PBL Netherlands Environmental
Assessment Agency

THE PROTEIN PUZZLE

The consumption and production of **meat**, **dairy** and **fish** in the European Union

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Foreword

The choices we make in what we eat do not only influence our own health, they also have a large impact on the environment. Over the last 50 years, diets in the European Union, generally, have shifted towards higher consumption levels of meat, fish and dairy. A similar shift is currently taking place in parts of Asia and South America, leading to a strong rise in global demands for meat, dairy and fish, and consequential increases in environmental impacts. Impacts on biodiversity, recources and reactive nitrogen are notably large, indicating that biodiversity policies also need to address the topic of food, in order to be effective.

This report focuses on the European situation, to support the discussion on the future of the European consumption and production of food. A large number of publications have already analysed and discussed the global picture, among them publications by the PBL Netherlands Environmental Assessment Agency, for example *Growing within Limits* (2009) and *Rethinking Global Biodiversity Strategies* (2010). Discussions about meat, dairy and fish at times become quite passionate. Sometimes this is because of the issue on inequality. There is a wide disparity between people suffering from malnutrition, on the one hand, and those used to throwing out food, on the other. Sometimes it is because food and lifestyles are intertwined and a critique of certain eating habits likens to a critique of certain lifestyles. And sometimes it is not the value we place on our food, but animal husbandry and fisheries that stir emotions. This report cannot deal with food in the round. What it aims to do, however, is to underpin this discussion with figures, facts and analyses. Given the difficulty of finding solutions, and the pivotal role of the 'protein' component in our diets, this report is titled *The Protein Puzzle*.

The European Union has a relatively large impact on both consumption and production of food, through various policies, of which the Common Agricultural Policy and the Common Fishery policy are the most prominent. Currently, both these policies are undergoing a reform. However, as this report concludes, not only EU policies, but also national government, consumers, retailers, farmers, fishermen and other actors have a large influence on the manner in which our food is produced. Seeing the facts, they have choices to make as well.
With this study, the PBL hopes to contribute to the quality of the debate on the future of food consumption and production.

Prof. dr. Maarten Hajer
Director of the PBL Netherlands Environmental Assessment Agency

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The Protein Puzzle: Main findings and summary

Main findings

Meat, dairy, eggs and fish are important components of the European diet
These animal products are not only important in terms of taste and tradition; they also provide essential nutrients such as proteins, iron, calcium and vitamins. Fish also provides essential fatty acids and vitamin D. Furthermore, livestock production and fisheries are important economic sectors for Europe's rural areas.

However, livestock production and fisheries have large environmental effects, both within and outside Europe
From a global perspective, impacts on terrestrial and marine biodiversity and emissions of greenhouse gases (GHG) and various forms of reactive nitrogen are most dominant. The large areas of land needed for grassland and feed production are an important cause of biodiversity loss. In the EU, about two thirds of the total agricultural area is used for livestock production. Around 75% of the protein-rich feed is imported, mainly from Brazil and Argentina where large areas of land are needed for its production.

Conversion of plant energy and proteins into edible animal products is a generally inefficient use of resource
These resources include land, water, fertilisers and fossil energy, among other things. This can be illustrated by the fact that, for each EU citizen, every day almost 3 kilograms of feed is consumed by EU livestock, 0.8 kilogram of which in cereals and 0.8 kilogram in grass (dry matter). This feed is converted into 0.1 kilograms of meat and 0.8 kilograms of milk, being the average EU consumption.

Livestock production is a source of greenhouse gas emissions and certain forms of reactive nitrogen

Around 10% of EU greenhouse gas emissions are caused by livestock production. Together, the beef and dairy sectors are responsible for two thirds of these emissions. A large quantity of nitrogen fertiliser is needed, each year, to sustain Europe's high production levels of grass, cereals and other crops. More than 80% of this nitrogen input is lost, leading to various environmental problems, including the loss of terrestrial biodiversity and algae blooms in coastal waters. There are large differences in greenhouse gas and nitrogen emissions between the various animal products and production practices.

Animal husbandry is associated with several ethical issues

These issues, among other things, are related to limited space, floor type and concentrated feeds, and to the breeds being used. Farm animals, especially when kept in conventional types of housing, experience various forms of discomfort. Animal diseases diminish not only animal well-being, but some animal diseases and the widespread use of antibiotics also cause human health risks. However, improving animal welfare generally leads to higher feed requirements and higher emission levels, thus implying a trade-off between animal welfare and environmental issues.

Many marine fish populations are overexploited. Despite new fishing grounds, EU catches are declining rapidly

Catches in the main EU fishing areas have declined by a third since the early 1990s, partly because of EU regulation to prevent overfishing. EU aquaculture is growing, but at a much slower rate than in other regions. Worldwide, 40% of fish production comes from aquaculture, compared with about 20% in Europe. The EU, therefore, relies heavily on imports to meet its demand for fish.

Average EU consumption of animal protein per capita is about twice the global average

Meat consumption in Europe is twice the world average; for dairy produce it is even three times higher. Average EU consumption of meat, dairy and fish has increased strongly over the last 50 years. The total per-capita protein consumption (including vegetable sources) is about 70% higher than recommended. This, in itself, probably would have no adverse effects on human health, if not for the associated intake of saturated fatty acids, which lead to increased risks of cardiovascular diseases. The average intake of saturated fatty acids is about 40% higher than recommended. Thus, a reduction in the consumption of livestock products, notably in high-fat products, would reduce the European disease burden.

Global demand for animal products is expected to increase significantly, in the coming decades, as a result of a growing global population and increasing prosperity

As a consequence, cropland and grassland areas are expected to expand by 10% to 20% over the coming decades, leading to significant losses of terrestrial biodiversity, especially in South Asia, Sub-Saharan Africa and South America. Moreover, greenhouse gas and nitrogen emissions related to agricultural production also are expected to increase. Globally, already around 30% of the total human-induced biodiversity loss is related to livestock production. Currently, about 80% of global commercial fish populations are being fully exploited or overexploited, leading to large impacts on marine biodiversity. Capture fisheries, therefore, are unlikely to be able to contribute to meeting the increasing fish demand.

Fish farming could be an option

Fish farming of predatory species, such as salmon, uses wild-caught fish as part of the fish feed. Further innovations in the composition of this feed, but also a switch to an increased consumption of herbivorous fish, would reduce the amounts of wild-caught fish required in fish feed. This would involve only a small increase in agricultural land used in the production of the feed for these additional numbers of farmed herbivorous fish. In this way, wild fish stocks would be protected, could recover and possibly provide higher catches in the future.

There are many options to reduce the impacts of livestock production

Main points of intervention are: shifts in consumption, reduction in food losses, changes in husbandry systems and animal breeds, feed conversion and feed composition, nutrient management, crop yields and land management. Modelling results demonstrate that significant reductions in environmental pressure are possible, at the global level, by improving crop yields and feed conversion and by a reduction in food losses along the food chain. The same results indicate that a reduction in the EU consumption of animal products would lead to a significant reduction in environmental impacts, mainly by reducing land conversion outside the EU. The fact that this would take place mainly outside the EU is partly a result of the current design of the Common Agricultural Policy (CAP), which stimulates European farmers to keep their land in agricultural production.

The options for the EU to reduce the impacts of livestock production can be grouped into three broad, partially complementary strategies: shifts in consumption, resource efficiency and producing with fewer local impacts

Consumption shifts, particularly a reduction in the consumption of livestock products, will not only have environmental benefits, but may also reduce the cardiovascular disease burden. This option is easy and robust, but changing consumption patterns is a slow cultural process. Improving production efficiency is already common practice, as there are many synergies between enhancing production and reducing costs. Further improvements along this route are certainly possible, especially regarding a better use of relatively cheap inputs (e.g. fertilisers) and reducing emissions. Producing with fewer local impacts may have negative environmental effects elsewhere, since production may be less efficient, such as in the case of improved animal welfare. More robust production systems with fewer local impacts, generally, lead to higher costs for farmers. However, if done properly, this would lead to lower societal costs by reducing local environmental impacts, animal suffering and public health risks.

Governments and actors in the food chain both could play a role in the implementation of the three strategies
Current policy and institutional setting mainly drive farmers and other actors in the direction of cost price reductions, and thus primarily support the 'efficiency' strategy. Policies aimed at reducing consumption hardly exist, and policies regarding producing with fewer local impacts are usually secondary to economic and trade policies. Especially the EU, but also the national governments, have a large influence on the agriculture and fisheries sectors. Main policy instruments are the Common Agricultural Policy and the Common Fisheries Policy, which are currently undergoing a reform. Food and agriculture may play a role in EU initiatives, such as 'Resource Efficient Europe'. Individual consumers and actors in food production have many opportunities to reduce the impacts of livestock production, independently from government actions. Consumers could shift to the consumption of products with lower environmental or animal welfare impacts. Retailers could expand their assortment of these products, and could enter into agreements with farmers and other food suppliers to improve production techniques.

Summary

I Introduction

European diets have changed significantly over the last 50 years, and some of these changes have been in the direction of higher intakes of meat, dairy, eggs and fish. These higher intakes have been accommodated by the rapid development and implementation of new agricultural production techniques. These techniques have made food cheaper and allowed for a shift in the European workforce towards industry and services. However, the increased production and the techniques deployed have also aggravated a number of environmental and other impacts from agricultural production and fisheries. These include effects on biodiversity, animal health and welfare and emissions of greenhouse gases and reactive nitrogen.

The global production of food is expected to increase even further. The demand for food, in particular outside the EU, is expected to increase during the coming decades, due to a growing world population and increasing prosperity. This is most likely to lead to additional biodiversity loss and higher emissions of greenhouse gases and nutrients. Furthermore, in spite of increased global consumption and production, almost one billion people are still suffering from malnutrition today.

In Europe, security of supply, health consequences and environmental effects of food consumption and production are of growing concern, not only to governments, but also to many retailers, food companies, farmers and consumers. The question therefore is:

are European diets sustainable and healthy, and, if not, what improvements could be made and how?

Focus on consumption and production of meat, dairy and fish

The focus of this study is on the consumption and production of animal products (meat, dairy and fish), for a number of reasons. There are concerns about animal welfare, greenhouse gas emissions, biodiversity loss, and resource use due to inefficient conversions of plant proteins into animal proteins. Meat and fish are partly interchangeable, in culinary as well as in nutritional terms, both being suppliers of protein. Regarding fisheries, there are concerns over the depletion of fish stocks and impacts on marine biodiversity. From the perspective of public health, many Europeans consume too many calories and saturated fats, mostly from animal origin. According to dietary recommendations, many people should consume more fish, fruit and vegetables. As meat, dairy and fish all are important sources of protein, and because they are partly interchangeable and can be replaced with vegetable protein sources, the problems may be framed as ‘the protein puzzle’. The fact that Europe is importing large quantities of protein-rich feed from North and South America, is another aspect of the same protein puzzle.

Focus on EU food system in global context

A further focus of this study is primarily on the EU food system, as the EU has a single market for food products. Moreover, there are many EU policies regarding food, agriculture and fish. The most prominent are the Common Agricultural Policy and the Common Fisheries Policy, both currently being reformed. Other EU policy areas, such as environmental policies and economically-oriented policies, for example on trade regulation and cohesion, also have an important effect on food consumption and production. Given the trend towards globalisation and the ongoing concentration of players in the food chain, food and retail companies also play a crucial role.

Aim and approach of this study

The central aim of this study is to stimulate an informed discussion about the future of the EU food system in a global context, focusing on the consumption and production of meat, dairy and fish, and their environmental consequences. The global and European food systems are very complex with many relationships and feedbacks. In order to support the discussion on the future of the EU food system with facts and figures, this study analyses the current EU food system and explores the effects of a number of possible pathways to reduce negative effects. A brief analysis is made of the global situation, followed by an analysis of the present EU consumption and production of meat, dairy and fish, based on an analysis of statistical data and literature reviews. The effects from a number of theoretical options regarding the consumption and production of meat, dairy and crop products are quantified by means of a combination of economic and integrated assessment models. The study concludes with a brief exploration of how the EU food system could be adjusted towards a more sustainable production and consumption of food.

II Global perspective and outlook

Global meat consumption is expected to increase strongly

Presently, around 16% of the global meat consumption takes place in the EU27. Compared to the EU, the consumption of animal protein in less wealthy regions is a factor of four to five lower. Many people in these regions do not consume sufficient proteins, which has adverse effects on human health and potential. The demand for proteins from animal products is projected to increase by more than 50% by 2030, compared to that of 2000 (figure 1), due to population growth and increasing wealth. Whether this projection becomes reality will depend on many factors, including environmental, economic and policy feedbacks.

Large areas of grassland and cropland are already needed for present levels of meat and dairy consumption. Given the projected increase in meat and dairy consumption, much more feed will be needed in the future. Crop production is projected to increase by more than 60% over the 2000-2030 period including the feed required in livestock production (figure 2). The additional amount of cropland needed for this production also will depend on increases in the crop yield. In the past, around 70% to 80% of the additional crop output was produced in higher crop yields. For the 2000-2030 period, cropland and grassland areas are projected to increase by 10% to 20%. The projected need for additional cropland and grassland areas implies risks of deforestation and conversions of semi-natural grasslands. This will not only lead to loss of biodiversity, but also to CO_2 emissions.

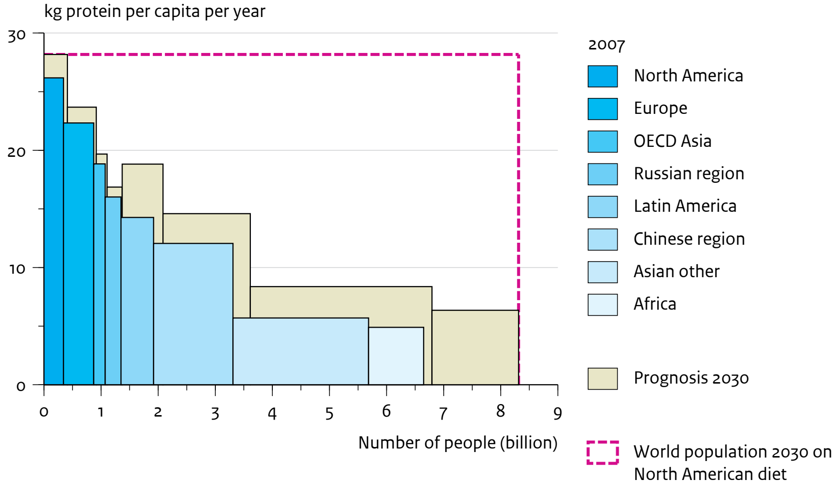
Large impact of agriculture and fisheries on global environment

Presently, global livestock and fish production both have a large effect on the environment:

- Global livestock production is responsible for around 12% of global greenhouse gas emissions. These emissions stem from animals and manure, from feed production and from land conversion, for example, from forest into pasture and from pasture into arable land.
- Around 30% of total terrestrial biodiversity loss may be attributed to livestock production. Livestock production also leads to substantial emissions of nitrogen in various forms (ammonia, nitrates), which in turn lead to losses of terrestrial and aquatic (including marine) biodiversity.

Because of the projected growth in global livestock production, all of these problems are expected to aggravate over the coming years, notably in Asia and South America. Furthermore, in spite of growing prosperity and food production, malnutrition is not expected to be eradicated over the next decades.

Figure 1
Global intake of animal protein per region



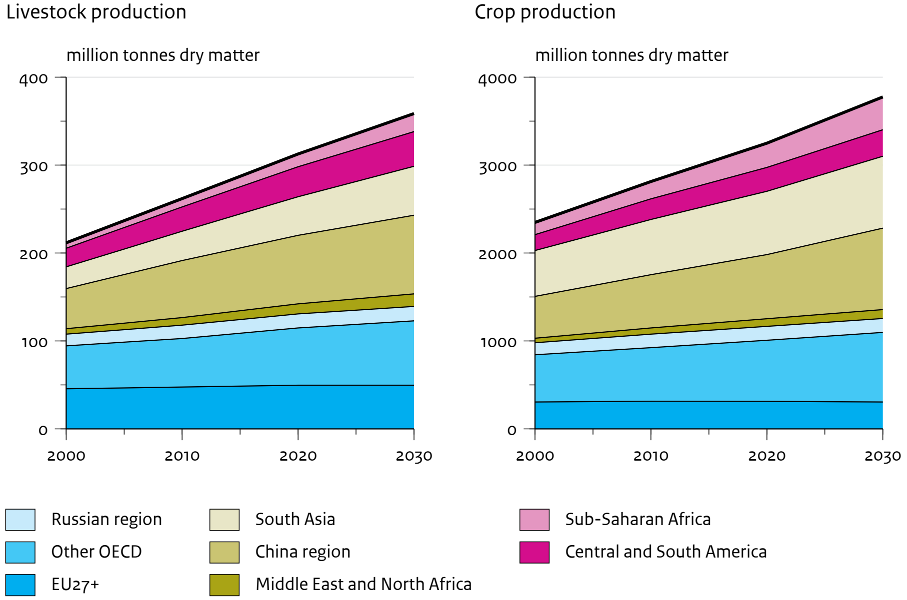
Source: Based on FAO (2006, 2010)
The global consumption of meat, fish and dairy products will increase due to increases in population and prosperity.

III EU consumption and production of meat, dairy and fish

Average EU consumption of animal products twice the global average
The average per-capita EU consumption of animal proteins in the form of meat, fish and dairy produce is about twice the global average. Within the EU, this consumption ranges from around 10 kilograms per person, per year, in Bulgaria and Slovenia, to 22 kilograms in France and Denmark. The main source of animal proteins is meat, of which the average consumption in Europe is about 52 kilograms (corresponding to 85 kilograms in carcass weight). Dairy is the second source of animal protein; average dairy consumption in the EU is equivalent to 300 kilograms in milk, and consists of milk and milk products, such as cheese, butter and ice cream. On average, only 10% of animal proteins consumed are from fish.

Strong increase in EU consumption of animal products over the last fifty years
The per-capita consumption of animal products in Europe has increased by around 50% over the 1961-2007 period, mainly due to increased welfare and relatively lower prices. Theper-capita consumption of poultry, in particular, has quadrupled since the 1960s, due to availability, reduction in price and the convenience trend, as poultry products are usually quicker to prepare. Pig meat consumption also increased, by 80%. Both kinds of meats increased without a corresponding reduction in any of the other meats.

Figure 2
Global livestock and crop production, LEITAP calculations

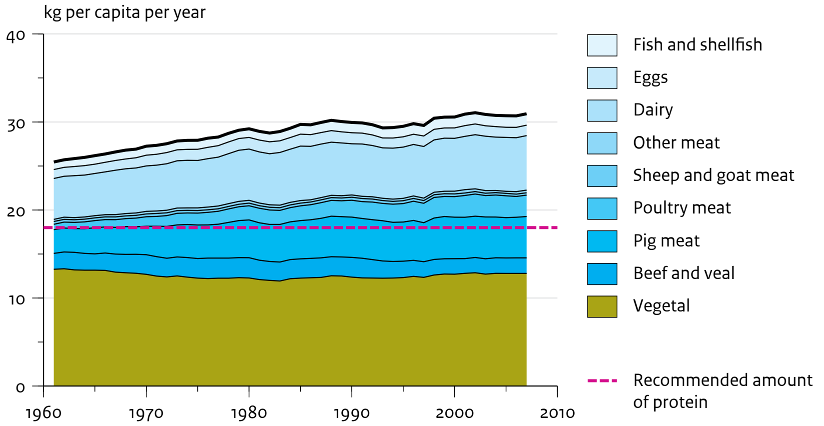


Source: PBL / LEI

Animal products have positive and negative health effects
Meat, fish and dairy produce are rich sources of vitamins, in particular vitamin B12, iron, calcium, zinc and other compounds. They are also primary sources of energy and protein in the EU. However, the energy intake and protein intake from animal and vegetal products in the EU are higher than recommended in WHO guidelines – for protein by as much as 70% (figure 3).

There are, however, also public health risks related to eating too many animal products. A high consumption of red meat is related to an increased risk of cancer. Red meat consumption in EU, currently, is twice as high as recommended by the World Cancer Research Fund. In addition, WHO guidelines recommend that the consumption of saturated fats be limited, due to the increased risk of cardiovascular diseases. For saturated fats, EU consumption levels, currently, are on average 40% higher than the maximum recommended amount (figure 4). Around 80% of saturated fats originate from animal products. A diet with lower amounts of meat and dairy would potentially increase human health and life expectancy. The consumption of fatty fish is related to a decrease in the prevalence of cardiovascular diseases; however, Europeans consume only about half of the recommended amount of fish.

Figure 3
Intake of protein in EU27



Source: PBL analysis, based on FAO (2010); Gezondheidsraad (2001); NEVO (2010); Schmidhuber (2007); Voedingscentrum (2008); WHO (2003b, 2007)

The increased consumption of animal products means that the total protein intake has increased over the last 50 years. The consumption of proteins per person is around 70% higher than recommended.

IV EU fisheries and aquaculture

Fish and shellfish originate from both catches and aquaculture. Since EU catches are declining and the increase in aquaculture production compensates only half of this decline, imports of fish into the EU27 are increasing.

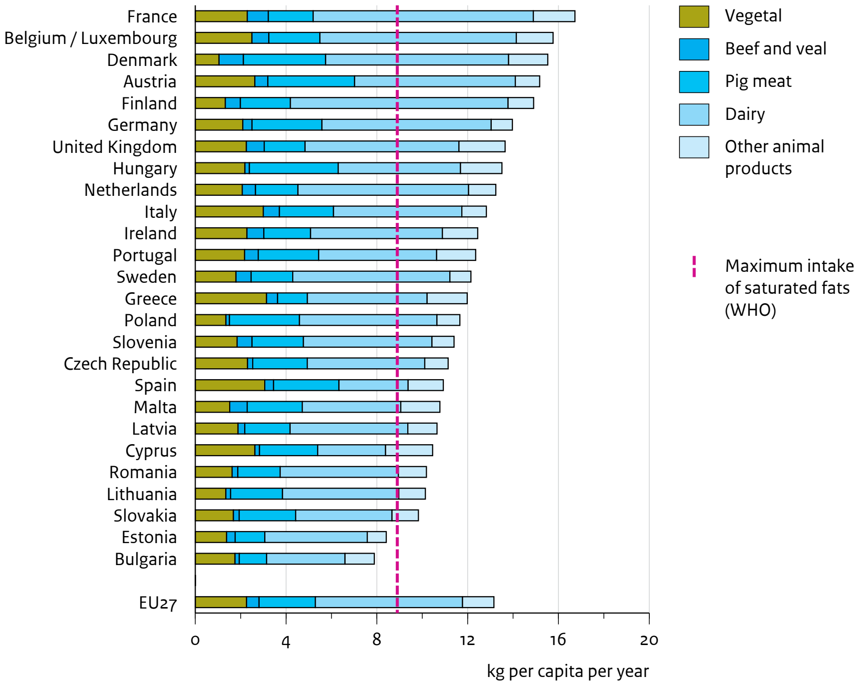
EU catches are declining rapidly, despite new fishing grounds

Catches by EU fisheries are declining (figure 5). This is partly due to the EU Common Fisheries Policy (CFP), which dates back to 1983 and was last modified in 2002. It comprises instruments for fleet reduction, a quota system, and management plans for several fish populations. However, despite the efforts made, overfishing has not been solved, as also stated in the EU Green Paper 'Reform of the Common Fisheries Policy'. The most important fishing areas for the EU fisheries are the North-east Atlantic Ocean and the Mediterranean Sea and Black Sea. Catches in these waters have dropped by a third since the early 1990s. Although EU fishing boats are travelling ever further and fishing ever deeper to find their catches, this compensates the declining catches from European waters only to a limited extent.

Marine and freshwater biodiversity is under threat and wild fish stocks are in decline. Globally, marine fish populations have declined by 24% since 1950. About 80% of

Figure 4

Intake of saturated fats in EU27, 2007



Source: PBL analysis based on FAO (2010); NEVO (2010)

In most countries, the consumption of saturated fatty acids is more than the recommended maximum amount.

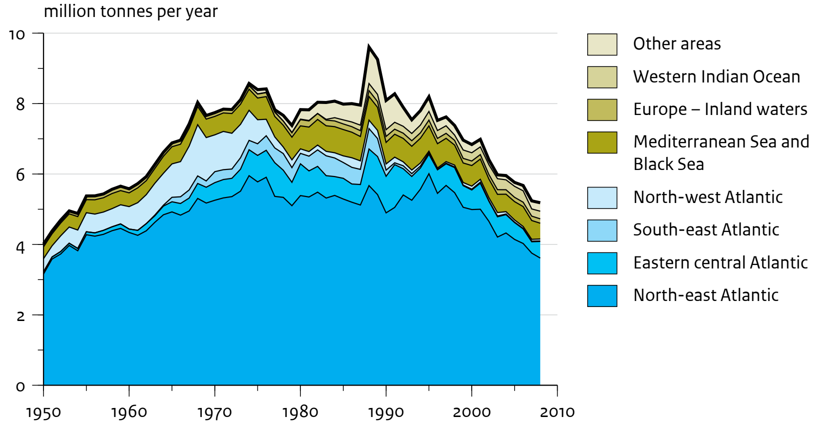
commercial fish populations are fully exploited or overexploited. In waters where the EU fishing fleet is active, the exploitation level is even higher than average.

Aquaculture: possibilities as well as problems

Smaller catches and growing fish consumption are driving the demand for aquaculture. Aquaculture production of fish in Europe has almost tripled since 1980. This has mainly been due to aquaculture in Norway; aquaculture in the EU27 has not even doubled and the increase has now stagnated. Globally, however, aquaculture has increased tenfold. Aquaculture production in the EU27, therefore, is growing much more slowly than it is worldwide.

A further increase in the cultivation of fish and shellfish could help to close the gap between growing demand and stagnating supply. Worldwide, around 40% of the produced fish currently originates from fish farms; The EU27 lags behind, at around 20%. However, aquaculture is not without its drawbacks, the most significant of which

Figure 5
Catches by EU27



Source: Eurostat (2010c); FAO (2010)

After a peak around 1990, catches made by EU countries declined rapidly, despite a trend to fish further away, for example, in the Indian ocean.

is the use of caught fish as fish feed. Other main problems are the conversion of coastal ecosystems and the nutrient pollution of coastal and inland waters. Furthermore, agricultural land is needed to produce crops, such as soy beans and cereals, for feed.

V The EU livestock sector

EU more or less self-sufficient in livestock products

The EU is a net importer of beef and sheep meat and a net exporter of pig meat and dairy products. However, quantities of both export and import are relatively small compared to EU production, thus, the EU is more or less self-sufficient in animal products. The analysis of the consequences of European diets, therefore, focuses on EU livestock production.

The EU livestock sector is diverse in type and size of farms

The total production value of the EU livestock sector is more than 140 billion euros. Milk (35%), beef and pig meat (each around 20%) are the sectors with the highest production value. The total EU27 meat production is around 44 million tonnes. The European livestock sector is diverse and can roughly be divided into two types. The first type is the sector with ruminants, such as cattle, sheep and goats, which graze for at least part of the year on most farms. The second type mainly consists of pig and poultry farms, where the animals usually are kept indoors, permanently (intensive livestock production). Across the EU27, these farms vary largely in size, number of livestock per hectare, and animal origin (farm-reared or purchased), and in composition of the feed that they use.

Feed is a key factor in the environmental effects of livestock production

Feed production requires large quantities of land, water and other inputs, and leads to significant emissions of greenhouse gases and nitrogen. The EU livestock sectors annually use around 500 million tonnes of animal feed. About 40% of this quantity is in grass (expressed in dry matter), 28% in cereals, and the rest consists of a range of products. About 60% of EU cereal production is used in animal feed. The dairy sector is the largest consumer of feed, with around 220 million tonnes, annually (figure 6), followed by the beef sector and the pig sector. For beef and dairy, grass is certainly not the only feed type. In the dairy sector, the share of grass in total feed is even below 50%.

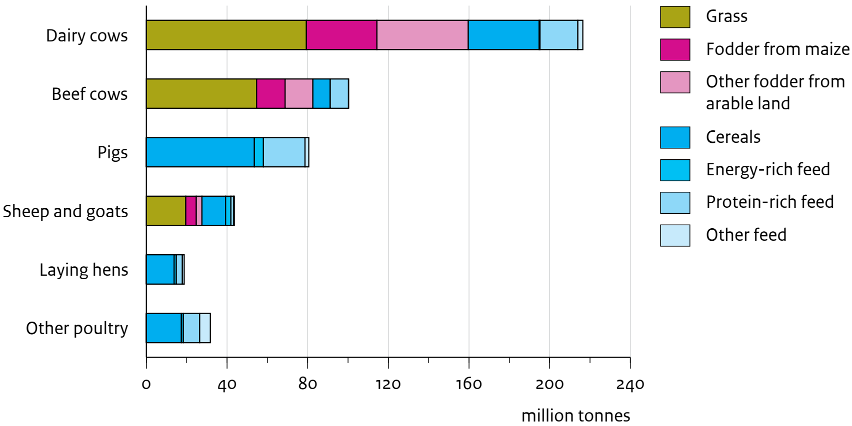
Feed can be roughly divided into three types: grass, feed crops such as cereals, and by-products. It is often argued that livestock production is a very efficient way of transforming products not suitable for human consumption, such as grass and by-products, into high-value products such as dairy and meat. However, this is only true to a limited extent. It is estimated that only 4% of dairy production and around 20% of beef production is connected to feed that comes from high nature value grasslands. Most of the grass in the EU originates from intensively managed grasslands, stimulated by fertiliser application. Extensive, high nature value grasslands have low yields. Moreover, some of the grasslands are temporary grasslands on land that could also be used for crop production.

On average, by-products only have a limited share in the total feed composition. Soybean meal is not a by-product of oil production, since the economic value of the meal is higher than that of the oil. Without the huge demand for feed, global soy production would be lower. The EU annually imports around 35 million tonnes in soybean meal equivalents, mainly from Brazil and Argentina. The EU is largely dependent on imports for the protein-rich feed component, as about 75% of protein-rich feed is imported, mainly in the form of soy products.

Development of the livestock sector strongly influenced by the Common Agricultural Policy

Domestic production, and import and export of both livestock and feed are significantly influenced by EU policies, notably the Common Agricultural Policy (CAP). Although the CAP has evolved over the last decades, it still has a strong effect, particularly through market protection and income support (Single Farm Payments). Import tariffs still exist for many livestock products. Given the fact that production costs within the EU are often higher than in countries such as Brazil and the United States, a reduction in EU import tariffs may lead to an increase in imports and, consequently, to a reduction in EU livestock production. Production quotas still exist for milk, but will expire in 2015. Other

Figure 6
Feed use per livestock sector in EU27, 2005



Source: Calculations based on Miterra-Europe

Around 65% of the feed in the EU is used in dairy and beef production: part of this is in the form of grassland products, but many crops are also being grown as feed. In total, 500 million tonnes of animal feed are used, annually, equivalent to around 1 000 kilograms per EU citizen.

regulations, such as sanitary measures, also have an important effect on imports and on production systems abroad.

The EU livestock sector has grown over the last decades. The former EU12 showed the strongest growth in the 1961-1985 period, when milk production increased by 70%, pig production by 120%, and poultry by 300%. Beef and milk production stagnated after 1985, mostly as a result of changes in policies. Pig and poultry meat production continued to grow by around 4%, annually.

VI Environmental impact of EU livestock production

Livestock production has a large impact on the environment; directly due to animal husbandry, and indirectly as a result of feed production. This study looks at the effects on biodiversity (as a consequence of land use and nitrogen emissions in the form of ammonia and nitrate) and climate change (through greenhouse gas emissions). Most of the environmental effects of EU livestock production occur within the EU itself, except for those from the cultivation of soy beans. These last effects are felt in the producing countries – mainly in Brazil and Argentina.

Over two thirds of agricultural land use in the EU27 is related to livestock production

Since good agricultural land is a scarce resource, the land area needed in agriculture is a key indicator of its environmental impact. A grassland area of around 65 to 70 million hectares is needed to produce feed for the EU livestock sector. In addition, a similar amount of arable land is needed to produce other feed, mainly in the form of cereals and forage, such as maize silage. About one third of this arable land is used to feed the animals in the European dairy sector. Grasslands are very diverse in terms of management, yield and biodiversity value. They range from semi-natural grasslands with low yields and high biodiversity values to heavily fertilised monocultural grasslands.

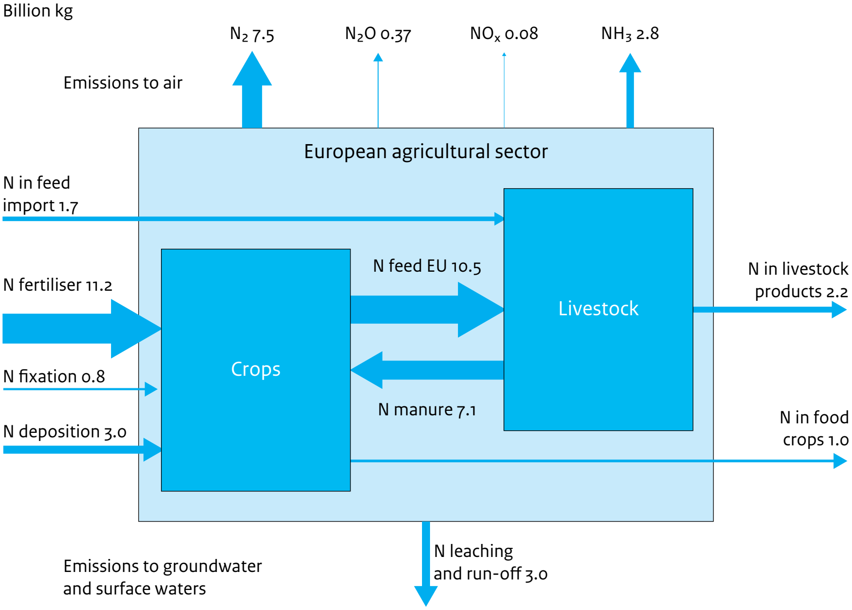
Significant amounts of land are needed outside the EU to produce protein-rich feed

EU livestock production also has an effect outside the EU through the import of feed. In Brazil and Argentina, most soy is grown on originally semi-natural grasslands, which have been converted into arable land. This in itself already has a negative effect on biodiversity. Furthermore, such expansions have also displaced livestock farmers and thus indirectly stimulated the conversion of Amazon forests into pasture for livestock farming that is being pushed out. In physical terms, about 20 million hectares outside Europe is needed to produce the protein-rich feed components. Since soy beans are cultivated for both oil and protein-rich meal, around 12 million hectares outside Europe may be attributed to European livestock production (for comparison: the arable land area used within the EU is around 120 million hectares).

Livestock production plays a pivotal role in reactive nitrogen losses

Crops and grass need nitrogen to grow, while animals need proteins in which nitrogen is an essential element. Since the invention of industrial nitrogen fixation, around 1910, it has been possible to produce nitrogen fertilisers at relatively low cost. The use of these fertilisers has boosted EU crop production and, consequently, its animal production. However, crops and animals do not absorb all the nitrogen input. The output/input efficiency of European agriculture is only 19% (figure 7). The rest of the nitrogen is lost; the livestock sector is the main source of nitrogen emissions. Most of the losses are in the form of harmless N_2, but large losses in ammonia and nitrate also occur, both potentially leading to the eutrophication of ecosystems. In many areas in Europe, nitrogen deposition levels are above the critical values. In general, agriculture is responsible for 50% to 80% of the total nitrogen load in watersheds; the rest mainly comes from industries and households. This nitrogen also negatively affects biodiversity in coastal zones. EU policy objectives for the quality of groundwater and surface waters are set in the EU Nitrate Directive and the Water Framework Directive. Stimulated by national and European policies, farmers have significantly reduced fertiliser use and nitrogen losses over the last 20 years while maintaining or even increasing production, and have thus increased nitrogen efficiency.

Figure 7
Nitrogen flows in agricultural sector in EU27, 2005



Source: Miterra-Europe

EU agriculture has a nitrogen efficiency of 19%. The livestock sector is one of the main causes of nitrogen losses to the environment. These losses occur in various chemical forms, such as ammonia (NH_3), nitrate (NO_3), nitrous oxide (N_2O) and the harmless N_2.

Effect of EU livestock production on biodiversity

EU livestock production is influencing biodiversity in a number of ways, most prominently through the use of agricultural land and emissions of nutrients (e.g. nitrogen) and pesticides. The impact of this land use on biodiversity is diverse. On the one hand, extensive livestock production, usually in the form of traditional farming systems, has led to a special kind of land management and corresponding rich biodiversity, albeit different from the pristine situation. The grasslands used in these farming systems are defined as High Nature Value Farmlands and are considered to be part of Europe's cultural heritage. They make up approximately 30% of grasslands in the EU15. Most of which are Natura 2000 sites. Discontinuation or intensification of the present management system would lead to a loss of this type of biodiversity. On the other hand, many farm animals are fed on products from either arable land or intensively managed (and fertilised) grasslands. The intensive cultivation of these areas negatively affects local biodiversity, for example, because of the loss of landscape elements. A second main pressure of livestock production on biodiversity is being caused by the emission of reactive nitrogen and other nutrients (e.g. phosphorus) and residues of pesticides.

EU biodiversity target

Concerning biodiversity, the European Council in March 2010 agreed on 'a headline target of halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss'. This would indicate that the biodiversity value of the High Nature Value Farmlands, which contain many European biodiversity hotspots, has to be ensured by the continued, extensive use of these areas. For more intensively used agricultural areas, the challenge is to maintain production at a relatively high level, while also augmenting local biodiversity values.

Greenhouse gas emissions: about 10% of EU27 emissions related to livestock sector

The livestock sector in the EU27 currently contributes more than 10% to the total greenhouse gas emissions from the EU27. This figure takes into account both direct emissions from animals and manure and those related to feed production, including land use. Main sources are enteric fermentation (methane) and soil emissions (nitrous oxide). Together, the beef and dairy sectors account for more than 70% of greenhouse gas emissions from livestock farming, while pig production accounts for around 13%. The contribution from poultry (4%) is small compared to its share of 25% in EU meat production, as poultry has low digestion emissions and a better feed conversion. The policy objective of the EU is to reduce total greenhouse gas emissions by at least 20%, by 2020, compared to 1990 levels.

Animal welfare and animal health

Although, strictly speaking, animal welfare and animal health are no environmental issues, they are very relevant to society and there are many links with environmental issues. Conventional types of animal housing lead to discomfort for farm animals. This discomfort is caused by poor air quality in stables, too smooth and often wet floors, the lack of stimulus offered by the environment, concentrated feed (leading to boredom), and disease. Some animals are also routinely subjected to interventions, such as beak cutting, tail docking, tooth clipping and castration. Concerning the relationship between the risks to animal health and human health, one of the main areas of concern is the development of resistant bacteria strains. Humans infected with these resistant bacteria may develop severe health problems. Furthermore, various EU Member States have faced serious problems over the last 10 to 15 years, due to outbreaks of animal diseases such as BSE (mad cow disease), foot and mouth disease, classical swine fever and avian influenza (bird flu).

VII Environmental effects of products and diets

Livestock products deliver important components in the European diet, but they also form a significant share of the environmental impact from consumption. The EU consumption of meat and dairy produce is responsible for about 10% of all EU greenhouse gas emissions from consumption. It also represents about one third of the total land use related to household consumption in the EU27. Most of the land is located in Europe, but also elsewhere, when related to imported products, such as beef and dairy, and imported feeds used in the production of European meat and dairy. Some of the greenhouse gas emissions that are related to European consumption are emitted outside Europe.

In general, food products of animal origin cause more environmental impact than do plant-based protein-rich products. This is mainly due to inefficient conversions of feed protein and energy into animal protein and energy. Moreover, only around 50% of the total animal is fit for human consumption.

The highest environmental impact is found for meat, in terms of land use and greenhouse gas per kilogram of product, with beef having the highest impact, followed by pig meat. Poultry meat causes the lowest impact, because of the higher feed conversion of poultry. Expressed per kilogram of protein, the impact of milk is in-between the ranges of pig meat and poultry.

Land use for ruminant meat production – such as beef and sheep meat – can be high, but this is mainly grassland, especially in extensive systems. Some of these grassland regions are not suitable for arable farming, and ruminant farming systems are the only systems possible. Furthermore, the land-use impact of grassland on biodiversity usually is lower than the impact of arable land. However, in addition to higher land use, beef production also has the disadvantage that it emits methane, a powerful greenhouse gas.

Generally, land use and greenhouse gas emissions related to farmed fish are within the same range as those of poultry. The impact on marine biodiversity depends on the use of forage fish in the feed; this is relatively high for predatory species, such as salmon, but low for herbivorous species, such as tilapia. Wild-caught fish, especially, has an impact on marine biodiversity. However, bottom-trawling fishing methods generally also emit high greenhouse gas emissions because of their high energy use.

Differences in impacts also exist within production categories, such as of beef or pig meat. This variation is mainly due to differences between production systems, although transportation is also an important factor for some products, especially in the case of air transport. The differences are partly due to differences in production circumstances, but in some cases efficiencies also could be improved. There are various opportunities, both within and between the various product categories, for reducing the environmental impact from the European diet and for mitigating climate change.

Although such changes in diets would be favourable, both to sustainability and health, there is some ambivalence related to fish. Although increasing fish consumption would be beneficial in terms of human health, it would have an unfavourable impact on marine biodiversity (section 7.4). In order to achieve the amounts of fish recommended for a healthy human diet, innovation is needed in aquaculture.

In summary, opportunities do exist for changing human diets to be more healthy and sustainable, but further steps are required.

