EIP-AGRI Focus Group

Mixed farming systems: livestock/cash crops

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Executive summary

The specialisation and intensification of European farming systems increased productivity but also led to serious consequences on the environment. These consequences include water pollution due to an excess of manure and slurries in certain areas and high reliance on external mineral and feed inputs, loss of biodiversity and lower resilience to climate change. These negative impacts are partially linked to the separation of livestock farming and cash crop production both at farm and regional level. Mixed farming systems (MFS) can use resources more efficiently by using crops and grasslands to feed animals and fertilising their fields with manure from the animals. Researchers and policy makers therefore see MFS as a possible alternative to specialisation.

Despite their potential advantages in terms of sustainability, the economic results of MFS are not as high as those of specialised systems, especially considering the remuneration of labour. But there is a large diversity of MFS, ranging from a simple coexistence of crops and livestock to complete integration which favours economic and environmental performance. Moreover, MFS are often located in less-favoured areas which, on the one hand makes them less economically viable compared to other areas. On the other hand however, they have a competitive advantage in terms of using the diversity of local resources (e.g. through reusing manure on crops and feeding livestock through local cropping systems). This also raises the need understand in which soil, climate and socio-economic conditions MFS are successful.

The Focus Group (FG) analysed successful case-studies of MFS at the farm and at regional level across the European Union highlighting relevant innovations. The FG also underlined the main barriers and opportunities to the development of MFS. Opportunities were mostly linked to practices promoting economic and environmental benefits while barriers were usually related to the social dimension. Thus, the FG explored technical and/or organisational solutions to enable sustainable MFS. To assess MFS sustainability compared to specialised farming, the FG highlighted the need for multictiteria analyses. The FG suggested specific indicators on economic, environmental and social dimensions.

The FG experts also provided recommendations for further studies regarding MFS. They specifically underlined three main issues. First, educational and advisory systems should encourage technical and organisational innovation through knowledge exchange and peer learning tools. Secondly, promoting regional co-operation between specialised farms could enhance ecosystem services provision. Thirdly, the 'multiple product basket' provided by MFS should be considered and valued. Participatory design approaches involving farmers could help develop sustainable MFS through multi-disciplinary research. Any further research should specifically analyse the interaction between crops and livestock and consider the socio-economic aspects of MFS. The FG suggested specific ideas for Operational Groups and further needs for research to better understand and test the sustainability of MFS.

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Introduction

A worldwide renewed interest for mixed farming systems

Over the last decades, European farming has been driven by the objective to increase food production. The global market, in particular the availability of cheap inputs (mineral fertilisers, animal feed), has introduced the logic of economies of scale. The intensification of farming systems was associated with specialisation of farms and regions, leading to a separation of livestock and cash crop production. This had drastic environmental consequences: water pollution due to an excess of manure and slurries, soil degradation, depletion of natural resources, loss of biodiversity and lower resilience to climate change.

As recoupling crops and livestock could optimise resource efficiency, researchers and policy makers see MFS as a possible alternative to specialisation. Using crops and grasslands for animal feeding and in return organic manure for fertilisation, MFS could recycle nutrients more efficiently than specialised systems. MFS could thus theoretically limit negative environmental impacts while maintaining agricultural production and diversifying sources of incomes. Still, existing models of European MFS are not performing well in economic terms compared to specialised systems: they face a low labour remuneration and higher workforce requirement, which questions their level of economic sustainability. There is thus a need to understand better if MFS could contribute to the three sustainability dimensions of farming (environmental, economic, social) and to what extent.

Aim of the EIP-AGRI Focus Group on mixed farming systems

The aim of the Focus Group (FG) was to take stock of current information available on MFS in Europe to understand under which conditions MFS are sustainable or not and **to what extent MFS should be promoted as a suitable alternative to specialisation**. For the purpose of its mandate the FG used the following working definition for MFS:

Systems including at least one type of cash crop and one type of livestock production, considered both at farm and at regional level, as a combination of specialised farms exchanging resources between them[1].

The FG definition of MFS covers all the potential types of integration between cash crops and livestock that can enable a more sustainable and resilient European agriculture while considering farm competitiveness. A number of different MFS currently exist or have existed in the past (see Annex A).

The FG members[2] exchanged knowledge from across Europe to identify where **innovation** and **research** can enhance the sustainability of MFS. In particular, the experts were asked to identify **knowledge gaps** that could be addressed through further research (e.g. under Horizon 2020 projects, including multi-actor projects) and propose **ideas for Operational Groups** or other innovative actions to develop knowledge exchange and address practical problems (with the support of rural development funding). The specific objectives of the FG on MFS were defined as follows:

1. **Take stock of the current status of MFS**, identifying their **strengths and weaknesses as regards to sustainability**
2. **Identify strategies to enhance sustainability of MFS across Europe,** through the analysis of successful **case-studies of MFS** both at farm and regional level.
3. Where relevant and possible, **describe environmental, economic and social impacts** of MFS.
4. Identify **priorities for research and innovation needs** and provide **ideas for Operational Groups** and other innovative projects.

[1]Systems based on agroforestry or sylvopastoralism and autonomous livestock system using crops only for animal feeding were considered outside the scope of the FG.
[2]The list of FG experts and a short description of the FG work are provided in Annex B.

1 Current status of MFS in Europe

1.1 Impacts of the intensification and specialisation of European farming

From the 1950s and until the late 70s, the objective of producing more food drove European farming policy. Both global agricultural markets and agricultural policies enhanced efficiency in producing more of a same product, e.g. favouring economies of scale through intensification, enlargement and specialisation. The availability of cheap mineral fertilisers and animal feed allowed farms to specialise either into cash crop or livestock production. Crop and livestock production have become increasingly decoupled both geographically and managerially resulting in many livestock units becoming heavily reliant on bought-in feedstuffs and straw and specialised arable units on purchased fertiliser. High prices and subsidies favoured cash crops where the soil-climatic conditions were favourable. The first pillar of the Common Agricultural Policy (CAP) helped investments to modernise agriculture such as irrigation and land management actions, which favoured the intensification and specialisation of cash crop production in some European regions.

The increased economic competition between production areas led to the regional concentration of livestock too, especially in the areas where the infrastructure and supply chain organisation favoured agglomeration economy. The protectionist agricultural policies of the EU and the communist countries guaranteed stable product prices and incomes, reducing the economic risk of specialisation. Although the EU farm policy evolved towards an open-market policy (e.g. removing price subsidies, market interventions and production quota systems), specialisation is still enhanced. As a result of the logic of economies of scale and/or agglomeration, farm size increased all over the EU, whereas the agricultural workforce tended to decline. Among the causes that explain this evolution, literature points to the opportunity cost of labour as a main driver. Favourable opportunities for labour outside agriculture (and higher wages) increased abandonment; farm enlargement (of the remaining farms) favoured specialisation and simplification of practices.

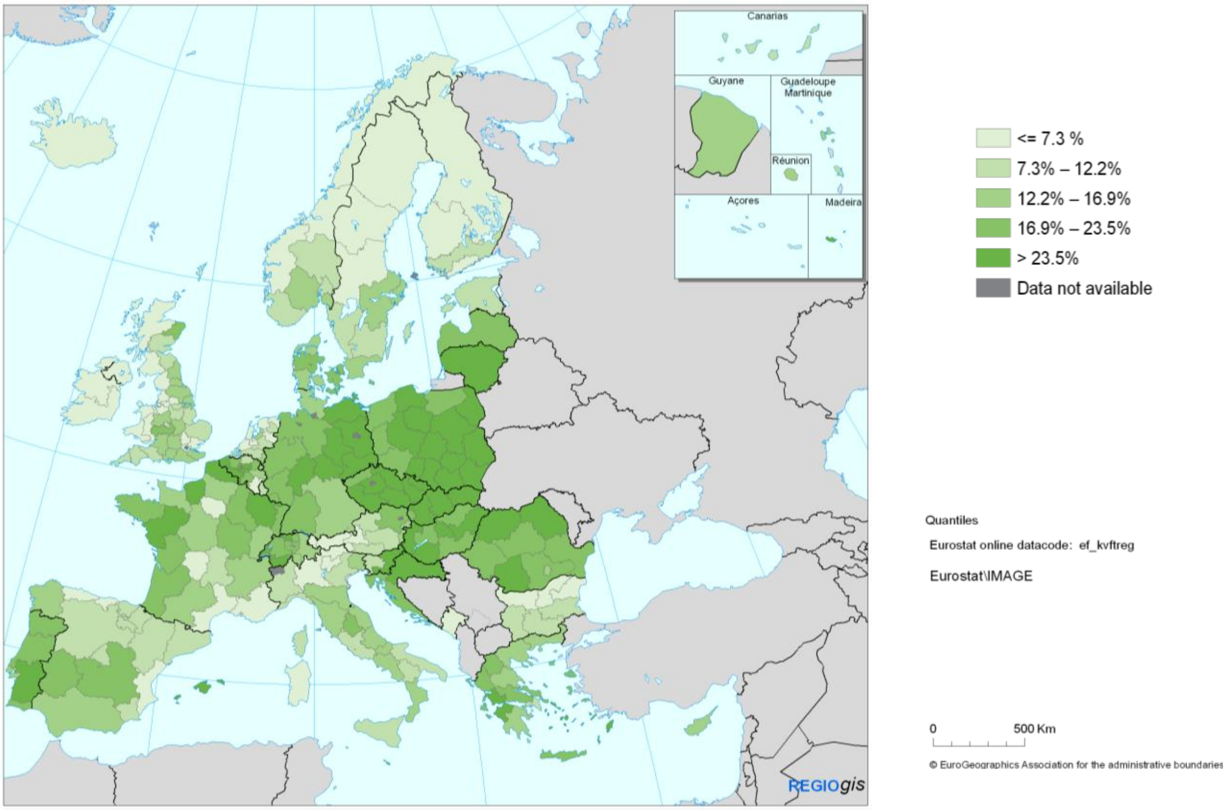
Although specialisation has obvious advantages for farmers, it also has a major downside. Due to the withdrawal of market intervention policies, market volatility has increased, causing high income risk for specialised farms. All over Europe, specialised crop farms have problems maintaining organic matter content and soil fertility. Straw has continued to be transported from arable areas to intensive livestock production systems but manure has not been returned due to issues such as cost and transport. The use of inputs, such as fertilisers and pesticides, has helped to overcome the need for rotations to build fertility and control weeds, pests and diseases, but is now facing serious economic and environmental limits. At the same time, high livestock density regions are facing water pollution due to an excess of manure and a high reliance on inputs, in particular on protein for feed. These current challenges result in a renewed interest of research and policy-makers in the MFS as a suitable alternative to specialisation to limit environmental impacts of farming (see for example: Soussana et Lemaire, 2012 ; Moraine et al., 2014).

