Research workshop on the sustainability of the EU's livestock production systems: a research agenda for Horizon 2020

14-15 September 2016, Brussels

Report
Contents
1. Introduction.............................................................................................................................................. 2
2. Reflections on livestock production systems ......................................................................................... 3
   Systems approaches and sustainability....................................................................................................... 3
   Sustainability in systems approaches......................................................................................................... 3
   Diversity..................................................................................................................................................... 4
   Sustainability assessment............................................................................................................................. 5
   Communication on multi-faceted issues......................................................................................................... 6
Livestock production systems ..................................................................................................................... 6
   Livestock from an environmental/ecosystem perspective ........................................................................... 6
   Livestock in the circular economy............................................................................................................... 7
   Livestock in food systems............................................................................................................................. 8
   Changing or redesigning systems............................................................................................................... 10
3. Research priorities..................................................................................................................................... 11
   Which governance/business models increase sustainability....................................................................... 11
   The role of consumers in sustainable livestock systems.......................................................................... 11
   Mapping the livestock production systems, their contexts and drivers...................................................... 11
   General frameworks for the analysis of livestock systems ....................................................................... 12
   How to improve data access..................................................................................................................... 12
   Accompanying the development of sustainable livestock systems......................................................... 12
   Towards "circular efficiency".................................................................................................................... 13
4. Conclusion................................................................................................................................................ 13
References..................................................................................................................................................... 14
Annex I: Participants & Programme............................................................................................................. 15
Annex II: Abstracts of presented papers....................................................................................................... 18
Annex III: Mindmap of the discussions....................................................................................................... 20

More information
Workshop web page:
production-systems

Disclaimer
This report assembles the contributions made by experts in the context of a workshop held on 14-
15 September 2016. These contributions do not represent the views of the European Commission.
1. Introduction

The EU's livestock sector is confronted with a complex mix of challenges, putting pressure on its sustainability. Considering the way it is often depicted, it would be a sector with only problems and little to no positive aspects. However, the reality is more complex and the positive contributions from the sector are often neglected, not quantified and sometimes not even evaluated. In most cases sustainability questions require more elaborated answers than a simple yes or no. To balance the different dimensions and grasp this complexity a more systematic perspective is needed. Such a perspective is also needed to make progress through research and innovation. One-sided and non-interactive research and innovation approaches are being criticized as not comprehensive enough. Integrated approaches should bring together different perspectives and dimensions, to come to more holistic solutions.

With this in mind a workshop was organised to build an accurate picture of the livestock production systems in the circular economy and to discuss activities necessary to build such a picture. The idea was to provide an overview of the issues at stake, to identify gaps in knowledge, bottlenecks and trade-offs and possible orientations in research with promising, holistic solutions. These solutions should take into account the three dimensions of sustainability.

Experts with diverse and multidisciplinary backgrounds have been invited to reflect jointly on the multi-faceted challenges related to the sustainability of European livestock production systems and on how research could address gaps in knowledge. The results of the discussion will feed into the drafting process for the agriculture related section of the upcoming H2020 Work Programme.

The following chapters provide respectively more information on the organisation of the workshop, the outcomes of the reflections, some suggestions on research topics and a conclusion.
2. Reflections on livestock production systems

The purpose of the workshop was to reflect on the sustainability of livestock production, its role within the circular economy and doing this from a systems perspective. This chapter will dig into the most important and recurring issues discussed during the two-day workshop, both looking into general principles and conclusions of systems approaches and sustainability, as well as issues specific to livestock production systems.

Systems approaches and sustainability

Sustainability in systems approaches

There is a general consensus on the three pillars of sustainability, i.e. the environmental, social and economic dimensions, sometimes complemented with additional aspects, depending on the needs and context. Each of these pillars comprises a world of other facets or objectives, making the sustainability agenda a very complex one.

To take into account this complexity a systems approach is needed. Irrespective of the scale at which an analysis is taking place be it at plot or food system level, as soon as it is about analysing multiple issues and objectives, including their interrelations, one moves towards a systems approach. For this workshop the focus of discussion was the livestock production system, mostly discussing on livestock production itself, but inevitably touching on many other aspects as well, e.g. diets, trade, global environment.

Besides the fact that there are many different definitions and perspectives on the components of sustainability, there are often also different emphases and different ways of looking at the relations between the components. An obvious example showing the discrepancies is the way the three pillars are prioritized in practice. Often a sequential approach is taken, in which economy is prioritized over environment and society. This is contradictory to the nested perspective, where it is argued that economy works within social relations, which in turn works within the environment.

