The drivers of livestock production in the EU

Deliverable No. 4.1

SUSFANS DELIVERABLES

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In the last decades the demand for animal source food (ASF) has increased. In response to a rising demand for ASF, animal numbers and animal productivity increased, due to science and technological developments. Currently we see that the demand for ASF is stagnating or decreasing due to socio-economic factors like environmental concerns, human health concerns and changing socio-cultural values (animal welfare). Given current high consumption levels of ASF in Europe, two main strategies can be followed to come to healthy and sustainable diets: reducing the impact of livestock production per kg of output by sustainable intensification, or improve human health and the environment by changing dietary patterns.

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Overview of WP4 driver deliverables

Generally, WP4 aims to develop a system understanding of the drivers of and prepare, collect and deliver the data for assessing FNS and its sustainability at the level of primary agricultural and fisheries production.

Within WP4, the deliverables D4.1 (drivers of livestock production in the EU), D4.2 (drivers of fisheries and aquaculture production in the EU), D4.4 (preliminary report on the drivers of crop production in the EU) and D4.5 (final report on the drivers of crop production in the EU) provide:

• An analysis of the drivers of livestock production in the EU;

• An analysis of the drivers of seafood production in the EU;

• An analysis of the drivers of crop production in the EU.

Table 1 gives an overview of the WP4 driver reports.

Table 1. Overview of WP4 driver deliverables

Production system	Methodology	Deliverable
Livestock	Qualitative analysis	D4.1
Seafood	Qualitative analysis	D4.2
Crops	Qualitative/quantitative analysis	D4.4 (preliminary deliverable)
Crops	Quantitative analysis	D4.5 (final deliverable, due in March 2017)

Generally, primary agricultural production is not only affected by economic factors, but highly depends on biophysical factors as well. The economic aspects and, partly, their interplay with biophysical factors are part of the modelling work within the SUSFANS toolbox. The WP4 driver deliverables provide a basic understanding of the multi-disciplinary production system. Since economic factors are covered in the SUSFANS toolbox and the scenario work, emphasis is thereby put on biophysical and technology developments. A general introduction to the concept of drivers in primary production and drivers in the context of production economics is given in the appendix of each of the deliverables.

Table 2 shows the different foci of the individual drivers in the SUSFANS conceptual framework (CF) (Zurek et al., 2016) and each of the WP4 driver deliverables. Relevant for the WP4 driver deliverables are the indirect drivers that affect the whole food system and the direct drivers for producers. Indirect food system drivers considered in the CF are economic developments, population dynamics, technological change, agriculture and trade policies, environmental issues, and culture and lifestyle choices. Direct drivers for producers according the CF are the regulatory environment, input and farm gate prices, contract opportunities, natural resource availability, available technology and producer and farm characteristics. The appendix provides a more detailed comparison of the drivers technological change and available technology.

Table 2. Different foci between WP4 driver deliverables and the CF

Driver	**CF (D1.1)**	**Livestock (D4.1)**	**Seafood (D4.2)**	**Crop (D4.4)**
Indirect drivers				
Economic development	-Summarized by growth in GDP -Impact on consumption, consumer and producer prices, wages in food sector -Market power and imperfect competition	-Summarized by growth in GDP -development of livestock production	-Societal drivers affecting seafood prices -Macro- and microeconomics of EU seafood production	-Refers to CF (D1.1)
Population dynamics	-Population growth (in developing countries) -Demographic changes -Composition of diets	-Population growth (in developing countries) -Demographic changes -Composition of diets	-Demographics and expected effects on seafood demand	-Refers to CF (D1.1)
Technological change	-Innovation -Technology development -Competition for land from emerging biotechnology	-Progress in feeding technology -Progress in breeding	-Historical development and the interplay between farmed and fished seafood -Technical innovations in society enabling growth	-Public and private research (breeding, fertilizer and plant protection, machinery)
Agriculture	-Impacts on	-Specific crop	-Fishing	-Specific crop

and trade policies	prices and diets -Price transmission between agricultural policies and consumer food prices -Price impacts through trade policies on commodity prices limited, highest effect on diets through general liberalization and economic growth -Impact of trade policies on price volatility -Effects on land use -Sanitary and phytosanitary regulations	policies between EU and other countries -Food policies -Trade policies	policies between EU and other countries -Food policies, trade barriers and regulations related to seafood -Beyond-EU regulatory environment of relevance to seafood production	policies between EU and other countries -Food policies -Trade policies -Relevant sanitary and phytosanitary regulations
Environmental issues	-Climate change impacts on crop and livestock sectors -Soil carbon sequestration -Reduction of emissions from land use and carbon sequestration in biomass -Biomass production for energy uses	-Global environmental impact of livestock production. Competition for land between feed and food production	-Environmental pressures of seafood production -Effects on seafood production from changing environment	-Climate change

	-Energy prices			
Culture and lifestyle choices	-Nutrition intake and changing dietary behaviours -Undernourishment, malnourishment and human health	-demand for livestock products over the years	-Consumer preferences related to seafood consumption	-Specific trends in crop consumption
Direct drivers				
Regulatory environment	-Common Agricultural Policy (CAP) of the EU -Common Fisheries Policy (CFP) of the EU -Different directives (e.g. water framework directive, Marine Strategy Framework Directive) -Food safety and related standards	-EU legislations and policies affecting livestock production	-EU legislations and policies affecting seafood production	-EU cereals regime -EU oilseeds regime -Fruits and vegetable policies
Input and farm gate prices	-Interplay supply and demand -Relation input and output prices -Input costs -Producer prices	-Trend in livestock prices	-General economic data on EU seafood production	-Input prices refer to CF (D1.1) -Trends in crop prices
Contract opportunities	-Contract farming as part of vertical integration -Relevance of contract farming in different production systems		-Hinders for aquaculture growth -Outsourcing of activities	-Refers to CF (D1.1)

Natural resource availability	-Determines feasibility of primary production -Includes land, climate, soils, water, fish stocks	-impact of current production levels on scare resources e.g. land use and future availability.	-Production capacity and current status of capture fisheries -The role for aquaculture related to general resource availability (e.g. seafood per capita, feed)	- Environmental setting on farm, refers to CF (D1.1)
Available technology	-Technology adoption & diffusion -Technology usage -Total factor productivity	Feeding and breeding technologies are adapted in e.g. diet formulations	-Science and management behind current production -Difference in technology between individual enterprises, e.g. farmers' knowledge, skipper effect -Status of production systems and technical progress needed -Production efficiency incl. by-product utilization	-Management

Producer and farm characteristics	-Personal attitudes, values and goals, experiences, social influences -Path dependencies through existing farm characteristics and farm structure -Vessel characteristics and fleet structure -Effect of socio-economic characteristics on risk aversion and management decisions	- type of farms - number of farms - animal numbers per farm	-Seafood production characteristics in the EU (technology, knowledge, prices and costs)	-Refers to CF (D1.1)

Table of Content

1 Introduction

In the last decades the demand for animal source food (ASF) in Europe has significantly increased. This increase in demand for ASF is caused by trends in key drivers, such as growth of the global human population, growing incomes, and urbanization. In response to a rising demand for ASF, animal numbers and animal productivity increased, due to science and technological developments. This increase in animal production contributed to nutritional security, generated economic benefits, resulted in improved livelihoods, and provided labour, but it also has drawbacks mainly related to human health and the environment (Thornton, 2010).

In Europe, the demand for ASF increased from 42 g of protein per person per day in 1961 to 61 g of protein per person per day in 2010. For an adult, the daily recommended intake of protein is approximately 57 g per person per day (EFSA, 2012), of which about one third is recommended to be from ASF (personal communication, Van ’t Veer and Geleijnse, 2016) especially for some population groups, such as pregnant woman (Meier and Christen, 2012). Consumption patterns in Europe are characterized by a high intake of animal protein, but also saturated fat, cholesterol, and calories (Hallström, 2015). This high intake can cause health issues, such as obesity, heart diseases, and cancer (Gerbens-Leenes et al., 2010; Micha et al., 2010; Kastner et al., 2012; Hallström, 2015). Although overconsumption of ASF can result in health issues, malnutrition and limited dietary diversity can also results in health problems. As ASF provides essential nutrients with a high bio-availability, such as iron, calcium, thiamine, vitamin B12, and Zn, simply eliminating ASF in European diets might, therefore, result in health problems.

Besides the complex role ASF play in providing healthy diets, the production of ASF also causes severe environmental pressure via emissions to air, water, and soil (Steinfeld et al., 2006). The livestock sector is responsible for about 15% of the total anthropogenic emissions of greenhouse gases (Gerber et al., 2014). The livestock sector also increasingly competes for scarce resources such as land, water, and fossil energy (Steinfeld et al., 2006; De Vries and De Boer, 2010). The dual challenge of the livestock sector is to contribute to healthy diets for a growing and more prosperous population, while at the same time reduce its emissions and increase its resource use efficiency. There is considerable uncertainty as to how the livestock sector will tackle this dual challenge. To this end, this chapter aims to provide insight in the current playing field livestock production is facing, by providing information on direct and indirect drivers of livestock production. The deliverable takes stock of production drivers of livestock production, in anticipation of more detailed assessments in the project including 1) an in-depth analysis of innovation and its sustainability impact in livestock supply chains in D5.2 and D5.4 and 2) a comprehensive assessment of production at regional level based on the CAPRI database will follow in D4.7 in M24.

2 Livestock production in the EU

2.1 Consumption and production of animal source food

Looking at the changes in consumption of protein from ASF over time (Figure 1), we see that the total amount of protein consumed from ASF in 2010 is about 15 grams higher than in 1960 (50 years earlier).

When considering the different types of ASF, egg consumption remains relatively stable throughout time, while milk consumption slightly increases with 5 grams in 50 years. Most of the variation in consumption of protein from ASF, however, originates from variation in meat consumption.

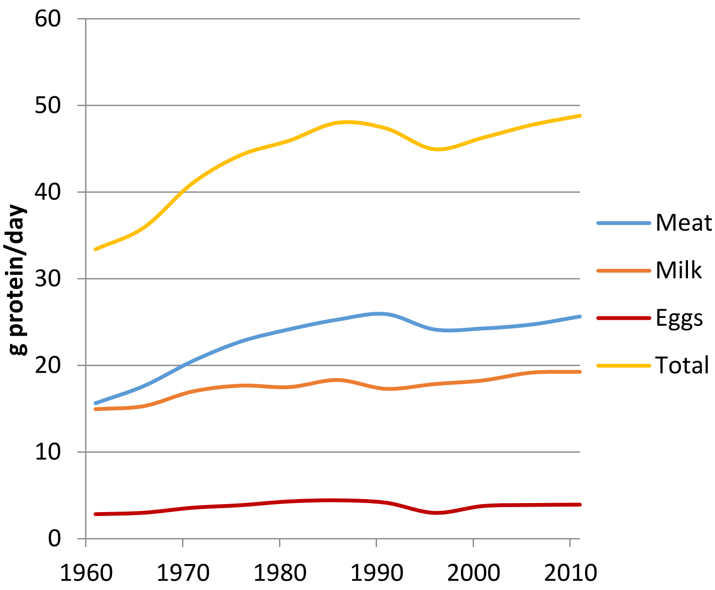


Figure 1 Animal protein consumption in Europe between 1961 & 2011 (FAOSTAT)

The steady increase in meat consumption up to 1990, is related to an increased consumption of bovine, pork and poultry meat (Figure 2). Thereafter, pork and poultry meat consumption continues to increase, while bovine meat consumption decreases heavily, causing a decrease in total meat consumption as well. Around 2000 bovine meat consumption stabilises, which combined with the still increasing pork and chicken meat consumption, causes total meat consumption to further increase.

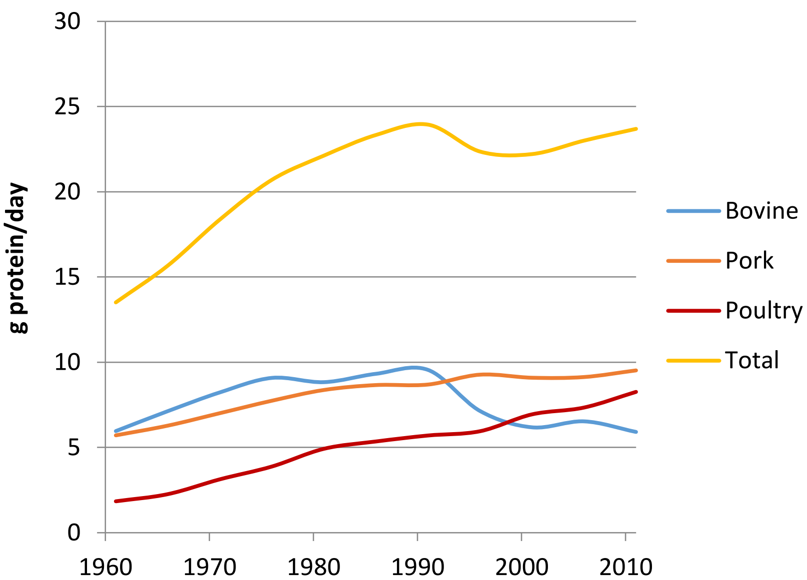


Figure 2 Meat consumption in Europe between 1961 & 2011 (FAOSTAT)

This rapid reduction in bovine meat consumption is related to a decrease in sheep and cattle numbers, as displayed in Figure 3. This figure also indicates that the increase in poultry and pork consumption is not related to an increase in animal numbers and must, therefore, be caused by either increased imports or increased productivity.

As indicated before, the consumption of meat increased steadily for all meat types up till 1990, after which the consumption of ruminant meat dropped significantly (Figure 2). Figure 1 shows that egg consumption also slightly reduced around that same moment. When analysing the consumption of ASF in different European regions (Figure 4), the cause of this depression becomes clear, as it occurred solely in Eastern Europe, experiencing the fall of the soviet union at that time.

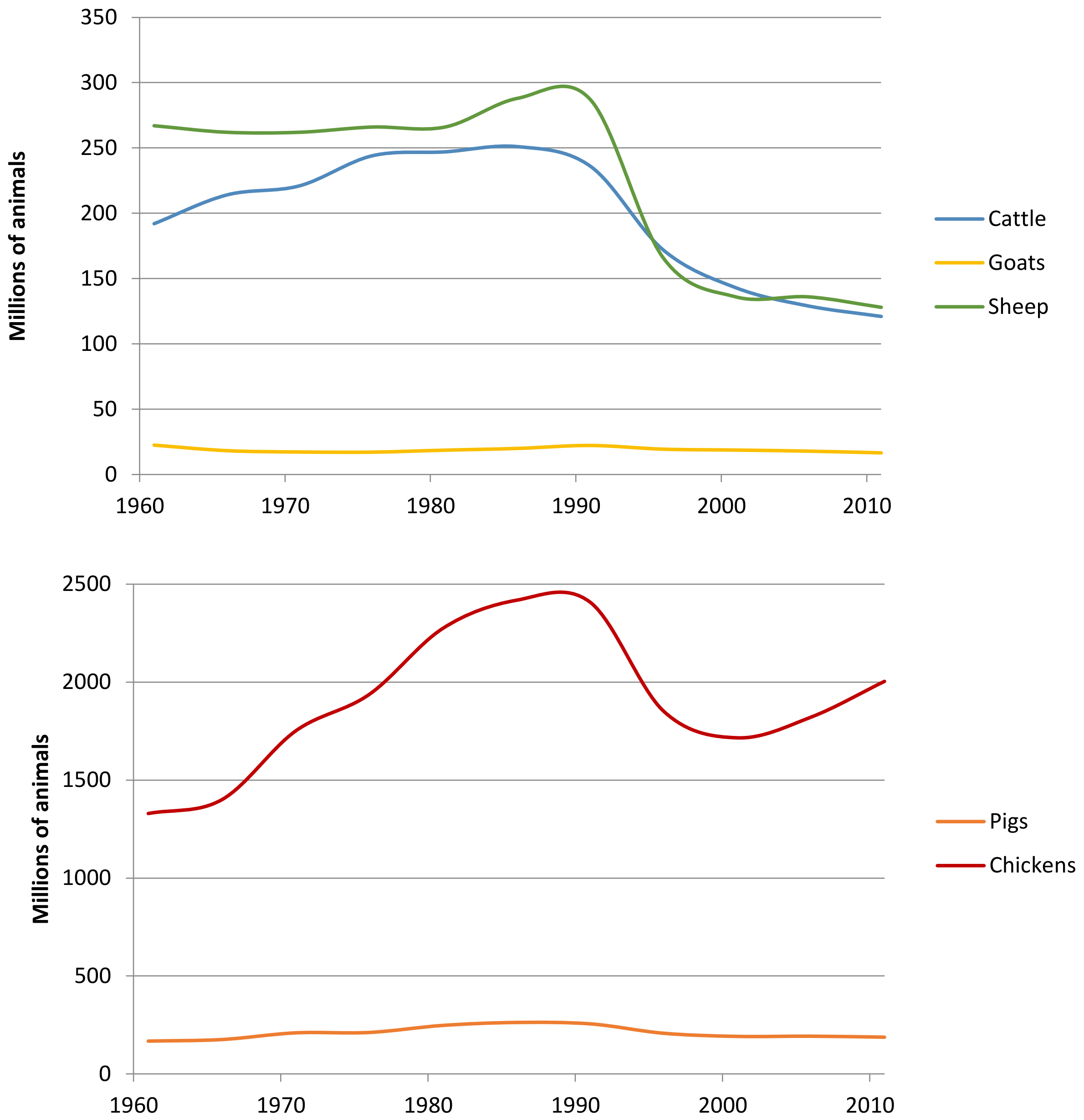


Figure 3 Amount of ruminant (top) and monogastric (botom) production animals in Europe between 1961 & 2011 (FAOSTAT)

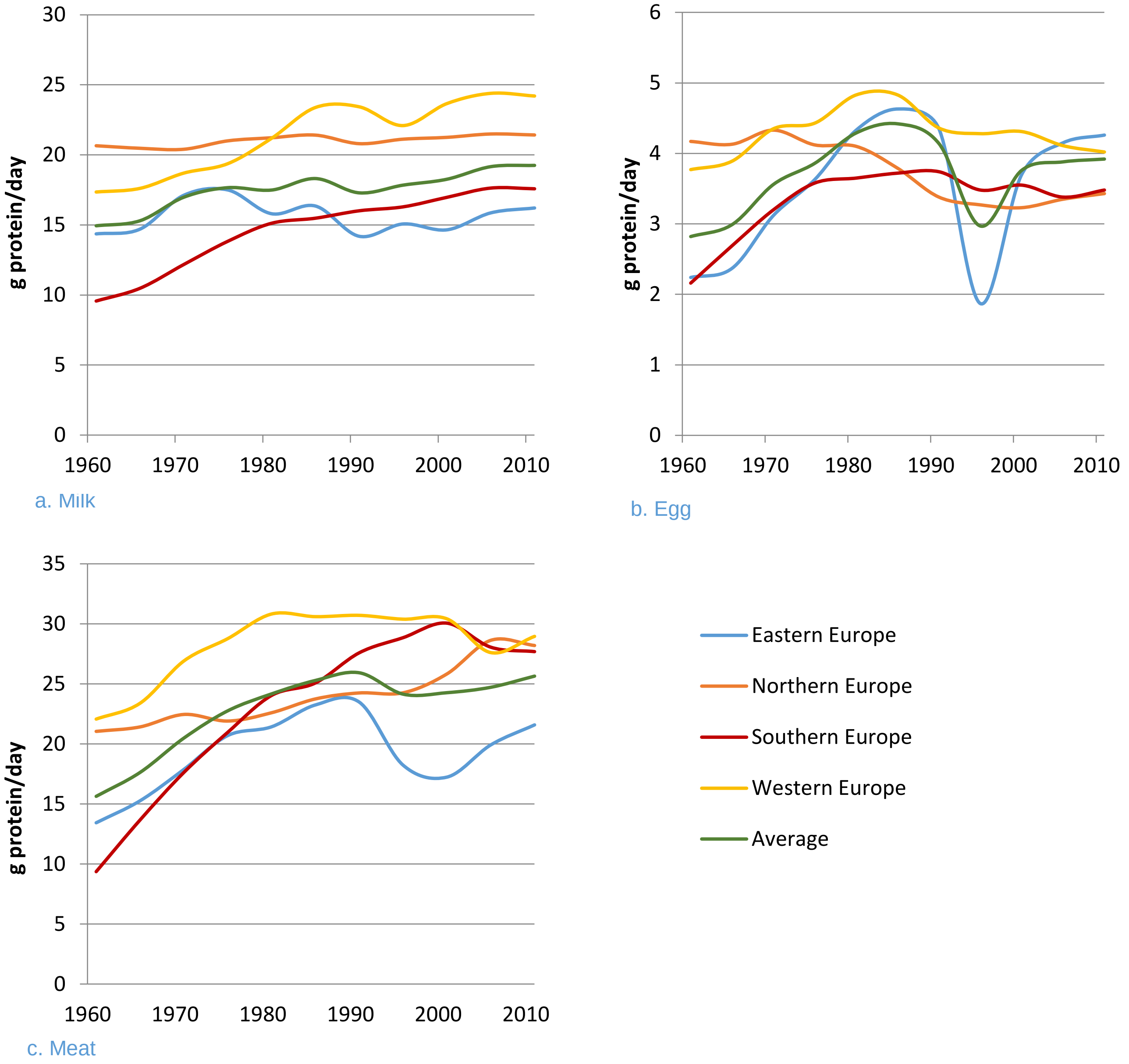


Figure 4 Animal Source Food consumption in different European regions between 1961 & 2011 (FAOSTAT)

3 Indirect drivers of livestock production

3.1 Population growth, GDP, and urbanization.

The increasing demand for ASF is largely caused by three key drivers, namely a growing population, increasing incomes, and an increase in urbanization.

Population growth in the EU

The European population has experienced a rapid increase in population size over the past 50 years. In more recent years, population size in Europe has stabilised (Figure 5), and it is expected to decrease in the near future. In contrast to Europe, the world population is still growing. Projections of the future world population vary and are highly uncertain. A recent estimate of the United Nations suggests that the world's population will exceed 9.7 billion people in 2050 (Bruinsma, 2003; UN, 2015). Global population growth, therefore, will increase the demand for food, even when world population as a whole ceases growing sometimes during the present century.