MFS could potentially address some of today's environmental challenges faced by agriculture through combining **livestock and crop production efficiently to limit external inputs**. Still, if MFS should be maintained or re-introduced, they **would need to demonstrate higher (or at least equal) economic, environment and social benefits compared to specialised farming**. There is thus a **need to consider their level of sustainability** and to what extent they could be a suitable alternative to specialisation.

1.2 Sustainability performance of MFS: barriers and opportunities

Despite the renewed interest in MFS, these systems are facing a number of barriers and are still declining in Europe representing about 14% of agricultural systems all over EU. The share of MFS varies across European countries, with a larger share in Eastern countries of the EU (Figure 1). The level of specialisation depends on economic context, labour availability and pedo-climatic conditions.

Figure 1: Share of Utilized Agricultural Area managed in MFS within EU countries (Eurostat EU-28, 2010)



Despite their theoretical sustainability performance, MFS have been disappearing at the farm level. This could be partly explained by their low economic performance and social (work) constraints. First of all, MFS are not achieving as good economic results as specialised farms (Figure 2). According to FADN[3] data, average productivity of mixed farms, in terms of output/input economic value ratio, is comparable to the productivity of all European farms. The efficiency in input is comparable between mixed farming and all types of farms. Still, the income per worker in mixed farms remained below the EU-27 average (Figure 2). Moreover, direct payments represent a substantial part of farm net value added for grazing livestock, mixed and field crop farms, due to their average farm size and the historical orientations of the CAP. These economic results could contribute to explain why MFS have declined across Europe.

[3] Farm Accountancy Data Network (2010-2013) analysed by the European Commission and published 2015.

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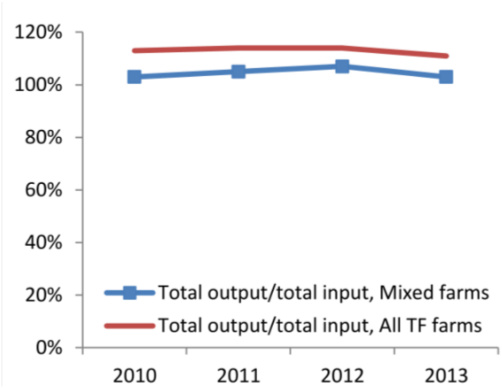
Figure 2: Average efficiency of mixed farms as compared to all types of farms (left); Average income per worker (right) (FADN, EC, 2015)



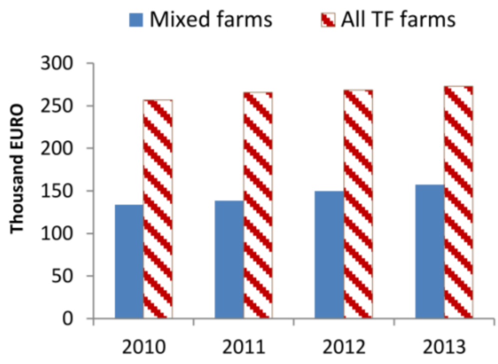


Table 1 summarises the major barriers for MFS development. Both at farm and regional level**, barriers are particularly linked to the economic dimension and the lower profitability of MFS. Efficient practices to integrate crops and livestock are needed to favour a lower reliance on inputs and thus achieve economic and environmental benefits.** Specific technical references and knowledge on such practices are lacking. Considering the social dimension, combining crop and livestock production increases labour and organisation because of multi-tasking. In particular the seasonal labour peaks (planting and harvesting time) could be difficult to deal with while the exchange of workforce is limited by the requirements of specialist skills. Also, for a mixed farm, the bureaucracy and administrative workload is expected to double, compared to a specialised farm. On top of this, the current education and advisory system is not providing adequate tools for farmers.

Table 1: Major barriers to the development of MFS in the EU

Dimension of sustainability	Barriers
Environmental	Lack of knowledge on innovative use of local resources and managing alternative crops
	Lack of technical and economic references to make use of locally-adapted practices in combining livestock and crops
Economic	Low short-term profitability at MFS farm level, low remuneration of labour in particular
	High cost and lack of logistics to transport and store feed and manure between farms
Social	Labour organisation and skills to manage both crops and livestock
	Farmers' willingness to cooperate to establish direct exchanges of feed and manure
	"Vertical' organisation of advising and education (top-down knowledge transfer)

The major opportunities are linked to synergies between the environment and the economic dimensions (Table 2). For instance, on the one hand the opportunity for technical improvements such as increasing legumes/grasslands in arable rotations benefits the environmental dimension as nitrogen will be recycled in the system and soil quality improved. On the other hand, limiting the use of inputs has benefits on the economic dimension of the MFS.

Table 2: Major opportunities for the development of MFS in EU-countries

Dimension of sustainability	Opportunities
Environmental	Increase self-sufficiency in animal feeding through multiple use of local resources/ efficient use of nutrients
	Recouple nitrogen and carbon cycle through legumes/grasslands in arable rotations
	Improve soil quality through organic manure and crop diversification
Economic	Added-value for local/sustainable quality branded products
	Valuing ecosystem services (landscape mosaic, PES…)
	Creating a market for a diversity of alternative crops
Social	Promote rural development (diversified jobs; link farming, food, tourism)
	Social and knowledge exchange between farmers at the regional level

Still, not all MFS are currently taking advantage of these opportunities to achieve good environmental performance. A macro-scale analysis by the FP7 Can together project[4] highlighted a large variability of mixed farms in terms of environmental performance. The project defined **a gradient of mixed farms according to the level of integration between crops and livestock**. **At one end of the scale, crops and livestock have low integration** - a simple coexistence between crops and livestock, with juxtaposed units interacting only through the market. **At the other end of the scale, crops and livestock are highly integrated** - self-sufficiency in animal feeding is possible by the diversification of crops and grasslands produced on-farm; parcels are fertilised through animal manure. **According to their evaluation, the more integrated farms were, the higher their environmentally sustainability.** The limited use of external inputs would also produce economic benefits thus balancing the results of the macro-scale FADN analysis presented before.

These findings **argue for a more precise definition of MFS** that should **not be seen as a generic catch-all solution for today's agricultural issues** but as a solution which can perform in specific soil-climatic and socio-economic conditions.

[4] https://ec.europa.eu/eip/agriculture/en/content/cantogether

2 Strategies to improve the sustainability of MFS

2.1 Improving the technical efficiency of MFS

When considering strategies to improve MFS sustainability, it is essential to recognise that **"one size does not fit all"** and that land capability plays an important role in the relative efficiency of MFS and specialised farming systems. On poorer lands, the management options are more limited, particularly because of issues such as slope and soil depth and climate. In such circumstances mixed farming may be able to provide self-sufficiency but a low conversion of inputs to outputs. In areas where the land is of good quality but is limited in availability for production, then very intensive specialised systems may be more efficient, at least in the short term. The infrastructures and services available in the area can also provide opportunities for MFS, for example, the presence of a specialist harvesting tractor would allow a farmer to experiment with diversified cropping without having to invest in new machinery.

MFS potentially allow **better use of resources** (e.g. energy, nutrients, land) than specialised systems. They also show higher potential in adapting to climate variations. Technical efficiency is usually defined as the conversion of inputs into outputs, but here we acknowledge both the efficiency of use of purchased inputs and the use of natural resource (e.g. soil and water). Compared to specialised systems, in MFS **improvements in efficiency are linked to the degree of synergy between components**. The degree of synergies between crops and livestock depends on the skills and motivations of the farmer.