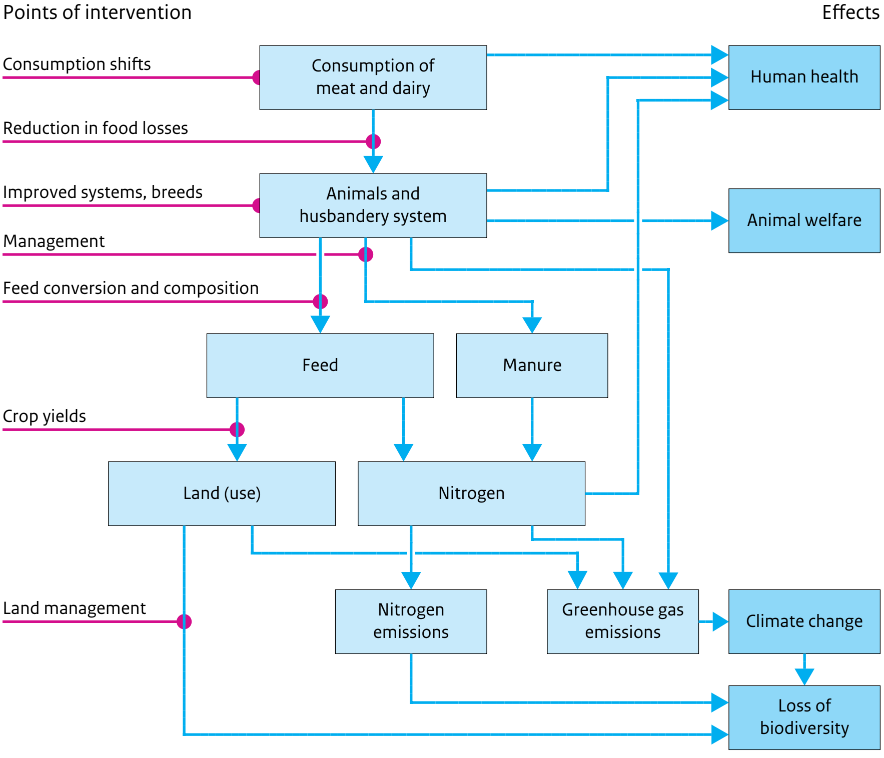
VIII Options for reducing negative effects of the EU food system

Many points of intervention along the food chain to reduce negative effects
There are many possible points of intervention to reduce the negative effects caused by the present EU food system, ranging from shifts in consumption patterns, to adaptations of husbandry systems, raising crop yields to reduce the land area needed, and improved management of manure and land (figure 8). For each point of intervention, multiple options exist. Examples are increased feed conversions or reductions in food waste. In some cases these options are directly related to possible policy measures, such as raising minimum standards of space required per animal in husbandry systems. In other cases, such as those of consumption shifts and increases in crop yields, policy measures or interventions by other actors will be less directly connected to these physical options.

Innovations in aquaculture could reduce effects on marine biodiversity
For the effects on marine ecosystems to be reduced, it is important to reduce the use of wild-caught fish as feed in aquaculture. Fish farming of predatory species, such as salmon, uses relatively large amounts of wild-caught fish as fish feed. However, a relatively small increase in agricultural land could be enough to produce feed for more farmed herbivorous fish, so that wild fish would be protected, could recover and possibly provide higher catches in the future. This would need to be combined with a switch in consumption from predatory to herbivorous species. Direct consumption of caught herbivorous fish instead of using them as feed for other fish, would also help. Another option – which is already ongoing – is to reduce the amount of wild-caught fish in fish feed. This could be achieved by replacing fishmeal and fish oil with additional vegetable ingredients and by improving the feed conversion. Furthermore, there are other options for farmed fish, which are similar to those for meat and dairy (figure 8).

Figure 8

Causal diagram of effects of meat and dairy consumption and points of intervention



There are many potential points of intervention at which negative effects of livestock consumption and production on human health and the environment could be addressed. Positive or negative side effects will always occur, due to the complex relationships within the food system.

Often trade-offs between improvement in animal welfare and environmental issues

A number of options for reducing certain negative effects simultaneously lead to improvements for other issues, as well (synergy), but they may also lead to the aggravation of others (trade-offs). In many cases there are synergies, for example, because several problems have the same origin. Reduction in the demand for animal products, in particular, will benefit biodiversity and human health, as well as reduce nitrogen and greenhouse gas emissions. The same synergies occur in the case of increased feed efficiency.

One of the most important trade-offs lies between animal welfare and environmental effects. To improve animal welfare, farm animals need more space and perhaps outdoor access. Different breeds are also needed, which sometimes grow less quickly, as in the case of broilers. These improvement would all lead to higher feed demand per unit of produce and more emissions from housing systems. Improved welfare conditions would lead to an additional feed use of around 10% for pigs and laying hens and 25% for broilers; in the case of organic production the additional demands would even be higher. This reduction in feed efficiency could be compensated either through innovation or by a shift in the consumption of animal products.

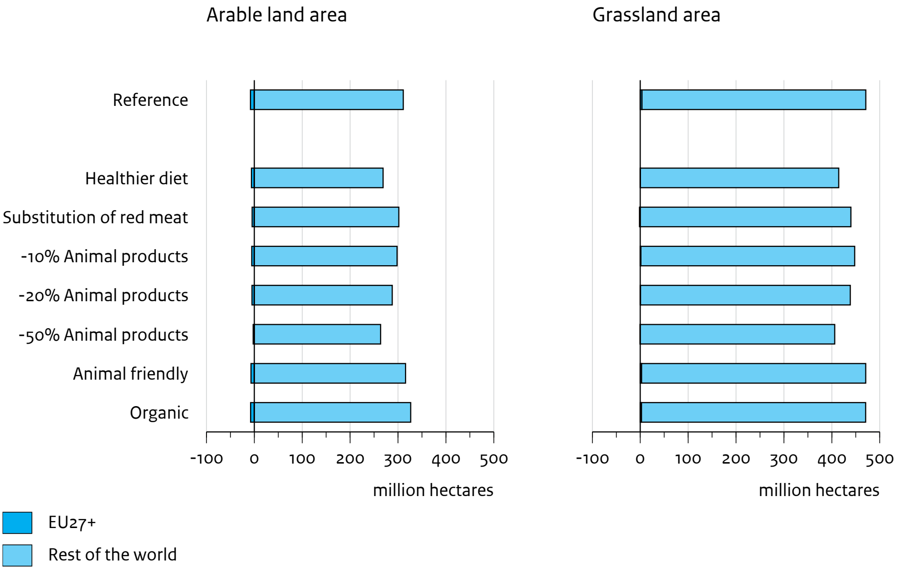
Quantification of effects from different options
In order to explore effects, an assessment of several options was made, using PBL's Integrated assessment model IMAGE in combination with two agro-economic models (the IMPACT model of IFPRI and the LEITAP model of LEI) for comparison. The economic models were used for calculating responses by consumers and producers in different world regions. Because of feedbacks and non-linearities in the food system, a simple upscaling of results from life-cycle assessments (LCAs) or simple extrapolation ('crop yields plus 10% means land area minus 10%') would not yield valid results. Two sets of options were developed, one for implementation at the global level, the other at EU level. The combined models enabled a quantification of, among other things, effects on food demand, regional crop and livestock production, land use and greenhouse gas emissions.

Global options would have significant effects on land area needed
The options defined on a global level mainly aim at increasing usable production, while minimising land area and greenhouse gas emissions. These options are:
- producing more efficiently (e.g. higher crop yields than assumed in the *Reference Scenario*, more livestock products per kilogram of feed);
- reducing supply chain wastes and losses with consequential decreases in demand and production.

All evaluated global options would result in less additional arable land and grassland needed compared to that in the *Reference Scenario*. Lower production costs and less waste would result in lower commodity prices, in turn leading to an increase in food consumption, which may mean less malnutrition. This reduction in arable land and grassland area, compared to that in the *Reference Scenario*, would also result in lower biodiversity loss and lower emissions of greenhouse gas and nitrogen.

Options at EU level would mainly have effect on land use outside the EU
Seven options have been defined at EU level. These options are mainly aimed at reducing environmental impacts and human health risks by reducing or altering consumption of livestock products. Two of these options were defined to improve animal welfare. The options analysed are:
- changing human consumption patterns (e.g. switching within a food category, such as meat, to products with less environmental impact, or from animal products to

Figure 9
Effects of EU options regarding agricultural land use, 2000 – 2030



Source: PBL / LEI

Globally, both cropland and grassland areas are projected to increase, between 2000 and 2030, as a consequence of the growing global food demand. If the EU were to reduce the consumption of livestock products, the expansion of arable land and grasslands would be considerably smaller than in the Reference Scenario. In the options that include increased animal welfare, slightly more arable land would be needed.

vegetal products (*Healthier diets*, *Substitution of red meat* (with poultry meat), *Reduced consumption of livestock products (10%, 20% and 50% less)*;
– shift to different production systems (*Animal friendly* and *Organic*).

The EU options presented some counter-intuitive results, especially those regarding dietary changes. Although, in these options, reduced demand for animal products would lead to a decrease in their EU production, it would still lead to a somewhat higher export of dairy, and pig and poultry meat, and to a reduction in beef imports. In the EU, decline in livestock production would result in some extensification of land use (i.e. lower yields) and in an increase in biofuel production. In addition, as the EU demand for feed would decrease, this would result in higher cereal exports. As a consequence, some non-EU countries would face a reduction in the demand for their products, which in turn would lead to a relatively greater reduction in agricultural area in those countries than would have occurred in the EU, where yields and livestock densities usually are much higher than outside the EU. Both a shift to a healthier diet and a 50% reduction in the consumption of animal products would lead to an actual reduction in, or avoided expansion of total arable area of 45 million hectares, which equals one third of the EU arable area. The same options would also result in an avoided expansion of grassland use outside the EU of around 60 million hectares, being about equal to the total EU grassland area (figure 9).

The fact that EU options would mainly influence land use outside the EU, may be partly explained by the design of the EU Common Agricultural Policy, which stimulates agricultural use of land by coupling the Single Farm Payments to the requirement to keep the land in 'good agricultural and environmental condition'. An additional explanation would be that land-use changes within the EU would mean land abandonment, while outside the EU this would result in less conversions from natural areas into agricultural land. The options *Animal friendly* and *Organic* both would lead to somewhat higher commodity prices and a larger increase in cropland than in the *Reference Scenario*, as a result of increased feed demand in both these options, and lower EU crop yields in the *Organic* option.

Environmental effects would be in line with those on land use. Especially the options *Healthier diet* and *Reduced consumption of livestock products by 50%*, would lead to substantial reductions in biodiversity loss, and to lower emissions of greenhouse gas and nitrogen.

The model results suggest that, usually, less than 50% of theoretical environmental benefits are actually achieved, because of feedbacks related to consumption and production. For example, price decreases would lead to an additional increase in consumption on the one hand, and to less efficient production, especially leading to lower yields, on the other. To some extent, these effects of rebounds and leakage may benefit other policy targets: lower food prices would mean a better affordability of food, and, hence, a potential means to reduce malnutrition. Extensification of production may also improve local environmental quality.

IX From options to strategies

Three strategies to reduce impacts

Along the food chain, there are a number of points of intervention to reduce the impacts from consumption and production of animal products (figure 8). For each point of intervention numerous opportunities exist. For example, higher crop yields may be achieved through better crop management and higher inputs, or by introducing new varieties. These opportunities can be grouped into three broader strategies: (i) *consuming less or different animal products*, (ii) *increasing resource efficiency*, and (iii) *producing with fewer local impacts*. These strategies are partly complementary to each other.

Consuming less or different animal products would reduce the size of livestock production, which in turn would lead to lower environmental pressure. This would include a shift towards more animal-friendly or less environmentally harmful production systems. In general, this strategy would lead to health benefits – human and animal. *Increasing resource efficiency* involves of a more efficient use of resources, such as land, water, and inputs such as nitrogen and phosphate. Examples would be higher yields per hectare, higher feed efficiencies, better management of manure and fertilisers, and reductions in food wastes. *Producing with fewer local impacts* focuses on mitigating local impacts, improving animal welfare and reducing animal health risks. Examples of opportunities related to this strategy are improving animal housing systems and breeds, and improved land management. Organic farming also falls within this strategy, and certain elements could also be applied in other farming systems, as well.

Consuming less or different animal products would lead to an increase in resource efficiency and a reduction in local environmental impacts. This, therefore, would be a robust strategy to follow. *Increasing resource efficiency* might lead to adverse local impacts, such as biodiversity loss and high emissions of nitrate in regions with high production levels. This means that increasing resource efficiency might be contrary to the strategy to reduce local impacts. The benefit of this strategy, however, is that, globally, less land and resources would be required. On the other hand, the *Producing with fewer local impacts* strategy may result in a less efficient use of resources, both at the European and the global level. Examples are poorer feed efficiencies due to increased animal welfare, and lower yields if large land areas would be reserved for ecological set-aside.

What role could the EU and national governments play to put these strategies into practice?
Current policies and institutional setting mainly drive farmers and other actors in the food chain in the direction of cost price reduction. This stimulates an efficient use of resources with an economic price that reflects their scarcity, but the current setting does not stimulate an equally efficient use of non-priced resources. Regarding the strategy *Consuming less or different animal products*, policies are practically non-existent, and with respect to the strategy *Producing with fewer local impacts*, policies are usually secondary to free market policies. By means of the Common Agricultural Policy and the Common Fisheries Policy, the EU has a large influence on the livestock and fisheries sectors. Food and agriculture may also play an important role in initiatives such as 'Resource Efficient Europe'. Policies could include financial instruments, such as 'getting the price right', legislation (e.g. on environmental and/or animal welfare), and encourage institutional changes, innovations and behavioural changes.

Actors in the food chain may act independently from governments
Consumers and other actors in the food chain could initiate and implement the strategies ahead of changes in policies and international institutional changes. Consumers could shift to products that have lower environmental impacts or are more animal friendly. However, they will probably only do so if they are well informed, by food companies and retailers, and if there are real choices to be made. The fact that 'sustainable' diets, in general, are healthier as well, may serve as another convincing

selling point. Retailers could enlarge their assortment of animal products that are produced under higher standards, as well as offer food products that serve as alternatives to meat and fish. In addition, retailers could enter into agreements with farmers and food suppliers, in order to develop new labels and improve production techniques.

Globally, improving food security while limiting environmental impacts is a major challenge

Improving food security while limiting local and global environmental impacts is a major challenge, especially in developing countries. The development of the agricultural sector is vital for a reduction in poverty in rural areas. Assisting in creating a strong agricultural sector should however not lead to the export of westernised diets. Improving efficiencies, such as higher yields, in theory, would benefit food security and the global environment. Increasing food production alone, however, does not guarantee an improvement in food security. In order to reduce hunger and malnutrition, a more targeted, pro-poor approach would be needed, based on local physical and socio-economic conditions.

The 'protein puzzle' is not easy to solve, and many questions remain unanswered, on more technical issues, as well as on how to change the institutional setting to initiate changes in production and consumption. Human consumption will always impact the environment, but there certainly is scope for increasing global food availability while limiting impacts on biodiversity, climate, animal welfare, and animal and human health.

FULL RESULTS

ONE

Introduction

1.1 Background

This report has been prepared by the PBL Netherlands Environmental Assessment Agency to contribute to the discussion on the future of Europe's consumption and production of food, in the global context of a rapidly rising demand. This increasing global demand, notably for meat, dairy and fish, creates a number of challenges (IAASTD 2009; PBL 2009, 2010). On the global level, the challenge is to improve food availability and reduce malnutrition, while strongly reducing biodiversity loss and emissions of greenhouse gases and nitrogen. The report focuses mainly on the EU consumption and production of food, placed in the context of this global challenge.

For the EU food system, the emphasis in this report is on the consumption and production of meat, dairy, eggs and fish. What are the impacts of the present levels of consumption on the environment? What are the options for reducing these impacts through changes in consumption or improvements in production methods? These questions are frequently asked in society and about which there is much debate.

For several reasons, this report concentrates on the consumption and production of animal products (meat, dairy, eggs and fish). For fish, the depletion of stocks and impacts on marine biodiversity are the main issues (Alder et al. 2007; Watson & Pauly 2001). For livestock production, there are concerns about animal welfare, greenhouse gas emissions, loss of biodiversity, and resource use due to the inefficient conversion of plant protein into animal protein. The FAO report *Livestock's Long Shadow* was the first to put these concerns prominently on the agenda (FAO 2006a). Given the increase in global prosperity, for many regions, a shift in consumption is expected, from vegetable products towards meat, dairy and fish (FAO 2006b; IAASTD 2009; Keyzer 2005; Thornton 2010).

From the perspective of public health, many Europeans consume too many calories and too much in saturated fats, the latter primarily of animals origin. According to dietary recommendations, many people should consume more fish, fruit and vegetables. As meat, dairy, eggs and fish are all important sources of protein, and because they are partly interchangeable or may be replaced by vegetable protein sources, the problem can be framed as the 'protein puzzle'. The future supply of proteins is a crucial factor in the global food system (Aiking 2011).

Biodiversity loss, greenhouse gas emissions, and the use and emissions of nitrogen, are the main environmental issues discussed in this report. Livestock and fisheries are not the only significant pressures regarding these issues. Rockstrom et al. (2009) argue that for these issues, the 'planetary boundaries have already been overstepped'. Livestock production is one of the main causes of emissions of various forms of reactive nitrogen (Galloway et al. 2010). Nitrogen and proteins are strongly connected, as nitrogen is one of the key components of amino-acids, the building blocks of proteins. In addition to these three environmental aspects, attention also is being paid to animal welfare, as this is a concern of many Europeans. Regarding the production and consumption of fish, the report mainly addresses the issues of impacts on marine biodiversity and the depletion of fish stocks.

This report presents a current and concise overview of facts and figures on present EU consumption, production and effects, as we felt that such an overview, to date, had been unavailable. It may add to a more informed discussion. With respect to human consumption, especially, many new calculations were made. This also applies to other aspects, such as feed use and environmental effects, and, in particular, to those related to the various livestock sectors. Many of the presented data, therefore, carry some uncertainty and we are open to suggestions for improved data or methods.

In order to gain insight into the question of how to reduce impacts by changing either consumption or production methods, a number of potential options were evaluated, using a combination of global agro-economic and environmental models. Calculations mainly concerned options at EU level. By making use of models, the many relationships and feedbacks in the European and global food systems could be taken into account. To the best of our knowledge, this study is one of the first that uses this approach to assess the effects of various options. It must be noted that results should be viewed as indications, not as predictions. This is especially the case, since the models have taken feedbacks in consumption and production into account, but possibly did not include policy responses. The report concludes with a first reflection on how changes in the food system could be initiated, and by which actors.

1.2 Structure of the report

Given the fact that the European food system is embedded in the global food system, chapter 2 starts with the global context. It describes the present consumption of meat, dairy and fish, worldwide, and discusses the questions around the effects from the production of these food products on the environment. Which changes are to be expected over the next 20 to 40 years? And which actors have a role in the global food chain?

The chapters 3 to 7 mainly focus on the situation in the EU. We look at the present consumption of meat, dairy and fish, in terms of quantity, as well as proteins and fats, and discuss possible consequential effects on human health. Chapter 3 addresses the question of how consumption patterns have evolved over the last 45 years. The structure of EU livestock production and its effects on the environment are subjects of chapters 4 and 5. Chapter 4 also provides a brief historical view of EU livestock and feed productions. Fisheries and aquaculture are discussed in chapter 6. Followed by a presentation and discussion of the environmental effects per unit of produce in chapter 7, as chapters 5 and 6 present the effects in a broader view, per livestock and fishery sector.

The results from the quantitative assessment of the various options for changing consumption and agricultural productions are presented in chapter 8. Finally, chapter 9 briefly discusses the broad strategies that may reduce impacts on the environment and on animal welfare, and the possible roles of the different actors (policymakers, consumers, farmers, fishermen, food industry and retailers).

TWO

The global and long-term context

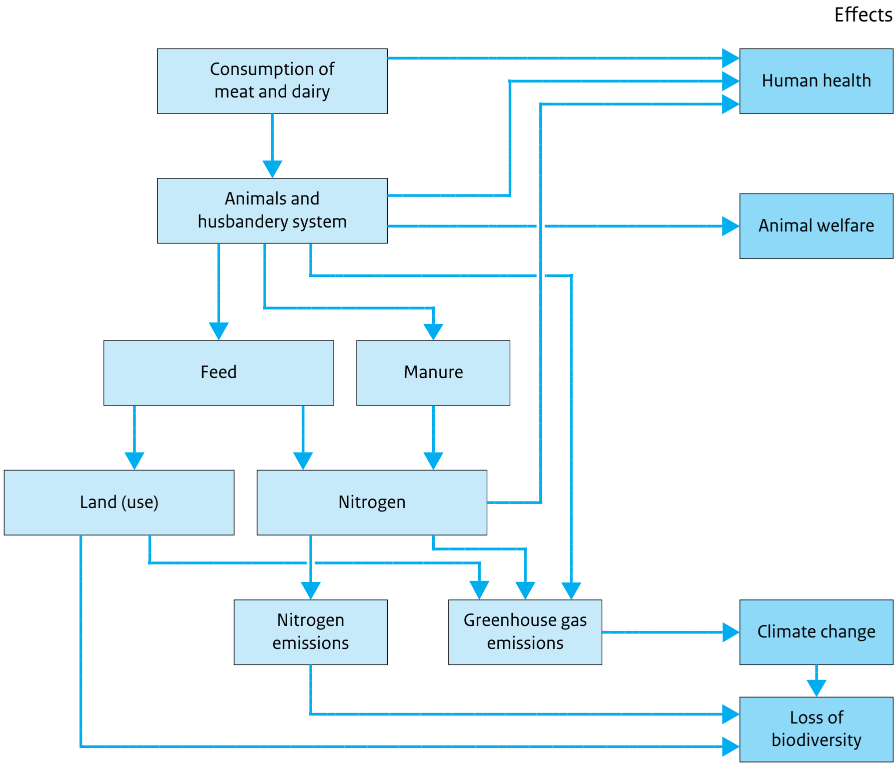
2.1 Introduction

Before focusing on the situation in the EU, in the following chapters, it is important to look at the situation and developments taking place at the global level. Production and consumption currently are changing rapidly in other regions, most notably in Asia and Latin America. Most of the EU Member States experienced similar rapid changes in the 1950-1985 period. The driving forces of these changes include a growing global population, an increase in wealth in many regions, technological developments, transformations of supply chains, and agricultural and bio-energy policies.

Section 2.2 describes the causal relationships within the livestock production system. Global consumption of meat, dairy and fish is described in section 2.3. Section 2.4 briefly describes livestock production, and section 2.5 provides some projections of how consumption and production of livestock products may develop over the coming decades. The land area needed for livestock production, as well as other environmental effects, are described in section 2.6. Fisheries and aquaculture and their effect on marine biodiversity are the subject of section 2.7. Section 2.8 discusses the importance of a nutritious diet, especially during childhood, in relation to malnutrition and the prevalence of hunger and poverty. The global food system and relevant actors are briefly described in section 2.9. Finally, section 2.10 summarises the main conclusions of this chapter.

Figure 2.1

Causal diagram of effects of meat and dairy consumption



Relationships between livestock consumption, production and their impacts on human health and the environment are complex and multifaceted.

2.2 Causal relationships in the livestock production system

Relationships between livestock consumption, production and their impacts on human health and the environment are complex and multifaceted. A schematic diagram of causes and adverse effects is presented in figure 2.1. This chapter briefly discusses each item in the diagram in figure 2.1 in a global context. Fish and aquaculture are not included in this diagram. The diagram starts with the human consumption of meat, eggs and dairy. To produce these products, animals are needed, which in turn require feed. To produce this feed, land is needed. As a consequence of animal production, there are adverse effects on human health (such as the transmission of diseases), animal welfare, biodiversity, and on the global climate as a result of greenhouse gas emissions. Nitrogen

Consumption and production projections
The most cited source for consumption projections is the FAO study *World agriculture: towards 2030/2050. Prospects for food, nutrition, agriculture and major commodity groups* (FAO 2006a), which is an update and extension of the 2003 study *World agriculture towards 2015/2030* (FAO 2003). The 2006 FAO report does not give a detailed projection of production. More recent projections, for example, the projection included in the International Assessment of Agricultural Science and Technology for Development (IAASTD 2009), are roughly in line with the FAO 2006 projection.
For this report, two new, related reference scenarios were made, using two agro-economic models: LEITAP (Van Meijl et al. 2006) and IMPACT (Rosegrant et al. 2008). These serve as a reference for evaluating different options to attain a more sustainable protein supply (chapter 8). The increase in livestock consumption and production is somewhat higher in the LEITAP projection than in the FAO projection. This also results in a higher demand for feed crops, but the results from both models compare reasonably well with FAO projections.

plays an important role in feed production, but is also a cause of harmful effects. This chapter discussed a number of these negative impacts, while chapter 5 describes these issues in more detail at the European level. The effects of consumption on human health are discussed in chapter 3.

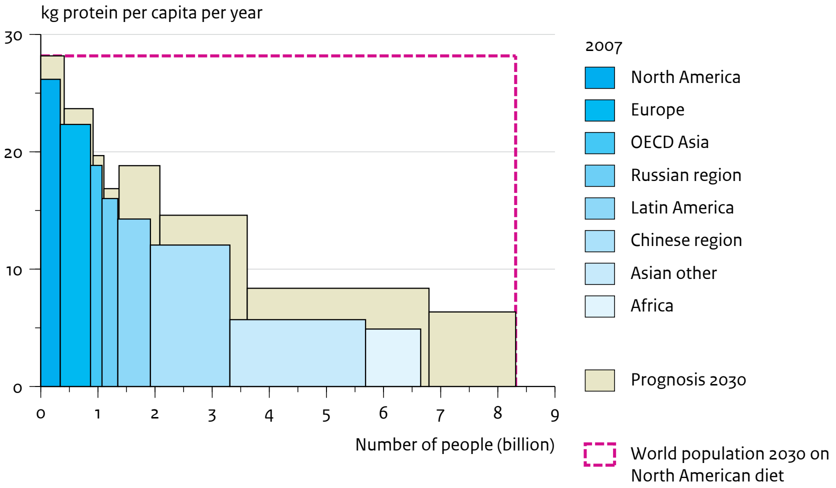
2.3 Consumption of animal products

Large differences in current consumption patterns

There are large differences between regions in their per-capita consumption of meat, dairy and fish. Globally, in 2007[1], the average per-capita consumption was around 40 kilograms of meat per year.[2] In Europe (EU27) and North America, the consumption level was two or three times this average. Consumption in China was around 53 kilograms per capita, whereas in Africa it was only 16 kilograms (FAO 2010a). There were also large differences in dairy consumption; consumption in North America and Europe was five to six times greater than in Asia and Africa.

The average fish consumption, worldwide, was around 17 kilograms per person (expressed in live weight). Japan, with 60 kilograms per capita in 2007, was a large consumer. Wealthier regions generally had a fish consumption of around 20 to 30 kilograms per capita. In regions such as Africa, Latin America and central Asia, average consumption was much lower, but there are large differences between countries. Globally, 15% of animal protein originates from shellfish and fish (FAO 2010a).

Figure 2.2
Global intake of animal protein per region



Source: Based on FAO (2006, 2010a)

Global consumption of meat, fish and dairy products will grow between 2007 and 2030 due to increases in population and prosperity.

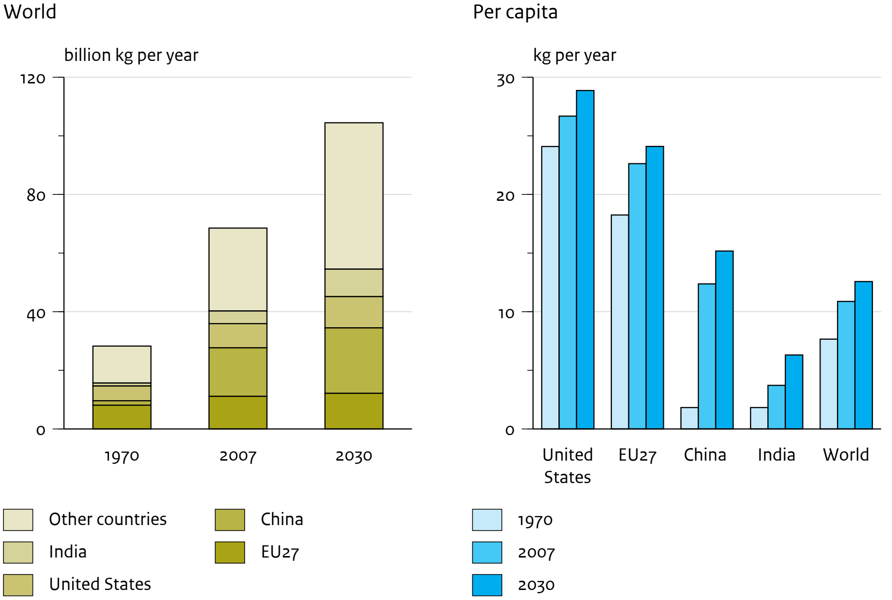
Wealthier regions consumed twice as much protein from animal products as other regions

Animal products, such as meat, fish, eggs and dairy are important sources of protein and minerals. Protein consumption from animal products in North America and Europe was about five times higher than in Africa (figure 2.2) and more than twice the world average (figure 2.3, right). The consumption of animal proteins was also relatively high in OECD Asia. Together, populations in these wealthier regions form 16% of the global population, but consumed 34% of all animal proteins. The EU27, with just over 7% of the global population, consumed almost 16% of available global animal proteins. Furthermore, worldwide consumption of animal proteins has more than doubled since 1970 (figure 2.3, left).

Meat consumption will more than double up to 2050

Meat consumption in rich regions is expected to increase by about 10% by 2030 (FAO 2006b). A much larger growth is expected in developing regions, such as Asia and Africa (figure 2.2). The total global consumption of meat is expected to increase by almost 70% between 2000 and 2030 (FAO 2006a) and by another 20% between 2030 and 2050. Total global consumption of milk is expected to increase by over 50% between 2000 and 2030 (FAO 2006a) and by another 20% between 2030 and 2050. If, in the future, nine

Figure 2.3
Supply of animal protein



Source: Based on FAO (2006a, 2010a)

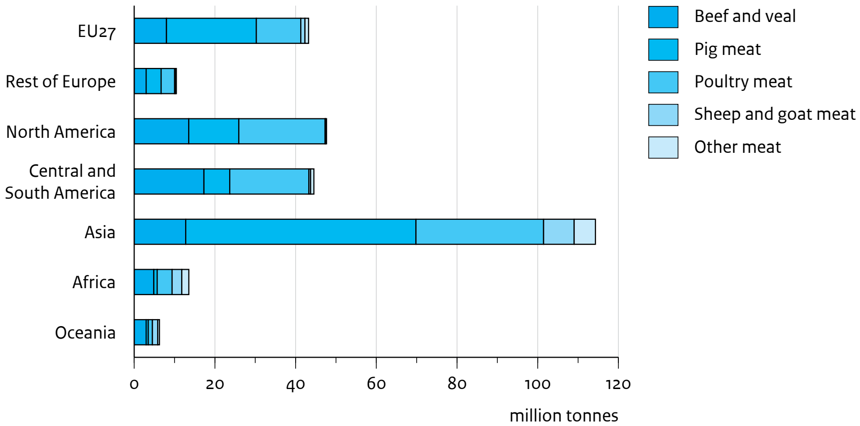
Left: Worldwide consumption of animal protein will increase by 52% between 2007 and 2030.
Right: Major differences in consumption of animal proteins between regions.

billion people would want to reach current Western consumption levels, then the global production of animal proteins will have to triple (figure 2.2).

Global prosperity and urbanisation result in higher meat consumption

Global meat consumption is increasing because of the increasing population and because people are becoming more prosperous and more urbanised, particularly in emerging economies (IAASTD 2009; Rae & Nayga 2010). Improved logistical systems also mean that meat, dairy and fish products become more widely available (Thornton 2010). Global fish consumption is also expected to rise; with demand for predatory fish increasing, in particular, due to its texture and taste, and the assumed health benefits from fish oils (FAO 2009a).

Figure 2.4
Global meat production, 2007



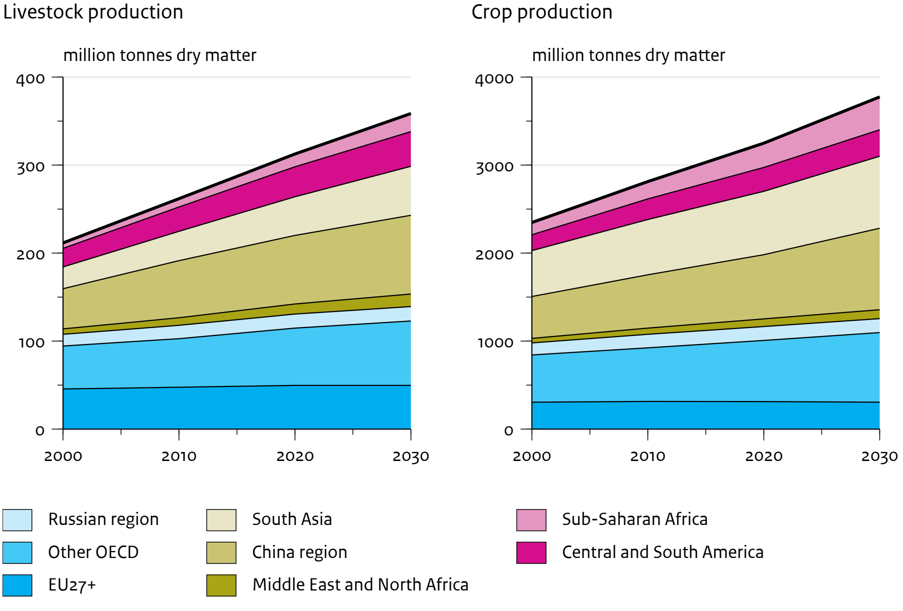
Source: FAOSTAT (2010)

2.4 Present livestock production

Strong global increase in meat production, but not in the EU
In 2007, EU meat production amounted to around 15% of the global meat production (figure 2.4). Compared with North America, the EU produces relatively more pig meat and less poultry. The EU share in global milk production was around 22% in 2008. Worldwide production of both meat and milk grew by about 25% over the last ten years, mainly due to growth in Asia and South America. However, over the same period, the production of milk and meat in the EU declined by 1 to 2%.

Trend towards intensification of livestock production
Throughout the world, livestock production systems vary greatly, from nomadic pastoralists to smallholder farms, to large farms with confined animals fed on feed produced elsewhere. There is a trend towards intensification of livestock production (FAO 2006b), combined with a strong increase in farm sizes. For example, half of the poultry in the United States currently comes from farms with over 600 000 broilers (MacDonald & McBride 2009). The increase in meat and dairy production is usually not based on a simple expansion of production, but is the result of a structural shift from pastoral systems towards mixed and industrial systems. In mixed systems, a substantial part (>10%) of the feed comes from crops or crop by-products rather than from grasslands. In industrial (also called landless) systems, the bulk of the feed (> 90%) is produced elsewhere (FAO 2006b). This shift is demonstrated by the fact that beef

Figure 2.5
Global livestock and crop production, LEITAP calculations



Source: PBL / LEI

and milk production increased by 40% over the last 30 years, while the global area of grassland increased by only 4% (Bouwman et al. 2005).

Shift from grass and waste to crop products as feed

Until around 60 years ago, most feed consisted of grass and waste or by-products (FAO 2006b). Cereals and other crops were usually too expensive to be used as feed for animals. This changed in the 1950s when crop production rapidly increased due to fertilisation, irrigation, mechanisation and improved varieties. Around a third of the global cereal production is currently fed to animals. Soybean meal has become a major source of protein and soy production increased by more than a factor of eight over the last 50 years (FAO 2010a). Monogastric animals such as pigs and poultry can make more efficient use of concentrated feeds and, therefore, have a comparative advantage over beef cattle, sheep and goats. This partly explains why global beef production doubled since the 1960s, yet chicken meat production increased almost tenfold (Thornton 2010).

2.5 Projected developments in consumption and production

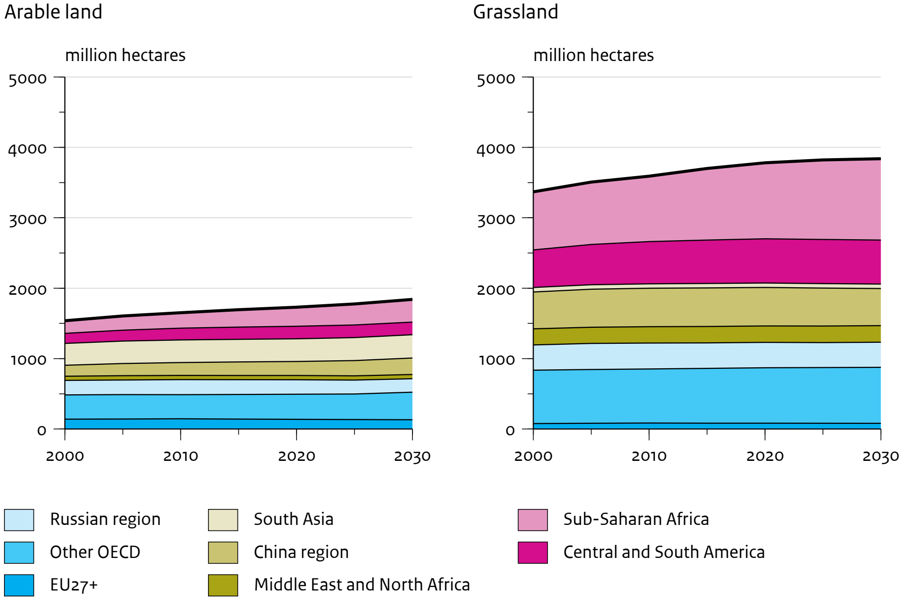
Global production of livestock products is projected to increase by 70% between 2000 and 2030, which is similar to the FAO projection (figure 2.5, left). This growth is expected to slow down towards the end of this period, both in relative and in absolute terms. For crop products, the total production is expected to increase by over 60% in the 2000-2030 period (figure 2.5, right). This somewhat lower growth reflects the shift from crop products to livestock products. The per-capita production of crop products will increase by around 20% over the same period, mainly as a result of a higher animal feed use needed per consumer. The increase in the consumption of livestock products is slightly greater in the LEITAP projection than in the FAO projection. This results in a higher demand for feed crops, although the results from LEITAP compare reasonably well with the FAO projections.

Main growth in both crop and livestock production in Asia
In the coming decades, the growth rates of both crop and livestock productions are expected to vary greatly between the different regions, due to differences in growth in demand and potential for area expansion or yield increase. The growth in livestock production will be the largest in Asia, but a marked increase is also anticipated in other OECD countries (figure 2.5, left). In the EU, livestock production is projected to increase by 9% over the 2000-2030 period, whereas crop production is projected to remain constant. The main growth in crop production is expected to take place in Asia and Africa, largely as a result of higher crop yields. Many recent studies and projects have focused on the challenges for the year 2050, but rapid changes are projected to already occur over the next ten years (OECD & FAO 2010). Most of the consumption growth will take place in developing countries, where for the following decade consumption of poultry and pig meat is expected to grow by 33% and 29%, respectively. China alone accounts for two thirds of the expected increase in global pig meat consumption.

2.6 Environmental effects of livestock production

Livestock production influences the environment in many ways. This can be positive, for example, because of contributions to the maintenance of highly appreciated cultural landscapes, but more often the influence is negative. For example, livestock production is a major source of greenhouse gases and nitrogen emissions. In addition, agricultural land use also has an influence on terrestrial biodiversity. This section briefly describes the environmental effects of present livestock production as well as the effects projected in the reference scenario.

Figure 2.6
Agricultural area in reference scenario



Source: PBL / LEI

Because of expected increases in yields, crop areas do not grow at the same pace as total production.

2.6.1 Land area needed

Livestock production uses around 80% of global agricultural land

About 1 500 million hectares are currently being used globally as arable land and about 3 500 million hectares as grassland (FAO 2003). Of the total arable land area, about one third is being used to produce animal feed. Livestock, therefore, is responsible for about 80% of agricultural land use.

According to the LEITAP model, the total arable area will expand by 20% over the next 20 years, which is clearly less than the increase in production. The largest expansion of arable area is projected to take place in Sub-Saharan Africa (figure 2.6). The total grassland area is projected to increase by 250 million hectares, mostly also in Sub-Saharan Africa. This is about 1.5 times the total EU agricultural area. Other projections, such as in the FAO study *World agriculture: towards 2015/2030*, result in a much lower grassland expansion in Sub-Saharan Africa (FAO 2003).

2.6.2 Present and projected greenhouse gas emissions from livestock farming

Ever since the publication of the 2006 FAO report *Livestock's Long Shadow*, it has been a well-known fact that livestock production is an important cause of greenhouse gas (GHG) emissions (FAO 2006b). The three most important sources of livestock-related greenhouse gas emissions are:

- emissions from animals and manure, mainly in the form of methane (CH_4) and nitrous oxide (N_2O);
- direct emissions from the cultivation and fertilisation of feed crops and pasture, mainly N_2O from fertilised soils and CO_2 from agricultural machinery;
- emissions from land-use changes, such as deforestation and grassland conversion (mainly CO_2);
- emissions due to the production of inputs (such as fertilisers), transporting and processing (mainly CO_2).

Livestock production responsible for approximately 12% of global greenhouse gas emissions

Determining the emissions that are caused by livestock farming is much more difficult than determining those from fossil fuels. Most uncertain are emissions from deforestation, in addition to methane and nitrous oxide emissions. According to calculations based on the Edgar 4.0 database, livestock farming was responsible for almost 6 Gt CO_2 eq annually, between 2005 and 2007, equalling more than 12% of global greenhouse gas emissions (JRC & PBL 2009). This is less than the FAO estimate, which names a share of 18% from livestock farming (FAO 2006b). There are two main reasons why our study arrived at a lower relative contribution. Firstly, the FAO assumed a lower level of total global emissions: 40.0, compared to 48.9 Gt CO_2 eq per year. Secondly, there is a difference between the calculated emissions from livestock farming. According to the Edgar database, these emissions amounted to 6 Gt CO_2 eq, compared with 7.1 Gt CO_2 eq per year according to the FAO. This difference is mainly due to the estimated nitrous oxide emissions: 2.2 Gt CO_2 eq according to the FAO and 1.0 Gt CO_2 eq according to the Edgar database. The Edgar database used the most recent (2006) IPCC Guidelines for the calculation of nitrous oxide emissions, while the FAO used its own calculations and previous versions of the IPCC Guidelines.

In the reference scenario, the greenhouse gas emissions related to agriculture, for the 2010-2030 period, are projected to increase by 25% compared to the 1990-2010 period. This is partly due to emissions related to land conversion, which is projected to take place in Sub-Saharan Africa and South Asia. Other projections, such as in the FAO 2003 study, indicate lower land conversion rates for these areas.

2.6.3 Livestock production and the nitrogen and phosphorus cycles

Although less obvious and less well-known by the general public than biodiversity loss or climate change, the global nitrogen (N) and phosphorus (P) cycles have changed greatly over the last hundred years due to human interventions, in particular, agriculture. These changes have led to significant effects on ecosystems (Rockstrom et al. 2009). The inputs of both N and P into the agricultural system have increased sharply. For N, this is mainly caused by the use of nitrogen fertilisers, which have been produced on a large scale since the development of the Haber-Bosch process, early in the 20th century (Galloway et al. 2010). Another human induced input of N is that of biological N fixation by grain legumes such as peas or soy beans and forage legumes such as alfalfa, clover and vetch. The input of phosphate has increased due to the use of P fertilisers derived from phosphate-rich rocks. A clearly positive effect of N and P inputs into the agricultural system is that of much higher crop yields.