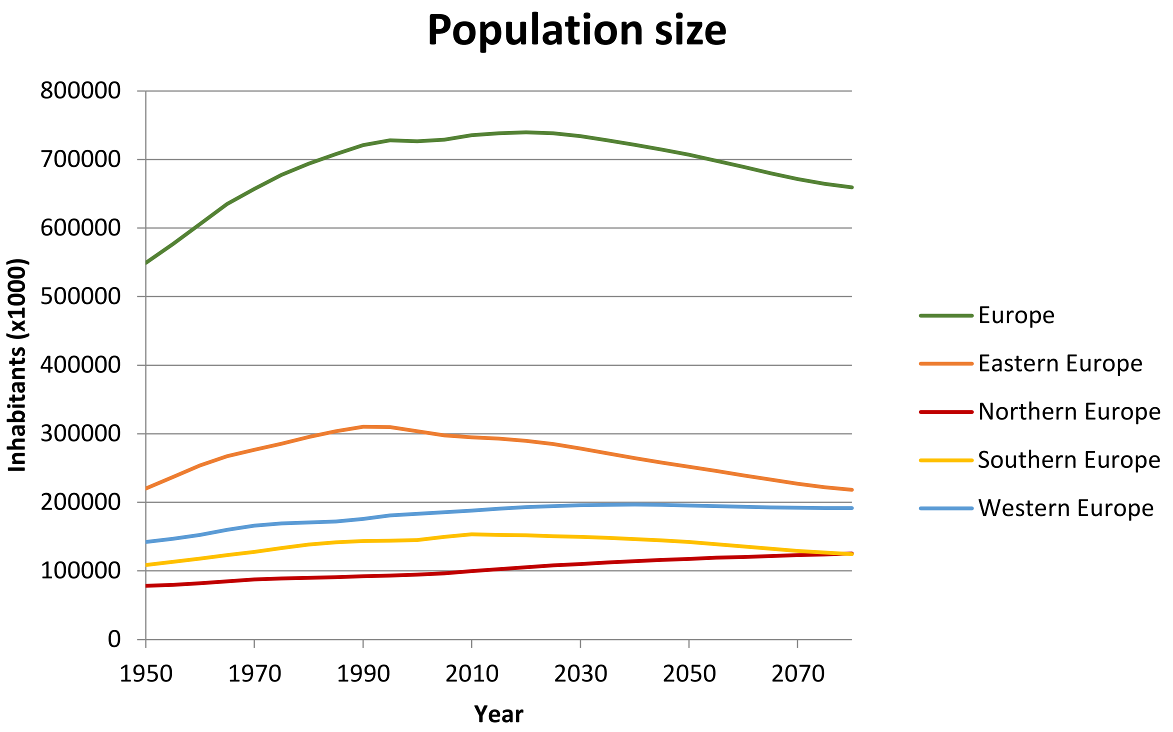


Figure 5 population development in different regions of Europe between 1950 & 2015 and estimations for future population development (FAOSTAT).

Gross domestic product versus demand for animal source food

Although there are large differences in income, overall people are becoming and will continue to become richer (Figure 6). A consequence of this increased income is that people are able and willing to pay more for their food. In general people tend to switch their consumption pattern towards an increased consumption of meat and dairy products, vegetable oils, fruits, vegetables and processed foods (Satterthwaite et al., 2010). Therefore, income growth is generally considered to be the strongest driver of increased consumption of ASF. Figure 6 illustrates the relation between GDP (Gross Domestic Product) and consumption of protein from ASF across European countries. This figure shows that an increase in income at first increases consumption of protein from ASF. However, at a certain point, consumption of ASF reaches a steady state and in some countries is even reducing. At that point an increased income no longer has an effect on protein consumption of ASF. Examples of such countries are Austria, France, and the Netherlands (Figure 7).

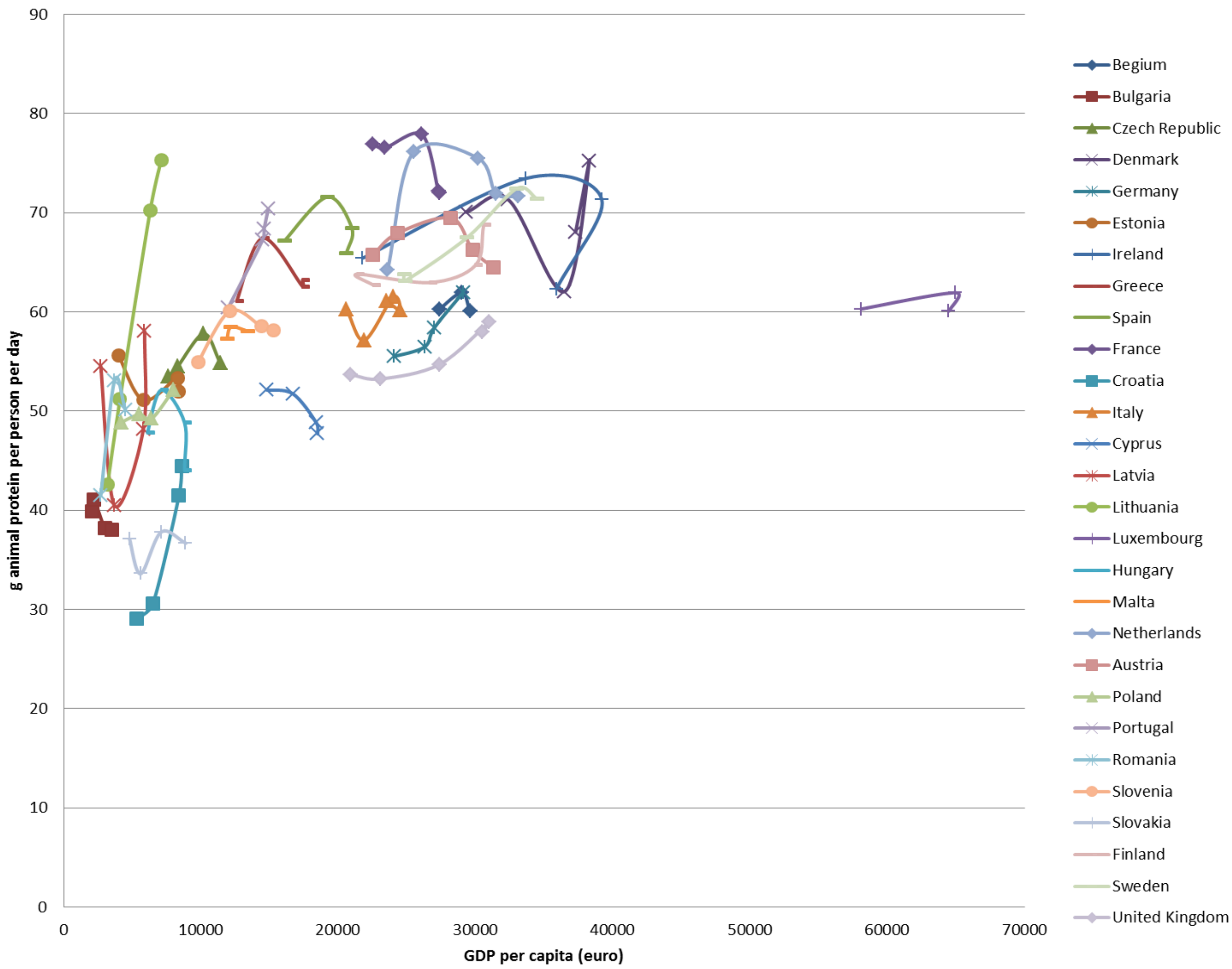


Figure 6 Per capita gross domestic product (GDP) and protein from animal source food consumption by nation for the years 1900, 1995, 2000, 2005 &2010. (FAOSTAT).

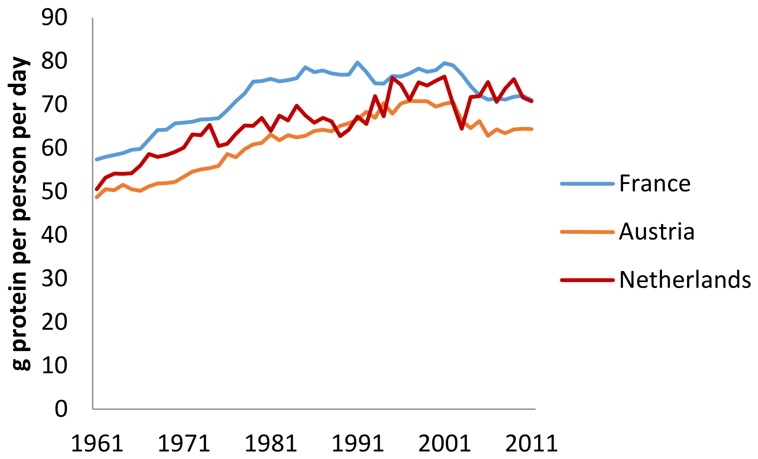


Figure 7 Consumption of animal protein in France, Austria and the Netherlands, between 1961 & 2011.

Increase in urbanization

Urbanization is defined as an increasing share of a nation's population living in urban areas (Satterthwaite et al., 2010). Most people move to urban areas in a response to better economic prospects compared with their home farms or villages. Urban areas have many advantages for improving living conditions, such as infrastructure and medical services. In 2008 the world's urban population exceeded the rural population (UNFPA, 2008). It is predicted that in 2050 two-third of the world population lives in urban areas. Also in the EU a strong trend of urbanization is observed, which is expected to continue in the coming years up to 2050 (Figure 8). Urbanization alters patters of food consumption, which may influence the demand for livestock products (Thornton, 2010). People in cities typically consume more food away from home and larger amounts of pre-cooked, fast and convenient foods than do people in rural areas (Satterthwaite et al., 2010).

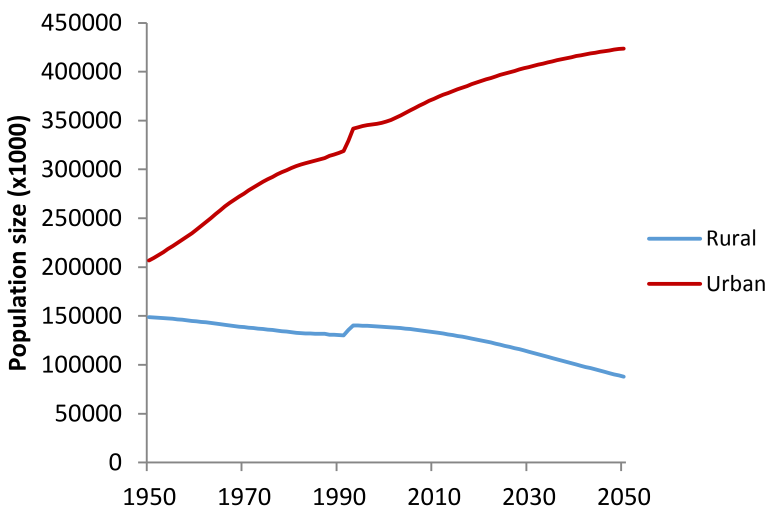


Figure 8 Urban and rural population development in the EU since 1950 and predicted population development up to 2050.

3.2 Political environment

The Common Agricultural Policy (CAP) is one of the oldest policies of the European Union. About 45% of the EU budget is used for agricultural, making CAP one of the most important EU policies (EU, 2016). The CAP was established after the wars in 1962 and aimed to feed the EU population. To accomplish this aim, incentives to increase production were provided by direct production support, border protection, and export support. Although sectors, as the pig and poultry sector, were never directly supported by the EU, they indirectly benefitted from CAP support through the subsidized cost of feed (Giannoccaro et al., 2015). Subsidized cost of feed encouraged an increase in production and, together with technological progress, this has led to intensification. The CAP was successful, even so successful that the policy resulted in a surplus of some livestock products, such as milk and butter. Those surplus products were sold on the world market for very low prizes. This resulted in problems in developing countries where farmers were not able to produce for such low prizes. To solve those problems the CAP needed a reform. The CAP reform in the 1990's, therefore, aimed to support extensive livestock production. A number of measures were taken to reach that aim, such as an upper stocking rate limit per farm unit and extensification premia. Extensification premia were supplementary payments for farmers that had a stocking density below 1.4 LU/ha. In 2003, the CAP reform focussed on decoupling, meaning, for example, that farmers were no longer paid according to the number of animals they kept. Measures such as extensification payments, agri-environmental scheme (AES) payments and less favourable Areas compensatory payments aimed to maintain diversity of livestock production systems (Giannoccaro et al., 2015).

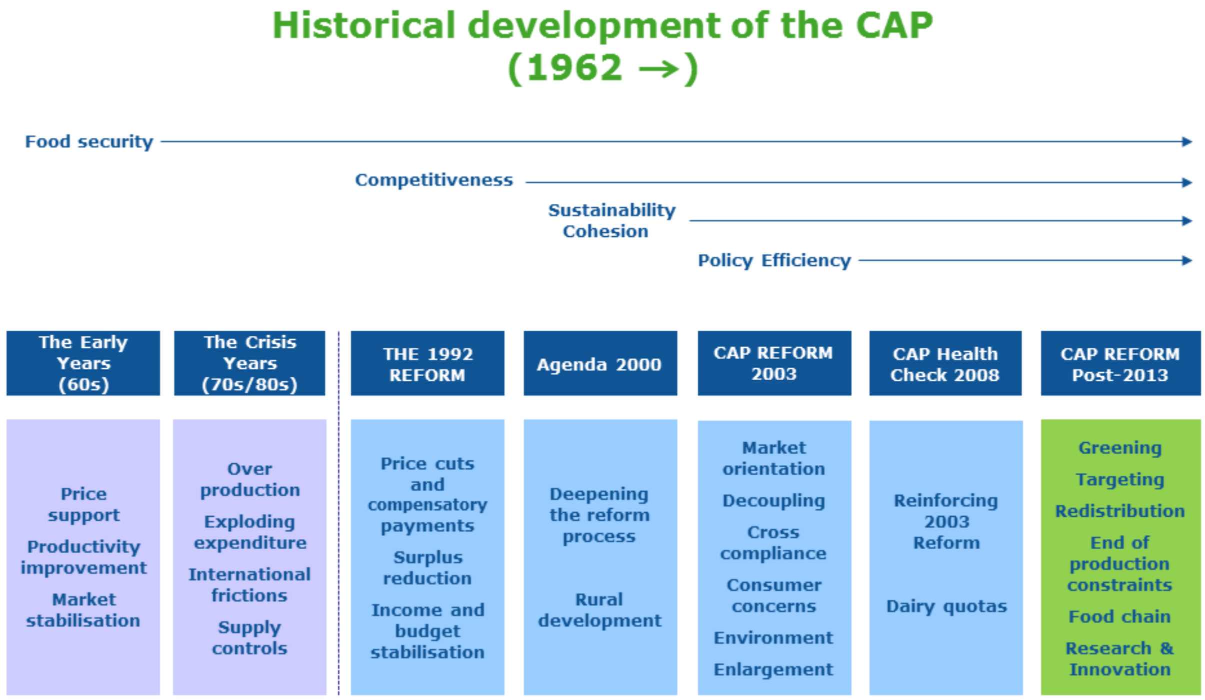


Figure 9 Historical development of the Common Agricultural Policy (CAP) (EU, 2016).

So, over the years CAP had changed substantially and currently tackles new challenges in search of a fairer and greener more competitive agriculture as displayed in Figure 9. More information about the historical development of the CAP can be found at http://ec.europa.eu/agriculture/cap-history/index_en.htm. In 2013 the CAP latest reform, three long-term objectives were developed to accomplish a fairer, greener and more competitive agriculture namely: viable food production, sustainable management of natural resources and climate action and balanced territorial development. To accomplish those objectives, the EU agriculture needs to attain higher levels of production of safe and quality food, while preserving the natural resources that agricultural productivity depends upon. The 2013 CAP no longer focuses on direct production support, but separate farm payments from production with additional 'greening requirements' (Andrew et al., 2016). In 1992 over 90% of total CAP budget was devoted to direct production supports. By the end of 2013 it decreased to 5%, and 94% of the budget was decoupled from production. Some main changes for the livestock sector are listed below:

- The abolition of the milk quota.
- Facilitated negotiation process between milk producers and milk processors. Dairy farmers negotiate about contract such milk price with producer organizations.
- 30% of the EU agricultural subsidies relates to measurements to improve the environment.
- Countries can support specialist beef production in marginal farming areas through coupled payments.

As research showed that CAP reforms in the past had a significant influence on the majority of livestock systems (Lefebvre et al., 2012; Giannoccaro et al., 2015) it is expected that the CAP reform of 2013 will also have an influence on livestock production. Giannoccaro et al. (2015) analysed, therefore, the post-2013 CAP influences on farmer decision making in terms of how many livestock units to keep. The results show that the member states that have most recently gained accession are most sensitive to CAP reforms, along with organic farmers and livestock systems located at hilly and mountainous areas. All are expected to show a decline in their numbers of livestock, while specialist dairy units are expected to increase (Giannoccaro et al., 2015). As the abolition of the milk quota is one of the big reforms and effects national policy we will zoom into this topic in more detail in 5.1.

3.3 Environmental issues related to livestock production

Food production impacts the environment via its emissions to air, water, and soil (Foley et al., 2011; Searchinger et al., 2013). The livestock sector, furthermore, competes increasingly for scarce resources, such as land, water, phosphorus sources, and fossil energy (Steinfeld et al., 2006; De Vries and De Boer, 2010; Leip et al., 2015). Below we explain in more detail the impact of livestock production on climate change, eutrophication, and acidification. Resource use will be discussed in more detail in 4.3. The environmental impact of different products on the environment is discussed in chapter 4.4. Another important environmental issue is biodiversity. Livestock affects biodiversity through land use mainly. Livestock production directly or indirectly modifies biodiversity habitats in about 30% of the global terrestrial area, dedicated to pasture or feed crops (Ramankutty et al., 2008). So far, however, a precise estimate of the effect of livestock production on biodiversity loss is missing, both at EU and global level.

Climate change

Food consumed in Europe is responsible for about 31% of the total European anthropogenic greenhouse gas emissions (Guinée et al., 2006; Huppes et al., 2006; Tukker and Jansen, 2006). The accumulation of greenhouse gasses in the atmosphere contributes to climate change. Climate change can have a negative impact on human health (Walther et al., 2002; McMichael et al., 2006), and caused an increased rate of sea-level rise in the last decade

(Church and White, 2006), increased bleaching and mortality in coral reefs (Stone, 2007) and increased the rate of large floods (Milly et al., 2002). Worldwide food consumption causes about 25% of the global anthropogenic greenhouse gas emissions (Tilman and Clark, 2014), the majority (60%) of this originates from livestock production (Gerber et al., 2013). Goodland and Anhang (2013), however, claim that over 50% of the global GHG emissions are related to livestock. The main difference between the estimation of Gerber et al (2013) and Goodland and Anhang (2009) is the inclusion or exclusion of respiration of CO_2 by livestock. Gerber et al. (2013) excluded CO_2 emissions from respiration by livestock, whereas Goodland and Anhang (2009) included CO_2 emissions from respiration by livestock. According to international guidelines on computation of GHG emissions from agriculture, however, CO_2 emissions from respiration by livestock are not included in the GHG calculations because they are assumed to be balanced by the CO2 uptake by the plants consumed by these animals.

Food production is responsible for more than 50% of all eutrophication in Europe (mainly via emission of nitrate (NO_3^-) and phosphate (PO_4^{3-}) to water; and ammonia (NH_3), and nitrogen oxide (NO_x) to air) (Guinée et al., 2006). Eutrophication (also referred to as nutrification) is associated with the environmental impacts of excessively high levels of nutrients that lead to shifts in species composition and increased biological productivity, for example algal blooms. Eutrophication is a phenomenon that can influence both terrestrial and aquatic ecosystems. Nitrogen (N) and phosphorus (P) are the two nutrients most implicated in eutrophication. In most terrestrial, natural ecosystems, the amount of N is the limiting nutrient and an increase of N will stimulate plant growth. N-eutrophication (for animal production, mainly NO_x, NH_3, NO_3^-), for example, has three main effects. First, the composition of vegetation changes towards N-loving species, which supersede rare plants typical of N-poor ecosystems. Second, the nutrient balance in the soil is disturbed, resulting in an increased risk of vegetation damage. Third, surplus N in the form of nitrate leaches to the ground water (Lekkerkerk et al., 1995). A high nitrate level in food or drinking water causes oxygen deficiency in blood, especially of small children (Davis, 1990).

In most freshwater systems, P generally is the factor limiting plant growth, and P-eutrophication (mainly PO_4^{3-}), therefore, results in excessive growth of algae and higher plants. When these overabundant plants die, their microbial degradation consumes most of the oxygen dissolved in the water, vastly reducing the water's capacity to support life. In many marine waters, however, N is often the growth limiting factor, although there are vast areas in oceans where several nutrients are limiting algae growth, including N, iron (Fe), copper (Cu) and zinc (Zn).

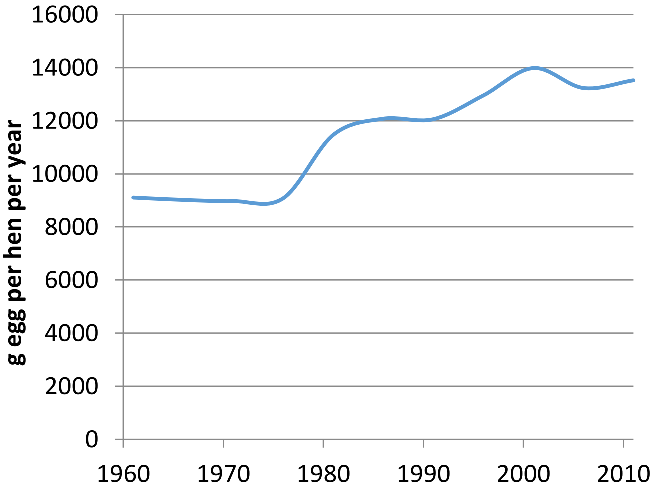
Acidification

Acidification of ecosystems results from emission of gasses (SO_2, NO_x, HCL, NH_3) into the air. What acidifying pollutants have in common is that they release protons (H^+ ions). A pollutants potential for acidification can thus be measured by its capacity to release protons. For example, NH_3 in the air neutralises atmospheric sulphuric or nitric acid and, when transformed into NH_4^+, is deposited on the soil. During nitrification of NH_4^+ into NO_3^- two protons ($2H^+$) are released. In an N-surplus situation, the net release of one proton eventually causes soil acidification.