Two main pillars for technical efficiency in MFS should be considered: i) **diversifying crop rotations both for sale and animal feeding sources while limiting external inputs** and; ii) **recycling animal manure to fertilise crops**. Considering these two pillars, a wide diversity of practices could be of interest (Table 3). Integration between crops and livestock in MFS can produce direct benefits such as using unharvested crop residues to provide grazing. The integration between components can also have indirect benefits such as maintaining habitat for biodiversity. Increases in technical efficiency and improved synergies between enterprises could lower reliance on external inputs. Compared to MFS, **specialisation shows benefits when there is low or no integration between components**. It is important to consider technical efficiency separately from intensity. Any discussion about innovation and fail factors needs to take into account the overall aim of a sustainable MFS. A further challenge in any discussion of technical efficiency of MFS is the **large number of potential combinations of crops and livestock and their interaction with the pedo-climatic conditions**.

Different crops covering the soils the whole year would limit soil erosion and nitrate leaching to water while providing organic matter. Some **cover crops could be considered as double-purpose enabling some flexibility to the system**. If needed, the cover crop could be dedicated to livestock feeding (being grazed or hayed). If not, the cover crops could be left on the soil to provide organic matter. **Integrating alternative crops in the crop rotations,** in particular legume-cereal crops or grazed legumes as main crops or in between two cash crops would be an adapted solution. **Manure management practices could be explored** to adapt the frequency of application and type of manure according to the local soil and climate and considering the crop rotation.

These general principles for combinations of practices allowing technical efficiency of MFS should be dealt with according to the specific context. Still, **a challenge for the technical efficiency of MFS is the large number of potential combinations of crops and livestock and their interaction with the pedo-climatic conditions**. Through 20 case-studies, the FG analysed specific successful combinations of crops and livestock at farm and regional level, highlighting their commonalities and specificities.

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Table 3: Successful examples of integrated practices in MFS improving technical efficiency and associated benefits

Agricultural practices	Examples of synergies	Associated benefits on sustainability/efficency
Manureused as fertiliser	Making the best use of self-produced manure through improved understanding of nutrient release to match crops' needs	*Reduced use of external inputs as fertilisers*
		Lower levels of water pollution (N and P loss) and soil improvement
Crop diversification and rotation design to feed the animals	Utilisation of self-produced feed (e.g. locally produced peas and beans, cereals and forages, including legumes)	*Improved product yield and quality (livestock health)/ lower reliance on feed inputs*
	Selection of crop varieties with specific properties (e.g. stubble suited to aftermath grazing, species with anthelmintic properties for animal health, …)	*Reduced reliance on external inputs*
	Accounting for pre-crop effects in rotation	*Improved soil structure via range of rooting depth, residue returns, etc.* *Reduction in fertiliser inputs.*

2.2 Successful case-studies of MFS at farm level

Among the 20 case-studies analysed, 14 case-studies of MFS were at farm scale. Some of the success factors identified are linked to the context, others to the specific farm considered. **These formed a practical basis to understand which associations of specific local conditions and combinations of agricultural practices are currently successful across Europe**. Two categories of MFS were considered here: i) MFS which have been maintained over time, and; ii) reintroduced MFS. Annex C describes the case-studies in terms of success factors for sustainable mixed farms.

Concerning the context, **most of the time we can observe that mixed farms have been maintained in less favoured areas**, where a local tradition for mixed farming has remained important. Most of the mixed farms have been traditionally maintained in areas which presented restrictions for intensification due to either soil (heavy, acid, etc.) or climate conditions or the topography (slopes mostly, at least partly).

The success factors at farm level are mainly technical, consisting of a combination of different practices to improve self-sufficiency. The holistic farming approach led to the real integration of animal and crop production, through producing feed for animals and using manure as fertiliser. Success factors can also be linked to social aspects (organisational, knowledge exchange with researchers...). **Some relevant innovations are directly linked with the local food system**, either to product marketing or to consumer information. These examples highlight the fact that the general combinations of practices presented in Table 1 should be adapted to specific context to achieve sustainability performance (economic, environmental, social).

At farm level, labour organisation to manage complexity is still a key barrier. A transversal question was how farmers were **managing complexity** to favour sustainable mixed farms. The whole system is supposed to be able to produce more (with less) than its individual parts, but this depends on an appropriate management of both crops and livestock. Managing both systems at a time requires higher **knowledge and skills.** There are currently knowledge gaps around the practices allowing a real integration between crops and livestock, e.g. using crops for livestock feeding and animal manure to fertilise crops. In addition, MFS requires higher **labour planning** at farm level..**Labour organisation** at farm level is a main barrier to the maintenance of mixed farms. The complexity of management of MFS includes the availability of skilled labour, the enhanced management and **decision making** skills required and, the potential risks associated with trying to manage multiple enterprises and their interactions. The example in the box below highlights how a farmer manages a complex MFS with a systemic approach and plans labour organisation. Trade-offs should be studied between higher complexity, flexibility and labour organisation.

An example of a complex, well-managed mixed farm, Cornwall, UK - *Farming a wide variety of soil types in close proximity brings many challenges which this local farm tried to overcome. The MFS farm considered used to have a simplified crop rotation with crops that can be combined, some winter, some spring sown, which were undersown with a new ley. Given the wet, maritime Cornish climate, grassland combined with livestock production are key to make sustainable use of the geographic advantages for future success. In terms of technical innovations, grazed fodder beets are seeded in spring, allocating low producing leys identified by weekly measurement. Male dairy calves for rose veal make use of secondary products from the primary dairy production, to get an additional and different income stream. Looking for synergies between crops and livestock could reduce workload and increase farmers' quality of life. Farmers have realised that having time off is important to keep future generations farming. Thus, cropping is carried out by contractors allowing more time for farmers for strategic thinking and management decisions.*

Two specific examples highlight more precisely the type of systemic innovations in mixed farms which allow the management of labour constraints while improving economic results and environmental aspects. The first is on improving the sustainability of an already existing mixed farm and the second on introducing and promoting a new model of sustainable mixed farm in a region.

An example of maintaining mixed farming at farm level
A biodynamic mixed farm based on recycling principles

The biodynamic/organic mixed farm Juchowo is located in the north-western part of Poland and covers about 1900 ha of land which is used for arable crops, vegetables, grasslands and nature conservation. The farm also has 370 dairy cows of two breeds (Holstein-Frisian and Brown-Swiss) plus offspring. The breeds were selected due to their longevity. Legume crops build the main pillar of the crop rotation and are a key factor to improve soil fertility. Different social activities in the farm include education, research and social therapy.

MAIN INNOVATIONS:

- **Improving feed autonomy of dairy cows**

Example: Production of high quality milk based on grass, hay and fodder consisting only of beet

- **Introducing conservation agriculture practices**

Example: Based on reduced tillage (only 10-12 cm till) to improve soil fertility, reduce soil erosion and compaction as well as limit fuel consumption

- **Developing innovative forms of education**

Example: Educational work at the Learning Place "Bio-Farm"



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An example of reintroduction of mixed farming at farm level
Self-sufficient crop-sheep farms with diversified marketed production

Two individual farms with a similar idea: introducing a moderate number of sheep on a farm with a long tradition of cash crop cultivation. Organic farming was introduced thanks to the availability of manure. Farmers want to lead an ecological way of living and farming. Sheep rearing can yield different products: wool, meat, hide, manure. Sheep feed on pastures, silage or hay and on surplus of cash crops (oat, wheat, faba bean, turnip, rape).

MAIN INNOVATIONS:

- **Re-introduction of traditional forms of knitting**

Example: Myssy-beanies, woollen ties of Finn sheep

- **Small-scale oil pressing**

Example: Grinding/milling of dry sweet pea; high quality cold pressed turnip rape seed oil

- **Marketing through REKO rings**

Example: Direct marketing by local farmers through Facebook groups

2.3 Successful case-studies of MFS at regional level

As previously highlighted in this report, **the current status of MFS in terms of the labour opportunity costs in the EU is particularly worrying**. When farmers decided to stop livestock (or crops) at farm level due to labour organisation, lack of workforce, reintroducing crop-livestock integration at the farm scale is no longer a possibility as the skills and network have disappeared. **Regional level integration between crops and livestock could therefore be developed through exchanges between specialised crops or livestock farms.** It could be a relevant alternative limiting the labour management and skills which need to be developed on farm. At the same time this allows the provision of a range of ecosystem services such as soils quality though crop diversification and manure use, water quality improvement and landscape heterogeneity favouring biodiversity.

Six examples of successful MFS implemented at the regional level were analysed by the FG. Regional MFS have been developed to locally reintegrate crops and livestock when farms are already specialised. **Even if the integration does not take place on the farm, the environmental benefits of crop-livestock integration are achieved at regional level.** Still, regional MFS are based on the coordination between multiple farmers to build the exchanges. Annex D provides an overview of the success factors for the introduction of sustainable MFS at regional level. As for MFS at farm level, **the introduction of exchanges between crop and livestock farmers is often suggested when the soil-climatic context is limiting for part of the considered region** (slopes, heavy slopes, etc.). As crop farmers are often located in better soil-climatic conditions, they could diversify their rotations to provide animal feed to livestock keepers who usually operate in less optimal conditions.

