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 agroecosystem 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.

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.

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

<table>
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<tr>
<th>Input or resource</th>
<th>Examples of synergies and management which facilitate improved efficiency in MFS</th>
<th>Potential results of increased technical efficiency (that is, better conversion of input into output)</th>
<th>Examples and geographic region or country where this is viable or not applicable. This includes synergies between farms as well as within a farm.</th>
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| Nutrients (fertiliser or manure) | • Making the best use of home produced manure through improved understanding of nutrient release from manures matched to crops.  
• Reduced fertiliser rates to allow for nutrients supply from manure.  
• Account for relationships between spreading technologies and crop requirements for tillage to conserve carbon. | Economic sustainability through improved product yield and quality (crop and livestock) or reduced cost of inputs.  
The economic sustainability of ruminant production systems (conventional or organic) is dominantly influenced either by animal feeding cost or feed manufacturing cost. From a management perspective nitrogen and phosphorus are key. | Improved techniques for manure management (use of manure on crops).  
If the manure is used on crops that will feed livestock then nutrients can be recycled efficiently. In some countries/regions e.g. Italy "Rural Development Program 2014-2020" finances the use of machines that make efficient use of slurry / manure (as an alternative to chemical fertilizers: Urea and Ammonium Nitrate).  
Serbia and other places - Synergies between farms are seen in cooperation between different organic farms.  
Livestock organic farms usually have enough manure for their own needs and any surplus is transferred to other organic farms.  
EU organic farming - organic poultry producers must have access to land so the manure can be utilised. If the farm has no land then a cooperation agreement must be drawn up. |
| Lower levels of water pollution (N and P loss) | | | Many tools are available to help with the N balance. For example, Calcola N in Italy [http://aqua.crpa.it-ngcontent.cfm?a_id=12681&tt=t_law_market_www&aa=tool](http://aqua.crpa.it-ngcontent.cfm?a_id=12681&tt=t_law_market_www&aa=tool)  
| Purchased or home produced feed | Utilisation of home-produced material – potential of locally produced peas and beans being incorporated into the diet which would reduce reliance of livestock on imported protein | Economic sustainability through improved product yield and quality (livestock). Manipulation of livestock diet can reduce methane emissions |
| Selection of livestock breed | Choice of livestock breed to match local natural conditions is very important especially in those farming systems that rely on locally available resources such as MFS especially organic farming | Livestock production benefits, potential reduced methane emissions |

Poland - Only composted manure applied in appropriate terms, doses and with use of optimal techniques. No application of artificial nitrogen and phosphorus fertilizers.

Poland - Almost closed nutrient cycling is maintained. There is a high level of self-sufficiency in fodder production as more than 80% of it is produced in the farm. High quality milk is based on own fodder (grass, hay and fodder beet) and different vegetables are the main market products. Almost no inputs in crop and animal production. Serbia - Genetic selection to improve nutrient use, feed efficiency and robustness in animals aims to reduce the cost of feeding in livestock production and thereby improve overall profitability.

Poland - Only own green fodder and hay are used as a fodder. No silage in the cattle diet – please see Text Box 2

Serbia – please see Text Box 1

Poland - Very resistant and long-lived races: Holstein-Frisian and Brown-Swiss are kept.

Italy – Native adapted breeds can be profitable in low input situations for regional products e.g. Parmesan (Gandinini et al. 2007)
<table>
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<tr>
<th><strong>Crop diversity and rotation design</strong></th>
<th><strong>Efficient use of home produced inputs reducing reliance on purchased inputs</strong></th>
<th><strong>Improved livestock health</strong></th>
<th><strong>Reduction in fertiliser inputs</strong></th>
<th><strong>Value of break crops in rotations. In UK inclusion of oilseed rape into cereals as a disease break. Also use of legumes allows reduction of fertiliser to following crop (See Zander et al. 2016)</strong></th>
<th><strong>Poland - Implementation of recycling agriculture based on own fodder and own natural fertilizers.</strong></th>
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<tr>
<td>Selection of crop varieties with specific properties - for example stubble suited to aftermath grazing.</td>
<td>Poland - Free stall dairy barn for cattle.</td>
<td>Poland NA</td>
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<td>Species with anthelmintic properties</td>
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<td>Accounting for pre-crop effects in rotation</td>
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<th><strong>Water</strong></th>
<th><strong>Improved livestock health</strong></th>
<th><strong>Better economic results through reduced production and irrigation costs.</strong></th>
<th><strong>Selection of appropriate summer crops e.g. Maize or Sorghum (Italy). Use of mulches and cover to maintain water.</strong></th>
<th><strong>Flood control</strong></th>
<th><strong>Poland NA</strong></th>
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<td>Improvement of water holding capacity of soil through effect of manures on soil structure and carbon storage. Choice of crops to suit water availability and provide feed value.</td>
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<th><strong>Energy</strong></th>
<th><strong>Improved profitability</strong></th>
<th><strong>Italy - Different use of crops to increase crude protein and starch / ha and increase carbon sink with incorporation of ley (eg Maize attached)</strong></th>
<th><strong>Poland NA</strong></th>
<th><strong>Increased carbon sequestration</strong></th>
<th><strong>Poland - High share of crops having positive effect on soil organic matter balance. Reduced soil tillage dominates. UK and Scandinavia - use of perennial legumes within rotations improves C sequestration. Serbia - Animal manure, when mixed with a carbon source such as straw or wood chips, makes compost. Manure and compost applications improve soil organic matter and biological activity.</strong></th>
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<td>Mixing manure with suitable feedstocks for anaerobic digesters.</td>
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<th><strong>Soil</strong></th>
<th><strong>Maintenance or improvement of soil fertility</strong></th>
<th><strong>Increased carbon sequestration</strong></th>
<th><strong>Poland - Very diversified crop rotation with high share of legumes and intercrops</strong></th>
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<th><strong>Poland - Maintenance of crop rotation and on-farm recycling.</strong></th>
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<td>Rotation - benefits for soil structure - range of rooting depth - residue returns. Allows incorporation of ley into the system. Livestock play a key role in the nutrient cycle, and can help in building and sustaining soil fertility</td>
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<tr>
<td>Improved soil structure and water holding capacity/drainage</td>
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| **Biodiversity** | **More appropriate use of land resulting in overall system benefits (land capability)** | **Poland - There are a lot different mixtures of crops in the crop rotation (especially mixtures of cereals with grain legumes).** | | | |
|-------------------|-----------------------------------------------|-----------------------------------------------------------------|------------------|----------------------------------------------------------------------------------|
| Balance between different crops and non-cropped areas | | | | | |
Overview of research – missing implementation – missing testing – missing 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.

3. Recommendations/ ideas for operational groups - recommendations to dissemination of results and solutions - 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 pedoclimatic 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.

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.

4. 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 pedoclimatic/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.

5. References


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.

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 around 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