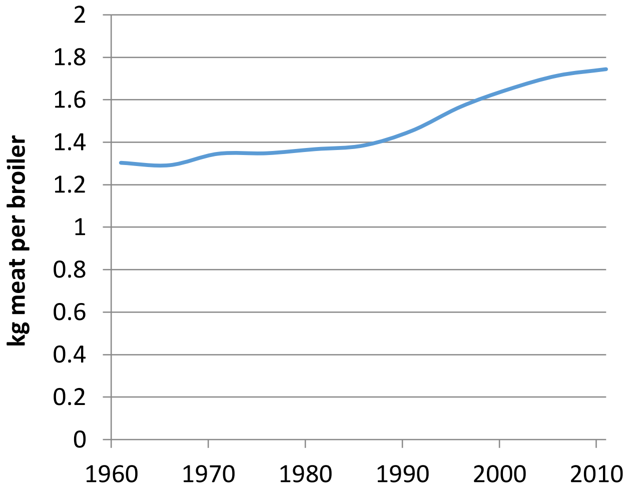
Acidification may result in a drop in soil pH and eventually in the release of free aluminium (AL^{3+}) ions in soil, which affects plant and root growth, increases risk of vegetation damage due to drought and diseases. Free Al^{3+} is also toxic for animals and humans, depending on its concentration.

3.4 Science and technological innovation

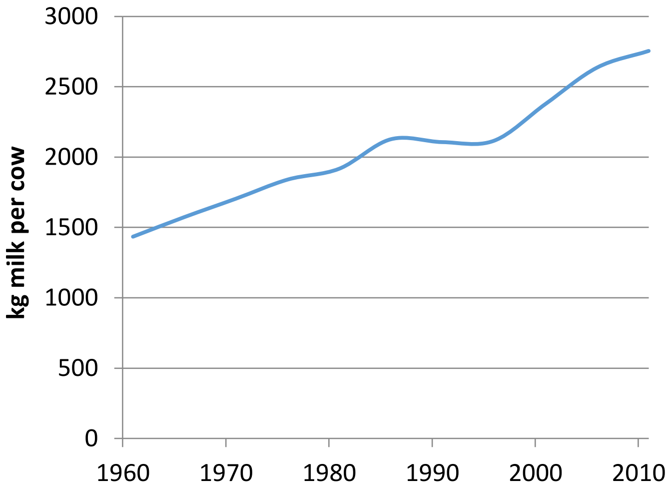
Animal productivity has increased enormously due to scientific development and technological innovations (Figure 10). Main drivers in the increase in animal productivity are developments in feeding, breeding, animal health, and livestock systems.



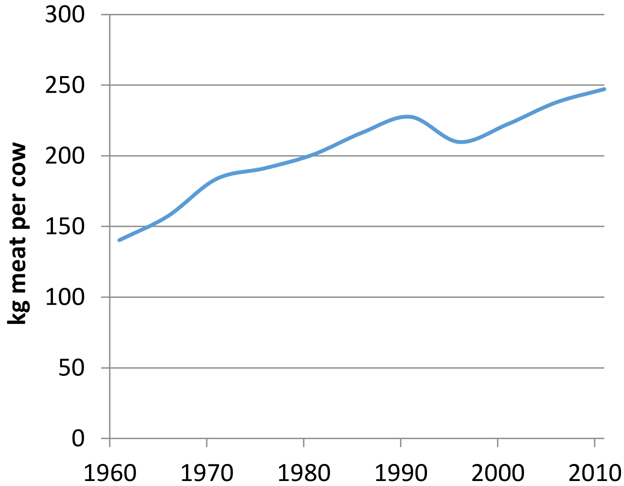
a) Egg



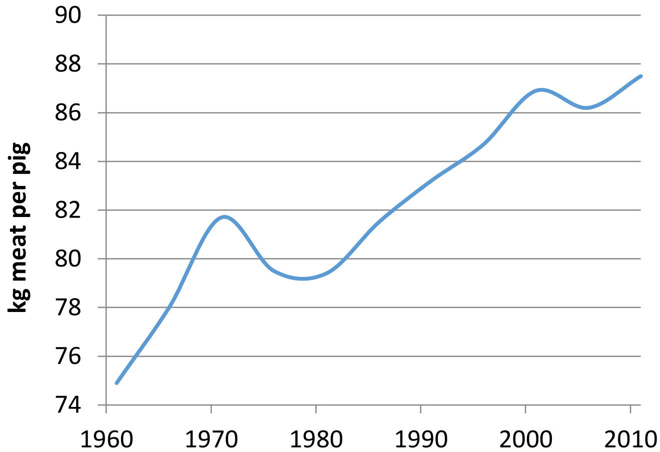
b) Broiler meat



c) Milk



d) Beef



e) Pig meat

Figure 10 Animal productivity in Europe between 1961 & 2011 (FAOSTAT)

Feeding strategies

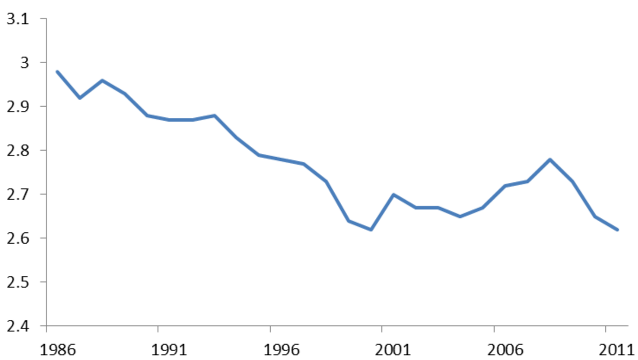
During the last decades the efficiency with which animals convert feed into animal products has improved significantly in the developed world, due to development and application of new technologies. Feed efficiency is defined as kg of animal product over kg of feed intake. Another measure of feed efficiency, which is commonly used, is the feed conversion ratio (FCR). The FCR generally is defined as the amount of feed used per kg of animal product. You have to be aware though, that the amount of feed consumed can be express in kg FM (fresh matter) or kg DM (dry matter), whereas the amount of animal product can be kg of live weight, kg of carcass weight, kg weight gain or kg edible meat. Moreover, FCR can be defined for an individual animal, or along the entire production chain. The exact definition of FCR, therefore, can have a huge impact on the final value.

The figure below shows the development of the FCR for fattening pigs in the Netherlands, defined as kg fresh feed per kg weight gain. The FCR of pigs decreased with 33% between 1986 and 2011. In general (for all livestock species) reducing the FCR can be achieved by balanced feeding, precision feeding, optimal use of amino acids and mineral micronutrients. High quality feed ingredients, therefore, are required. A shift from the use of low quality roughages, agricultural co-products or food waste towards high quality agro-industrial by-products and concentrates can be seen. As an example, about 70% of the cereal grains used in developed countries is fed to livestock. The increased use of concentrate feed explains the rapid growth in production of monogastrics, especially poultry. A disadvantage of the increase in grains, however, is that those grains are also suitable for human consumption. No matter how efficiently food is produced, direct consumption of cereals by humans is ecologically more efficient than consumption of livestock fed with these cereals. One way to measure the efficiency of livestock systems in producing food, is to compute human-edible energy and protein conversion ratios. These conversion ratios represent the amount of energy or protein in animal feed that is potentially edible for humans over the amount of energy or protein in that animal product that is edible for humans. Ratios above 1, which we commonly observe for EU broilers, laying hens, pigs, and grain-fed cattle, are unsustainable, because animals produce less edible energy than they consume (Wilkinson, 2011). A ratio above 1 implies that animals produce less energy or protein than they consume, which is unsustainable from the perspective of global food security. A ratio below 1, which is often the case for EU milk production systems, does not immediately imply efficient land use in terms of global food security, because these conversion ratios do not yet include the fact that, for example, grass fed to dairy cows can be produced on land suitable for the cultivation of human food crops, or in other words, they do not include the opportunity costs of land for human food production.

So, from an animal perspective using high quality feed cultivated on highly productive croplands results in a better animal performance (better FCR). However, improving land use efficiency of livestock systems from the perspective of food supply would imply feeding livestock mainly by-products from arable production or the food processing industry, that are not edible for humans; or grazing of livestock on “marginal land”, i.e. land with low opportunity costs for arable production.

Breeding strategies

Besides feeding technology, breeding technology has significantly improved animal productivity. The speed and precision with which breeding goals can be achieved has increased considerably over the last decades. Genetic advances are much faster in shortcycle animals, such as poultry and pigs, than in species with a longer generation interval, such as cattle. In all species, feed efficiency and related parameters, such as growth rate, milk yield and reproductive efficiency, have been major targets for breeding efforts. Figure 11b shows, for example, that the number of piglets per sow in the Netherlands increased with 32% between 1986 and 2011. Note, however, that this increase is not only due to genetic improvements but also due to e.g. improvement in animal health or housing systems. Genetic improvements related to consumer demands such, as fat content, are also of increasing importance. While advances have been made in breeds developed for temperate regions, results have been limited in development of breeds of dairy cows, pigs and poultry that perform well in tropical low-input environments.



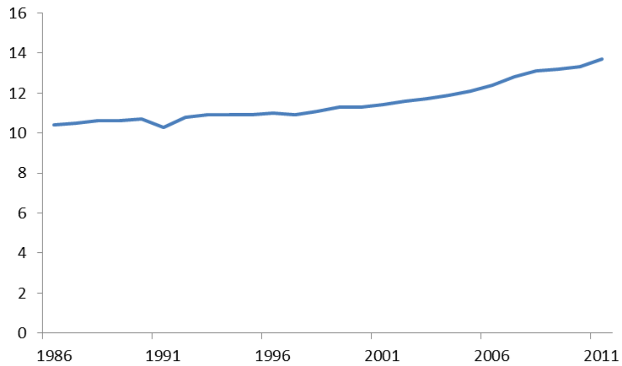


Figure 11a: feed conversion ratio of growing pigs (kg feed/ kg bodyweight) and b) number of piglets per sow between 1986 & 2011.

Livestock systems

Technological developments resulted in changes in livestock production systems as well. As a consequence we have seen considerable structural changes in EU livestock farming since the 1980s. Smallholders on mixed farms have gradually given way to larger-scale, specialised livestock holdings (EU stat). So, farming systems become more intensive in terms of animal numbers, animal density and animal productivity. Since the early 1980s, there has been a steady downward trend in the number of livestock on agricultural holdings across the EU (EU stat). Intensive farming systems have economic advantages, especially in poultry and pig production. Therefore, much of the production response to the growing demand for ASF has been through industrialized production. Intensive livestock systems are characterised by intensive use of inputs (e.g. feed), technology and increased specialization of production, focusing on a single species. Feed ingredients are cultivated off-farm, either domestically or internationally. Mechanical technologies substitute human labour, e.g. milking robots. In the Netherlands we see roughly that about 75% of the dairy farmers are specialized farmers. Those farmers intensified their system resulting in an increased number of animals per farm and an increased production per animal (Figure 12 and Figure 13). The other 25% of the farmers in the Netherlands diversified their activities. Those farmers have certain side activities, e.g. home-selling of cheese, camping sites or bed and breakfast. In the figure below you can see that the number of pig farms in the Netherlands on average decreased, while the number of fattening pigs per farm increased.

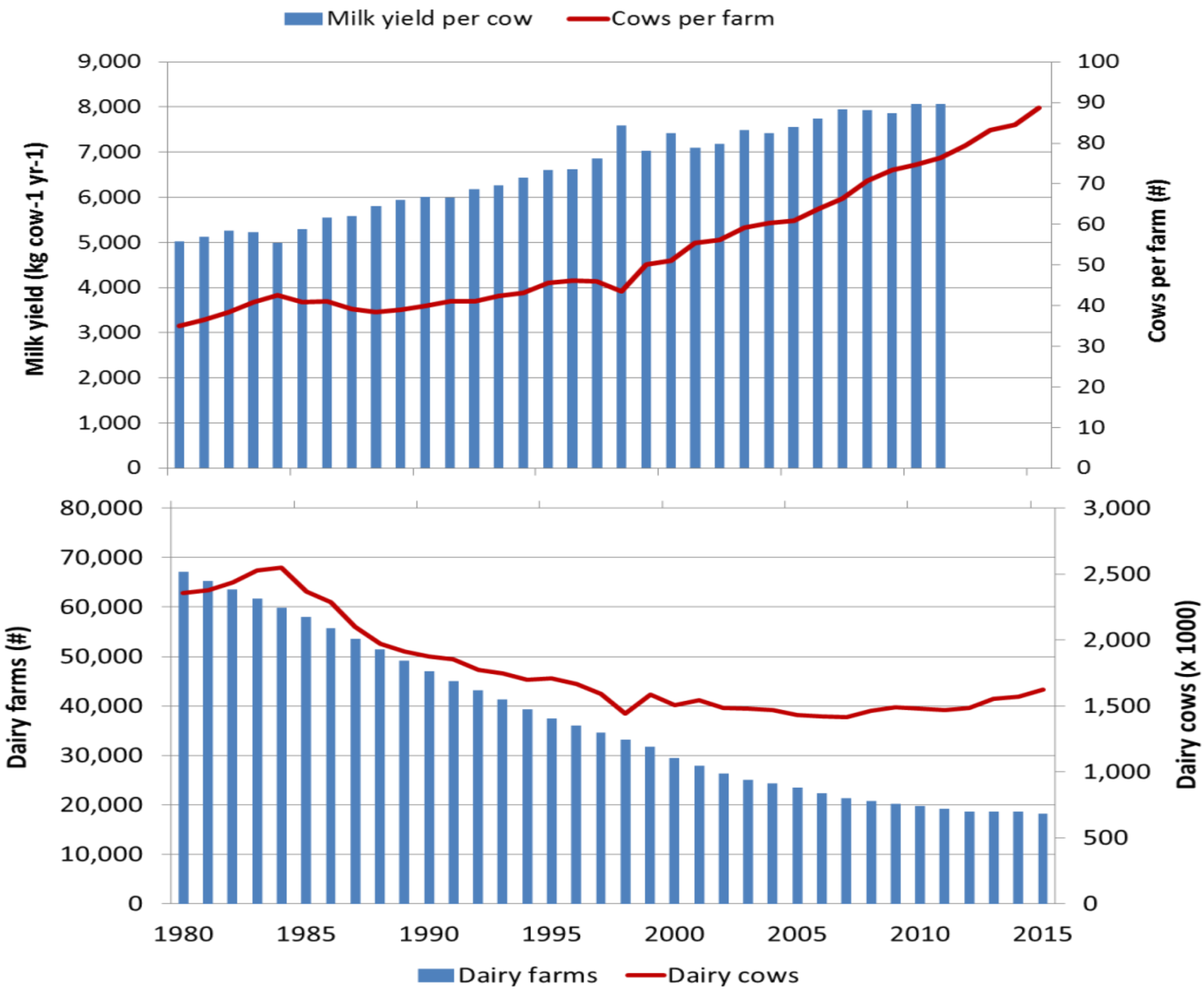


Figure 12 Relation between productivity and farm size (above) and number of dairy farms and dairy cows (below) in the EU between 1980 &2015

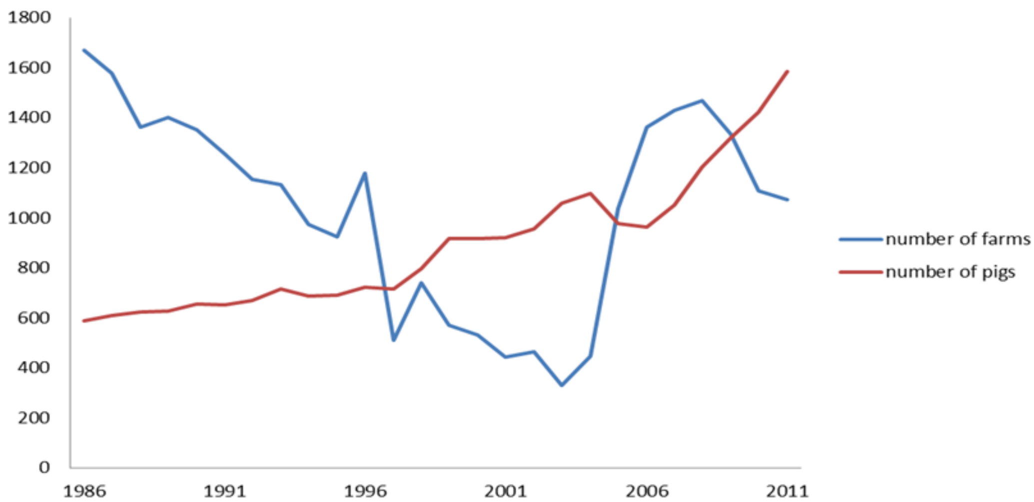


Figure 13 The number of farms and the number of fattening pigs per farm between 1986 and 2011.

3.5 Culture and lifestyles

Consumer demand in Europe

Consumer behaviour is changing, and this is especially true for their behaviour concerning the purchase of animal products, in particular meat. Consumers are becoming richer and food is not only perceived as nourishment, but also plays a role in “enjoyment, preference, ethics, culture, safety, prestige, impulse” (Gracia and Albisu, 2001). Four major trends were identified by Gracia and Albisu (2001) to describe food consumption in the EU:

1. The proportion of total expenditure allocated to food products is reducing even further, which is a typical consequence of increasing wealth;
2. High quantities of food are consumed;
3. There is a change in the structure within meals and within a day;
4. More and more of the meals are consumed outside of the home, and instead in restaurants, schools and at work places.

Consumers expect two things from their food products:

1. Respect of traditions of local culture in the preparation of the food,
2. Healthy and safe food respecting both animals and the environment, with a heightened interest in local and organic products (Hodges, 2003; Hodges, 2006).

Consumers are demanding more and more information and adequate labelling of their food products. Consumers are concerned about the quality of the food products they purchase, but they are increasingly affected by quality cues other than those shown by the meat itself, i.e. extrinsic cues. For example, organic meat is perceived as being of higher quality than conventional meat (Figure 14). In a German study (described in Grunert, 2006), participants were asked to rate different extrinsic cues of pork meat products based on how well they understood them and how important they thought they were (Figure 15). They were then asked to provide reasons for the importance of the 5 top cues (Figure 16). The 5 most important extrinsic cues were ‘No GMO feed’, ‘Fat percentage’, ‘No pesticide residues’, ‘Animal friendly transport’ and ‘Animal friendly farm’. The reasons given when asked why these are important revolved around health concerns and responsibility for nature and all living things.

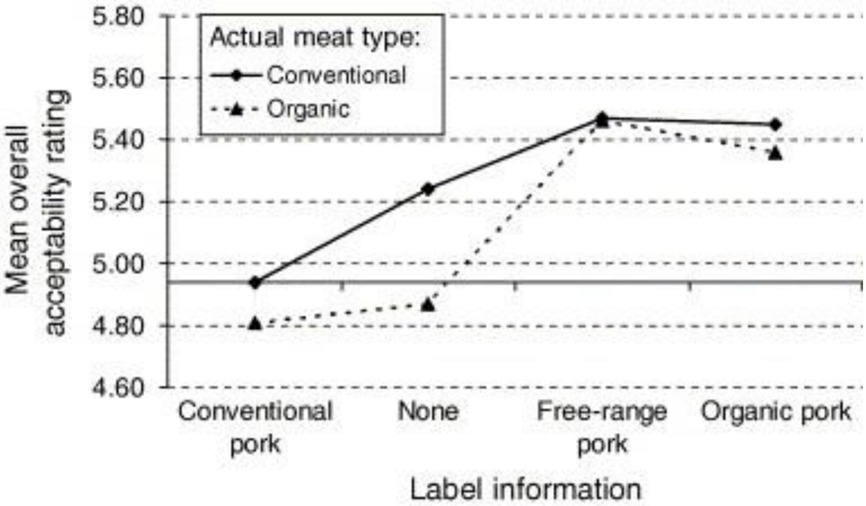


Figure 14 Impact of label information on perceived quality of pork meat. Source: Grunert (2006).

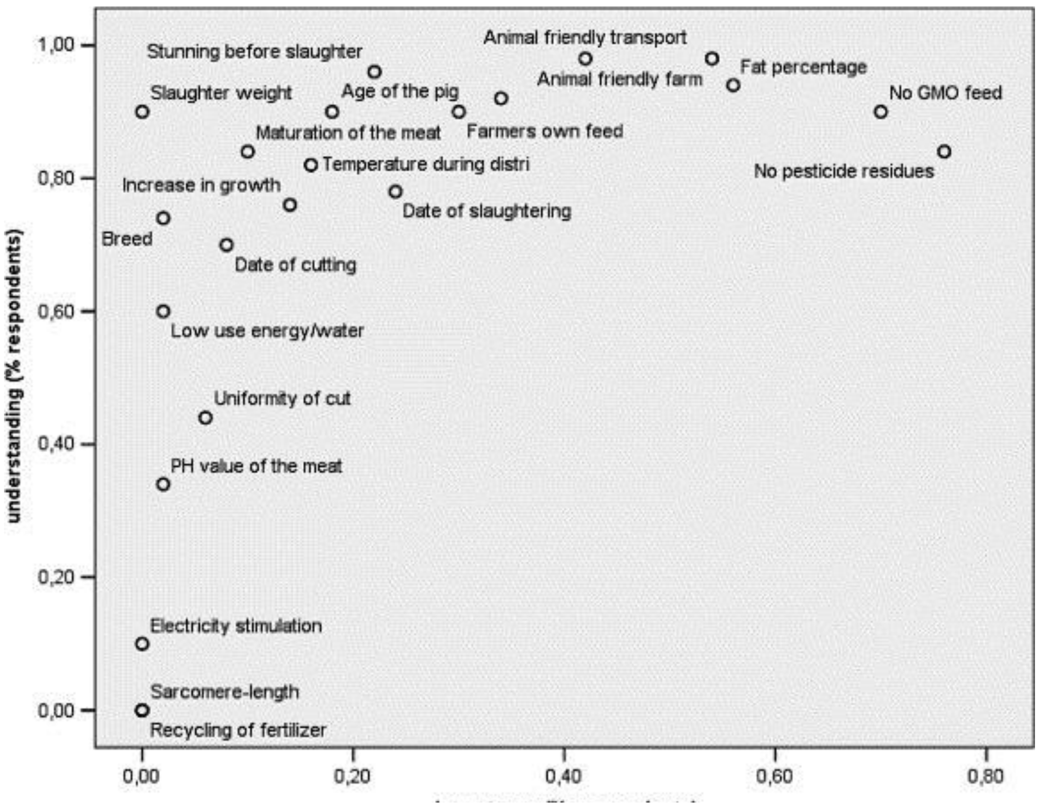


Figure 15 Ratings of different types of information about pork meat products based on how well they were understood and how important they were perceived to be. Source: Grunert (2006).

