animal task force

A European Public-Private Platform

Plants for the Future

European Technology Platform

Research and Innovation towards a more sustainable and circular European agriculture Exploring synergies between the livestock and crop sectors

Joint position paper

September 2019

About the Animal Task Force (ATF)

ATF is a European Public-Private Partnership and a leading body of expertise linking European industry and research providers for developing innovation in the livestock sector. We work together to identify actions that are needed to foster knowledge development and innovation for a sustainable and competitive livestock sector in Europe.

About Plants for the Future ETP

The European Technology Platform (ETP) 'Plants for the Future' is a membership-based platform representing the agricultural innovation chain from fundamental plant research to crop production and food processing. The ETP "Plants for the future" strives to share realistic views from multiple perspectives as such transparency forms the basis for better decision making. The ETP is committed to stimulating solution-oriented research and innovation to meet the needs of the Agri value chain, end consumers and society.

Executive summary

The Goal & the Challenge

There is growing customer expectations about safe, healthy and nutritious products, environmentally safe and more sustainable production methods, livestock health and welfare, reduction of land and resource use, product availability at affordable price, product recyclability and fair incomes for farmers. Therefore, high on the agenda of food system stakeholders is the migration towards more sustainable practices and products while securing business continuity and meeting societal expectation. To truly match the societal expectations, an adaptation of the sector would be required.

The "Animal Task Force (ATF) Public Private Partnership" and the "Plants for the Future" European Technology Platform (Plant ETP) opted to consider the entire crop-livestock value chain. They have identified R&I opportunities for gains in sustainability in food systems with a short-, mid- and long-term horizon. To this end, the ATF and Plant ETP conducted workshops in 2017 and 2018 that thanks to the overarching sector approach delivered insights complementary to those provided by specific plant and animal production vision papers.

It was assumed that in the coming decades

- Europe will aim to progressively reduce its dependency on importing proteins for animal feed. An alternative increased production of European protein crops would also benefit the environment by nitrogen fixation, reduced use of synthetic fertilisers and pesticides, improved soil quality and enhanced biodiversity.
- European agriculture will strive to adopt circular approaches to further improve efficiency while reducing its climate and environmental impact. By strengthening the connection between livestock production and cropping systems synergies may be derived from novel feed sources, fertilizers and agricultural practices.

R&I Priorities

R&I priorities deal with improving integration between livestock and crop production to improve overall agricultural sustainability with due focus on environmental, social and economic challenges. Several R&I areas were identified:

- Refining the current LCA to capture the multidimensionality, complexity and variability of agricultural systems and assess progress towards more sustainable food systems;
- Supporting circularity in the agricultural systems with development of innovative and safe food, feed, livestock value chains. This includes the development of a master plan for balanced food production, the development of a panel of new annual/biannual/multiannual crops and green forages complementing the traditional crops, and the development of manure as commercial biofertilizer;
- Developing bio-refineries for increased European protein and nitrogen self-sufficiency including improvement of methods for plant and manure processing and extraction and use of plant secondary metabolites for animal care;
- Improving genetics of agricultural crops for reduced environmental impact and fit as animal feed. This concerns in priority the yield, improvement and reduced sensitivity to pest of crops including grain legumes, increased protein content and protein bio-availability of the plant protein fraction in the different crops as part of an overall strategy. Complementary precompetitive

research is needed to introduce crop biodiversity targeting tolerance to stress, efficient use of resources as well as root development and functioning;

- Improving genetics and feeding strategies in farm animals with a focus on increased robustness and feed efficiency while developing animal feeding systems based on more variable feed as well as feed of lower nutritional value. Plant secondary metabolites can substitute the use of antibiotics for improved animal health and more healthy products.

Governance & Stakeholders

Migration to a new level of sustainability in the agricultural value chain will require a multitude of supportive instruments, appropriate market pull and perspective on sound economics, and societal engagement. R&I priorities are to:

- Develop learning scenarios taking into account high impact trends and uncertainties, at the food system level with a special focus on farming;
- Develop a framework that allows actors to study and simulate new food system management situations;
- Develop transferable know-how by analysing case examples of food systems in transition and identifying conditions and factors that promote the success of new organizations, new value chains, learning processes and overcome lock-in phenomena;
- Explore and demonstrate business models to integrate innovation into local circularity approaches: e.g. the use of forage in crop rotation, innovative management of manure, etc.

We encourage the development of influence diagrams that place the value chain central and visualize the flow of interactions between value chain players in a time order, and thereby highlighting the needs for R&I and other support measures. It is such common view that will at the basis for stakeholder engagement and appropriate messaging to society.

Impact

The overall R&I impact of the suggested approaches are expected to

- Rejuvenate agriculture, supported by healthy and functional soils and ecosystems;
- Facilitate transition to a circular bio-economy with resource efficient food production;
- Reduce European dependency on protein import;
- Reduce the use of mineral fertilisers and pesticides;
- Develop production methods maintaining and restoring biodiversity, soil and ecosystems health and providing attractive landscape;
- Move towards a Carbon neutral agriculture supporting the COP21 and "4 per 1000" initiatives;
- Develop a proper evaluation of impacts of agri-food systems, critical for adopting innovative and performing production methods.
- As such, the parallel innovation efforts in the European livestock and crop sectors at multiple starting points across the agricultural value chain, will contribute to the Sustainable Development Goals (particularly SDG 1, 2, 3, 5, 8, 9, 12, 13, 15) and the COP21 Paris Agreement.

Contents

Introduction: An Animal Task Force – "Plants for the Future" European Technology Platform (ETP) initiative

Multiple work streams across the globe look into ways to sustainably produce affordable food of sufficient nutritional quality and diversity for all under challenges such as climate change mitigation and adaptation, environmental sustainability including maintenance of biodiversity and preservation of carbon in agricultural soils. The "Animal Task Force (ATF) Public Private Partnership" and the "Plants for the Future" European Technology Platform (Plant ETP) opted to consider the entire livestock-crop value chain to identify R&I opportunities that enable a sustainable food system meeting those challenges while securing fair incomes for farmers. To this end, the ATF and Plant ETP conducted in 2017 and in 2018 workshops that thanks to the overarching sector approach delivered insights complementary to those provided by specific plant and animal production vision papers. This was followed by open discussion at the ATF general assembly in March 2019 that enabled exchange with policy makers and facilitated participatory approach.

It was assumed that, in the coming decades, Europe will aim to progressively reduce its dependency on importing protein for animal feed and on fossil energy for mineral N synthesis and that European agriculture will strive to adopt circular approaches to further improve efficiency while reducing its climate and environmental impact. In this setting, the ATF-Plant ETP working group embraced multi-actor R&I proposals with involvement of researchers and stakeholders covering the whole food system: farmers, supply chains, processing and production industries, retailers, consumers, policy makers and NGOs. Our main finding is that there is need and workable basis for new collaborative interfaces across the value chain to conduct, test and implement the proposed R&I. The recommended multidisciplinary project proposals have time horizons ranging from short and mid-term to long-term time and take into account social aspects.

