EIP-AGRI Focus Group
Mixed farming systems: livestock/cash crops

MINIPAPER 2: IMPROVING THE TECHNICAL EFFICIENCY OF MIXED FARMING

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1. Introduction

Over the last 100 years, crop and livestock production have become increasingly decoupled both geographically and managerially resulting in many livestock units becoming heavily reliant on bought-in feed and straw and specialized arable units on purchased fertilizer. In some areas there is evidence of declining soil fertility in arable agriculture which may in part due to declining reliance on animal manures. 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. Without ruminants in the farming system grass leys become uneconomic and thus rotations tend to change to all arable systems without the soil fertility building properties of leys. 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.

Integrated crop/livestock systems potentially provide better resource utilization (e.g. energy, nutrients, land use) than specialised systems and also improved ability to adapt to a more variable climate than non-integrated systems with associated risk reduction. 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 also the use of natural resource inputs (e.g. soil and water). In MFS compared to specialised systems, improvements in efficiency are linked to the degree of synergy between components. The extent of synergies between enterprises depends on the ability to integrate the operations of the farm enterprises. So, synergies can produce direct benefits such as unharvested crop residues being used to provide grazing. These interrelationships or synergies between components can also have indirect benefits such as habitat or other agro-ecosystem benefits. Increases in technical efficiency and improved synergies between enterprises could lower reliance on external inputs. Specialisation shows benefits over mixed systems when there is evidence of dis-synergy between components.

The diagram below aims to highlight issues of integration and synergy in integrated crop livestock systems compared to specialised systems. The diagram shows 3 models for nutrient flows, as an example of resource use, in farming systems a) a traditional mixed farming concept b) production systems where crop and livestock systems are spatially close together but not fully integrated and c) where crop and livestock systems are disconnected over a short or long distance.

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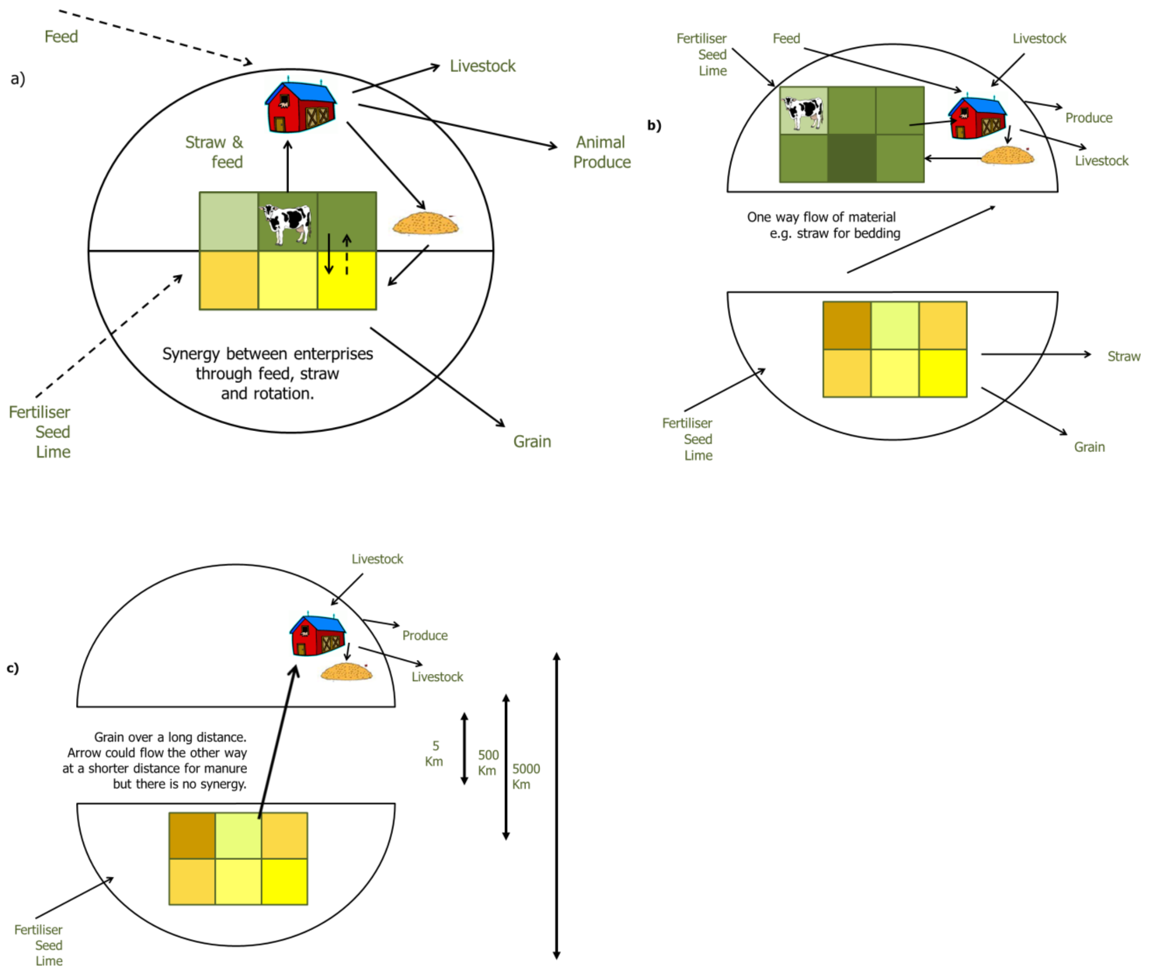
Figure 1: Nutrient flows in MFS models a) a traditional mixed farming concept b) production systems where crop and livestock systems are spatially close together but not fully integrated and c) where crop and livestock systems are disconnected over a short or long distance