![Figure 1 Different models of sustainability with respective prioritization of components (Baret 14/09/2016)](image)

The existence of different perspectives and priorities is fuelled by trade-offs. Because of the multiple components of the sustainability agenda, there is normally no one system performing better on all aspects than the other systems. One component of a system can be maximized, but when there is a

1 For example: organic production systems perform better on a number of criteria compared to conventional systems. However, they have a lower yield per ha than conventional systems.
combination of components with possible trade-offs, it becomes more difficult to 'maximize'. Instead, the term optimization is better suited.

Optimization involves making choices within trade-offs, which is a political rather than a scientific exercise. Science can contribute to this by capturing the complexity within and among systems and exposing the relations between different components of the sustainability matrix. Another implication of these trade-offs is the absence of silver bullets. Concepts put forward as silver bullets have to be taken cautiously and analysed from different perspectives, as they most likely do not outperform other approaches or concepts on all aspects.

**Diversity**

Closely linked to the trade-offs is the diversity in contextual factors and practices. They both play a determining role in the functioning of the system. It is thus important to recognize and learn from the diversity within and among production systems and their contexts. This has important implications for research. "One size fits all" solutions do not exist. Research and innovation need to take into account the conditions in which the respective systems are embedded, for change on the ground to happen.

Another implication of these local conditions and local optima is that it is not always possible to move in a gradual way from one system to another. Often gradual improvement can move a system towards a peak or optimum as shown in the figure below. However, this might be only the best performance for the respective system, while even better performance might be possible in a different system. The move from one to the other might seem counterintuitive when considered within the logic of a specific system which would imply a reduced performance (at first). Cross-system analysis can be a tool to go beyond gradual changes, leading to insights about different optima.

![Figure 2](image)

*Figure 2 Agricultural yield or profit as a ‘fitness landscape’ of peaks and valleys with respect to only two out of many possible variables. Many agricultural practices are close to a local optimum (black quadrilateral) and most research helps us climb the local peak, but it cannot discover other, possibly higher peaks (grey region). (Weiner 2003 in Baret 14/09/2016)*
As systems approaches can be important tools for research and innovation, they somehow have to be integrated in current research and innovation practices. Here, people are key. Working across scientific disciplines or economic sectors, including different types of stakeholders (research, farmers, food chain partners, etc.), implies involving different perspectives and different systems as a starting point. It can lead to having more complete within-system and cross-system insights but also to communication problems and challenges due to differences in priorities of different stakeholders.

Research participants in the workshop acknowledged the benefits of multi-actor and/or multi-disciplinary approaches. However, an important lock-in mechanism of the research community works against this. In addition to the prevalent "mono discipline" in research education, the pressure for publications does not favour such approaches, as they require more time and result in publications in usually lower ranked journals.

The key elements for unlocking the potential of systems approaches to bring transition were summarized as:

- A participatory approach to innovation
- An acknowledgment of the diversity of pathways
- A shift from plot to farm and food systems
- Integration of cultural dimension and education
- The need for significant funding of research for alternative systems: new pathways means new assessment methods and new expertise
- A prospective approach to agriculture to get out of path dependency

(Baret 14/09/2016)

An example of diversity in pathways is the difference between Eastern and Western Europe. Participants acknowledged the need to recognize and study the differences and to provide sufficient funding through the inclusion in research projects.

**Sustainability assessment**

Sustainability and systems approaches go well together. However, in order to take stock of the evolution and communicate about sustainability, one needs to be able to measure it.

As already mentioned, there are different perspectives on sustainability. Not all stakeholders attribute the same weight to the same component. Sustainability for one does not per se mean sustainability for the other. The question arises on who is legitimate to make choices in this? A possible solution is the use of participatory approaches, to come to a set of indicators and weights supported by the relevant stakeholders. Given the diversity in contexts and systems, there is no single tool working in all conditions. There is a need for flexibility, which can partly be accommodated by frameworks allowing for adaptation to the specific needs of the assessment, e.g. the Sustainability Assessment of Food and Agriculture systems (SAFA) from the FAO.

One of the limitations is also the ability to measure. Depending on the context, some measurements can be technically or economically too demanding. The increasing availability of data, linked to more and better sensors, as well as the infrastructures for data sharing, might help in overcoming some of the current limitations. However, this will likely be insufficient to confront challenges such as the

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2 Although there seems to be improvement in this matter, e.g. "Agricultural Systems" is a journal with a rather good impact factor.
globalisation of food chains. The latter makes the analysis more difficult, as it may overlook distant, indirect and temporally delayed effects.

Linked to the temporal dimension is the issue of resilience. Resilience, as a key feature of sustainability is adding a layer to the sustainability matrix. Existing indicators do not consider the ability or the likelihood that the current system state can be maintained over time during and after shocks of different kinds. Assessing the ability to absorb and adapt to stresses and shocks is challenging due to the high level of uncertainty around them. Research is needed on indicators or proxies to include resilience in sustainability analyses.

