the wider potential environmental cost to society of their production. Under the latest Common Agricultural Policy (CAP) rules there should be a gradual transition to rewarding farmers for diversifying their crops and producing more protein crops such as peas and beans, which may encourage greater use of home grown feeds, but demand for land for energy crop production may hinder progress.
Recent changes to introduce greening within the CAP may see mixed and integrated farms receive increasing payments at the expense of more industrial units, but this depends significantly upon national implementation.

One major impact of Cantogether will be the policy recommendations which can be done to the European Commission. Four main categories of recommendations are based on Cantogether findings:

1. To have a vision for animal productions in the European agriculture. What is the European project for animal productions, larger and specialised farms concentrated on a limited part of the European territory? That is the current trend. If not, a clear alternative vision and strong measures are necessary.
2. To explore in depth commodification of environmental impacts. If profitability is the main drivers for economy, tools based on a market logic could be used to encourage the production of other common goods.
3. To mitigate market effects by the mean of market instruments. Cooperation can be fostered by intermediation tools that public policies can support. On the other hand, diversified systems, economically weaker than specialised one, must be protected against market aggressive volatility by adapted tools that also need public support.
4. To encourage cooperation and synergy. The vision of mixed agricultural activities must include complementarity at higher level than farm level to avoid constraints and impossibilities.

MAIN DISSEMINATION ACTIVITIES AND EXPLOITATION OF RESULTS

The following section "Use and dissemination of foreground" will precise all the dissemination measures relating to the project.
To sum up these measures:

- 15 scientific papers (in peer review publication) (plus 8 submitted)
- 3 chapters in scientific books (plus one in preparation)
- 19 communications in international conferences
- 32 communications in technical meetings (regianl or national level)

To illustrate, here are some representative papers:
(published or accepted)

Hanegraaf M.C., Den Boer D.J. and H. Korevaar (2014) Praktijktoetsing van een gebiedsgerichte aanpak van water- en bodemkwaliteit Biogas Science 2014
Hanegraaf M.C., Vertès F., Corson M.S., Den Boer D.J., Moraine M. and H. Korevaar (2015) Developing mixed farming systems at regional level: examples from intensive dairy farming Grassland Science in Europe, Vol. 20
Marton S, Zimmermann A, Kreuzer M, Gaillard G (2016) Comparing the environmental performance of mixed and specialised dairy farms: the role of the system level analysed. Accepted Journal of Cleaner Production
Moraine M Duru M, Therond O,. (2014). Diagnostic des enjeux et conception de systèmes intégrant culture et élevage sur le bassin versant de la vallée de l'Aveyron. Innovations Agronomiques, 39, 55–66.
Moraine, M., Duru, M., Nicholas, P., Leterme, P., & Therond, O. (2014). Farming system design for innovative crop-livestock integration in Europe. Animal : An International Journal of Animal Bioscience, 1–14. http://doi.org/10.1017/S1751731114001189

(submitted and in revision)

Avadi A., Nitschelm L., Corson M., Vertès F., An LCA-based approach for environmental assessment of agricultural regions: case study of a French catchment. (Journal of Life Cycle Analysis)
Baumgartner D, Lansche J, Mantovi P, Marton S, Gaillard G, Leterme P Integrating animal and crop production through installation of a biogas plant – The case of a commercial dairy farm in Northern Italy (Agricultural systems)
Hanegraaf M.C., Doppenberg G, Den Boer D.J., and Korevaar H. Upscaling soil carbon and nutrient losses from dairy farms in a high nature landscape (Abstract is accepted, paper due end feb 2016)
Martin G, M. Moraine, J. Ryschawy, M.A. Magne, M. Asai, J.P. Sarthou, M. Duru, O. Therond Crop–livestock integration beyond the farm level: a review of prospects and issues (Agricultural Systems)
Marton S, Zimmermann A, Kreuzer M, Gaillard G Environmental ans socio-economic benefits of a division of labour between lowland and mountain farms in milk production systems (Agricultural Systems)
Moraine M Duru M, Therond O A social-ecological framework for analyzing and designing crop-livestock systems from farm to territory levels (Renewable Agriculture and Food Systems)
Moraine M, Grilmaldi J, Murgue C, Duru M, Therond O Co-design and ex-ante assessment of crop-livestock systems at the territory level: a case study in southwestern France (Agriculture Ecosystems Environment)
Moraine M., Melac P., Ryschawy J., Duru M., Therond O. Designing scenarios of technical and organizational innovation towards crop-livestock integration among farms within a group of organic farmers (Agricultural Systems)

Otherwise an e-learning course have been produced. The objectives of the e-learning course are to define the MFS, to give some insights about the methodology for designing them, to present the main results of Cantogether project about their in-depth assessment according to the three pillars of sustainability, to draw some recommendations for the policy-makers. The course can be accessed for free at the following address: http://cantogether.agrocampus-ouest.fr

e) The address of the project public website, if applicable as well as relevant contact details.

Project website: http://www.fp7cantogether.eu

Contractors involved:

1 Institut national de la recherche agronomique – INRA - France
AgrocampusOuest AC
2 Stichting Dienst Landbouwkundig Onderzoek- Plant research international - DLO-PRI - Netherlands
3 Federal Department of Economic Affairs - Agroscope Reckenholz-Taenikon Research Station ART FDEA-ART - Switzerland
4 Aberystwyth University - Institute of Biological, Environmental and Rural Sciences ABER - United Kingdom
5 Swedish Institute for Food and Biotechnology – SIK - Sweden
6 Irish Agriculture and Food Development Authority – TEAGASC - Ireland
7 Rothamsted Research – RRES - United Kingdom
8 Christian-Albrechts-University Kiel – Institute of Crop Science and Plant Breedin – CAU - Germany
9 Institute of Soil Science and Plant Cultivation – IUNG - Poland
10 Zaragoza University - UNIZAR - Spain
11 Fondazione CRPA Studi e Ricerche – FCSR - Italy
12 Association de Coordination Technique Agricole – ACTA - France
13 CROPEYE - Netherlands
14 C.L.W. Environmental Planners Ltd. - Ireland
15 Celtic Pride - Celtic - United Kingdom
16 GeoSpatiumLab S.L - Spain
17 COOPEDOM - France
18 Oviaragon - Spain
19 TSM Treuhand GmbH - TSM - Switzerland
20 MORGAN FAMILY PARTNERSHIP / 7Y SERVICES - MORGAN FAMILY- United Kingdom
21 Arbeitsgemeinschaft zur Förderung des Futterbaues – AGFF - Switzerland
22 INRA Transfert – IT - France
23 IFIP Institut du Porc Association – IFIP - France
24 Terres Inovia - France
25 ITAB - France
26 ARVALIS - France
27 Institute de l'élevage – IE - France
28 FORSCHUNGSZENTRUM JUELICH GMBH – JUELICH – Germany
29 NUTRIENTEN MANAGEMENT INSTITUUT NMI BV – NMI – Netherlands
30 SP SVERIGES TEKNISKA FORSKNINGSINSTITUT AB – SP - Swede