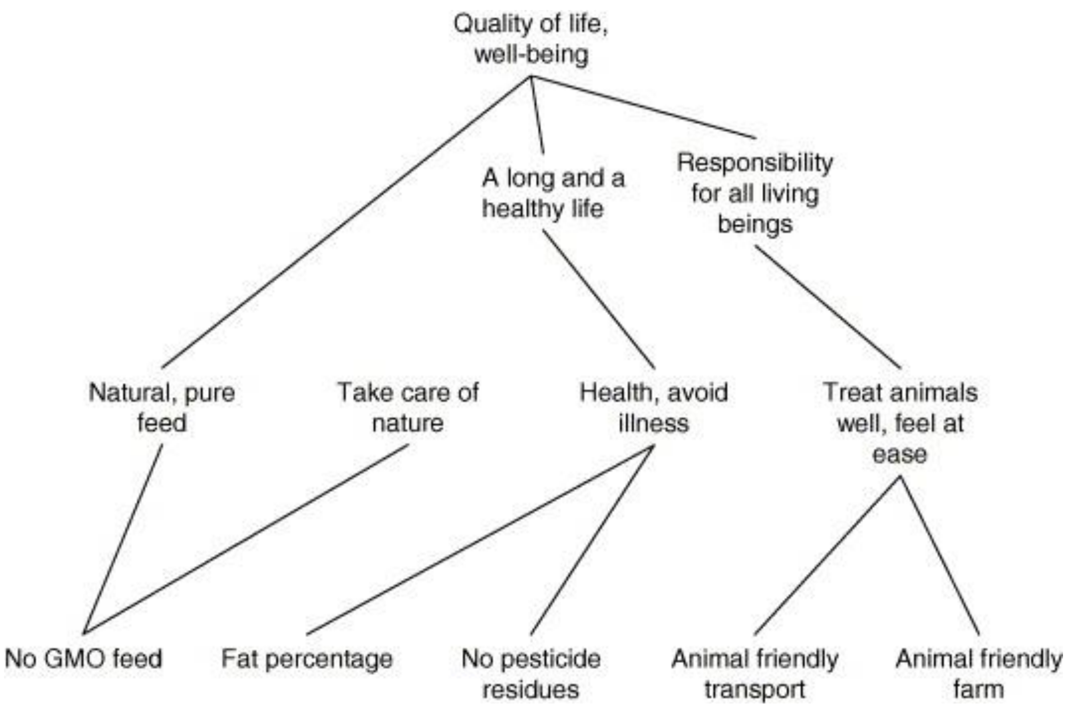


Figure 16 Reasons given for the importance of the five more important components presented in Figure 2. Source: Grunert (2006).

With the increasing demand for information, there is also a lack of trust due to certain so-called 'food scandals'. This increase in demand for information may also stem from the increase in consumption of processed food, with ingredients being less obvious/visible.

Many of the preferences demonstrated by consumers are based on familiarity and habit (Gracia and Albisu, 2001). These cultural differences in diet within Europe originally came from variations in the availability of food products. For example, countries around the Mediterranean consume much olive oil, because that is where it is produced and thus the availability was high in the past, but countries in Northern Europe do not, despite this product being now readily available across Europe (described in Gracia & Albisu, 2001).

French consumers are more conscious of quality, while German consumers and more conscious of health and environmental aspects (reviewed in Gracia and Albisu, 2001). Most French, Spanish and Italian consumers are very focused on tradition and are not interested in fast food options, whereas German consumers are more focused on health than tradition, and consequently consume many fruits and organic products (Gracia and Albisu, 2001). French, German, British and Danish consumers were further classified into five categories: uninvolved (price focused), careless (focused on ease of cooking), rational (focused on health and environment benefits), conservative (stick to habit, no interest in new products) and adventurous (focused on self-fulfilment, creativity and social events) (reviewed in Gracia and Albisu, 2001). European consumers have also been divided into the 'Northern European consumers', with meals consisting of one dish of meat and vegetables, and 'Southern European consumers', with meals consisting of many smaller dishes (Gracia and Albisu, 2001). The distribution of sales across different types of retail is shown for selected EU countries in Table 1. Novel (electronic) distribution means, drive consumers to search increasingly for convenience and specialties (Gracia and Albisu, 2001)

Table 1. Percent sales in different types of retail in Europe in 1998. Source: Gracia and Albisu (2001).

Country	Hypermarket	Large supermarket (1000 to 2500 m2)	Small supermarket (400 to 1000 m2)	Self-service	Traditional
Austria	12	15	40	29	4
Belgium	15	43	30	8	5
Denmark	17	22	36	22	2
Finland	23	25	26	22	4
France	51	24	20	5	0
Germany	25	18	36	16	6
Greece	9	14	32	22	23
Ireland	11	32	10	41	6
Italy	14	18	21	24	22
Netherlands	5	29	54	11	1
Portugal	41	18	11	11	19
Spain	34	11	15	19	21
Sweden	13	35	32	17	3
UK	45	29	13	8	5

A good understanding of cross-cultural differences in the perception of risks is also important as this may affect how different countries (in Europe) will respond to novel technologies, such as for examples genetic engineering, and these disparities can cause conflict (Finucane & Holup, 2005).

Demand for organic products

There is currently a rapid increase in the demand for sustainable, organic and local food products (reviewed in Kearney, 2010). Organic production in particular has seen a tremendous growth recently with an 82% increase from 2006 to 2008 (Kearney, 2010). The amount of organic land accounted for 30.4 million hectares worldwide in 2010 (Kearney, 2010). In Europe, 5% of the land is certified organic, with the main countries involved in organic production being Italy, Germany and the UK. The main two reasons put forward by consumers for buying organic food are that it is healthier and better for the environment.

A vegetarian lifestyle

The first vegetarian society was established in the EU, in 1847 England, followed by the International Vegetarian Society founded in 1908. In the 1960s and 1970s, vegetarian diets were thought to be linked to a risk of nutrient deficiency, and were as a consequence not popular amongst the general western population. Health benefits of these diets became known via epidemiologic studies in the 1980s and 1990s, demonstrating positive impacts on obesity, ischemic heart disease, diabetes, certain types of cancers and overall longevity (Leitzmann, 2014). Increasing scientific evidence of these positive impacts of vegetarianism on health, as well as increasing ethical, environmental and social concerns regarding animal products, has slowly lead to an increase in acceptance and popularity of vegetarian diets. Vegetarian diets, however, still represent a minor part of worldwide diets, except in India where one third of the population is vegetarian due to their religion (Table 2). Leitzmann (2014) states four main reasons why vegetarianism is probably going to increase in coming years: 1. Ethical concerns about the way farm animals are raised and an increased interest in organic practices; 2. Concern about the environment and global warming, and a wish to minimise waste and excesses; 3. Health concerns, arisen from both poor nutrition and zoonoses; 4. Concern of overall sustainability and the preservation of a good quality of life for generations to come.

Table 3. Proportion of vegetarians in selected countries. Source: (Leitzmann, 2014).

Country	Proportion of vegetarians (%)
India	35
Italy	9
Great Britain	9
Germany	9
Netherlands	4
USA	4
Canada	4
Austria	3
Switzerland	3
France	2

Culture

Culture is defined as the shared values of a race, nation or group of people, with values being defined as highly valued objectives, whereas ethics are defined as the "moral component of decisions reflecting self-interest or concern about the well-being of others" (Hodges, 2006).

"The changing culture of Western society is now embracing values beyond cheap food" (Hodges, 2006). An important part of agricultural sustainability is societal values, which indicates that agricultural sustainability is not fixed in time, and will change as values vary (Boogaard et al., 2008). Livestock production systems are valued by society other than simply because of their role in food production, for example, they hold value through farming activities, farm income, animals, landscape, nature, environment, farming culture, national culture and services for society (Boogaard et al., 2008).

Old cultural landscapes in Europe are threatened by modern agriculture, urbanisation and recreation (Vos and Meekes, 1999), but it is difficult to maintain these landscapes and define their importance by valuing them economically (Vos and Meekes, 1999). What is the (economic) value of nature? What is the value of culture? These questions need answering to help protect important cultural landscapes in Europe (Vos and Meekes, 1999). On top of old landscapes, traditional breeds of livestock also have an important cultural value to local inhabitants (Yarwood and Evans, 2003). The maintenance of these traditional breeds of livestock is now stimulated by the European legislation. "Research has revealed that there is a distinct geography of livestock breeds and that specific breeds of traditional farm animals can contribute to local identity, culture, landscape character and, in particular, environmental management" (Yarwood and Evans, 2003). Particular breeds of livestock, instead of species, have been shown to contribute to linking agriculture with the environment, by:

1. Contributing to biodiversity by maintaining unique genetic material, as well as reducing environmental impact by forcing lower levels of farming intensity;
2. Helping with conservation via their unique grazing/feeding habits;
3. Contributing to the identity of local rural environments;
4. Being part of environmental heritage (Yarwood and Evans, 2003).

4 Direct drivers of livestock producers in the EU

4.1 Regulatory environment per country: the abolition of the milk quota in the Netherlands as a case

CAP reforms are imbedded in national policies. One of the latest changes within the CAP reform was the abolition of the milk quota, which largely affected the dairy sector. In this chapter we will describe how the abolition of the milk quota influences the Dutch dairy sector, affects other regulations, and the environment. The Netherland is chosen as an example because livestock density in the Netherlands is the highest of Europe.

Impact of the abolition of the milk quota on milk production and milk prices

In 1984, milk quotas were introduced in Europe to address oversupply in the market. The quota policy restricted the amount of milk to be produced by each member state, and consequently by individual farmers. Since April 2015, the EU milk quota system is abolished, as a response to the increasing global demand for milk and to agreements on trade liberalization in global dairy markets (EU, 2015). The abolition of the quota system allows farmers to increase their milk production, resulting in an increase in milk production in EU (Figure 17 and 18). In 1983, the year before the implementation of the milk quota, milk deliveries in the Netherlands was about 13.2 billion kg. After the implementation of the quota system, milk deliveries rapidly decreased and stabilised in 2005, around the 11 billion kg (Figure 18). The incremental abolition of the milk quota in 2006 resulted in a slow increase of milk deliveries (Figure 18) (www.zuivelnl.org, 2016). Compared to 2015, 2016 levels are even higher showing that production levels continue to increase (Figure 19). Although milk production is increasing, we still see a decrease of the number of farms and a strong increase in the numbers of cows per farm, as described before in chapter 4.4.3 (Figure 12). From 2013 onwards, when we see a strong increase in milk production, we also see that milk prices and farmers income are decreasing from 2014 onwards (Figure 20 and Figure 21).

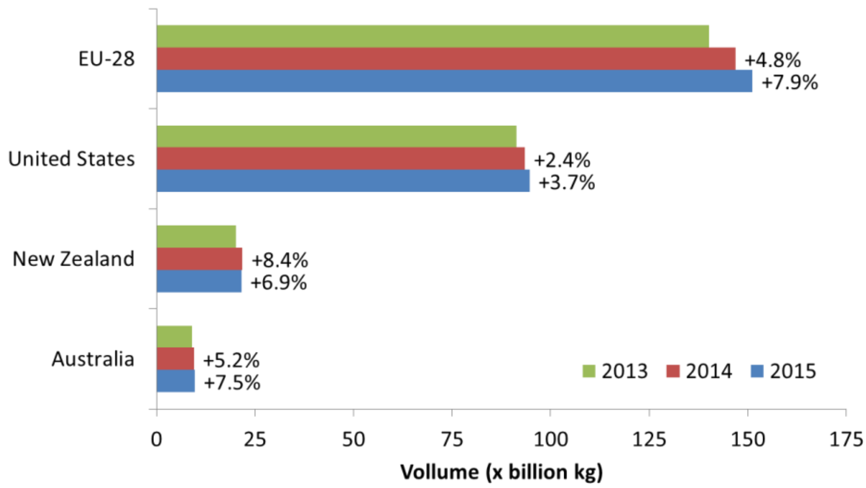


Figure 17 Milk deliveries in EU-28, United States, New Zealand, and Australia, in 2013, 2014 & 2015 (www.zuiverlnl.org)

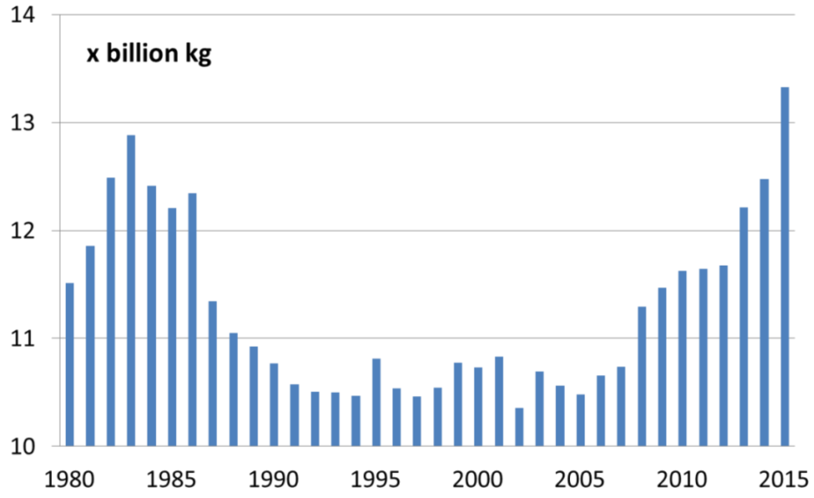


Figure 18 Milk deliveries in the Netherlands (from CBS, 2016).

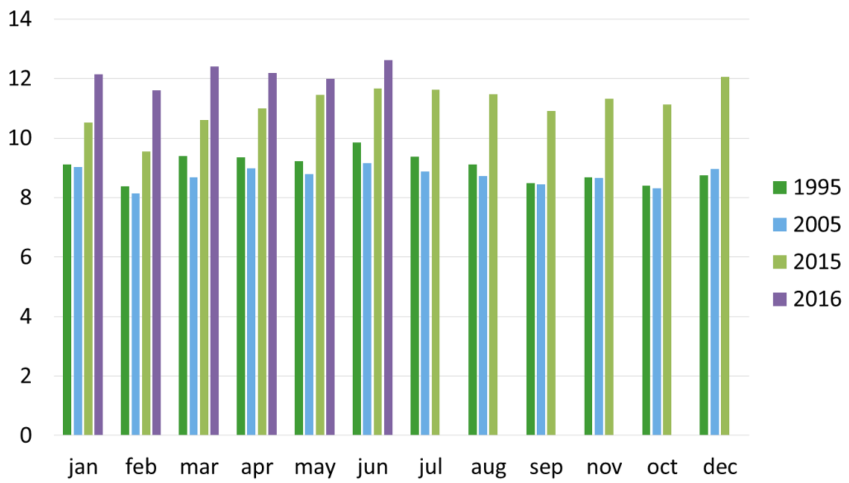


Figure 19 Milk deliveries in the Netherlands per month, showing a continuous increase after the abolition of the milk quota.

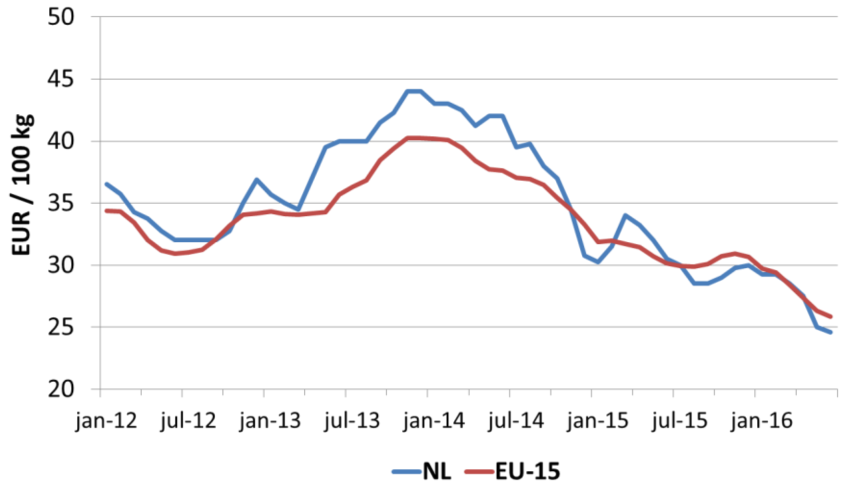


Figure 20 Development of European and Dutch milk price between 2012 & 2016.

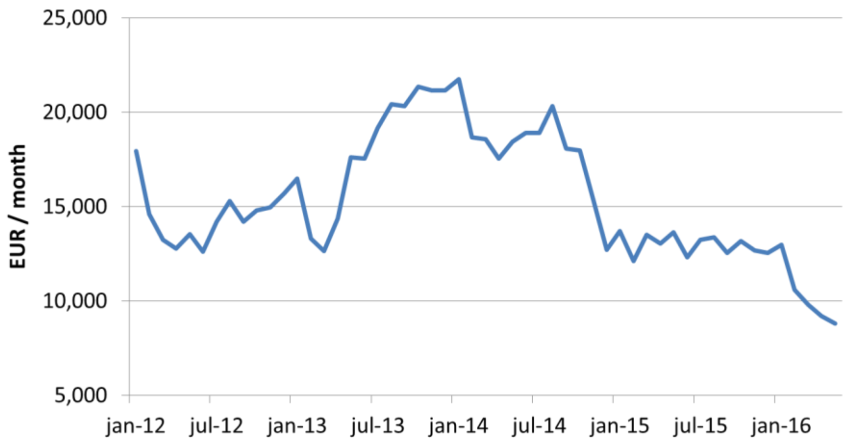


Figure 21 Gross margin (in €/month) from milk production in Europe between 2012 & 2016.

Impact of the abolition of the milk quota on Dutch environmental policies.

A high livestock density in the Netherlands results in a high production (i.e. excretion via manure) of nitrogen (N) and phosphate (P_2O_5) per ha, which causes environmental problems, such as eutrophication of ground and surface water (Oenema et al., 2005). To control N and P surplus in relation to milk production, Dutch dairy farmers have to comply with EU and national environmental regulations. Below we provide an overview of the Dutch environmental policies and how they are affected by the abolition of the milk quota based on recently published work of Klootwijk et al. (2015).

Already in 1991 the European Nitrates Directive was introduced, aiming at reducing the negative effects of nitrogen surpluses on water quality (Nitraatrichtlijn, 2014). To ensure compliance with the Nitrates Directive, the Netherlands introduced the mineral accounting system (MINAS) in 1998. MINAS was based on a farm-gate balance approach, using farm level inputs and outputs to determine a farm specific surplus of N and P_2O_5 (Oenema and Berentsen, 2005). Nutrient surpluses at the farm level that exceeded levy-free surpluses were charged. MINAS was considered a step forward in environmental policy, because a nutrient surplus is a better indicator for nutrient leaching than manure application standards, and because MINAS gave farmers the autonomy to determine how to reduce their surplus.

A judgement of the European Court about the lack of compliance of MINAS with the Nitrates Directive, in combination with other practical reasons like increasing administrative burdens and possibilities of fraud, led to the abolition of MINAS in 2006, and to the introduction of three fertilizer application standards, being the third milestone. The first standard comprises a maximum application of 170 kg nitrogen from animal manure per ha of land. Several member states, including the Netherlands, obtained a derogation to go beyond the 170 kg limit, under certain country-specific conditions. Derogation is specific for these member states because they have a high proportion of grassland and a relatively long growing season, justifying a higher nutrient uptake (EU, 2010). Current derogation regulation in the Netherlands prescribes that farms with at least 80% grassland are allowed to apply, dependent on soil type and region, 250 kg of nitrogen from animal manure per ha on all of their land. Farmers that get this derogation are not allowed to use synthetic phosphate fertilizer. To receive derogation for the period 2014-2017, the Netherlands have to comply with a phosphate production ceiling of 172.9 million kg per year and a nitrogen production ceiling of 504.4 million kg per year for the entire Dutch livestock sector. In addition, the second standard comprises a maximum application of nitrogen fertilizer per ha of land, including mineral nitrogen from manure, and accounts for nitrogen fixation, deposition and mineralization. The third standard comprises a maximum application of phosphate fertilizer per ha of land, including phosphate from manure. Although there is a certain overlap between the first and second standard, all three standards apply to every Dutch dairy farm. The application standards for nitrogen and phosphate fertilization were decreased several times over the past decade. Farmers exceeding these standards can be brought to court.

To comply with the phosphate production ceiling set by the EU as a condition for derogation, the Dutch government prescribed the dairy sector a phosphate production ceiling of 84.9 million kg per year based on the production level in 2002. In 2014, however, this limit was exceeded with 0.7 million kg of phosphate (CBS, 2015). To limit further growth as a result of the quota abolition, a new manure policy, referred to as the ‘Dairy Act’, was adopted in December 2014 as a framework law. This Dairy act prescribes routes for handling the phosphate surplus at farm level and limits an increase in phosphate production at sector level. The concrete content of this law consists of three parts that were developed over time based on progressive insight. Figure 22 shows the implication of these three parts for a farm of which the area remains constant, but the number of animals increases.

The starting situation is given by the reference phosphate surplus of a farm in 2013 which is defined as the production minus the application room (refer to surplus A in Figure 22). Phosphate production is defined here as the number of livestock times fixed phosphate excretions per type of livestock, and phosphate application room as the number of hectares times the phosphate application standards. Previous legislation stipulated that part of the reference surplus should be processed based on region-specific rules (i.e., 30% in the South, 15% in the East, and 5% in other regions of the Netherlands; Nitraatrichtlijn (2014)), the remaining part can be disposed to other Dutch farms with application room.

The first part of the Dairy act, developed in 2014 and introduced in 2015, prescribed that any increase in phosphate surplus on top of the reference surplus needs to be fully processed. Manure processing implies manure treatment in such a way that phosphate is removed from the national manure market, which can be done by manure destruction (incineration or gasification to ash), manure treatment or by exporting manure. When developing the second part of the Dairy act in the course of 2015, a maximum was set to the volume of the extra phosphate surplus that may be fully processed (refer to surplus B in Figure 22). This maximum was determined by the phosphate production of a farm in 2014.

