ROLE, IMPACTS AND SERVICES PROVIDED BY EUROPEAN LIVESTOCK PRODUCTION

Short summary of the collective scientifc assessment report
at the request of the French ministries responsible for Agriculture and the Environment,
in cooperation with the French Environment and Energy Management Agency (ADEME),
November 2016

INRA
SCIENCE & IMPACT

Livestock production is a sector of major economic importance that defines many European rural areas. It has become the focus of controversy over the past decade or more, particularly with regard to the environmental impacts it causes. In this context, it seemed useful to support this debate with a critical review of the state of scientific knowledge on the role, impacts, and services – environmental, economic, and social – associated with European livestock production. Accordingly, the French ministries responsible for Agriculture and the Environment, in cooperation with the French Environment and Energy Management Agency (ADEME), requested INRA to undertake a collective scientific assessment addressing the many consequences – for the environment and the climate, for employment and labor, for markets, and for a variety of social and cultural issues – related to the production and human consumption of animal products (cattle, sheep, goats, pigs, and poultry). Analysis of these diverse dimensions was based on assessment methods utilized and described in the international scientific literature. Using a broad, analytical overview as a starting point, the review proceeded by identifying the "service bundles" associated with livestock production in contrasting areas*. Interactions among impacts and services makes it possible to identify tradeoffs and options for livestock production systems.*

Livestock's Long Shadow: A landmark report from the FAO

Livestock production and the consumption of animal products have received extensive coverage both in the media and in research over the past decade. An influential report published by the Food and Agriculture Organization (FAO) in 2006, "Livestock's Long Shadow,"[1] framed the debate in terms of a tension between food security objectives and the damaging environmental and climate impacts associated with livestock production. Calculating the livestock sector's contribution to greenhouse gas emissions (GHG) at 18% of the global total – revised to 14.5% in 2013 – the report identified livestock production as a major contributor to global climate change. It also highlighted the dominant spatial coverage of livestock production (occupying three-quarters of agricultural land area worldwide), the disruption it causes in large-scale biogeochemical cycles, and the low protein-conversion efficiency of grain-fed ruminants as major issues facing the livestock sector and society at large.

The share of animal products in the human diet

This environmental assessment, subsequently revised and softened by FAO and others, cast a critical eye on the sharp increase in global food demand for animal products occurring in industrialized and emerging countries. Environmental concerns add to public health recommendations linking dietary shifts to the development of diet-related chronic diseases, as well as with the arguments advanced by animal rights movements and an increased interest in vegetarianism. Emphasis is thus often placed on the benefits of reducing meat consumption in the human diet. A handful of technological innovations, meanwhile – such as laboratory-grown meat and the potential of feeding insects to animals (as an alternative to vegetable proteins) or to humans (as an alternative to traditional animal proteins) – have also been well covered in the press.

Agricultural transitions reexamined

These debates surrounding livestock production methods and food choices are echoed by broader social concerns regarding our prevailing development model and its role in damaging the biosphere. Various attempts to redefine modes of production seek to preserve productivity while at the same time enabling better management of environmental impacts. The concept of "ecological intensification," for example, emphasizes bioengineering; "precision livestock production" uses transmitters, robots, and statistical data to guide and optimize management interventions; agroecology seeks to reground agricultural systems based on the use of ecosystem services. All these options have emerged in a context of recurrent tensions within markets for European animal products, the challenges of which appear to go beyond simple economic uncertainty and instead suggest a transition from a "productivistic" model towards "lower-input" models that remain to be fully worked out.

[1] Steinfeld, H., Gerber, P., Wassenaar, T., Castel V., Rosales, M., de Haan, C. 2006. Livestock's long shadow: Environmental issues and options. Rome, Italy. FAO, 390 pp.

Evaluating impacts and benefits of livestock

The impacts and benefits of livestock production have been examined in the scientific literature using a range of disciplinary approaches and evaluation criteria, with impact intensity varying widely according to livestock production type. Some of these approaches have been the focus of previously completed research reviews and will thus not be described in detail here.[2] Aspects relating to human nutrition and food product quality have been excluded as introducing too large of a field of investigation.

The services considered here are those provided by livestock operations. They relate to the benefits society enjoys from the activities of livestock production and/or the use of animal products. This meaning is thus not equivalent to the idea of ecosystem services, which correspond to biophysical processes that benefit humans.

Studies of the positive and negative impacts of livestock production are generally based on multi-criteria assessments. Life-cycle analysis (LCA) methodologies occupy a central place in such studies because LCA provides a basis for standardizing assessments at a large scale. LCA makes use of increasingly detailed data, proven and shared methods, and a growing number of specific indicators. The value of LCA lies in its ability to jointly evaluate several types of impacts across all stages of the life cycle of a product. Economic, social, and cultural aspects are generally poorly accounted for in environmental analyses. The use of other methodologies is thus useful to assist in decision-making.

Regardless of the approach adopted, certain precautions should be kept in mind when interpreting and comparing results. Understanding the perimeter used for an assessment, for example, is complex: is it based on the environmental or the socio-economic boundaries of the system? Should it take into account direct, indirect, or induced effects? Etc. Results can vary depending on the scale under consideration: for example, an increase in animal productivity may translate into lowering the resources used per animal, but an increased demand for resources at the level of the farm operation and even more so at the level of the region.