It is important 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 land the management options are more limited, particularly by issues such as slope and soil depth as well as climate. In such circumstances mixed farming may be able to provide self-sufficiency but a low conversion of inputs to outputs. MFS may also be able to provide specialist products or commodities e.g. the use of very extensive mixed systems to maintain clean water for selling as bottled water. In areas with limited land available for production and where the land is of good quality then very intensive specialist systems may be more efficient as least in the short term. The infrastructure in the area can also provide opportunities for MFS, for example, the presence of a machinery ring with specialist harvesting machinery could allow a farmer to experiment with diversified cropping without having to invest in new machinery. However, the maintenance of natural resource quality may be an issue in the longer term.

The objective of this paper is to explore how the technical efficiency of existing mixed farming systems can be improved by identifying and managing synergies between components.

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2. Improving the technical efficiency of mixed farming systems.

State of play

If mixed farming systems are to be compared with other types of farming system then technical efficiency is one possible measure. It needs to be combined with the other social, environmental and economic measures discussed in other sections to allow a full analysis of the sustainability of mixed farming. It is important to consider technical efficiency separately from intensity. Any discussion of innovation and fail factors needs to respect the overall aim of the MFS in terms of the difference between a farm driving at self sufficiency versus a farm driving at maximum production of saleable produce. Indicators of the value of MFS need to be developed which can indicate efficiency across the range of intensities. A further challenge in any discussion of technical efficiency of mixed farming is the vast number of potential combinations of crops and livestock and their interaction with the pedo-climatic conditions.

Many options for improving technical efficiency will come from specialist systems e.g. developments in crop protection. Here we aim to focus on those improvements which relate directly to synergies between different farm enterprises. This requires slightly different thinking from a more specialist approach to improving technical efficiency. A good example of this comes from plant breeding and the development of dual purpose crops which can provide some grazing and still give an economic yield or alternatively crops bred to provide residue with specific properties for grazing. We also recognise efficiencies can come from improvement in components, such as the plant breeding example, improvements in technology, such as manure handling facilities and also through improved management decision making such as rotation design.

Innovation process and fail factors

Table 1 indicates what improving technical efficiency through the improved use of different inputs (purchased and natural or home produced resources) could contribute to the farm system and the wider environment. The degree of improvement possible will depend on a number of factors including the type of MFS. This needs to be assessed in terms of the degree of synergy between components and the extent to which this can be improved. As can be seen from Diagram 1 there are opportunities for farm level synergies as a result of resource use complementarity where the crop and animal components of the system are interdependent (Fig 1a) which will not be realised in the scale of 1c. Examples of farms operating low input systems with home produced livestock feed are given in Text Box 1 and 2.

Table 1: Impacts of increased technical efficiency in MFS and identification of the synergies which facilitate this (Based on Watson et al. 2017).