The introduction of MFS at regional level is **often favoured by the cooperation of researchers and farmers through participatory schemes**. The innovation in the social organisation scheme is very interesting and diverse in the case-studies of MFS at regional level. **The type of coordination may vary according to the size of the group and their common objectives regarding economic performance and autonomy of decision.** For instance, farmers could create marketing groups to collaborate. Such social organisation could range from two farmers exchanging crops to the involvement of a local cooperative developing new local-sourced markets. For all the case-studies, the implementation of MFS at the regional level is **a local solution to a local problem** (water management, pollution from nitrates, lack of organic fertilisers, volatility of the input market, etc.). **The implemented innovations are technological** (e.g. for manure treatment) **or technical** (e.g. mixed crops). **Most of the innovations are organisational too,** favouring the collaboration between farmers or at least their organisation on the market. To highlight relevant innovations at the regional level, two of the case-studies are briefly presented here.

An example of introduction of mixed farming between farmers at regional level
U-turn from nutrient spillovers to a valuable fertilizer

This regional integration relies on 48 local farmers in South Tyrol, Italy, who founded a company to work with a local Biogas industry, an advisor and a researcher. Dairy farming is a core agricultural activity in the area, but the vast concentration of cattle in the valley has led to nutrient spillovers. On the other hand, in some regions of South Tyrol there is a high demand on nutrients for vineyards. This cooperation initiative allows exchanges of nutrients between the two sectors through conditioning of manure digestate via a biogas plant.

MAIN INNOVATIONS:

- Farmers see **nutrient surpluses as a common problem** and are involved in implementing the solution
- Treatment of digestate residues facilitates the transportation of an **organic fertiliser**



An example of introduction of mixed farming through a cooperative at regional level
A French cooperative developing local markets: La Dauphinoise

This regional integration relies on the cooperative La Dauphinoise that organises exchanges of goods between grain producers and livestock farmers (who are located within 100 km from each other). The cooperative provides for the harvesting and storage and delegates the trituration of soya to a local oil firm. The cooperative area is rich in quality livestock production schemes, and most feed specifications require non GM soya. The initiative concerns the creation of a local soya supply-chain.

MAIN INNOVATIONS:

- **Technological innovation**: **soya extraction process** (expeller) with heat and pressure avoiding the use of solvents.
- **Organisational innovation: implementation** of **mid-term contracts** (prices defined yearly) to secure soya supply for livestock and soya market opportunities for crop farmers. Creation of a local brand aimed at promoting French origin feeding (Loc'Alp)

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3 Toward sustainable mixed farming systems: indicators for farmers, policy designers and… consumers

Any initiative to enhance MFS should take the diversity of MFS into account and evaluate the sustainability performance and progress margins of different types of MFS, mainly considering the potential of integrating crops and livestock. Multicriteria evaluation could be used as an opportunity for learning and improving current systems. Assessing the potential environmental, economic and social performance of different types of MFS as regards to sustainability would enable farmers to make more informed decisions about: a) whether they could viably practice mixed farming, and; b) which type of mixed farming (e.g. farm level or landscape level) might suit their farm, skills and resource base. Existing sustainability indicators are mostly conceived for specialised farms and not easily usable by all farmers for self-assessment.

3.1 Indicators for the economic dimension

Concerning the indicators on the **economic dimension** (Table 4), *risk management* in the short and long term is key. Indicators of *resilience* included the rate of diversification of sold products. *Long- and short-term sustainability* were considered by FG experts equally important. **These indicators derive from the accounting system of the farm, are easy to retrieve and to use.** Other indicators are linked to input use efficiency and easy to retrieve too.

Table 4: Indicators suggested to evaluate the economic dimension of sustainability of MFS

Criteria	Possible indicators	Relevance of the indicators for MFS
Long-term sustainability	1.Net income (farm level, share of cash crops and livestock) 2. Rate of diversification *(respective Gross Margins in livestock and in crops)* 3.Level of debt 4. Frequency of investments	MFS could balance risks between crops and livestock (specialised farm gets often better results but higher variability of income over years) ➔ *MFS are supposed to be more resilient as they could diversify product and be thus less sensitive to market fluctuation for one product* MFS invest more but could develop economies of scope (equipment, buildings, …) MFS needs a long term view
Short-term sustainability	1. Cash flow 2. Short-term debt (overdraft) 3. Labour productivity	Less sensitivity to the global market due to diversification of products sold (crops, livestock products,…) Farmers invest more in MFS (for both crops and livestock) If well-managed, farmers could have a great labour productivity in MFS in combining tasks over the year
Input use efficiency	1. Resource use efficiency (*input/output)* 2. Cost of inputs	MFS are supposed to better recycle N,P and C so to have a greater resource use efficiency and lower use in inputs (feed/fertilisers) Cost should be considered at local level and farm level

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3.2 Indicators for the social dimension

Concerning the **social dimension indicators** (Table 5), the assessment of the "quality of life" of farmers is linked to indicators of *labour organisation* and *workload* in MFS and developing thresholds to evaluate labour in MFS. A major barrier for the use of these indicators is related to the fact that **they are mostly qualitative and their evaluation is linked to the farmer's perception**, e.g. labour workload is more or less acceptable according to the farmer.

Table 5: Indicators suggested to evaluate the social dimension of sustainability of MFS

Criteria 	Possible indicators	Relevance of the indicators for MFS
Labour management	1. Hours of free time (labour balance evaluation) 2. Number of jobs created on-farm/locally	The multi-task labour organisation is higher in MFS More jobs are created in MFS both on-farm as more tasks have to be considered, and locally as diversified local products could be sold in the area
Cooperation between farms at regional level	1.Transactional costs (Time spent) *(including time spent helping others, in planning meetings, in training, …)*	Farmers collaborating for regional MFS need to share workload, planning and knowledge. Time spent in the establishment of regional MFS should be assessed to consider the involvement of the farmer.
Knowledge exchange	1. Time spent in training *(discussion/training groups, with adviser, internet/books, intergenerational exchange)*	Knowledge exchange is particularly needed in MFS as farmers have to develop diversified skills and knowledge As this could be achieved between farmers or through more conventional training or alone on the internet looking through references, different categories of knowledge exchange should be considered.

3.3 Indicators for the environmental dimension

Concerning the **environmental dimension indicators** (Table 6), high importance is given to *soil quality* indicators that can be **directly observed and measured by the farmers**, For instance *soil erosion*, *earthworm counting* to evaluate soil life, observation of *soil texture* and *organic matter* or *carbon sequestration* through the colour of soils. These indicators seemed easy to measure and very relevant since soil quality is key for MFS.

Table 6: Indicators suggested to evaluate the environmental dimension of sustainability of MFS

Criteria 	Possible indicators	Relevance of the indicators for MFS
Soil quality	1. Soil compaction 2. Soil texture 3. Soil organic matter 4. Carbon sequestration in grasslands 5. Share of soil covering (crops, grasslands, cover crops)	Key to measure the positive impacts of MFS on soils through arable-grasslands rotations and grazing (limiting erosion, …)
Water quality and quantity	1. N and P content of water 2. Quantity of water use by year and by crop	MFS are supposed to limit water pollution through arable-grasslands rotations and to have a lower use of water
Biodiversity **Landscape (proxys)**	1. Number of species 2. Number of habitats (agroecological elements, …) 3. Diversity of the landscape structure – (Shannon/Simpson index) or land cover	MFS are expected to encourage biodiversity MFS contribute to diversify landscape elements
Energy efficiency	1. Energy balance at the farm and regional levels	Energy balance is supposed to be better in MFS, as less energy is needed to import feed and fertiliser
Nutrient efficiency & climate change mitigation	1.Farmgate nutrient balance (N,P) 2.Carbon footprint	MFS are supposed to better recycle N,P and C so to have greater resource use efficiency and lower inputs use

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4 Recommendations for fostering sustainable MFS

This part of the report aims at summarising the main recommendations of the FG and listing the main needs for research as well as ideas for Operational Groups to favour the development of sustainable MFS. Three main issues are underlined by the FG. First, knowledge exchange and peer learning tools should be developed to encourage technical and organisational innovation. Secondly, there is a need to favour l co-operation between specialised farms and enhance ecosystem services provision at the regional scale. Thirdly, the 'multiple food basket' provided by MFS should be considered and valued. The specific proposals for Operational Groups and further research suggested by the FG encourage to better understand and test the sustainability of MFS.