Choice of functional unit, providing the basis for the quantification of performance indicators, can likewise alter appreciation of the magnitude of certain effects. Thus, calculating emissions per "kilo produced" vs. per "hectare used" can change the relative ranking of different livestock systems. The choice of functional unit depends on a study's specific objectives (general, local, short or long term).

Finally, it is sometimes difficult to interpret indicators, particularly when seeking to specify thresholds of vulnerability. Deciding, for example, whether 10% lameness on a dairy farm is acceptable or not, involves a large measure of subjectivity.

[2] The most important of these is the assessment on nitrogen in livestock systems: http://institut.inra.fr/Missions/Eclairer-les-decisions/Expertises/Toutes-les-actualites/Expertise-Les-flux-d-azote-lies-aux-elevages

Multiple impacts and services from European livestock farms

Examination of the impacts and services provided by European livestock operations has been organized within the five major domains of our analytical framework (see box, p. 3). This framework enables us to consider in turn livestock operation effects on: markets, labour and jobs, inputs, the environment and climate, and certain social and cultural factors.

Markets

Food consumption: Accounting for close to 60% of daily protein ingested, European consumption of food products of animal origin is twice the global average. Consumption of animal proteins has held steady in Europe since the 1990s, albeit with some substitution of products (Figure 2). Two social phenomena appear to mark the evolution of European diets: i) a certain "de-animalization" of meat consumption, expressed in the substitution of red meats by white meats (mainly poultry), and by increased reliance on processed products that hide the animal origin; ii) the development of foods produced under quality labels, reflecting European appeal for heritage or high-culinary value products. This trend toward high-quality production processes and products also reflects distrust in the agri-food industry.

Analytical framework: "Service bundle" resulting from livestock production

In order to simultaneously consider all the dimensions of the impacts and benefits of livestock operations, we developed an analytical framework enabling us to visualize those impacts and benefits in terms of "service bundles."

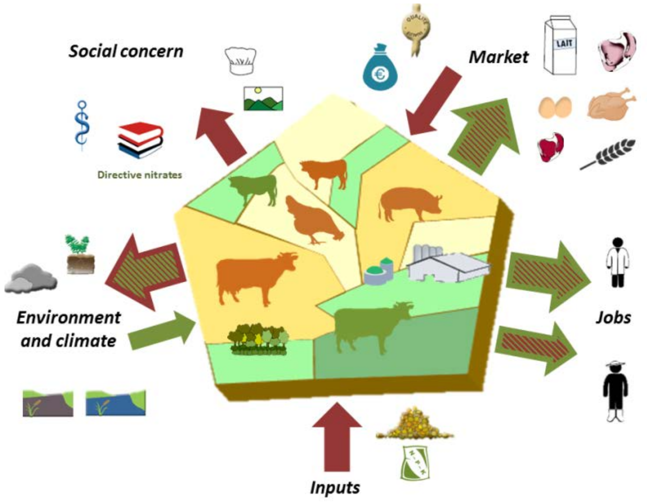
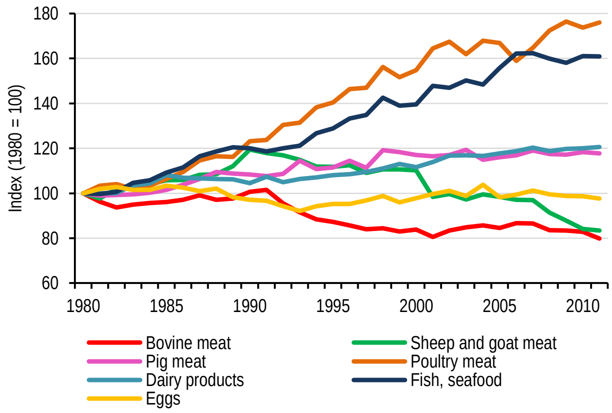


Figure 1. Representation of service bundles from livestock production

The central pentagon represents a livestock production system within its rural area. That setting includes key landscape features as well as the agro-industrial activities that supply and are supplied by the livestock farms. The **livestock production region** is described in terms of its key features: species, herd size (indicated by the size of the animal icon), feed source (green animal = pasture, brown = feed concentrates). **Land use** is represented by two shades of green for permanent or temporary grassland and two shades of yellow for the various annual crops.

This system interacts with **five interfaces**: markets, work and employment, inputs, environment and climate, and social and cultural factors. **Pictograms** represent the principal elements within these different areas: food products, financial transactions, feed concentrates, rivers, legal directives, etc. The magnitude of these impacts is represented by the size of the **outward-pointing arrow**, the color of which indicates whether effects are positive (green), negative (red), or mixed (hatched, with the dominant effect indicated by the color of the outside border). **Inward-pointing arrows** represent pressures on the livestock production systems or on external resources (inputs): risks, predation, social pressures, etc.