**Communication on multi-faceted issues**
When making choices regarding the above-mentioned issues, there is another overarching problem. To allow for effective and efficient communication, there is a need for balancing respectively complexity and simplicity. Indicators need to be useful; oversimplification entails a high risk of missing important aspects. An example of this is linking incentives to practices which are deemed to be useful in all conditions. It is argued that linking incentives to performance is better suited to the complexity of agricultural systems.

On the other hand, it is hard to communicate on complexity. This is especially relevant outside the research community, where indicators are used to support decisions, but the user often is reluctant to take into account the full complexity, including its trade-offs. Science can contribute to this by capturing the complexity within systems (approaches) and exposing the relations between different components of the sustainability matrix, by analysing the diversity among systems. The challenge is how to effectively communicate on them, to effectively guide the decision making process in personal or political spheres, especially in case the choices involve trade-offs.

The question of how sustainability is evaluated and communicated is central to developing tools which take account of the social and environmental dimensions in the food chain or other incentive frameworks.

**Livestock production systems**
The analysis of livestock production systems can be done from various perspectives. A selected number of them are listed here, reflecting their role in the discussions of the workshop.

**Livestock from an environmental/ecosystem perspective**
Efforts have been made to quantify the environmental footprint of livestock production in Europe. Agriculture is acknowledged to contribute to a number of environmental problems related to nitrogen, sulphur, phosphorus and greenhouse gas emissions, changes in land-use, water eutrophication and biodiversity. The livestock sector accounts for a large share of these agricultural impacts.

Several pathways are suggested to reduce these impacts. Taking the nitrogen cycle as starting point in their analysis, Leip et al. (2015) show that there is a need for both demand and supply side interventions in the EU. On the supply side, the most promising points of intervention are: improvements in feed production (e.g. precision agriculture and agronomic nitrogen use efficiencies), livestock production (e.g. grazing and feeding management and feed supplements, improved herd structures), or housing and manure management.
Manure management remains a source of concern regarding the environmental footprint of livestock. Part of the damaging impact of animal production in areas with high concentration of farms is dealt with under the nitrate directive. Mitigation efforts taken as a result of this directive include transport and processing of manure. The former, which generates environmental agglomeration inefficiencies, is claimed to be inefficient from a greenhouse gas perspective. However, analyses show that these inefficiencies are minor. More precisely, they would only lead to a reduction of 0.13% of the carbon footprint of the produced meat (pig sector). The most important reason is that storage of manure is the principal emitter of greenhouse gases (Willeghems et al. 2016). This means that improving the efficiency and safety of manure management should remain on the agenda. Manure can be considered as 'ecomine': turning pollution into value.

Considering only the negative environmental impacts of the sector would give a distorted image. In many areas livestock contributes to biodiversity and landscape management. Grasslands for grazing are important carbon stocks. If applied well, manure is a valuable fertilizer, containing important nutrients to sustain plant growth and healthy soils, rich in organic matter. The following environmental qualities are the ones specific livestock production systems can be contributing to3:

- Landscape (HNV)
- Biodiversity
- Nutrient cycling
- Carbon storage
- Water quality & Flood regulation
- Recycling of by-products and use of non-arable land (Ryschawy et al. 2015)

Both negative and positive impacts of livestock production systems should be analysed on a case by case basis. There are indeed large variations depending on species, systems and specific contexts. As mentioned before, the evaluation of certain ecosystem services or disservices is a challenging task. Indeed, in the environmental domain there is an urgent need for conversion of measuring methods and development of measuring tools.

**Livestock in the circular economy**4

In a circular economy approach, several of the environmental services and disservices are enhanced or discouraged, to create a system where no pollution and waste is generated and where material flows either remain within the system or return safely to the biosphere. This contrasts with the linear model of production where resources are extracted and used and return in the form of waste or pollution to the biosphere.

Owing to the inherent inefficiencies of biological feed conversion and to the higher energy demands of sustaining animals, current livestock production systems fit more with a linear production model than the circular one5. Efforts are being made to close loops. Yet, the environmental section above shows clearly that achieving this poses significant challenges. Questions arise whether it is even possible and if so, under what conditions.

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3 Based on a French case, Ryschawy et al. (2015)
4 This section is mostly based on the discussion paper prepared for the workshop by Shane et al. (2016).
5 In case the efficiency is evaluated considering the amount of energy or protein ingested by animals that could be edible for human (and not total energy/protein intake), the picture changes. Grazing dairy cows produce 0.25 kg of protein per kg of total protein intake but 1.5 to 4 kg per kg of human edible protein consumed by the cow.
A first argument against is that, in some cases, trying to achieve a closed-loop agriculture would impede the valorisation of products in the wider bio-economy, which does not feedback (directly) into the agricultural system. Another argument against is globalization. Sustainability is a multilevel concept. It is not necessary that closure of resource loops takes place at farm level to ensure sustainability. However geography and logistics matter and it is difficult to take into account geographical distribution of costs and benefits of livestock systems.