4.1 Adapt educational, training and advisory systems to the specificities of MFS

"Farmers' skills to farm in a mixed way are getting lost. We have to improve their competences in these areas" - FG expert

Knowledge exchange and peer learning to enhance farmers' skills

The examples of existing MFS and the experience of farmers are important sources of knowledge for MFS development throughout Europe. Because part of this knowledge is tacit, a participatory learning approach is very suitable to make it more explicit. A first recommendation is to create a **peer learning network between existing MFS**: the diversity across Europe could enhance learning options and could also reduce the isolated position of these farms in a specialised world. **Peer learning networks could address both conventional and organic MFS.** Such networks require proper facilitation and organisation to: identify learning issues, support the exchange of (tacit) knowledge within the network, and organise access to relevant sources of knowledge outside the peer network. A peer network by definition consists of knowledge exchange between peers (experienced farmers). Still, it would be **valuable to organise access for other actors** (advisors, research, policy makers) who are interested in MFS, for instance through seminars, field visits and thematic networks. E-tools, such as web fora or other web-based tools, could also be used to stilumate this interaction. The EIP-AGRI could support such approaches.

"The best idea to educate people in lost skills is by creating groups that gather and share experience." - FG expert.

Develop more 'holistic' teaching and advising

The specialised education and training system is not delivering people with knowledge on MFS. The teachers and trainers are mainly specialists, and so are the students and trainees. It will be very hard to change the structure of this system, but it might be less difficult to solve the problem in a practical way. For example, devising projects involving teachers, trainees, farmers, advisors etc. could help to increase the knowledge and understanding of 'the other sector' and the pros and cons of cooperation. They could also participate in interactive design processes as experts. In most countries, education and training around organic farming is much more integrated (holistic) than those around conventional agriculture and so are the combination of practices on organic MFS, considering the integration between components. Depending on the case, it would be very effective to link conventional with organic education and training.

Develop farmers' knowledge on MFS strategic management to motivate young farmers

Time spent by farmers on strategic planning activities related to their farm business is often undervalued and low on their list of priorities. Farmers in MFS have to manage diversified tasks and develop a holistic approach. As the time spent in strategic management is undervalued and not taught, farmers in MFS often get the feeling of having too much work because they lack planning tools. The farmer - in most cases the owner of the farm business - is responsible for the strategic direction of the business and is also the manager and worker at the farm as well, so his perspective on MFS is important for any attempt to re-introduce the MFS concept in European agriculture.

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Developing case studies of different types of farming systems and valuing the different activities farmers undertake in their businesses on a day-to-day and annual basis would be an effective way of demonstrating to other farmers the benefits of taking time away from activities such as milking cows or ploughing a field. The latter are economically fairly low cost activities, and spending more time on potential high return, strategic business planning would be more beneficial. A better understanding of the benefits of (re)introducing MFS so as to raise awareness among farmers would encourage strategic management.

4.2 Enhance regional integration between crops and livestock

"We should talk about the diversified landscape mosaic provided by MFS and related environmental functions" - FG expert.

Considering MFS as an option for landscape management that enhances biological regulations and provides ecosystem services

Landscapes could be diversified through MFS, which would provide ecosystem services such as soil quality and biodiversity. **New practices favouring landscape management** could be explored at the farm level or at regional level by exchanges between specialised farmers. In the case of the regional level, farmers are mainly specialised in rearing animals or producing crops. Cooperation between them is essential to **reduce buying animal feeding** from far away, which is important from both an environmental and an economic point of view. **Cooperation between farmers or between farming sectors and the other local actors would lead to the improvement of landscape heterogeneity or the maintaining of cultural aspects linked to agricultural production** *(grasslands in the mountains, …).* For instance, crop farmers could introduce grass areas or strips along their crops to sell it to livestock farmers. Crop farmers could in particular introduce legumes as a main crop or cover crop which would provide nitrogen to the soil while feeding the animals. Farmers could be paid for the ecosystem services provided in terms of soil quality, water quality and biodiversity enhancement (see example below).

Diversified landscapes through arable-grasslands rotations associated to forests in Spain
In Galicia (Spain) temporary grasslands lasting between 4 and 5 years are usually sown with annual species (red clover or Trifolium pratense and Italian ryegrass or Loliummulti florum) that are used to cover the soil as soon as possible but that disappear after a year of sowing. This is usually associated to silage harvesting. The sown mixture also includes perennials (white clover or Trifolium repens and English ryegrass or Lolium perenne) that are predominant after one year of sowing and are usually associated to grazing and usually not harvested. Local plants, such as carragenates provide an excellent feedstuff for animals during the shortage periods. The animals graze forestlands and at the same time use crops produced in arable lands to be fed. Another Galician example is the use of chestnut lands to rear pigs during the autumn in those areas where the steep slopes make chestnut harvesting unprofitable. Chestnut processors can sell chestnuts that are not adequate for human consumption to livestock farms, obtaining an animal product of high quality.

"The problem is not just about knowledge, it is about behaviour, it is about building the habit of cooperating" - FG expert.

Enabling cooperation between farmers to favour MFS integration at the regional level

A main barrier to the maintaining or reintroducing MFS is the low motivation of young farmers to develop MFS alongside the lack of knowledge and skills concerning regional integration of crops and livestock. The need of **knowledge exchange networks** was suggested as a solution to this barrier. Specialised farmers should be helped to redevelop skills in MFS through collaboration. In particular, **farmers collaborating to develop a MFS at the regional level could organise collective training sessions to develop a deeper knowledge on the farms involved**.

Another important aspect of collaboration between specialised farmers to build crop-livestock integration is linked to **the planning of exchanges and trust within the collective of farmers** involved. Knowledge exchange would help production planning and exchanges regarding possible solutions. Farmers could therefore share production techniques from one type of farm to another, e.g. between crop farms and

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livestock farms. To favour trust, the collective of farmers could establish **mid-term contracts to fix the prices of crops sold between them even if the global market fluctuates**. This could be discussed to limit the economic imbalance between crop farmers and livestock producers. **Farmers could establish a collective insurance to anticipate adverse climatic events.** This would help protect farm systems against the global market and climate fluctuations and create solidarity and trust between them.

Mixed farming systems at regional level in South-Western France

A study conducted in Aveyron River Basin aimed at developing ideal mixed farming systems by connecting specialised crop and livestock areas. Prospective scenarios were conceived to diversify maize monocultures and short cereal rotations. Inserting temporary alfalfa grasslands in cropping systems was a main lever considered. At plot level, such diversification of crop rotations was supposed to reduce the pressure of water withdrawals for irrigation and the use of fertilisers and pesticides on crops, and improve soil fertility through a semi-perennial soil cover and through symbiotic N fixation by alfalfa. At landscape level, the development of alfalfa plots was thought to favour interconnected habitats for biodiversity and better resources for pollinators. In the scenarios, the coordination of cooperatives from the crop and livestock sectors was expected to lead to the development of a new supply chain for harvesting, processing, transporting and distributing alfalfa to livestock systems where farmers currently purchased large amounts of costly protein-rich concentrates. Further development of the study aims at implementing the scenarios of land use, firstly to insure the viability of alternative cropping systems with alfalfa and the interest of alfalfa products for livestock farmers. This prospective work was conducted by researchers together with farmers and supply chain stakeholders, and involved water board authorities and advisory services in the conception of more sustainable systems through regional crop – livestock integration.

"If agriculture is diversified it is more appealing for people. Mixed farms are more appealing for people" - FG expert

4.3 Considering the multifunctional basket provided by MFS to add value to MFS products

Apart from food, MFS also produce non-market goods such as cultural landscapes, biodiversity conservation and carbon sequestration though better land management. The recognition of the multifunctional basket of products of MFS could compensate for the lower economic benefits and risk linked to MFS management. It is therefore essential to **explore the possibilities of consumer-led development, marketing and integration in innovative food chains** for groups of products coming from MFS, either at the farm or the regional levels. An indicator framework should be developed to better **evaluate the "multifunctional basket" of products/services provided by MFS.** The specificities of MFS to make a better use of local resources to produce food could attract farmers and consumers. Farmers would be motivated to take up MFS if its benefits to the risk management of farms and cooperatives were clear. Positive effects of MFS on resilience (the level of external input use, market price fluctuations) should be quantified through multicriteria evaluation taking into account economic, environmental and social dimensions.

In order to develop MFS, implementing **monetary compensation for economic losses** at the farm level or local level is needed. An increasing proportion of consumers hold ethical concerns about how food is produced on-farm and the way agrifood chains operate. The increasing distance between producers and consumers and the accumulation of power by a few big operators along the chain are often perceived negatively by citizen groups. **Including MFS specificities into existing labels or branding for 'local' and 'sustainable' products** could be considered (for origin, production system, footprints, optimisation of energy use or nutrient cycles). This would allow farmers in MFS to be recognised by society and could encourage young farmers to apply MFS. Still, consumers' preferences as regards sustainable food systems and drivers vary considerably across Europe (e.g. GMO-free, phytosanitary-free, locally-sourced products, use of quality schemes, preserving diverse landscapes, etc.). Therefore this solution is more likely to work at the local level, if an effort is made to make labels understandable. **Consumers would therefore be able to pay for MFS if they were informed on the 'multifunctional basket of products' they provide.** As farmers and consumers are losing a 'common language', first-hand experience of MFS in practice should be included in the marketing toolbox, for example the REKO rings (see below).