The overall impacts of the suggested approaches are:

- Rejuvenated agriculture supported by healthy, functional soils and ecosystems
- Facilitated transition to a circular bio-economy with resource efficient food production
- Proper evaluation of impacts of agri-food systems
- Reduced European dependency on imported protein
- Reduction in the use of chemical inputs: mineral fertilisers, pesticides, antibiotics and environmental impacts
- Carbon neutral agriculture supporting the COP21 and "4 per 1000" initiatives
- Resource efficient food production preventing water scarcity and mitigating climate change with minimal emissions per nutritional unit produced
- Production methods maintaining and restoring biodiversity, ecosystems health and providing attractive landscape
- Robust and efficient animals adapted to new lower nutritional value feedstuff and changed climate conditions
- Reduction and prevention of antimicrobial resistance (AMR)
- Support to the UN-Sustainable Development Goals (particularly SDG 1, 2, 3, 5, 8, 9, 12, 13 and 15).

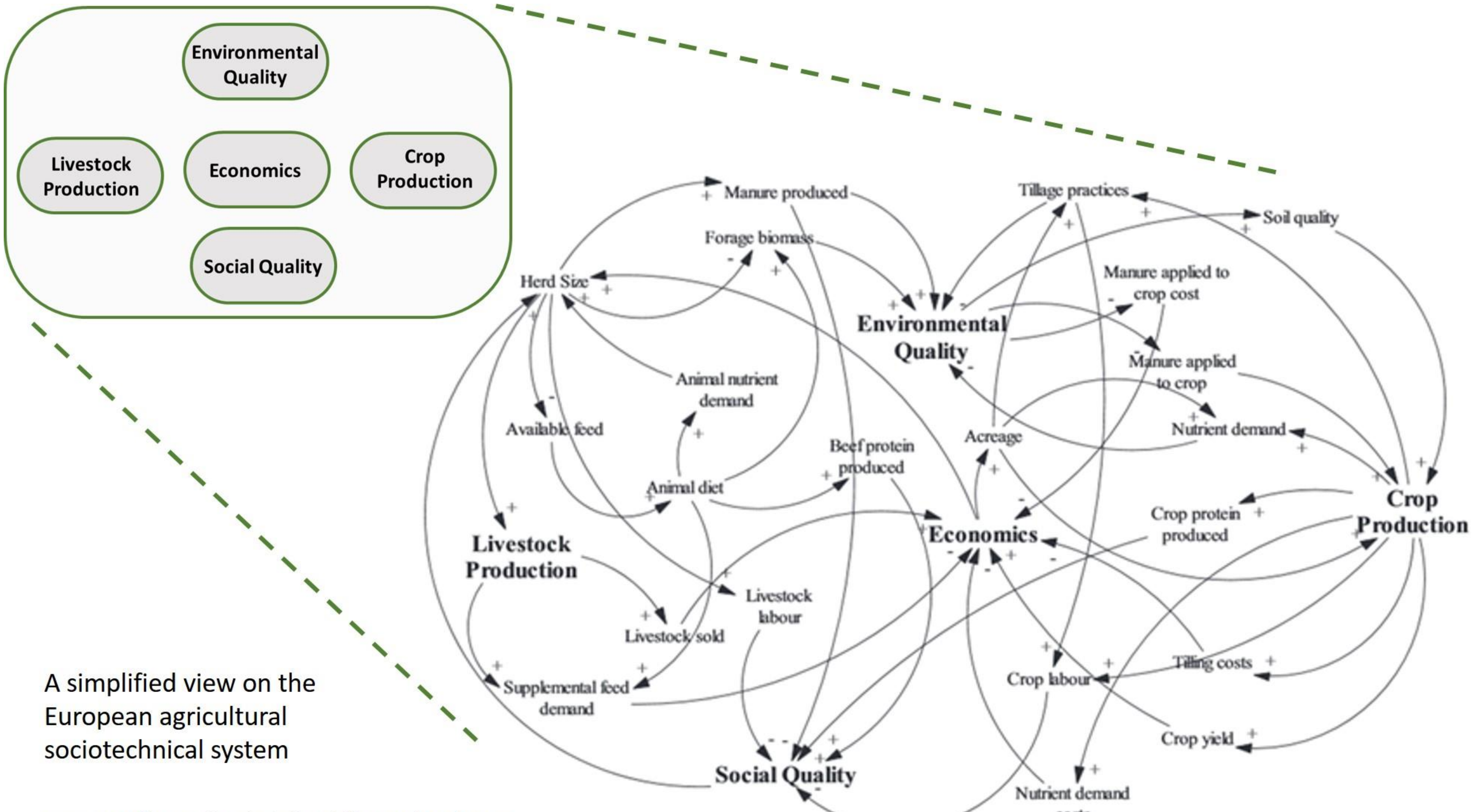
Part 1. Agriculture as part of a more sustainable development

Projections of how the world may develop over the next decades, point towards the unsustainability of exploitation of the earth resources, and predict irreversible changes to climate and biodiversity. In this setting, focus needs to be on agriculture as it uses 37 % of the world's land, 70% of all fresh water, and 30% of the total annual global energy consumption (agro-food sector, World Bank 2010). Through development and deployment of sustainable production methods, the environmental impact of agriculture can be changed to a level better than todays. Examples are reduction of reactive N emissions, storage of more carbon and organic matter in soils, increasing soil moisture-holding capacity and water infiltration and preserving rural landscapes and biodiversity, as well as reduced emission from livestock and ethical sustainability like welfare of the animals and the farmers.

Agriculture being probably the oldest value chain in the world, offers employment to nearly 30% of the global society (World Bank, 2010), and is characterized by a broad diversity of products (food, feed, fibre and fuel…), production methods, input needs, waste streams, supply chains and business models.

This implies that to increase sustainability of agriculture while further growing and tailoring its output, there is an unprecedented variety of short-, mid- and long-term wins depending on geographic location, local culture and policies, product type(s), ways of producing, and prevalent business models. In addition, societal concerns and political settings strive to encourage shift to more sustainable, healthy and nutritious diets, which offers fundamental levers to rethink how agricultural production should look like in the different environments and social settings.

To facilitate transition towards more sustainable agriculture, changes should be introduced across the entire agricultural value chain including behaviour of the end consumer. Depending on the position and role within food systems, the nature and timing of the impact of such changes will differ. The scope of the current position paper is to outline how parallel innovation efforts in the European livestock and crop sectors at multiple starting points across the agricultural value chain, may create substantial gains in sustainability.