Only a small fraction of nitrogen input ends up in food

Globally, about 170 Tg of nitrogen enters croplands each year, around 70% of which is lost to the environment and 30% is taken up by crop products. Of this 30%, around 20% is fed to animals and around 10% is consumed directly by humans. Of the 20% that is fed to animals, 17% is lost to the environment and only 3% enters the human food chain (Galloway et al. 2010). This means that of every 100 kilograms of nitrogen input, only around 13 kilograms will enter the human food chain. The remaining part is lost to the environment.

Nitrogen is lost to the environment in many forms

Nitrogen losses to the environment occur in many different forms, with various ecological consequences. Among the most notorious effects are eutrophication, hypoxia and loss of biodiversity caused by the leaching of nitrate and other forms of nitrogen to fresh and saline waters (Diaz & Rosenberg 2008; MA 2005). Other adverse effects of nitrogen losses are described in chapter 5.

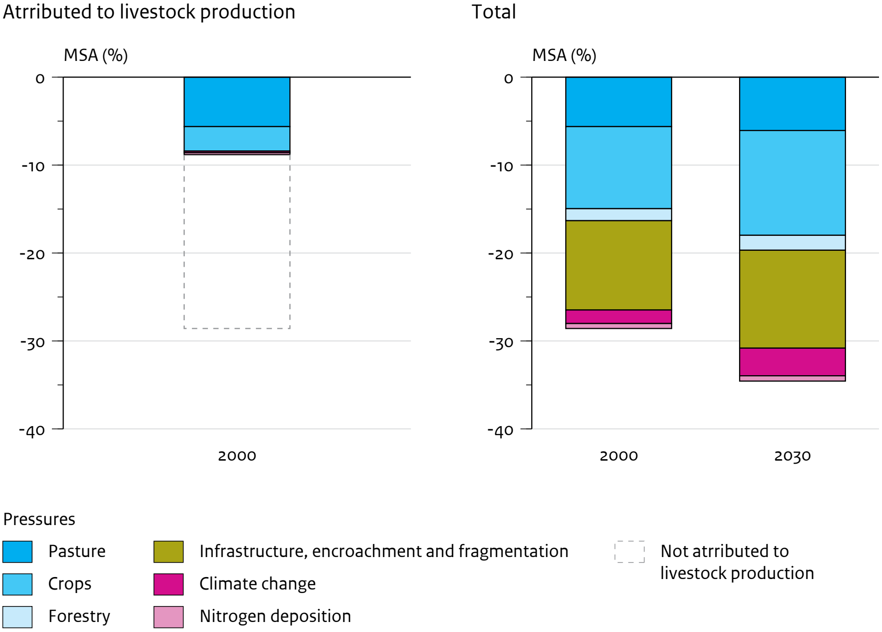
There are a number of reasons for the high nitrogen losses. One of the most significant is the availability of relatively cheap nitrogen fertilisers that reduce the need for farmers to prevent nitrogen losses and preserve the nitrogen in the land-crop-animal-manure-land cycle. The second major reason for these losses is the concentration of intensive livestock production in certain regions (FAO 2006b). Feed containing nitrogen and phosphorus is transported to these regions, but it is usually too expensive to transport the subsequent manure back to the original fields on which the feed crops were grown, which may even be on another continent. Instead, the manure is disposed of in various ways, often leading to pollution of groundwater and surface waters.

Global nitrogen surplus is projected to increase by 29% up to 2030

The global nitrogen surplus is projected to increase by 29% between 2000 and 2030, mainly in Asia, South America and Sub-Saharan Africa. These results are derived from PBL calculations, based on the methodology described in Bouwman et al. (2009). The surplus increase is not a real problem in Africa, where fertiliser use and nitrogen emissions are generally low; but emissions in Asia are already high and this will lead to an aggravation of environmental problems. Emissions are expected to decrease in the EU due to a combination of increased efficiency in nitrogen use and stabilisation of EU agricultural production.

Figure 2.7

Pressures driving global biodiversity loss in reference scenario



Source: Calculations based on PBL (2010)

Global biodiversity is projected to decrease over the coming decades, mainly at the expense of tropical ecosystems. The expansion of arable land is projected to be one of the main driving forces up to 2030.

2.6.4 Effect of livestock farming on terrestrial biodiversity

Although the exact effect of livestock farming on global terrestrial biodiversity is hard to determine (for a number of reasons), it is evident that its impact is significant. Two of the main reasons why the effect is so difficult to determine are: (i) livestock influences biodiversity in many ways (e.g. see FAO 2006b) and (ii) the concept of biodiversity has different interpretations, a fact that has consequences for the selection of indicators used for monitoring biodiversity trends (PBL 2010).

There are several indicators to quantify biodiversity and species richness (PBL 2010). The indicator used in this report is the relative mean species abundance (MSA) of originally occurring species (Alkemade et al. 2009). This indicator provides the degree to which terrestrial ecosystems are still 'natural' or 'original'. It takes into account both the number of species and the size of their populations. Natural ecosystems have a score of 100%. The MSA is assigned at pixel level and can be aggregated over large areas. When aggregating, the indicator weighs all ecosystems equally, so that a hectare of natural desert and a hectare of tropical rainforest will both score 100%. No biodiversity indicator is perfect and the MSA indicator also has its pros and cons, as discussed in more detail in the PBL study *Rethinking Global Biodiversity Strategies* (PBL 2010). The MSA indicator is used in this chapter for illustrating the effect of current livestock production on terrestrial biodiversity and the development of biodiversity in the reference scenario. Chapter 8 describes how the MSA indicator has been used for computing the effect of different options on biodiversity.

The methodology of the MSA indicator

To calculate the MSA indicator, the areas of natural and disturbed ecosystems are combined with their (remaining) biodiversity quality. Factors taken into account include the effect of fragmentation due to infrastructure, the influx of nutrients and the impact of climate change. The strongest impacts, however, tend to be related to land use and land-use intensity. For example, in areas of intensive arable farming and intensively managed grassland, an average of around 10% of the original biodiversity remains. Extensively used grassland, on average, retains some 70% of the original biodiversity, but for forest converted to grassland this is only 10% (Alkemade et al. 2009). In areas of urban use, the MSA value is between 0% and 10%.
Globally aggregated loss in MSA, currently, is around 28% (figure 2.7). This may seem quite small, but the decrease in MSA is tempered by the large areas covered by deserts and tundra and the Arctic regions. These areas are all still relatively intact. Most of the original biodiversity has already been lost in Europe and in large parts of North America, India, China, Argentina and Brazil, in particular.

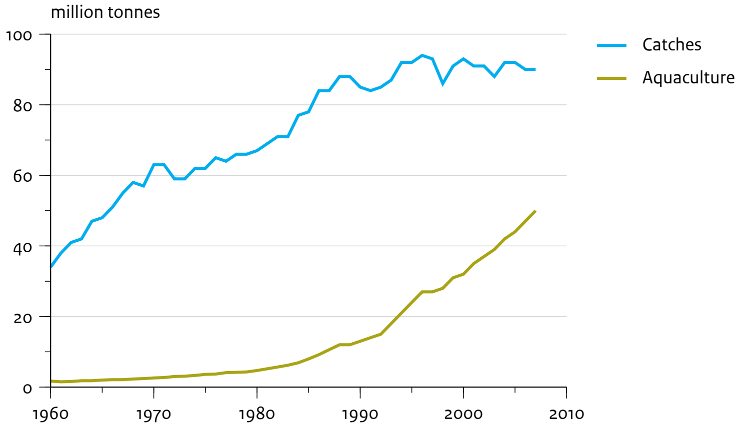
Livestock farming is responsible for 30% of the present global loss of terrestrial biodiversity

The contribution of livestock farming to the present global loss of biodiversity is estimated to be around 30% (figure 2.7). The main impact of livestock production is caused by its large land use. In addition to losses caused by pastures, about a third of the biodiversity loss resulting from croplands can also be attributed to livestock. Although extensively used grasslands still have a relatively high biodiversity, the aggregated biodiversity loss is quite large, given the extent of these areas. Combined with the effects on biodiversity due to the use of croplands and nitrogen deposition, this leads to a large total effect from livestock production on global biodiversity. The share of livestock production in the more general pressures, such as biodiversity loss due to infrastructure, encroachment and fragmentation, could not be determined and, therefore, has not been accounted for in the contribution of livestock production to global biodiversity loss. In should be noted that the estimate of 30% carries a high degree of uncertainty.

Continued global loss of biodiversity is expected

The global MSA is expected to decline further, over the coming decades, as a result of further land conversion, fragmentation and the impact of climate change and nitrogen deposition. Livestock production plays a role in all these processes (figure 2.7).

Figure 2.8
Global fish production



Source: FAO-FISHSTAT

The global fish catch stagnated since around 1990, but production of fish from aquaculture increased rapidly, mainly in the form of freshwater fish production in Asia.

2.7 Fisheries and aquaculture

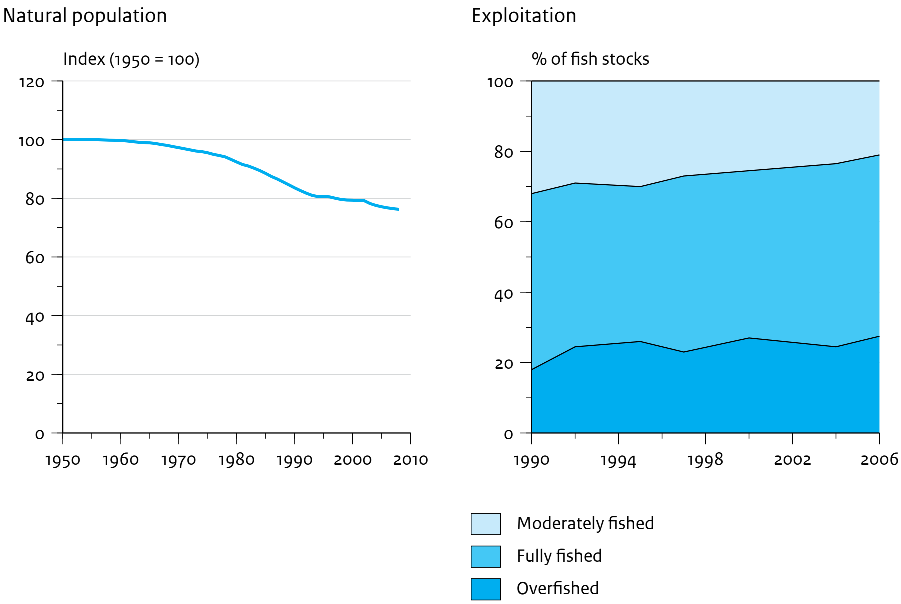
2.7.1 Global fish production

The global catch (including shellfish) in 2006 was 82 million tonnes from the sea and 10 million tonnes from fresh water (lakes and rivers). Approximately two thirds of the catch was consumed; the rest was largely processed into fishmeal and fish oil and used in aquaculture and, to a lesser extent, livestock farming.

Since around 1990, the global fish catch – from marine areas in particular – has stagnated (figure 2.8) (FAO 2009a,b). In contrast, volumes of farmed fish (including shellfish) have increased fourteen-fold since 1970, particularly in Asia. Almost 90% of the farmed fish comes from Asia, and is mainly freshwater fish. Nowadays, about 40% of fish consumed comes from aquaculture (FAO 2009a,b).

Global fish consumption has increased in recent decades and will probably continue to do so (Delgado et al. 2003; FAO 2009a). Wild catches have reached their limits, so that the growing demand will have to be met from aquaculture.

Figure 2.9
Global marine biodiversity



Source: Alder et al. (2007); FAO (2009b)
Nearly 80% of fish stocks are either fully fished or overfished. Global marine biodiversity has declined.

2.7.2 Environmental effects of fisheries

Almost 80% of fish populations are either fully fished or overfished
Fisheries have caused an overall decline in biodiversity. Fish species are declining in numbers, the average fish size is getting smaller and marine biodiversity as a whole is under pressure (Jackson 2009; Watson & Pauly 2001). An estimated 27% of fish populations throughout the world are overexploited, and between 1990 and 2006 the commercially fished fish stocks that are either fully fished or overfished increased a further 10% to 80% (figure 2.9).

Future catches will be below maximum sustainable levels
The natural population of marine fish decreased by 24%, since 1950 (figure 2.9) (Alder et al. 2007). The larger fish species have declined the most (Alder et al. 2007; PBL 2010); only certain smaller fish species are able to flourish, because the larger fish species have been removed. In a sustainable system fish populations are more balanced and catches could be larger (PBL 2010). In places throughout the world, where fish populations have been overexploited or depleted, future catches potentially could be larger and of more

commercial value if fish stocks were restored to support maximum sustainable yield levels (PBL 2010).

Catch requires more effort

As fish stocks decline, fishermen have to travel further and fish in deeper waters to maintain catch volumes (MA 2005). Worldwide, about 13% of the *marine* catch is from the 'high seas', being the international waters, outside the 'exclusive economic zones' (EEZ) (FAO 2009a). As a consequence, the effort (and fuel) needed to catch a given amount of fish is steadily increasing.

Fisheries responsible for 0.5% of global CO_2 emissions

Fishing vessels accounted for 1.2% of the global oil consumption in 2000, amounting to about 0.5% of global CO_2 emissions (134 Mt CO_2) (Tyedmers et al. 2005). Energy use depends strongly on fishing method. Demersal fisheries require about 500 litres of diesel per tonne of fish. The energy use in pelagic fisheries varies from 100 litres per tonne for herring and mackerel to more than 3 000 litres per tonne for tuna (longline fishing) (Tyedmers 2004). About 75% to 90% of the energy use related to fisheries concerns the direct use of fuel for propulsion. The remaining energy use concerns energy inputs associated with vessel construction and maintenance, and provisions of fishing gear, bait and ice (Tyedmers 2004).

More than 10% of the catch is thrown overboard

A considerable amount of each catch (the so-called by-catch) does not consist of the target species and is often discarded. Fish is thrown back for various reasons: fish may be too small, have little or no commercial value, or belong to a species for which fishery has no quota. Due to differences between markets, the same fish species (caught in the same spot, at the same time) may be either discarded or be considered commercially valuable fish. It is estimated that over 10% of the reported landed catch, worldwide, is discarded (9.5 million tonnes) (FAO 2005). Most of the sea life that is thrown back does not survive and is at best feed for scavengers such as shrimps, crabs and seagulls. However, the amount of discarded by-catch has been larger in the past, as the introduction of reduction measures and the use of by-catch for local consumption and aquaculture have resulted in a decrease in the amount of by-catch that is being discarded (Garcia & Rosenberg 2010).

Fisheries are also associated with damage to other habitats and marine life, such as dolphins, turtles and sea birds, damage to coral reefs and to the seabed and bottom-dwelling organisms. The last particularly applies to demersal fisheries.

2.7.3 Environmental effects of aquaculture

Aquaculture is associated with a number of environmental problems. A key issue is its dependence on wild-caught fish as a basis for fish feed, depending on the species farmed. Aquaculture also has an impact on terrestrial ecosystems because of the use of vegetable fish feed ingredients such as soy. Depending on fish species, type of feed used, cultivation method and fish farm location, there are other problems too, such as eutrophication of surface waters, damage to valuable coastal ecosystems, spreading of diseases and pollutants to wild fish populations, and energy and water use.

Farming of predator species such as salmon requires ten times more wild-caught fish than is needed to feed herbivore species such as tilapia

Traditionally-farmed fish such as carp are fed all sorts of waste products or are bred in integrated systems, mainly in Asian countries. However, fishmeal and fish oil are increasingly used as feed. This feed is obtained from smaller wild-caught fish (such as anchovies and sardines) and is mainly used in the cultivation of fish species higher up the food chain (predatory fish). The cultivation of a kilogram of predatory fish such as salmon requires about four kilograms of wild-caught fish in feed (although the need for wild-caught fish has decreased in recent years, see chapter 6). For naturally herbivorous species such as tilapia, only about 0.3 kilograms of wild-caught fish is used per kilogram (Tacon & Metian 2008), while shellfish such as mussels do not usually require any additional feed.

One fifth of wild-caught fish is used in aquaculture

Production of fishmeal and fish oil has been relatively stable over the last 20 years (Jackson 2009). Main producers of fishmeal and fish oil are Peru and Chile, together accounting for about half of the total production. Main consumers of fishmeal are China and Japan. In 1980 only 10% of the fishmeal production was used in aquaculture, but, by 2006, this had increased to about 60% (Jackson 2009; Tacon & Metian 2008). The remaining amount of fishmeal is mainly used in livestock feeds, especially for pigs and poultry. The estimated use of fish oil in aquafeeds increased from 35% in 1995 to 90% in 2006 (Tacon & Metian 2008). Almost 50% of the world's fish oil production is used in Europe (Seafish 2009). Currently, the entire global aquaculture sector uses almost 17 million tonnes of catch per year (Tacon & Metian 2008). This represents about 20% of the total fisheries catch.

About 1% of agricultural land used for aquaculture

Aquaculture also requires some agricultural land for the production of crops, such as soy and wheat, for fish feed. Globally, approximately 1% of agricultural land (15 million ha) is indirectly in use for aquaculture (PBL 2010).

Krill is also used as feed, although to a very limited extent and this is still in an experimental phase. The energy costs involved in harvesting krill are high and it is open to debate whether using this new biomass source will be considered acceptable (Bostock et al. 2008, 2010). Recently a quota for the harvesting of krill around Antarctica has been set, which is disputed in the scientific community (CCAMLR 2010).

In some regions, aquaculture causes eutrophication

In aquaculture, part of the feed is lost. This, together with excretion, leads to emissions of nitrogen and phosphate to surface waters in open aquaculture. In total, aquaculture contributes about 4% to nitrogen emissions and 2% to phosphate emissions (Overbeek et al. in prep.). The global contribution by shellfish was less than 1% in 2000 (Pawlowski et al. in prep.). Emissions in estuaries and coastal waters in Southeast Asia, however, are considerable, particularly in China where the contribution of aquaculture to nitrogen and phosphate emissions may amount to as much as 50%, leading frequently to algal bloom.

Energy requirement of fish farming similar to that of livestock farming
Greenhouse gas emissions from aquaculture vary widely depending on the type of cultivation. Electricity consumption is the main consideration in aquaculture on land, where, with adequate water treatment, this ranges from 0 to 10 MJ per kilogram of trout (Bostock et al. 2008). This is much less energy than for wild-caught fish, but this figure does not include feed production. Including feed production, the energy use varies between 33 and 290 MJ per kilogram of fish (chapter 7). These energy requirements are of the same order of magnitude as those of livestock farming (Halweil 2008).

Damage to coastal ecosystems
Fish and shrimp farms in tropical countries are often established in mangrove forests, coral reefs and other biodiversity-rich coastal ecosystems. This affects marine biodiversity, as these areas are the nurseries for wild fish and other organisms. Furthermore, these areas are important in preventing flooding.

Aquaculture, particularly in open systems, where the farming is in direct contact with the sea, lakes or rivers, is also associated with other concerns. As fish can escape from cage systems such as those used for salmon and trout, aquaculture may lead to genetic pollution of wild species. Furthermore, disease may spread to wild populations, and remnants of medications used also end up in the aquatic environment, although there have been major improvements in this area (Bostock et al. 2010). Pesticides used for combating parasites and fungi may also end up in the aquatic environment.

2.8 Consumption and production of animal products, malnutrition and poverty

Fish, meat and dairy products generally provide high quality protein, vitamins and minerals. During childhood, in particular, quality nutrition is essential for human well-being. This is not only a question of sufficient calories, but also of adequate amounts of proteins, vitamins and minerals. In the case of malnutrition, additions of modest amounts of livestock products to children's diets can be of substantial benefit to physical and mental health (Alderman et al. 2006; Neumann et al. 2003; Sen 1999).

The number of undernourished people in the world in 2010 was estimated by the FAO at 925 million, most of whom live in Asia and the Pacific region (FAO 2010b). Although the percentage of undernourished people dropped from over 30% in 1970 to between 16% and 18% in 2010, the absolute number has increased from 900 million to 925 million (FAO 2010b). The first Millennium Development Goal, aimed at a halving the number of undernourished people by 2015, will be difficult to achieve.

Hunger and food insecurity also expected to persist in the longer term; partly as a result of expected higher food prices and partly because of poverty. According to several outlooks, food prices will be higher in the coming decades than they have been over the 1985-2008 period (IAASTD 2009; OECD & FAO 2010), although there are projections that indicate otherwise. These higher prices are mainly due to the increasing demand for agricultural products (section 2.3). The nutritional situation (in terms of supply) for the majority of people is expected to improve over the coming decades, but hunger and poverty are not expected to be eradicated by 2050. For example, child malnutrition is projected to decline from 149 million children in 2000 to 99 million in 2050 (IAASTD 2009). At the same time, and also in developing countries, obesity problems may worsen as a result of oversupply, with low-nutritional food and low intakes of fruit and vegetables.

Livestock production and fisheries are also important sources of income for many people in developing countries. The higher food prices offer opportunities for farmers, not only in industrial countries, but also for smallholders in developing countries. Local conditions (e.g. infrastructure, education and market access) and policies will determine whether smallholders can take advantage of these opportunities.

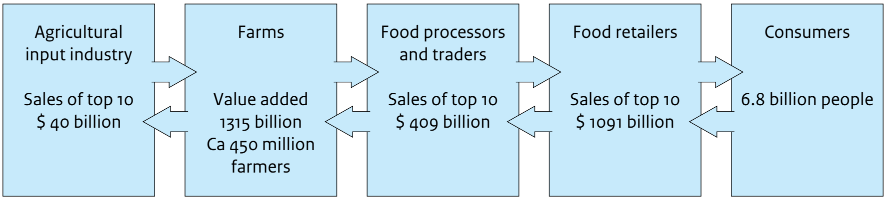
2.9 The global food system

As a result of general globalisation, the food system has become more global, too; at least in a number of ways. Although the trade in food commodities has not increased significantly over the last 40 years (relative to the production), the different food markets have become more integrated (Von Braun & Díaz-Bonilla 2008). Furthermore, the role of multinational companies in the food chain has become much stronger.

National markets are linked to the global food system

Although most food is still both produced and consumed within the same country (Gehlhar & Regmi 2005; Von Braun & Díaz-Bonilla 2008), trade links national food markets to the global market, causing price transmissions to other countries. This was demonstrated by recent spikes in food prices (in 2008 and 2010), all over the world, influencing farmers and consumers in all countries. Therefore, it is possible to speak of a 'global food system', which can be defined as 'a system that links national and local food systems from around the world in a clearly defined manner, for example, through trade, information sharing, technology, or some other observable way' (Pinstrup-Andersen 2002).

Figure 2.10
Global food chain



Source: After Von Braun and Díaz-Bonilla (2008)

Meat products are traded to a lesser degree between countries[3] than are cereals and vegetable oils. This might be due to aspects such as sanitary measures and trade protection, and to the fact that meat is more difficult to transport and conserve (Von Braun & Díaz-Bonilla 2008). Oil seeds (or their components oil and protein-rich meal) are a particularly highly-traded commodity at the global level.

Concentration in the food chain

Food is produced by approximately 450 million farmers and consumed by 6.8 billion consumers (figure 2.10). In other parts of the food production chain, relatively few, often multinational, companies control inputs, processing and selling of food products.

This is certainly true for the agricultural input industry, where relatively few companies hold high market shares in seeds, pesticides, fertilisers and genetic materials (Von Braun & Díaz-Bonilla 2008; UNCTAD 2009). A consequence of this is not only that a few large companies have a large control over one link in the food chain, but it has also led to a narrowing of the genetic variability of farm animals. For example, global markets for broilers are supplied by four companies and for laying hens this is only two (Gura 2008). The positive side is the development of highly productive, highly efficient livestock. However, the risk of low intra-species diversity is both less resilience and a higher probability of inbreeding (UNCTAD 2009).

The global markets for cereals and oil seeds are also dominated by a few large players. More companies are active in the food processing step, with fewer global brands in meat, dairy and fish products than, for example, in beverages or confectionery. A limited number of companies also have a high share of the market in the last step of the food chain (restaurants and supermarkets). The market share of supermarkets is rapidly increasing in cities in developing countries, often leading to the 'westernisation' of diets (Pingali 2004; Popkin 2006).

Another trend is that those at the end of the food chain are gaining increasing influence over the rest of the food chain. Retailers and restaurant chains often have their own suppliers, consisting not only of food processing companies, but of farmers as well. One of the reasons for this is concern over food security. Another reason is the strong growth in the private labels of supermarket chains.

2.10 Conclusions

Today's per-capita consumption of animal products in richer parts of the world is two to three times higher than the global average. The consumption and production of animal products has increased greatly over the last 50 to 60 years. In some regions, this has had a positive effect on human well-being by reducing malnutrition, since animal products (including fish) are an important source of proteins. In richer regions, however, the increased consumption of animal products has contributed to overconsumption, notably in energy and saturated fats.

Current levels of fishing are leading to depletion of fish stocks and decline in marine fisheries. Today's livestock production has, in various ways, a large, mostly negative effect on the environment:

- Global livestock production is responsible for around 12% of global greenhouse gas emissions. These emissions partly originate from (i) animals and manure, (ii) feed production and (iii) land conversion (forest to pasture or pasture to arable land).
- Almost 80% of agricultural land use is related to livestock production.
- Around 30% of the total loss of terrestrial biodiversity can be attributed to livestock production. Livestock production also leads to various emissions of nitrogen (ammonia, nitrates), which lead to losses in terrestrial and aquatic (including marine) biodiversity.

The demand for food, biofuels and other agricultural products is expected to increase strongly in the coming decades, due to the combination of a growing population and increased wealth. For example, the global demand for meat is expected to grow by more than 20% in the coming decade. This projected growth will put additional stress on scarce resources such as land, water and fertilisers.

Because of the projected growth in global livestock production, all the described effects are expected to aggravate over the coming years, notably in Asia and South America. In spite of growing food production, malnourishment is not expected to be eradicated in the coming decades. It is to be noted, however, that malnourishment is generally not caused by insufficient production of food, but by poverty and lack of access to food.

Finally, national and continental food systems have become integrated into the 'global food system'. A concentration of actors has occurred in certain links of the global food chain, giving them increased influence on this food chain, as is the case for the agricultural input industry, food processors, traders and retailers.

Notes

1 This was, at the moment of publication, the most recent year for which worldwide data were available from FAOstat.

2 The consumption given here is expressed in 'carcass weight'; the actual intake of boneless meat is about half of this (see text box in chapter 3).

3 Given the common market, the EU here is seen as one country.

THREE

EU consumption of animal products

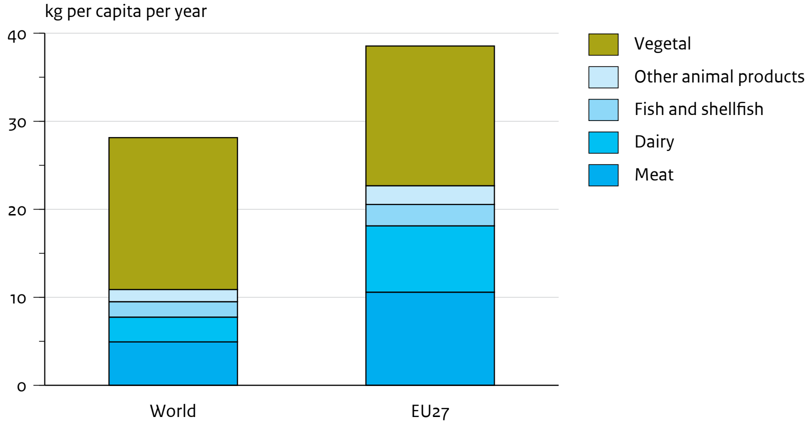
3.1 Introduction

Meat, fish and dairy products are important components in the human diet and many people appreciate their taste. These products provide proteins, energy, minerals (e.g. calcium) and vitamins, and fish also contains omega-3 fatty acids. Humans depend on animal products for certain nutrients, such as vitamin B12. Vegans – who consume no animal products at all – have to add nutritional supplements to their diet to obtain vitamin B12.

This chapter looks at the consumption of fish, meat and dairy products. The previous chapter presented an overview of global consumption and the impact of growing consumption on the environment. Europe is a prosperous continent, as a result of which the consumption of meat, fish and dairy produce is generally relatively high. Section 3.2 compares European consumption to global consumption. Consumption in Europe has not always been as high as it is now, as is shown in section 3.3. There are also differences between countries within Europe (section 3.3). Factors determining consumption are described in section 3.4. More detailed information about the differences in consumption of the separate products is given in section 3.5. In addition to meat, fish and dairy products, livestock is also used in other products, such as animal fats that are used in pastries or biscuits. Section 3.6 describes these livestock by-products.

Section 3.7 describes the related health effects. In addition to the positive health effects from eating animal products, there are also negative effects resulting from a high consumption of animal products in Europe (section 3.7). Finally, section 3.8 summarises the main conclusions of this chapter.

Figure 3.1
Protein supply, 2007



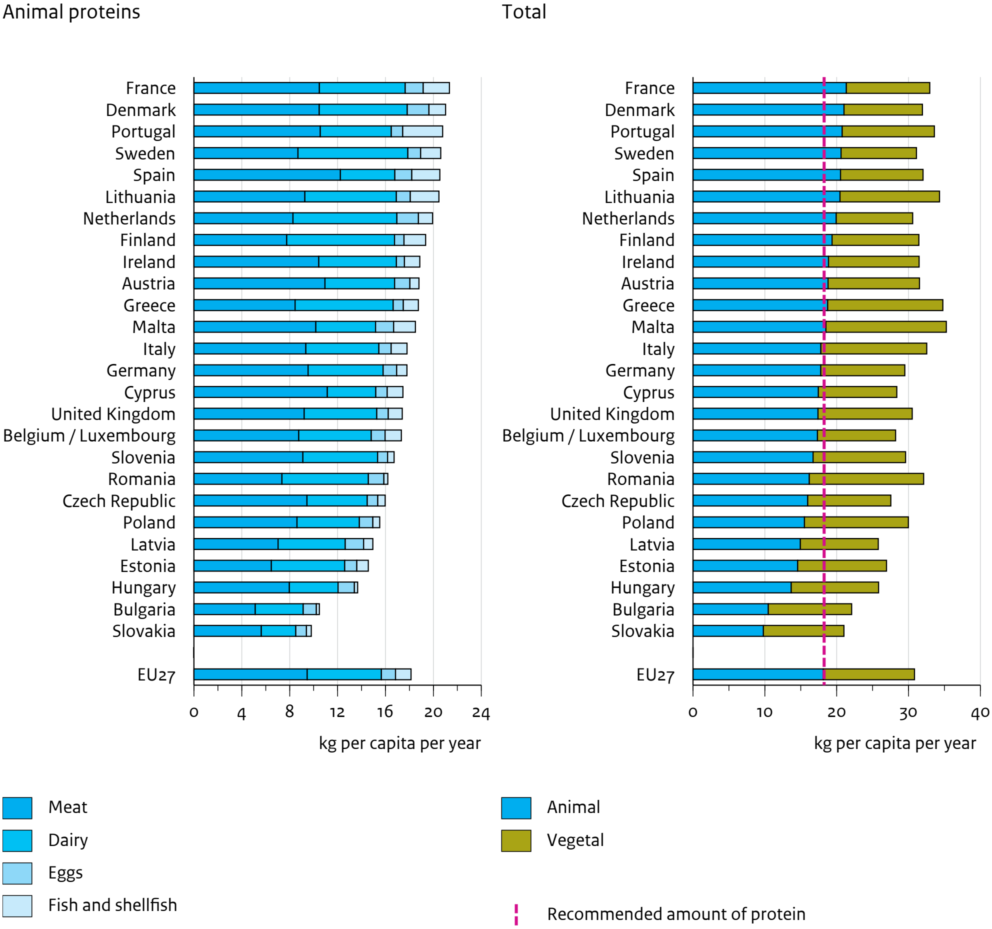
Source: FAO (2010)
EU per-capita consumption of proteins from animal food products is more than double the world's average.

3.2 European consumption compared to global consumption

European consumption of animal products higher than global average
The average consumption of proteins per person is much higher in Europe than globally; this applies in particular to the consumption of animal proteins. On average, each European consumes twice as much animal protein than the global per-capita average (figure 3.1). National consumption levels were compared by adding up the protein content in the various products, as animal products are rich sources of proteins for humans. Making comparisons by adding up the weights of the different products resulted in an overestimation for products with a high water content, such as milk. Therefore, countries should be compared in terms of protein consumption (see annex[1]).

Dairy consumption three times the global average
There are large differences between the different products. Meat consumption in Europe is twice the world average and for the consumption of dairy produce this is three times the world average, but fish consumption is only 30% higher. Fish is an important source of protein in many countries in the world, but less so in Europe. On average, only 10% of animal proteins consumed are from fish.

Figure 3.2
Intake of proteins in EU27, 2007



Source: PBL, based on FAO (2010)

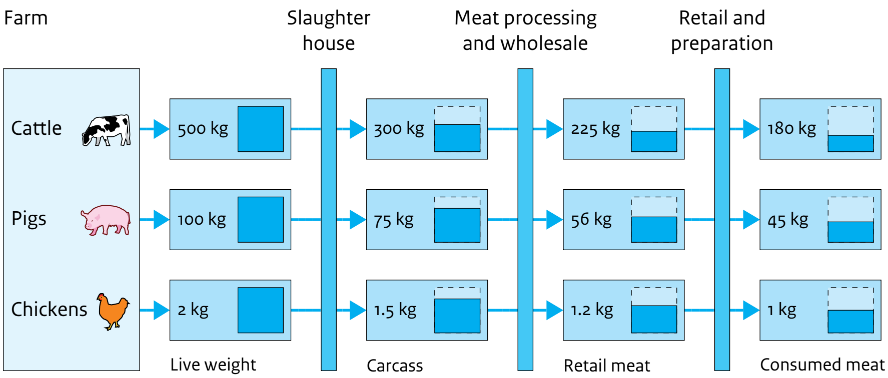
Left: The difference in consumption of animal protein between the Member States is more than a factor of two. Right: Total protein intake shows smaller differences but is higher than recommended, in all Member States (see section 3.7).

From farm to fork: differences in consumption, supply and intake
Consumption can be measured top-down (agricultural or economic statistics) or bottom-up (retail or individual food consumption surveys). The consumption data used in this chapter are taken from FAO food balance sheets (FAO 2010), which are measured top-down. These data are based on national agricultural statistics and represent the annual *supply* of food available to the population. Both imports and exports are taken into account. In the case of meat consumption, FAO data are expressed in carcass weight at slaughterhouse exit level (i.e. excluding offal and hide, but including most bones). Many steps in processing and transportation take place between farm and fork, during which food losses may occur (figure 3.3). Processing, retail and household losses all take place after the carcass weight has been established and, therefore, have to be discounted when calculating consumer intake.

In this report, the FAO data are taken as the basis for calculating the actual intake of meat. The percentage of retail (saleable) meat from the carcass weight is assumed to be 70% for ruminants, 75% for pigs and 80% for chickens (Blonk 2008). For fish, 40% of the live weight is assumed to be fillet (De Vries & De Boer 2010). When calculating the *intake*, a total 20% in retail and household losses (Milieucentraal 2009) are also accounted for. A recent study in the United Kingdom showed higher household losses for meat and fish (23% of purchased amount) and relatively lower losses for dairy and eggs (9%) (Quested & Johnson, 2009).

Individual intake data are available from food consumption surveys held in several EU Member States. Due to differences in methodology (e.g. different interview techniques), surveys from different countries are not always comparable. Moreover, time series are often incomplete because of the high costs of conducting such surveys. For example, the European Concise Food Consumption Database (CEFCD), compiled by the European Food Safety Authority, does not contain complete time series for all EU countries (http://www.efsa.europa.eu/en/datex/datexfooddb.htm).
Elmadfa has presented a more complete overview of the intake of nutrients (e.g. total protein) from individual food consumption surveys (Elmadfa 2009). Comparing our calculated protein intake with these data, the calculated protein intake for the EU27 seems to be 7% higher than the average intake reported by these consumption surveys, which are known to underreport the intake by about 10%.

Figure 3.3
From farm to fork, overview of losses in the meat chain



Source: PBL, based on Blonk (2008); Luske & Blonk (2009)

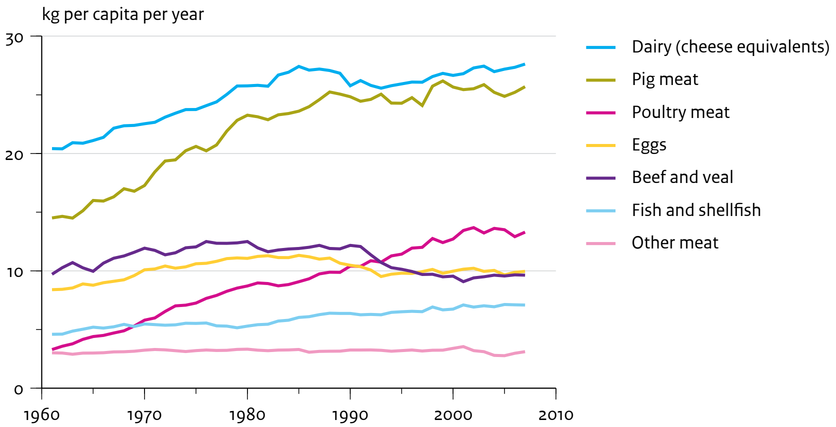
3.3 Differences between Europeans in consumption of animal products

Consumption of animal products in old Member States is higher than in new ones
Looking at the consumption of animal products within Europe, there are large differences between countries (figure 3.2, left). France, Denmark, Portugal, Sweden and Spain have the highest consumption of animal protein, with consumption in France more than twice that of Slovakia. The lowest consumption of animal proteins is generally found in the new Member States.

In addition to proteins from animal products, there are also vegetable sources of proteins. The consumption of animal proteins is lower in new Member States, but their consumption of vegetable proteins is higher than the European average. The difference between old and new Member States in total protein consumption – including vegetable protein – is therefore slightly less (figure 3.2, right).

Large differences in composition between meat and dairy diets
Differences also exist between countries in the composition of animal protein diets. For example, Sweden and Spain are both top consumers of animal products in the EU. However, the Spanish consume the highest amount of meat and one of the smallest amounts of dairy products, whereas the Swedish consume the highest amount of dairy produce (figure 3.2, left). The consumption of meat, dairy and fish products in the United Kingdom and Germany seems to resemble the EU average. However, there are differences in meat consumption. The consumption of pig meat makes up half the total

Figure 3.4
Intake of animal products in EU27



Source: PBL, based on FAO (2010)
The per-capita consumption of pig meat and poultry, in particular, has increased since 1961.

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meat consumption in the EU, but it is much higher in Germany, and represents only a quarter of meat consumption in the United Kingdom (figure 3.6, left).

Intake is only about a half of the supply
The actual protein intake by humans is less than the supply of protein for consumption. Parts of the products – meat, fish and dairy – are lost during preparation and cooking due to the removal of inedible parts, such as bones, or are lost in waste (see text box From farm to fork). In general, protein intake, thus, is only about half the amount that is supplied (figure 3.3).

Per-capita consumption of animal products 50% higher than in the 1960s
Consumption of animal products in Europe has not always been what it is today. The share of animal proteins in the total protein intake increased from 48% in 1961 to 59% in 2007. The average consumption of animal protein, per capita, is currently 50% higher than in the early 1960s.

Sharp increase in poultry consumption
Consumption of poultry in particular has risen sharply; the per-capita consumption in 2007 was more than four times that of 1961 (figure 3.4). This has to do with the emergence of large-scale broiler farming systems, which have reduced prices considerably. The convenience trend may also have contributed, as poultry products are usually quicker to prepare.

Table 3.1
European population and animal protein consumption

	1961	2007	Increase 1961-2007
Population EU27 (million)	407	494	20%
Consumption of animal protein (kt supply per year)	6 200	11 200	80%

Source: FAO (2009, 2010)

Per-capita consumption of pig meat has increased bij 80%. Although the consumption of poultry and pig meat has strongly increased, it has not replaced other types of meat. The consumption of beef, for example, has remained fairly constant: following a slight increase, it has shown a noticeable decline since the early 1990s. This may be partly due to the BSE crisis in the 1990s (Roosen et al. 2003). Other factors may be that most beef products require a relatively longer preparation time than other meats and that beef is generally more expensive than chicken or pig meat.

In addition to the meat consumption, per-capita consumption of dairy products and fish also increased since 1961, by 30% and 60%, respectively.

3.4 Drivers affecting consumption

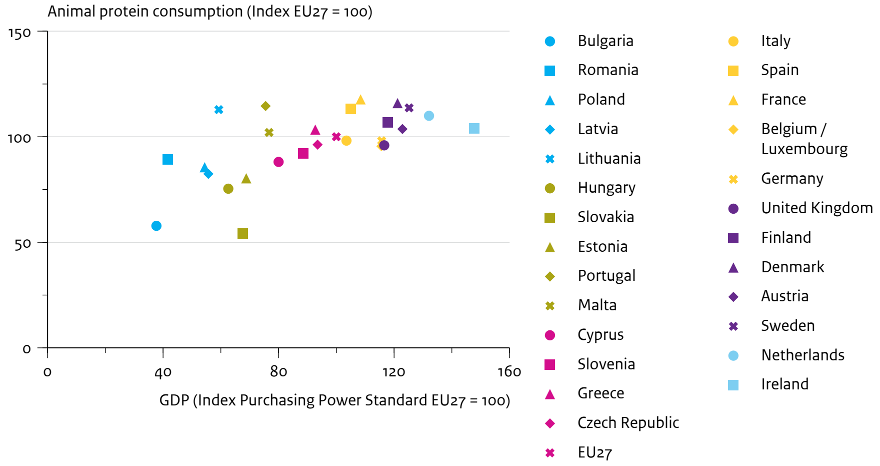
Growth in consumption of animal products sharper than population growth
Meat consumption in Europe increased substantially, during the 1960s and 1970s, to double the previous levels. Meat consumption generally increases with income according to an S curve. In richer countries, such as those of Europe, this curve has largely reached its end point, and so has the increase in meat consumption (Smil 2002).

The EU consumption of animal protein, however, has increased by 80% since the early 1960s. This is only in part due to population growth. While the population in the EU27 increased only slightly, consumption of animal protein increased much more strongly (table 3.1).