To be meaningful a sustainability assessment needs to start from an analysis of the carrying capacity of the resource base. Globalisation of food chains makes this analysis more difficult, as it needs to take account of distant, indirect and temporally delayed effects. "Circularising’ activities in Europe can help close resource loops where resources are consumed but may not return critical resources (e.g. water, macro-nutrients) back to the point of production. The circular economy must address this virtual trade of resources which is closely linked to the impacts of ‘circularisation’ through space and time." (Ward et al. 2016)

Having the circular economy in the absolute sense, i.e. at global level and involving all resource flows, as a utopia, does not mean one cannot establish loops with a more restricted scale or scope. Or that some of the principles behind the concept could not be used to improve the sustainability of the sector. The focus on system efficiency and circular resource flows is important to increasing sustainability of the production systems. Even when there are relatively closed loops, the productivity of the loop can vary. Enhancing the productivity of each loop is key. In this respect it is argued that a 'circular efficiency' approach is more suitable and more realistic than the absolute 'circular economy'.

"It is generally assumed that the ‘circular economy’ transition for agricultural materials offers clear benefits to EU industries from an economic, social and environmental perspective. This assumption needs careful thought because it is quite possible that ‘circularisation’ could cause economic and social stress unless properly analysed before implementation. Are we sure that circular economy always uses less resources, or is it just different ones; does it create more jobs and financial flows within the economy, or just displace established ones, perhaps with less jobs or financial flows; are businesses founded on ‘circularising’ agricultural waste long-term secure if the source of that waste is inefficient and will eventually have to be reduced?’ (Ward et al. 2016) Even in a circular livestock economy energy will have to be taken from the outside. What are the developments of livestock systems in relation to the evolution of energy systems?

**Livestock in food systems**

Increasing attention goes to the concept of food systems. The different challenges related to food are often interlinked and require integrated approaches across the food - and value chains.

Regarding the latter, it is important to note that the different livestock value chains show very distinct patterns. What is common however, is that there are fewer players up- and downstream the value chain, putting farmers in a difficult bargaining position. Recognising that they have less market power, initiatives have emerged (e.g. producer unions in France, the British poultry council). Another solution is moving towards non-price competition as marketing strategy. By differentiating a product,

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6 A good example of implementing the no waste principle is the optimized utilisation of by-products coming from slaughterhouses. Many slaughterhouses manage to valorise all products streams.
for example by including and communicating on the production of public goods or by producing higher quality products\textsuperscript{7}, farmers can escape the fierce price competition among their peers.

Nevertheless, the majority of farmers operate within a system based on price competition. Compounded with increased market volatility, this results in periodically high pressure on revenues and profits. It imposes a heavy burden on farmers and discourages young farmers to enter the sector. Furthermore, it drives the need for innovation at farm level while reduces the potential to do so at the same time.

Obviously consumers have an important role to play in the value chain. The following picture shows the concerns consumers have regarding livestock systems:

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{ figure3.png}
\caption{Societal concerns related to livestock production (Delanoue et al. 2015)}
\end{figure}

This results in different attitudes or typologies of consumers, according to a study done in France (Delanoue et al. 2015):

- Abolitionism (already no or few consumption of animal products);
- Alternative. Disagree with current ways of livestock production, including indoor farming. Strong reduction of consumption in progress or in mind. «Flexitarians» like;
- Optimisation. Consumption could be maintained. Ask for improvement & transparency in livestock breeding practices;
- Competition awareness. Do not want strong regulations for domestic productions / abroad; and
- Passive consumption. No interest for ways of livestock farming, neither supply chains vitality.

An important flow of feed consumption is in direct competition with human food. Feeding strategies excluding components that compete with direct human food crop production, i.e. based on grassland and by-products from food production, can thus both have environmental and ethical consequences.

Several studies show that there is scope for such strategies. However, they would not allow to sustain the current level of livestock production and consumption. Research done by Roos et al. (2015, 2016) and Schader et al. (2015) investigates the production potential of livestock based on

\textsuperscript{7} Quality can mean a lot of different things: tradition, culture, image, territorial links, production methods, organoleptic characteristics, etc.
sustainable feed and the capacity to satisfy different demand scenarios. This implies to develop demand-side strategies. In other words, the role of animal production in sustainable diets is being questioned. Combining human dietary needs with production potential of specific livestock systems can provide valuable insights.