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Local marketing groups called REKO rings: *In a recent study, consumers where asked to reveal the reasons for joining local marketing groups (REKO rings) in Finland. The most positive feature was that farmers gain a fair price for their product, followed by the openness of the production system as in REKO rings farmers have to tell customers about their management systems. Consumers claim that leaving supermarkets (and other retailers) out of the picture will eventually be an economic solution for themselves too. Thus, locality and short marketing chains mean that: a) more of the final value goes to the farmer and; b) the money circulates locally. Farmers can enhance the attractiveness of their products by having a higher trust in environmental benefits of their own farming system, by describing it understandably and by depicting the effect of their production strategy on the economics of the local society.*

Another way of favouring the multifunctional product basket provided by MFS would be **to develop a specific policy framework including subsidies for good practices in MFS at the farm or regional level**. For instance, **agro-environmental measures** could encourage farmers to adopt a systemic view of the farm. In France, farmers have already entered into a dedicated MFS farm agro-environmental scheme which guides their way of producing (on-farm feed production or contracts for buying-selling crops for feed). Farmers are getting 152€/ha to 234€/ha[5] for the area under the policy framework. Other policies could **favour collective organisation of farmers in order to develop regional exchanges of products**. They could be labelled as groups of economic and environmental interest and thus be recognised and paid for their efforts. Finally, the opportunity of **payment for ecosystem services** could encourage MFS at the farm and regional level as MFS favour soil, water quality, biodiversity through diversified landscapes and rely as much as possible on local resources.

4.4 Ideas for Operational Group projects to foster MFS

MFS development and design has no blue-prints. The diversity in agriculture, farmers, soil, climate, infrastructure, policies and economics across Europe requires tailor-made solutions, developed and managed in close cooperation with local farmers, supported by advisors, supply chain actors and other relevant stakeholders. Such local MFS will have different set-ups, different objectives and different performance. This variety could make MFS initiatives difficult to compare across Europe, but very successful from the local actors' point of view. Table 7 summarises ideas for Operational Group projects to test concrete solutions to foster sustainable MFS in their specific contexts.

[5] http://agriculture.gouv.fr/mesures-agro-environnementales-et-climatique-maec-et-aides-pour-lagriculture-biologique http://agriculture.gouv.fr/sites/minagri/files/ok_pac-fiche-maec-polyculture-elevage_monogastriques.pdf (last accessed 04/05/2017)

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Table 7: Ideas for Operational Groups

Key issue	Ideas for Operational Groups
Labour-management	**Test new managerial solutions found by farmers to deal with complexity and risk in MFS** *Analyse existing case-studies of well-managed MFS; develop a labour-balances analysis based on farm surveys; develop participative approaches with groups of farmers to consider their management strategies and develop scenarios; identify management tools to assess MFS labour requirements and associated costs so as to facilitate integration between farms.*
Soil quality	**Identify best MFS practices in real farms to optimise soil quality** *A case-study approach would allow good practices to be considered, linking surveys on practices and soil analysis; mapping of soil quality and its evolution could be the base for discussions with farmers. In particular, identify proper use and optimisation of organic fertilisers (manure) in different pedo-climatic areas.*
Technical efficiency	**Develop locally-adapted multicriteria evaluation of MFS** *Identify and validate existing case-studies of MFS practices that generate positive impacts and increase farm profitability. Adapt multicriteria evaluation framework together with local actors; define the right balance in a multipurpose system (arable – grasslands – livestock – perennial crops) to achieve farmers' objectives and provide ecosystem services. Test the technical efficiency of mixed farming variants under several pedo-climatic conditions to enable more informed decision making.*
Technical efficiency	**Identify best practices to optimise energy/nutrient cycles including combination of already existing practices** *Consider and analyse technical and economic data in MFS developing arable-grasslands rotations including cover crops to feed the animals; explore new techniques and technologies (mixed crops, methanisation,…); consider for instance grazing systems based on grass or immature crops and mixed crops, arable-grasslands rotations, crop residues, etc.*
Marketing	**Develop marketing strategies to add value to MFS products and integrate specificities of MFS into already existing value chains** *Develop new products and analyse diversified bundles of services provided by MFS so as to diversify production and increase farm resilience. Develop new business models to make profit out of multifunctional approaches (for example, creating riparian buffers to prevent pollution, erosion etc.)*

Some other innovative actions have been mentioned, such as **communication on successful MFS to help (re)attract farmers towards these type of systems**. For instance, effective strategies to manage crops and livestock should be indentified and dissemination throughout the EU. **Mapping areas of the EU could highlight where MFS is most profitable**. Innovative actions should consider knowledge exchange too. **Develop peer to peer learning networks for knowledge exchange and good practices between farms** to facilitate the maintaining/adoption of MFS at farm level and through cooperation schemes between farms. **Live learning networks or webplatforms** could be tested for connecting relevant actors in successful MFS.

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4.5 Research needs: Implement participative and holistic research to improve MFS

"For creating mixed systems you need knowledge from different specialties, therefore you need some kind of integration between areas of knowledge" - FG expert.

Implementing a participative and interactive design of MFS with farmers is needed to promote technical and organisational innovation. This eventually calls for holistic and multi-disciplinary research to consider the interaction between crops and livestock.

Participative MFS design to test new combinations for managing crops and livestock

Participative design of MFS would allow the development and exchanging of knowledge on technical issues in mixed farming relevant to a particular region e.g. in less intensive agricultural areas in Northern Europe, improvement of home-grown legume-based forage or grain legumes to improve livestock nutrition. This could be carried out using so called **"mother and baby" trials.** This is an approach commonly used in developing countries **where a replicated trial is carried out in a research station with a group of farmers.** This research on MFS should be based on multidisciplinary approaches to consider the whole MFS and its environment with a 'holistic' understanding.

Because MFS have to be developed for specific situations and because MFS are complex systems, interactive design approaches would be very effective. There are several interactive design approaches available. In such processes, **all relevant stakeholders (farmers, experts, private and public actors) are involved.** They contribute to the design criteria, discuss and adapt the design itself and play an important role in the realisation of the research activities. An approach ideally suited to improving the technical efficiency of MFS would be the development of a "Serious Game" specifically designed for MFS and applied to specific farms context, like the Forage Rummy Game designed by INRA[6]. Board games such as this allow groups of farmers to use their empirical knowledge to design farming systems. "Forage rummy" for example, can help to design livestock systems based on the understanding of forage crop and grassland production, animal nutrition, production and reproduction.

Interactive MFS design to fully capture socio-economic aspects

There is a major point of attention concerning interactive design approaches: **the design process should not only focus on the technical and agronomical part of the system, but also on the socio-economic aspects**. Farmers tend to perceive cooperation as a loss of freedom and independence if they have no experience in cooperation; experienced farmers are usually much more positive. This is a serious issue in interactive MFS design with farmers. **Models and tools (e.g. web based management tools) to deal with complexity from other sectors should be developed.** Such tools could then be adapted to real farm management in practice using case studies in a range of different agro-ecological environments across Europe and for a range of mixed farming variants. The use of case studies would be an instrument to transfer acquired knowledge, models and tools adapted to the broader agricultural sector. Main research needs for the development of MFS are summarised in Table 8.

[6] Martin G, Felten B and Duru M. 2011. Forage rummy: A game to support the participatory design of adapted livestock systems. Environmental Modelling & Software, volume 26, Issue 12, Pages 1442–1453

Table 8: Needs for research around MFS

Main topic	Needs for research
Evaluation of MFS sustainability	**Multicriteria evaluation of economic and environmental benefits of adopting MFS as compared to specialised systems** *Consider the temporal scales of MFS exploring long-term effects through environmental-economic models, FADN databases and case-study approaches (multidisciplinary approach). Compare technical performance of MFS with specialised farms, building on the FADN analysis provided by the FP7 Cantogether project and decline these to specific case-studies with different MFS (based on a mapping of MFS in different pedo-climatic contexts and considering both economics and policies). Analyse trade-offs between profitability and long-term economic viability and environmental benefits to reconsider relevant options for MFS as compared to specialised systems.*
Labour organisation and complexity management	**Identify and adapt tools for the analysis of labour requirements throughout the year and time spent in management** *Develop management models for farmers for different MFS. Knowledge mapping (sources of info to deal with complexity) and development of web based tools. Develop approaches for understanding how farmers have achieved (or failed) dealing with complexity. Capitalise on 'story telling' by farmers and consider temporal trajectories of change of practices and decision making to maintain or make more sustainable their MFS. Capitalise on skills developed by farmers in MFS that could be needed to manage complexity.*
Mapping of technical efficiency of MFS	**Mapping different MFS models across EU to identify pedo-climatic and economic conditions where MFS can have the highest economic and environmental benefits as compared to specialised systems** *Identifying through mapping common success factors and successful combinations of practices locally adapted to different areas. Build a typology of MFS according to their orientation (environmental/sustainability or productive/marketing) and link these to specific contexts. Analyse the different benefits and possible efficiency gains of MFS in high productive areas and in less productive areas.*
Soil quality	**Research on nutrients and carbon cycling efficiency through MFS** *Explore innovative and traditional combinations of practices to recouple nitrogen and carbon cycles. Diversification of arable-grasslands rotations should be explored to achieve feed autonomy, provide soil organic matter and limit the use of water and mineral fertilisers. Mixed cropping, cover crops and manure management technologies (e.g. methanisation, manure treatment …) should be explored as well as the advantages of implementing them.*
Animal feeding efficiency	**Research on how farm by-products, cover-crops and dual-purpose crops could be efficient for animal feeding** *Specific research should be dedicated on the valorisation of diversified by-products, cover-crops and dual-purpose crop for animal feeding (e.g. beet or maize residues grazed by cattle or used as feed for monogastrics). Some cover crop or dual-purpose crop could be seeded to cover soil and limit soil erosion and valorised by the animals if needed. Specific combinations of mixed crops, cover-crops or residues should be tested in specific soil-climatic areas and for different types of livestock.*