Consumption increased, whereas expenditure decreased
Growing prosperity and wider availability together with low product prices, have played an important role in the change in the consumption of animal products. Meat, fish, eggs and dairy products all have become more affordable. In the Netherlands, these products are now 35% cheaper, in real terms, than they were in 1960 (CBS 2010). Before 1955, meat, fish and dairy products were luxury items that only few people could afford in their daily diets.

Figure 3.5

Relation between GDP per capita and consumption of animal protein in EU27, 2007



Source: Eurostat (2010c); FAO (2010)

Consumption of animal products is higher in cases of higher GDP per capita (Purchasing Power Standard).

Recent data on prices and expenditures for Europe – just as in the Netherlands – show a decrease in the share of expenditure on meat products in the total household expenditure. This share decreased from 5.1% in 1996 to 3.7% in 2007 (EU Harmonised Indices of Consumer Prices), while the per-capita supply of meat showed a slight increase (4%) over this period (FAO 2010). This is partly due to the decreasing relative price of meat (the price of meat increased by 43%, and prices of consumer goods increased in general by 48% between 1996 and 2009) (Eurostat 2010a).

Higher expenditure on meat in new Member States

Almost 40% of EU expenditures on food is spent on animal products; the per-capita expenditure on meats is 750 euros, on milk, cheese and eggs it is 440 euros, and on fish and seafood 213 euros. Expenditures differ between old and new Member States. In the new Member States, per-capita expenditure on meat is relatively high; in Lithuania and Estonia between 5% and 6% of the total expenditure on food relates to meats, and in Romania this is as high as 9%. However, this expenditure is relatively low (2.1% to 2.6%) in the United Kingdom, Luxemburg and the Netherlands. Although this is mainly due to differences in income, it is also related to culture. For example, the percentage is relatively high in wealthy southern European Member States (4% to 5% in Italy, France and Spain).

Prosperity is main driver

According to Harris, eating habits are determined by technological, social-demographic, ecological and institutional factors (Harris 1998). In addition to price, prosperity and availability, other factors also explain differences in consumption, the most important of which is consumer awareness, which corresponds with a lower consumption of animal products (Regmi & Gehlhar 2001; Schroeter & Foster 2004). Furthermore, higher levels of emancipation (Luomala 2005; Schroeter & Foster 2004) and population age (Regmi & Gehlhar 2001) also correspond with lower consumption of animal products. There is also a relationship between food crises and decreasing consumption, as in response to the BSE crisis and the outbreak of animal diseases (Regmi & Gehlhar 2001; Van der Zijpp 1999). Urbanisation, on the other hand, is related to a higher consumption of animal products.

Despite these other influencing factors, prosperity still largely determines the level of consumption of animal products. In general, a higher income corresponds with a higher consumption of animal proteins (figure 3.5).

The different Member States show distinct consumption preferences, but the relationship between prosperity and levels of consumption of all animal products is generally clear. Rich countries with a relatively low meat consumption, such as Sweden, the Netherlands and Finland, show higher consumption levels of dairy products (figure 3.5). Looking at the individual products, for example pig meat or dairy products, the consumption seems less related to prosperity. In general, cultural aspects and the supply of nationally produced foods together determine the products of choice.

3.5 Consumption of animal products in more detail

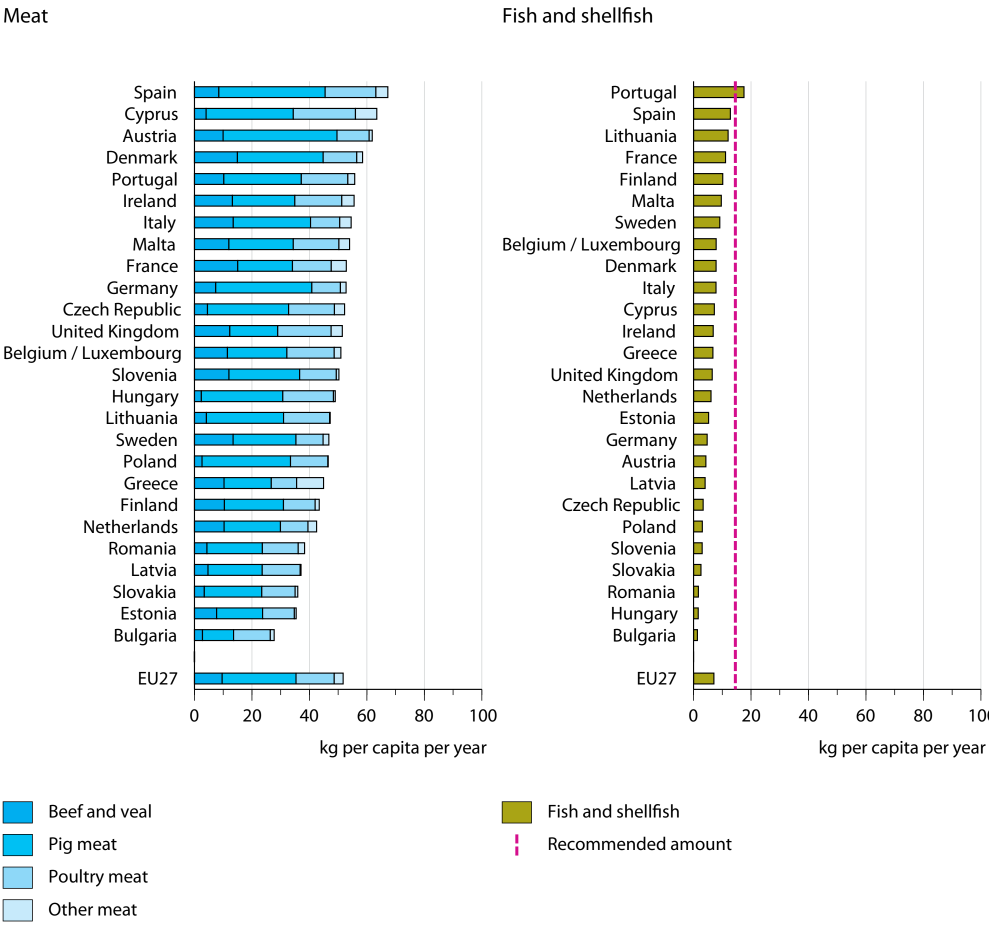
Consumption in Mediterranean countries higher than EU average

The southern Member States (including France) are currently responsible for half the total meat consumption in the EU27, while their share of the EU population is only 38%. The highest meat consumption is found in Spain, Austria and Cyprus. In these countries, the consumption of meat is around 65 kilograms, per capita (figure 3.6, left). This is almost a quarter more than the European average (intake of 52 kilograms, per capita, corresponding to 86 kilograms in carcass weight). Even in Mediterranean countries with a diet that traditionally contains less meat, the consumption of meat has increased sharply. The level of meat consumption in these countries is currently even higher than the European average.

Pig meat is the most popular type of meat

Looking at the different types of meat, it is clear that pig meat is the most popular type of meat in Europe (figure 3.6, left), as it constitutes half of all the meat consumed.

Figure 3.6
Intake of meat, fish and shellfish in EU27, 2007



Source: PBL, based on FAO (2010)

Left: Pig meat is the most popular type of meat, but consumption levels differ per EU country.

Right: Fish consumption differs between countries by factor of ten.

Countries with the highest levels of meat consumption – Austria and Spain – also consume the most pig meat.

There are major differences between European countries in the consumption of beef. The average beef consumption is nearly 10 kilograms per capita, but this varies from just over 2 kilograms in Hungary to around 15 kilograms in France and Denmark.

Accounting for a quarter of the meat consumption, the share of chicken is currently greater than that of beef. Per-capita consumption is the highest in Cyprus, the United Kingdom and Hungary. Sheep and goat meat are not much consumed in Europe, and their consumption is mainly attributed to southern Europe and the United Kingdom.

Fish consumption differs between European countries by a factor of ten
European supply of fish and shellfish currently is around 22 kilograms per capita (intake is about 7 kilograms, see text box in section 3.3). This amount is mainly in fish and, to a lesser extent, shellfish. Consumption has increased by more than 50% since the early 1960s (figure 3.4). Southern Europe plays a major role in European fish consumption. The Portuguese eat the most fish in Europe, which is more than ten times the per-capita consumption of the Bulgarians and Hungarians, who consume the least fish (figure 3.6, right).

Consumption of dairy produce differs by a factor of nearly three between the highest and lowest consumption countries
Dairy products are an important source of protein, and account for a third of the animal proteins consumed in the EU (figure 3.2, left). Finland and Sweden have the highest levels of dairy consumption (almost 50% more than average), followed by the Netherlands and Greece. In Greece, France, Denmark and the Netherlands, a lot of cheese is consumed, while residents in Finland and Ireland consume a lot of milk. In Sweden consumption levels are high for both milk and cheese.

3.6 By-products from animal production

Whole animal is consumed, but half of it not in the form of meat
In addition to meat, dairy produce and eggs, there are many other products that come from animals, such as leather, medicines and pet food. In terms of weight, livestock farming supplies a more or less equal volume in animal by-products that are almost entirely used in other food and non-food products (Luske & Blonk 2009). A cow consists of approximately 45% meat, for a pig this is 55%, and a chicken delivers roughly 60% saleable meat.

Half of protein-rich by-products are used in pet food
Most animal parts that are not sold as meat, such as organs, skin and bones, are also utilised. In the Netherlands, for example, about half of the protein-rich by-products (e.g. offal) are used in pet food, mainly for cats and dogs. The rest is used in feed, organic fertilisers and technical applications. Hides and bones, for example, are used to make gelatine, which in turn is used in confectioneries, patisseries and desserts. Gelatine is also used in technical applications, such as photo printing, and in medicines, soap and paper.

Animal fat in biscuits and shampoo

Another non-meat product is animal fat, which is used for example in cakes, sauces and soups, but mainly in animal feed and non-food products, such as cleaning agents, shampoo, plastics and lubricants. Finally, slaughterhouse waste that is restricted from processing, such as cattle brains and rejected animals, are incinerated and the resulting energy is used. In the Netherlands, such waste makes up about 6% to 10% of the live weight of all slaughtered animals.

Production of alternatives is less efficient

By-products from livestock farming represent about 10% of the total livestock value. Most by-products, however, could be replaced by alternatives, so that, strictly speaking, current livestock farming would not be indispensable because of its by-products. Only for a small number of applications the by-products lack an alternative, such as heparin, an anti-coagulant extracted from lungs and intestines. However, currently production of alternatives for by-products is less efficient than continued use of livestock by-products. Moreover, production of alternatives would also create environmental pressures in the form of greenhouse gas emissions and land use (Luske & Blonk 2009).

3.7 Consumption and health effects

3.7.1 Animal products in the European diet

Meat, fish and dairy products are important elements in European diets

In Europe, the growing consumption of meat, dairy and fish is related to human health. Meat, fish and dairy products are rich sources of vitamins, iron, calcium, zinc and other compounds. In the European diet, meat delivers a significant amount of iron (16% to 20%). It is also an important source of vitamin B12; 47% of the vitamin B12 is obtained from meat. Collectively, all animal products (i.e. meat, dairy and fish) deliver 93% of our vitamin B12 and 25% of our iron (RIVM 2010). Iron deficiency anaemia has detrimental health implications, particularly for new mothers and young children. Some EU countries experience low intakes of iron in young children and women of child-bearing age (Elmadfa 2009; McLean et al. 2009).

Dairy products are important for calcium in the European diet. In Belgium and the Netherlands, about 60% to 65% of the calcium is obtained from dairy products. The rest of the calcium is delivered in bread, vegetables and legumes. Legumes, in particular, have a high calcium content, but their consumption in Europe is low. The other animal products – meat, fish and eggs – are not very important in providing calcium (2% to 3% of the intake, in Belgium and the Netherlands). Although convincing evidence exists that the combined intake of calcium and vitamin D reduces the risk of osteoporosis in people older than 50 (WHO 2003a), their intake is inadequate in some European countries (Elmadfa 2009).

Requirement of 10% to 15% protein content in energy intake
In addition to the basic guideline based on body weight, there is also a WHO requirement for a protein intake of between 10% and 15% in the total dietary energy supply (derived from the WHO's main recommendation, WHO (2007)). The recommended energy supply is about 2 200 kcal (2 500 kcal for young men and 2 000 kcal for women, and less for children and elderly people (WHO 2007). This results in a recommendation of 18 to 27 kilograms of protein per capita, per year (50 to 75 g per day), the lower limit being the same as the recommendation based on weight.

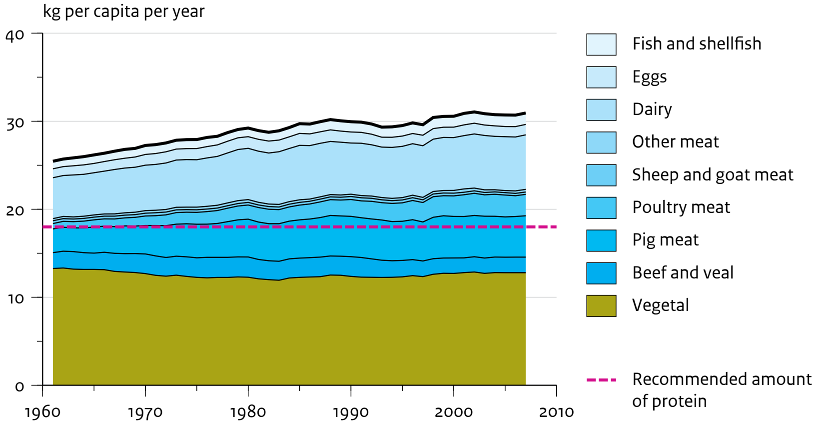
Fish contains long-chain omega-3 fatty acids, and oily fish are particularly rich in these fatty acids. Oily fish, such as herring and mackerel, contain 5% to 20% fat, compared with 1% to 5% fat for white fish. Fish is also a source of vitamin D.

Furthermore, 59% of the protein consumed in the European diet is from animal products, most of which comes from dairy produce and pig meat (FAO 2010). Fish, meat, eggs and dairy produce deliver approximately 30% of the energy intake (FAO 2010). The trend of growing consumption levels for meat, fish and dairy in Europe is not always beneficial to human health, and is already leading to overconsumption. In addition, animal products account for 54% of fat and even 80% of saturated fat in the European diet (this includes animal fats contained in other products) (see section 3.7.3). Some health gains may be achieved by reducing or changing diets.

3.7.2 Protein consumption

Dietary guidelines
The World Health Organization (WHO) has made a recommendation regarding the amount of protein required per kilogram of human body weight for a healthy diet. It advises a daily protein intake of 0.83 grams of protein per kilogram of human body weight for adults (WHO 2007). This is the safe intake level. The estimated average value is 0.66 grams per kilogram of body weight. However, minimum required levels of protein are higher for children, and pregnant and lactating women. For the whole population, the average recommended protein intake, per capita, is 50 grams per day, equal to just over 18 kilograms per year. This value is calculated using Dutch reference weights (Gezondheidsraad 2001) and the Dutch population pyramid (CBS 2009). The value of 18 kilograms of protein per capita is assumed to also apply to other Europeans.[2] In the case of a balanced diet, no adverse health effects are to be expected from eating too much protein.

Figure 3.7
Intake of protein in EU27



Source: PBL analysis, based on FAO (2010), Gezondheidsraad (2001), NEVO (2010), Schmidhuber (2007), Voedingscentrum (2008), WHO (2003b, 2007)

Protein consumption is currently significantly higher than the recommended amount (70% more than the recommended 18 kilograms per capita, per year).

Protein consumption 70% higher than necessary

In the EU27, in 2007, the average consumption of protein was about 31 kilograms per capita, per year, nearly 60% of which in animal protein (figure 3.7). This refers to the actual protein intake, excluding waste (see text box of section 3.3).

As a result of the increasing consumption of animal products, the intake of animal protein has also increased. Since 1961, the intake of animal protein per capita in Europe has risen by more than 50% (figure 3.7). As the intake of vegetable protein hardly decreased in this period, the total intake of protein increased. Together with the consumption of vegetable protein, for example in bread, the total protein consumption in Europe is about 70% higher than would be required. Although there are differences in protein consumption levels between Member States, consumption levels in all are higher than would be necessary (figure 3.2, right).

Energy intake higher than healthy

The average human body weight in Europe is much higher than what would be considered healthy; many people are overweight (BMI=25 to 30 kg/m^2) or obese (BMI≥30 kg/m^2).[3] The daily caloric (energy) intake by Europeans has risen over the past decades, while energy expenditure may have decreased (although the relative importance of these two changes is controversial). In 1965, for example, the average energy supply was 15% lower than in 2007. Nowadays, the share of overweight and obese people in the EU varies from 37% in France to 61% in the United Kingdom (Eurostat 2010b). The prevalence of overweight has risen strongly in the EU in the past decades, especially in the Mediterranean Member States (EU platform on diet 2005).

In order to reduce body weight, the advice is usually to become more physically active or to reduce energy intake by decreasing the consumption of foods with a low nutrient density and a high energy density (energy-dense foods) (EFSA 2010). This does not immediately concern animal products, as these are rich in nutrients. However, even within a healthy diet there are possibilities for reducing protein intake. Even if Europeans were to reduce their energy intake to the recommended level, current protein consumption would still be 15% higher than the upper limit of the WHO recommendation and 70% higher than the lower limit (see text box for protein content in energy intake).

3.7.3 Consumption of fat

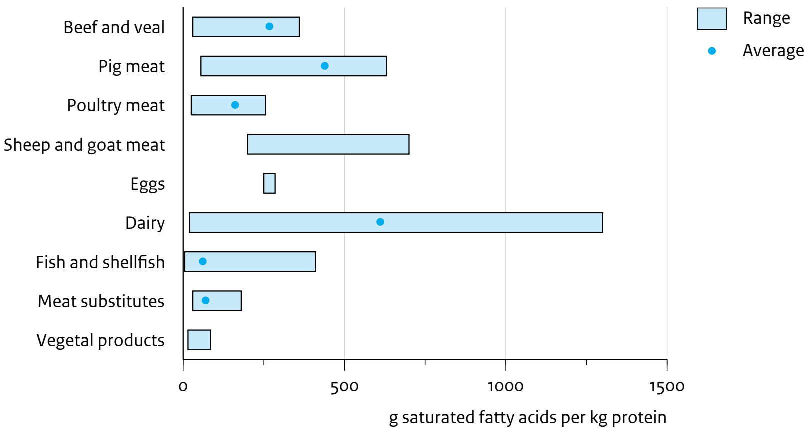
Dietary guidelines
Health authorities recommend a limited intake of saturated fatty acids (SFA) because of the increased risk of cardiovascular diseases associated with these fatty acids (Ischemic heart diseases). In the Netherlands, with a population of about 16 million people, more than three thousand new cases of cardiovascular disease are diagnosed each year, and more than 700 deaths per year are associated with the overconsumption of saturated fats (RIVM 2004).[4]

Stamler identified the composition of a heart-healthy diet based on various intervention studies (Stamler 2010). In this diet the saturated fat content has been reduced to between 6% and 7%. The WHO recommends that a maximum of 10% of the daily energy intake should come from saturated fatty acids. To translate this recommendation into a maximum amount of grams per day, it has to be combined with the recommended daily energy intake. However, this recommended intake strongly depends on physical activity. According to the Netherlands Nutrition Centre (Voedingscentrum 2010), an intake of 2 250 kcal per day is recommended for inactive adults. If we assume this value is valid for the total EU27 population, it would correspond to a maximum amount of 9.3 kilograms per year.[5]

Consumption of saturated fat more than 40% higher than recommended maximum
Animal fats are rich in saturated fatty acids. Beef, pig and chicken fat contains around 35% to 40% in saturated fatty acids, butter fat 65% and fish oil about 20% (NEVO 2010). Vegetable oils and fats contain less saturated fatty acids. Most vegetable oils contain 10% to 15% in saturated fats. Palm oils, coconut cream and cacao butter are vegetable fats with high percentages of saturated fatty acids, while rapeseed oil has the lowest.

Figure 3.8

Saturated fat protein ratio, 2010



Source: NEVO (2010)

In general, animal products have a higher saturated fat content than vegetal products.

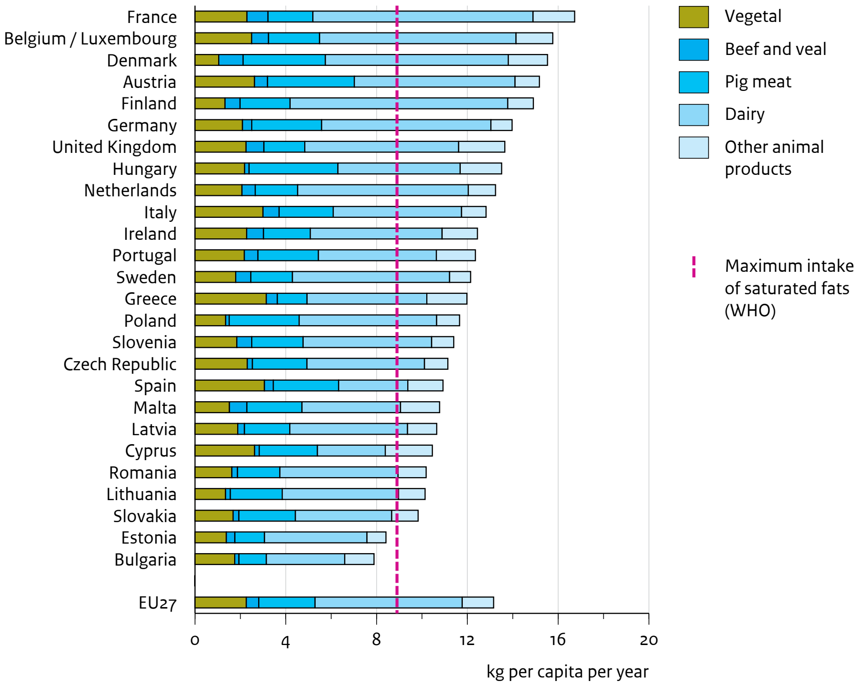
Based on FAO and NEVO data, it can be calculated that the average intake of saturated fatty acids in the EU27 is 13 kilograms per capita, per year (FAO 2010; NEVO 2010) (figure 3.9). This is about 42% higher than recommended. This corresponds very well with Schmidhuber (2007), who found the average consumption of saturated fatty acids in the EU25 to be 11.7% of the daily energy intake (2001/2003). It can be calculated that this corresponds to an annual 13.5 kilograms per capita (see annex).

Eighty per cent of saturated fats are of animal origin

Animal products are a significant source of saturated fatty acids in Europe. We calculated that animal fats make up 80% of the consumed saturated fatty acids (PBL calculations, based on data from FAO (2010) and the Dutch Food Composition Database (NEVO) (2010)). Meat and dairy consumption are responsible for a large share of the intake in animal fat (in the Netherlands, meat and dairy make up about 50% of the saturated fatty acid intake). The rest is consumed in animal products in processed foodstuffs (e.g. biscuits, pastry, sauces). The intake of animal fats, therefore, should be reduced by approximately 40% in order to meet the recommended maximum amount. This could be realised by eating leaner or less animal products or by substituting them by vegetal products, as meat and dairy products generally contain more saturated fats than vegetal ones (figure 3.8, also see annex).

The difference in the consumption of animal fats between EU countries is more than a factor of two. The per-capita consumption of animal saturated fatty acids is highest in

Figure 3.9
Intake of saturated fats in EU27, 2007



Source: PBL analysis based on FAO (2010) and NEVO (2010)

The consumption of animal fats differs by more than a factor of two between European countries. In most countries the consumption of saturated fatty acids is more than the recommended maximum amount.

France (figure 3.9). Only in Estonia and Burgaria the consumption is less than the maximum recommended intake. Overall, the consumption of saturated fatty acids is more than the recommended maximum intake in most European countries.

The consumption of saturated fatty acids has been addressed by health authorities in recent decades and by measures taken by the food industry, aimed at the decreased use of saturated fatty acids in processed food.

A reduction in the consumption of animal products that contain high percentages of saturated fats would be beneficial to human health. Substitution of these products by vegetables would also be better for human health as vegetables also contain other essential compounds, such as fibres, the current consumption level of which is too low in Europe (WHO 2003a).

3.7.4 Red meat

Dietary recommendations

Beef, pig, sheep, goat and horse meat are all red meats. Scientific reports suggest that the consumption of too much red meat increases the risk of intestinal cancer. Recently it has been noted that, although a substantial body of epidemiological evidence suggests that the intake of red and processed meats is probably associated with increased risk of colorectal cancer, to date it has not been possible to discern a clear dose-response relationship, nor could a threshold level be indicated for their intake (SACN 2010). This is due to inconsistencies in the categorisation and quantification of red and processed meats intake (SACN 2010). Concordant studies suggest reducing red and processed meats in diets. People consuming more than 160 grams of red meat per week have a 35% higher chance of intestinal cancer (Norat et al. 2005). The World Cancer Research Fund recommends that the average consumption of red meat should be no more than 16 kilograms per year, of which little to none should be processed meats (WCRF & AICR 2007).[6] The recent UK report argues that it may be advisable for adults with relatively high intakes of red and processed meats to consider reducing their intakes (e.g. it is estimated that those above the 75th percentile consume over 90 grams per day) (SACN 2010).

Consumption of red meat double the recommended amount

Many people in Europe eat much more than the recommended limit of 16 kilograms per year. On average, Europeans consume about 37 kilograms per capita, per year, of pig meat and beef. In the EU15 this is even as much as 39 kilograms. Austria leads with 50 kilograms per year, and Bulgaria consumes the least with 14 kilograms per year.

3.7.5 Fish

Dietary guidelines

Fish and shellfish are sources of essential vitamins, such as niacin, and minerals, such as selenium and iodine. Fish, particularly oily fish (fatty fish) contains the omega-3 fatty acids DHA and EPA (known as fish oils). Fish is also a rich source of vitamins A and D. Fish consumption, particularly that of oily fish, decreases the risk of cardiovascular disease (CVD) (Kromhout et al. 1985, 1995; RIVM 2004; Voedingscentrum 2009). This is thought to be due to the long chain omega-3 fatty acids (long chain n-3 polyunsaturated fatty acids (EPA and DHA) in fish, although, as fish also contains other ingredients, such as a high quantity of vitamin D, it may also be due to other compounds (Kromhout 2010).

Both in the United Kingdom and in the Netherlands, people are advised to eat at least two portions of fish per week, one of which in fatty fish, based on a review of scientific evidence that related fish consumption (oily fish, especially) inversely to coronary heart disease (CHD) (the UK Government has defined a portion as being 140 grams) (UK Department of Health 1994; Voedingscentrum 2009). In total, seven European countries have addressed the consumption of fish in their guidelines (Food-Based Dietary

Guidelines) (EFSA 2010). In Denmark the advice is to eat 200 to 300 grams of fish per week, in Austria this is 150 grams, and in Estonia people are advised to eat fish 2 to 3 times a week. Lithuania and Slovenia advise eating poultry, fish and pulses rather than fatty meats, and in Portugal the advice is to eat fish more often, without a set amount being given (WHO 2003b).

Although there is no WHO guideline on fish consumption, European countries are not the only ones with such recommendations. In China, for example, people are advised to eat 50 grams of fish or shrimps per day (Ge et al. 2007).

Consumption of fish is only half the recommended amount
From a health point of view, many Europeans do not eat enough fish. On average, they consume 7 kilograms in fish and other seafood per year, which is half the recommended amount of about 14.5 kilograms, per capita. For example, in the United Kingdom, adults consume only 103 grams of white fish and 50 grams of oily fish per week, while the advised amount is a portion of 140 grams per week of both types of fish (Henderson et al. 2002).

There are major differences between EU countries with regard to fish consumption, but in hardly any country does consumption meet the recommended level. Although the Portuguese consume more than twice the EU average and are the only Europeans that eat the recommended 14.5 kilograms, their government advises that they eat even more fish. The Spanish consumption of seafood is almost in line with the recommended amount, but in the east European Member States people still consume less than a quarter of the amount recommended in the guidelines (figure 3.6, right). Increased fish consumption, however, would also increase the pressure on aquatic biodiversity (see chapter 2).

3.8 Summary

European consumption of meat, fish and dairy produce is higher than the global average. However, consumption in Europe has not always been at this level. In the 1960s the consumption of these products was only two third of the current amount. Due to prosperity and cost price reduction, the total consumption of animal products has strongly increased. Consumption has increased since the 1960s, while the amount spent on animal products as a proportion of the total household expenditure has declined.

The consumption of poultry and pig meat, in particular, has increased, without a reduction in other types of meats such as beef. In addition to the increase in meat consumption, the consumption of dairy and fish products has also increased, so that total animal protein consumption in the EU has increased by 50% since 1960.

There are still differences in the consumption of animal products within Europe, with consumption levels in countries such as France and Denmark being more than double those in, for example, Bulgaria and Slovakia.

The consumption of animal products is related to both environmental impacts and health implications. Meat, fish and dairy produce are rich sources of vitamins, vitamin B12 in particular, iron, calcium, zinc and other compounds. In the EU, these products are also primary sources of energy and protein. EU energy intake and protein consumption are higher than recommended in WHO guidelines – as much as 70% higher in the case protein consumption.

Furthermore, there are some risks related to eating too many animal products. Although excessive consumption of red meat is related to an increase in cancer, the consumption of red meat in Europe is still twice as high as that recommended by the World Cancer Research Fund. In addition, consumption of saturated fats should be limited according to WHO because of the increased risk of cardiovascular diseases. However, the consumption of saturated fats in Europe is currently higher than the recommended maximum amount (42% higher). As 80% of saturated fats originate from animal products, a reduction in animal products is favourable to health. A shift in the consumption of proteins from animal products – which generally also contain high amounts of saturated fats – to vegetal products would be more healthy.

In contrast, fish consumption in the EU is lower than recommended. Although the consumption of fish is related to a decrease in heart disease, most Europeans only consume about half the recommended amount.

In light of the negative health effects from eating saturated fats and too much red meat, a diet with lower amounts of meat and dairy would be better for human health. Moreover, substituting meat by vegetables would also be better, as vegetable consumption should also increase. Substituting meat by vegetal products, such as vegetal burgers, could also be more healthy as these products generally contain less saturated fats.

In summary, opportunities exist for changing diets to be more healthy.

Notes

1 The annex to this report can be viewed online or downloaded from www.pbl.nl/en.

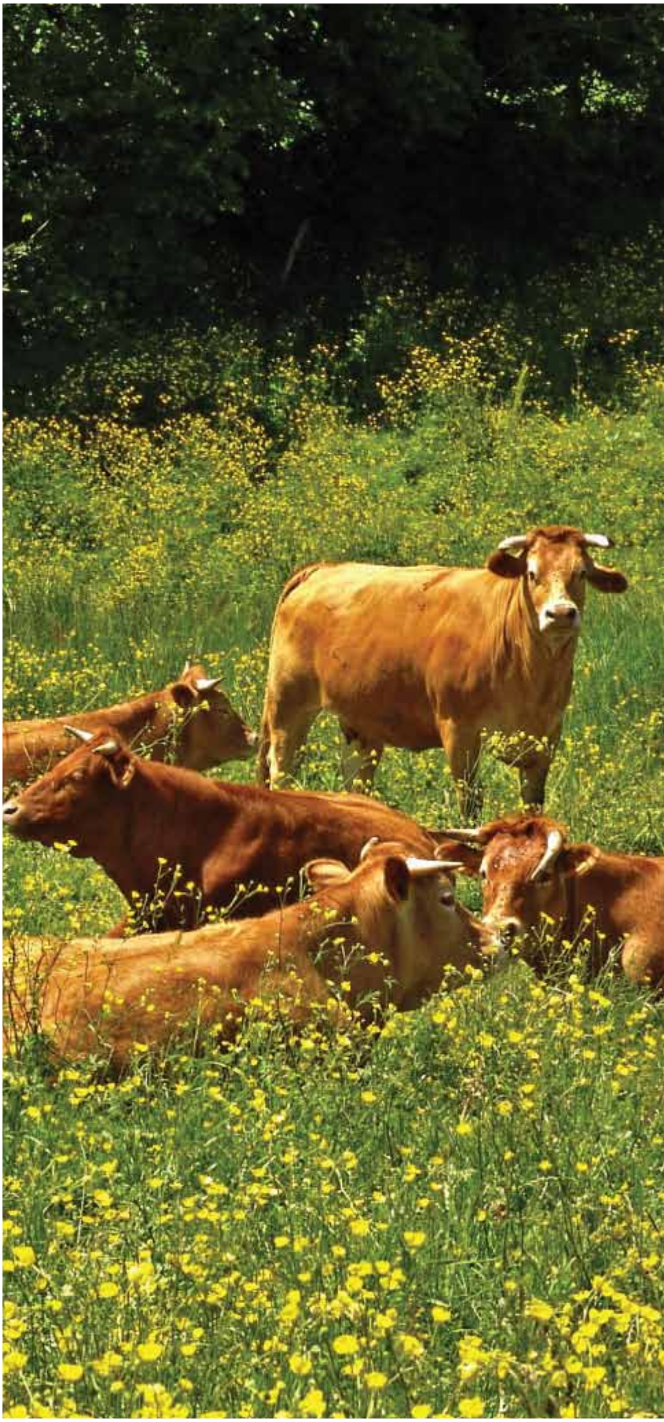
2 This is in line with the UK recommendation, in which the recommended energy intake for overweight people is based on that for healthy people with similar lifestyles but with a lower (more healthy) body weight (SACN 2011).

3 We related protein consumption to recommended healthy body weight (reference weight) (Body Mass Index, BMI<25 kg/m2). If we were to relate it to the current, unhealthy adult body weight in Europe of about 73 kilograms (Eurostat 2002), the intake would still be 40% higher than necessary.

4 There is currently some scientific controversy on saturated fat and heart disease. Siri-Tarino has questioned the relationship between the two (Siri-Tarino et al. 2010), but Stamler (2010) questions the validity of that study.

5 Elmadfa (2009) found an energy intake in the EU27 of 2 225 kcal (9.3 MJ) per day, which is in line with the Dutch recommendation, but being based on consumption surveys for which underreporting may occur, and given the rise in the prevalence of obesity, this value may be regarded as optimistic.

6 Red meat is also a source of iron, and iron deficiency is estimated, globally, to be the most common cause of anaemia, including in the developed countries (Hercberg, et al. 2001; WHO 2008). However, the most recent report on iron emphasises the importance of a healthy, balanced diet that includes a variety of foods containing iron, which is more important than focusing on iron particularly from meat (SACN 2010). The degree to which red meat would be essential in our diet is unknown.



FOUR

EU livestock farming sector

This chapter describes the EU livestock sector today, and how it evolved since 1960. Some knowledge of the functioning of the European livestock sector will help to understand the issues around livestock production and to spot opportunities and barriers for change. In addition, the chapter pays special attention to feed, since many of the environmental effects of livestock production are related to feed production.

The livestock sector is varied, not only because of the different animal species reared, but also because farming systems are very diverse across the EU. It is a complex sector, among other things because animals do not provide just one product, but often a combination of products, both food and non-food, such as wool and leather. Even meat itself is not a homogenous product, with large price differences between the most valued and the cheapest parts of the same animal. The feed sector too is complex. The livestock sector is dynamic, and profound changes took place over the last 50 years.

4.1 Livestock farming sectors

Farm animals can be roughly divided into two groups: ruminants, which are (at least partly) fed on grass, and monogastric animals, such as pigs and chickens (table 4.1). The latter are sometimes referred to as granivores. In general, pigs and chickens are housed indoors, in intensive livestock production systems, whereas most ruminants graze at least part of the time. Another difference between farms with ruminants and intensive livestock farms is that most ruminant farms produce a significant share of the animal feed themselves (mostly in the form of grass and maize), whereas intensive livestock operations purchase a significant part of the animal feed.

Production systems for beef in particular and, to a lesser extent, dairy produce, are very diverse, while the production systems for pigs, chickens and eggs are relatively similar between countries and farm businesses (De Vries & De Boer 2010; Topliff et al. 2009). Production systems do not correspond to particular farm types: for example, chickens can be held on either small or large farms, or on farms that are specialised or mixed.

Farm types and sizes differ considerably across the EU
In general, there are large differences in farm sizes and degrees of specialisation between the poorer and richer Member States. In some Member States, farms are quite small and resemble the situation of many farms of western Europe in the 1950s. However, even in richer Member States, there are large differences in average farm size (Vrolijk et al. 2009).

Limited share of organic farming
Organic livestock farming only has a limited share in most countries (Eurostat 2007), with the exception of organic sheep farming, which has a relatively high share in some countries (up to 25% in Austria). The share of organic pig and poultry farming is below 2%.

4.1.1 Dairy and beef farms

Dairy production mainly takes place on specialised farms, since modern dairy production demands high investments in machinery, including milking machines. Although most dairy farmers sell their milk to dairy processors, some either sell milk directly to consumers or process their milk into cheese and other dairy products. The modern, highly productive milk cows generally require feed of a higher quality than do beef cattle. Many dairy farmers, therefore, use concentrated feed in addition to grass and maize silage.

Farms with beef cattle vary from smallholder farms on semi-natural grasslands to highly specialised fattening farms that depend on purchased feed. The farm sizes also vary hugely across the EU. On many farms, ruminants graze outdoors during the summer season and, thus, collect their own feed. However, in some regions there is a trend to keep more animals indoors all year round.

Sixty per cent of beef and veal production is connected to dairy farming
Dairy cows and their calves represent around 60% of EU beef and veal production (Topliff et al. 2009). Beef cattle, largely bred from ‘suckler cows’, account for about 40% of the beef production. This is different from the situation in countries such as Argentina, Brazil and the United States, where 75% to 90% of the beef production comes from beef cattle. Part of the beef livestock is kept in extensive farming systems, where a large part of the feed consists of grass. In the EU, these systems are mainly found in hilly and mountainous regions. Another part of the beef livestock is fed on other fodder and cereals besides grass. Approximately 10% of the meat production is veal from calves that mainly receive a milk-like feed to produce white or light-coloured meat.

Table 4.1
Various types of livestock and purpose

	Animal species	Purpose
Ruminants	Cattle, sheep, goats	Milk, meat, wool, landscape management, traction
Pigs	Pigs	Meat, co-products
Chickens	Chickens	Eggs, meat
Other poultry and game	Turkeys, geese, rabbits, minks, foxes	Meat, eggs, fur
Other	Horses	Traction, hobby

Sheep and goats play a minor role in total livestock production. Generally, the more marginal areas are used for keeping sheep and goats, although in some regions goats are kept for milk production in more intensive systems. Furthermore, in certain areas, sheep and goats play an important role in maintaining existing landscapes.

4.1.2 Pigs and poultry

Large differences in farm sizes across the EU
Most pigs and poultry are kept indoors, in stables, often characterised by the term 'intensive livestock farming'. They are fed on animal feed, mainly consisting of cereals and protein-rich materials (e.g. oil meals, pulses and beans). In many countries, pig and poultry farms often have become highly specialised. Not only do they keep just one animal species, they often also specialise in just one production phase, such as breeding or fattening. There are large differences in farm sizes throughout the EU. For instance, an average of 16% of the fattening pigs are kept on farms with more then 2 000 pigs (Monteny et al. 2007). This percentage ranges from over 40% in Ireland and Italy, to less than 5% in Austria and Poland.

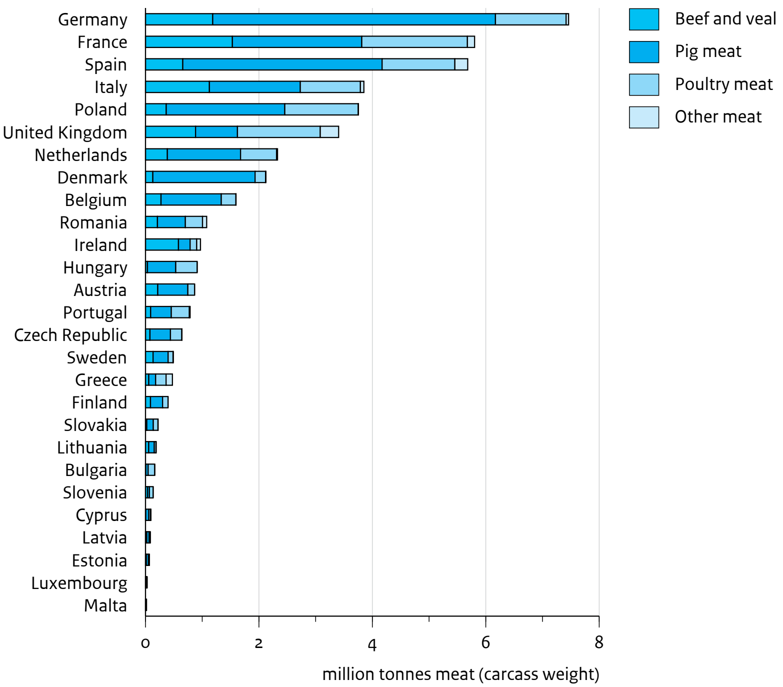
The poultry sector not only includes chickens, but also species such as turkeys, ducks and guineafowls. Moreover, the production of laying hens and broilers also takes place in two completely different systems.

4.2 Production of meat and dairy

Total meat production in the EU amounted to more than 44 million tonnes in 2007. More than half of this was in pig meat, a quarter in poultry, and beef accounted for almost 20%. The share of lamb and goat meat was only small. Largest producers were Germany, France and Spain (figure 4.1).

Total dairy production from cattle amounted to more than 148 million tonnes in 2008. The largest dairy producers were Germany and France. Egg production was more than

Figure 4.1
Production of meat in EU27, 2007



Source: DG Agri (2009)

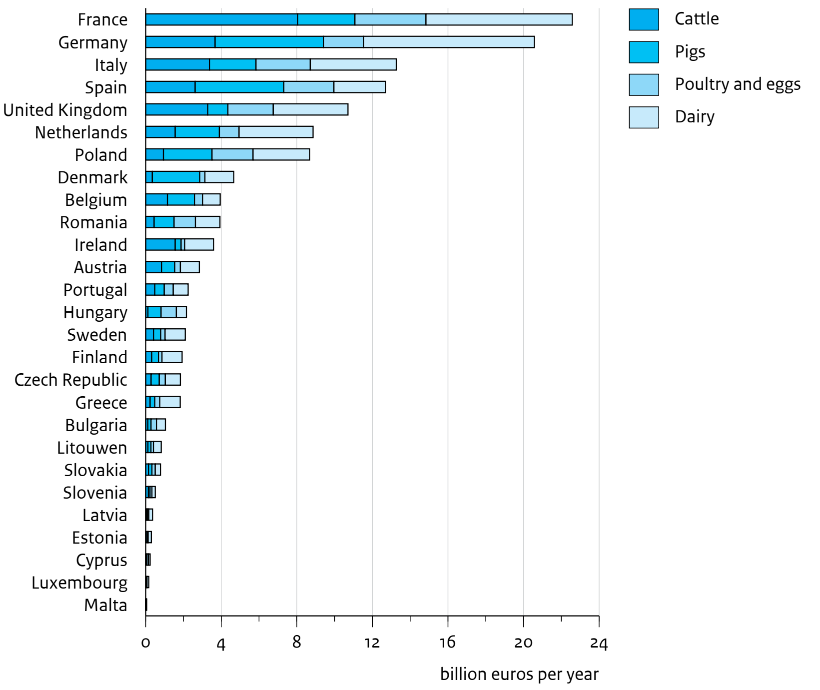
7 million tonnes in the same year. Germany, France, Spain and Italy were each responsible for around 12% of the total EU egg production.