Figure 2. Change in animal protein consumption per person in the EU-28 from 1980 to 2010 - Source: FAOSTAT



Production: At the scale of the European Union (EU), animal production accounts for approximately 45% of retail agricultural value. A third of all farm animals – especially dairy, pigs, and poultry – are concentrated within a small number of areas (Denmark, the Netherlands, northern Germany, western France). The "average European livestock farm" uses 34 hectares of agricultural land area and has a herd size of 47 LSU[3], with a high level of variation according to livestock systems and countries (farms in the newer European member-states being considerably smaller on average).

International trade: The commercial movement of animal products between EU member-states is significant, and has been increasing over the past decade. Demographic shifts and economic development in emerging countries have spurred global demand for animal products, stimulating an increase in exports beyond the EU, notably for the dairy and pork sectors. Competition within European and international markets is intense; France's share of European animal product exports has fallen since 2000, while Germany's has risen (a shift not entirely due to the difference in labor costs between the two countries).

Associated sectors: European industries linked to animal production (milk and meat processing, feed for livestock) have an annual turnover of approximately €400 billion (2013). Although the total number of companies is high, these agri-food sectors are dominated by a few large corporations of global importance. Large-scale supermarkets accounted for 54% of retail food product sales in 2012, with the remainder sold through other outlets (markets, butchers, restaurants, etc.). Recent years have also seen a shift toward increased concentration among European purchasing groups, initiated by the large-scale distributors.

Across all these sectors, the search for improvements in cost-efficiency and differentiation based on quality and labeling programs play a key role in the competitiveness.

Labour and jobs

Direct and indirect employment: European livestock farms employ roughly 4 million people (salaried and non-salaried), 80% of whom reside in the more recent EU member-states. Mixed crop-and-livestock and dairy farms account for the largest share of jobs (37% and 25%), far ahead of pig and poultry farms (8%), which are fewer in number but larger in size and have the largest percentage of salaried positions. The livestock production sector provides more than a million salaried positions in the EU. The multiplier effect of direct employment is estimated to be between 1.2 and 2.5, depending on the sector, and is generally higher for meat production than for dairy. Some geographical areas are highly dependent on such jobs, given the importance of animal production in the local econo-

[3] LSU = *Livestock unit*, is defined as the equivalent of one 600-kg dairy cow producing 3000 kg/milk per year.

my. In France, total employment linked to livestock production is believed to account for 3.2% of all jobs.

Work: The average livestock farm typically has 1 to 2 workers. Family labor continues to decline, and is being replaced by salaried employees, agricultural labor services, and new collective arrangements. Salaried employees represent 15% of workers on livestock farms across the EU, with strong variations by country (ranging from 2% in Belgium to 50% in Denmark). The appeal of livestock farming as a career seems to be weak, with difficult working conditions and the lack of recognition accounting for disinterest among younger generations.

Technology and automation: Livestock management practices are changing rapidly. Technology and automation have a direct impact on labor hours, making it rational to seek to streamline livestock production practices. Some of these efforts are controversial, however: increasing labor productivity tends to reduce producers' affective relation to the animals, which alters the symbolic value and the underlying rules of the profession.

Worker health and safety: These issues are poorly represented in the scientific literature. The agri-food industries, which includes slaughterhouses, show elevated rates of illness and injury resulting from repetitive work tasks, standing postures, noise, and time spent working in low temperatures. Within livestock production, physically difficult work is decreasing but work that is mentally difficult is increasing, and is linked to a rise in stress levels. Next to with cancer and cardiovascular diseases, suicide now occupies a significant place among causes of death for farmers.

Inputs and resources utilized

"Inputs" includes resources used both directly and indirectly by livestock operations: crops, land, water, fertilizers, and energy. Input and resource use have become key to interpreting the environmental efficiency of livestock production, with debates pointing to livestock farming's large territorial footprint resulting from low rates of conversion of plant proteins into animal proteins, the delocalization of protein supplies, and pressure on biodiversity.

Animal feed: European livestock farms annually consume 220 million metric tons of cereals and oil-seed/protein crops, half of which are fed in the form of protein- and energy-rich compound feed concentrates. The EU imports 70% of the oil-seed/protein crop proteins (primarily soya) it feeds to animals. If proteins contained in all concentrated feeds are counted, the protein-dependence of the EU drops to 40%, and it is lower still if one counts the proteins contained in rough forages and grasses.

Land use: Cows in grass-based systems require more land area than poultry or pigs, but they can make use of grasslands and rangelands on land unsuitable for cultivation, thus not competing with the production of biomass for human consumption. Within the EU, approximately 74 million ha of permanent grassland (including 17 million ha in upland areas), 10 million ha of temporary grassland, and 35 million ha of land in forage cereal crops (equal to 60% of the total planted area) are dedicated to feeding the European livestock herd. Half of the cereal hectarage is used to feed pigs, a quarter to feed poultry and a quarter to feed ruminants. Estimates vary as to the amount of arable land outside the EU that is used to feed European farm animals, with totals depending on how land area is calculated and what assumptions are made regarding yields and the allocation land area to different by-products.