The second part will be introduced in 2016. In an attempt to tie dairy production more closely to the use of land within the same farm, any phosphate surplus on top of surplus A and B (refer to surplus C in Figure 22) should be partly processed and partly applied to additional land that should be purchased or hired by the farm. Requirements regarding the percentage of this surplus C for which extra land should be acquired depend on the level of the total phosphate surplus in the year of analysis (i.e., 0% if the surplus is <20 kg ha^{-1}, 25% if the surplus is 20-50 kg ha^{-1}, and 50% if the surplus is >50 kg ha^{-1}; Rijksoverheid (2015)).

As signals indicated that phosphate production in the dairy sector will grow considerably in spite of the new manure policy, the third part of the Dairy act was announced by the Dutch government in July 2015. This part consists of phosphate quota at the farm level to restrict total Dutch phosphate production in order to comply with the national production ceiling of

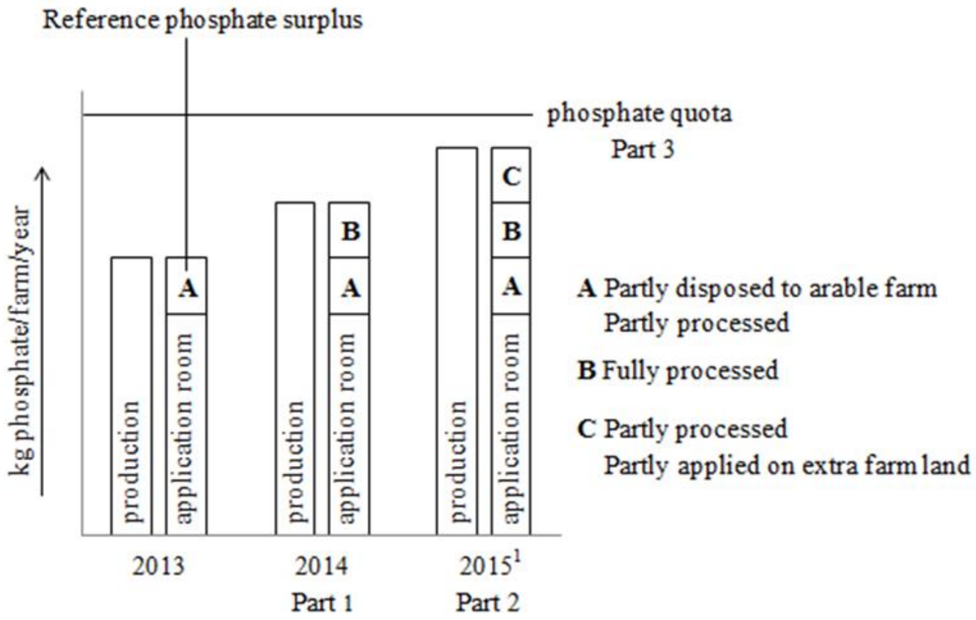


Figure 22. New Dutch manure policy after quota abolition, referred to as the 'Dairy Act'.

[1]The total surplus of 2015 can be based on farm specific excretion factors, whereas calculation of surpluses A, B and the phosphate quota are based on standard excretion factors per type of animal.

172.9 million kg phosphate per year set by the EU. Each farm is assigned a farm specific phosphate production quota based on the average number of cows present on the farm in July 2015 and standard excretion factors (RVO, 2014). The date that this new quota system was announced and the counting date with regard to the number of animals on the farm were aligned to avoid anticipation of farmers on this new legislation. Quotas can be transferred between dairy farms.

Whereas calculation of surpluses A, B and the phosphate quota are based on standard excretion factors per type of animal, the actual phosphate surplus in the year of analysis can be based on farm specific excretion factors.

This overview of milestones in Dutch environmental policies shows that dairy farmers continuously have to anticipate on uncertainties and changes in both local and EU regulations.

4.2 Livestock product prices

Although the prices (standardised to USD) received by farmers for ASF vary throughout the EU, generally the same trends in price change are found in each country between 2000 and 2014 (Figure 23, 24 and 25). For all products this implies a gradual increase in price, with a price peak in 2008 and a smaller one in 2012. Both these peaks in are related to the financial crisis that onset in 2007 (UN, 2011). The peak of 2008 referred to as the start of "food price crisis" was set on by extreme droughts in 2006 combined with high oil prices. More general causes of the "food price crisis" are, amongst others, the changing diets in the expanding middle class and the increasing use of agricultural products for fuel. Compared to the price received by the farmers, the consumer price is more stable, but also gradually increases as displayed in figure 26.

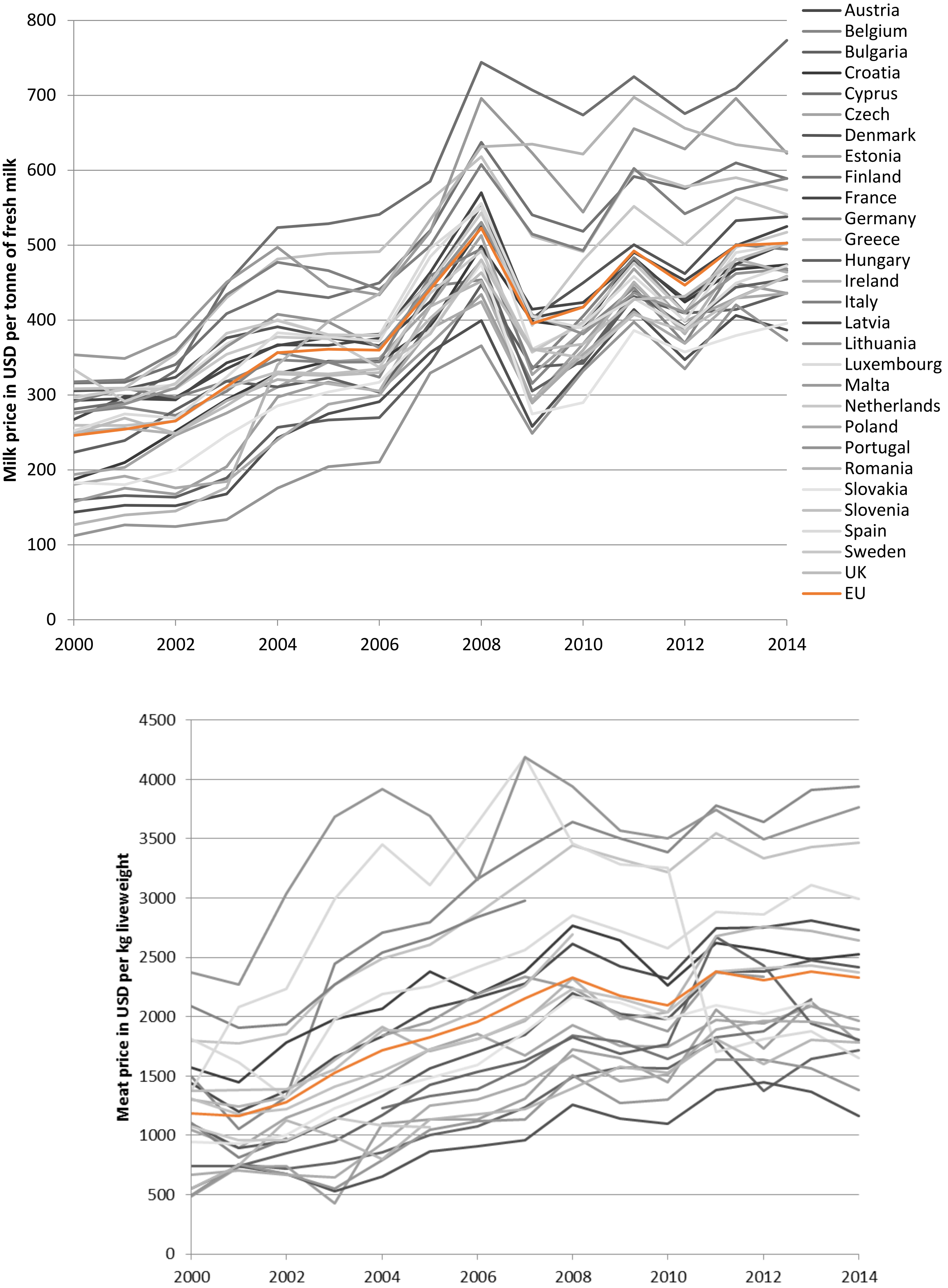


Figure 23 development of milk (top) and ruminant meat (bottom) price in the EU between 2000 and 2014 (FAOSTAT)

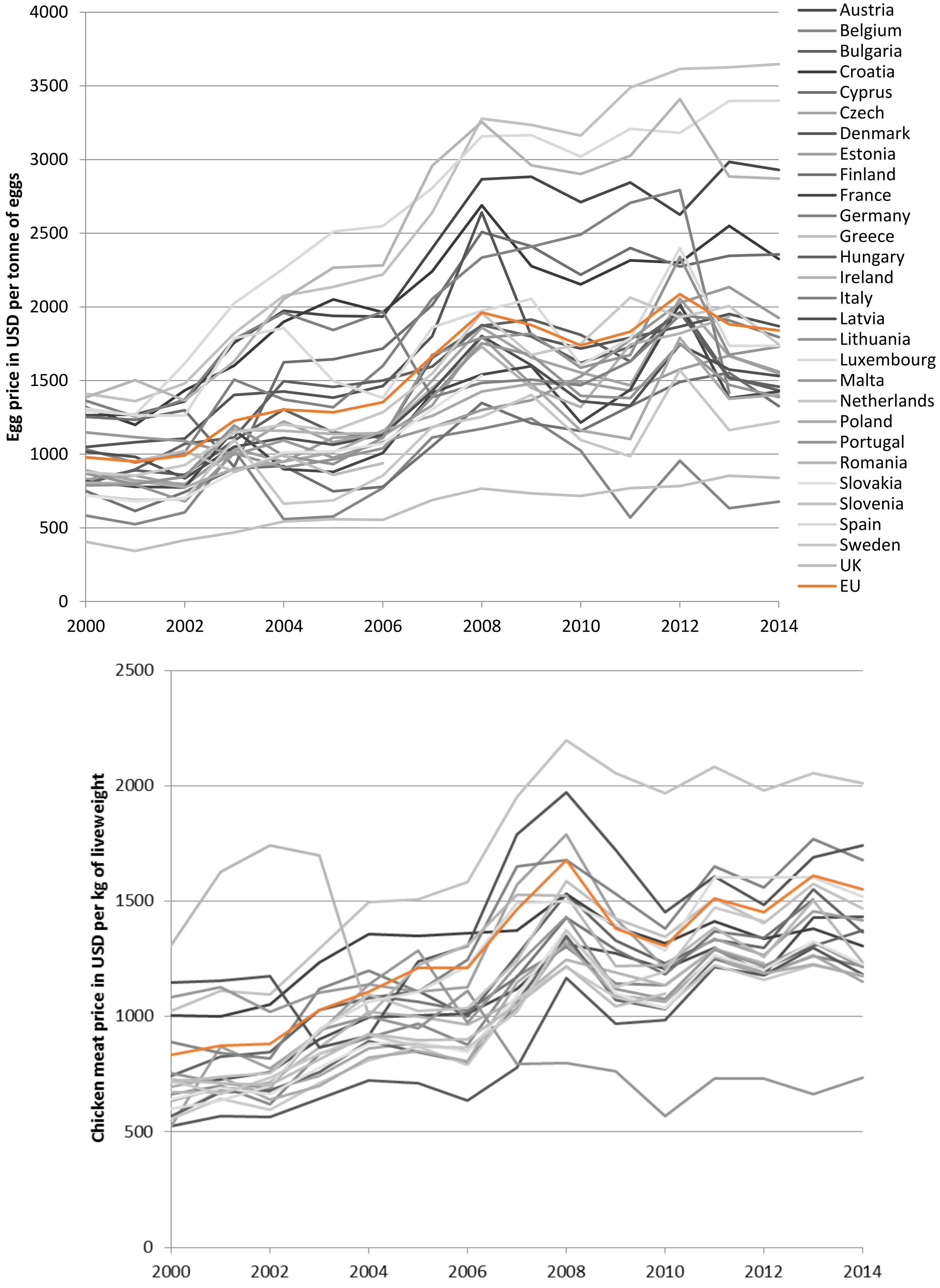


Figure 24 development of egg (top) and poultry meat (bottom) price in the EU between 2000 and 2014 (FAOSTAT)

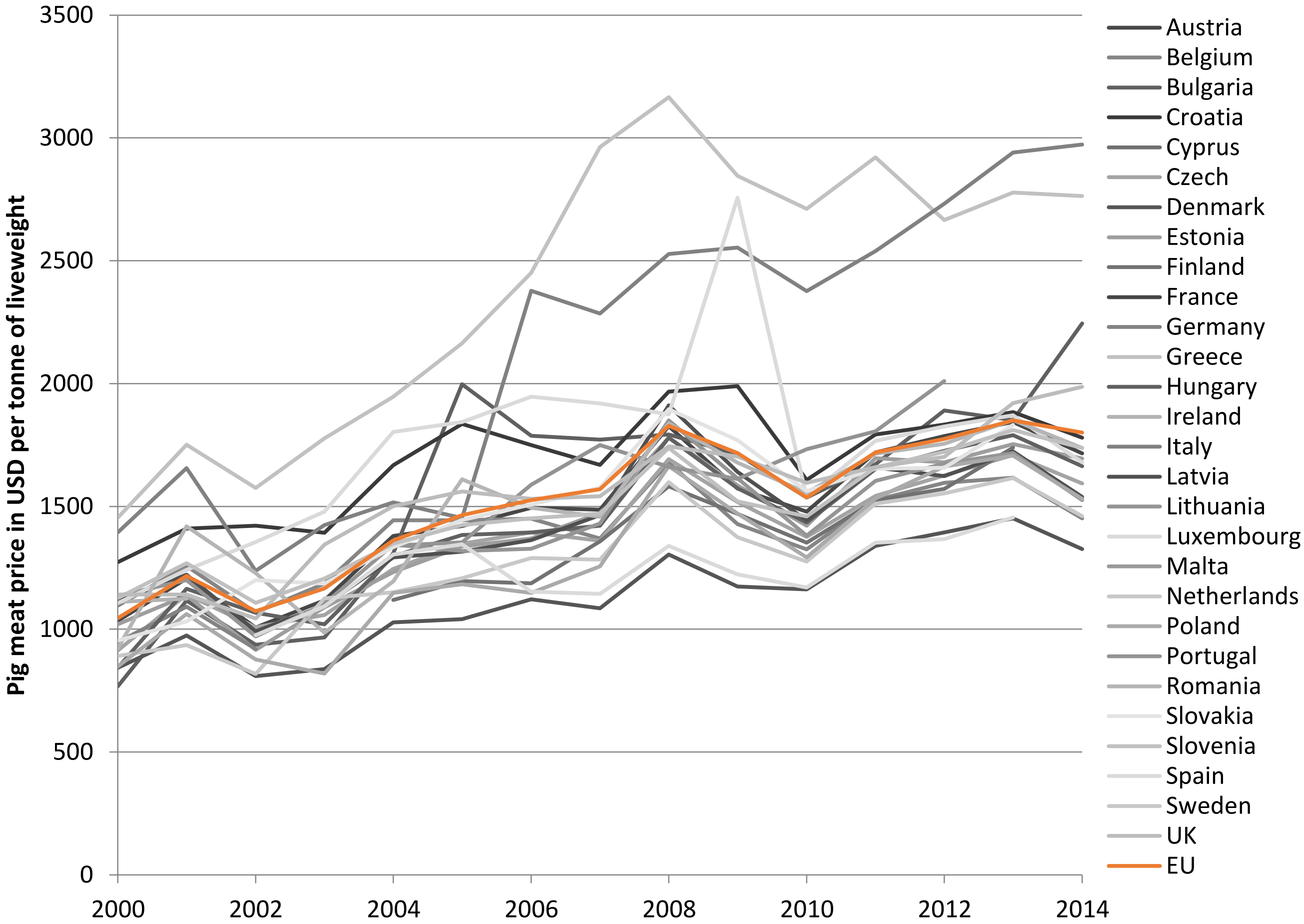


Figure 25 development of pig meat price in the EU between 2000 and 2014 (FAOSTAT)

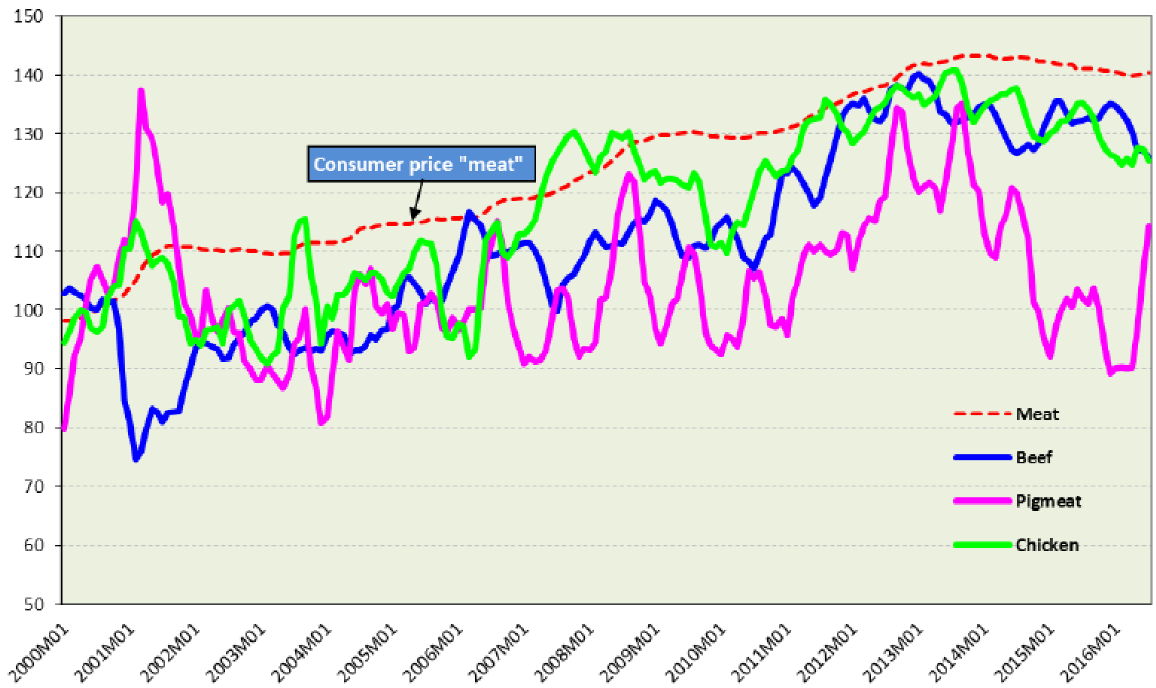


Figure 26 Variation in market and consumer price index (2000 = 100) for meat in the EU between 2000 and 2016 (EC Price dashboard)

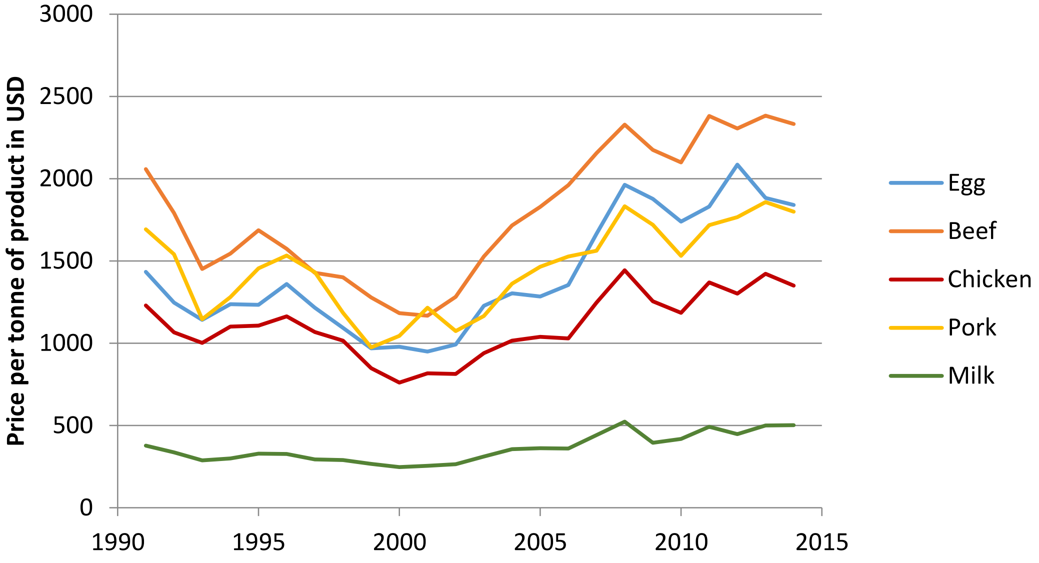


Figure 27 Price development of types of animal source food between 1991 & 2014

Figure 27 shows that also on a longer term the market price of the different animal products follow the same trend. Prices are relatively high in 1991 due to the peak of the BSE outbreak in the United Kingdom and related policy (Nathanson et al., 1997). Thereafter, prices decrease until a new peak in 1996, which coincides with the large scale Swine Fever epidemic in Europe (FAO, 1998). This epidemic obviously drove up the market price of pork, but may have also affected prices of other ASF products, which may have been used to replace the scarce pork. A second peak in market prices is found only for pork in 2001, this peak might be related to the foot and mouth disease epidemic; a disease that mainly formed a problem for pigs (The Royal Society, 2002).

4.3 Natural resource availability

The natural resources that sustain agriculture, such as land and water, are becoming scarcer and are increasingly threatened by degradation. To be environmentally sustainable, therefore, natural resources should be used in economies or societies at a rate not exceeding their regenerative and absorptive capacity. Not exceeding the regenerative capacity implies compensating the reduction of a resource, such as crude oil or fossil phosphorus, by a substitute that can provide equivalent functions, e.g. provider of energy or nutrients. In this way, the functions of natural resources are assumed to remain available, completely and indefinitely (Hueting and Reijnders 1998). Important natural resources related to livestock production that are addressed in this section are land, water, nitrogen, and phosphorus.