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Main topic	Needs for research
Knowledge exchange	**Explore the knowledge aspects involved in maintaining or developing MFS** *Identify the management skills and competences to be developed for MFS (for example looking at how complexity and risk is managed in other business and industries) and the role of the agricultural knowledge and innovation systems. Explore the possibility of implementing knowledge exchange through participative approaches on case-studies and digital platforms.*
Cooperation between farms	**Indentify management strategies to organise exchanges of crops and manure between farmers and counter risks** *Quantify risks of different MFS models and their resilience. Explore logistics, organisational levers to favour the development of successful cooperation (case-studies, on-farm surveys, implementation of contractual agreements, insurance schemes …)*
Marketing and labelling the MFS "multifunctional product basket"	**Develop marketing and labelling strategies for MFS products aimed at raising consumers' and farmers' awareness on the benefits of MFS** *Combine already existing added-value chains and labels to the specificities of MFS, analyse the "multifunctional product basket" or "bundle of services" provided by MFS and develop communication strategies to communicate and attract people towards MFS.*
Landscape	**Evaluate the benefits of MFS at landscape level (landscape mosaic as alternative to specialisation) to provide multiple ecosystem services** *Such as biodiversity enhancement and water quality and quantity regulation. Considering in particular the interest of including woody vegetation, conservation agriculture and permanent grasslands to improve existing MFS and their impacts on landscape mosaic.*

Process of the FG

The Focus Group (FG) on 'Mixed farming systems: livestock/cash crops' was launched by the European Commission, DG AGRI in 2015 as part of the activities carried out under the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI).

It brought together 20 experts (see Annex B) from across the EU to share knowledge and practices and answer to the following question: "*How to develop livestock/cash crops interactions and promote their benefits as a sustainable alternative to farm or territorial specialisation?*"

In order to address the main question the FG was confronted with four specific tasks:

1. Take stock of the current status of MFS, identifying their strengths and weaknesses as regards to sustainability
2. Identify strategies to enhance sustainability of MFS across Europe, through the analysis of successful case-studies of MFS both at farm and regional level
3. Where relevant and possible, describe environmental, economic and social impacts of MFS
4. Identify priorities for research and innovation needs and provide ideas for Operational Groups and other innovative projects

At the first meeting of the FG (Dublin, Ireland – November 2015) mainly focused on the two first specific tasks. In preparation to the meeting, a **starting paper** was developed to kick-off discussions. The FG members also provided case-studies of existing MFS in their countries. At the end of the meeting, the experts identified key topics for further analysis and discussion, which was done through the production of dedicated **minipapers.** A second FG meeting (Bologna, Italy – March 2016) allowed the FG to consider more closely the two last specific tasks. The final report of the FG builds upon the outcomes of the FG discussion and the contribution of the experts provided through the concrete examples and the minipapers.

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ANNEX A: Definitions of mixed farming systems relevant for the Focus Group

MFS have been defined in many ways. This annex presents a summary of the most common definitions currently found in literature. It illustrates the context of the definition chosen for the FG.

Commonly, MFS are defined as "the association of crops and livestock in a coordinated framework, more often at the farm-level, even if the association can be considered at the regional level" (Schiere and Kater, 2001). Whereas American and Australian researchers always considered "integrated crop-livestock systems" with an explicit focus on integration between crops and livestock, European research studies had a tradition to use the terms "mixed systems" or "MFS. They therefore include all farming systems involving both cash crops and livestock in their definition of MFS even when the agricultural practices do not manage properly crops and livestock interactions so as to produce economic and environmental benefits. This separation tends to evolve with some European researchers focusing on integration between crops and livestock, insisting on the importance of real coordination (Moraine et al., 2014).

European definitions

European research studies use the terms "mixed systems" or "mixed farming systems" to consider all farming systems involving both crops and livestock (Havet et al., 2014; Schiere and Kater, 2001; Wilkins 2008). The definition is large and includes all systems having at least one livestock unit and some crop production, dedicated either for cash crops or for animal feeding only. A combination of crops and livestock is considered but not clearly defined.

MFS were first considered at the farm-level (Ryschawy et al., 2014; Schiere and Kater, 2001). Through the EU FP7 CANTOGETHER project, the concept has been more recently enlarged to regional level, considering exchanges between crop farmers and livestock keepers within a small area (Moraine et al., 2014). Moraine et al., 2014 considered that "animals represent groups of animals (e.g. species, breeds, age groups), while crops (cash crops, forage crops) and grasslands (cut/grazed, permanent/rotated) represent a range of species or species mixtures. The three components are interconnected to differing degrees. Direct interactions occur in space, either simultaneously (e.g. grasslands grazed by animals) or over time in the form of a sequence (e.g. temporary grasslands could be integrated in crop rotations). Indirect interactions correspond to flows of material (e.g. manure) or energy. By varying the size and degree of overlap of the three components, it is possible to represent the structure of a wide range of crop–livestock systems."

Specifically, in European statistics, Standard Gross Proceeds is used to define mixed crop-livestock systems: more than 1/3 of Standard Gross Proceeds should be obtained through cash crops and more than 1/3 of Standard Gross Proceeds should be obtained by livestock production. This definition is used to classify farms within a specific class by the Farm Accountancy Data Network (FADN). FADN or national databases such as AGRESTE for France are considering MFS according to these thresholds of Standard Gross Proceeds considering both the economic weight of crash crops and livestock at the farm-level but no integration between them.

Non-European definitions

The FAO considers MFS as "The best known form of mixed farming is when crop residues are used to feed the animals and the excreta from the animals are used as nutrients for the crops."

Mixed farming is considered by the FAO as probably the most benign agricultural production system from an environmental perspective because it is, at least partially, a closed system (Schiere and Kater, 2001). The waste products of one enterprise (crop residues), which would otherwise be loaded on to the natural resource base, are used by the other enterprise, which returns its own waste products (manure) back to the first enterprise. Because it provides many opportunities for recycling and organic farming and for a varied, more attractive landscape, mixed farming is the favourite system of many agriculturalists and environmentalists.

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More precisely, Seré et al. (1996) defined MFS as "having more than 10 percent of the dry matter fed to animals coming from crop by-products or stubble; or where more than 10 percent of the total value of production comes from non-livestock farming activities."

American research studies use the term "integrated crop-livestock systems" with the specific acronym ICLS (Franzluebbers et al., 2014; Hendrickson et al, 2008). The integration between crops and livestock is better explained here and spatially explicit. For Hendrickson et al. (2008): "Integrated agricultural systems have multiple enterprises that interact in space and time, resulting in a synergistic resource transfer among enterprises. Dynamic-integrated agricultural systems have multiple enterprises managed in a dynamic manner".

Franzluebbers et al. (2014) underlined that ruminants associated with arable cropping when associated spatially and temporally with arable cropping is an essential foundation for integrated crop-livestock systems (ICLS), either within single farms or among specialised farms within a region. The farm and landscape level were both considered at least theoretically since Russelle et al. (2007) introduced the regional level.