From: J.P. Walters et al. Ecological Modelling 333 (2016) 51-65

Figure 1 - Visual illustrating the complexity to be dealt with when shifting from specialized to circular and integrated agriculture

Part.2: The need to rejuvenate and renew agriculture – the challenges and challengers

1. A common definition and assessment of sustainability

To manage change to a more sustainable agricultural approach, it is critical to define the base line starting point and to track progress. The desired change is multi-faceted as it includes the provision of nutrient-rich, diverse and affordable food for an increasing world population, combined with an efficient use of nutrients, minimal climate and environmental impacts and the provision of environmental and societal services. In this complex setting, a common definition of sustainability is crucial to implement changes in a coordinated fashion. To assess the sustainability of agricultural systems, several approaches have been used depending on the purpose and the complexity of the required indicators. The most common method is Life Cycle Assessment (LCA).

An important European development in the LCA field is the Product Environmental Footprint (PEF) methodology. Like a regular LCA, a PEF study measures all quantifiable environmental impacts over the life cycle of a product, including emissions to water, air and soil, resource use and depletion, and impacts from land and water use. However, it has more stringent rules than a regular LCA and may have product category-specific rules. This offers the advantage that PEF studies within a product group can be compared.

However, there are flaws in LCAs applied to agriculture. An example is the assessment of the carbon footprint (CF). LCA treats all carbon emissions equally, whereas loss of soil carbon should be a matter of concern in the long term. To this end, future LCA should use more accurate models for long-term events such as soil carbon dynamics. Furthermore, the spatialization of LCA remains a methodological issue, even if certain frameworks have been proposed (Nitschelm et al., 2017[1]).

In addition, LCA does not consider the nutrient content of foods and the usual LCA indicators are insufficient to evaluate all services. Moreover, these evaluations should also include social and economic indicators such as impacts on biodiversity and animal/human welfare. Furthermore, advance on new indicators is also required to valorise specifically the production of benefits from low input systems. In short, the usual LCAs are unable to visualize the multidimensionality, complexity and variability of agri-food systems. Consequently, currently used LCAs are unsuitable to predict future sustainability including biodiversity and social as well as economic aspects, and are poorly adapted to evaluate the performance of current and circular agricultural systems. Overall, there is value in developing integrated system methods and indicators to assess sustainability and climate impact of the agricultural practices as a basis for better decision making in markets and policies.

[1] Nitschelm, L., Aubin, J., Corson, M.S., Viaud, V., Walter, C., 2016. Spatial differentiation in Life Cycle Assessment LCA applied to an agricultural territory: current practices and method development. J. Clean Prod. 112, 2472-2484.

2. Integration of livestock and crop agricultural production

The Green Revolution was based on novel and largely linear approaches to improve agricultural productivity. This has progressively led to livestock and crop production becoming both more intensive, more specialised and spatially more separated in some regions, with often short-term economics being the principle driver. These latter two developments, specialisation and spatial separation, constitute a barrier to leverage the benefits associated with integrated livestock and crop production. Monoculture crop production drives on optimised use of field machines and pesticides. After many years of use, this has resulted in a fall in soil quality (low organic C content in cropping area, high P content in livestock area), as well as an increased use of fossil energy to produce the inorganic fertilizer thereby leading to air and water pollution and driving climate change. Furthermore, simplification of rotations, intensification of grassland management and pesticide use has resulted in a loss of biodiversity and habitats for wild fauna. Intensification of livestock production practices has also increased issues with animal health and welfare and local overproduction of manure is causing risks of eutrophication.

The foregoing undesired side effects of crop and livestock production could be tackled at least in part by changing the interplay between these sectors. Of the terrestrial agricultural biomass produced annually, 25% is used by humans and the remaining 75% (mostly from grassland, by-products, and crop residues which are not edible for humans) is converted through animals into food with a high nutritious value and into manure. Importantly, 33% of cereal output that is human-edible[2], is used as feed for livestock. By integrating crop and livestock production schemes at local level, a new dynamics can be created as many crop and livestock production parameters are interdependent. Proximity of livestock and crop production facilitates the use of manure to improve soil organic carbon content and to serve as fertilizer delivering N and C for crop production. Refining of manure may allow transport over longer distances and export. The ability of livestock to utilize a huge range of biomasses helps to diversify rotations with the subsequent advantage of closing nutrient cycles and of fighting pests and invasive species associated with monocultures while reducing the use of phytosanitary products and enhancing or maintaining biodiversity[3].

To maximally exploit the more sustainable practices and products that in the coming 20-30 years will be become available, a systems approach is required. It should consider the social and planetary boundaries, resource limitations and climate and environmental impacts, and aim at a paradigm shift towards circular resource use efficiency including waste streams, while securing business continuity and global competitiveness of European agriculture. By strengthening the connection between livestock production and cropping systems synergies may be derived from novel feed sources, fertilizers, agricultural practices, and soils quality.

[2] Mottet, A., Global Food Security (2017), http://dx.doi.org/10.1016/j.gfs.2017.01.001

[3] Agroecosystem Diversity https://www.sciencedirect.com/book/9780128110508/agroecosystem-diversity

3. A protein plan for Europe

With respect to protein sources, the EU has a long-lasting structural deficit. The shortage is a consequence of historic policy choices, the difficult European agronomic conditions, and the associated low profitability of protein crops. Over the past 15 years, the EU made multiple efforts to increase the European protein production, but without much success. The current level of self-sufficiency is approximately 78%[4]. The primary gap is some 13,5 Mio tonnes of soymeal that is used for feed production. As global demand for protein is still rising, the associated price volatility puts a business risk to the European food industry. The European Parliament therefore adopted in a resolution of 17 April 2018 a European strategy to enhance sustainability of protein imports and to reduce its dependence on such protein imports. The proposed support actions include promotion of protein crop cultivation in the EU (mainly legumes), improvement of its profitability, and leveraging crop rotation (pre-cropping) benefits.

Successful implementation of this strategy would result in multiple changes at the farm level. It would cause shifts in land use, adoption of crop (and livestock) rotation and associated shifts in use of fertilizers, pesticides, and land treatment, and re-balance forage versus crop cultivation, etc. Increased production of proteins for feed purpose would in addition further stimulate local circular farming approaches, enhance biodiversity, improve soil quality, and add to rural vitality.

Overall, an increased production of European protein crops will contribute to EU food self-sufficiency and benefit the environment by nitrogen fixation, reduced use of synthetic fertiliser and pesticides when included in rotation, improved soil quality, enhanced biodiversity, thus overall support the circular bio-economy and presumably reduce fossil fuel usage due to reduced imports. The EU protein plan offers policy support to migrate towards a more sustainable European agriculture.

[4] EU protein balance sheet 2011-17.xls: 60% self-sufficiency, not yet including ~18% contribution of green forages (personal communication A. Döring, FEFAC).