Land

Global livestock production occupies about 30% of the permanent ice-free land on our planet, when all cropland and grassland used for feed are included (Steinfeld et al., 2006). In 2012, about 5 billion hectare of land was used for agriculture (FAO, 2015), of which about 70% was used for livestock production (Steinfeld et al., 2006). The livestock sector is the world's largest user of agricultural land, through grazing and the use of feed crops. Of the 5 billion hectares of agricultural land, about 1.6 billion hectares is arable land, of which 33% is dedicated to feed-crops (Steinfeld et al., 2006). Currently about 80% of new croplands replace forests (Foley et al., 2007; Gibbs et al., 2010; Foley et al., 2011). Assuming 9.7 billion people in 2050, then about 0.16 ha of cropland is available per person. Production of a vegan diet, for example, requires about 0.14 ha per person without any waste (Van Zanten et al., 2016). Expectations are that to feed the world population in 2050, an additional 0.2 to 1 billion ha of arable land is needed (Tilman et al., 2011). About half of the pastoral land and much of the natural land, has the potential to be converted to arable land (van Zanten et al., 2016). Expansion of agricultural land, however, is undesired because it is in conflict with the need to preserve nature (Smith et al., 2010; Wirsenius et al., 2010), and because land conversion results in emission of greenhouse gases (Gerber et al., 2013). High productive croplands, therefore, should be used to produce human food instead of livestock feed. Figure 28 shows a map of land use intensity for the European Union representing the situation in 2000 (IVM, 2016), and figure 29 shows the grazing livestock density.

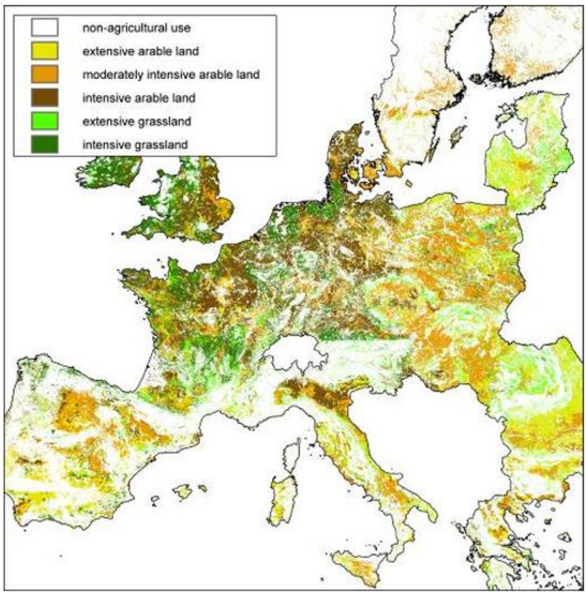


Figure 28 Land use intensity for the European Union in 2000 (IVM, 2016)

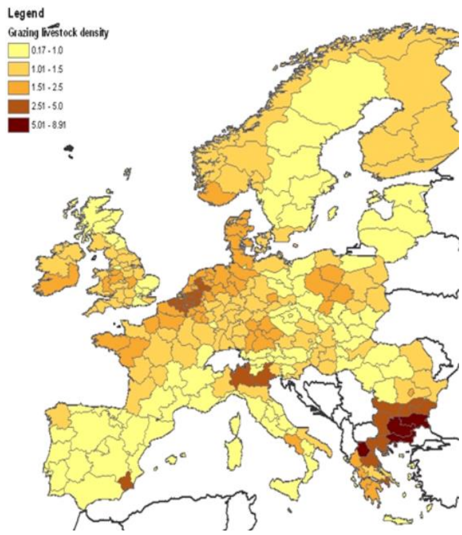


Figure 29 Grazing livestock density in Europe in LSU/ha in 2005 (EUSTAT)

Water

Freshwater in sufficient quantity and adequate quality is a fundamental ingredient for human wellbeing and ecosystem quality. Although we consider water as a renewable resource, its availability, in terms of the amount available per unit time in a specific region, is finite. Figure 30 shows the total renewable water resources per inhabitant in 2014, and Figure 31 shows the proportion of renewable water resources withdrawn. The number of people living in regions with absolute water scarcity (i.e., <500 m^3 renewable freshwater per capita per year; Rijsberman, 2006), is expected to increase from 1.2 billion today to 1.8 billion by 2025. Two-thirds of the world population is projected to be suffering from water stress by 2025 (Molden, 2007), due to a variety of factors such as population growth, pollution of existing resources, climate change, urbanization and changing lifestyles. Human health can be affected by lack of freshwater for hygiene and human consumption and water shortage for irrigation resulting in malnutrition. Furthermore, freshwater scarcity might affect biodiversity in surrounding ecosystems and result in depletion of (fossil) water resources (De Boer et al. 2012).

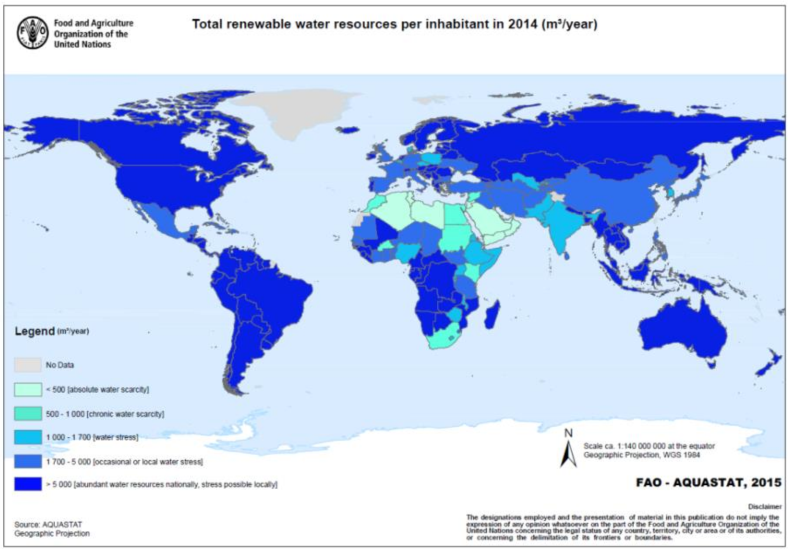


Figure 30 Total renewable water resources per inhabitant in 2014 (FAO, 2016)

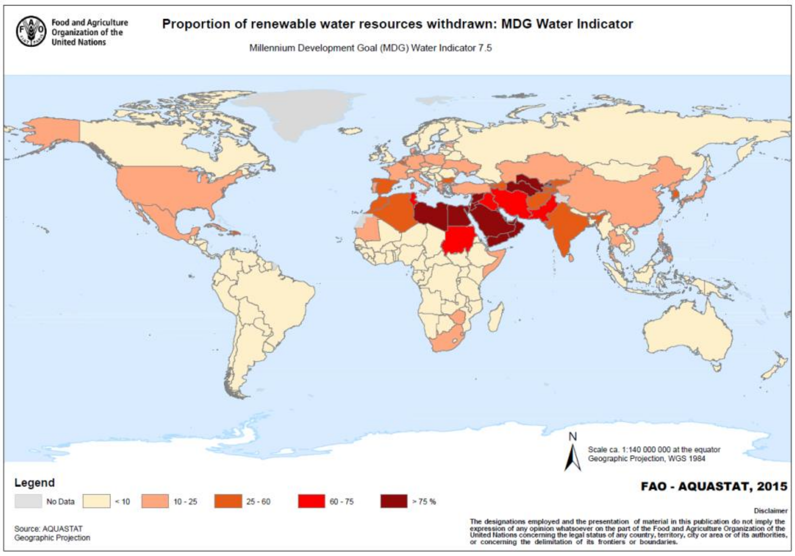


Figure 31 Proportion of renewable water resources withdrawn (FAO, 2016).

At a global scale, the majority of the freshwater is used to produce food (WWAP, 2009). Two different types of water uses can be distinguished: non-consumptive water use and consumptive water use (CWU). Freshwater withdrawals for domestic and industrial purposes normally have large return flows that, although often degraded as a result of pollution, can in principal be reused downstream, and are therefore considered as non-consumptive use. CWU includes mainly irrigation water of rain water evaporated by feed crops or grassland (Falkenmark and Lannerstad, 2005). Compared to evaporative water, the importance of drinking and cleaning water is relatively small (De Boer et al., 2013). This section will focus on CWU and is largely based on a review of Ran et al. (2016).

Traditionally, assessments of CWU in agriculture have focused on withdrawals from water bodies and aquifers for irrigation and industry (e.g. Shiklomanov, 2000). Figure 32 shows the proportion of total water withdrawal for agriculture, industries and municipalities per continent (FOA, 2016). About 8% of global water withdrawals relates to livestock (Steinfeld et al., 2006). These figures, however, do not include the consumption of large amounts naturally infiltrated rainfall in the soil, used by feed crops and grassland for evapotranspiration. To illustrate the importance of both soil moisture and water withdrawals for sustainable agricultural production, CWU can be divided into green water, which refers to soil moisture available to plant growth, and blue water, which refers to liquid water stored in water bodies (Falkenmark, 1995). The important role that green water resources play in agricultural production was highlighted at the end of the 1990s (e.g., Rockström et al., 1999). Today the concepts of green and blue water are widely used to describe and assess water use in agriculture, including livestock production. While blue water can be managed in both time and space, green water is coupled to land use and primarily supports plant growth on cropland or grassland, and other terrestrial ecosystem services (Schyns et al., 2015).

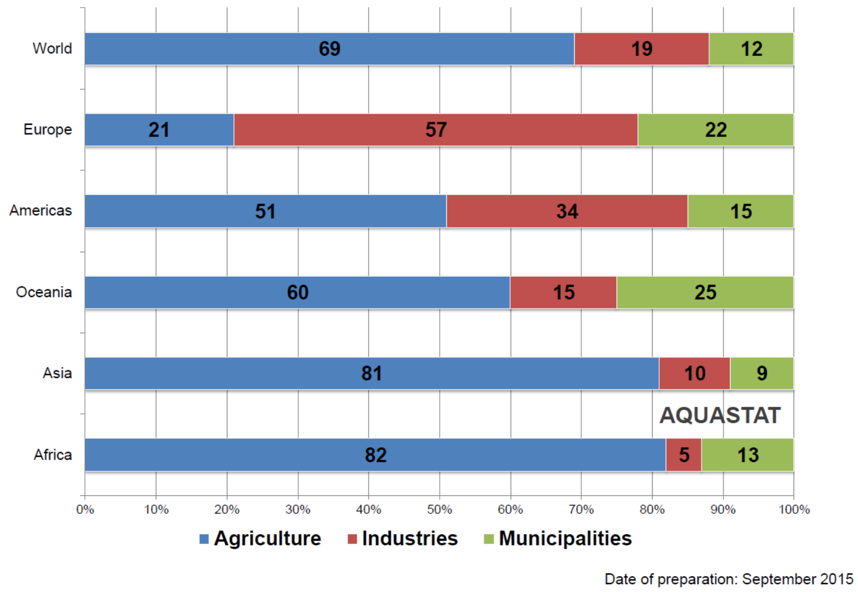


Figure 32 Water withdrawal (i.e., blue water use) ratios by continent. About 8% of global water withdrawals relates to livestock production.

Green water dominates water use in agricultural production and globally accounts for about 80% of the CWU on agricultural land (e.g. Rockström et al., 2014). In livestock production, green water accounts for 90% of total CWU (Mekonnen and Hoekstra, 2012), since livestock production largely depends on rain fed grazing land. Figure 33 shows the contribution of blue and green water use to total water consumption related to three types of livestock products (Mekonnen en Hoekstra, 2012).

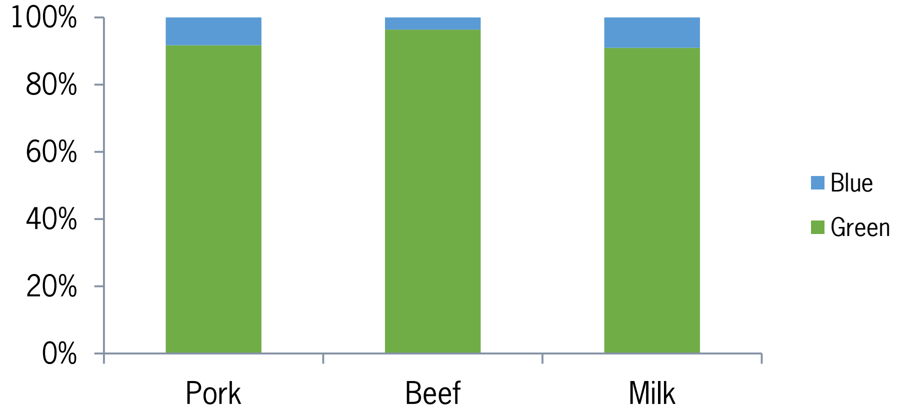


Figure 33 Contribution of blue and green water use to total water consumption related to different types of livestock products.

In total about 98% of the total CWU, green and blue, in livestock production can be attributed to evapotranspiration during plant growth, e.g. feed crops, roughage and pastures. Only about 2-8% of the CWU originates from blue water used as drinking water, for servicing and as feed-mixing water (Mekonnen and Hoekstra, 2012). Estimates of the total global agriculture water footprint (blue and green) indicate that livestock appropriates 29%, with pasture alone accounting for almost 14% of global agricultural green water use (Mekonnen and Hoekstra, 2012). Given the levels of blue water scarcity in many regions (Figure 32 and 33), future challenges related to water use and water availability in agriculture will be linked to more efficient, but also increased, use of green water resources (Rockström et al., 2009; Ran et al., 2016). This especially counts for livestock production, which is largely rain fed. We have to acknowledge, however, that in case rain-fed livestock production is using land unsuitable for production of human food crops, this green water can be used for food production via livestock only.

Nitrogen

Nitrogen (N) is essential for life on earth; it is a component in all amino acids (building blocks of protein) and nucleic acids (DNA and RNA), and essential for photosynthesis and plant growth. In the environment, N is present in diverse chemical forms (e.g., organic N, ammonia (NH_3), nitrate (NO_3^-), nitrogen gas (N_2). It passes between the biotic environment and abiotic environment via diverse processes, which altogether form the nitrogen cycle (Figure 34).

The atmosphere is the largest N reservoir, i.e. about 78% of the N in the atmosphere is N-gas (N_2). Although N_2 is abundant in the atmosphere, it is not accessible to most living organisms. The same holds for (organic) N in sedimentary rocks. N_2 is referred to as in-reactive N; most of the other forms of N are referred to as reactive N. The abundance or scarcity of reactive N co-determines how much food we can produce on a piece of land. There are two main pathways to transform un-reactive N into reactive N (NH_4^+ or NO_3^-): via industrial N_2-fixation (production of synthetic N-fertilizer) and biological N_2-fixation (through legumes such as beans, peas and clover). At present, industrial N_2-fixation is more important for global food production than biological N_2-fixation (Galloway et al. 2002).

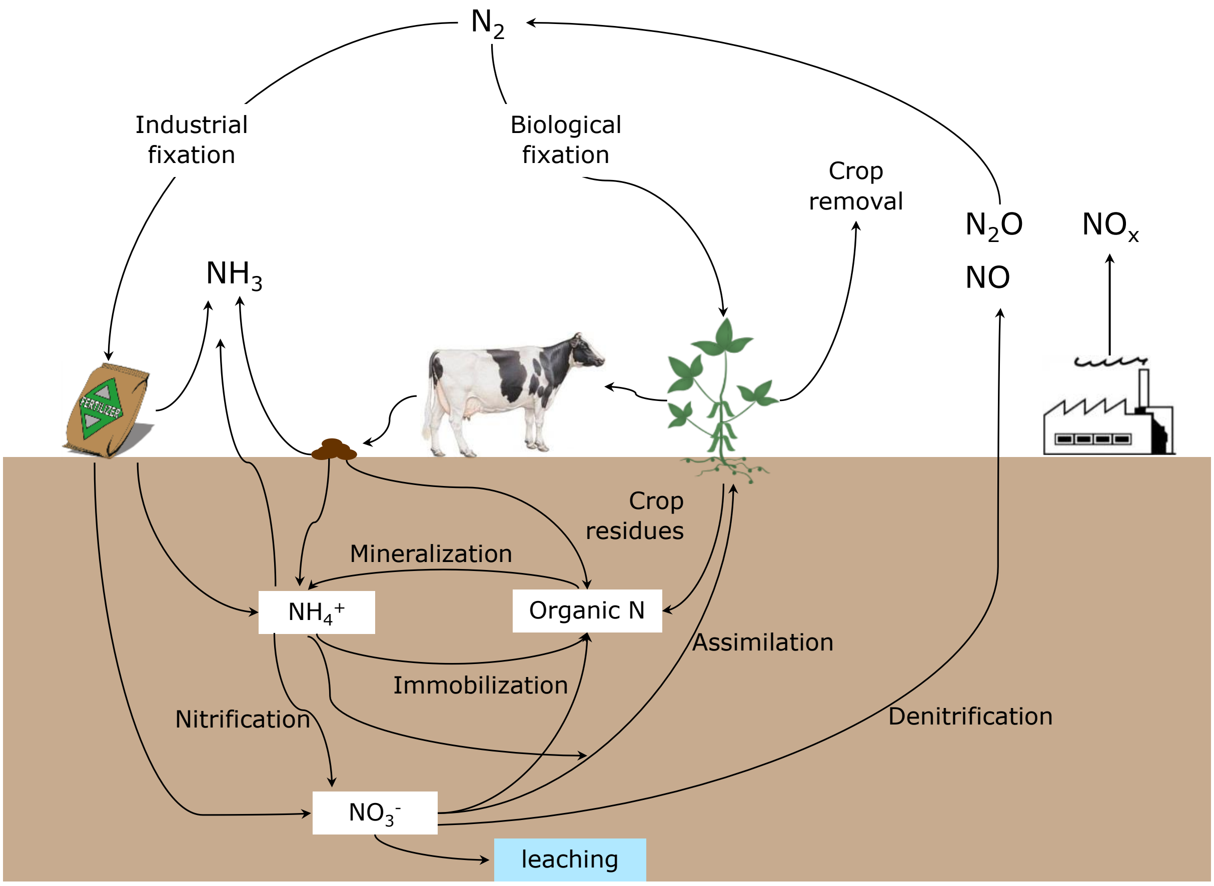


Figure 34 The main pathways of the nitrogen-cycle including livestock.

Human activities, including livestock production, have changed the balance in the natural N-cycle, and resulted in excessive release of various forms of N into the environment. Important pathways of N-emissions resulting in environmental pollution include the emission of NH_3 from manure management and application of synthetic and organic N fertilizers to the field; emissions of N_2O and NO_x from nitrification and denitrification of NO_3^- in soils, manure storage facilities and water bodies; emission of NO_x from burning of fossil fuels; leaching NO_3^- into groundwater (dependent on soil drainage, rainfall, availability of NO_3^- in the soil, and crop uptake); and run-off of NH_4^+ and NO_3^- from fertilizers into surface water.

Figure 35 shows the N flows in Europe (EU-27) in 2005 (Westhoek et al., 2014). The figure shows a close link between the crop and livestock production system via the exchange of feed and manure, resulting in considerable emissions to air, water and soil. The majority of the N output via crops is used as livestock feed, and not as human food. The main N inputs into the EU agricultural sector are mineral N fertilizer, N deposition and imported N via feed.

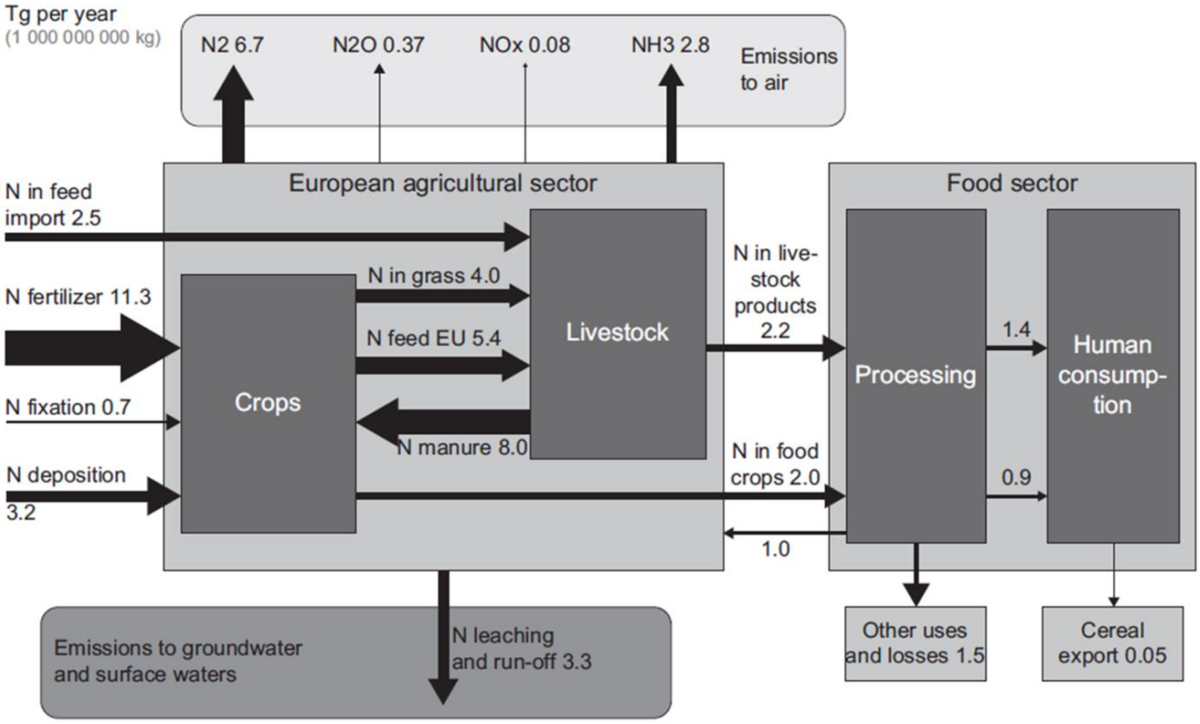


Figure 35. Overview of N flows (Mt N/yr) in EU-27 in 2005 (Westhoek et al., 2014).

The level of N losses related to livestock production depends on the N efficiency of the different processes along the production chain, including feed/crop production and animal production. Figure 36 shows the N use efficiency of different livestock species. The N use efficiency at animal level is usually defined as the output of N in animal products over the input of N in feed. The N use efficiency varies between livestock species, and depends on management factors, such as the diet, environmental factors such as climate, and the health of the animals. Results show that poultry tends to have the highest N use efficiency, followed by pigs and dairy cattle. Beef has the lowest N use efficiency. This relates to the low reproductive rate of cattle, and the fact that all N losses related to growth and maintenance of the mother cow are attributed to beef. It should be noted that these results do not consider the fact that cattle consume products that are inedible for humans, while pigs and poultry are mainly fed on grain and other types of feed that can be consumed by human directly.