4.2.1 Economic value of livestock farming

Total value of the animal production in the EU27 amounts to more than 143 billion euros (DG Agri 2008, 2009, 2010). Of this total, milk production makes up around 35%, beef and pig meat each account for more than 20%, and poultry and eggs for 16% each. France and Germany are the biggest producers (figure 4.2). The EU exports around 5 billion euros per year more than it imports in various livestock products. There are major differences between EU countries, in terms of whether they are net importers or exporters.

To be able to maintain present animal production levels, the sector consumes large quantities of animal feed, a considerable part of which is imported (see section 4.4).

Figure 4.2
Value of livestock production in EU27, 2007



Source: DG Agri (2009)

This concerns mainly soy in the form of soy beans and soybean meal. The net import value of animal feed (raw materials) amounts to more than 11 billion euros per year.

4.2.2 Degree of self-sufficiency, EU import and export

Judging from the import and export values of different livestock products, the EU is a modest net exporter, with a net value of around 5 billion euros, which is 3.5% of the total value of EU livestock production. Main import products are beef and lamb, while main export products consist of dairy products and pig meat (table 4.2).
For most animal products, the EU self-sufficiency (expressed in quantity) is around 100% (figure 4.3). With self-sufficiency we mean the ratio between domestic production and consumption. It is less for beef (96%), lamb and goat meat (79%), but notably more than 100% for pig meat.

Table 4.2
Net import and export values of various commodities

Commodity	Net import value (-) or export value (+) in million euros	Main trading countries
Butter and butterfat	350	New Zealand (import), Russia, Iran (export)
Milk powder	390	Algeria
Cheese and curds	1,990	United States, Russia
Milk and milk products	2,350	Algeria, Saudi Arabia
Beef	-1,170	Argentina, Brazil, Uruguay
Pig meat	2,960	Russia, Japan
Lamb and goat meat	-960	New Zealand
Poultry	-360	Brazil, Thailand (import), Russia (export)
Animal feed (mainly soy)	-11,200	Brazil, Argentina, United States

Source: DG Agri (2009)

4.3 Factors that shape EU livestock production

There are a number of factors that determine the present structures and locations of EU livestock production. These factors include agricultural policies (mainly the Common Agricultural Policy), and the necessity for farmers to reduce their cost prices, often leading to upscaling of their farms, and a concentration of livestock production in certain areas.

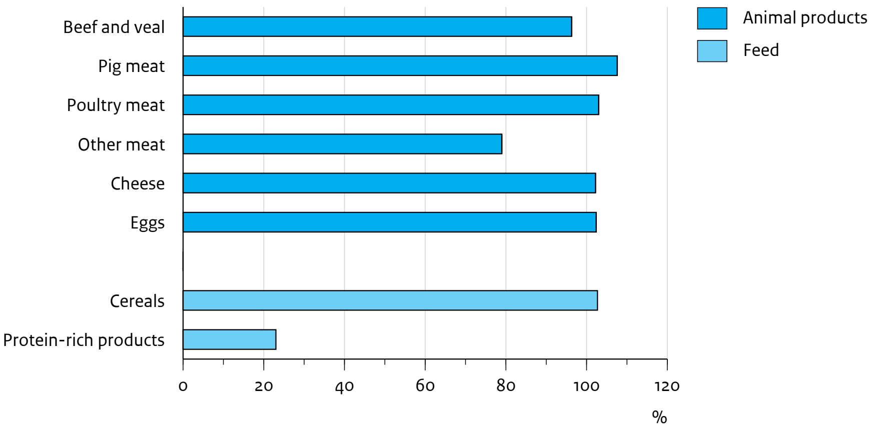
4.3.1 The present EU Common Agricultural Policy

Influence of Common Agricultural Policy and other EU policies on livestock sectors remains large

The EU Common Agricultural Policy (CAP) remains an important factor for the livestock sector, although its influence probably has decreased over the last decades (see also section 4.5.2). The CAP is due to be reformed by 2013. The most important aspects of the present CAP are:

– Income support for farmers in the form of Single Farm Payments. Some regions receive extra support (Less Favoured Areas).
– The milk quotas. However, these will expire in April 2015. A ‘soft landing’ is foreseen, by gradually increasing quotas between 2009 and 2015. The abolishment of the milk quotas probably will lead to a redistribution of milk production in the EU, with a shift from regions with more difficult production conditions to more favourable areas. In

Figure 4.3
Self-sufficiency in animal products and feed in EU25, 2005



Source: DG Agri (2009)

The EU is reasonably self-sufficient (expressed in volumes) with regard to animal products and cereals, but not in protein-rich feed materials.

the Netherlands and Denmark in particular, present quotas are fully used, indicating a potential for expansion of their dairy production.

- For suckler cows, goats and sheep, Member States may retain current levels of coupled support.
- Measures that address disadvantages for farmers in certain regions specialising in the dairy, beef, sheep and goat meat sectors are extended to include economically vulnerable types of farming within these sectors.
- Protection from global markets in the form of import tariffs for meat and dairy produce.
- Export subsidies. However, these are intended to be phased out.
- Although not part of the CAP, the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) of the World Trade Organization (WTO) is also important to the European livestock sector, as it sets standards for the importation of livestock products.

Abolishment of import tariffs would affect especially the EU beef production

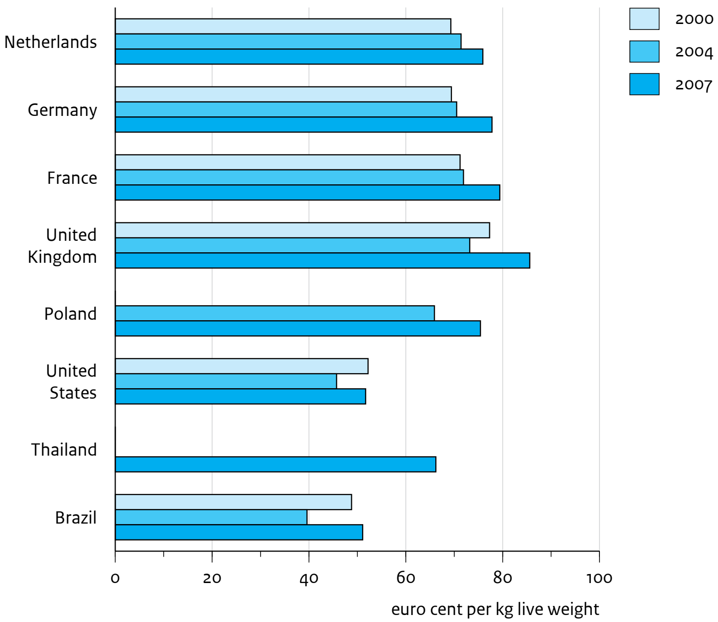
Import tariffs still have to be paid on many commodities imported into the EU (table 4.3). Imports from the world's 48 poorest countries have tax-free access. A certain amount of imports from countries such as New Zealand and Australia is also exempt from taxes. Complete liberalisation (no income support; free trade through abolishment of import tariffs) probably would have strong consequences for European livestock sectors, since EU production costs are generally much higher than those in countries

Table 4.3
EU import tariffs for various products

Product	Import tariff
Beef	100%
Lamb	60%
Pig meat	30%
Poultry meat	53%
Butter	101%
Cheese	68%

Source: DEFRA (2005)
A tariff of 100% means that the imposed tax equals the original price of the product. The presented tariffs are approximate averages, as in reality the tariff structure is very complex with many different tariffs per product type.

Figure 4.4
Production costs of poultry meat



Source: Van Horne (2009)
Large differences in production costs exist between countries.

such as Brazil and the United States (Topliff et al. 2009). According to the Scenar 2020-2 study, full liberalisation could mean that EU beef production would decline by more than 30% (compared to the reference scenario) (Nowicki et al. 2009). This, in turn, may lead to land abandonment in marginal areas (Nowicki et al. 2009; Rienks 2008), which would have negative consequences for biodiversity in High Nature Value Farmlands (EEA 2004, 2009). It would also cause a shift of production towards regions outside the EU, particularly to Latin America (Verburg et al. 2008), causing increased pressure from expansions into natural areas in these regions.

According to the same study by Scenar (2020-2), the intensive livestock sectors would be less affected if the import tariffs were to be discontinued. A reduction in production is projected, from 3% for pig meat to 7% for poultry (Nowicki et al. 2009). In the first Scenar 2020 study, the impact was assumed to be much higher, with a projected reduction in EU poultry meat production of 37% (Nowicki 2006-1). Given the fact that production costs in the EU currently are much higher than in the United States, Thailand and Brazil (section 4.3.2), it can be expected that even if EU pig and poultry productions would remain at the same level, as projected in the Scenar 2020-2 study, the abolishment of import tariffs will have a large effect on the EU production structure, since farms with high production costs would no longer be able to compete,

4.3.2 EU production costs in a global context

There are significant differences in production costs between countries, mainly due to differences in feed, labour costs and efficiency. For example, the United States and Brazil are the cheapest producers of poultry meat (figure 4.4).

Modern livestock farming is dependent on many resources

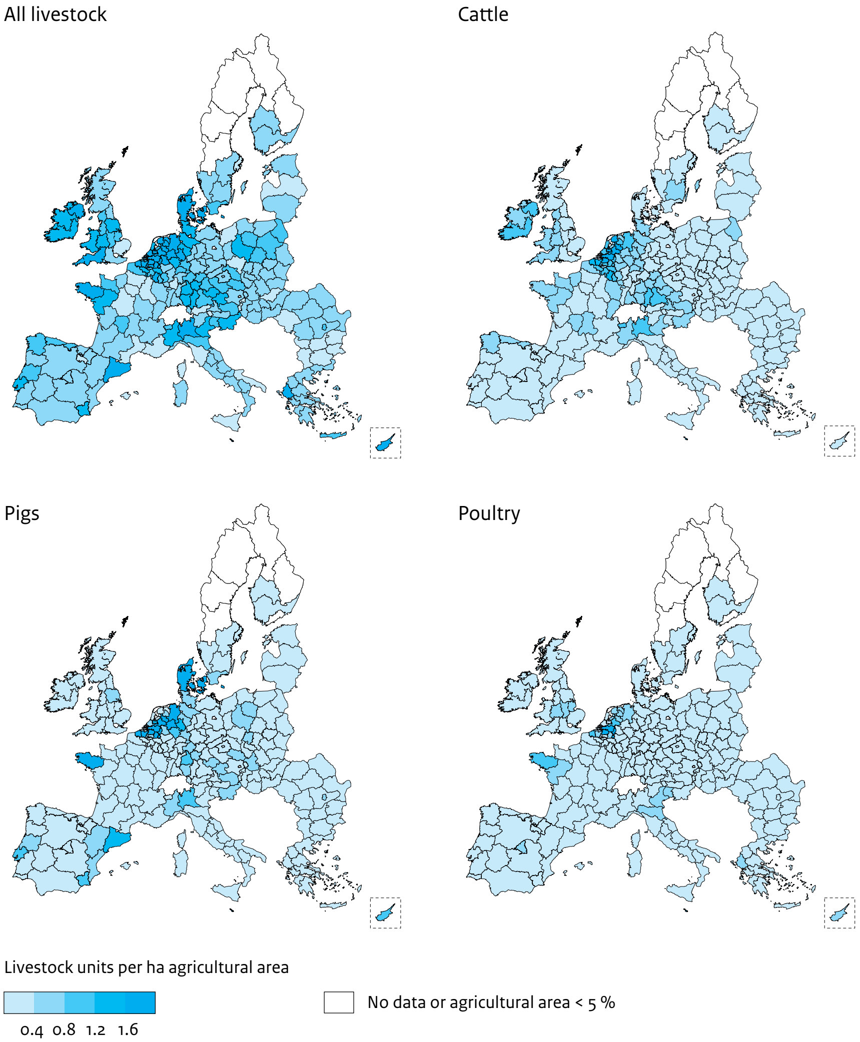
Today's livestock farms require a number of inputs. These include animals (genetic material), feed, land, housing and transport. The different feed components usually come from various continents and consist partly of specially cultivated products and partly of co-products. Meat itself is also divided into different products. Various types of meat come from a single animal species, and are valued differently in different countries or regions. Animals also supply many by-products, only some of which, for example leather, are recognisable to consumers. Other by-products are important as raw materials for medicines, industrial applications and pet food (see chapter 7).

4.3.3 Distribution of livestock farming

In many EU countries, intensive livestock farming is concentrated in specific regions, such as in Brittany (France), the Po Valley (Italy), North Brabant (the Netherlands), and West Flanders (Belgium) (figure 4.5). There are two likely main reasons for this concentration. The first is the proximity of urban areas with many consumers. The second is the economies of scale on the supply side. This is not only relevant to the livestock farms themselves, but to the whole production chain, including feed production, animal breeding, slaughtering and processing (FAO 2006). For the importation and distribution of feed, in particular, proximity to harbours is a great advantage.

Figure 4.5

Livestock density agricultural area in EU27, 2005



Source: Miterra-Europe

There are pros and cons to this process of geographical concentration. The advantages are cost reduction, better opportunities for a good knowledge infrastructure, and a reduction in travel distances for live animal transports. Among the disadvantages is the fact that relatively large quantities of manure are being produced, generally in surplus to

Table 4.4
Feed composition for different types of livestock

	Ruminants Cattle, sheep	Monogastrics (pigs, poultry)
Grassland	Grass, hay, silage	-
Other fodder	e.g. Fodder maize, alfalfa	-
Products from arable land	Cereals (wheat, barley, maize, rye) Legumes (pulses, beans)	
Co-products and by-products	Oil meals (soybean, sunflower, rapeseed) Corn gluten feed, brewers grain, molasses	
Additives	Vitamins, enzymes Minerals (P, Cu, Zn)	
Synthetic amino acids	Not common	Methionine, Tryptophan

local or regional nutrient requirements. This may cause overfertilisation and consequent nutrient losses. Furthermore, outbreaks of animal diseases may be more difficult to control.

4.4 Production and use of animal feed

Feed plays a pivotal role in livestock production, in different ways. Animals need feed to live and grow. In many cases, the feed costs make up more than half of the total production costs. Furthermore, many of the environmental effects of livestock production are in fact related to feed production (chapter 5).

4.4.1 Overview

Animals are mainly fed on grass, cereals, co-products and by-products
Types of feed differ greatly between animal species, particularly between ruminants and monogastric animals, such as chickens and pigs (table 4.4). On the basis of origin, three types of products can be distinguished: (i) grass and grass products from grasslands, (ii) main products of arable land (e.g. cereals and legumes), and (iii) co-products and by-products. The main co-products used in animal feed are meals (also called cakes) from oil production, for example, from soy beans, sunflowers and rapeseed. By-products are generated in the production of beer and sugar and the processing of maize and other food products. In some cases, it is debatable whether a product is in fact the main product, a co-product or a by-product (see text box *On the use and economy of by-products*). Vitamins, enzymes and minerals are added to animal feed. Antibiotic growth promoters were previously included in pig and poultry feed, but their preventive use has been banned in the EU since 2006.

Statistical information on feed use is uncertain and incomplete

Reliable statistical information on the production and use of animal feed in the EU is lacking. The quantity of industrial compound feed is well-known, as is its composition (at an aggregate level). However, the 150 million tonnes of compound feed amount to only around one third of the total quantity of animal feed. Other sources of feeds and fodder that are more difficult to quantify are:

- by-products directly supplied to farms; these are often wet products which are not transported over long distances;
- cereals grown and used as feed on the same farm;
- Grass and other feed crops, such as fodder maize.

The quantities of these feeds are generally not well-known and, therefore, have to be estimated in various ways. Another complicating factor is that feed composition is dynamic and varies almost on a daily basis depending on availability and price of raw materials. Legislation (e.g. restrictions on the use of bone meal because of BSE) and competition with other sectors (e.g. with aquaculture for fish meal) also have an impact on the composition of animal feed.

About 75% of protein-rich products originate from outside Europe

On the basis of feed composition, a distinction can be made between energy-rich and protein-rich products. Energy-rich products include cereals and their by-products. Protein-rich feeds are legumes, such as peas and beans, and oil meals. The largest proportion of energy-rich raw materials used in feed is grown within the EU, whereas about 75% of protein-rich products (expressed in proteins) come from outside Europe (FEFAC 2009). However, most feeds contain proteins, thus, energy-rich products and grass also add to the protein supply.

Sharp increase in compound feed production

In intensive farming in particular, as well as in other livestock sectors, many farmers use compound feeds. Manufacturers of compound feeds mix various raw materials together for specific kinds of animals. Production of compound feed in the EU increased considerably over the last 50 years, from 15 million tonnes in 1960 (for the EU6) to 130 million tonnes in 2008 (for the EU15) (FEFAC 2009). The turnover of the European compound feed industry in 2007 amounted to 41.6 billion euros (FEFAC 2009).

Obviously, not all animal feeds consist of manufactured compound feeds. Ruminants devour great quantities of roughage, such as grass, hay, silage and straw. Many farmers grow crops for feed, in addition to grass, mostly in the form of cereals and maize silage. Some livestock farmers also purchase certain feed components (e.g. cereals or wet by-products) and mix it on-farm into a complete animal feed. These practices partly depend on farm structure in the region and partly on feed availability.

Table 4.5
Feed and fodder use in the EU (2005) for cattle, pigs, poultry, sheep and goats

Type of feed or fodder	Mt per year
Grassland products	>150
Fodder (including products from temporary grassland)	110
Cereals	140
Protein-rich products (including oil meals)	61
Other products (mainly by-products)	20
Total	>490

Source: Calculations based on Miterra-Europe (Lesschen et al. 2011)

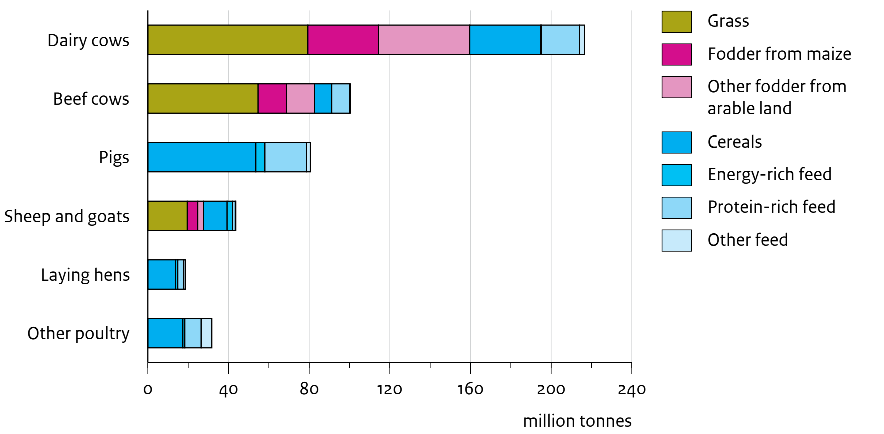
4.4.2 Feed use in the EU: origin and breakdown per livestock category
Total feed use in the EU amounted to around 490 million tonnes (expressed in dry matter) in 2005. A specification of this value per origin is given in table 4.5.

The total amount of 490 million tonnes means that an average of one tonne of animal feed is used per EU citizen, each year, equalling around 3 kilograms per day. The annual amount of cereals used corresponds to about 350 kilograms per citizen, or almost 1 kilogram per day. By-products play a minor role. In addition to grasses and fodder, cereals and oil meals are dominant. About 60% of the EU cereal production is used as animal feed.

Figure 4.6 is based on the same data as table 4.5, and specifies according to animal category or production sector. It shows that, in 2005, the dairy sector used about 44% of the total amount of animal feed, for the beef sector this was 20%, and the pig sector used around 16%. Of the total quantity used by the dairy sector, around 55% originated from grassland and other roughages and 45% was in the form of cereals, co-products and by-products. The feed quantities have been translated into hectares of land used for their production, see chapter 4.

4.4.3 Feed conversion
Feed conversion is a measure of the efficiency with which animals convert feed into a gain in body weight or usable product. There are large differences in feed conversions between the various species (see also chapter 7). The feed conversion of cattle is usually much less than that of pigs or poultry. The high feed consumption per kilogram of beef is partly due to the long time that it takes for an animal to reach slaughter weight, and partly due to the amount of feed needed by suckler cows. A suckler cow gives birth to one calf per year. This calf needs between one and three years to reach the slaughter weight, depending on local farming conditions. This is very different from the broiler sector, where one broiler breeder hen produces about five eggs per week. After hatching, the chicks are ready for slaughter in six weeks.

Figure 4.6
Feed use per livestock sector in EU27, 2005



Source: Calculations based on Miterra-Europe (Lesschen et al. 2011)

Animals are able to convert no more than 10% to 30% of their feed intake into edible products

There are several reasons why losses occur and why animals cannot convert all their feed into edible products:

- animals need a certain amount of feed as their maintenance energy requirement;
- the parent animals need feed as well;
- some animals die before they reach slaughter weight;
- animals are only able to utilise part of the energy and nutrients contained in the feed;
- not all animal parts are edible: based on the live weight of animals, roughly between 30% and 60% ends up in shops.

Most animal production systems lead to additional use of land and other resources

All these losses mean that animal products, in general, are far less efficient (in terms of land and other required inputs) than crop products. Exceptions are when animals are fed on materials that are not suitable for human consumption or that are not grown on land suitable for other crops, such as grasses and many by-products. However, these sources could feed only approximately 40% to 50% of the EU livestock. The rest of EU livestock production depends on products that are grown especially as feed on soils that would be suitable for growing crops for human consumption. The exact numbers are difficult to determine, partly because of a lack of reliable statistical data on feed use, and partly because animals rarely are fed on grass products and/or by-products alone.

On the use and economy of by-products
Agriculture and food production are complex processes in which raw materials such as harvested crops are refined or separated into components, resulting in co-products or by-products. Co-products are products with revenues similar to those of the main product. By-products are products that have substantially lower revenue than the main product (UNFCCC 2010).

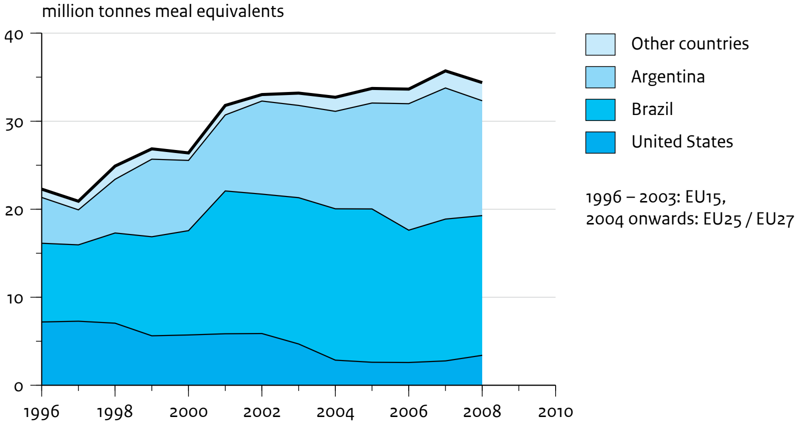
Examples of co-products include meals (oil cakes), which are left over after the oil has been pressed out of seeds. Examples of by-products are molasses and beer malt from the production of sugar and beer, citrus pulp and many other waste products from the food industry.

It is sometimes suggested that it is due to livestock farming that these products are valorised; without it they would be waste. Such an effective use of co-products and by-products often results in a lower environmental impact than if only the main products were used. However, it would be incorrect to fully ignore the environmental impacts of by-products and co-products. Without using them in livestock farming there could be other applications for these co-products and by-products, such as in pet food or for the production of biofuels. Furthermore, the main product perhaps would be no longer economically viable to grow without the by-product, or there could be a shift (e.g. due to other cultivars) in proportions between main product and by-product.

There are various ways in which environmental impacts may be attributed to main products and by-products, in life cycle assessments (LCAs). One of the commonest ways to do this is based on the economic value of the various products. Thus, for soy, for example, the economic value of the oil is about 40% and that of the cake 60%. Based on this economic allocation, the environmental impact of soy cultivation would have to be allocated to the oil and the meal in the same ratio.

Due to many developments, feed conversion has vastly increased over the last 50 years, notably in pig and poultry production (see section 4.5). As the purchase or production of animal feed is an important cost factor for livestock farmers (feed costs often make up 40% to 60% of the total production costs), there is a strong incentive for farmers to improve feed conversions. Nevertheless, for example, given the large differences in feed conversions between farms, but also between countries (Hoste & Puister 2009), opportunities for reducing feed use exist. There is, however, a trade-off between improving feed conversion on the one hand and animal health and welfare on the other (chapter 5).

Figure 4.7
Import of soybean meal in EU



Source: PBL analysis based on DG Agri (2008, 2009, 2010)

Imports from the United States have decreased, while imports from Brazil increased.

4.4.4 Soy bean: production and use

Soybean meal is by far the dominant source of protein-rich animal feed ingredients, but also one that is heavily debated. Reasons why soy beans are under discussion include:

- the environmental consequences of soybean production and its rapid expansion, in particular with regard to deforestation in the Brazilian Amazon Basin;
- the socio-economic impacts, particularly regarding the displacement of small-scale farms and farm labourers, and the strong dependency on patented seed from only a few companies;
- the question why Europe imports so much soy (soybean meal) and does not produce similar products itself;
- the fact that most of the soy beans produced (and exported to the EU) are genetically modified (GM) varieties.

Some facts and figures

Global soybean production has greatly increased over the last 50 years. Around 1960, production was dominated by China (the origin of soy) and the United States. Brazilian production of soy beans as a mainstream commodity kicked off in the early 1970s, partly as a means to generate foreign currency. The EU presently imports around 34 million tonnes of soybean meal every year. This quantity increased significantly over the 1996-2008 period (figure 4.7). Notably, imports from Argentina and Brazil have increased, while imports from the United States decreased.

Environmental consequences of soybean production

The area used for growing soy in both Brazil and Argentina has increased rapidly in recent decades, largely at the expense of extensive rangelands (Smaling et al. 2008). In Brazil, this mainly took place in the cerrado region. Large-scale expansion of soybean production also occurred in seasonally dry forest regions, such as the Chaco in central Argentina (Zak et al. 2008). Direct deforestation of tropical forest in the Amazon region has occurred only to a relatively small extent (Fearnside 2008; Mann et al. 2010; Simon & Garagorry 2005;) because of poor logistics and suboptimal environmental conditions for soybean production. It is generally accepted, however, that the indirect impact of soybean expansion on deforestation is much more important (FAO 2010a; Nepstad et al. 2006). From a macroeconomic view, one could simply describe this as displacement, as ranching areas move into the forest to make place for soybean production. From an actor point of view, one could even postulate a multiplier effect, since the capital gains from selling rangeland in a region suitable for soybean production allow ranchers to expand their herds and convert a much bigger area of Amazon Rainforest into new rangeland. The reality on the ground is much more complex (Fearnside 2008; Sparovek et al. 2009), which makes it impossible to precisely quantify these effects.

The expansion of soybean production in Brazil and Argentina has had positive and negative social consequences. While its cultivation significantly contributes to economic growth and prosperity by providing jobs in agribusiness and tax revenue to governments, there are accounts of incidents involving local small-scale farms being lured or bullied into producing soy beans and subsequently being trapped in a spiral of debt, and forced to sell their land; or being simply displaced (CAPOMA 2009; Steward 2007). Soybean cultivation also requires much less (although better trained) labour than traditional crops.

Use of genetically modified crops for soy

Soybean imports mainly come from Brazil, the United States and Argentina; they are the world's leading soybean producers. All three of these countries practice large-scale genetically modified soybean cultivation, meaning that most of the beans exported to Europe are also from genetically modified (GM) varieties. Only Brazil exports GM-free soy beans to the EU, mainly for organic production and for direct human consumption. Problems sometimes arise when soybean shipments contain traces of unapproved GM maize varieties.

Bindraban et al. (2009) looked into 12 popular claims regarding the agro-ecological impacts of genetically modified soy production in Argentina and Brazil. The GM soy that is currently commercially grown in these countries is Roundup™ Ready (RR) soy, which is tolerant of the herbicide glyphosate. They found no scientific evidence for most alleged environmental impacts specifically related to the RR varieties. However, while RR soy was found to have encouraged the adoption of zero tillage, a widely acclaimed soil and water conservation practice, it has probably also contributed to a build-up of herbicide

The Round Table on Responsible Soy (RTRS) Association

The Round Table on Responsible Soy (RTRS) Association is an international multi-stakeholder initiative, set up in 2006, which promotes the use and production of responsible soy. Members include producers (mainly from Latin America, India and China), stakeholders from industrial, trade and financial sectors (e.g. Syngenta, Nestlé, Unilever and Rabobank), and NGOs (e.g. WWF, Solidaridad), and local rural societies.

The principal instruments to accomplish the RTRS goals are the development, implementation and verification of a global standard, and the commitment to this standard by the stakeholders involved in the value chain. A first version of the standard was issued in June 2010 (RTRS 2010). It contains a number of principles and criteria regarding legal compliance, labour conditions, community relations, good agricultural practice and environmental responsibility. An example of the last is to not expand soybean cultivation into areas that were cleared of native forest after May 2009. A certification scheme based on this standard is expected to become operational in 2011.

The RTRS is not uncontested. Some see it as a greenwashing initiative, mainly for not taking a stance against GM technology, pesticides, the use of soy for biofuels and soybean expansion *per se*.[1] Others just find the standard too relaxed. Steward (2007) criticises the scheme for its lack of attention for semi-natural secondary forests, and for its lack of regard for local non-indigenous communities. Supporters of the scheme argue that this approach is the only way to move an entire sector step by step towards greater sustainability. It would also fit well in comprehensive nature conservation strategies, such as described by Nepstad et al. (2006), to end deforestation in the Brazilian Amazon Basin, by combining the efforts of local and federal authorities, private companies, NGOs, local communities and funding mechanisms, such as the UN Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD).

resistance in weeds, to which some farmers have responded by increasing herbicide applications.

Why does Europe not produce more protein-rich material itself?

Compared to the United States, Brazil and Argentina, the EU production of oil crops (providing protein-rich meals) is relatively small. One of the reasons for this is that the growing conditions in Europe are generally better for competitive cereal and grass production than for oil crops. The cereal sector also has had the advantage of being able to develop while being shielded from the world markets, because the EU regulated the internal market with intervention prices combined with import tariffs. As early as in the so-called Dillon negotiation round of the General Agreement on Tariffs and Trade (GATT), at the beginning of the 1960s, it was agreed that oil and protein crop products would be exempt from import tariffs and other forms of import regulation. The United States, in particular, was very keen to protect its trade position in oil crops. In the framework of the Blairhouse Agreement (1992), the United States and the EU agreed to limit the EU domestic support of oil and protein crops. This relatively unfavourable position for these crops also meant that research and development (e.g. for genetic improvement) has been very limited over the last decades. An important reason for the popularity of soy, compared to other legumes for which growing conditions in the EU are more favourable, is its amino-acid composition (protein composition), which matches very well with the requirements of most animals. Other crops, such as rapeseed and cereals, lack certain amino acids. Furthermore, peas and most beans contain certain compounds (anti-nutritional factors) that limit their maximum content in animal feed (Jezierny et al. 2010). Because of the EU biofuel policy, the production of notably rapeseed has increased rapidly in recent years, producing rapeseed meal as a by-product, which already is substituting soybean meal to some extent. It has to be noted, however, that arable land is needed in the EU for the production of these biofuels.

4.5 Historical development of the livestock farming sector in the EU

Major changes have taken place in Europe's livestock and feed production since around 1955. It is not possible to single out one factor or key driver, but a number of interrelated developments enabled a steep increase in production, farm sizes and labour productivity. This led to lower (real) prices of livestock products. Given the differences in the development of Member State countries between 1960 and 1990, and limitations in data availability, this section focuses on the historical developments in the 12 Member States that formed the EU between 1986 and 1995 (the founding EU6 countries plus the United Kingdom, Denmark, Ireland, Greece, Spain and Portugal).

The main drivers of change in recent decades were:

- The rapid increase in consumer wealth led to a strong increase in demand. The emergence of supermarkets also created new demand, for example, through the introduction of numerous convenience products (e.g. prepackaged chicken breast and other cuts of meat).
- One of the key drivers was the Common Agricultural Policy (CAP), which resulted in generally high and stable product prices (see section 4.5.2).
- The availability of cheap fertilisers and energy. The use of nitrogen in the EU12 increased from around 2 million tonnes in 1955 to 9 million tonnes in 1986. This was followed by a reduction to around 6.5 million tonnes in 2005, mainly due to more efficient use. This cheap fertiliser not only greatly enhanced the crop production and

thus livestock production, it also enabled a spatial separation of crop and livestock production. Fertilisers could be used, rather than a recycling of nutrients by using manure, making manure a 'waste' product in certain regions, with the resulting environmental problems.

- The mechanisation of crop production, which, in combination with production increases, made feed much cheaper.
- The development of new housing systems, such as battery cages for laying hens and free stalls for dairy cattle, vastly increased labour productivity. Many of these developments were stimulated by the need for this increase in labour productivity (thus reducing labour costs).
- The development in animal feeding techniques, animal breeding and veterinary sciences, including vaccines and the preventive and curative use of antibiotics.
- The increased education and skills of farmers.
- Institutional factors such as macroeconomic growth and stability, including access to credit and national and local government support of the sector.
- Developments in the whole production chain with upscaling and concentration in areas such as feed production, slaughter houses and processing.

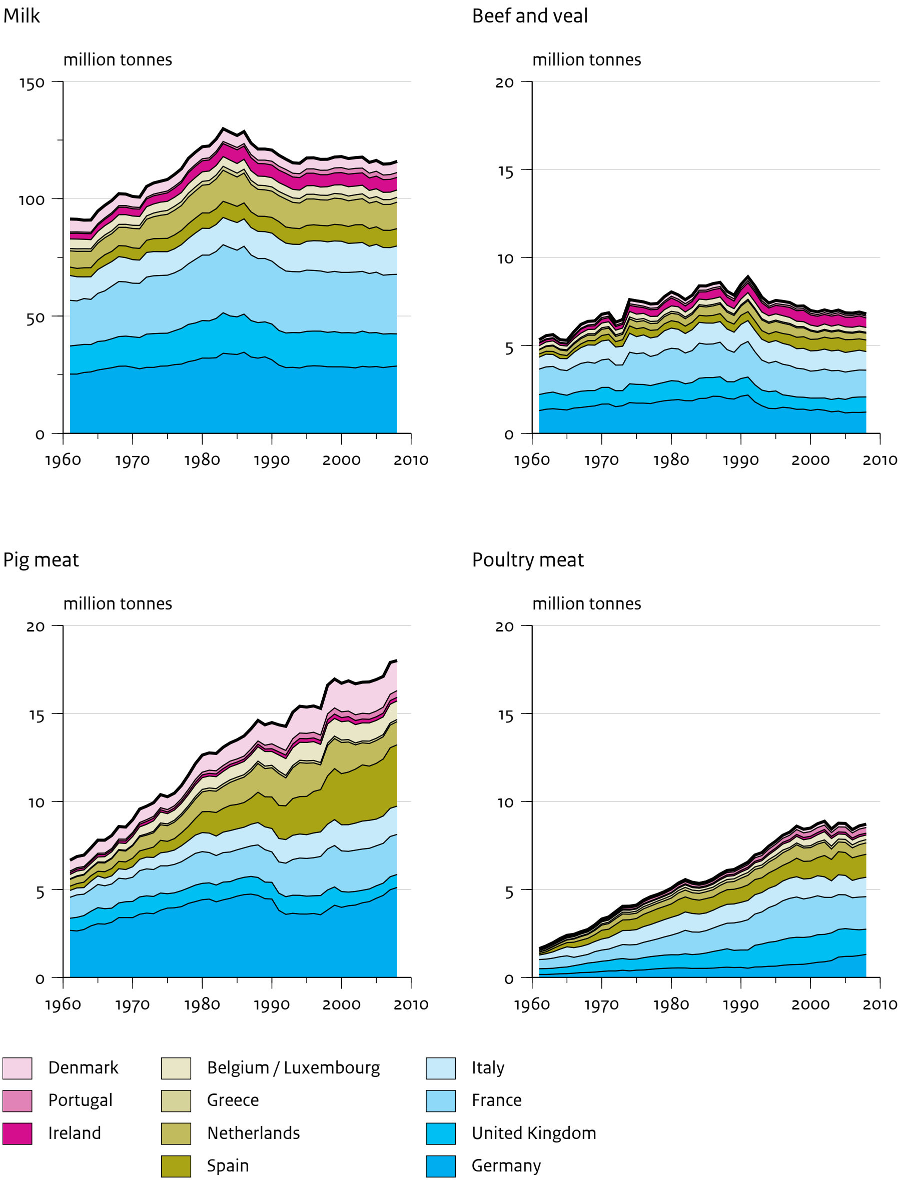
4.5.1 Developments in livestock production

Growth in milk production led to the introduction of milk quotas
Milk production increased by almost 50% in the 1961-1985 period. This was greatly stimulated by technical developments as well as by the CAP, which guaranteed high prices. Surpluses, which started to occur after 1975, were exported to the world market through export subsidies. In 1984, milk production was regulated by the introduction of the milk quota system, resulting first in a drop in milk production, followed by stabilisation at a lower level. Milk production per cow increased sharply from between 2 000 and 4 000 kilograms in 1960 to present levels of between 7 000 and 9 000 kilograms per cow. Numerous innovations (particularly better milking machines) resulted in a sharp increase in labour productivity.

The production of beef cattle in the EU12 increased over the period from 1961 to around 1986, but relatively less than the production of poultry and pig farming. After around 1989, possibly as a result of the introduction of milk quotas, there was a decline in production. The BSE crises also suppressed beef consumption and production.

Largest growth in pig production
The production of pig meat increased almost three-fold in the 1961-2008 period. In absolute terms, the growth in pig meat production was larger than that in poultry and beef. Production increased most steeply in Spain and Denmark, as well as in Germany and the Netherlands (figure 4.8). In the beginning of this period, most pigs were produced on mixed, usually small, farms, while at present, most pigs are produced on highly specialised farms. Many farms now even specialise in either breeding or fattening. Significant technical progress has also been made in pig production during

Figure 4.8
Production of meat and milk in EU12



Source: FAOSTAT (2010)

this period, for example, in feed conversion, piglets per sow and labour productivity. This resulted in a strong price drop in pig meat prices relative to beef. Around 1960, pig meat was about 50% more expensive than beef. By 1994, it was 50% less expensive (Bansback 1995).

Strong increase in poultry production due to introduction of broilers
The production of poultry meat in the 12 Member States (EU12) in 1961 was only 1.6 million tonnes per year, and production had already doubled since 1955. Over the 1961-2000 period, the increase was five-fold, after which a certain degree of stabilisation occurred (figure 4.8). The main reason for this huge increase was the development of a new breed of chickens (broilers) that grew much faster than the original laying hen. Before 1955, most of the poultry meat was meat from laying hens and their male chicks. In combination with new housing techniques and better feeds, the new breeds led to a rapid increase in poultry meat production. The broiler chickens were introduced in the EU from the United States in around 1955. At that time it took approximately 73 days to produce a chicken that weighed about 1.5 kilograms (MacDonald & McBride 2009). Today, it takes around 40 days to produce a chicken that weighs about 2.2 kilograms (Van Horne 2009). Labour productivity and feed conversion also have increased significantly. The downside of these developments is the negative consequences for animal welfare (see chapter 5).

Egg production has also increased since 1961, but not as steeply as the production of poultry meat. Production increased by 50% between 1961 and 1980, since when it has been more or less stable. Improvements have also been made in egg production, notably in the number of eggs per laying hen. The introduction of the battery cage caused a steep increase in farm scale and labour productivity, but, again, at the expense of animal welfare. The cages are to be banned in the EU from 2012 onwards. Already in many countries alternative systems have been introduced, such as free range systems.

4.5.2 The role of the EU Common Agricultural Policy

The EU Common Agricultural Policy (CAP) (and previous national policies) has greatly influenced the development of both crop and livestock sectors within the EU, over recent decades. The objectives of the CAP included an increase in productivity, stabilisation of markets, securing the availability of supplies and providing consumers with food at reasonable prices.

Market and price support led to relatively high and stable prices, thus stimulating production
The main policy objective in the first period of the CAP (1962-1992) was to provide 'market and price support'. In general, this meant a set minimum internal market price for a number of commodities (notably cereals, milk, sugar and meat), combined with a system of import tariffs and export subsidies. The internal market price was generally higher than the world market price. Import tariffs (tax on imported products) were therefore necessary to shield EU farmers from cheaper imports from countries outside

the EU. Any surplus on the EU market had to be exported to the world market by means of export subsidies. The relatively high and stable prices were one of the factors leading to the marked increase in production. As EU production grew, intervention stocks and exports (and export subsidies) increased as well. These were not only a burden to the EU budget; they increasingly distorted the world market. To limit EU production, quotas were introduced for milk in 1984.

The high internal market prices for cereals also meant that feed prices were high. Cereal imports were faced with high import tariffs, but commodities such as manioc and corn gluten feed were exempt from these import tariffs. This led to the situation in which the EU had to export cereals financed by export subsidies, while importing cereal substitutes. This not only led to higher EU budgets, but also to resistance from other countries in trade negotiations (GATT/WOT). This resulted in a reduction in EU cereal prices following the MacSharry reforms of 1992.

Shift from market and price support towards direct payments
During the second period of the CAP (1992-2003), internal market prices were significantly reduced for a number of products (e.g. cereals, beef and sheep meat). Farmers were compensated for lower prices through direct payments (income support), but still had to produce the commodity to receive such payment ('coupled payments').