ANNEX B: List of Focus Group members

Surname, first name	Profession	Country
Bernués, Alberto	Scientist	Spain
Bogdanovic, Vladan	Other	Serbia
Brewer, Andrew	Farmer	United Kingdom
Christensen, Ove Gejl	Other	Denmark
Dal Prà, Aldo	Farm advisor; scientist	Italy
de Wolf, Pieter	Applied scientist	Netherlands
Franco, Pedro	Farm advisor	Portugal
Gilliland, John	Other	United Kingdom
Ievins, Indulis	Farm advisor	Latvia
Kosec, Boštjan	Farmer	Slovenia
Laitenberger, Klaus	Expert from agriculture organisation, industry or	Ireland
Moraine, Marc	Scientist	France
Mosquera Losada, Maria Rosa	Expert from NGO	Spain
Mäkiniemi, Kirsi	Scientist	Finland
Nicholas-Davies, Phillipa	Scientist	United Kingdom
Ramonteu, Sonia	Expert from agriculture organisation, industry or	France
Stalenga, Jaroslaw	Scientist	Poland
Zlatar, Domagoj	Farmer; other	Croatia
Tröster, Michael	Other	Germany
Watson, Christine	Scientist	United Kingdom
Facilitation team		
Cossu, Fabio	European Commission - DG AGRI	
Ryschawy, Julie	Coordinating expert	France
García Lamparte, Andrés Manuel	Task manager	Spain
Guimarey Fernandez Beatrix	EIP Service Point	Spain

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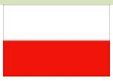
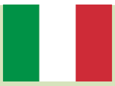
ANNEX C: Case-studies of successful MFS at the farm-level

Case-study	*Context-specific characteristics*	Farm success factors
 **Cattle/sheep-ley-arable organic farms**	• ***Traditional mixed farming area*** • *Local soil-climatic conditions favouring grass* • *Agri-environment schemes*	• Legumes-arable rotations favouring soil quality and biodiversity while self-sufficient animal feeding • Organic management (improved livestock health/clover to improve soil and limit inputs) • Keen grassland management
 **Dairy-crop-vegetables biodynamic farm**	• ***Regional rural renaissance*** • *Between Atlantic and continental climate*	• Implementation of an environmentally and socially sound system of organic farming • Grass and beet residues to favour feed autonomy of dairy cows • Conservation agriculture (improved soil quality + reduction of costs for fuel) • Innovative forms of education
 **Crop-dairy systems**	• ***Local tradition of mixed farming*** • *Hot summer /heavy clay soils* • *DPO for the milk (Parmigiano Reggiano, Grana Padano)*	• Research development on the farm for feed self-sufficiency (wheat hay/silage, and sorghum, soy protein replacement incl. peas, field beans)
 **Poultry-beef-sheep-pork-cereal-vegetable-fruit biodynamic farm**	• ***Local tradition of Camphill communities to be resilient and self-sufficient.*** • *Wet, mild summers and wet winters.* • *Fertile loamy soil, gentle slopes.*	• Bio-dynamic principles practised on holding. • Farm enterprises (crops and livestock) interlinked and rotated around the holding. • Poultry grazed on wide grass strip/verge surrounding the vegetable field • Social and therapeutic farm
 **Cattle-sheep-goat organic farms**	• ***Local tradition of MFS with cattle/sheep/goat*** • *Temperate, with influence of mountain climate* • *Acid siliceous soils*	• Diversification of cattle/sheep/goat production to be commercialized • Improving sustainability of animal husbandry and feeding practice through use of local natural resources
 **Sheep-cereal farms**	• ***Traditional sheep-cereal system*** • *Less-favoured area (poor soils/scarce water)* • *Local objective of maintain rural activity* • *Semi-natural grasslands are communal*	• Mixed farms having flexibility to face uncertain climate and market conditions • Crop diversification to increase self-sufficiency in animal feeding • Recognised socio-cultural and economic value of ecosystem services provided by Mediterranean agroecosystems • New quality product: "LechalOjinegro" meat and meat products

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Case-study	*Context-specific characteristics*	Farm success factors

Crop-grass-beef-sheep system	• ***Local area of mixed farms moving towards specialisation***
	• *Topography limits cropping areas*
		• Improving soils and maximizing the potential of different land types
		  • A mixed farm without combinable arable crops
		  • Self-sufficient farm in animal feeding and fertilisers
		  • includes sheep, beef and turkey fattening enterprises
		• Work closely with meat buyers (specific branding for beef called Celtic Pride)

Dairy-crop farm	• ***Local tradition of MFS*** • *cold winter with frequent summer droughts* • *plains with sandy soils*	• Diversification of arable-legumes rotation for self-sufficient livestock feeding and increase soil fertility • 18 motivated farmers involved in the cooperation / group marketing
Forest-pig system	• ***Local tradition of mixed farming.*** • *Temperate with summer droughts* • *Steep slopes*	• Involvement and cooperation between farmers and researchers • Increasing autonomy in pork feeding and fertilising through crop-livestock interactions • Diversification of products commercialised
Dairy-grass-crop farm	• *Temperate maritime climate* • *Mixture of poorly drained gleyed soils and free draining brown earth soils on undulating lowland*	• Systems with high technology and remuneration allowing family succession. • Increasing value of output by being an environmental example / Increasing profits by increasing milk yield from grass per hectare per year: • Extending the grazing season and limiting feed inputs • Reducing fertilizer inputs (GPS analysis) • Renewable energy production to reduce heating costs (biomass boiler)
Cattle-crop experimental farm	• ***Local tradition of mixed farming*** • *Mild maritime climate.* • *Mixed soils* • *Flat part and slopes*	• University of agriculture farm for education purpose / Open days seminar • Reintroduction legumes/grasslands • Manure and waste management (biogas and electricity production)
Crop-sheep farm	• *Southern boreal, warm summers with semi-cold winters with some snow. Short growing season (ca. 170 d)* • *soil are clay, silt, sand*	• Farmers' own will to pursue ecofriendliness and self-sufficiency • Re-introduction of going-back-to-roots craftsmanship in knitting /multipurpose sheep production: wool, meat, hide, manure • Crop rotation to self-sufficiently feed the sheep as a high priority • Small-scale oil pressing, grinding/milling of dry sweet pea • Marketing through REKO rings (local food from farmers)

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Case-study	*Context-specific characteristics*	Farm success factors
 **Dairy-pig-crops farms**	• ***Local area with specialised conventional farms*** • *Temperate with 800 mm rainfall / year* • *From sandy to clay soils*	• Converting from conventional farming to organic farming in diversified production getting higher prices • Objective of a better health of people and animals /reduce allergy • Reduce pollution (soils/drinking and ground water) • Thinking of the reorganisation of advisory service for organic farmers

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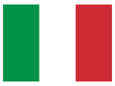
ANNEX D: Successful case-studies of introduction of MFS at the regional level

Country	*Success factor in the context*	Farms success factors
 **Organic beef-grass-crops farms**	• *Summer droughts* • *Heavy soil*	• Cooperation developed between two motivated farmers/ Group marketing of two farms • Pasture system with rotation (cereals, alfalfa - grazing, Maize-climbing bean mixtures to feed the animals)
 **Sheep-grass-crop farms**		• Residues of brassica crops being utilized by on-farm livestock or as green manure • Work closely with supermarkets • Specialist cash-crops growers working with smaller farmers.
 **Crop farms and beef/sheep farms**	• *Fluctuation of protein-sources feed*	• Need for reduction of irrigated areas due to lack of water • Supply of protein-rich fodders for livestock farms at a stable price • Participative design of technical and social practices between farmers and researchers • Involvement of cooperatives in the process
Non-GM feeding autonomy through a local cooperative 	• *Very volatile market for soya*	• Try to find a satisfying price for both sides : soya growers and livestock producers • local feeding autonomy in non-GM soya for livestock producers engaged in quality schemes • Local demand for non GM-feed for livestock
Grazing design between four farms 	• *Local farm desertification* • *Soil erosion problems*	• Participative design between researchers and four farmers • Soil erosion control by designing obstacles for water • Planned grazing control through rotational grazing
Collective methanisation unit for 48 livestock farmers 	• *High demand on organic nutrients by vineyards (cash crops) in south Tyrol* • *Nutrient surpluses of local livestock farms*	• 48 local motivated farmers involved with researchers and advisers • Farmers see nutrient surpluses as a common problem • Treatment of digestate residues leads to a proper organic fertilizer
Experimental cooperation between two farms 	• *Interest of the researchers in the potential of exchanges between farms* • *Concerns around soil quality degradation*	• Farm owned by a private famers • Combining feed and arable crops in a sustainable cropping scheme • Optimize the fertilisation and organic matter supply within the mixed system in line with concerns about soils

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The European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP-AGRI) is one of five EIPs launched by the European Commission in a bid to promote rapid modernisation by stepping up innovation efforts.

The **EIP-AGRI** aims to catalyse the innovation process in the **agricultural and forestry sectors** by bringing **research and practice closer together** – in research and innovation projects as well as *through* the EIP-AGRI network.

EIPs aim to streamline, simplify and better coordinate existing instruments and initiatives and complement them with actions where necessary. Two specific funding sources are particularly important for the EIP-AGRI:

- the EU Research and Innovation framework, Horizon 2020,
- the EU Rural Development Policy.

An EIP-AGRI Focus Group* is one of several different building blocks of the EIP-AGRI network, which is funded under the EU Rural Development policy. Working on a narrowly defined issue, Focus Groups temporarily bring together 20 experts (such as farmers, advisers, researchers, up- and downstream businesses and NGOs) to map and develop solutions within their field.

The concrete objectives of a Focus Group are:

- to take stock of the state of art of practice and research in its field, listing problems and opportunities;
- to identify needs from practice and propose directions for further research;
- to propose priorities for innovative actions by suggesting potential projects for Operational Groups working under Rural Development or other project formats to test solutions and opportunities, including ways to disseminate the practical knowledge gathered.

Results are normally published in a report within 12-18 months of the launch of a given Focus Group.

Experts are selected based on an open call for interest. Each expert is appointed based on his or her personal knowledge and experience in the particular field and therefore does not represent an organisation or a Member State.

*More details on EIP-AGRI Focus Group aims and process are given in its charter on:
http://ec.europa.eu/agriculture/eip/focus-groups/charter_en.pdf

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