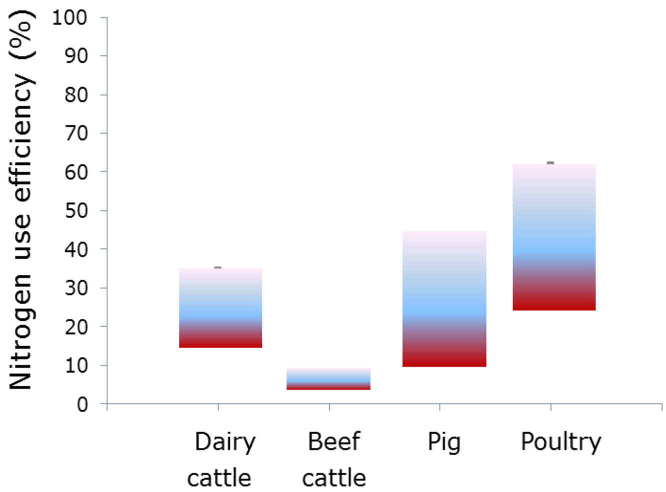


Figure 36 Nitrogen use efficiency (%) of different livestock species. Results are based on a non-exhaustive summary of nitrogen use efficiency results found in literature (Gerber et al., 2014).

Phosphorus

Phosphorus (P) is another essential nutrient for plant and animal production. The P-cycle is much simpler than the N-cycle because P doesn't exist in gaseous forms (Figure 37). The global availability of P rock reserves used for the production of P fertilizers, however, is limited (Cordell et al. 2009).

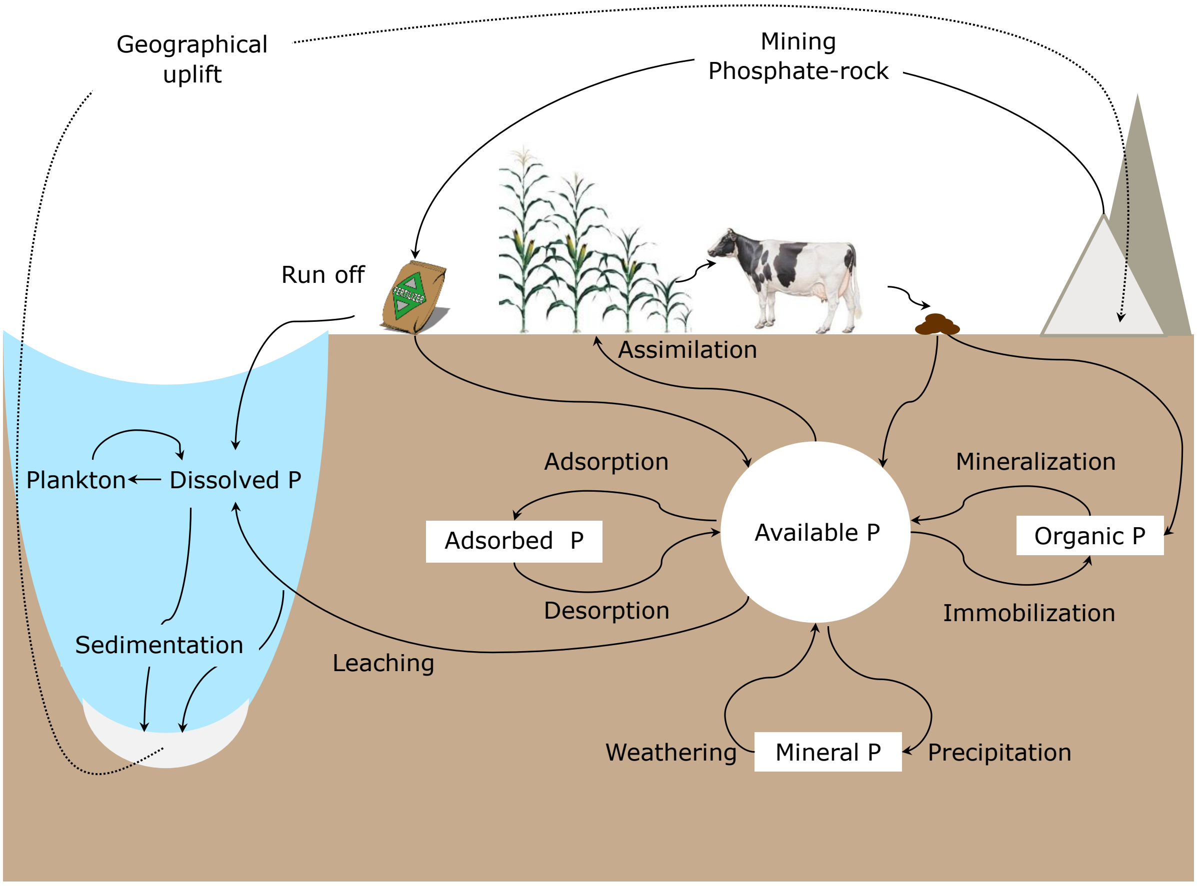


Figure 37 The main pathways of the phosphorus (P) cycle, including livestock.

The largest source of P used in agriculture is phosphate rock, which is mined for the production of synthetic fertilizers and additives. Global phosphate-rock mines are concentrated in only a few countries, such as Morocco, China, USA, meaning that the rest of the world highly depends on these countries for their P supply for plant and animal production. Some researchers estimated that phosphorus reserves are expected to be completely depleted in 50–100 years and that global phosphorus production will be highest around 2030, whereas the International Fertilizer Development Centre in a 2010 report estimates that global phosphate rock resources will last for several hundred years (300-400 years). Notwithstanding this variation in time of expected P depletion, the fact that P will be depleted is generally acknowledged. New formation of phosphate-rock through geographical uplifting of sediments is an extreme slow process. Unlike nitrogen, P therefore, is considered a non-renewable resource also referred to as fossil P.

The soil from which plants obtain P typically contains only small amounts of it in a readily available form (i.e., P in the form of dissolved inorganic P). If soils are deficient in P, food production is restricted unless P is added in the form of fertilizer. Hence, to increase the yield of plants grown for food, an adequate supply of P is essential. In some parts of the world, excessive use of fertilizer and especially manure P, however, resulted in high P-surpluses (i.e. P input > P output), and consequently large amounts of P accumulated in soils. Figure 38 shows a global overview of countries with P deficits and surpluses. High P-surpluses are found mainly in countries with high densities of livestock, as in parts of Western Europe (MacDonald et al., 2011). The resulting P accumulation may lead to P saturated soils, which are threatening surface waters through leaching and run-off of P. Loading surface waters with P may cause excessive growth of algae and suppression of biodiversity (Sawyer 1966). Although other sectors, like industry and households, also contribute to P losses into the environment, agriculture contributes to a high extent. In the Netherlands, for example, agriculture contributes about 50 % to the total P losses to surface water (www.emissieregistratie.nl).

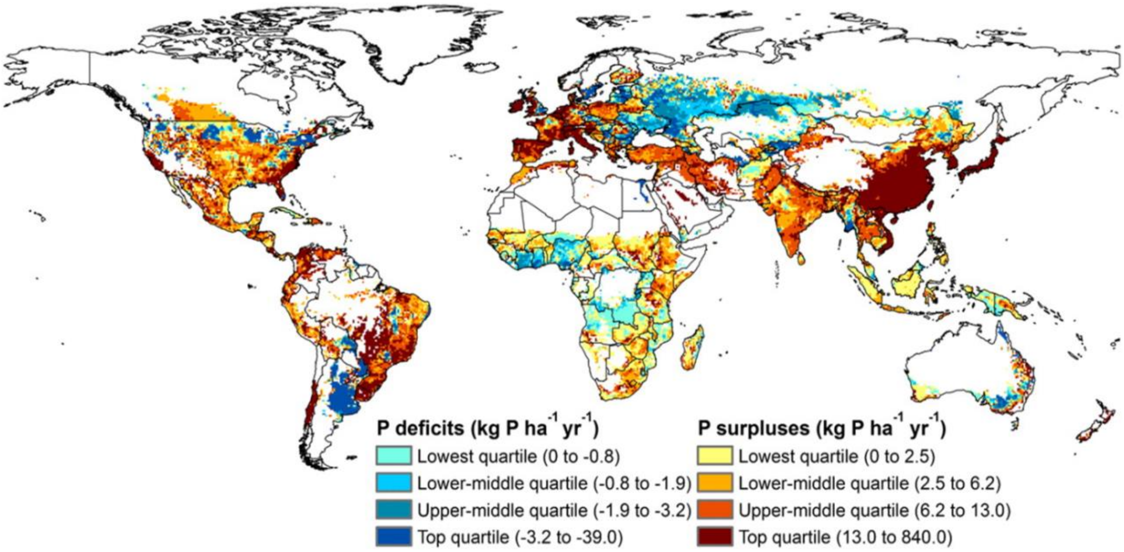


Figure 38 Distribution of P deficits and P surpluses across the world (From MacDonald et al. 2011).

Both aspects, scarcity of mineable rock phosphate and excessive P accumulation in soils, in some regions, implicate a necessity for a more sustainable P-use. Agricultural production can contribute to this by an increase of P use efficiency. Phosphorus use efficiency is usually defined as P-output per unit of P-input. Figure 39 shows the P use efficiency of different livestock species. Increasing P use efficiency may be possible by decreasing the P-input while maintaining the P-output, for example by balancing dietary P levels and animal requirements. In countries like the Netherlands an increase of P use efficiency may also be obtained by a better utilization of accumulated P in the soil, by a better utilization of P from locally available sources, such as animal manures and wastes, and necessarily by a reduction of P-input from external sources, such as P in synthetic fertilizer.

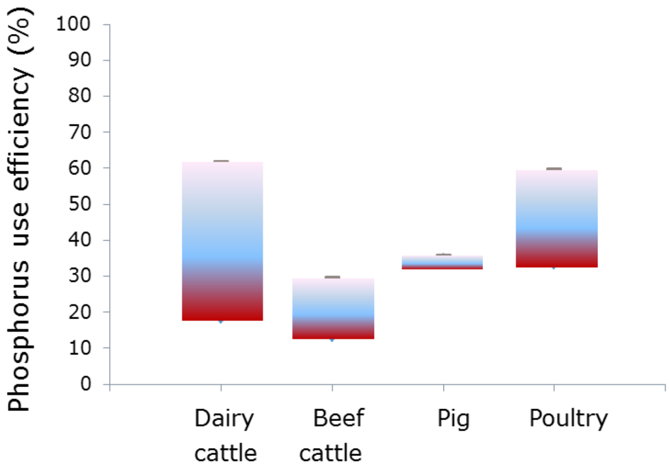


Figure 39 Phosphorus use efficiency (%) of different livestock species. Results are based on a non-exhaustive summary of phosphorus use efficiency results found in literature (Gerber et al., 2014).

4.4 Livestock products and their impact on the environment

De Vries and De Boer (2010) showed that there is a large variation in the environmental impact among livestock products. Compared to beef production, production of pork and chicken results in lower emissions of greenhouse gases (Figure 40).

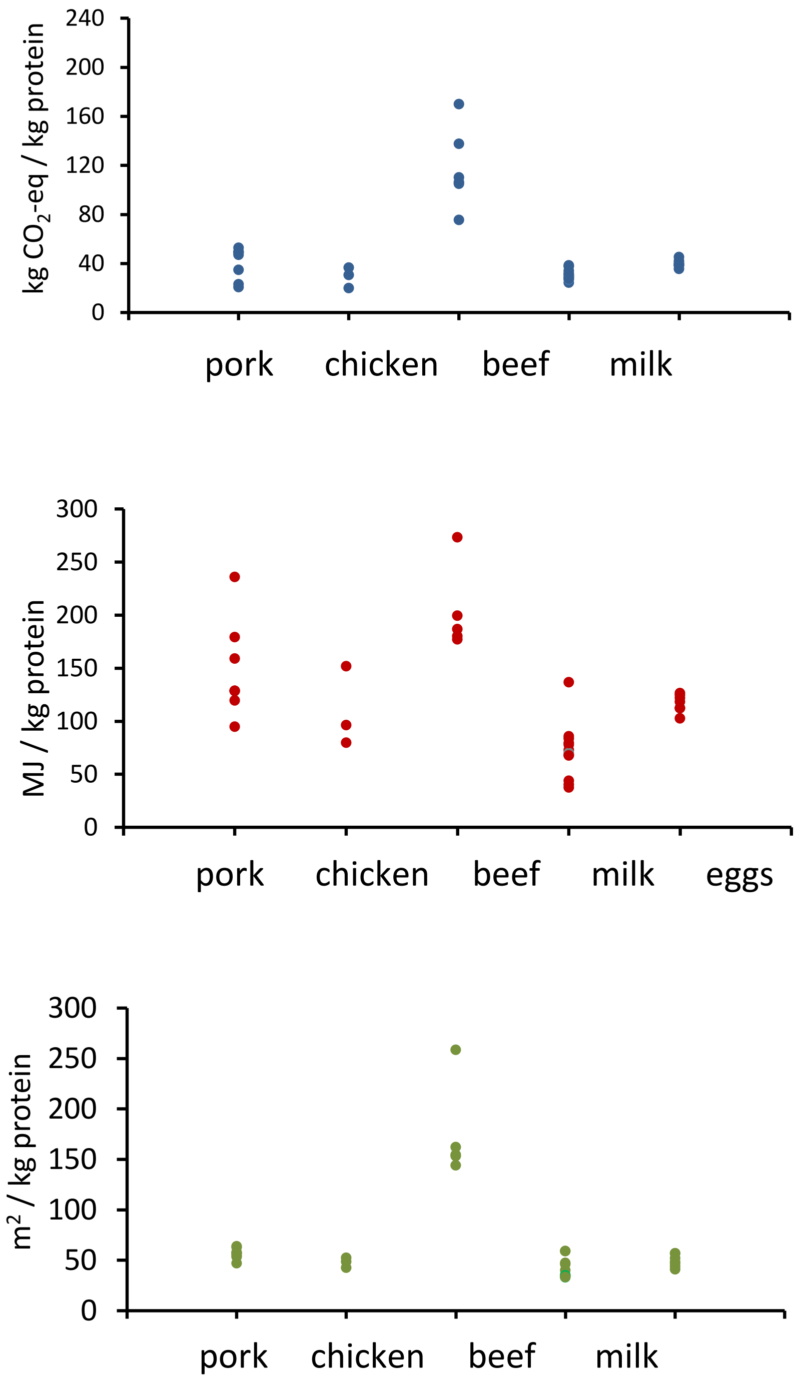


Figure 40 Global warming potential expressed in kg CO_2-eq; energy use expressed in MJ; and land use expressed in m^2 per kg of protein. Each point represents a study or scenario within a study (Adapted from De Vries and De Boer (2010)).

Differences in environmental impact among the production chain of pork, chicken, and beef can be explained in part by differences in feed efficiency, reproduction rate, and enteric methane (CH_4) emission between monogastrics and ruminants (Garnett, 2009; De Vries and De Boer, 2010). Comparing the environmental impact of livestock production (Figure 41), feed production and utilization of feed has the largest impact on greenhouse gas (GHG) emissions and land use (LU) (De Vries and De Boer, 2010; Gerber et al., 2013). About half (47%) of all GHG emissions produced globally by the livestock sector are related to feed production (Gerber et al., 2013). If we look at the contributions of different processes to total GHG emissions from dairy production, the main sources of GHG emissions are enteric fermentation (CH_4), feed production (mainly CO_2 and N_2O), and manure management (CH_4 and N_2O) (Van Middelaar et al., 2011; Gerber et al., 2013) (Figure 41). Enteric fermentation and feed production each contribute about 30% to total emissions, whereas manure management contributes about 20%. Including emissions from changes in land use (mainly CO_2) increases the contribution of feed production. Production and combustion of energy sources used during on-farm processes contribute only about 4% to total emissions, whereas energy used during downstream processes contribute about 11% (included transport and processing of the milk, up to the retailer). (Van Middelaar, 2014). If we look at the contributions of different processes to total GHG emissions from pig production (Figure 42), the main source of GHG emissions is related to feed production followed by piglet production (Van Zanten et al., 2015). Piglet production was defined as the sum of rearing gilts and sows and their piglets that are needed for the production of finishing-pigs. The impact of piglet production mainly related to the use of feed for piglets, gilts, and sows.

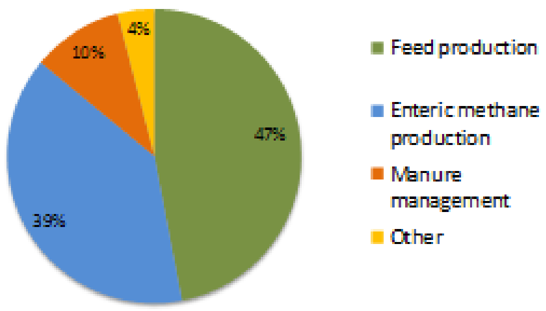
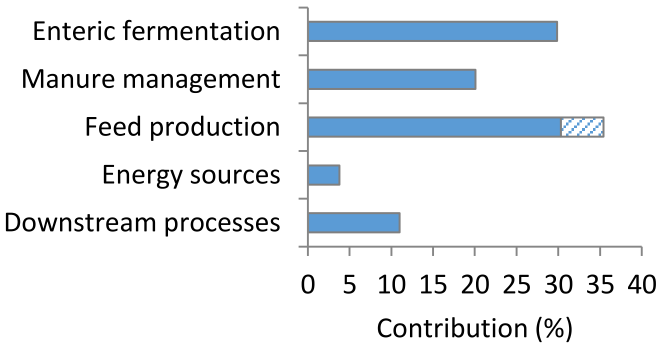


Figure 41 GHG emissions (%) related to various processes of the livestock sector. (Gerber et al., 2013)



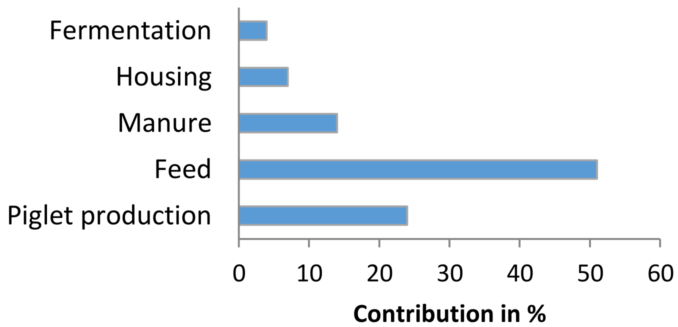


Figure 42 Contributions of different processes to total GHG emissions from dairy production (left) and pig production (right) in developed countries. The dashed fill shows the contribution of changes in land use for feed production. Dairy: (Van Middelaar, 2014), pig (Van Zanten et al., 2015)

Not only between livestock systems large differences occur but also among a livestock production system. The results of a review of De Vries et al. (2015) showed, for example, large differences in environmental impacts, among beef systems (Figure 43 and 44). Systems studied in this review were classified by three main characteristics of beef production: origin of calves (bred by a dairy cow or a suckler cow), type of production (organic or non-organic) and type of diet fed to fattening calves (<50% (roughage-based) or ≥50% (concentrate-based) concentrates). The results of the review showed that environmental impacts of beef produced in dairy-based systems were lower than those of beef from suckler-based systems. No large differences in GWP were found between organic and non-organic systems, whereas eutrophication potential, acidification potential and land use were higher, and energy use was lower for organic systems. GWP, land use, and energy use were lower in concentrate-based systems compared with roughage-based systems (De Vries et al., 2015).

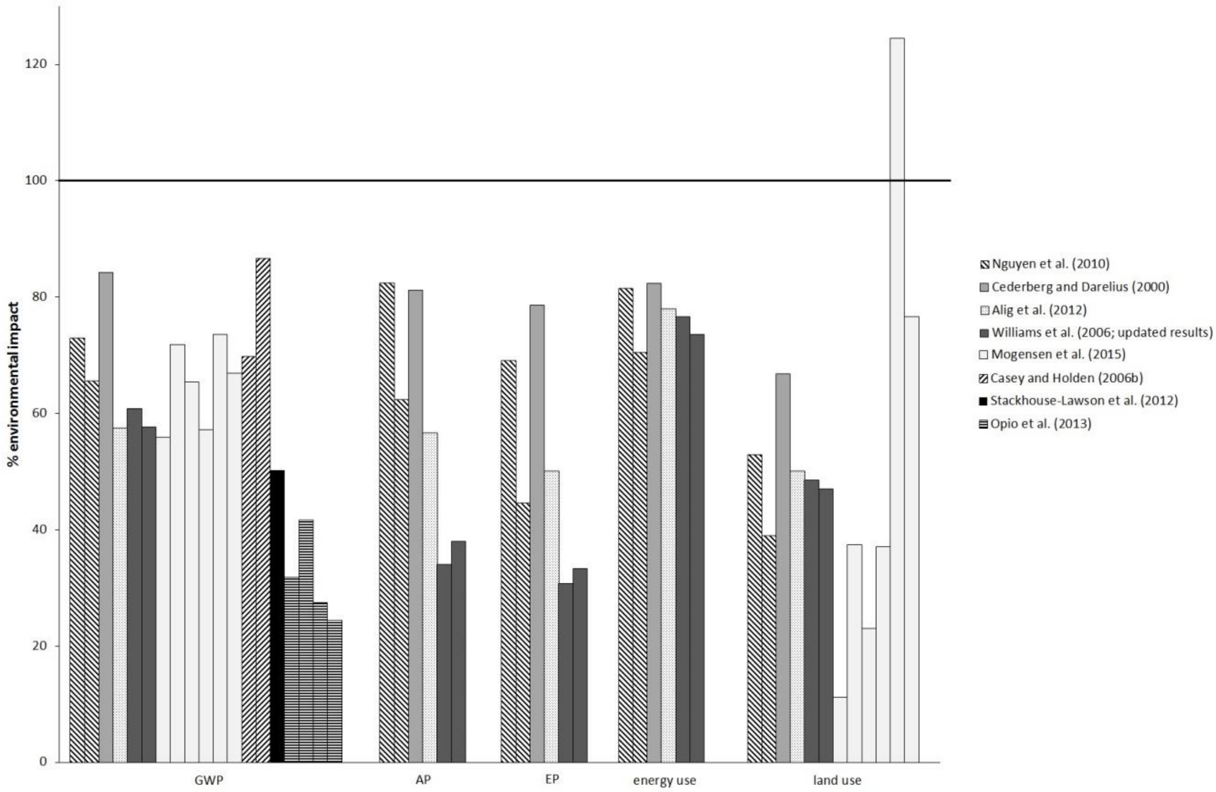


Figure 43 Environmental impacts (%) per unit of product of dairy-based relative to suckler-based beef production systems (GWP=global warming potential; AP=Acidification potential; EP=Eutrophication potential).