Management practice	Synergy	Potential results of increased technical efficiency (better conversion of input into output)	Examples
Temporal and spatial dynamics of use of manure in rotations	Improved crop quality and yield in terms of protein and nutrient content; More even distribution of manure over farmland area as opposed to area close to farm buildings	**Reduce external inputs of N and P?** Yes **Influence on environmental impacts:** Reduced N in runoff, N leaching and nitrous oxide. Reduced loss of P	Kronberg & Ryschawy 2017

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Management practice	Synergy	Potential results of increased technical efficiency (better conversion of input into output)	Examples
Pre treatment of manures e.g separation of solid and liquid	Separated manure fractions allows selection for materials with N:P-ratios that match the N:P ratio required by crop. Solid fractions are rich in organic N, and mineralisation of this into plant-available forms is necessary for adequate utilisation of solid fraction N.	**Reduce external inputs of N and P?** Yes **Influence on environmental impacts:** Reduced loss of P. Fractionation may alter nitrous oxide emissions after spreading.	Fangueiro et al 2012; ten Hoeve et al 2014; Hjorth et al 2010; Rigolot et al 2010
Accounting for legacy P fertilizer in soil	Matching P supply from manure and fertilizer with P present in soil	**Reduce external inputs of N and P?** Yes **Influence on environmental impacts:** Reduced loss of P from soils.	Withers et al. 2014
Home produced feed replaces imported feed	GHG emissions potentially reduced reliance on imported protein	**Reduce external inputs of N and P?** Yes **Influence on environmental impacts:** Reduced GHGs	Battini et al 2016
Increased crop diversity in rotations	Produces feeds with different nutritional profiles; more efficient use of soil resources; increased productivity; Alters N : P in incorporated residues (precrop) which in turn influence nutrient availability to following crop	**Reduce external inputs of N and P?** Reduced fertilizer input **Influence on environmental impacts:** Reduce loss of P through erosion, leaching and GHGs, build soil fertility	Martin et al., 2016; Moraine et al. 2017; Preissel et al 2015
Include cover crops and green manures in arable rotations which may or may not be grazed	Inserting legumes in between cash crops increases feed self-sufficiency; more efficient use of soil resources; opportunities for recycling of nutrients through crop residues	**Reduce external inputs of N and P?** Reduced fertilizer input **Influence on environmental impacts:** Reduce loss of P through erosion, leaching and GHGs; build soil fertility	Franzluebbers & Stuedemann, 2007; Ryschawy et al. 2014
Introduce mixed species leys into arable rotations – these may be grazed.	Increased N from biological N fixation; more efficient use of soil resources; potential fodder and manure returns increased productivity	**Reduce external inputs of N and P?** Reduced fertilizer input **Influence on environmental impacts:** Reduce loss of P through erosion, leaching and GHGs, build soil fertility	Alard et al. 2002; Franzluebbers, 2007; Ryschawy et al. 2014
Introduce alternative forages into grassland systems	Potential for high yield and N content of subsequent crop following ploughing of grassland; Cereal/grain legume intercrops provide high quality livestock feed;	**Reduce external inputs of N and P?** Reduced fertilizer input **Influence on environmental impacts:** Risk of increased N loss by leaching and GHG from ploughing long-term grass	Rotz et al 2005

Management practice	Synergy	Potential results of increased technical efficiency (better conversion of input into output)	Examples
Making use of stubbles and residues	Stubble e.g. maize grazed by cows	**Reduce external inputs of N and P?** Reduced fertilizer input **Influence on environmental impacts:** Risk of increased N loss by leaching and GHG from urine and faeces on stubble	Dumont et al 2013; Gliessman 2006; Liebig et al. 2012
Subsitution of crops with different energy and nutrient profiles suited to livestock feed	Changing the balance between degradable protein and energy in the ration can reduce N loss from livestock e.g. substituting maize silage for grass silage	**Reduce external inputs of N and P?** Reduced fertilizer input **Influence on environmental impacts:** Reduced N loss	Rotz et al 2005
Increase the diversity within the agroecosystem	Introduce trees, to diversify the land area and feed animals	**Reduce external inputs of N and P?** Reduced fertilizer input **Influence on environmental impacts:** Reduced N and P loss through improved capture of nutrients.	Bealey et al. 2014; Patterson et al. 2008

Global Seed – Serbia's first organic dairy farm:
Size: 2000 ha
Crop-Livestock integration: All cattle feed is home produced on farm
Land use: 40% grass, 60% cereals, no vegetables

- *Products: Organic milk and beef*
- *Cattle breed: Holstein, Red Holstein, Brown Swiss*
- *Number of cattle: 1800*
- *Milk yield per cow: 6500 litres*
- *Main barrier: High percentage of heifer replacement per year, non-optimal body condition score of dairy cattle*

A biodynamic mixed farm in Poland based on ecological recycling agriculture:
Size: 1900 ha
Land use: 18% permanent grasslands, 74 % arable lands (mainly fodder crops), 0.1 % vegetables, 7.9% non-agricultural area.Crop-livestock integration: The farm operates three different legume-supported rotations fitted to three different soil types on the farm. These produce feed for the dairy herd.