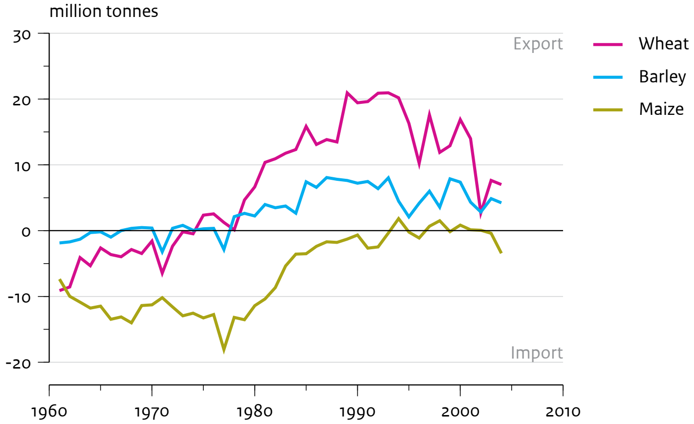
During the third CAP period (from 2003 onwards), a shift was made towards decoupled payments ('Single Farm Payments'), at least in most countries and for most commodities. Decoupled meant that the production of a specific product was no longer a condition for payment. Coupled payments remained in place for beef, goats and sheep, in many Member States. Import tariffs also remained for a number of products.

4.5.3 Animal feed

Doubling of cereal use as feed between 1961 and 2007
Over the last 50 years, the quantity and composition of animal feed has changed significantly. This section focuses on the energy-rich products (for protein-rich products, see section 4.4.4). Cereals are the dominant source of energy-rich products, but other products are also being used, such as tapioca (cassava), corn gluten feed and all sorts of by-products. In 1961, roughly half the available cereals in the EU12 countries were used as feed; in 2008 this was over 60%. In absolute terms, the use of cereals as feed has doubled over this period to around 120 million tonnes (FAO 2010b).

EU evolves from net importer to net exporter of cereals
Until 1973, the EU10 countries were net importers of both wheat and coarse grains (figure 4.9). Imports in 1961 were about 18 million tonnes per year. Cereal production actually increased during this period by 25%, but the demand for feed also increased considerably. Cereal production increased largely due to higher yields per hectare, since the land area under cereal cultivation remained roughly the same. Around 1973,

Figure 4.9
Net trade of cereals in EU12



Source: PBL analysis based on USDA-ERS (2010); Eurostat (2010)
The EU evolved from net importer to net exporter of cereals.

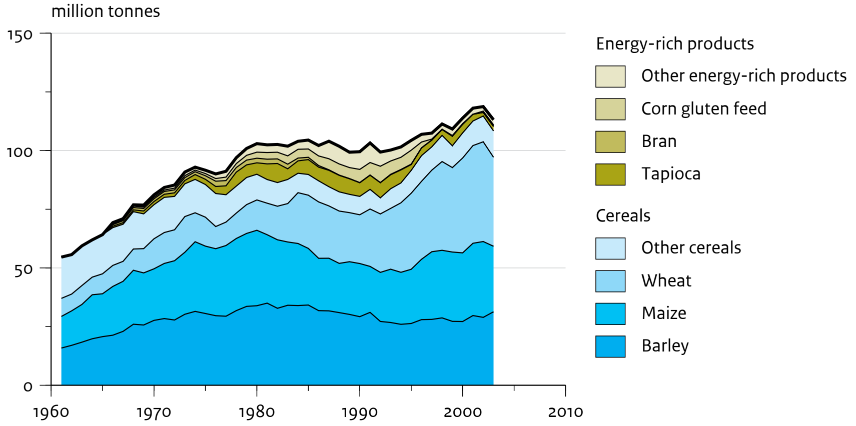
the EU (then composed of ten countries) became a net exporter of wheat, but was still importing maize. Around 1985, the EU became a net exporter of cereals.

The internal EU cereal prices were cut following the MacSharry reforms (see section 4.5.2). As a consequence, more cereals were used in animal feed, resulting in a sharp decline in the import of tapioca (from Thailand and elsewhere) and corn gluten feed (figure 4.10). The total import of corn gluten feed, tapioca and other energy-rich products amounted to 20 million tonnes for the EU12 countries, around 1990. This has dropped to about 3 million tonnes, today. Use fluctuates considerably from year to year, depending on the cereal prices. If cereal prices are low, then so is the import of energy-rich commodities. If cereal prices are high, the import of energy-rich commodities increases.

4.6 Conclusions and summary

EU livestock production has increased significantly over the last 50 years, notably in dairy produce and pig and poultry meat. In the richer Member States in particular, farms have specialised and the average number of animals per farm has increased rapidly. The main driving factors of these developments were a strong increase in demand, the availability of relatively cheap feed, technological developments and agricultural policies. Dairy, pig and poultry farms in particular, tend to be concentrated in certain

Figure 4.10
Type of energy component in feed in EU12



Source: PBL analysis based on USDA-ERS (2010); Eurostat (2010)

The use of animal feed increased with the growing livestock sector in the EU. Energy-rich products in particular were imported during the 1980-1992 period, but due to the MacSharry reform of the CAP, cereal prices were lowered, resulting in a higher share of domestic cereals and lower imports of alternatives.

regions in Europe, partly due to economies of scale on both the supply side (e.g. feed companies) and output side (slaughter houses and the food processing industry).

The production costs of most livestock products have been significantly reduced in recent decades, as a result of various factors. The introduction of new technologies has led to higher labour productivity and higher feed efficiencies, notably in the pig and poultry sectors. Due to the fierce competition, however, prices of livestock products have been lowered even further, driving farmers in the direction of increased farm sizes. The minimum farm size required to acquire sufficient income is still steadily increasing.

The EU is more or less self-sufficient regarding meat and dairy, with the exception of beef, sheep and goat meat, for which products the EU is a net importer. For dairy products and pig meat, the EU is a modest – relative to the production – net exporter. The present level of production of livestock products has been highly influenced by the EU Common Agricultural Policy (CAP). Production quotas for milk have been effective from 1984 onwards, but will expire in 2015. Income subsidies and import tariffs have also influenced livestock production in the EU. The EU livestock sector is partially shielded from world markets by means of import tariffs. These are effective for many dairy products, beef, sheep and pig meat, and poultry. They impede or reduce the import of these products from regions where production costs are lower, such as Brazil, Australia and the United States. An abrupt abolition of these import tariffs could suppress EU livestock production significantly, although consumer preferences and regulations such as sanitary measures could partially mitigate this effect.

Feed is an essential production factor in livestock production. The EU livestock sector uses around 500 million tonnes of animal feed annually. About 30% of this is in grass, 30% in cereals and the rest consists of a range of other products. An average of around 3 kilograms of feed per day is being used per EU citizen, of which 0.8 kilogram is in cereals. The EU is self-sufficient in its cereal use, but not in that of protein-rich feed. Most of the feed is being used in the dairy sector (around 220 million tonnes). The pig and poultry sectors are dependent on specially cultivated products such as cereals. Over 60% of the EU cereal production is being used as animal feed. By-products play only a minor role in animal feed. Co-products (e.g. soybean meal) play a larger role.

The EU annually imports around 35 million tonnes of soybean meal, a major source of protein-rich feed, mainly from Brazil and Argentina. The imported quantity has increased over the last ten years. Most of the expansion in soybean cultivation has taken place on semi-natural grasslands in Brazil and Argentina, which have been converted into arable land. However, this expansion might have displaced livestock farmers and may thus have indirectly stimulated the conversion of Amazon forest into pastures.

A number of options exist for reducing feed use per unit of animal production. These include:

- improved management, or innovations to make nutrients and energy better available to animals;
- optimising feed or digestion, especially for ruminants, could reduce greenhouse gas emissions from animals;
- enhancing the use of by-products and waste, which would reduce feed demand;
- reduction in the protein content of animal feed, for example through better management or innovations, such as improving protein uptake or adding amino-acids. This pathway could reduce nitrogen emissions as well as reduce the dependency on the importation of protein-rich feeds.

Note

1 See for example: The Round Table on Ir-responsible Soy. Certifying soy expansion, GM soy and agrofuels. April 2008. http://archive.corporateeurope.org/docs/soygreenwash.pdf.

Impact of EU livestock farming on the environment

5.1 Introduction

The preceding chapter described European livestock farming, including the volumes and origin of the feed necessary for livestock production. This chapter looks at the effects of European livestock farming on the environment and on animal welfare. Given the multiple environmental impacts of livestock, a selection had to be made, and the focus is therefore on issues that have a national, European or even global character. The main end points identified from that perspective are biodiversity and climate change. The main pressures on these end points are land use and land-use change, and emissions of nitrogen and greenhouse gases. Nitrogen emissions and zoonosis may also affect human health. Given the societal concerns, this chapter also includes the aspect of animal welfare.

It has to be noted that, given the scope of the report, each subject is only discussed in brief. Most of the information has been based on literature. New data and insights were used for generating data on land use, greenhouse gas emissions, and the relationship between animal welfare and feed use.

5.2 Land use

Land is an essential factor in livestock production
Since grasslands and croplands are needed to produce feed, land is an essential factor in livestock production. In Europe, many natural areas were converted into agricultural land, centuries ago. In other regions, large-scale land conversion is more recent, as in the

United States during the 19th century or presently in South America. This section looks at how much and what type of land is needed for the production of feed in the European livestock sector. Extra attention is paid to grasslands, given their importance to livestock production.

5.2.1 Policy goals and objectives

There are no direct EU policy goals regarding land use, but the type and extent of land use is an important factor in many respects:

- Good agricultural land is a scarce good, both in Europe and globally. An increase in the demand for agricultural commodities may lead to land conversion inside or outside Europe.
- Land, being a production factor, has to remain in a good state, in order to sustain agricultural production in the longer term. Processes such as erosion or salinisation may hamper the sustainable use of land. Production of crops and livestock is called the provisioning service, in terms of ecosystem goods and services.
- Land also plays a central role in other ecosystem goods and regulating services such as climate and water (e.g. flooding), and in cultural services such as beauty (landscapes) and recreation.
- The type and intensity of agricultural land use largely determine the conditions for biodiversity (see section 5.5) and the level of greenhouse gas emissions (section 5.4).

5.2.2 Status and developments

Cropland and grassland areas

More than two thirds of EU agricultural areas used for livestock production

Feed can be produced on both grassland and cropland, although intermediate forms exist, such as temporary grassland. Cropland areas used for feed production are located both within and outside the EU, for example, in Brazil and the United States. More than half of the arable land is used for producing feed and fodder for the livestock sector (table 5.1).

Most of the required land area is needed for dairy farming, followed by beef production (figure 5.1). Together, these two sectors utilise around 87 million hectares, around 53 million hectares of which is grassland, not including temporary grasslands. The 35 million hectares of arable land needed for the dairy and beef sectors combined, is almost as large as the total arable land area needed for the pig and poultry sectors. This is in contrast to the general perception that for beef and milk production the only feed required would be grass. Temporary grasslands are included in the category of arable land. For sheep and goats, around 20 million hectares is being used. The arable land area needed in the pig sector is around 22 million hectares, approximately 18 million hectares of which are located in Europe and 4 million outside Europe. Poultry farming uses 14 million hectares of land. All data are derived from the Miterra-Europe (Lesschen et al. 2011; Oenema et al. 2007) modelling system, which uses input form the CAPRI model (Britz & Witzke 2008).

Table 5.1

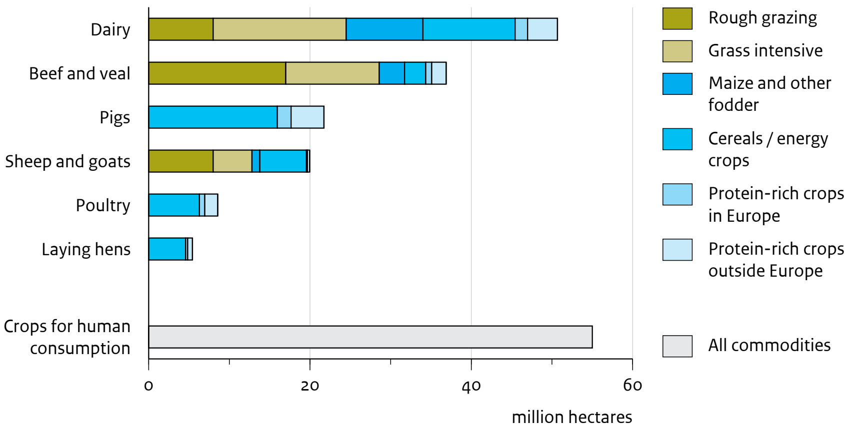
Land use in farming, in million hectares

	EU27	Outside EU
Grassland	65-70	
Arable land used for feed and fodder production	60-70	10-14
Total land area used for livestock farming	125-140	
Arable land used to produce food for direct human consumption	50-60	
Total agricultural area	185-190	

Source: Calculation based on Miterra-Europe: Lesschen et al. (2011); Oenema et al. (2007)

Figure 5.1

Land use per sector in EU27, 2005



Source: Lesschen et al. (2011)

Around 60% of the land use for livestock production is for beef and dairy production. The category 'fodder' includes maize silage and grass from temporary grassland.

A considerable area of arable land outside Europe is being used for feed production in the European livestock sector, particularly for the production of protein-rich feed ingredients. For the total European livestock sector, this amounts to around 12 million hectares (see 'Allocating land use for protein-rich materials'). In total, the European livestock sector is responsible for the use of approximately 79 million hectares of arable land, 67 million hectares of which within Europe and 12 million hectares outside Europe.

Allocating land use for protein-rich materials

When allocating land use to commodities and thus to certain livestock sectors, a problem arises for protein-rich feed materials. In many cases these materials are co-products from oil crops, such as soy and rapeseed (see chapter 4). One hectare of soy beans produces around 500 kg of oil and 2 000 kg of soybean meal. It would not be correct to allocate the full hectare of soy beans for meal production, as the yield from the same hectare produces oil as well. One of the methodologies used in life-cycle assessments (LCA) is economic allocation, which takes the economic value of the two co-products into account. Oil accounts for around 40% of the economic value of soy beans, while soybean meal accounts for 60%. These factors, however, may fluctuate from year to year. This implies that 0.6 hectares would be needed for the production of 2 000 kg soybean meal. This approach has been followed in this study to convert the way feed is considered; from a co-product to a land-use application. It means that around 10.5 million hectares is allocated for the production of 34.5 million tonnes of soybean meal, the quantity imported into Europe (FEFAC 2008, 2009). About 87% of the proteins imported for feed is in the form of soy beans (meal); the rest in the form of other products, such as corn gluten feed and meal from rapeseed, cottonseed, copra and palm. If we apply the same land-use factor (calculated on the basis of proteins produced per hectare) to the other protein-rich products, an additional 1.5 million hectares outside the EU27 can be attributed to feed production for EU livestock. The total land area needed outside Europe to produce protein-rich feed for the EU livestock sector, therefore, is around 12 million hectares.

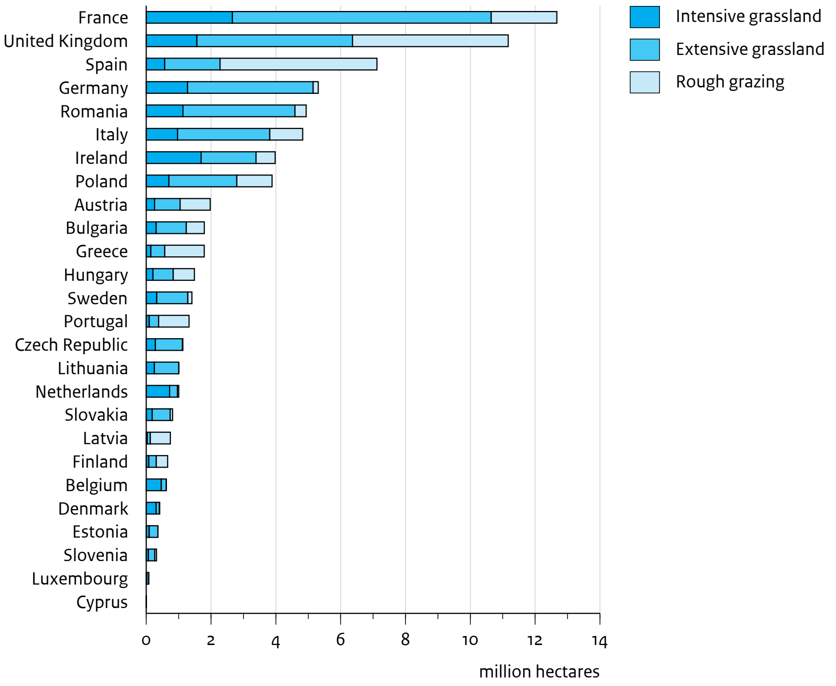
Uncertainties in land area and allocation of land area per sector

In our calculations, the allocation of land area to the various livestock sectors obviously bears a degree of uncertainty. The greatest uncertainty is in the allocation of grassland area to specific types of livestock. This is done by a top-down methodology, starting from the total area available. The uncertainty, therefore, mainly lies in the distribution over the production of beef, dairy, and goats and sheep (especially the land allocated to rough grazing) and not in the total area. With respect to the area allocated to the production of soybean meal, the uncertainty partly lies in the economic allocation factor.

Grassland

Grasslands in Europe are important, both in terms of area and in their share in animal feed production. The grassland area in the EU is about 65 to 70 million hectares, which makes up a third of the agricultural land in Europe (Smit et al. 2008). The exact area of grassland under agricultural use is not precisely known, since some grassland uses have been included incorrectly or incompletely in the European farm structure survey (FSS), examples being seasonal lets and the use of common land (Paracchini et al. 2008).

Figure 5.2
Grassland in EU27, 2006



Source: Miterra-Europe

Temporary grasslands are also excluded, as are small farms. This means that, in most countries, the FSS data underestimate the actual amount of grassland.

Grasslands are very diverse in terms of management, yield and biodiversity value
European grasslands are very diverse in terms of management and physical properties, and therefore also in grass yields and biodiversity. They vary from species-rich, semi-natural grasslands to heavily fertilised, temporary grasslands with a monoculture (often perennial ryegrass (*Lolium perenne*)). The proportion of intensive grassland, extensive grassland, and areas with rough grazing, varies strongly between Member States (figure 5.2). Approximately 19% of the total amount of artificial nitrogen fertiliser applied in the EU is used on grassland (EFMA 2009). Grasslands can be divided into temporary and permanent grasslands. Temporary grasslands are areas where grass is grown on land that is regularly ploughed, since the grass is in rotation with other crops. Most of the temporary grasslands are intensively used, and have a low biodiversity value.

Yields from grasslands vary greatly, depending on climate, soil and management. In north-western Europe, grass yields of more than 10 tonnes of dry matter per hectare are achieved, while yields in the Mediterranean region amount to less than 1.5 tonnes per hectare (Smit et al. 2008; Velthof et al. 2009).

From the point of view of biodiversity, the semi-natural grassland features have by far the greatest value (Hopkins 2009), while the biodiversity of fertilised, 'improved' grassland is no greater than that of intensively used arable land. Almost 40% of the grassland production is from intensively managed grassland that covers only 20% of the total grassland area.

Grasslands not only deliver feed, but also are important for biodiversity and carbon sequestration
Part of the permanent grassland not only is relevant for livestock farming, but also is considered of great importance to biodiversity. Most prominent are the High Nature Value farmlands (Paracchini et al. 2008; Veen et al. 2009; see section 5.5). However, other grasslands also may be important for biodiversity. Furthermore, grasslands are often important for landscape value as they have become a feature of the 'traditional' agricultural landscapes. These are generally high valued landscapes. Permanent grasslands are also a carbon sink, and their top layer contains a relatively large quantity of carbon. The convertion of these grasslands into arable land would lead to significant carbon emissions (section 5.4).

Grass: an environmentally friendly feed?
It has been argued that, since grasslands are there, anyway, using them by mowing and for grazing are perfect ways of transforming inedible products from otherwise non-suitable land into edible products for human consumption, such as meat and dairy. This is certainly true for a part of the present grassland areas. However, most of the grassland production does not take place on semi-natural grasslands, but is from moderately to intensively managed grasslands, which are fertilised (leading to nitrate leaching and ammonia emissions) and sowed with high-yielding grass varieties. Temporary grasslands as well as some of the permanent grasslands could be used for direct food production. They could also be turned into arable land. The suggestion that the use of grasslands is by definition environmentally friendly, and that grasslands are predominately on soils unsuitable for other production, is therefore debatable.

5.2.3 Technical options, trade-offs and co-benefits
Given the global pressure on land use caused by population growth, increasing prosperity and biofuel policy (see chapter 2), it would be useful to limit the amount of notably arable land and intensively managed grassland. This could help to reduce deforestation, although the global demand for food and feed is certainly not the only factor influencing land-use changes (Lambin et al. 2001, 2003). Apart from reducing the demand for feed, fuel and food, increasing crop yields could help to reduce the required land area. The scope and effects of yield increases differ strongly per region. In general, the potential for crop yield increases is larger outside the EU, although there are

certainly areas within the EU where yields also could be increased. It should be noted that the reference scenario as presented in chapter 2 already assumes a yield increase. The side effects of raising crop yields very much depend on the circumstances. In the EU, raising crop yields could lead to higher inputs and other ways of intensification, in turn, leading to a higher risk of emissions and negative effects on biodiversity. However, if an increase in crop yield is achieved by following a more sensible approach, for example, through a more knowledge-intensive form of integrated farming, this could even lead to lower impacts on the environment.

5.3 Nitrogen use and emissions

The significantly increased use of nitrogen (N) fertilisers in the 1950-1985 period boosted crop production and, consequently, also livestock production in Europe (chapter 4). The present level of livestock production would not be possible without the use of these fertilisers. Parts of the nutrients applied, however, are lost to the environment, with negative effects on biodiversity and human health. Nitrogen, in particular, can have a cascade of negative effects (Galloway et al. 2002; Oenema et al. 2007):

- eutrophication of both inland and coastal surface waters;
- emissions of ammonia and atmospheric deposition of N causing eutrophication and acidification, and contributing to the formation of secondary particulate matter and health impacts;
- raised nitrate levels of surface waters and groundwater, making them less suitable as sources of drinking water;
- emissions of nitrous oxide (N_2O), a very powerful greenhouse gas, which also contributes to stratospheric ozone depletion.

Agriculture is not the only source of nitrogen emissions. For example, the burning of fossil fuels in power plants and engines causes emissions of NO_x, and sewage systems release nitrate and organic nitrogen to surface waters. However, major reductions in NO_x emissions and emissions from sewage systems (due to wastewater treatment) have been achieved in the EU over the last 15 years (EEA 2007).

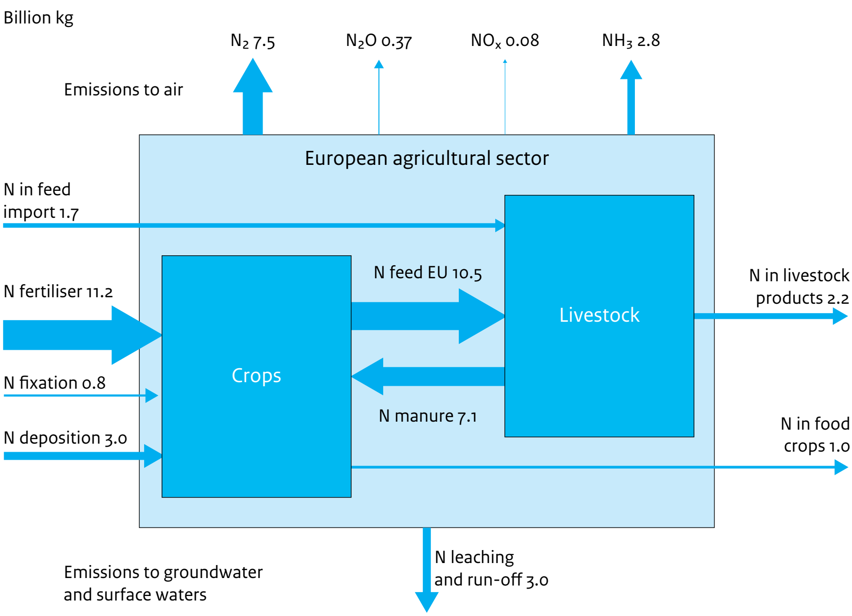
5.3.1 Status and developments

Large losses in the form of ammonia and nitrate

In 2005, the total amount of nitrogen in fertilisers in the EU27 was around 11.2 million tonnes, while other inputs (nitrogen fixation by plants and bacteria, nitrogen deposition and nitrogen in imported feeds) provide an addition total input of 5.5 million tonnes. The total amount of nitrogen in animal excretion was estimated at 10.0 million tonnes (Oenema et al. 2007, 2009). The nitrogen in manure, combined with that in fertilisers, is applied to the soil (minus the nitrogen lost in the form of ammonia). About 44% of this nitrogen is taken up by crops; the rest either accumulates in the soil or is lost to the environment. For 2005 was estimated that the annual loss of N in the EU27 due to the

Figure 5.3

Nitrogen flows in agricultural sector in EU27, 2005



Source: Miterra-Europe: Lesschen et al. (2011); Oenema et al. (2007)

EU agriculture has a nitrogen efficiency of 19%. The rest of the nitrogen is lost to the environment, partially in harmful forms such as ammonia (NH_3) to the air and nitrate leached to groundwater and surface waters. The livestock sector plays a pivotal role in these losses.

volatilisation of ammonia was about 2.8 million tonnes and that 3.0 million tonnes was lost (mostly as nitrate) due to leaching (Oenema et al. 2009). The input into European agriculture totalled 16.7 million tonnes, while only 3.2 million tonnes ended up in products for human consumption. The mean nitrogen use efficiency in the EU27 was 19%.

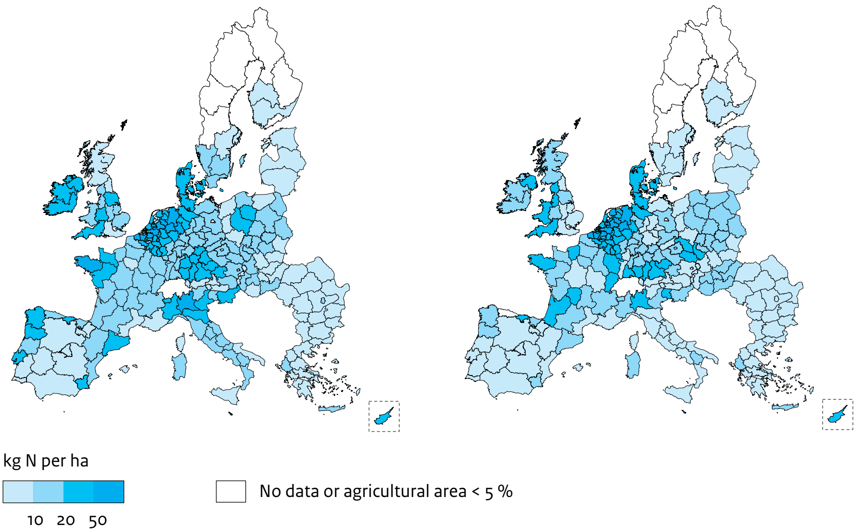
Large share of nitrogen losses related to livestock production

The mean nitrogen surplus per hectare of agricultural land varies greatly between Member States (figure 5.4), with the highest value being in the Netherlands (around 280 kg N per ha) and the lowest in Slovakia (24 kg N per ha) (Velthof et al. 2009).
A surplus means that input through fertilisers and manure is higher than removal in the form of agricultural products. A high surplus generally indicates high nitrogen losses. In larger Member States, especially, there are major regional differences, with relatively high N surpluses in regions such as Brittany, northern Italy and north-west Germany. In general, nitrogen surplus closely correlates with livestock density.

Figure 5.4

NH_3 emissions and nitrogen leaching in agricultural areas in EU27, 2000

NH_3 emissions | Nitrogen leaching



Source: After Oenema et al. (2007)

The use of nitrogen fertiliser has dropped significantly in most European countries, following a peak around 1986. This reduction probably has been due to environmental policies (regulation as a result of the Nitrate Directive, awareness raising), combined with changes in the Common Agricultural Policy, such as the introduction of milk quotas and reduced commodity prices. The effects of the reduced input also have become apparent in water quality. Recent reports by the European Commission have indicated that 66% of groundwater sites and 70% of surface water sites across the EU15 show stable or decreasing nitrate concentrations over the 2004-2007 reporting period, compared to the previous (2000-2003) reporting period (European Commission 2010a, 2010b). Nevertheless, in many regions nitrate (or total nitrogen) concentrations in groundwater and surface waters still exceed the standards.

Large share of nitrogen losses related to livestock farming

Nitrogen losses to the environment, generally, are closely related to livestock production. This can be seen by comparing the maps for ammonia and nitrate emissions (figure 5.4) with livestock densities (figure 4.6). Ammonia losses are mainly from manure. These losses occur in stables, from manure storage and from applying manure to fields. Nitrate losses generally occur when the available nitrogen in the soil is not absorbed by crops. This is the case when either the timing or the quantity of the nitrogen supply is not in line with the uptake by crops. Since the nitrogen, generally, is released slowly from manure, the timing is not always right. Furthermore, the availability of large quantities of manure that have to be disposed of may lead to overfertilisation.

5.3.2 Policy objectives and policy instruments

- The EU Member States have agreed to reduce ammonia emissions. Each country has an emission ceiling for the year 2010 that has been set in the National Emission Ceilings Directive (NECD; 2001/81/EC). Individual Member States are free to design policy instruments for reducing their ammonia emissions.
- Large intensive livestock farms are regulated more directly, namely through the Directive on Integrated Pollution Prevention and Control (96/61/EC). These farms have to limit their emissions according to the best available techniques (BAT).
- Regarding the leaching of nitrate, the Nitrates Directive (91/676/EEC) aims at the protection of waters against pollution caused by nitrates from agricultural sources. Member States are required to have regulations in place to reduce the leaching of nitrates to groundwater and surface waters.
- Regarding water quality in general, the EU has adopted the Water Framework Directive (2000/60/EC), establishing a legal obligation to protect and restore the quality of waters across Europe. The directive sets out a precise timetable for action, with 2015 as the target year by which all EU waters should be in good condition.

5.3.3 Options, trade-offs and co-benefits

Oenema et al. (2009) describe three groups of measures that were seen by experts as most promising for reducing nitrogen emissions (both leaching and gaseous emissions). These groups of measures are:

- balanced fertilisation, combined with improved crop and manure management;
- low-protein animal feed (lower protein (nitrogen) content of feed);
- NH_3 emission abatement (e.g. low-emission application, covered manure storage and low-emission housing techniques).

Clearly, these are very broad groups of measures, which can be elaborated more precisely. Although Oenema et al. (2009) focus on measures to reduce nitrogen emissions from agriculture, most of the measures focus on aspects of livestock production, such as manure management and animal feeding and housing. This emphasises the crucial role of livestock in nitrogen management.

5.4 Emission of greenhouse gases

Livestock farming leads to the emission of greenhouse gases in various ways. The largest effect of livestock farming is not due to carbon dioxide (CO_2) emissions, but to methane (CH_4) and nitrous oxide (N_2O) emissions. Both gases are much more powerful greenhouse gases than carbon dioxide, with a global warming potential of 25 for methane and 298 for nitrous oxide (IPCC 2007). Because of the different greenhouse gases, emissions are expressed in CO_2 equivalents (CO_2 eq).

Ruminants produce methane gas as they digest feed. Methane and nitrous oxide are also released from stored manure. The use of manure and artificial fertiliser also leads to the emission of nitrous oxide. Carbon dioxide and N_2O are released during the production of artificial (nitrogen) fertiliser. The amount of greenhouse gas emissions related to the transport of animal feed, livestock and animal products, is relatively small compared with that from other sources. Considerable quantities of CO_2, methane and nitrous oxide are released from the soil following deforestation and the conversion of grassland into agricultural land.

5.4.1 Policy objective

The EU has agreed on a reduction in total greenhouse gas emissions of at least 20% by 2020, compared to 1990 levels. This reduction is to be achieved partially through the EU Emission Trading System (EU ETS). For sectors not included in the EU ETS, such as agriculture, transport, building and waste processing, national emission targets for 2020 have been set ranging from -20% for the richest Member States to +20% for the poorer ones, compared with 2005 levels (Decision No. 406/2009/EC on effort sharing). Member States will be responsible for defining and implementing policies and measures to limit emissions of the different non-ETS sectors, according to their national targets. In the EU *Roadmap for moving to a competitive low carbon economy in 2050* it is assumed that agriculture can achieve an emission reduction of -42% to -49% by 2050, compared to 1990 levels of greenhouse gas emissions (European Commission 2011). This means that the agricultural sector is projected to be responsible for a third of the total EU emissions in 2050. This indicates again that there are possibilities to reduce greenhouse gas emissions from agriculture, although agriculture will remain an important source of these emissions.

The Common Agricultural Policy (CAP), therefore, probably will also consider measures to reduce greenhouse gas emissions from agriculture. The EU working document *The role of European agriculture in climate change mitigation* (SEC 2009, 1093 final) concludes that there is 'unused potential for cost-effective mitigation activities in EU agriculture'.

5.4.2 Status and developments

Around 10% of EU greenhouse gas emissions are related to livestock production
According to calculations made using the Miterra model, the total in greenhouse gas emissions attributed to European agriculture, in 2005, was 616 Mt CO_2 eq (Lesschen et al. 2011; Oenema et al. 2007; Velthof et al. 2009). The livestock sector emitted a total of 538 Mt CO_2 eq. In 2007, the total of greenhouse gas emissions in the EU27 amounted to 5 360 Mt CO_2 eq, including emissions from international aviation and shipping, but excluding net CO_2 removals from land use, land-use change and forestry (EEA 2009a). The share of livestock farming in total European greenhouse gas emissions, therefore, was more than 10%.

In these calculations, the emissions related to arable land used for feed production were attributed to the livestock sector. Given that around 50% of arable land in Europe is used for feed production, this is a considerable amount.

Emissions related to livestock production are higher than National Inventory Reports show

For various reasons, our calculated amount of 616 Mt CO_2 eq in emissions that can be attributed to the agriculture sector is higher than the amount of 462 Mt CO_2 eq reported by the EEA (EEA 2009a). The EEA bases its figures on the National Inventory Reports, as supplied by the Member States. There is a category titled 'agriculture' in these reports, but a number of emissions directly related to agriculture fall under other emission categories. These other categories have been included in our calculations. They concern, among other things, emissions related to the production of artificial nitrogen fertiliser (73 Mt CO_2 eq for the entire agricultural sector), emissions from liming and the decay of organic materials in soils and peat (51 Mt CO_2 eq), and from the use of fossil fuels in agricultural machinery and electricity (46 Mt CO_2 eq).

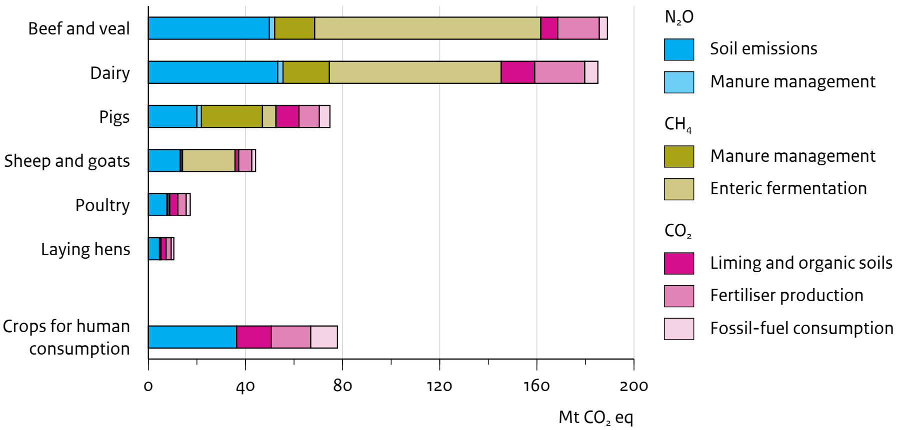
Emissions related to soybean production in Brazil and Argentina are difficult to quantify

Direct emissions of nitrous oxide related to the cultivation of soy beans in South America for use in the EU, have also been included. These account for around 4 Mt CO_2 eq per year (Lesschen et al. 2011). The emissions caused by deforestation in Brazil and the conversion of pasture and scrubland in Argentina have not been included in this figure, because it is difficult to attribute these to the cultivation of soy. Deforestation mainly occurs because of logging and extensive livestock farming. However, there is also a relationship with the cultivation of soy beans and other crops, since the conversion of grassland into arable land may cause the extensive livestock production to expand into forested areas. The FAO proposes that the emissions due to deforestation be attributed to soy cultivation. If we were to adopt the FAO method, this would amount to an annual emission of 134 Mt CO_2 eq (FAO 2010). According to that study, the attributed emissions would be 0.9 kg CO_2 eq per kg soybean cake from Argentina and 7.7 from Brazil.

Transport and processing emissions relatively minor sources

A number of emission sources were not included because information on them was difficult to quantify. This refers to the emissions resulting from the transport of inputs (e.g. feed) and products, and the emissions from the processing of agricultural products. Various life-cycle assessment (LCA) studies, however, show that these sources are relatively minor (see chapter 7). It must be stressed that greenhouse gas emissions from agriculture and land-use change are difficult to quantify. National and European estimates are inferred from activity data and emission factors, and are inherently uncertain.

Figure 5.5
Greenhouse gas emissions per sector in EU27, 2005



Source: Based on Miterra-Europe calculations
The sectors with the largest share in the emission of greenhouse gases are those of dairy cows and beef cattle.

Greenhouse gas emission levels from agriculture have dropped significantly since 1990
In the 1990-2007 period, greenhouse gas emissions from the agricultural sector dropped by 11% in the EU15. For the EU27, emissions from agriculture dropped by more than 20% during this period (EEA 2009a). The main reasons for these decreases are the shrinking stocks of farm animals (e.g. due to milk quotas and reductions in livestock numbers in central Europe) and a reduction in the use of nitrogen fertiliser. This has resulted in a decrease in emissions of methane and nitrous oxide. The Nitrates Directive in combination with a growing awareness among farmers about fertiliser efficiency have led to a reduction in the use of artificial fertiliser. Emissions have stabilised in recent years.

Beef and dairy production account for 70% of greenhouse gas emissions from the EU livestock sector
In a break down into sectors, most greenhouse gas emissions in the EU come from beef and dairy farming (figure 5.5). Together, these two sectors account for more than 70% of the greenhouse gas emissions from livestock farming. How the emissions are divided between beef and dairy is difficult to determine because around 60% of EU beef production comes from dairy cattle. For this study, the emissions related to the 'production' of calves and heifers were attributed to beef livestock, whereas the emissions from dairy cows were attributed entirely to dairy farming.

Pig farming contributes more than 13% to the greenhouse gas emissions from livestock farming, and poultry about 4%. The contribution from poultry is small compared to its approximately 25% share in EU meat production. This may be explained by the low digestion emissions from poultry and a better feed conversion, compared to ruminants.

The amount of carbon in European soils is estimated at around 275 Gt CO_2, which is around fifty times the annual amount in EU greenhouse gas emissions (Schils et al. 2008). Around 50% of the total carbon stock is located in three countries – Sweden, Finland and the United Kingdom – because of their extensive peatland areas. Around 20% of the carbon stock is located in peatlands in other countries, mostly in the northern parts of Europe. Only a small part of these peatlands are being used for agriculture. Approximately 100 Mt CO_2 eq are emitted, annually, from the cultivation and drainage of peatlands (Schils et al. 2008). Agricultural land can also permanently sequester carbon, as in the case of natural and managed grasslands (Leip et al. 2010). Given the vast quantities of carbon stored in European soils and the limited potential of soils to fix additional carbon, priority should be given to preventing soil carbon loss by limiting the conversion of grassland and peatland and by minimising the drainage of peatlands.

5.4.3 Technical options, co-benefits and trade-offs

With a share of 10%, the livestock sector is one the major contributing economic sectors to European greenhouse gas emissions. Although possibilities certainly exist to reduce greenhouse gas emissions from the livestock sector, it has to be noted that a livestock sector with zero emissions is not realistic. Agriculture depends on many open, natural processes that will always result in emissions.

How could greenhouse gases from livestock farming be reduced? In the framework of this report only a very brief and broad overview of the options can be presented, based on the extensive literature that is available. A number of options exist for reducing greenhouse gas emissions from livestock production:

- Methane emissions from enteric fermentation may be reduced in different ways, for example, by modifying feed composition (shift to easier digestible products such as cereals instead of grass), feed additives, and animal breeding (e.g. see Beauchemin et al. 2008). One risk of shifting towards more cereals is that it might lead to land conversion (Garnett 2009).
- Methane emissions from manure may be reduced by optimised storage or by anaerobic digestion.
- Measures, such as improved management of mineral fertilisers and manure (timing, quantities, application methods), to reduce N_2O emissions may even have net benefits for farmers (MacLeod et al. 2010). There are also co-benefits with nutrient management policies.
- Carbon could be preserved within soils by preventing the conversion of grassland into arable land (Schils et al. 2008).

Although there are certainly perspectives and techniques available to reduce methane emissions in a cost-effective way to a certain extent, abatement costs readily increase after the cheapest measures have been taken (Van Vuuren et al. 2006). Reductions in methane emissions of the order of 10% to 20% appear to be possible at costs that are comparable to those in other sectors, but actual possibilities will vary regionally and even be farm specific. Farmers, to date, have received no incentives to reduce methane emissions, and most measures have few co-benefits for the farmer.

5.5 Biodiversity

Livestock farming impacts local and global biodiversity in various ways (see also FAO 2006). The most significant are:

- Land use: livestock farming requires a lot of land, in the form of grassland or arable land. As a result of human interventions, the original vegetation and associated fauna disappear or change. In some cases, human intervention in the form of low-input extensive management has led to more diversity (High Nature Value farmlands).
- Emissions of nutrients (nitrogen and phosphate) to groundwater and surface waters, affecting aquatic and marine biodiversity.
- Emissions of nitrogen to air (mainly in the form of ammonia) and consequent deposition, affecting terrestrial biodiversity.
- Loss of genetic diversity of farm animals, especially in highly industrialised systems.
- Water consumption by animals, irrigation of crops and changes in hydrology, such as draining of land.
- The use of and emissions from medicines, pesticides (including de-worming drugs and anti-tick treatments) and hormones, or their residues.
- The spread of exotic grasses introduced for livestock farming, which may displace natural grass vegetation (e.g. wetlands and riparian areas), and which may inhibit the restoration of disturbed ecosystems.
- Built structures and infrastructure in rural areas, causing the fragmentation of habitats.

Given the complex relationship between biodiversity and livestock production, this subsection focuses on the effect of land-use changes due to livestock production. Section 5.3 already briefly discusses the effect of nutrient emissions.

5.5.1 Policy objectives and instruments

The EU Environment Council, in March 2010, agreed on a biodiversity target for 2020 'of halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss'. This target was endorsed by the European Council during its spring meeting of 2010.