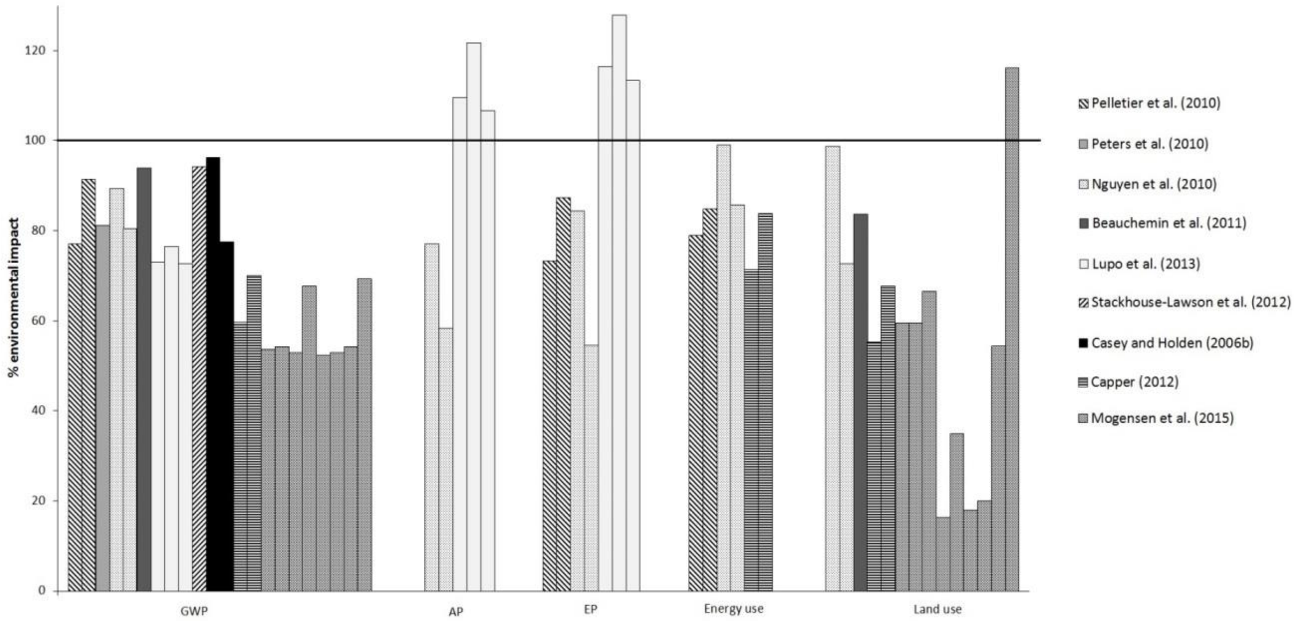


Figure 44 Environmental impacts (%) per unit of product of concentrate-based relative to roughage-based beef production systems (GWP = global warming potential; AP = acidification potential; EP = eutrophication potential).

4.5 Available technology

Technologies that become available for farmers are a result of developments in science and innovations. In 3.4 an overview was given how scientific developments in feeding, breeding, and farming systems can increase animal productivity. In this paragraph we just want to mention that to accomplish such an change in animal productivity not only developments in science are needed but technology should also become available for farmers. You can think of innovations such as a milking robot which should be affordable for farmers to buy or farmers corporations that spread knowledge related to breeding and feeding strategies.

5 The future prospect of livestock production and their challenges

Besides the main direct and indirect drivers that are described above, the livestock sector has future challenges to maintain or improve sustainable livestock production. Below we discuss some of those challenge namely dealing with animal diseases and zoonoses, use of antibiotics, and animal welfare.

5.1 Animal diseases

Animal diseases generate a large range of biophysical and socio-economic impacts. During the last few decades, however, we have seen a reduction in the impact of diseases in Europe, as a result of more effective drugs and vaccines (Perry and Sones, 2009). We have at the same time also encountered new diseases, such as Spongiform Encephalopathy (BSE) and avian influenza. Europe faced a few serious outbreaks of Bovine Spongiform

Encephalopathy (BSE), Classical swine fever (CSF), Avian Influenza (AI) and foot-and-mouth disease (FMD), i.e. BSE in 1992, CSF in 1997 and 2000 and FMD in 2001.

At present, it appears very difficult to assess the change in diseases status in Europe, because of a lack of monitoring data in all member states. Future occurrence of diseases will remain diverse and dynamic. Travel, migration and trade will continue to foster spread of diseases, whereas climate change might start to also change spread of diseases.

Zoonoses

Zoonoses are infections or diseases that can be transmitted directly or indirectly between animals and humans, for instance by consuming contaminated foodstuffs or through contact with infected animals. We can distinguish two main categories: food-born and non-food born zoonotic diseases. Food-borne zoonotic diseases are transmitted through consumption of contaminated food or drinking water, and can cause, for instance, campylobacteriosis and salmonellosis, and Creuzfeldt-Jakob disease (via Bovine Spongiform Encephalitis (BSE) in cattle). Unlike other food-borne diseases, which are spread by micro-organisms, BSE is caused by a prion, i.e. an abnormal form of a protein. Non-food borne zoonotic diseases are transmitted by vectors, i.e. living organisms that transmit infectious agents from an infected animal to a human or another animal. Examples of important non-food borne zoonotic diseases are avian influenza and Q-fever. There are many factors that can lead to the emergence of zoonotic diseases, e.g. environmental changes, human and animal demography and changes in farming practice. In the Netherlands, we had serious outbreaks of avian influenza (2003) and Q fever (2007-2010). The outbreak of Q fewer between 2007 and 2010 in the Netherlands, for example, resulted in more than 4000 human infections.

Use of antibiotics in the livestock sector

In industrial systems, antibiotics are standard added to livestock feed to increase productivity. The use of antibiotics in agriculture leads to the development of antibiotic resistance. This has resulted in a growing public concern, especially related to the transmission of resistant bacteria from animals to humans. In the Netherlands there is a strong policy to reduce the use of antibiotic in the livestock sector. However, the Dutch situation does not reflect the world situation e.g. in the United States the livestock sector uses about 80% of the total antibiotics used in the U.S.

5.2 Animal welfare

The increasing animal numbers and animal efficiency leads to an increasing amount of animal welfare issues. Animal welfare issues are mainly caused because livestock housing systems, animal feeding systems and genetic selection are based on increasing productivity leading to a decreased relation with the natural environment of the species. Animal welfare issues are e.g. stereotype behaviour such as tong rolling by calfs, feather pecking by layiung hens or broilers and tail biting by fattening pigs.

Definition(s) of animal welfare

The well-being, or so-called welfare, of the animals we use for our own benefits, such as farm animals, is an important societal concern and forms an important part of agricultural sustainability. Animal welfare is a complex concept and many definitions have been put forward in an attempt to address this complexity. One of the most comprehensive definitions, sees animal welfare as a combination of 1. Good biological functioning, hence the absence of disease, injuries, and physiological dysregulations or dysfunctions, 2. Natural living, including both an environment with natural features as well as sufficient opportunities to express natural species-specific behaviours, such as for example rooting in pigs and dust-bathing in chickens, and 3. Maximising positive emotions and feelings, or so-called affective states (e.g. playfulness, enjoyment of a food component, satisfaction), and minimising negative affective states (e.g. apathy, boredom, stress, loneliness) (Fraser, 2003, 2009; Fraser et al. 1997). The number of scientific articles relating to farm animal welfare has grown readily in the past 30 years (Figure 45).

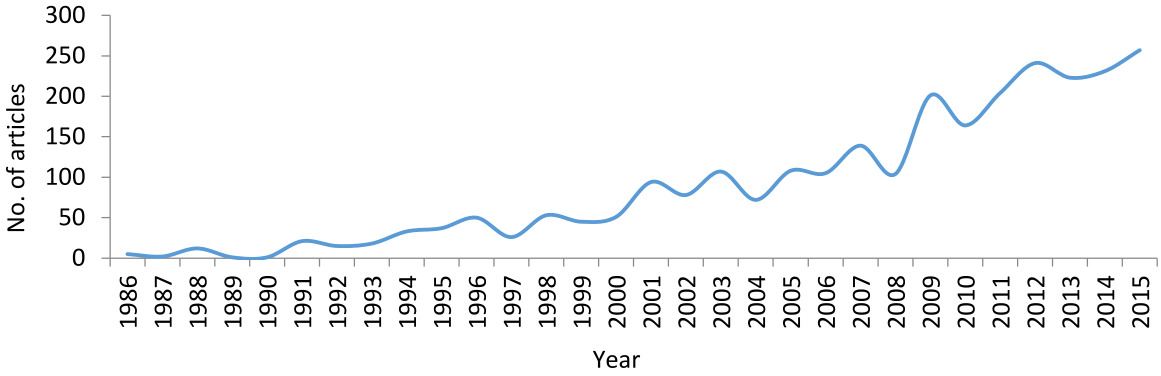


Figure 35 Number of papers on farm animal welfare published in last 30 years, using Web of Science as search engine and the keywords Farm AND Animal AND Welfare.

Animal welfare is generally viewed as a continuum from bad/negative welfare (i.e. suffering) to good/positive welfare (i.e. well-being) (Broom, 1991; Ohl & van der Staay, 2012). Welfare is a characteristic of the animal that relates to its current experienced sensations and feelings and, thus, requires the animal to be conscious (Hemsworth et al., 2015). Of course, we do not have direct access to the subjective feelings of another individual, but these can be measured indirectly via a number of indicators. For a long time, the main aim of welfare scientists was to alleviate negative states, including pain, diseases, suffering, and hence good welfare was defined as the absence of negative states. More recently, the aim is to provide animals with a good quality of life and stimulate positive affective states.

Concern over animal welfare

The importance of animal welfare depends on many socio-cultural aspects: “Interpretation of welfare status and its translation into the active management of perceived welfare issues are both strongly influenced by context and, especially, by cultural and societal values.” (Ohl and van der Staay, 2012). For example, religion and political orientation have been linked to views about animal welfare: the more liberal the religious or political stand-point, the higher the concern for animal welfare (Deemer and Lobao, 2011). In areas of the world where animal welfare is not a priority, it may only be possible to bring changes to animal welfare when these correspond to human gain, such as improvements in productivity, which can occur through improvements in health but also behaviour. These particular areas may also show interest in animal welfare when this gives them access to more markets. Certain societies treat animal welfare as a consumer preference while others treat it as a public-good issue (i.e. everyone benefits from it).

Animal welfare concerns were originally raised by societies in relatively wealthy nations, originating in the UK with ‘Animal Machines’ (Ruth Harrisson, 1964) and the Brambell Report (1965), and spreading throughout the EU and other developed countries. Global standards for animal welfare, relating mostly to transport and slaughter of farm animals, were adopted by members of the OIE in 2005, demonstrated that animal welfare is now a global issue. The World Organisation for Animal Health (OIE), with its 178 members, plays an important role in setting global standards of animal welfare. It has introduced the following definition: “Animal welfare is a complex international public policy issue, with important scientific, ethical, economic, cultural, religious and political dimensions and which also raised important international trade policy considerations.” (OIE, 2002). This definition is completed by the following, to add a scientific perspective: “Animal welfare means how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behaviour and if it is not suffering from unpleasant states such as pain, fear, and distress. Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling and humane slaughter/killing. Animal welfare refers to the state of the animal: the treatment that an animal receives is covered by other terms such as animal care, animal husbandry, and humane treatment.” (OIE, 2009).

Trends and drivers

Global food animal production has increased and is increasing readily, with most of this growth occurring in developing countries. In the industrialised world, this increase in production was met by replacing extensive systems by confinement housing and practices enabling intensive production, especially in species fed concentrated diets (i.e. poultry and pigs), and by concentrating production on fewer farms (Fraser, 2008). Animal welfare issues encountered in developed countries mostly relate to the confinement and lack of movement opportunities for farm animals (Fraser, 2008). Systems that restrict movement significantly, such as battery cages for laying hens, gestation stalls for sows, and crates for veal calves have received much public and scientific attention, and are now banned in the EU.

“The important drivers of animal welfare change are diverse. Advances in animal welfare science have provided an increased understanding of animal sentience; evolving societal values and attitudes have influenced how society responds to animal welfare issues; increased environmental awareness and ethical reasoning have influenced how people think about animal welfare issues and international agencies, the retail sector and a large number of professional and industry groups have all driven progressive changes in animal welfare.” (Bayvel et al., 2012).

Society’s increasing concern for animal welfare in the industrialised world has been the main driver for improvement in farm animal welfare in these countries. The focus here has been on confinement systems due to a demand for a more natural life for farm animals (Fraser, 2008a). This led to a number of actions from various stakeholders: “governmental, regulatory and policy making bodies, producers, marketers, citizens and consumers, scientists, retailers or service providers, non-governmental organisations (NGOs) and animal advocacy groups” (Matthews, 2008). Taken together, these actions led to significant changes in production methods and improvements in farm animal welfare (Fraser, 2008a; Lawrence and Stott, 2009). These actions were:

- New legislation (‘minimum-requirement legislation’) on production, transport and slaughter (especially in the EU), with a focus on the ban of highly confined systems such as gestation stalls for pregnant sows, crates for veal calves and battery cages for laying hens

- Voluntary standards and assurance schemes developed by producer organisations, NGOs, restaurants, retailers and scientists, in order to meet public demand for improved farm animal welfare (e.g. Rondeel: http://www.rondeel.org/). Farm assurance schemes, such as for example 'Beter Leven' (Fig.7) can stimulate improvements in animal welfare. Other schemes include e.g. the organic certification and Freedom Foods (RSPCA).
- Scientific research focusing on problems faced in confinement systems (e.g. space allowance, flooring, air quality and abnormal behaviours), on methods for assessing animal welfare on-farm (e.g. Welfare Quality protocol), and on the development of novel technologies (e.g. milking robots and enriched cages).

Despite public concern for animal welfare, however, consumers are not always ready to pay for higher standards of animal welfare (IGD, 2007). One problem might be a lack of appropriate and clear labelling of products, which necessitates valid and practical on-farm animal welfare assessment protocols. Consumers also assume it is the responsibility of other parties (farmer, retailer) to assure a reasonable level of animal welfare. There is a great importance of multidisciplinary research, in particular economics and animal welfare (Lawrence and Stott, 2009), because it may be possible to advocate improvements in animal welfare from the initiative of the farmer in cases where improvements lead to reductions in costs of raising animals (Lawrence and Stott, 2009). For example, improving dairy cattle health or reducing pig neonatal mortality will reduce on-farm costs. In addition, cattle and pig temperament was previously linked to meat quality (D'Eath et al., 2010; Coombes et al., 2014).

6 Conclusion

In this document, we described the main drivers that might affect the future of European livestock production. In the last decade there was a clear increase in consumption of animal source food. As a response the livestock sector increased production by increasing the numbers of animals per farm and increasing the productivity of livestock. Science and technology played an important role in this intensification process. Currently we see that the demand for ASF in Europe is stagnating, and in some countries even reduces due to socio-economic factors like environmental concerns, human health concerns, and changing socio-cultural values (animal welfare). Currently, the total average intake of protein from only animal source food in Europe is higher than the recommended total protein intake from a health perspective showing that European diets are affluent in animal source food products. High intake of animal source food products can, however, results in health issues and there is also considerable agreement that livestock production have a major impact on the environment. So, given current high consumption levels of ASF in Europe, two main strategies can be followed: reducing the impact of livestock production per kg of output by sustainable intensification, including a continuous focus on improving feed efficiency, breeding for productivity, and control of diseases. Or improve human health and the environment by changing dietary patterns. In WP5 possible innovation packages are described that determine pathways towards sustainable healthy European diets.

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Appendix

Drivers of primary production

„Hazell and Wood (2008) define a driver as 'any natural- or human-induced factor that directly or indirectly brings about change in an agricultural production system'. They distinguish global-scale drivers, country-scale drivers and local-scale drivers. According to their nomenclature, global-scale drivers affect all agriculture around the world and include trade expansion, value chain integration, climate change, agricultural support in the Organisation for Economic Cooperation and Development (OECD) and the Word Trade Organisation (WTO), globalization of science and knowledge, technology and products relevant to agricultural development. As such, they are almost identical with our indirect drivers of the agro-food system. Country-scale drivers affect agriculture within a country (e.g. infrastructure, market access) and local-scale drivers are specific to each local geographical area and different types of agricultural production systems. However, the drivers they subsume under country- and local-scale drivers largely differ from our category of direct drivers. In our framework, direct drivers are defined as drivers that directly affect the decision-making on site.

The ultimate decision-making of agricultural production takes place on the farms. The farmers/fishers or producers make their decisions based on a variety of drivers. Examples of decision-making processes in fisheries and their influence on the efficiency of the fishery and its products are given in Ruttan and Tyedmers (2007) and Ziegler et al. (2015). Drivers that affect the producers directly are reviewed in the following.

Öhlmér et al. (1998) identify eight elements of decision-making at the farm level: (1) values and goals, (2) problem detection, (3) problem definition, (4) observation, (5) analysis, (6) development of intention, (7) implementation, and (8) responsibility bearing. Values and goals are internal direct drivers and briefly reviewed below. External direct drivers mainly affect the problem detection. Once a problem due to a change in external drivers is detected, more information is gathered in the elements problem definition and observation, which finally lead to a decision process and a potential change in production activities (Öhlmér et al., 1998).

Within the EU food system, several drivers that influence actions and decision-making processes of primary agricultural and fishery producers can be distinguished. Although a strict assignment of these factors to different categories is barely possible due to their interdependencies, the drivers that are mentioned in the literature are broadly classified into a number of categories" (Zurek et al., 2016).

Drivers in the context of production economics

Primary agricultural and aquaculture production means transforming inputs into outputs (please note that this does not necessarily apply to capture fishery). In its simplest form, a farm produces a single output for which it uses N inputs (e.g. labour, machinery, feed, fertilizer, etc.). This relationship can be summarized in a production function

$$q = f(\mathrm{x})$$

where q is a function f of x $= (x_1, x_2, \ldots, x_N)$ inputs. Assuming these inputs x are under the control of the decision maker, other inputs like climate might be outside the control of the decision maker and could be added as inputs z leading to production function

$$q = f(\text{x,z}).$$

There is plenty of literature on properties of production functions and their various transformations (e.g. (Coelli et al., 2005)). Clearly, decision making will be affected by both controllable and uncontrollable inputs. In the framework of the drivers considered here, all biophysical drivers are inputs that are outside the control of the farmer. Controllable inputs usually have prices attached to them (e.g. machinery, feed, fertilizer). Depending on these inputs prices, farmers may decide based on a cost function approach where costs are minimized:

$$c(w, q) = \min_x \text{w'x}$$

where w $= (w_1, w_2, \ldots, w_N)$ is a vector of input prices. In addition to input prices, farms might also consider output prices in their decision making. Assuming profit maximizing behavior, this can be represented by a profit function:

$$\pi(\text{p,w}) = \max_{\text{q,x}} \text{p'q} - \text{w'x}$$

where profit π varies the M with output prices p $= (p_1, p_2, \ldots, p_M)$ (Coelli et al., 2005). This highlights the importance of both input and output prices in the decision-making process.

Inputs as well as output prices are, in turn, affected by various other drivers. “In economic theory, the price for any specific good is determined by the interplay between supply and demand. As market conditions change (supply and/or demand shocks), price adjustments take place. This way, prices transfer information about markets” (Zurek et al., 2016). Mainly, prices are affected by the indirect drivers considered here: broader economic development, population dynamics, technological change, agriculture and trade policies, environmental issues and culture and lifestyles.

Besides the price information, other factors affect decision-making on farm directly. Thus, the regulatory environment has to be taken into account, contract opportunities might provide options for cost-reduction through collaboration with others and exploiting scale effects, as mentioned above, natural resource availability has a direct impact as well as the available technology and producer and farm characteristics.

Technological change vs. available technology

One of the main differences of the WP4 deliverables among each other and compared to the SUSFANS Conceptual Framework (CF) is related to the indirect driver ‘technological change’ and the direct driver ‘available technology’. Since the distinction between those two is not necessarily clear, how they are treated in the CF and in the WP4 driver deliverables is shown in Table 4. The interpretation and usage of these terms in the WP4 driver deliverables highly depends on the production system and the different foci required for their analysis. Generally, one might argue that even the indirect driver ‘technological change’ very directly affects primary producers.

Table 4. Technological change vs. available technology

Document	Indirect driver 'technological change'	Direct driver 'available technology'	Comment
CF (D1.1)	- Innovation - Technology development	- Technology adoption & diffusion - Technology usage	The distinction here is that an innovation is not necessarily used on farm. This depends on technology adoption and diffusion. Usually, there is a considerable time gap between the actual innovation and the use on farm.
Livestock (D4.1)	- Progress in feeding technology - Progress in breeding	Feeding and breeding technologies are adapted in e.g. diet formulations	Feeding and breeding strategies aiming to increase productivity will eventually become available on farm. The time gap in which the farmers adopt the breeding and feeding strategies will depend on things as profitability, feasibility and on the corporation the farmer is joining.
Seafood (D4.2)	- Historical development and the interplay between farmed and fished seafood - Technical innovations in society enabling growth	- Science and management behind current production - Difference in technology between individual enterprises, e.g. farmers' knowledge, skipper effect - Status of production systems and technical progress needed - Production efficiency incl. by-product	The distinction here is that the indirect drivers are those related to the history behind the status and drivers for current production systems, including other technological development in society enabling growth, whereas the direct drivers are those related to the available and needed technology of current production systems

		utilization	
Crop (D4.4)	- Public and private research (breeding, fertilizer and plant protection, machinery)	- Management	This translates into the concept of technical progress in terms of (1) increasing crop potential through public and private research and (2) decreasing the yield gap (i.e. the gap between potential and actually achieved yields) on farm

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