Energy: Livestock production consumes approximately 45% of all energy used in agriculture (28 Mteo/year in the EU). The energy required to produce a kilo of protein varies depending on the product category (beef requiring more energy than pork or poultry) but also within production categories (pork varying from 95 to 236 MJ/kg; milk from 37 to 144 MJ/kg). Depending on the type of feed used, indirect energy consumption (for processing fertilizers and concentrated feed materials) can represent 50 to 80% of total energy requirements. Livestock operations can also be energy producers via the use of effluents to produce biogas. Germany produces two-thirds of European biogas, with nearly 9000 farms participating, whereas France uses less than 1% of its effluents for biogas production.

Phosphorous: The use of phosphorous in agriculture, primarily as a fertilizer, has increased fifteen-fold since 1950. Phosphorous is a non-renewable resource. As a nutrient fed to animals, most supplied phosphorous is eliminated in animal wastes (the retention rate is about 20%). It is thus recycled as a fertilizer and contributes approximately 40% of crop phosphorous inputs in France. Excess phosphorous remaining in soils can be a source of pollution. The phosphorous contained in animal products is the principal source of this element in the human diet.

Water: Because water is highly unevenly distributed across the landscape, indicators of water consumption per unit of product are only relevant within a given context. Assessement methodologies for water consumption refer to different types of water ("blue" water used for livestock or irrigation of forage crops, "green" water stored in soils) and use a variety of indicators (consumption levels, use efficiency, hydric stress). Given these factors, findings are so widely variable as to be difficult to compare: according to different sources, production of a kilo of beef can require 27 liters or 53,200 liters of combined blue and green water, a kilo of pork from 4,800 to 6,000 liters, etc.

Environment and climate

Greenhouse gases (GHG): As a significant contributor to anthropogenic GHG emissions, livestock operations have a clearly negative impact on climate change. In the EU, roughly 42% of emissions from livestock production come from animal feeding, 22% from enteric fermentation, 19% from livestock effluents and 17% from direct and indirect energy consumption (livestock production and associated sectors). As a result of enteric fermentation, ruminants are responsible for 60% of GHG emissions from European livestock farms. Conversely, grassland systems are capable of long-term carbon storage in soils under permanent grass, which has a positive effect on the climate.

Air quality: Livestock farms are also the principal emitters of ammonia (accounting for 90% of ammonia emissions). Ammonia is a precursor for fine particulates, which are a major public health concern. The primary particles are harmful to the health of individuals working in confined animal production systems (mainly poultry houses). The contribution of ammonia to the formation of secondary particles affects all areas of the EU, but has not been quantified.

Soils: Livestock operations alter the biological and physical functioning of soils by contributing organic matter and nutrients favorable to soil fertility, but can also contribute biological, pharmaceutical, and chemical contaminants. These impacts vary according to soil use (arable crops vs. grasslands). The most positive effects are linked to the use of grasslands, especially permanent grasslands; the most negative effects result from high animal densities. Evaluating the cumulative effects of different types of impacts on the life in the soil is too complex to enable conclusions as to an overall positive or negative effect.

Water quality: In areas of high animal density, nitrogen and phosphorous leaching and runoff contributes to the eutrophication of waterways (lakes, rivers and coastal areas), as well as to a loss of water quality and an increase in water treatment costs. The EU has placed a strong emphasis on monitoring and reducing nutrient loading from effluents (the Nitrates Directive). Loading per hectare is the key aggravating factor, but impacts will also depend on the sensitivity of receptor environments.

Biodiversity: The positive effects of livestock farming on wild biodiversity are associated with the use of permanent grasslands and upland areas, environments rich in floral and faunal diversity that would afforest or close over in the absence of livestock grazing. Biodiversity in agricultural areas increases in the presence of livestock production because of grassland use (even temporary grasslands) and crop diversification, and through the maintenance of hedgerow and silvo-pastoral landscapes. The loss of permanent grasslands and increased fertilizer use, among other factors, have reduced plant diversity levels associated with livestock production. Experimental trials have however shown positive effects of mixed forage species both for production (nutritional quality and quantity consumed) and for resilience in the face of climate variations.

The biodiversity of domestic livestock species, on the other hand, has fallen sharply. A handful of specialized breeds now predominate, with large population sizes and covering large geographic areas. The genetic basis for these breeds is narrow, limiting the potential for adaptation, particularly in dairy cows. The institutional context has become more favorable to the maintenance of local breeds since 1992, however.

Social and cultural factors

Issues linked to animal health: 75% of emergent human infectious diseases are of animal origin. Over the past ten years, the movement of infectious agents (bird flu, catarrhal fever, etc.) has accelerated, underlining the increasingly global nature of health risks. Livestock diseases are responsible for 20% of production losses at the global level.

The spread of antibiotic resistance has brought increasing scrutiny to the question of the misuse of antibiotics in livestock production. Resistance can be diffused into the environment through manure spreading, with antibiotics exerting selection pressure on bacterial flora in the soil. This process remains difficult to qualify or to quantify, however. In addition, many biological agents (pathogenic microorganisms, viruses, parasites) and chemical substances (synthetic hormones) present in effluents are also potential contaminants.