- *Products: Organic milk and vegetables*
- *Cattle breed: Holstein-Friesian and Brown-Swiss*
- *Number of cattle: 370 milking cows*
- *Milk yield per cow: 6300 litres*
- *Main barrier: Poor quality soils and water deficit.*

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3. Needs for research

There is plenty of agronomic research evidence of improvements in technical efficiency, for example, nutrient use efficiency in crops being demonstrated as the field scale, however, there is often a gap in translation to the farm scale. These benefits are not universal and can vary with pedoclimatic conditions e.g. where the use of legumes can be very beneficial in low fertility situations they may only serve to increase possible nutrient losses in nutrient enriched environments.

Research at the farm scale is often limited by cost but both spatial and temporal scales are important in determining the technical efficiency of a farming system. In a mixed system based on a crop rotation some effects will only become apparent over the timescale of a rotation. The benefits of, for example, shelter belts or agroforestry which result from a changed physical environment need to be measured but may be gradual. Planning also needs to take in the scale of the farm and the spatial arrangements of productive land, housing, hedgerow, forest , wetland and wild areas. This allows for synergies between enterprises to be optimised.

There is scope for a Europe wide project which uses land capability together with mapping of markets as a base for assessing where MFS are viable and where more specialist farms are always going to outcompete mixed farming on economic grounds. However, in intensively farmed areas there is a second question about where lower input, more self-sufficient MFS could benefit the overall environment e.g. in water quality terms. This kind of assessment could then be used to focus the Knowledge Exchange and dissemination projects suggested below.

There is also a need to develop indicators capable of showing the value of mixed farming compared with the value of specialised farming. A key challenge is the temporal issues as, for example, carbon sequestration of loss of carbon from soils may only be discerned through long-term trends due to variability in short term samples and the current technical difficulties in measuring small increases in soil carbon.

Research should also address technical issues of particular relevance to mixed systems respecting that they could also benefit more specialised systems e.g. development of fertiliser recommendations that take account of precrop and undersowing techniques; livestock feeding recommendations for livestock that can account for on-farm byproducts e.g. stubbles; development of dual purpose crop varieties (either for cutting and grazing or to provide residues with particular properties).

Participatory approaches could be useful here, although there is a need to take into account that the skill of the farmer and farmer decision making also play a role in success. In practice it is the more innovative and progressive farmers that are currently demonstrating improved technical efficiency.

4. Recommendations for how to ensure a broader take up

Demonstrate the technical efficiency of mixed farming variants to enable more informed decision making.

Improved technical performance at the whole farm level and in relation to individual management practices or synergies between components could be demonstrated through a network of monitor farms. There is no one formula for mixed farming across the EU as the success is dependent on the prevailing pedo-climatic and socioeconomic conditions. However, it is much more likely that models can be identified on a regional basis.
This could be rolled out through regional innovation networks such as that described by Bloch et al. (2015), where researchers and farmers work together in a cycle of analysis, planning, action and reflection, using SWOT (strengths, weaknesses, opportunities and threats) analyses to structure the process of farm improvement.

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Participatory approaches to improving individual technical aspects of mixed farming

This would allow development and knowledge exchange on technical issues in mixed farming relevant to a particular region e.g. in less intensive agricultural areas in N Europe, improvement of home-grown legume based forage or grain legumes to improve livestock nutrition. This could be carried out using "mother and baby" trials approaches where a replicated trial is carried out in a research station with a group of farmers trying a more limited range of treatments within their own system, often referred to as "mother and baby" trials and more commonly used in developing countries (Snapp, 2002). Another approach which would be ideally suited to improving the technical efficiency of MFS would be the development of a "Serious Game" for MFS like the Forage Rummy Game designed by INRA (Martin 2015). Board games such as this allow groups of farmers to use their empirical knowledge to design farming systems. Forage rummy design livestock systems based on understanding of forage crop and grassland production, animal nutrition, production and reproduction.

5. Epilogue from the group: broader ideas, things that the group would like to say but don't fit into the FG framework – general recommendations etc.

The identification of pedo-climatic/economic conditions where MFS have the potential to be more efficient than specialised systems would help move to a situation where it is easier to improve the efficiency of existing MFS and the effective design of new systems. It might be worth considering a typology of MFS which allows differentiation between those aimed at self-sufficiency and the provision of ecosystem services and the more market oriented systems. This could also allow focus on the improvement of traditional systems/production of traditional regional products important geographically with the EU.

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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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