The so-called 'second nutrition transition' occurring in Europe is ringing some alarm bell in the food industry. Can new consumer trends foster system change? An increasing number of policy experiments are being made to steer consumption into more healthy and sustainable diets, such as in the field of public procurement, taxation, rules for food commerce, education. How effective can these attempts be? What authorities are legitimate to set healthy or sustainable diets? To what extent are these policies affecting individuals' freedom?

**Changing or redesigning systems**

If research and innovation is to lead to change in practice, the system has to be considered as a whole. Implementation of new practices is often impeded by constraints which have been overlooked in the development phase. Economic and social mechanisms such as lock-in mechanisms have important impacts on system dynamics, which need to be considered when talking about innovation or change. One such mechanism impeding change is the lack of research on alternatives. The bulk of research funding goes to conventional production systems. However, adequate funding for research, innovation and education is needed to guarantee the development of alternatives. Education is indeed also crucial. Research and innovation increase the potential knowledge base for agriculture. Agricultural knowledge and innovation systems play a key role in disseminating this knowledge and help realizing a sufficient uptake to bring actual change on the ground.

Obviously, the take-up of alternatives needs to be coupled to an incentive. The most obvious incentive is a sufficiently high (economic) return on investment, but often there is a (perceived) disconnect between actions and impacts, so no obvious incentive. This governance gap makes the implementation of many socially and environmentally friendly practices very challenging. However, there are mechanisms – regulatory or market driven - to overcome this:

- New business models could allow for marketing certain social and environmental goods, which are now lacking proper incentive mechanisms. Intensive livestock farming systems have proven themselves competitive. As environmental and health policies may change the set of incentives and constraints to farmers, it is necessary to figure out which business models will fit into the new context. To which extent can crowd funding, cooperatives, new trends in large supermarkets or connecting consumers and producers with digital means deliver on this? Research on the different governance/business models and their capacity to include other dimensions of the sustainability matrix is needed.

- Moreover, regulation can mitigate the disconnection between impacts and actions by providing a framework for incentive or disincentives. When developing a regulatory framework, the point of obligation is crucial, i.e. where to intervene? The nature of the intervention is equally important. For example the issue of practice - versus performance-based payments? With the increased availability of data, is there more room for performance-based payments? And what would be the (dis)advantages?
As already mentioned when talking about local optima, change can be gradual, moving closer or further away from local optima, or disruptive. Some technologies seem to have the potential to thrive such disruptive changes: new livestock and feed, nanotechnologies or digitalization.

When doing research on change, it is important to look beyond direct impacts. Simple lifecycle analysis (LCA) can indeed provide insights about specific products or practices. However, the consequences of change or replacement within a system also need to be analysed, including the interactions between the different components of the systems. A new generation of evaluation methods, taking into account circularity, is required to produce more pertinent evaluations. Systems perspectives are not only important to analyse changes, or the lack thereof. Attention to the different components of a system and their respective relations can also point to changes with highest potential and feasibility. Studying the design of the system can be an important source of inspiration.

3. Research priorities
Experts were asked to translate discussions into priorities for research and innovation. The list below results from priority clustering of three parallel sessions.

Which governance/business models increase sustainability
Transition to sustainable production systems needs to be translated into reality via governance models. There is a diversity of governance models accommodating the demand for specific non-economic issues. More research on these governance models, including private business models, is needed. What are the existing models? Looking for new boundaries; are there new governance models possible? Do they actually deliver a higher sustainability? How do we realize an effective wider implementation of result-based environmental and social policies? What is the value – and potential for change - of detailed production data flowing through the value chain?

The role of consumers in sustainable livestock systems
There is a growing awareness that intensive, externally feed-based livestock systems are not sustainable. Going for sustainable livestock systems may require a reduction of the total availability of animal-based food. At the same time, consumer demand can be a driver for system change, as it is already evident with consumption trends in Europe. What will sustainable diets look like? Will they include an adaptation of consumers' behaviour to a different mix of quantity and quality? To what extent is consumers' behavioural change possible? What are the impacts? What is the implication for production systems? How to align the production systems with healthy diets? How to include and inform about the diversity of livestock systems along the food chain?

Mapping the livestock production systems, their contexts and drivers
Sustainability assessments of the environmental impacts of livestock production systems are often dominated by a reductionist view of livestock systems. There is a need to understand and distinguish between different livestock production systems or even food systems, to analyse and inform about the trade-offs in sustainable optima. Sufficient attention should be devoted to social issues, such as farmers' identity in society, livestock farming and social values, etc.
It is also necessary to contextualize these systems, and their sustainability impact, in the wider socio-ecological systems in which they operate. This contextualization should allow understanding dynamics and drivers, to be able to reproduce or upscale sustainable initiatives.