Heritage and cultural aspects: Typically French, Dutch, or Balkan cheeses, Italian charcuterie and other dried meats – all these and more testify to the richness of European food heritage linked to animal products. The number of EU quality labels (PDO: protected designation of origin; PGI: protected geographical indication) continues to rise, approaching 600 in 2015. Nevertheless, the transmission of artisanal skills and knowledge remains uncertain. Pastoral livestock systems also contribute to the creation of readily identifiable cultural landscapes that are attractive to a largely urban European society.

Animal welfare: Animal protection was introduced into European law in the 1990, with the goal to establish a common framework for livestock management, transport, and slaughter practices. Such a legislation is necessary considering the number of animals bred and slaughtered each year in the EU. The evaluation of animal welfare is, however, a complex task. Livestock farmers' practices vary widely, and "best practices" are poorly recognized by labels, although some countries have developed them (the United Kingdom, the Netherlands). Animal welfare is nevertheless better addressed in production for quality labels than in other forms of agriculture.

The challenge of developing an overall assessment

Given the multiplicity of these effects, their variability by region and product, their non-cumulative nature, and the uncertainty of some assessments, drawing up a balance sheet of positive services and negative impacts of livestock farming and animal products is a challenge. Totaling up results from disparate domains into a single impact value is not really practicable, and is open to critique in that it risks masking major negative impacts behind a handful of positive impacts.

In general, the positive dimensions of livestock farming tend to correspond to production, trade, and some cultural aspects, whereas the negative effects relate to environmental impacts and resource pressures. It must be remembered, however, that maintaining the continued viability of livestock farming's positive aspects necessarily entails limiting the reach of its negative aspects.

The "service bundle" methodology

A new approach centered on antagonisms

Research examining several services or "service bundles" simultaneously is rare. The few studies of this sort that have been done, however, suggest that an increase in the provision of one service is often counterbalanced by the reduction of another. High levels of services cannot be obtained simultaneously in all domains; thus compromises must be sought. Compromise at the level of the livestock production system is typically considered as a tradeoff between the production of goods on one side and environmental impacts on the other, the goal being to minimize the latter without reducing production. This tension between production and environmental services is meaningful at all scales (including fields, farms, and regions as well as at the global level).

Relationships between services are not necessarily linear: the laws of response can include thresholds, optimums, inflection points, etc. For example, the curve for carbon sequestration in a grassland shows an inflection point at a moderate level of production intensity, whereas primary production stabilizes; this level thus corresponds to the optimum tradeoff.

Examining compromises between services implies a simultaneous consideration of their spatial coincidence, their interactions, their respective change factors and whether those factors are linked to management of the system or region or to exogenous forces (market shocks, climate change, etc.). This interconnection of multiple factors suggests the need to adopt of a very large analytical framework. Social and cultural dimensions are often neglected or underestimated due to the difficulty of identifying indicators. In practice, however, they can tip the balance between two contrasting situations.

Use of global modeling and scenarios in analyzing compromises

The primary value of methodologies relying on modeling and scenario simulations lies in the work of assembling diverse information from a variety of sources that can be used to give an overall coherence to the resulting projections. This type of approach can highlight synergies and antagonisms among the various services associated with livestock farming (with respect to both the livestock-producing region and feed-providing regions), as well as the compromises that emerge out of those interactions. When the working assumptions and limitations of such methodologies are clearly defined, such approaches can facilitate their further discussion.

Reducing or modifying the composition and share of animal products in the human diet is regularly used in simulations as a way of limiting the environmental impacts of livestock production, with ricochet effects on land areas allocated to livestock and livestock feed crops. As a general rule, such scenarios underline the environmental desirability of reduced consumption of animal products coupled with 100% pasture-fed ruminants and the improved use of by-products in other livestock feeding. A total elimination of livestock farming, however, would not seem to offer the highest level of environmental services. This situation implies the existence of an optimal level of animal products in the human diet.

Studies such as these generally pay little attention to the effect of price in channeling demand for different types of food. Nor do they engage closely with studies looking in detail at consumer habits and preferences, a key factor in evaluating the actual impact of such shifts on consumption patterns and on the environment. Finally, the social consequences associated with these scenarios, while sometimes mentioned, are rarely quantified.

Service bundles and options for different European livestock production zones

These approaches to evaluating bundles of services, undertaken at a large scale, are limited by the fact that the diversity of European livestock systems and regions can yield contrasting bundles of services. For this reason, this collective scientific assessment employed an analytical grid describing bundles of services associated with different types of geographical areas. Based on the preceding overview, two fundamental factors govern the variability of livestock production effects and can help us differentiate regionalized bundles of services: animal densities and methods of animal feeding. Other livestock system characteristics (animal species, herd management, soil use, system intensification, manure management) are all directly linked to these two key factors.