Two EU directives form the core of the EU biodiversity policy: the Habitats Directive (92/43/EEC) and the Birds Directive (2009/147/EC). Other environmental legislation, such as the Water Framework Directive, support these directives. The Habitats Directive is built around two pillars: the Natura 2000 network of protected sites and the strict system of species protection. For protected species and habitats, Member States have the obligation to maintain or restore at a favourable conservation status. Natura 2000 is an EU-wide network of nature protection areas established under the Habitats Directive. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats. Agro-ecosystems cover 38% of the surface of Natura 2000 (EEA 2010a).

Regarding agriculture, the EU co-finances agro-environment schemes that stimulate farmers to provide environmental services that go beyond following good agricultural practice and basic legal standards. Examples of such schemes are the environmentally favourable extensification of farming, the management of low-intensity pasture systems, the preservation of landscape elements, such as hedgerows, ditches and woods, and the conservation of high-value habitats and their associated biodiversity.

5.5.2 Status and developments

Continued loss of biodiversity, notably in agro-ecosystems
Despite many policy efforts, biodiversity loss continues in many parts of Europe, although particular policy measures have certainly had a positive impact (EEA 2010b). In agricultural ecosystems, in particular, many species have an unfavourable conservation status. For example, the European Union's common farmland birds declined by 20% to 25%, between 1990 and 2007, whereas common bird populations decreased by about 10% during the same period. The EEA concludes that the Common Agricultural Policy (CAP) is not changing enough to reduce biodiversity loss (EEA 2009b). Nearly 30 species in the Habitats Directive and nearly 40 species in the Birds Directive are linked to agro-ecosystems.

Agricultural intensification and land abandonment are two of the main pressures on biodiversity linked to agro-ecosystems in Europe (EEA 2010b). Decreasing crop diversity, the simplification of cropping methods, the use of fertilisers and pesticides and the homogenisation of landscapes all have negative effects on biodiversity in agricultural areas (Le Roux et al. 2008). A total of 76% of habitat types associated with agriculture had an unfavourable conservation status over the 2001-2006 reporting period, compared with 60% for non-agricultural habitats (EC 2009).

Effect of EU livestock production on EU biodiversity significant, but difficult to determine
It is hard to single out the effect of livestock production on biodiversity in agricultural ecosystems, compared to that of other agricultural sectors. Moreover, the effect of livestock production on biodiversity might be positive or negative, depending on

High Nature Value farmlands

According to the different sources, the share of High Nature Value farmlands in the EU varies between 32% and 43% of agricultural land (Paracchini et al. 2008). The term High Nature Value (HNV) farmland has been introduced to characterise low-input farming systems with high biodiversity. HNV farmland areas are typically extensively grazed uplands, alpine meadows and pastures, steppes in eastern and southern Europe and dehesas and montados in Spain and Portugal (Paracchini et al. 2008). While intensification generally has taken place in areas with favourable conditions for agriculture, these more marginal areas continue to be managed more extensively. HNV farms manage about 30% of the total grassland area in the EU15 (EEA 2009b), where sheep and goats are the main type of livestock. Only about 2% of milk production in the EU15 takes place on HNV farms. Large areas of HNV farmland are found in Spain, France, Italy, Poland, Romania and Germany. In addition, Slovenia, Austria and Greece rate very high in terms of the proportion of HNV to total agricultural area.

Land abandonment is a risk in HNV farming. As mowing or grazing of semi-natural grassland is usually quite labour intensive, there is a risk that semi-natural grassland will no longer be managed and the farming aspect will disappear. Abandonment may affect biodiversity if livestock is not replaced by free roaming wild (or semi-wild) ruminants (Laiolo et al. 2004). If pastures turn into forested ecosystems, biodiversity change will occur, though not necessarily with negative effects on biodiversity. Intensification is another risk, for example, through the use of artificial fertiliser and the sowing of highly productive strains of grass. This will lead to changes in botanical composition, and thus in the total biodiversity of grassland.

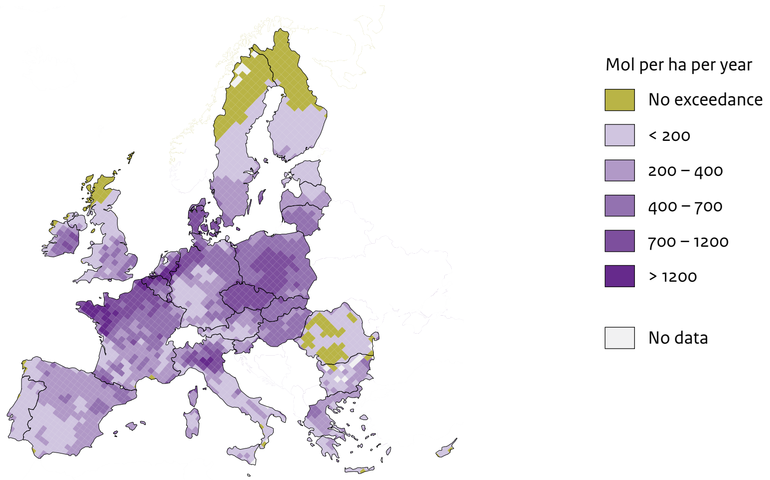
the management and the local situation. In regions with extensive grazing systems, livestock has a positive effect in maintaining species-rich grasslands and meadows, as is further described below. In areas with intensive arable production, the feed demand is one of the driving forces for intensification. Given the fact that the area used for livestock production makes up about two thirds of the total agricultural area (section 5.2), it is clear that livestock production has a large effect on EU biodiversity.

Livestock is a major source of ammonia emissions, affecting terrestrial biodiversity

Livestock is responsible for 85% to 90% of the ammonia emissions in Europe (EEA 2007, 2010c). Ammonia emissions and subsequent deposition contribute to both acid deposition and eutrophication. Ammonia emissions in the EU27 were reduced by 24% in the period from 1990 to 2008 (EEA 2010d). This has been due partly to specific measures taken to reduce ammonia emissions and partly to a general reduction in nitrogen fertiliser use.

Impacts of acid deposition include adverse effects on freshwater ecosystems and damage to forests, crops and other vegetation. Eutrophication may lead to changes in

Figure 5.6
Exceedance of critical loads of nitrogen in EU27, 2010



Source: Hettelingh et al. (2007, 2008)

In many areas of Europe nitrogen deposition is higher than the critical load, meaning that the biodiversity of terrestrial ecosystems is negatively affected.

species composition and dominance, and toxicity effects. Ammonia is not the only component responsible; NO_x emissions have similar effects on acidification and eutrophication. In many regions, nitrogen depositions exceed the critical load, implying that there would be a negative impact on biodiversity (Hettelingh et al. 2007, 2008) (figure 5.6). Ammonia emissions may also have adverse impacts on human health, as they contribute to the formation of secondary particulate aerosols (EEA 2010c).

Nitrogen also main driver of eutrophication in coastal waters

Eutrophication in coastal waters is defined as an overload of nutrients (notably nitrogen), causing accelerated growth of planktonic algae and higher plant forms. It may lead to toxic algal blooms, oxygen depletion (anoxia), fish kills and shifts in the structure of the food web. In north-western Europe and the Danube river catchment area, diffuse pollution from agricultural sources contributes 50% to 80% to the total nitrogen load (EEA 2007). Industry and households (through sewage) are other sources, but emissions from these point sources have been reduced, among other things through improved sewage treatment. Eutrophication in coastal areas is a major problem in the eastern and south-eastern parts of the Baltic Sea, and in parts of the North Sea, the Mediterranean Sea, and the Black Sea (EEA 2007).

5.5.3 Technical options, trade-offs and co-benefits

Creating an ecological infrastructure in intensive areas and maintaining extensive farming systems

Several options exist for enhancing local biodiversity in agricultural areas (Bradbury & Kirby 2006; EEA 2009b, 2010e; MacDonald et al. 2000). These can be roughly divided into three groups, two of which apply mainly to intensively used agricultural areas:

- The first group aims to conserve, restore or create elements, such as hedgerows, small ponds, buffer strips and other habitats. Together, these elements may create an 'ecological infrastructure' which provides a habitat mosaic for species (EEA 2010e). These elements, in many cases, also promote other ecosystem services, such as climate and water regulation and cultural services.
- The second group of options aims to reduce agricultural intensity, for example, by using less fertilisers or pesticides, or by growing other crops, generally leading to lower yields. The main trade-off concerning lower yields is that more land will be needed elsewhere in the world, with potential negative consequences for local biodiversity. Farmers will generally require payment in order to deliver public goods that go beyond good agricultural practice and basic legal standards.
- The third group contains options for conserving biodiversity values of the High Nature Value farmlands and other areas with extensive farming systems with significant biodiversity value. In these areas the continuation (and sometimes restoration) of the present management systems is crucial. Given the risk of abandonment, payments and other interventions would be needed to stimulate sustained management. Paying land managers to continue farming and to maintain and restore landscape elements will also enable more people to work in rural areas, since this will provide additional income.

There is a trade-off between the local extensification and the promotion of local biodiversity on one hand, and the aim to have high crop yields in order to reduce land use and spare nature elsewhere, on the other. This is elaborated in chapters 8 and 9.

5.6 Animal welfare and animal health

There is growing public interest in the subject of animal health and welfare. Although these are not environmental issues, they are important aspects in a number of ways. Many Europeans are concerned about animal welfare. Animal health issues may have large effects, both directly on the livestock sector itself and on human health, for example, as in the case of zoonosis. There is also a link between animal welfare and environmental issues, because improvements in animal welfare often have environmental consequences.

5.6.1 Policy objectives and instruments

Since 2009, the responsibility towards animals has been included in the Treaty of Lisbon (TFEU): 'In formulating and implementing the Union's agriculture, fisheries, transport, internal market, research and technological development and space policies, the Union and the Member States shall, since animals are sentient beings, pay full regard to the welfare requirements of animals, […]'. There is also EU legislation on farm animal housing, in particular, for laying hens (Council Directive 1999/74/EC), calves (Council Directive 91/629/EEC) and pigs (Council Directive 2001/88/EC and Commission Directive 2001/93/EC), on the transport of animals and on their slaughter or killing. The use of battery cages for chickens will be banned from 2012 onwards. In organic livestock farming much stricter standards apply to animal welfare than in conventional agriculture. These standards have also been laid down in EU legislation. A general and popular set of recommendations is the 'five freedoms' framework. The current form of this is: freedom from hunger and thirst; freedom from discomfort by providing an appropriate environment including shelter and a comfortable resting area; freedom from pain, injury and disease; freedom to express normal behaviour by providing sufficient space and proper facilities; and freedom from fear and distress (FAWC 2009).

5.6.2 Status and developments

Conventional types of animal housing often lead to discomfort

Animal welfare is more difficult to measure than, for example, numbers of animals or emissions to the environment. In addition, the perception of animal welfare is partly subjective and differs significantly between individuals. According to an extensive study carried out for the Dutch Government, the conventional types of animal housing often cause discomfort (Leenstra et al. 2007). The problems for many animals include air quality in stables, smooth and often wet floors, the lack of stimulus offered by the environment, the concentrated feed (leading to boredom) and disease. Some animals are also routinely subject to interventions, such as beak cutting, tail docking, tooth clipping and castration. Problems have arisen in the broiler chicken sector, in particular, because of the strong emphasis on growth rate and feed conversion (SCAHAW 2000). This has led to a situation where some animals ultimately cannot walk properly or even die prematurely.

Progress has been made, for example, in more group housing and the forthcoming battery cage ban

Animal welfare has improved in certain areas over the last twenty or thirty years, partly as a result of EU legislation. Improvements include group housing for dairy cattle, sows and veal calves, as well as the introduction or reintroduction of free-range systems for laying hens. There are also farmers managing organic production systems, or systems with improved animal welfare, such as free-range for laying hens. The products of these farms are usually labelled and sold at higher prices, to compensate for the higher production costs.

Table 5.2
Main characteristics of three husbandry systems for laying hens, broiler chickens and pigs

	Conventional	Improved system	Organic
Laying hens	Cage system	Non-cage system (no outdoor access)	Free-range with outdoor access
Broiler chickens	Rapid growing (42 days) No outdoor access 19-21 chickens per m^2	Slower growing (56 days) (Limited) outdoor access 14 chickens per m^2	Slower growing (81 days) 10 chickens per m^2 Outdoors: 4 m^2 per chicken
Pigs	0.7-0.8 m^2 per pig	1.0 m^2 per pig	1.3 m^2 per pig Outdoor access

Source: Based on www.voedingscentrum.nl

5.6.3 Technical options, trade-offs and co-benefits

The animal welfare of farm animals may be improved in a number of ways. One way is to adapt their housing to give animals more space, sheds with daylight and possibly outdoor access (table 5.2). Specific management measures may also be implemented, such as providing environmental enrichment, feed which keeps the animals occupied for longer, and measures on litter. In the broiler chicken sector, the introduction of more robust, slow-growing breeds could offer a solution to problems resulting from rapid growth rates.
One problem in switching to better management systems is that most measures cost money and, in many cases, only a limited number of consumers are willing to pay more. The additional costs are generally due to a greater demand for feed, increased housing costs and the extra labour requirement.

More feed needed in husbandry systems with improved animal welfare
Housing systems that provide farm animals with more freedom and space, lead to higher feed consumption and sometimes greater greenhouse gas and nutrient emissions (table 5.3). This is a minor issue, as long as the number of improved systems remains limited, for if all EU livestock farmers were to switch to improved systems, this would have a significant effect on the feed area required. The reduced use of antibiotics and the discontinued use of growth promoters, copper and zinc would also generally result in less efficient feed conversion and therefore a higher land use per kilogram of meat or eggs. Although this would be no reason for not switching to systems that provide better animal welfare, these trade-offs do need to be taken into account.

A general direction might be the development of robust livestock farming. According to Van der Veen et al. (2009) robustness involves two aspects: resistance and flexibility. They state that a strategy towards robustness would involve, among other things,

Animal health

The use of growth promoters and antibiotics is particularly relevant for the subject of this report. Antibiotic growth promoters have been banned in the EU since 2006 (EC 2007), after which time the curative use of drugs has increased. One of the main areas of concern is the development of resistant bacteria strains, such as Methicillin-resistant Staphylococcus aureus (MRSA) and Extended-Spectrum Beta-Lactamases (ESBLs). Humans infected with these resistant bacteria may develop severe health problems.

Various EU Member States have faced serious problems over the last 10 to 15 years due to outbreaks of animal diseases, such as BSE, foot and mouth disease, classic swine fever and avian influenza (bird flu). The concerns related to animal health stem from the public health and food safety aspects of animal health, as well as the economic cost of animal disease outbreaks.

Table 5.3
Feed conversion for laying hens, broilers and pigs, in different housing systems

Type of animal	Unit	Conventional	Improved system	Organic
Laying hens	kg feed per kg eggs	2.02	2.23	2.44
Broilers	kg feed per kg meat	1.75	2.20	2.63
Pigs	kg feed per kg carcass	3.55	3.97	4.31

Source: Oenema et al. (2010)

diversity, heterogeneity and redundancy, whereas systems aiming at an optimised performance have efficiency, homogeneity and enlarging the scale of production as their characteristics. The latter systems are more vulnerable to perturbations. Robustness of production animals can be improved by selective breeding (Star et al. 2008).

What are the consequences of improved animal husbandry systems for feed conversion? There is, as yet, little published research that compares feed requirements of alternative animal housing systems with those of conventional systems. Oenema et al. (2010) gathered some information based on practical experiences (table 5.3). For laying hens and pigs, improved husbandry systems lead to an increase in feed use of approximately 10%, whereas organic production leads to an increase of about 20%. The figures are much higher for broiler systems (25% (improved) to 50% (organic)), due to the longer lifespan of the broilers in these systems.

In addition to the higher feed requirement, higher labour input per unit of product on organic livestock farms or farms with improved animal welfare, is one of the factors that result in higher production costs. In terms of employment, however, this might be seen as an advantage, leading to better perspectives for smaller farms and more jobs in general, in rural areas.

5.7 Summary

This chapter has provided a brief overview of the environmental aspects of the European livestock sector. The main issues are:

- Around 70% of the agricultural area in Europe is being used for livestock production, with consequential effects on biodiversity, water use and the use of other resources. Around 12 million hectares outside Europe are also being used for the production of protein-rich products (e.g. soy beans), mainly in Brazil and Argentina. This equals around 10% of the European crop area.
- Biodiversity is under stress and the abundance of many species is declining in intensively managed agricultural areas within the EU. Extensive grazing systems play an important role in maintaining the present condition of the High Nature Value farmland of the EU, but due to the difficult production conditions these areas are at risk of abandonment.
- The nitrogen efficiency (output-input ratio) of European agriculture is only 19%. A large part of the losses stem from livestock production. Nitrogen emissions are high in several EU regions, leading to negative effects on biodiversity as a result of the deposition of ammonia or eutrophication of fresh waters and coastal waters. Agriculture is responsible for 50% to 80% of the total nitrogen load in many watersheds.
- Livestock production (including feed production) is currently responsible for 10% of the total EU greenhouse gas emissions .
- The production of soy beans in South America for feed has negative effects on local biodiversity and probably contributes to deforestation through displacement effects (chapter 4).
- Housing conditions of notably pigs and poultry in conventional types of stables cause these animals a number of discomforts.

Objectives have been set at EU level for most environmental issues, including biodiversity (halting biodiversity loss and degradation of ecosystems by 2020), the reduction in greenhouse gases (a 20% reduction by 2020) and the improvement of water quality (relevant for nitrogen emissions). Livestock production plays a pivotal role (in case of biodiversity and nitrogen) or is at least significant (greenhouse gas emissions) in most of these environmental issues. A range of technical options exist for reducing emissions and other negative impacts, and progress has been made in many cases over the last 20 years, resulting in a significant reduction in nitrogen and greenhouse gas emissions.

Many of these options for reducing nitrogen and greenhouse gas emissions, the impact on biodiversity and the feed area needed, and for improving animal welfare, are interlinked. Sometimes there are co-benefits (e.g. between reductions in nitrogen and greenhouse gas emissions); in other cases there are trade-offs (e.g. between animal welfare and feed area and emissions). One of the major obstacles to making improvements is that these options are costly. Given the small margins for livestock producers (chapter 4), this often prohibits progress

Fisheries and aquaculture and environmental impacts

6.1 Introduction

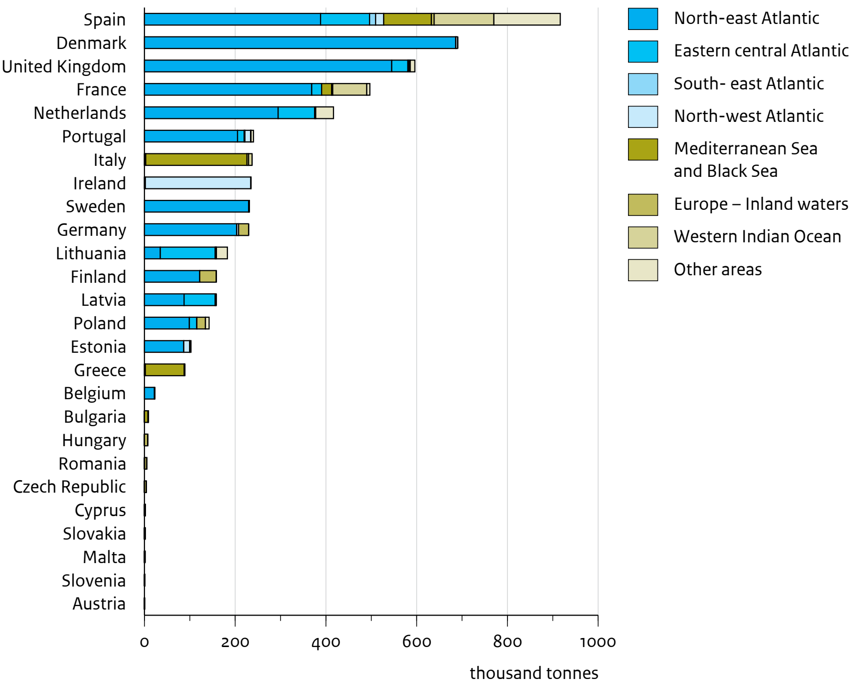
Fisheries and aquaculture supply the world's human population with fish. Most wild-caught fish goes to consumers, however, part of the catch is processed into fishmeal and fish oil, mainly used in fish feed in aquaculture and in livestock feed. Depending on the fish species, fish feed may also be partially or entirely based on plant products. The fish consumed in Europe is not only supplied by European fisheries and European aquaculture, but is also imported from elsewhere (from both capture fisheries and aquaculture).

Section 6.2 describes the European (especially EU27) fisheries sector; section 6.3 the aquaculture sector, and section 6.4 gives an overview of the European fish supply, including external trade. The subsequent two sections focus on the environmental aspects of fisheries (section 6.5) and aquaculture, including fish feed production (section 6.6). Sections 6.7 and 6.8 describe policy-driven and sector-based developments that enhance the sustainability of fish production. Finally, the main conclusions from this chapter are summarised in section 6.9.

6.2 Fishery developments in Europe

Spain is main fishery country in the EU27, but for Europe as a whole this is Norway
In 2008, EU27 fish landings made up 6% of the world's total (EC 2009a) . The fisheries sector of the EU27 is the third largest in the world, following China and Peru, in terms of the amount of fish landed. The biggest fishery countries in the EU are Spain, Denmark,

Figure 6.1
Fish and shellfish catches in EU27, 2008



Source: Eurostat

Spain, Denmark, the United Kingdom, France and the Netherlands are the countries with the largest catches.

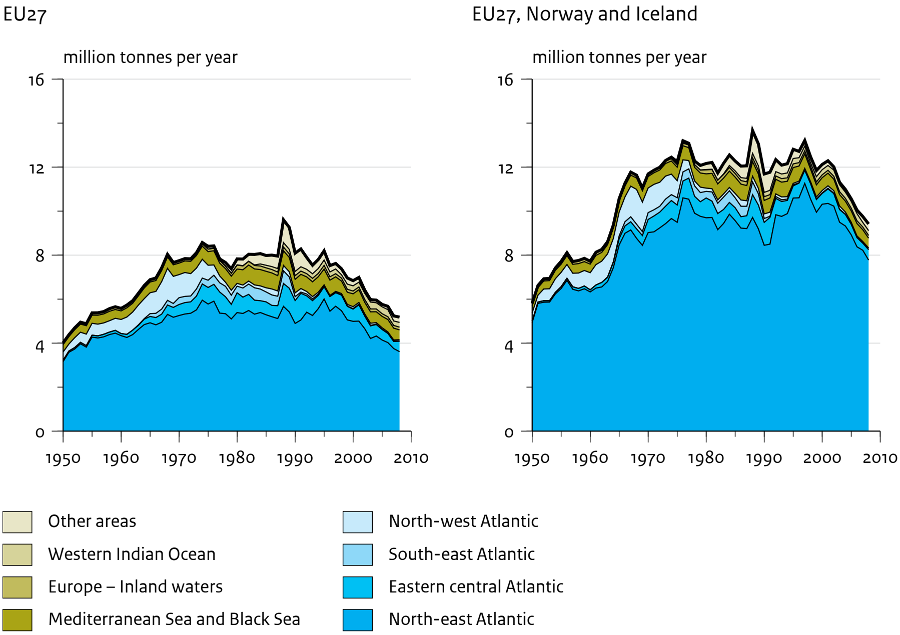
France and the United Kingdom, which together catch more than half the EU27 total (figure 6.1). The biggest fishery countries in Europe, however, are not part of the EU. These are Norway and Iceland, with catches in the same year (2008) of 2.4 and 1.4 million tonnes, respectively. Although Spain is the main fishery country in the EU27, its catches are not even half those of Norway.

Catches declined since the late 1990s

EU27 fish landings between 1950 and 1967 doubled to around 8 million tonnes per year. Subsequently, they remained fairly stable for a long time before declining again, starting in the late 1990s to about 5 million tonnes in 2008 (FAO 2009a) (figure 6.2, left). A similar picture applies to European landings including those of Norway and Iceland; these doubled between 1950 and 1975, also remained fairly stable up to 1990, and then showed a gradual decline to around 9.5 million tonnes in 2008 (FAO 2009a) (figure 6.2, right).

Figure 6.2

Catches by European countries



Source: FAO-FISHSTAT

After peaking in around 1990, catches by European countries declined rapidly, despite the trend of fishing further away, for example, in the Indian Ocean.

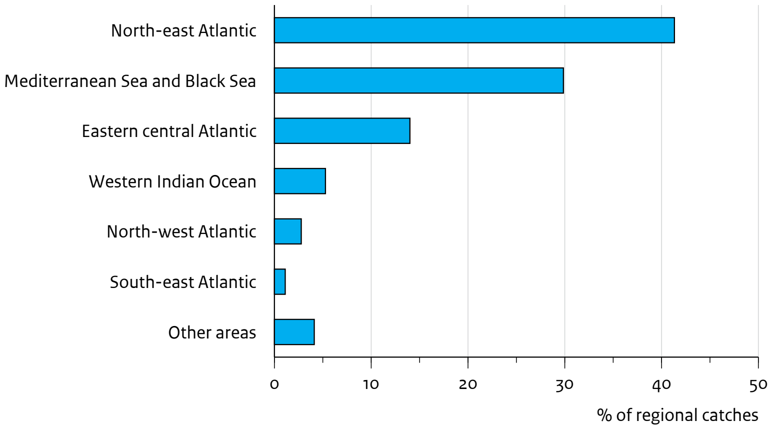
Catch declined in most important fish region

The EU27 catch from the north-east Atlantic Ocean – the most important region – has declined by about a third since the early 1990s. Catches from other regions, often much further away, have only been able to compensate this decline to a certain extent or temporarily (figure 6.2). The decline in landings in the past 15 years can be attributed to a combination of declining stocks and EU policy. While the overall picture might seem quite stable, fluctuations in individual stocks have been large. For example, in the North Sea, herring was endangered by overfishing in the 1970s but has since recovered, whereas cod was very abundant in the 1970s, but numbers have decreased by 90% since.

Seventy per cent of European catches are from the north-east Atlantic Ocean

Most fish landed by the EU27 (70%) originates from the north-east Atlantic Ocean. Other important fishing areas are the Mediterranean Sea and the Black Sea, and the eastern central Atlantic Ocean (figure 6.2; see figure 6.8 for the FAO regions). Smaller

Figure 6.3
Share EU27 in regional catches, 2008



Source: FAO-FISHSTAT

EU catches are an important part of regional catches, both in the north-east Atlantic Ocean and in other regions.

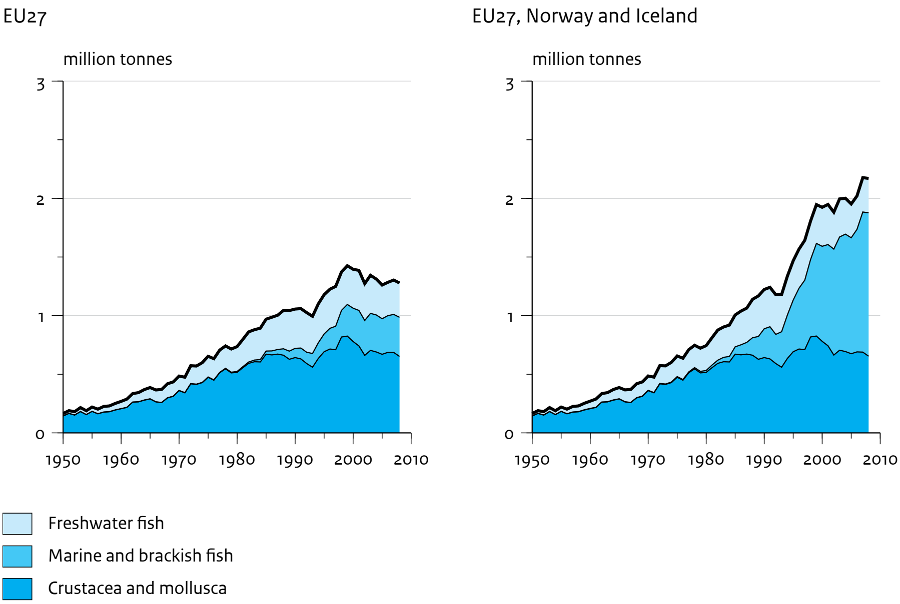
proportions of the EU fish landings come from the western Indian Ocean, European inland waters and other regions, including the Pacific Ocean.

EU fisheries are the leading players in the north-east Atlantic Ocean, the Mediterranean Sea and in the Black Sea (figure 6.3). Furthermore, in the eastern central Atlantic Ocean, the EU share amounts to 15%.

In terms of fish species, those mostly caught by the EU fleet are Atlantic herring (13% of catches), sprat (10%), blue whiting (7%), Atlantic mackerel (6%), European pilchard (5%), sand eel (4%), Atlantic horse mackerel (3%), Atlantic cod, yellowfin tuna, Cunene horse mackerel and anchovy (each 2%) (EC 2010).

Number of fishing boats decreased by 20% between 1995 and 2008
The size of the European fishing fleet has shown a downward trend over the last 20 years. The number of fishing boats in the EU15 declined by 20% between 1995 and 2008, gross tonnage by 10% and engine power by about 15% (EC 2009a, 2010). The same trend holds for those countries that have since acceded to the EU. In 2008, the number of fishing boats in the EU27 was almost 87 000, with a combined tonnage of 1.9 million Gt and an engine power of 6.9 GW (EC 2009a, 2010). Approximately 20% of EU fishing boats are over 12 metres long; the highest percentage of all continents (FAO 2009b). While the number of fishing boats may have decreased, this does not automatically mean that fish catches have decreased, as well. Technical measures, such as fish sonar and the use of

Figure 6.4
Aquacultural production



Source: FAO-FISHSTAT

Aquaculture in Europe as a whole is still increasing, though in the EU27 it has stagnated over recent years.

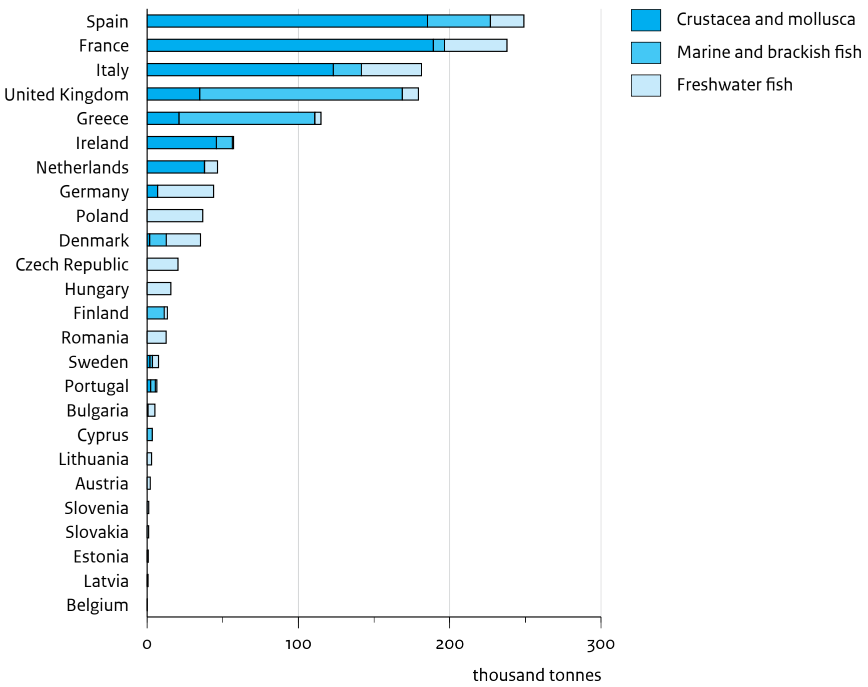
wider nets (e.g. in otter trawl fishery), have partly counteracted the effect of decreasing fleets.

Economic importance of the EU fisheries sector is overall modest but locally significant

The economic importance of the fisheries sector is modest. Turnover is about 6 billion euros (compared to 3.5 billion euros for the aquaculture sector and over 22 billion euros for the processing sector) (EC 2008, 2010). Some 140 000 people are employed in EU fisheries (EC 2010), in addition to 65 000 in aquaculture and 125 000 in the processing sector. The fisheries sector is struggling with poor economic returns due to declining fish stocks and rising costs. At the same time, it is facing increasing competition from alternatives, such as farmed pangasius and tilapia from Asia.

Many coastal communities in Europe are economically dependent on small-scale recreational and coastal fishing. The fisheries sector also has an important cultural heritage function in these coastal areas.

Figure 6.5
Aquacultural production in EU27, 2008



Source: Eurostat

Four countries, together, produce more than half of the aquacultural production in EU27.

6.3 Aquaculture developments in Europe

Aquaculture in the EU27 increased until 2000 but is now stagnating

Production in the EU27 countries greatly increased between 1950 and 2000, after which it stagnated (figure 6.4, left). These countries currently produce about 1.3 million tonnes of fish and shellfish from aquaculture. The biggest producers are France, Spain, Italy and the United Kingdom (over 10% each) (figure 6.5). About half of the production consists of shellfish; finfish is equally divided between marine and freshwater species. The shellfish species most produced in the EU27 are mussels, oysters and clams (together 50%), and finfish species are rainbow trout, Atlantic salmon, gilthead sea bream, common carp and European sea bass (EC 2010).

Farming of marine fish is increasing in Norway
Norway is the biggest European producer, with salmon as the main species (production 830 million kg). In 2007, European aquaculture as a whole produced about 4% of the global production, subdivided into marine fish (more than 1 000 million kg), freshwater fish (300 million kg) and shellfish (700 million kg). The volumes of shellfish and freshwater fish have dropped slightly since 2000. The marine fish volume, however, has continued to increase, mainly due to the non-EU country of Norway (figure 6.4) (FAO 2009a).

Worldwide, 40% of fish production is from aquaculture, compared with 20% in Europe
While the global increase in the production of fish is mainly due to the emergence of aquaculture (see chapter 2), this is less the case in Europe. In Europe, about 20% of fish production is from aquaculture, compared with 40% worldwide. Aquaculture production in the EU27 has stagnated over recent years, while global aquaculture production is still growing strongly (particularly in Asia). The main causes of this stagnation are the relatively high costs of labour and land. Other factors are the stricter regulations concerning location, water consumption and water pollution (Bostock et al. 2008). The EU has a relatively strong position in technically advanced (and environment friendly) recirculation systems, but faces competition, particularly from Asian countries where production costs are two to three times lower.

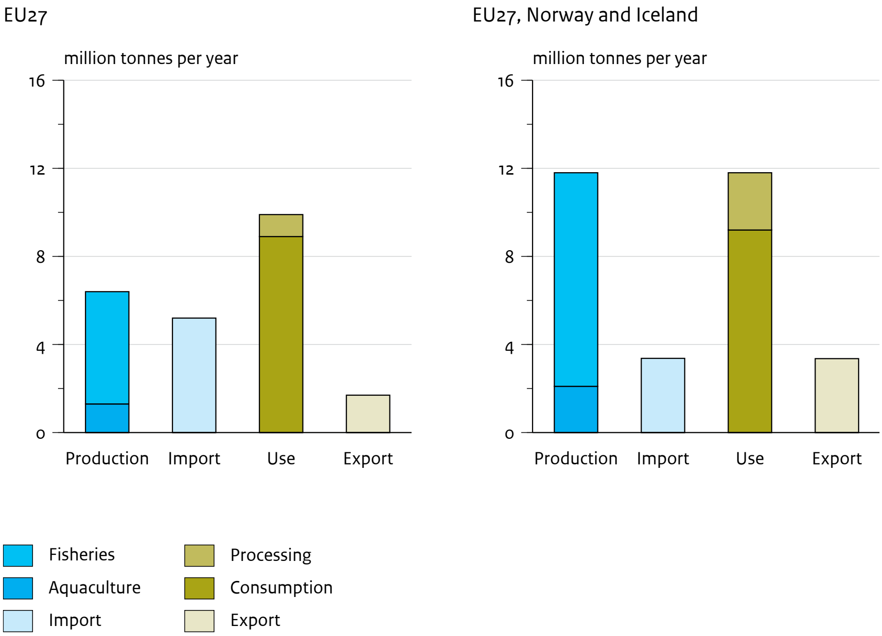
Predatory fish important for aquaculture in Europe
Although Europe as a whole produces only 4% of the global volume, this represents about 9% of the commercial value (Bostock et al. 2010; FAO 2009b). Finfish produced in Europe are mainly (>80%) predatory species (Overbeek et al. in prep.), which are the most profitable.

European cultures of seaweed (macroalgae) and microalgae is very limited, although this is a potentially promising sector. Seaweed is a protein-rich product that can be used both for human consumption and as a raw material in the production of fish feed.

6.4 Overview of European fish supply

EU27 relies heavily on import to meet fish demand
The supply of fish in the EU, added up to more than 10 million tonnes, or 22 kilograms in live weight, per capita. This was about 30% more than the global per-capita average and, today, slowly continues to increase (see chapter 3). As only about 50% of the demand in the EU27 is filled by EU production (fisheries and aquaculture), the remainder is imported (figure 6.6). Some of the imports are from other European countries, in particular, from Norway and Iceland.

Figure 6.6
Supply balance of fish, 2007



Source: PBL, based on data from EC (2008, 2010), EU Exporthelp and IFFO

The EU27 relies heavily on imports to meet the fish demand. For Europe as a whole, production roughly equals demand.

Production and consumption are more balanced, for Europe as a whole, although some of the catches are made in non-European waters, and aquaculture partly relies on imported feed.

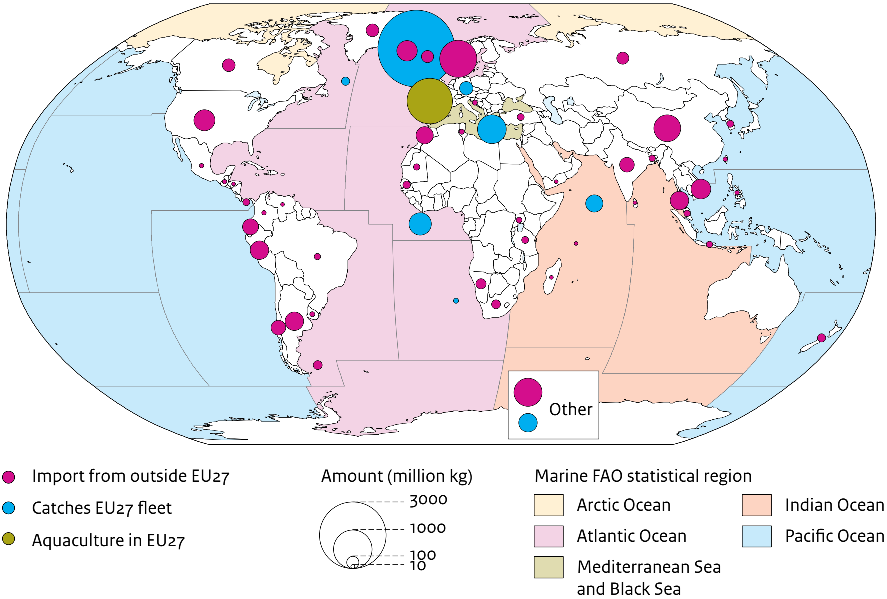
Imports from all over the world are increasing

Imports have steadily increased over the years to compensate for declining catches, while demand for fish and fish products has been rising. The EU imported 5.6 million tonnes of fish and shellfish in 2008, with a value of over 16 billion euros, from all over the world; in particular, from Norway, China, the United States, Iceland, Vietnam, Peru, Argentina and Thailand (figure 6.7) (EC 2010). EU imports have risen by a third since 1995. The fish species imported most are salmon, pangasius, tilapia and tropical shrimps.

Although the EU27 is a net importer, it also exports fish

Although the EU27 is a net importer, a considerable amount of fish is also exported – including some of the fish that was first imported. Exports amounts to about 1.7 million tonnes, adding up to almost 3 billion euros. Some exports, for instance to China, consist

Figure 6.7
Fish imports, catches and aquaculture of fish in EU27, 2007



Source: PBL analyses, based on Eurostat

Fish in the EU27 originates from all over the world. Fish and shellfish are imported mainly from Norway and Southeast Asia.

of fresh fish that will be reimported after processing. Exports from the EU27 rose slightly between 1995 and 2002, but have since more or less stabilised.

The EU27 is a net importer of fish and shellfish, but the non-EU countries Norway and Iceland are net exporters: in 2007, Norway exported 1.3 million tonnes and Iceland 0.5 million tonnes (EC 2008).

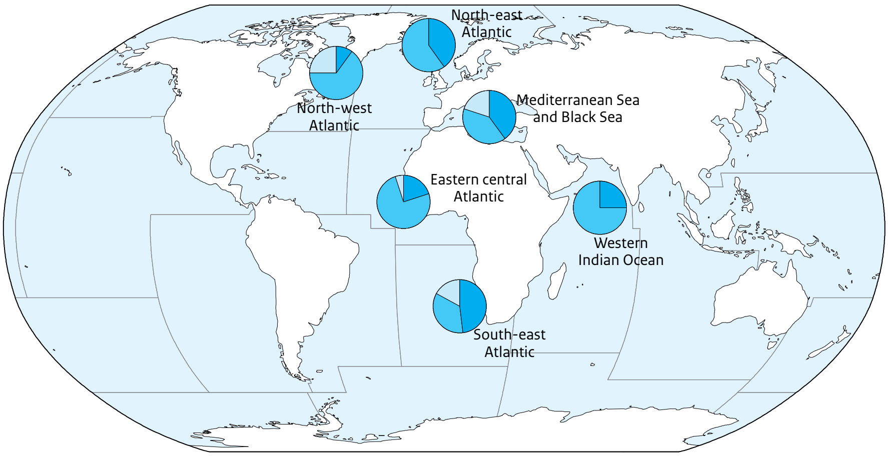
6.5 Environmental impacts of fisheries

Depletion of fish stocks

As mentioned in chapter 2, world fish stocks are rapidly declining, about 55% of the exploited fish populations are fully fished and 25% are overfished (FAO 2009b). These percentages are much higher in the marine regions where the EU fishing fleet is active, especially in the north-east Atlantic ocean, where most of the EU catches are made (figure 6.8) (IUCN 2009). Globally, 25% of fish stocks are overfished, but in European seas, as much as 88% of commercial fish stocks are overfished and 30% are

Figure 6.8

Overfishing of fish stocks in main fishing regions of European fleet, 2005



Overfished

Fully fished

Moderately fished

Source: IUCN (2009)

Especially in the north-east Atlantic, where most of the EU catches are made, more fish stocks are overexploited or fully exploited, relatively speaking, than elsewhere in the world.

even outside safe biological limits, which means that they may not be able to recover (EC 2009b). This is in line with a study by Sissenwine and Symes (2007), which indicates that 81% of fish stocks were overfished in 2006. A well-known marine species that is threatened with extinction from overfishing is the bluefin tuna. Some freshwater species are also highly under threat, such as the European eel; overfishing is one of the causes of its decline, too (De Graaf & Bierman 2010).