**General frameworks for the analysis of livestock systems**

Evaluation and communication on sustainability should rely on good indicators and frameworks. Many of the necessary metrics are underdeveloped or difficult to put in practice. Also the diversity of needs from different stakeholders is difficult to capture in one or more indicators, which makes the indicators often less appropriate for the end user. Which indicators are useful to go where we want to go? What are the sustainable limits of the use of the different natural resources? What is the potential of digital technologies to improve measurement and analysis? How to balance simplicity and complexity?

The diffusion of a systems approach to the analysis of livestock systems is constrained by existing barriers between disciplines. So far attempts to develop projects strongly based on inter- and trans-disciplinary approach have generated outcomes of uncertain scientific quality, if measured on existing disciplinary parameters. One of the reasons of this weakness is that, at present, a conceptual framework for the analysis of livestock systems - allowing different specialists to communicate with each other - does not exist.

How to come to an alignment in methodologies of sustainability assessment? This may include defining a general framework for a sustainable circular economy related to livestock and tackling the challenge of setting system boundaries and scale of analysis in sustainability assessment.

**How to improve data access**

Data is at the core of research. Much data is stored in dispersed databases and difficult to access for the research community. For example, Member States and their respective paying agencies have a huge amount of information which is not used for research or policy development. Improving the access to- and merging different existing databases would be to the benefit of research and innovation in the sector. In addition, the increased availability of farm-level data due to cheap sensors and better connectivity could be integrated and used for research and decision support. Precision farming is becoming a reality in some contexts, and its application on large scale may prove revolutionary. How will the digital revolution impact present livestock systems? How can we create an enabling environment for digital innovation in the sector, solving data ownership and interoperability issues? What would it mean in terms of sustainability?

**Accompanying the development of sustainable livestock systems**

Although an increased overall efficiency may not necessarily be sufficient to get livestock systems fully sustainable, state of the art knowledge and foreseeable technology developments let us guess that there is a wide efficiency gap between actual livestock farming and the theoretical optimum. The principles of the circular economy and a stronger focus to implementation in real contexts are key to filling this gap.

Moving towards more sustainable livestock systems will require new models for competence development and the development of learning systems across sectors and food chains.

Part of this knowledge intensification can be done with the help of decision-support tools including models and other digital applications. They lead to a stronger awareness of sustainability and the
impacts of certain interventions. The research community can help in developing the right tools for the right people.

Towards "circular efficiency"
Although the mainstream livestock production system is criticized as too reductive, its attention on economic/technical efficiency can deliver environmental gains if it rests to a sufficient extent on circular resource flows.

Addressing bottlenecks to transform biomass into food, feed and other products is needed. How to improve the turnover of loops in livestock systems? Some domains with potential:

- Reducing input requirements of livestock systems
- Assessing and controlling flows of biomass in a given production area
- Valorizing non-competitive feed (with human food)
- Improving efficiency and safety of manure management
- Considering manure as 'ecomine': turning pollution into value
- Valorizing byproducts of livestock systems through the biorefinery concept
- Developing smart farming

4. Conclusion
Livestock production systems are embedded in complex environments and confronted with multiple challenges. Therefore, the group of experts stressed the need for more integrated approaches in research and innovation. Bringing the complexity of the relations between the different components of the system in the picture is a promising avenue for further research, as it is needed for a complete understanding of the system. This is necessary for describing the state of play and managing the sustainability of the system. Also the applicability of innovations and the prevention of undesired outcomes would benefit from systems approaches.

In line with the intention to contribute to research and innovation policy, discussions resulted in more questions than answers. Resolving these questions should help the sector to cope with a complex mix of challenges in the coming years and decades. As a first step, a number of research priorities were put forward, which will be considered for the development of H2020 Work Programme 2018-2020.
References

Baret, P. "System thinking for transition". Brussels, 14/09/2016. Presentation


8 http://www.agrocycle.eu: a Sino-EU H2020 project addressing the application of the ‘circular economy’ across the agri-food industry
Annex I: Participants & Programme

In an attempt to come to a holistic perspective, people from different disciplines were invited. Below one can find the list of participants, with their respective specializations and affiliations. Although the organisations of the respective experts are mentioned, it should be noted that they were invited on a personal basis.