A typology of European regions (Figure 3) based on animal density per agricultural hectare and on the percentage of permanent grassland within the utilizable agricultural land area thus enables us to distinguish three categories of European livestock production regions:

- i) Areas with high animal densities and minimal permanent grassland, accounting for 30% of the European livestock herd and 11% of utilizable agricultural area in Europe. In these areas questions of pollution management are central.
- ii) Grassland areas, where grassland productivity determines both levels of production and strategies of product differentiation (35% of the European herd on 33% of utilizable agricultural area). Animal densities in these areas can be variable.
- iii) Areas with both crops and livestock, including a wide range of dynamics from complementary crop-and-livestock systems to situations where livestock production is being pushed out in favor of expanded crop production (27% of the European herd and 32% of utilizable agricultural land).

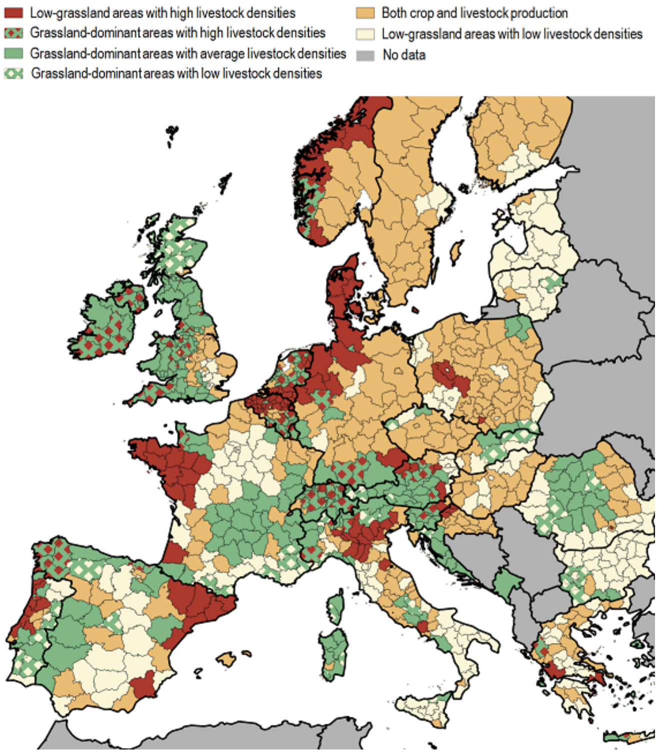


Figure 3. Typology of European livestock production areas
(Source: INRA based on Eurostat, 2010)

Low-grassland areas with high animal densities

The bundle of services in areas with high animal densities and minimal grassland is strongly oriented towards supplying markets at competitive prices (Figure 4). The primary characteristic of these areas is their high level of production per unit of land area, made possible through the use of confined animal production facilities. Because of the volumes produced, unit costs of production are relatively low; farmers may seek to further reduce costs by optimizing their animals' food conversion indices. These factors combine to improve the balance sheet of resource use per animal.

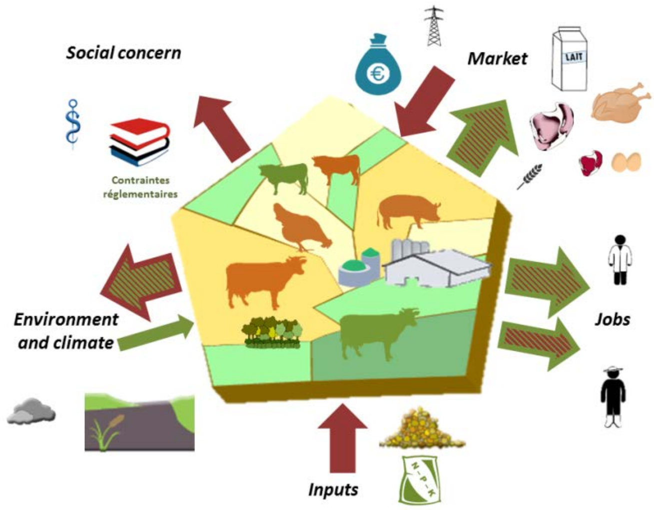


Figure 4. Service bundle in low-grassland areas with high livestock densities

Livestock operations like these are concentrated around agri-industrial centers, with strong linkage effects upstream and downstream of the supply chain. They operate within a context of international competition, with strongly integrated systems based on significant capital investment and increasing levels of consumption and production. Products issuing from these agricultural operations and areas are primarily large-volume foodstuffs sold via national, European, and international markets. Farmers receive a relatively low margin per unit of product but have a higher average turnover than livestock farmers in more extensive systems, thanks to the volumes involved and the level of economic performance. Such systems are also highly sensitive to economic factors over which actors have no control (global markets for both inputs and outputs). Farmers have limited bargaining capacity as a result of asymmetries in market power relative to the rest of the production chain.

While high animal concentrations in a given area enable productivity gains, they also give rise to nuisances and pollution (risks of deteriorating water quality and eutrophication, smell nuisances, etc.). The ecological demand on resources of such systems is sharply debated, since although it may be low on a per-kilogram-of-product basis, it is high on a per-hectare-utilized basis; and the system is also highly dependent on the use of resources imported from elsewhere (proteins, water, etc.). Animal welfare issues are another focus of debate.