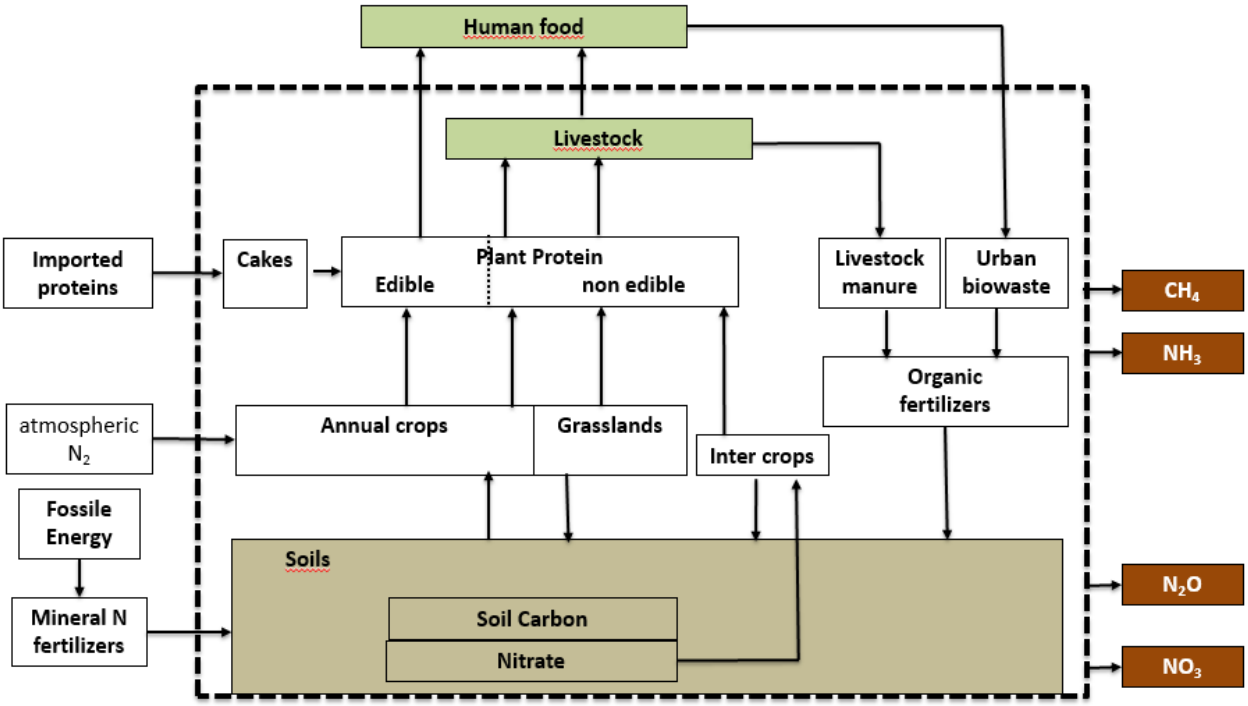


Figure 2. The interplay between protein autonomy, N fertilisation, N_2 symbiotic fixation and environmental impacts. European agriculture uses annually ~25 Mt of nitrogen: 11.2 Mt of synthetic fertilizer, 7.1 Mt of livestock manure, 5.8 Mt from crop residues and 1 Mt from symbiotic fixation (Leip et al., 2011). These quantities largely exceed crop requirements and the surplus contributes to nitrate leaching, ammonia volatilization, and N_2O and NO emissions. Furthermore, synthesis of mineral N fertilizer requires 60 Mcal fossil energy per kg N. Data modelling of a reduced use of synthetic fertilizers combined with more efficient use of manure and increased cultivation of grain and forage legumes is likely to reveal that practice shifts may meaningfully lower negative side effects of fertilization in European agriculture.

4. A society calling out for agriculture to change

Trend analyses reveal growing customer expectations about safe, healthy and nutritious products, environmentally safe and more sustainable production methods, livestock health and welfare, reduction of land and resource use, product availability at affordable price, product recyclability and fair incomes for farmers. Several of these expectations are actively running as business examples already today inside the European agricultural value chain. A primary headwind for engagement by food systems are the cost and risk associated to switching to new products, production processes and services while securing business continuity.

To truly match the societal expectations, a full conversion of the sector would be required, and target nearly every aspect. It would require the deployment of instrumentation, technology and know-how new to the agricultural sector, some of which may exist in other sectors and turn out to be transferable, others needing research and innovation first. It also would require new business models with new value share principles and profitability, as well as supportive policies and legislation. Living up to customer expectation should therefore be seen as multi-year, progressive process, possibly leading to increased prices for food and drinks at consumer level. However, as for protein crops and for a second phase of the Green Revolution, the changes called for by society can help the sector to make progressively gains in sustainability. Society can influence sustainable food production through the political system, but also more directly through consumer choice. However, this has to be matched with accurate and appropriate information on the sustainability of food purchased. Currently, there is little product information to guide consumer choice, and this needs to be addressed.

Part 3. Towards a circular agriculture building on a strengthened link between the livestock and plant sectors

1. More Sustainable land use – Circular economy of arable and livestock agriculture to deliver social and planetary health

A primary change driver in Europe is coming from the broadly accepted goal to migrate towards more sustainable and circular agro-food systems. Circular agriculture implies to shift from a focus on efficiency of single products towards efficiency of the whole, therefore seeking the best compromise between tailoring products to customer needs, improving production, using natural resources, and minimizing climate and environmental impact.

Circular agriculture calls for approaching the food system as a whole and from all dimensions. Importantly, it would require businesses to rethink their purpose, expertise, location, infrastructure, logistics, operating processes and business models. A prime challenge for stakeholders will be to deal with the numerous production, economic and policy inter-dependencies. This complexity points at the value of nationally and regionally coordinated implementation plans and underpins the opportunity for Europe to take a lead in establishing circular agricultural systems with minimal environmental impact as well as to introduce new business models and value share principles. It implies that the entire agricultural value chain should rethink and optimize the use of all resources at local, regional, national and even global level, and solutions are likely to include more sustainable land use and a strengthened interconnection of arable and livestock systems as part of a circular and more sustainable bio-economy.

It is essential to develop science-based management strategies to reduce the current reliance on non-renewable and resource-intensive inputs and at the same time to anticipate an increasingly unpredictable climate. Circular agriculture implies to optimize land use by maximizing food production with minimal climate and environmental impacts and provision of ecosystem services by boosting synergies between cropping and livestock production systems. Feeds, fertilizers and soil are key to such changes. It requires keeping as much as possible residuals of biomasses and food processing in the food system by using them e.g. as animal feed.

Strategies towards a more sustainable and productive agriculture may also consider to produce plant-based food and feed by crops growing almost year-round with diversified rotations, to enhance the use of plant protection products with the lowest environmental footprint, to close nutrient cycles with a targeted use of animal-based fertilizers and mineral fertilizers, to stimulate soil fertility (stability, water holding capacity, nutrient, microbiome), and to maximize the use of biomass not edible to humans for feed, such as by-products of the food-chain. Cultivation of multiple sources of biomass such as grassland, cash-crops, intercrops or new crops (i.e. legumes) will contribute to the diversification of crop rotation schemes.

Livestock will play a critical role in adding value to this biomass and are mandatory to achieve an optimal utilization of biomass components across industries. Overall, crop and livestock systems should become more integrated at multiple scales e.g. on farm with arable and livestock rotations or at a regional/national scale through by-products and the transfer of manures/slurries to arable farms.