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
<th>Expertise</th>
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<tbody>
<tr>
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</tr>
<tr>
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</tr>
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<td>Sustainability of production systems</td>
</tr>
<tr>
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<td>Università di Pisa, IT</td>
<td>Rural sociology</td>
</tr>
<tr>
<td>Buysse Jeroen</td>
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<td>Nutrient cycling and policy modelling</td>
</tr>
<tr>
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<td>Advisory services and agro-economy</td>
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<tr>
<td>De Wolf Pieter</td>
<td>Wageningen University, NL</td>
<td>Integrated farming systems</td>
</tr>
<tr>
<td>Garay Robert</td>
<td>Research Institute of Agricultural Economics, Budapest, HU</td>
<td>Agricultural and environmental policy analysis</td>
</tr>
<tr>
<td>Gaspar Paula</td>
<td>Universidad de Extremadura, ES</td>
<td>Sustainability, organics, cooperatives</td>
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<tr>
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<tr>
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<td>Food chain</td>
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<tr>
<td>Klopčič Marija</td>
<td>University of Ljubljana, SL</td>
<td>Animal Husbandry and Knowledge Transfer</td>
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<tr>
<td>Leip Adrian</td>
<td>JRC, Ispra, IT</td>
<td>Environmental – and policy modelling</td>
</tr>
<tr>
<td>Makkar Harinder</td>
<td>FAO, Roma, IT</td>
<td>(Sustainable) animal nutrition and global perspective</td>
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<tr>
<td>Noe Egon</td>
<td>Aarhus University, DK</td>
<td>System approaches in livestock</td>
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<tr>
<td>Perrot Christophe</td>
<td>Institut de l'Elevage, FR</td>
<td>Livestock economics and territorial economics</td>
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<tr>
<td>Peyraud Jean-Louis</td>
<td>INRA / Animal Task Force, FR</td>
<td>Animal nutrition</td>
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<tr>
<td>Piccinini Sergio</td>
<td>Centro Ricerca Produzione Animale, IT</td>
<td>Biogas production</td>
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</table>
The workshop consisted of 3 main parts, respectively taking an environmental, socio-economic and systems perspective. Each section was initiated by one or more presentations on the subject, followed with extensive time for debate. To facilitate the latter, a series of questions was proposed. The experts were invited to reflect upon these questions beforehand.

A mind-map (Annex II) was prepared on the basis of the discussions of the first day, serving as starting point for the discussions on the second day. To capture more thoughts and insights from the experts, 3 breakout sessions were formed, discussing on central issues emerging from the first day’s debate.

**Programme**

**14 September**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>10:15 - 11:00</td>
<td>Registration and coffee</td>
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<tr>
<td>11:00 - 12:00</td>
<td><strong>Opening</strong></td>
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<td>- Tour de table &amp; Outline of the workshop</td>
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<td>- Philippe Baret: Opening presentation on systems approaches</td>
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<td>12:00 - 13:00</td>
<td>Lunch</td>
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<td>13:00 – 14:00</td>
<td><strong>Presentations on the environmental dimension</strong></td>
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<td>- Adrian Leip: Impacts of European livestock production: nitrogen, sulphur, phosphorus and greenhouse gas emissions, land-use, water eutrophication and biodiversity (15min)</td>
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<td></td>
<td>- Jeroen Buysse: How much can spatial relocation of livestock production alleviate environmental impact? (15min)</td>
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<td>14:00 - 15:00</td>
<td><strong>Debate 1</strong></td>
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<td>- Besides reducing the production/consumption, is there any other (mix of-) technical solution(s) which could turn the sector environmentally sustainable?</td>
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<td>- In which domains can we expect significant evolutions reducing the environmental pressure?</td>
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<td>- To what extent is manure used, efficiently? Do we sufficiently understand the role of manure and its substitutes?</td>
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<td>- Grasslands: How to take into account other ESS provided by grassland, e.g. biodiversity. What do we know of C stocks and sequestration potential in EU? Is the trend towards replacement of grasslands by crop production to go on?</td>
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</table>
- How many people can we feed in Europe with livestock production purely based on by-products and grassland?
- Which questions do we have to answer to better understand the environmental dimension of the sector? Which issue is of particular relevance for the environmental sustainability?

15:00 - 15:30 Coffee break

15:30 - 16:30 Presentations on the socio-economic dimension
- Christophe Perrot: Socio-economic picture of the European livestock sector (15min)
- Shane Ward & Nicholas Holden: 'Circular economy' applied to the livestock production sector (15min)

16:30 – 18:00 Debate 2
- Which are the principal drivers behind the lack of new entrants in the sector? Do we have to and how can we increase the number of new entrants?
- To which extend can the utilisation of by- and co-products as feed make the sector more profitable?
- To which extend is it possible to efficiently/economically include the by-products from the sector in the circular economy? Which downstream value chains have un(der)explored economic potential? To what extent is slaughterhouse waste used, efficiently? Which value for livestock co-products: wool, leather?
- What is the potential of the value chain to turn the sector more environmentally sustainable? How can this potential be amplified?
- Which technological game changers will bring significant economic threats/opportunities?
- Which questions do we have to answer to better understand the social and/or economic dimension of the sector? Which issue is of particular relevance for the social/economic sustainability?