In the case of monogastric animals, options in these areas involve: (i) improving feed conversion efficiency through breeding, animal management, and ration composition; (ii) facility design (HQE norms, air filtering and circulation, animal welfare, etc.); (iii) improving the value of animal products; (iv) animal and herd/flock health; and (v) handling of effluents to facilitate export and recycling (drying methods, biogas production, etc.). In ruminant systems, the main action mechanism is increasing access to pasture, which, if achievable, will reduce the need for external inputs and generate less local pollution than the use of forage maize.

Livestock production in grassland-dominant areas

The second livestock production area type involves primarily ruminants and is characterized by a high degree of self-sufficiency in the supply of inputs. Grass-based livestock systems don't necessarily seek to maximize production, but instead try to make the best use of local resources, limiting both mechanization and mineral fertilization of pastures (Figure 5).

Utilizing non-cultivable lands and/or protected natural areas, these systems tend not to compete with crop production for human consumption.

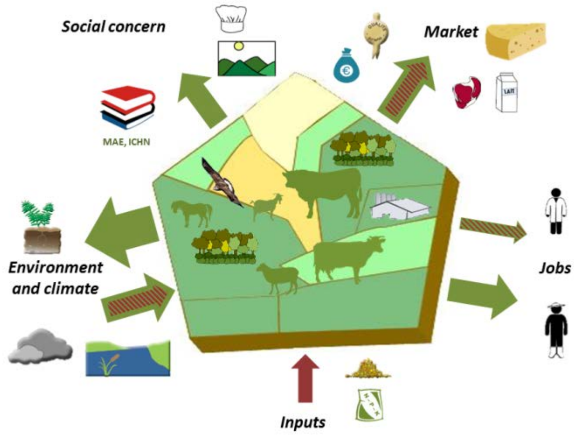


Figure 5. Bundle of services in grassland-dominant areas

On-farm forage production does not necessarily eliminate the purchasing of concentrates, however, especially in mountainous areas. Animal breeds tend to be locally adapted. Production conditions for these systems (longer animal growth cycles, lower food conversion efficiency, etc.) result in GHG emission levels that are higher per unit of product than those in non-grassland areas with higher animal densities. Thanks to low animal densities per area and the role of permanent grassland in carbon sequestration, however, their environmental impact per unit of land area is generally limited. This impact can rise however when animal densities are increased.

With lower apparent land productivity, these grassland systems generally have lower economic profitability than other systems, but revenue per hectare may be comparable where the farms and regions can benefit from the area's environmental potential and the distinctiveness of its products. Grassland-dominant regions thus offer a bundle of services with lower production levels than in the preceding case, but can benefit from an image of product quality while limiting pressures on the local environment.

Compromises in these areas thus seek to maintain good environmental performances without penalizing (or even while improving) production potential. When economic circumstances are unfavorable, grass-dominant areas can be faced with a double threat of intensification or abandon. The principal risks in these areas are closely linked to soil and climate conditions and how those might change over time.

Only those action mechanisms that are appropriate to the local context can be applied. The balance between productivity performance and environmental performance depends first of all on grassland management: length of the grazing period, use diversification, production output. At the level of the landscape, additional action levers are available relating to the coordination of agricultural and natural areas. Production chain organization is likewise crucial for getting maximum value out of products – particularly those sold under a quality label (PDO/PGI, certified organic, other labels) – as well as for sharing added value among different sector actors. Finally, ensuring the durability of the compromise in this case requires a tight coordination between sector governance and regional governance, including the involvement of natural resource managers.

Areas with both crop and livestock production

Areas with both crops and livestock (including monogastrics as well as ruminants) feature the most heterogeneous livestock production systems both in terms of size and in terms of production strategies. Mixed crop-and-livestock systems making use of the complementarities between arable crops and animals are the ideal type within these areas (Figure 6), allowing for the highest provision of services, in particular by improving soil quality, ameliorating the tightness of biogeochemical cycling (nitrogen, carbon), and enhancing habitat diversity.

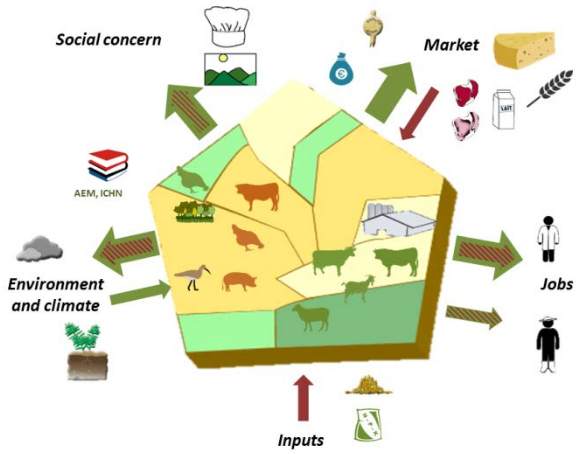


Figure 6. Bundle of services in areas with both crop and livestock production

This association between plant and animal production is only partially effective in areas where crop and livestock production coexist, however. Livestock production has suffered from competition with crop agriculture, which has been more strongly supported by markets backed up by significant public subsidies. Changes in land use threaten the existence of grasslands, with remaining mixed crop and livestock farms often restricted to less favorable areas (steep slopes, wet areas, etc.). Loss of livestock farms can also result from a lack of manpower and/or work organization within the mixed farm, leading some actors to advocate for the maintenance of livestock farms and their benefits.