2. Dedicated crop and animal breeding to enhance circularity and protein self-sufficiency in food systems

Both crop and animal breeding have over decades contributed to major gains in productivity at farm level. Central is now the question whether integrated approaches can offer in the mid- and long-term meaningful contributions to the desired migration to increased agricultural circularity and protein self-sufficiency.

A running proposal is to co-evolve and tailor future nutritional content and digestibility of crops to improve metabolic efficiency of livestock. Improved knowledge about link between the genetics of animals and nutrient demand, uptake, use and excretion as well as between the genetics of crops and nutrient quality and composition and quantity, would offer possibilities to optimise crops for feed purpose, and to improve the animal's capacity for improved digestibility and nutrient uptake. Genotype-environment interactions should be considered both in crop and animal breeding as well as in crop-animal adaptation. Along the same lines, breeding of animals and crops may focus on reducing input and loss of carbon from the soil as well as ensuring no net contribution of climate gases and emissions to the environment from the food sector.

Breeding efforts should focus on species that are envisaged in future farming systems. For crops, this is about higher protein yields and improved amino acid composition, lower carbon footprint, lower resource input requirements and lower emissions to water catchments. For example, protein yield from multispecies swards including grasses and legumes is twice that of cereals. Associated is the development of strategies for bio-refinery for extraction of protein for monogastrics supporting increased protein self-sufficiency and increased carbon sequestration. Thus, use of mixed cropping of grasses and legumes may in the near future be of increased importance.

Combinations of grain legumes and cereals can be very productive and require little fertilizer and phytosanitary treatments. They are double purpose crops that can be harvested early as fodder or later as grains. Breeding objectives therefore may shift towards species that can be cultivated in mixed settings. Similarly, breeding objectives for cereals grains, legumes grains and forage[5] may focus on protein concentration and amino acid balance, having in mind biorefinery processes as obligatory intermediate step because of co-product strategies.

Reduction/elimination of anti-nutrients in plants and increased resistance to mycotoxin-producing fungi is also a key element to improve feed efficiency and therefore optimise protein conversion from plants to animal products whilst maintaining animal welfare.

For livestock, breeding efforts should focus on improved digestive and metabolic efficiency, resilience and adaptive capacities of animals and ability to use food of varying and lower nutritional value than actual feeds.

[5] Protein concentration is especially important for young animals.

Part 4. Among avenues for improvement: topics for research and innovation and their expected impacts

Transitioning towards more sustainable and circular agriculture demands optimised management of natural resources in the food system. It requires researching for new farming practices, breeding for new and improved species, varieties, and breeds used in different geographical areas and seasons, and developing new technical solutions. The overall objective is to achieve a balanced food production while taking into account social as well as planetary boundaries.

1. An LCA upgrade to track progress towards more sustainable farming

To evaluate the progress made, it is necessary to have adapted and effective evaluation tools. LCA, a product-based approach, compares production methods covering the entire product cycle. However, it has important limitations with respect to measuring the interplay between products and activities. The LCA method should make progress in several directions: (i) The method should count incoming and outgoing flows while taking into account dynamics of phenomena; (ii) The LCA should enable to spatially determine contributions of services and other impacts, as well as that of the regionalization of approaches; (iii) LCAs should use more accurate models for long-term events such as soil C dynamics or the effects of livestock manure inputs on soil biology; (iv) The usual LCA indicators should be extended to evaluate all services. The inclusion of additional indicators needs to be developed particularly to evaluate low-input systems such as organic livestock farming. Organic systems are always in tension between global impacts that are unfavourable to them, and local impacts that are more favourable, but for which there are not always good indicators (biodiversity, jobs, etc.). Development of economic indicators would preferably allow to quantify cultural services, and territorial dynamisms. Finally, consequential LCA approaches are rich in perspectives, but still need to be developed to evaluate the economic and environmental consequences of options that can be proposed and ensure there will be no major trade-off between sustainability goals in the long term. This will require significant modelling work.

Expected innovations

- **LCA methods adapted for system evaluation considering the various interactions**
- **LCA methods that more precisely take into account biological processes**
- **LCA methods able to cope with local specificities such as soils types and climatic factors**
- **Instruments offering a meaningful baseline against which progress can be measured.**

2. Supporting circular agricultural systems

An integrated approach to cropping systems and livestock production is one of the pillars to develop circular agro-food systems in Europe, as outlined below.

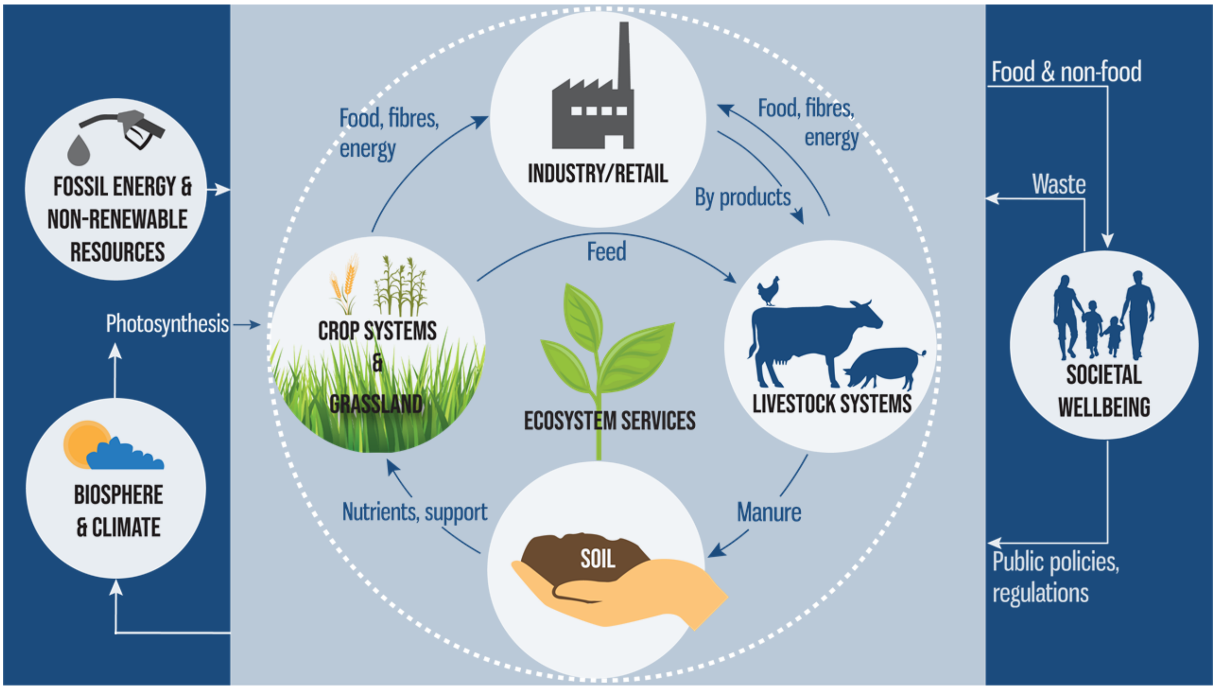


Figure 3: Livestock's role in realizing a European sustainable circular Bioeconomy (source ATF Vision paper)

- Development of a masterplan for balanced food production.