15 September

8:30 – 9:00 Coffee

9:00 – 10:00 Setting the scene
Jean-Louis Peyraud, Gaetan Dubois & Jean-Charles Cavitte: A summary of the debates of the previous day will be presented, to set the scene for the discussions in a systems perspective

10:00 – 12:00 Debate 3 – Systems approach
Discussions on three emerging issues:
- Livestock in the circular economy?
- How to include the environmental - and social dimension in the livestock economy?
- What is the/a farming system?

12:00 – 13:30 Lunch

13:30 – 16:00 Debate 3 – Systems approach (continuation)

16:00 – 17:00 Conclusion of the workshop

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9 Adjusted during the workshop, to capture the central issues emerging from the first day's debate.
Annex II: Abstracts of presented papers

Three of the presentations made during the workshop were based on publications. Below one can find the respective titles and abstracts.

Impacts of European livestock production: nitrogen, sulphur, phosphorus and greenhouse gas emissions, land-use, water eutrophication and biodiversity

Authors: Adrian Leip, Gilles Billen, Josette Garnier, Bruna Grizzetti, Luis Lassaletta, Stefan Reis, David Simpson, Mark A Sutton, Wim de Vries, Franz Weiss and Henk Westhoek

Abstract: Livestock production systems currently occupy around 28% of the land surface of the European Union (equivalent to 65% of the agricultural land). In conjunction with other human activities, livestock production systems affect water, air and soil quality, global climate and biodiversity, altering the biogeochemical cycles of nitrogen, phosphorus and carbon. Here, we quantify the contribution of European livestock production to these major impacts. For each environmental effect, the contribution of livestock is expressed as shares of the emitted compounds and land used, as compared to the whole agricultural sector. The results show that the livestock sector contributes significantly to agricultural environmental impacts. This contribution is 78% for terrestrial biodiversity loss, 80% for soil acidification and air pollution (ammonia and nitrogen oxides emissions), 81% for global warming, and 73% for water pollution (both N and P). The agriculture sector itself is one of the major contributors to these environmental impacts, ranging between 12% for global warming and 59% for N water quality impact. Significant progress in mitigating these environmental impacts in Europe will only be possible through a combination of technological measures reducing livestock emissions, improved food choices and reduced food waste of European citizens.

Can spatial reallocation of livestock reduce the impact of GHG emissions?

Authors: G. Willegheems, L. De Clercq, E. Michels, E.Meers, J. Buysse

Abstract: Historically, concentrated livestock production and, consequently, manure production and management have resulted in considerable environmental impacts in many parts of Europe. The region selected for the current case study was Belgium which is characterized by input-intensive animal production within a geographically concentrated land area. In this study, the effect of a reduction in manure pressure through spatial distribution of CO2 equivalent emissions was investigated and the impact on the carbon footprint verified through a consequential life cycle approach. This was accomplished by investigating the marginal spatial impact on CO2 emissions of a decrease in manure pressure. An economic and environmental optimization was conducted using mathematical linear programming and the main differences between both approaches determined. The results of the model simulations show that, while the economic optimum is achieved by maximizing the transport of raw manure until fertilization standards are fulfilled and subsequently processing the excess manure, the environmental optimum, from a carbon footprint point of view, is achieved by separating all manure, as this strategy causes the least CO2 emissions, mainly due to the limited manure storage time. Moreover, the analyses indicate that rearrangement of the spatial distribution of livestock production in Belgium will not substantially decrease CO2 emissions. As the
study demonstrated that manure storage is the main contributor to the carbon footprint, solutions should instead be sought by changing these storage systems. This article contributes to the methodology of the consequential life cycle approach by linking carbon footprint analysis with an economic model that simulates manure disposal decisions driven by legal constraints and market forces.

The 'circular economy' applied to the agriculture (livestock production) sector – discussion paper elaborated under the AgroCycle project

Authors: Shane M. Ward, Nicholas M. Holden, Eoin P. White, Thomas L. Oldfield

Abstract: Agriculture is a critical sector of the EU economy, providing the food, feed, and bioresources that help sustain society. This sector in particular is at the centre of the challenges associated with population growth, food security, climate change and resource scarcity. In the last 50 years, agriculture has become more resource intensive, relying heavily on the availability of fossil inputs in the form of synthetic nitrogen and phosphorus fertilisers, oil derived agrochemicals and fossil fuels. ‘Circular economy’ principles can offer many opportunities for agriculture in general, and livestock production in particular, to become more resource efficient. This paper presents ten key questions that are relevant to understanding the role of the ‘circular economy’ in livestock production.

10 http://www.agrocycle.eu: a Sino-EU H2020 project addressing the application of the ‘circular economy’ across the agri-food industry
Annex III: Mindmap of the discussions

Zoom left side (Statements, challenges and drivers related to the sustainability of livestock production systems)
Zoom right side (Potential research needs)