Given the risks of livestock farms disappearing from these areas, action levers seek to combine the benefits available from integrated crop and livestock systems with conditions allowing for the maintenance of livestock production. More diversified rotations can increase the feed self-sufficiency of livestock farms, particularly through the inclusion of legume species. Planting intermediate crops or catch crops can also improve animal feed self-sufficiency. Other possibilities that have been tested with success include introducing ruminants or poultry into orchards, vineyards, or rice fields. Finally, the use of forage resources from trees or shrubs could help limit the sensitivity of the production system to climate change.

Where technological and organizational barriers inhibit the reintroduction of animals onto crop farms, local complementarities between specialized livestock farms and specialized crop farms can be considered. Such arrangements seek to realize the advantages of an integrated system without introducing new labor demands. Complementary exchanges like this can help livestock farms remain viable. In other areas, the survival of mixed crop-and-livestock farms and/or mixed livestock farms has been supported by defined product standards and labeling programs that guarantee a just return for quality products.

Conclusions and future research

Assembling an inventory of economic, environmental, and social impacts of European livestock farms helps us appreciate the broad range of outcomes associated with livestock production, even if it cannot be used to deliver an overall balance sheet. A regionalized "bundles of services" methodology, combined with the evaluation of groups of services by regional type, helps us understand how different effects interact, and thus what a balance sheet of positive and negative impacts might look like. Such an approach also suggests how action levers can be adapted to the territorial configuration of service bundles. Thus in areas with high animal densities, pollution management (especially point-source pollution) and input reduction are key concerns, whereas in grassland-dominant areas, attention is focused on grass productivity and finding ways to differentiate products for higher-value markets. Areas with both crop and livestock farming need to organize themselves to support continued livestock production if they are to benefit from the advantages of integrated systems.

The effects of climate change were not considered in this assessment, including with regard to action levers. A supplementary study would be needed to understand the role of livestock farms in mitigating and adapting to climate change.

Deepening our analysis of bundles of services by regional type, thinking about how these different types interact and interrelate, anticipating how they may evolve, both together and individually, requires further research into several different areas.

To better include all services provided by livestock farming: While integrated impact assessments typically quantify negative environmental effects (resource pressure, pollution, etc.), positive effects can reduce pollutants, emissions, and/or resource consumption. Some of these services remain poorly accounted for in life cycle assessments. The bundles of services approach seeks to remedy this, but the literature is still relatively theoretical and does not always make it possible to include the added values that have been identified, particularly within modeling exercises. This is the objective of cost-benefit analyses, but such analyses have rarely been applied to livestock systems.

To make service bundles more visible: In addition to the challenges of quantification and the weighting of livestock production impacts, another challenge is to make those impacts visible. Research seeking to understand service bundles in a holistic fashion might make it possible to make them more evident, and thereby help to support relevant public policy efforts.

To refine analysis of the effects of reducing the consumption of animal products: Studies evaluating the effects of changes in the human diet are often presented in an *a priori* normative way. They make small allowance for the complexity of food behaviors or for impacts on production sectors. Other factors that should be introduced include the nutritional quality and nutritional impacts of animal products, the substitutability of different foods, changing food preferences on the part of consumers, and mechanisms influencing how production sectors function.

The collective scientific assessment

A collective scientific assessment is a review and critical analysis of the current state of scientific knowledge on a specific topic. It provides perspective on the debates and controversies that exist within different scientific communities, highlights uncertainties that should be considered when interpreting results, and identifies knowledge gaps that need to be addressed in future work. It is not intended to provide specific policy guidelines or recommendations. Work on the expertise is governed by a set of guidelines, the basic principles of which are competence, impartiality, diversity, and transparence.

The expert group appointed for this assessment was made up of 27 researchers, a third of whom were external to INRA. Their areas of expertise were divided equally among the animal sciences, the environmental sciences, and the economic sciences, and the social sciences.

The bibliographic corpus was assembled after querying the Web of Science™ and EconLit databases. The experts selected and added references based on their areas of expertise. The final bibliographic corpus was made up of approximately 2,450 references, (articles, book chapters, reports, regulatory documents, etc.). Complementary statistical materials were used to contextualize the results for the European situation

To learn more:

Dumont B. (ed.), Dupraz P. (ed.), Aubin J., Benoit M, Bouamra-Mechemache Z., Chatellier V., Delaby L., Delfosse C. Dourmad J.Y., Duru M., Frappier L., Friant-Perrot M., Gaigné C., Girard A., Guichet J.L., Havlik P., Hostiou N., Huguenin-Elie O., Klumpp K., Langlais A., Lemauviel-Lavenant S., Le Perchec S., Lepiller O., Méda B., Ryschawy J., Sabatier R., Veissier I., Verrier E., Vollet D., Savini I., Hercule J., Donnars C. 2016. Rôles, impacts et services issus des élevages en Europe. Synopsis of the collective scientific assessment. INRA (France). .

The full report, synopsis, and this short summary of the collective scientific assessment are available on the INRA website.

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