  - The proposal is to assess which combinations of crops genetics and livestock genetics are best grown in which regions/locations. The assessment will include parameters such as soil type, environmental and climatic factors, and [Genetics X Environment] interactions regarding both crops (species and varieties) and livestock (species and breeds). The assessment ratings will take in consideration both human and planetary health.

  - The overarching purpose of the masterplan is to enable an integrated approach to crop and livestock production. It will offer use options for land not suitable for growing human edible-crops, for co-product strategies, etc., and circular approaches leveraging the potential of livestock to improve soil health in connection with crop rotations.

- Identify & develop a panel of crops to enable a circular economy by alternating with and complementing the traditional row crops. Key features of such crops should be:

  - Resource efficiency: crops such as legumes which deliver biological agricultural solutions (N fixation) need R&I to improve economic profitability to facilitate their use in crop rotation schemes to lower the demand on chemical agriculture when cultivating e.g. cereal crops.

  - Diversity in cultivation requirements: to develop cropping systems maximising production per ha and per year, a panel of crops with complementary cultivation requirements would allow for crop-rotations with cover-crops, mixed planting, and dual-purpose crops, etc. Such cropping systems should be less demanding in terms of fertilizers and pesticides and restore soil quality. As livestock is capable to use much more diverse biomasses than humans, such approach should improve the food production per unit of land even when new crops are not edible to humans.

➢ Adaptation of crops and forage to anticipated volatility of weather (temperature, water availability) due to climate change. This may include the use of new species/varieties and innovative agricultural practices and has urgency in some European countries (Southern countries).

➢ Introduction of green forages (grasses, legumes) in rotation is underexploited as protein source and as source for a co-product. The protein yield per hectare per year is as high as that of soybean as the harvestable biomass is several-fold greater due to multiple yearly harvests. Protein yield of forage legumes as lucerne is for instance twice as high as that of grain legumes. Thanks to this favourable starting point, highly feasible R&I on mixed cropping of grasses and forage legumes may offer farmers a sound economic alternative in the near future. By covering the soil all year round, forages will also have a possible benefit in erosion control, reduced nitrate leaching and probably the storage of C (at least for deep-rooted species) and they may serve as a cornerstone to promote circularity. Furthermore, integrated forage production in crop rotation management will support biodiversity. The prime R&I issues are:

- Improving productivity and functionality.
- Optimisation of cultivation and harvesting regimes and procedures.
- Handling of the harvested green biomass.

• Development of innovative feed-livestock value chains. The key R&I opportunities are:

➢ Optimised nutrient utilisation in the food systems by a better use of human inedible and/or local feed resources to replace feed resources that could also serve for human consumption directly and by reducing losses. This will require (i) more knowledge on human inedible and/or local feed resources and the creation of new chains of alternative feed resources and by-products of the food chain, thereby reducing wastes; (ii) optimization of nutrient utilization within raw material sources across industries, as a driving force to develop new processes and technologies and (iii) development of new and innovative models on the nutrition of farm animals which are expected to better use alternative resource, while significantly contributing to a further reduction of energy and nutrient losses and a better quality of animal product.

➢ Development of local self-sufficiency: alternative grassland strategies, alternative feed crops and proteins sources, better use of by-products & local sources, logistics to improve collection of waste streams, new feed evaluation techniques to estimate quickly and at low cost the feeding value of new feed, technological treatment of feed ingredients to improve feeding value.

➢ Identification of the most important actual and emerging hazards in animal feed and (new) feed resources which should be monitored and controlled, will require the development of early warning tools to disseminate information on prevalence of botanical impurities / mycotoxins in crops and by-products from crop processing and developing decontamination processes.

- ➢ Many of the diversification crops are not suitable for human consumption. Valorization of these biomasses as feed, improvement of exchanges between livestock and crop farms and management of safety will require organizational adjustments towards the development of new value chains.
- ➢ Models (based on consequential LCA) to determine the trade-offs in environmental-socioeconomic impact when decisions are made concerning the use of by-products and alternative resources.
- ➢ To develop systems that utilise food waste to generate livestock edible protein, such as insects.

- Development of manure as commercial bio-fertilizer6.
  - ➢ This would include procedures to compost and standardize manure into a fertilizer as an alternative to mineral fertilizers. The unique selling point is that it ensures recycling of several nutrients including N and P where world resources are limited. It also contributes to improvement of soil C sequestration and soil fertility. These solutions based on circular economy principles offer huge potential benefits in a quadruple win process by (i) reducing load of nutrients in intensive livestock production (from exports); (ii) supplying N, P and C in areas specialized for arable land thus contributing to reduce the use of mineral fertilizers and to improve soil fertility and (iii) supporting a reduction of dependency on (imports of) P and fossil energy required to produce mineral N fertilizers.
  - ➢ Sequestration of carbon within the soil.
  - ➢ The above development is crucial to organic farming, which strives to connect crops and livestock, and may depend on manure for soil fertility and organic nutrient supply.
- Smart use of field margins and set-aside areas. This requires optimisation of the use of field margins and non-productive land to enhance bio-diversity and survivability of pollinators.

Expected innovations

- **Enablement of new, local business models based on integrated cropping and livestock production approaches;**
- **Local production of a broader range of food and feed products offering new sales opportunities;**
- **Development of more diverse rotations and diversification of feedstuffs resources;**
- **Linkage between diverse cropping systems and livestock production for more sustainable and circular agro-food systems;**
- **New healthy and nutritious plant and animal-based food produced with efficient use of resources.**

[6] https://www.bbc.co.uk/news/science-environment-48043134

3. Development of bio-refineries for increased European protein and nitrogen self-sufficiency

To maximise the use of local protein to feed animals and/or humans, it will be necessary to develop novel bio-refinery approaches, and methods to improve edibility and nutritional value. R&I focal areas should include:

- Improvement of methods for plant processing:
  - Extraction and processing of proteins from green biomass (grass, legumes)
  - Upscaling of bio-refining methods to extract proteins for feed for monogastrics and using the remaining cake for ruminants to meet industry-requirements for quantity, quality and costs
  - Development of new and shorter technologies to extract oil from oilseeds grain to improve the nutritional quality of remaining cakes improving productivity and functionality
  - Development of technologies to reduce ruminal degradation of protein of cakes and whole grains in the rumen of ruminants while preserving the high intestinal digestibility
  - Optimization of methods for extraction from crops specific proteins for specific requirements (e.g. young animals or carnivorous fish species) or of other nutritional substances such as vitamins or antioxidants and tannins to improve animal health while reducing use of antimicrobial
- New biobased industries for producing amino acids needed as feed additives
- Crops contain secondary metabolites which may exert functions supporting animal health / welfare and may lead to animal-based products with additional nutritional quality for humans. The use value of secondary metabolites for these two purposes has hardly been assessed and have the potential to help reduce the need for antibiotics and offers options to develop innovative food products. Key to this is identification and extraction of health promoting components from plants that support health in livestock e.g. plant secondary metabolites that can play a role in preventive health management strategies as an alternative to antibiotics.
- The development of innovative processing of manures may help to maximize the recovery of N and P, to increase the homogeneity of the processed products. The innovations concern:
  - Development of novel anaerobic digestion procedures delivering digestates adapted to the needs of agriculture as well as the development of appropriate treatments to extract N and P.
  - Development of novel phase separation techniques for manure and/or digestates to obtain a liquid and solid phase that subsequently could be granulated to facilitate recycling. Technical innovations need to be found to facilitate the transport and spreading of digested and non-digested effluents when the plants need them
  - Development of new technologies to valorise urban biowastes and their P-richness and, to a lesser extent, livestock effluents, requires new technologies to ensure the safety of their application with elimination of biological, organic and inorganic contaminants

Expected innovations

- **Protein for monogastrics and fibre pulp for ruminants from biomass obtained from mixed cropping extracted based on new bio-refining techniques supporting European protein self-sufficiency**

- **High quality proteins sources for monogastrics and ruminants**
- **Production of health supporting secondary metabolites for livestock towards increased disease resistance and a reduction in antibiotic resistance**
- **New processing methods for handling manures for a more efficient use of manures**
- **Support for the development of a circular agriculture including increased carbon sequestration.**

4. Genetic improvements in agricultural crops with reduced environmental impact and improved fit as animal feed and contribution to overall resilience (carbon sequestration)

Improving protein yield and amino acid composition of proteins of agricultural crops is technically feasible. Unfortunately, the costs of R&I and the timelines involved to build out one or more economically sound protein crop business cases vis-a-vis the current major feed crops is prohibitive. To increase protein sufficiency in the EU it is therefore recommended to focus the R&I on developing a growing EU-level Information/Knowledge Platform that may benefit protein production in all European agricultural crop production, rather than to focus on boosting productivity and amino acid composition in one or two protein crops of choice. The proposition to establish a knowledge platform offers a valid alternative because most of the protein production is from crops that are currently not considered as protein crops. Proposed R&I initiatives include:

- Development of a Knowledge Platform enabling breeders to start efficient breeding programs based on phenotyping and genomic information. New breeding technologies (NBT) may aid in developing new varieties with high protein production (reflecting a combination of productivity and protein concentration) and low carbon footprint considering the challenges of dealing with complex traits (Hawkins and Yu, 2018).
- Development of precompetitive research:

  ➢ Pre-breeding efforts with distantly related crops as landraces or wild varieties to introduce new biodiversity targeting resource use efficiency and tolerance to stress and volatile weather conditions. As this relates to a long-term effort that is not profitable for breeding companies, R&I and risk funding mechanisms are required to establish the foundation for a European pre-breeding platform addressing the future breeding needs

  ➢ Research initiatives to optimise the “below ground” aspects of crop cultivation and harvesting. Focus may be on crops and varieties with well-developed roots for improved root function, superior sequestration of soil carbon and capability to reduce/restore soil degradation, as well as the associated agricultural practices and machinery required to take benefit from the optimised “below ground” crop architecture and functionalities. Incentives for farmers to base future production on such varieties will need to be developed.
- Improvement of plant protein production:

  ➢ Yield improvement of forage and grains legumes, increased nutrient use efficiency, reduced sensitivity of grain legumes to pest, and optimisation of cultivation and harvesting practices to maximize yield per annum and to minimize environmental impact;

- ➢ Optimization of content, digestibility and/or bioavailability of the protein fraction in the different crops as part of an overall strategy for increased European protein production as the digestibility and/or bioavailability varies among crops and among varieties within crops. R&I may focus on cost-effective protocols;
- ➢ Development of new varieties better adapted to mixed cropping as such crops will most likely be the ones that will be used for bio-refinery;
- ➢ Pending sufficient market-pull originating from e.g. organic farming or from consumer willingness to pay premium prices: start breeding for better amino acid composition both for feed and food use. Despite the intrinsic logic to start breeding for better amino acid composition, the economics behind these efforts are capped by the market value of amino acid supplements and miss currently the appropriate economic incentive.

Expected innovations

- **Establishment of a growing Knowledge Platform as source of key parameters for genetic improvement of agricultural crops and biological processes and associated genes and alleles that enable to alter protein production and specs. Such platform will increase over time its predictive value as academia will enter new findings and pre-breeders, breeders and farmers will enter practical feedback on outcomes**
- **Pre-breeding and breeding programmes targeting goals contributing to the circular bio-economy, agricultural sustainability and climate change mitigation and adaptation**
- **New processing methods, agricultural practices and machinery reducing production losses and environmental impact**
- **Support for the development of a circular agriculture including increased carbon sequestration.**

5. Genetic improvements and innovative feeding strategies in farm animals with focus on increased robustness and resource efficiency

All major farm animal species are improved using breeding programs, however, with widely different goals and levels of efficiency. Feed efficiency is of major importance in many animal breeding programs as feed is the most important cost (~70%, Rabobank 2019) in livestock systems. Feed efficiency is also an important component in improved resource efficiency contributing to a more sustainable agriculture with reduced environmental and climate impact. Effects of selection are very dependent on the definition of efficiency. Feed efficiency as the ratio of output to input is improved if selection is on output like milk yield and weight gain. Basically, it is due to a "thinning" effects of energy use for maintenance. Shirali *et al* (2018) compared ratio-based traits versus linear indicators of metabolic efficiency and showed that the latter can lead to considerable improvement in "real" biological efficiency whereas use of ratio-based traits still improves efficiency but may deteriorates metabolic efficiency. Enhanced metabolic efficiency is key for a resource efficient protein utilization and a focal point in improvement of efficiency in organic production. In addition to animal breeding, a better link between crop and animal research would allow to develop crops that are better suited to meet the animal needs and improve digestibility and nutrient uptake and thus resource efficiency whilst maintaining good animal health and welfare[7] potentially also by the use of plant secondary metabolites. The key R&I opportunities are:

- Development of precompetitive research:
    - ➢ With due consideration of e.g. robustness and functional traits, efforts must be made to increase "real" metabolic feed efficiency in farm animals for improved resource efficiency. This includes research into better measures of feed intake and metabolic efficiency as well as development of efficient bio-indicators for these traits. Implementation requires new sensor technology for extensive phenotyping and use of genomics in breeding programmes.
    - ➢ Determinants of animal feed efficiency need to be reconsidered in a context where animals can be fed with feedstuffs that are sometimes of lower quality and above all more diversified than today, and where inter-individual differences may be exacerbated.
    - ➢ Better understanding of the potential trade-offs between feed efficiency and disease resistance and robustness of animals (immune system).
    - ➢ Understanding and quantification of the relationship between methane production and the efficiency of plant cell wall digestion in ruminants.
    - ➢ The development of new tools to predict animal production and emissions in response to a change in amount and nature of feed supply as an addition to conventional research in animal nutrition that aims at calculating a ration and composition for a given production objective without considering limit on the available feeds.
- Improvement of animals in line with circularity:
    - ➢ Use of genomic selection (and possibly New Breeding Technologies – NBTs) in breeding programs to develop ruminants, but especially monogastrics that are more robust, and able to adapt to future climate conditions and to utilize more variable feed as well as feed of lower nutritional value to reduce direct competition with human food;
    - ➢ Parents of future production animals should be low GHG emitters pr. unit product produced to reach a lower net carbon foot print from food systems;
- Development of improved management strategies for providing proteins for livestock, to adapt the protein supply precisely to the need of the animals. This should take advantage of precision feeding to fit each animal or individual homogenous groups and also take into consideration the animal developmental stage and behavioural needs.

Expected innovations

- **Improved understanding of the biology of metabolic feed efficiency in farm animals for improved resource efficiency**
- **Development of breeding programmes (genomic selection and NBTs) for increased robustness and resource efficiency in livestock**
- **Robust and efficient animals adapted to new lower nutritional value feedstuff and changed climate conditions**
- **Innovative tools to predict the multiple response of animal to diet changes**

[7] Inappropriate feeds can be one of the major drivers for welfares issues, not only in terms of health problems, but also damaging behavioural abnormalities (e.g. injurious pecking in laying hens, which also potentially has large economic consequences).

- **Development of precision feeding to better use protein sources.**

6. Governance and roles of stakeholders to promote changes over time

The ATF-P4F task force believes that a European way forward should build on a collective stakeholder change initiative to gradually evolve to more sustainable practices and products, while securing business continuity and global competitiveness.

This implies that change initiatives often may have an evolutionary nature, and that for those with a more disruptive character, business continuity and risks need to be properly managed. A major hurdle to introduce a smooth European change process is caused by the complexity of the agricultural supply chain itself: food systems players are spread across the globe and subjected to different policy, insurance and subsidy frameworks as well as to different trade agreements, operational modes, business models and profitability. This implies that the reach of European change initiatives should often go beyond Europe to be successful. Moreover, as the "as is"- situation is so diverse for the different actors, it will be necessary to develop change measures appropriate for sub-groups at specific locations with tailored expectations for impact, risk, cost and time. To migrate to a new level of sustainability in the agricultural value chain, initiatives should drive on push-pull dynamics involving individual or multiple supply chain clusters so that the intended effect can stabilize, achieve the desired quality and turn economically sound.

In Europe, agriculture is part of a highly complex sociotechnical systems that due to its historic choices and specialization is "locked in" into a subset of crops and livestock production chains. It is the result from traditions and multiple interdependencies between actors accustomed to cooperation that strengthened over time, and limit today the flexibility and entrepreneurial behavior of the actors. To break out of this situation, it will be necessary to target coordinated innovation at different levels in parallel. For example, adopting a new virtuous crop in a rotation scheme requires both preparatory thinking about its market valorization as well as about the accompaniment to its technical mastery. Technical innovation scenarios, structural changes, and public policies and support measures are best assessed in their value chain context, and implementations should be pre-discussed with e.g. farmers and other stakeholders in the value chains to understand the best way forward.

In this setting, R&I priorities are to:

- Develop learning scenarios taking into account high impact trends and uncertainties, at the food system level with a special focus on farming. To appreciate urgency and the specifics of the different R&I options promoting a more sustainable food system, the ATF-Plant ETP task forces proposes that the different R&I options are mapped onto an influence impact diagram showing the value chain players and how and when progress moves through the value chain to reach the market over time. The visualization of the flow of events (see example figure 3) clarifies in a time order who does what, and how it affects the system overall.

Shift to circularity in production systems			impact waves based on changing demand and sector response (in years)			
stakeholder group		action	0-2,5	2,5-5	5-15	15-30
end consumer	< academia >	Focus on sustainable products				
retailer		provide customer with transparancy on production sustainability				
		intensify marketing products on sustainability of production				
		start marketing products based categories on production sustainability				
producer		install source origin traceability				
		rejuvinate ad/or supplement product portfolio				
processor Includes slaughterhouse, dairy, factories (plants)		install source origin traceability				
		install tailored bio-refinery approaches				
		co-localize with integrated production centers				
trader		install source origin traceability				
farmer		develop and implement meaningful traceability parameters related to production sustainability				
		install new business models to leverage sustainability advantages of integrated food, feed, fibre and fuel production				
farm supplier		develop new genetics at plant and livestock level to optimise productivity				

Figure 4 - Visual illustrating how impulses trigger a stepwise migration from specialized to circular, integrated agriculture. Left part shows the stakeholders groups from bottom to top as they are organised in the agri-food value chain. Academia is well positioned to each of those stakeholders to provide innovation. Societal concern about e.g. climate change opens opportunities for the retail sector to market products with a reduced environmental impact. This opportunity requires a direct interaction with the farmer who short term may provide what is at hand (first wave), and in a second instance produces products optimised for the new business purpose (second wave). This new market reality will enable the farm supply chain to further innovate and improve the offering of the farmer in due time (third wave). The business realisation requires additional technologies such as block chain, LCA for sustainability, labelling up to consumer level, and value share across the stakeholders involved. The different steps and stages are expected to require dedicated R&I including public and public private partnerships. Legend to figure: Blue arrow: demand wave; brown arrow: response wave - Field colour shows waves of structural change.

- Develop a framework to study and simulate management situations incorporating a collaborative dimension between actors. Most often the objectives cannot be achieved by individual strategies and will be obtained by collective strategies (horizontal collaborations between farms that exchange goods or share resources, vertical collaborations between actors of a value chains or different value chains). The coordination challenges arising from the combination of individual initiatives and collective approaches are likely diverse and have few precedents, indicating a need for further exploration and study.
- Analyse case examples of systems in transition to identify conditions and factors that promote the success of new organizations,

new value chains, learning processes and, on the contrary, lock-in phenomena.

- Explore and demo business models to integrate innovation into local circularity approaches: for example the use of forage in crop rotation, innovative management of manures etc.
- Public policies can support changes in production systems in different ways. Here, R&I includes (i) new CAP design including the instruments of the second pillar; (ii) supports for investments in the sector ; (iii) measures to "protect innovation niches" during the experimentation period and the structuring of practices and actors thanks to investment aids, tax exemption measures, support for the networking of actors. Public policies should also help to re-organize collective funding (public and private) of the varietal selection sector.

The ATF-Plant ETP task force recognizes the urgency for the food system players to get their act together and start working on shifting agriculture towards a higher level of sustainability. It requires commonly agreed tools to measure impact of products and processes, and a shared approach towards society that ultimately through it buying behaviour will enable progress. Due to the maturity of food system value chain, migration will require tailored R&I across the value chain as well as supportive policies and business risk mitigation instruments.

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