CO_2 emissions related to catches decreasing, but energy use per kilogram of fish is increasing

Declining fish stocks and greater distances travelled to catch these fish, globally, have led to a decrease in energy efficiency of fisheries, over the last decades (chapter 2). This also applies to European fisheries. EU27 fisheries were responsible for 0.24% of the total CO_2 emissions in the EU27 (10.5 Mt CO_2) in 2006 (Eurostat). The original EU15 countries contributed more than 90% to these emissions. CO_2 emissions from EU15 fisheries declined by almost 11% in the 1995-2006 period, as a result of reductions in fleet, engine power and fishing days. However, as catches of the EU15 decreased by nearly 30% during this period, CO_2 emissions from fuel use for propulsion of fishing boats rose from 1.6 to 2.1 kilograms per kilogram of fish, resulting in a higher energy use per kilogram of fish.

This increase, among other things, has been due to a shift in fishing practice: from coastal and deep sea fishing to trawling, and to fishing boats having to operate further away.

Much fish discarded in the North Sea

The worldwide problem of discards also applies to European fisheries. The discard rate in the north-east Atlantic Ocean is estimated at 13% of catches, higher than the world average. The highest percentage of fish is discarded in the North Sea, estimated at 20% to 30% of catches (500 000-900 000 tonnes, per year) (FAO 2005). In certain types of fisheries, by-catch volumes exceed those of targeted fish species, for example, in bottom trawling for sole in the North Sea and in certain areas and periods, when by-catches can even be as large as 90% (Catchpole et al. 2005). In practice, the present quota system actually serves to encourage by-catch discards (see chapter 2). However, a system of quota distribution that would avoid this is under discussion in Europe (see section 6.7).

Fishery also has an impact on other organisms and animals

European demersal fisheries have an impact on the seabed and bottom-dwelling organisms. Certain areas in the Dutch part of the North Sea, for instance, are disturbed by demersal fisheries several times a year, while restoration of their bottom fauna would take several years (OSPAR 2010). Another example are the low populations of non-target species in the North Sea, such as dolphins and sharks, which are often caught unintentionally in fishing nets.

6.6 Environmental impacts of aquaculture

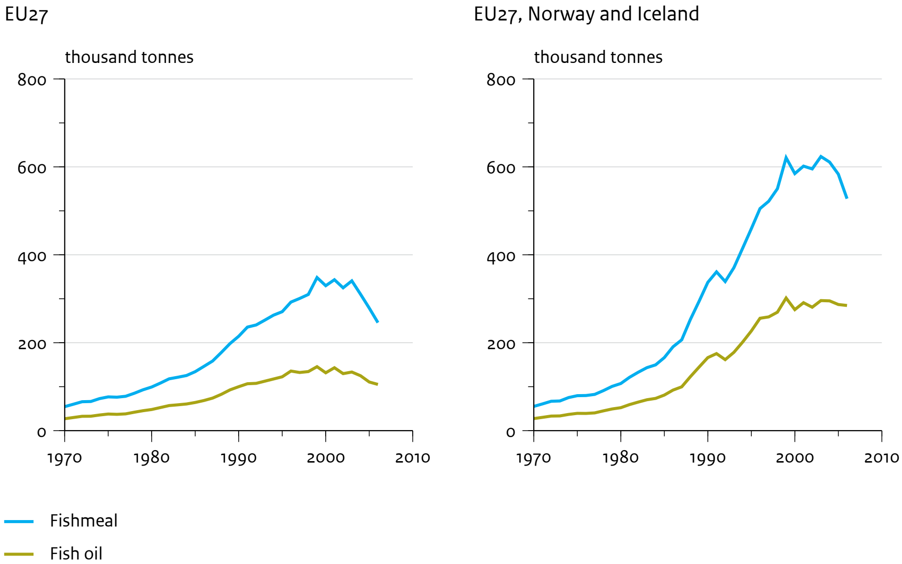
The main environmental impacts of aquaculture are presented in chapter 2. The focus in this section is on those aspects specific to the European situation.

6.6.1 Wild-caught fish used as feed for aquaculture

European aquaculture uses a relatively large amount of fishmeal and fish oil

Between 1970 and 2000, because of the growing aquaculture production (figure 6.4), the use of fishmeal and fish oil increased rapidly, also in Europe. The use of wild-caught fish for aquaculture in the EU27 rose steadily up to 2000, after which it decreased to about 2 million tonnes by 2006 (Overbeek et al. in prep.). This is more than 2% of the global catch. Feed for aquaculture in Norway and Iceland was based on 3.5 million tonnes of wild-caught fish. Since 2000, the use of fishmeal and fish oil has been declining, due to changes in feed composition for predatory fish. The fraction of fishmeal in compound feed decreased, among other things, triggered by an increase in the price of fishmeal (FAO 2009b). The higher production of aquaculture in Europe as a whole, means that the use of fishmeal and fish oil is over double that of the EU27 (figure 6.9).

Figure 6.9
Use of fish-feed components in aquaculture



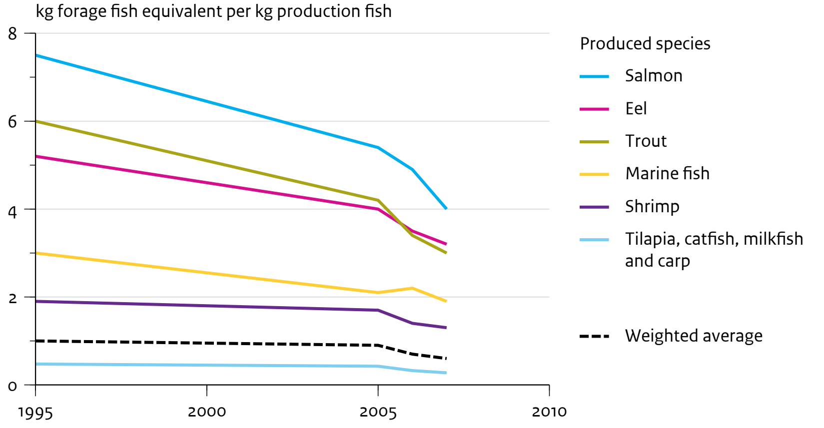
Source: PBL, based on Overbeek et al. (in prep.)
The use of fish meal and fish oil in Europe as a whole is twice that of the EU27.

European aquaculture uses a relatively large amount of fishmeal and fish oil. Although Europe is responsible for only 4% of global aquacultural production, their share of fishmeal used in aquaculture is more than 20% that of global fishmeal use, and for fish oil this is almost 40%. This is due to the high proportion of predatory fish in European aquaculture, which represents over 80% of the finfish production (Bostock et al. 2008; Overbeek et al. in prep.).

Share of fishmeal and fish oil in feed reduced

In recent years, there has been a downward trend in the percentage of fishmeal and fish oil used in compound feed. This has been achieved through more accurately measured amounts of feed and by using more fish waste or by-catch as well as more vegetable material. Between 1995 and 2007, the amount of forage fish needed per kilogram of farmed fish was considerably reduced for several predator species (figure 6.10). The amount of fishmeal in salmon feed, for example, was reduced from 60% in 1985 to 35% in 2008, and may even be but further (Halweil 2008; Tacon & Metian 2008). The global average is already well below 1.0 kilogram in forage fish per kilogram of farmed fish, because global aquaculture is dominated by herbivorous and omnivorous species, as is also stated in chapter 2.

Figure 6.10
Feed conversion in aquaculture



Source: Tacon & Metian (2008)
The amount of wild-caught fish in fish feed is gradually decreasing.

Although the use of wild-caught fish is decreasing, thus reducing the impact on marine biodiversity, concerns have been expressed over feeding fish a vegetarian diet (is it not detrimental to fish welfare?) (Bostock et al. 2010). However, the finite supply and price increases for fishmeal and fish oil mean that the demand for alternatives will increase.

6.6.2 Other impacts of aquaculture

Land use for fish feed production is relatively low
As alternatives for fishmeal mainly consist of plant material, aquaculture requires some agricultural land for the production of these components of fish feed, notably soy and wheat. Between 1970 and 2006, the size of agricultural land required for fish feed doubled to approximately 0.1 million hectares in the EU27. This was due to an increase in volumes of farmed fish, as well as the more recent increased share of plant material in the feed of predatory fish species. The share of plant material has increased, both due to the replacement of fishmeal with soy and the limited availability of waste from the food processing industry.

Land use for European aquaculture as a whole was about 0.21 million hectares in 2006. This was only 1.5% of the land used for global aquaculture (PBL 2010), while 4% of the global aquaculture production takes place in Europe. This low percentage is due to the low numbers of herbivorous and omnivorous species in European aquaculture.

Europe contributes to eutrophication, especially through open farming systems
Open farming systems, in particular, contribute to the eutrophication of surface waters, through nitrogen and phosphate emissions (chapter 2). The EU contributes to these problems through its own open farming systems, such as those for salmon, and also through the import of farmed fish from elsewhere, for example, pangasius from Vietnam. Eutrophication and other water quality problems are better managed in the closed (recirculation) systems that are also operated in Europe, especially for some freshwater species.

Impacts of import and production on coastal ecosystems
Some aquaculture in tropical countries has a major impact on mangrove forests and coral reefs (chapter 2). Part of this impact can be attributed to Europe because of its importation of tropical shrimps.

In Europe itself, there are problems of damage to coastal landscapes and associated disputes with the tourism sector in places with many fish farms, such as the Norwegian fjords and parts of the Mediterranean Sea. There are also restrictions on further aquacultural expansion because of shipping routes and harbour activities, particularly in the Mediterranean Sea. A number of European countries have included aquaculture in their spatial planning (Bostock et al. 2008).

Overall assessment of European aquaculture relatively positive
European aquaculture is also implicated in problems, such as water pollution by medicines and pesticides, spread of diseases and genetic pollution of wild fish species, as mentioned in chapter 2. Similar to those of eutrophication, these problems mainly apply to open farming systems. Fish farms in Europe must observe certain directives concerning emissions to water. The European Water Framework Directive has set high standards for aquaculture (Bostock et al. 2008).

The environmental aspects of *marine* aquaculture in 64 countries were assessed by Trujillo in 2008 (Trujillo 2008). European shellfish production scored relatively well. In the EU27, the farming of predatory species, such as salmon and sea bass, scored much lower, but generally still higher than the aquaculture in countries from which the EU imports. In another recent assessment of *marine finfish*, European fish farms also scored higher than those in Asia (GAPI 2010).

Aquaculture could be beneficial in the restoration of marine biodiversity
Aquaculture may be used for restoring natural fish stocks, if the amounts of fishmeal and fish oil that are currently being used as feed for farmed fish could be reduced. This could be achieved by replacing fishmeal and fish oil with additional vegetable ingredients, by improving the feed conversion and shifting from farming carnivorous fish to more herbivorous fish species. This development has already begun (section 6.6.1). There are also developments in alternative feed types, such as algae, and invertebrates (e.g. sandworms), or feed based on methane, but these are all still in the initial stages and

have their own barriers and adverse effects (Rood et al. 2006). An increase in the prices of fish oil and fishmeal, could be instrumental in the introduction of these alternatives, as production costs of these alternatives are currently relatively high.
Expanding the farming of herbivorous species could be an option, as only a small increase in agricultural land would be enough to produce feed for increasing amounts of herbivorous fish, so that wild fish could be protected; stocks could recover and possibly provide higher catches in the future (PBL 2010). Although aquaculture competes with agriculture for land (land use per kilogram of protein for farmed herbivorous fish is comparable to that used for poultry (chapter 7)), efficiency in aquaculture could be increased through improved technical solutions and management practices (Bostock et al. 2010).

6.7 Regulatory policy

6.7.1 Fisheries

Common Fisheries Policy with associated Financial Instrument not sufficient for solving problems
Since 1983, the main fisheries policy framework for the EU Member States has been the EU Common Fisheries Policy (CFP), which was mainly aimed at fleet reduction, the assessment of the Total Allowable Catch (TAC) of selected fish stocks, and a quota system for the distribution of TACs over countries. Species management plans were established for several fish species, such as for cod, plaice, and European eel, for which the general policy was insufficient.

Advice on the TACs is provided by the International Council for the Exploration of the Sea (ICES) – a collaboration of international marine ecology and fishery scientists – which also reports on the status of stocks and proposes measures (e.g. ICES 2010).

The European Fisheries Fund – and formerly the Financial Instrument for Fisheries Guidance (FIFG) – has effectuated the EU policy since 2007, with a budget, for example for 2007, of 430 million euros. Since 2002, when the CFP was modified, stakeholders have been more involved in its implementation. However, despite efforts to reduce the fleet overcapacity and overfishing, and despite some successes such as the restoration of herring stocks, the structural problems have not been solved adequately (Sissenwine & Symes 2007).

Common Fisheries Policy will be reformed in 2012
These problems are addressed in the European Commission Green Paper 'Reform of the Common Fisheries Policy' (EC 2009b). A reformed policy will be launched in 2012. Elements of the policy will be a 'maximum sustainable yield' (MSY), changes in the quota system, avoidance of by-catches and also an improved economic position for fisheries.

Certification (e.g. MSC) will also be encouraged, but should be initiated by the sector itself. In some countries, policies are already changing in line with the coming reform.

Maximum sustainable yield is aimed at a recovery of commercial fish stocks. Furthermore, there are indications that, after recovery, catches may even be able to increase again, once they are in line with the maximum sustainable yield (Alder et al. 2007; PBL 2010). However, it is unclear whether this principle will sufficiently reduce the full impact of fisheries on ecosystems.

In the past, the EU fisheries policy has shown to be difficult to enforce, as measures are not easy to implement and also because of counteracting processes. However, it is too early to speculate on the results of the policy reform.

Fisheries are also affected by other policies

Other policy agendas relevant to European fisheries are: the Marine Strategy Framework Directive (2008), aimed at an ecologically sound management of the European seas; the allocation of protected marine (and also freshwater) areas within the Natura 2000 policy; and the energy policy (e.g. the establishment of offshore wind parks).

EU aims to strengthen fisheries policies in other countries

The EU aims to contribute to the sustainability of fisheries in other regions, mainly by supporting the Regional Fisheries Management Organisations (RFMOs). Through partnership agreements, European fisheries have access to fish stocks in remote seas. In 2008 agreements have been made with 15 countries, mainly in western Africa and around the Indian Ocean (OECD 2010). While the main aim of these agreements is to ensure access for EU fishing boats to foreign fishing grounds, they also intend to contribute to strengthening fisheries policy in these partner countries.

6.7.2 Aquaculture

Strengthening the lagging EU aquacultural sector

In view of the growth stagnation of the EU aquaculture sector, the European Commission (EC) presented a ‘Strategy for the sustainable development of European aquaculture’ in 2002 (EC 2002). As the intended growth was not achieved, the EC published ‘A new impetus’ for this strategy in 2009, with the objective to increase the sustainable and innovative development of the sector, including aquaculture itself, research and technology, and certification standards, and a focus on high-value sectors (EC 2009c).

Until 2006, funding for this policy came from the FIFG and from national contributions, totalling about 75 million euros per year (a modest 7.3% of the total FIFG budget). Over the 2007-2013 period, the EFF (European Fisheries Fund) will spend some 150 million euros per year on the ‘axis 2’ measures, which include aquaculture, inland fisheries, processing and marketing (totalling about 28% of the total budget for fisheries and aquaculture) (Bostock et al. 2008).

Sector is facing increasing competition from tropical countries
Although the aquacultural sector stands to profit from these policy instruments, it is doubtful whether the EU will be able to withstand increasing competition from tropical countries where production costs are lower by a factor of 2 to 3. This of course also depends on future developments on the demand side.

6.8 Market-based incentives

In addition to government policy, NGOs and the private sector are also taking important initiatives to enhance the sustainability of fish production. For example, the MSC label (Marine Stewardship Council) has been developed for wild-caught fish. Initiated in 1999 by the WWF and Unilever, it is now a broad partnership, and MSC is the internationally accepted standard for 'sustainable' wild-caught fish. Criteria are those of no overfishing, limited impact on the environment and good fisheries management. The current market share of MSC fish (certified or nearly-certified) averages around 12% and is rapidly increasing (MSC 2010). The certification process has clearly led to improvements in the involved fisheries. At the same time, it is recognised that certification is not the only way to achieve sustainable fisheries worldwide.

Parallel to the MSC label for wild-caught fish, an international certification body for farmed fish (Aquaculture Stewardship Council, ASC) has recently been founded, initiated by WWF and the Dutch IDH (*Initiatief Duurzame Handel* (Sustainable Trade Initiative)), to become operational in 2011 (IDH 2009; ASC Aquaculture Stewardship Council 2010). The ASC is based on the Aquaculture Dialogue process, started in 2004 and facilitated by WWF US. These are multi-stakeholder roundtables that have already developed standards for salmon, shrimps, tilapia and pangasius, while those for other species are nearly completed. In addition to food safety and social aspects, these standards also cover a range of environmental aspects such as pollution, energy use, animal welfare and feed use.

The public acquaintance and spread of MSC and ASC products is enhanced by NGOs as well as by retailer organisations in some countries. There are also agreements between the fisheries sector, NGOs and governments to promote certification.

6.9 Summary

Global fish landings are stagnating, despite increased fishing efforts. The landings by European fisheries are declining even faster, due to a combination of declining stocks and the EU quota policy. EU fishery as a whole is the third largest in the world, although the most important European fishing country is Norway. The major fishing areas for European fisheries are the north-east Atlantic Ocean, the Mediterranean Sea and the Black See. Catches in these areas have dropped by a third since the early 1990s. European fishermen are travelling ever further and fishing ever deeper to find their catches, but this compensates only to some extent or only temporarily for the declining catches in European waters.

Marine and freshwater biodiversity are under threat and wild fish stocks are in decline. Globally, marine fish populations have declined by 24% since 1950. About 80% of the commercial fish populations are fully exploited or overexploited. In waters where the EU fishing fleet is active, the exploitation level is even higher than average.

Smaller catches and growing fish consumption are driving the demand for aquaculture. Aquacultural production in Europe has almost tripled since 1980. This has mainly been due to the Norwegian production; aquaculture in the EU27 has not even doubled, and the increase has now stagnated. Globally, however, aquaculture has increased fourteen-fold since 1970. Thus, aquacultural production in the EU27 is growing much more slowly than it is worldwide.

Since EU catches are declining and the increase in aquacultural production compensates only half of this decline, fish import into the EU27 is increasing.

A further increase in the farming of fish and shellfish could help to close the gap. Some 40% of consumed fish already consists of farmed fish. However, aquaculture also brings its own problems. The most significant of these is the use of wild-caught fish in fish feed, although the percentage of fish in the fish feed is already decreasing. However, about 20% of the global fish catch is still being used for fish feed in aquaculture.

Other main problems are the conversion of coastal ecosystems and the pollution of coastal and inland waters. Aquaculture also requires some agricultural land for the production of crops, such as soy, for fish feed. Policy should be based on the sustainable management of aquatic ecosystems on the one hand, and reduction in negative side effects of aquaculture on the other.

From a sustainability point of view, it is important to further reduce the use of fishmeal and fish oil in aquaculture. In addition to the increased efficiency and feed substitution in predatory fish cultures, a switch from predatory to herbivorous species, or the direct consumption of caught herbivorous fish, would also contribute to this, although no policy has been set in this direction. A small increase in agricultural land would be enough to produce more farmed herbivorous fish.

SEVEN

Environmental effects per unit of product

7.1 Introduction

The preceding chapters describe the environmental impacts from the livestock and fisheries sectors overall, but do not provide information on the impact per unit of product. All production steps, including feed production and processing, and distribution of food products, have an impact on the environment and together determine the impact of a product. This chapter looks at the environmental impact of each product, in particular, at land use (is also an indirect indicator for biodiversity; chapter 5) and greenhouse gas emissions (also called carbon footprint). This life-cycle or chain approach is different from the approach taken in the preceding chapters (chapters 5 and 6), which looked at the environmental impacts of the various livestock and fisheries sectors.

The life-cycle assessment approach for determining the environmental impacts of production chains is described in section 7.2. Section 7.3 describes the environmental impact expressed per weight of product.

As fish, meat and dairy produce are important sources of proteins (chapter 3) and a comparison on the basis of weight is not always fair, section 7.4 analyses the environmental impacts per kilogram of protein, and compares these with vegetable protein sources. Section 7.5 analyses the steps in the various production chains. Section 7.6 analyses the environmental impacts of the consumption of meat, fish and dairy produce, as these products are important elements of the human diet in Europe. It looks at the environmental impacts both inside and outside Europe. Intervention prospects are described in section 7.7, and section 7.8 concludes the chapter with a summary.

7.2 The Life Cycle Assessment approach

A method commonly used for analysing the environmental impacts of products and services is the environmental life-cycle assessment (LCA). This is an internationally recognised method, for which guidelines are provided by the ISO standards 14040 and 14044. Specific standards have been set for quantifying greenhouse gas emissions (BSI 2008) and LCAs can be used in identifying the steps in a production chain that cause the highest impacts. LCAs also facilitate a systematic comparison between different products or production methods.

Feed conversion dominates the variation between different products
For this chapter, a meta-study of 44 published LCA studies was carried out, enabling a comparison of the environmental impacts of various products (the studies are listed in the annex[1]). Most of these studies covered the chain from cradle to farm gate. As studies worked on various model assumptions and with different functional units, comparisons could not easily be made. Since the functional unit used for expressing the environmental impact differed between studies (e.g. carcass weight, live weight, retail meat), we recalculated this environmental impact according to kilogram of retail meat, in order to render the data from the different studies comparable. In section 7.4, the environmental impact is expressed per kilogram of protein, to enable comparison between different types of products.

The studies mostly used the default factors from the IPCC guidelines for greenhouse gas emissions (IPCC 2006). Where studies accounted for emissions related to land use and land-use change, we recalculated these to greenhouse gas emissions, excluding those from land use and land-use change. After such recalculations it was concluded that the effects of differences in methodology were minor compared to the effects of various production systems. For example, the variation in global greenhouse gas emission from milk was about 20% to 30%, due to differences in assumptions and data (FAO 2010). Feed conversion, in particular, dominated the variation between different products.

7.3 Environmental impact per weight of product

The environmental impacts of the different products were shown to vary widely (table 7.1). There appears to be a clear difference in environmental impact between animal products and vegetable products. The average carbon footprint and land use for meat, fish and dairy produce is higher than that for vegetable products. Since the environmental impact of arable land usually is higher than that of grassland, two types of land use were distinguished.

Table 7.1

Carbon footprint and land use related to protein-rich products

Product	Carbon footprint kg CO_2 eq/kg	Land use m²/kg	Of which grassland (m²/kg)
Beef and veal (16 studies, n=29)	9-129	7-420	2-420
Feedlot systems (n=4)	14-40	15-20	ca 2
Mixed systems/dairy calves (n=8)	9-42	15-29	2-26
Meadow systems, suckler herds (n=9)	23-52	33-158	25-140
Extensive pastoral systems (n=6)	12-129	286-420	250-420
Culled dairy cows (n=2)	9	7	ca 5
Pig meat (10 studies, n=13)	4-11	8-15	
Poultry (4 studies, n=5)	2-6	5-8	
Eggs (4 studies, n=5)	2-6	4-7	
Sheep meat (4 studies, n=5)	10-150	20-33	ca 18-30
Milk (9 studies, n=11)	1-2	1-2	ca 1
Cheese[1]	6-22	6-17	ca 7
Soy milk (1 study, n=1)	1	1	
Shellfish (3 studies, n=5)	1-86		
Fish (fisheries) (5 studies, n=5)	1-7		
Farmed fish (6 studies, n=10)	3-15	2-6	
Meat substitutes containing egg or milk proteins (1 study, n=2)	3-6	1-3	0-2
Meat substitutes, 100% vegetal (2 studies, n=4)	1-2	2-3	
Pulses, dry (2 studies, n=3)	1-2	3-8	

Carbon footprint and land use related to protein-rich products, per kilogram of product, from several LCA studies (cradle to retail, n = number of analysed products, for land use this number may be less).

1 *Based on milk and data from Berlin (2002). For cheese, 6 to 7 kilograms of milk are required (Blonk et al. 2008).*

2 *Only land used for vegetal feed component.*

Beef, sheep meat and trawled lobster showed by far the highest carbon footprint per unit of weight, although large differences exist within beef production. Ruminant meat from extensive production generally had the largest carbon footprint per kilogram. This is partly explained by the fact that ruminants emit methane through enteric fermentation, enabling them to digest grass. Low carbon footprints per units of weight were generally found for mussels, some other shellfish, milk, poultry and vegetable products. Land use ranged from about 1 m^2 per kilogram for milk, soy milk and some vegetable products, to over 400 m^2 per kilogram for beef from extensive production systems.

7.4 Environmental effects compared on the basis of protein content

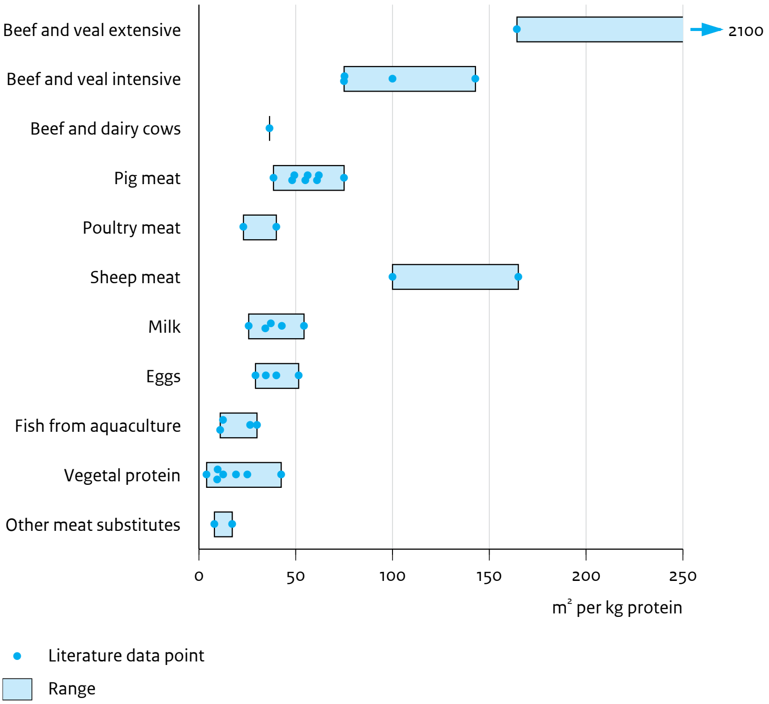
As products contain different percentages of nutrients, a comparison on the basis of weight is not always fair. For example, milk contains a lot of water, so that the environmental impact per kilogram of product is lower than that of products with a low water content, such as meats. Because animal products, among other things, are important sources of proteins in the human diet (chapter 3), a comparison based on protein content would be fairer. For this study, protein contents were obtained from the Dutch food database (NEVO 2010) (see also the annex).

7.4.1 Land use and greenhouse gases

Animal products usually have higher impact than vegetable products
Differences between products are smaller when comparing environmental pressures per kilogram of protein than when comparing on the basis of weight (figures 7.1 and 7.2). In a comparison on the basis of protein content, the environmental impact of milk is in the same range as that of poultry and pig meat. The difference between animal products and vegetal products still exists. Average greenhouse gas emissions related to meat, fish and dairy produce are about ten times higher than those of vegetable products, and the average land use related to animal products is about five times that of vegetable products. Vegetal proteins have an amino acid composition that is less digestible for humans than animal proteins (expressed in a Protein Digestibility Corrected Amino Acid Score), therefore, generally speaking, 20% more proteins are needed in a vegetarian diet, and 30% more in a fully vegan diet (Gezondheidsraad 2001). Although EU diets contain more protein than required (see chapter 3), no corrections were made for this difference in amino acid composition.

Beef usually has the highest impact and vegetal products the lowest
Greenhouse gas emissions range from about 4 kg CO_2 eq per kilogram of protein, for vegetal meat substitutes, pulses, mussels and herring, to over 600 kg CO_2 eq, for extensive grazers. The differences between products are mainly due to differences in

Figure 7.1
Land use per protein source

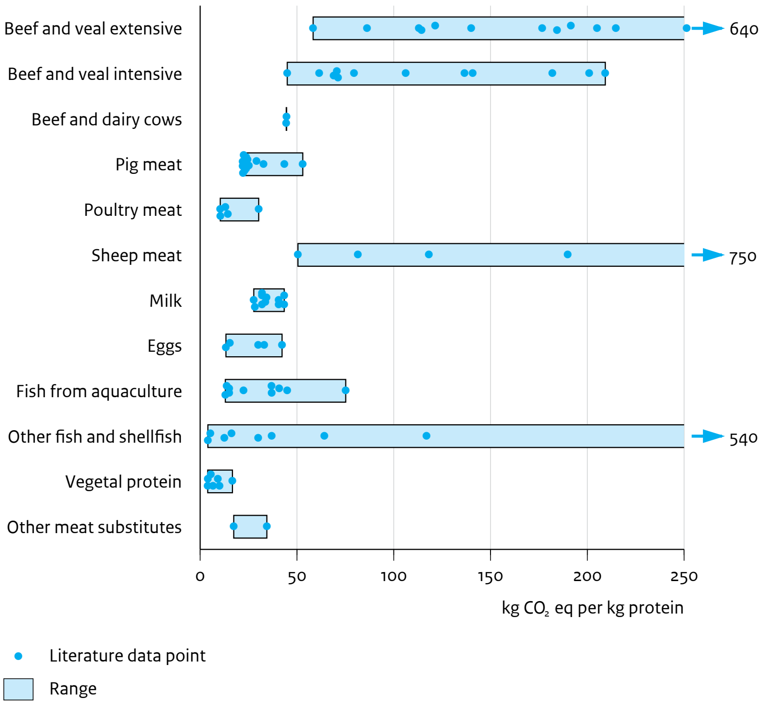


Fish from aquaculture: only land use for vegetal component of fish feed
Other meat substitutes: enriched with egg or milk proteins

Source: PBL, based on several LCA studies; see also annex

production systems. Methodological differences also play a role, but these seem to be of less importance. The difference between different animal products are mostly related to feed conversion. Carbon footprint and land-use figures for beef are usually much higher than for other types of meats. Pig meat, cheese and milk are in more or less in the same range. In general, poultry and eggs have a lower impact. Vegetal products mostly have the lowest carbon footprint and land use. Just as certain shellfish, although some do have a large impact. The large differences in impacts from shellfish is due tot the broad variation in production systems, and this is also the case for beef. Impacts related to pig meat and poultry differ far less, because of greater homogeneity in production systems.

Figure 7.2
Greenhouse gas emissions per protein source



Other meat substitutes: enriched with egg or milk proteins

Source: PBL, based on several LCA studies; see also annex

Greenhouse gas emissions and land use related to beef are relative high, but land use is partly grassland

The carbon footprints of beef and lamb are relatively high, because ruminants use enteric fermentation, which releases the greenhouse gas methane. Beef also generally requires more land than other types of meat, but this largely concerns grasslands, especially in extensive systems (up to 100% grassland). Some grassland regions are not suitable for arable farming (also see chapter 5). In such places, grazing by cattle or other ruminants are the only option for converting vegetation into nutrients suitable for human consumption. A negative consequence of this grazing is the loss of possible carbon sinks, as without grazing, such terrains would slowly become forested, and would thus store carbon.

Because grazing animals have been around for a very long time, nature has adapted to grazing, which has led to a richness in species. This biodiversity is now often preserved through extensive grazing, albeit mostly by newly introduced grazers. The balance shifts when grazing becomes too intensive, and grasslands deteriorate in several stages of erosion, such as in parts of South America (Ponsioen et al. 2010).

Large differences in environmental impacts of beef

A large difference exists in beef farming systems; from intensive European fattening calf production to very extensive pastoral systems in South America. The production of a kilogram of extensively farmed Brazilian beef causes roughly three to four times as many greenhouse gas emissions as a kilogram of intensively farmed European beef. And land use is roughly ten times higher. However, beef production in Brazil is becoming more intensive, which resulted in a 75% reduction in land use between 1970 and 2007 (from 800 to 200 m2 per kg carcass weight). The carbon footprint has also more than halved over this period (from 70 to 30 kg CO_2 eq per kg) (Ponsioen et al. 2010).

Beef from dairy cows has a lower impact than other beef

The environmental impact of meat originating from culled dairy cows is low, compared to meat from beef cattle. This is the result of the relatively efficient co-production of meat and milk in intensive systems, with relatively low proportions of roughage in the feed. However, dairy cows generally yield low value meat, only suitable for stewing and mincing.

Dairy produce and beef from dairy cows show less variation in impact

Extensive dairy farming is generally not an attractive production system, as dairy cows need regular milking and high quality feed, and on-farm distances therefore cannot be too great. For this reason, livestock management systems for milk production vary less, as do the greenhouse gas emissions and land use related to these products. Greenhouse gas emissions per kilogram of protein for dairy produce are similar to those for pig meat. Those related to cheese are slightly higher than to milk, as methane emissions from cows are the main contributor to the carbon footprint of all dairy produce, and the emissions from the processing of milk for the production of other dairy products are of less importance (Berlin 2002; Blonk et al. 2008).

Pig meat from less intensive husbandry relates to higher greenhouse gas emissions

The carbon footprint of pig meat lies between that of beef and poultry; most values are around 25 kg CO_2 eq per kilogram of protein. Greenhouse gas emissions from organic and free-range pig meat are about 20% to 50% higher than those from conventional systems (Basset-Mens & Van der Werf 2005; Kool et al. 2009). Apart from the type of husbandry, feed composition is also an important factor in the impact of pig meat (Basset-Mens & Van der Werf 2005).

Poultry has relative low impact

Poultry meat has a small environmental impact, compared with other types of meats, in terms of both greenhouse gas emissions and land use (figures 7.1 and 7.2). Land use and greenhouse gas emissions related to eggs are of the same order of magnitude, or a little higher. Free-range eggs have a 10% higher carbon footprint (Mollenhorst et al. 2006).

Impact of animal welfare measures relatively small, considering the wide variety in environmental impacts related to animal products

Animal welfare has become an important issue in Europe, especially the limited living spaces and fast growing rates (chapter 4). Although an improvement in these aspects usually means higher feed requirements and therefore higher land use and greenhouse gas emissions per kilogram of product (chapter 5), the current extra impact is relatively small, considering the large ranges between products and even within product categories. For example, although better animal welfare has 20% to 30% more impact on the environment (chapter 5), there can be as much as a factor of three difference in impact between the various regular production systems of poultry. Moreover, some optimised free-range production systems have lower impacts than the average regular ones. Implementing some improved welfare options would result in a modest increase in the scores for these animal products, but the overall conclusions regarding the differences between products would still be valid.

Farmed fish is more or less comparable to poultry in environmental impact

There are differences between environmental impacts of the farmed fish sector, due to differences in production methods; for farmed salmon there can be more than a factor of two difference between production systems. The carbon footprint of farmed fish is comparable to that of poultry, and the land use – for the vegetable feed component – is somewhat lower or comparable, depending on the type of production. As land use is only an indicator for the impact on terrestrial biodiversity (chapter 5), the impact of shellfish on aquatic biodiversity (chapter 6) is not accounted for in this indicator.

Shellfish has an impact on marine biodiversity

Although shellfish usually has a relatively low land use or none at all – and therefore a low impact on terrestrial biodiversity – it does have an important impact on marine biodiversity (chapter 6). Because wild-caught fish is used in fish feed, the feed conversion of forage fish into production fish is an indicator for the impact on marine biodiversity (figure 6.10). Farmed predator fish, such as salmon, usually use more forage fish, compared to vegetarian fish, such as pangasius, although the feed conversions are still being improved. Looking at differences between crustaceans, European mussel cultivation has a low carbon footprint and scores well on several other sustainability indicators (chapter 6) (Trujilo 2008). Other shellfish, such as oysters and cockles, also have good scores on the sustainability indicators. The worst scores are for tropical shrimp and prawn cultivation and fisheries.

Greenhouse gas emissions related to wild-caught fish are determined by fishing method

Greenhouse gas emissions related to Spanish mussels and Baltic herring are comparable with those related to vegetal products. Greenhouse gas emissions related to wild-caught fish depend on the fishing method. For example, redfish, flatfish, cod and crustaceans are caught by bottom trawlers, but also in demersal trawling (just above the seabed), in traps, or come from aquaculture. Bottom trawling and longline fishing generally use more energy than other fishing methods (Tyedmers 2004). For example, lobsters that are caught using bottom trawling carry a very high carbon footprint (over 500 kg CO_2 eq per kilogram of protein). Bottom trawling also usually has high discard rates and destructive effects on the seabed (Davies et al. 2009). In addition to the fishing method, stock densities and distance to fishing grounds also determine the environmental impact of fish and shellfish products (Harman et al. 2008). Therefore, fishing methods add to the differences in impacts between the various consumption fish.

Vegetarian products without any animal proteins have the lowest greenhouse gas emissions

There is nearly a factor of six difference in greenhouse gas emissions between vegetarian products (pulses and meat substitutes). Some vegetal meat substitutes contain milk or a small amount of egg proteins. The lowest levels of greenhouse gas emissions are related to 100% vegetal meat substitutes, and those enriched with milk proteins have the highest levels. In terms of land use, however, the difference is practically non-existent. Both kinds of substitutes, generally, have lower land-use and greenhouse gas emissions than those related to poultry, although levels for some substitutes are comparable.

7.4.2 Other impacts

Nitrogen and phosphorus emissions related to pig meat and beef are higher than those of poultry

In addition to the global problems surrounding greenhouse gases and land use, other issues may also be very relevant, such as animal welfare, eutrophication, emissions of pesticides, the use of hormones, and the depletion of resources (chapters 2 and 5). The disruption of the natural cycles of the macro-nutrients nitrogen (N) and phosphorus (P) is an important environmental issue in agriculture, and especially in animal husbandry and aquaculture. A range of about 2 to 20 g PO_4 eq per kilogram of livestock product was found in a review of 25 LCA studies of livestock products (all eutrophication emissions of N and P are expressed in phosphate equivalents) (De Vries & De Boer 2010). Animals with high feed conversion efficiencies, such as poultry, have the lowest N and P emissions (see also chapter 5), whereas pig meat and beef have the highest. The emissions are mainly determined by the emission of NH_3 and the leaching and run-off of nitrate and phosphate. All these factors may differ strongly depending on climatic and soil conditions, and are often unknown. Compared to the variation in greenhouse gas emissions per product, the difference in eutrophication emissions between products is less.

7.5 Production chains

Feed and husbandry had the highest impact in meat and dairy production chains
In our study, feed production and husbandry appeared to be the most important sources of greenhouse gas emissions in the production chain of meat products (see also figure 7.3). Feed production also dominated greenhouse gas emissions from aquaculture. In land-based aquaculture systems, the energy use of water pumps was also very relevant. In fisheries, the energy consumption by the fishing boats was often the most important, especially in the case of bottom trawling.

In the production chain of vegetal meat substitutes, crop production and energy consumption in food processing were the most important sources of greenhouse gas emissions.

Food miles contribute one fifth to the carbon footprint of meat and dairy produce
The long distribution distances in the food chain have received a lot of attention in the media and have been cause for public concern. The mileage of food can be very high; an average transportation distance of over 8 000 kilometres in the life-cycle chain of food products was calculated by Weber and Matthews (2008). Despite this large distance, transportation on average accounts for only 11% of the carbon footprint of food.

The most relevant transportation in the meat and dairy produce chain seemed to be the distances travelled by soy, beef and chicken, from South America to the EU (ca 12 000 km). As this usually takes place using large ships, the energy use per tonne-km is very low; bulk carriers emit about 25 to 250 times less greenhouse gases per tonne-km than trucks (Spielman et al. 2007). Truck transport across Europe, therefore, may have a greater environmental impact than a transatlantic crossing. Air freight, however, produces about five times more greenhouse gas emissions than trucks (Spielman et al. 2007). The cooling of the products during transport and storage could have a large additional impact, but the same applies here: the larger the volumes, the less additional impact per tonne-km. This is illustrated in the daily energy consumption for deep-freeze storage, which was 15 times less for large facilities than for small facilities (Carlsson-kanyama & Faist 2000).

The share of emissions from transportation of animal feed in total greenhouse gas emissions amounted to about 10% for pig meat and poultry and 12% for salmon (figure 7.3) (Blonk et al. 2008). Post-farm transportation accounted for less than 10%, except for pig meat and poultry, which amounted to 12%. So, in the production chains of salmon, pig meat and poultry, total transport made up about one fifth of the carbon footprint, which is not completely negligible. In the United Kingdom, of the total carbon footprint, a share of 15% to 55% for transport and refrigeration was found for several shellfish products (Harman et al. 2008). Fresh produce generally has higher shares; for flown-in fresh tuna from the Maldives, the share due to air transport was even as high as 95%.

Comparison with other European studies

Comparing the results from life-cycle assessments (LCAs) with those from other methods, puts the LCA results in a broader perspective. Other assessment methods are: the IMPRO study based on Input-Output analysis (Tukker et al. 2009; Weidema et al. 2008), Multi-regional Input-Output MRIO analysis (Wilting 2008), Miterra-Europe (Lesschen et al. 2011), and the JRC-GGELS study which uses Miterra-Europe methodology as well as the CAPRI model (Leip et al. 2010).

Ranking of products according to impact is the same in all methods

The results are approximately in the same order of magnitude (see the annex). For example, LCAs for pig meat showed a range of 4 to 11 kg CO_2 eq per kilogram of product, and results from the other methods were in the range of 5 to 15 kg CO_2 eq. The results for poultry were even closer: 2 to 6 kg CO_2 eq per kilogram of product, compared to 2 to 5 kg CO_2 eq for the other methods. In general, compared to LCAs, the input-output analyses resulted in higher values for greenhouse gas emissions, because these included processes outside the system boundaries of LCAs, such as the services and production of capital goods. This is less important for land use as these 'background' processes hardly contribute to total land use. In general, Miterra-Europe land use values fit in the LCA range for European products, and the IMPRO and MRIO values are somewhat higher because of imports of non-EU products with high impacts, such as beef from South America (see also table 7.1)

The ranking of products per kilogram of product was more or less the same in all methods; milk had the lowest values and beef the highest. The ranking of meat was also the same, with beef having the highest impact, followed by pig meat, and poultry having the lowest impact.

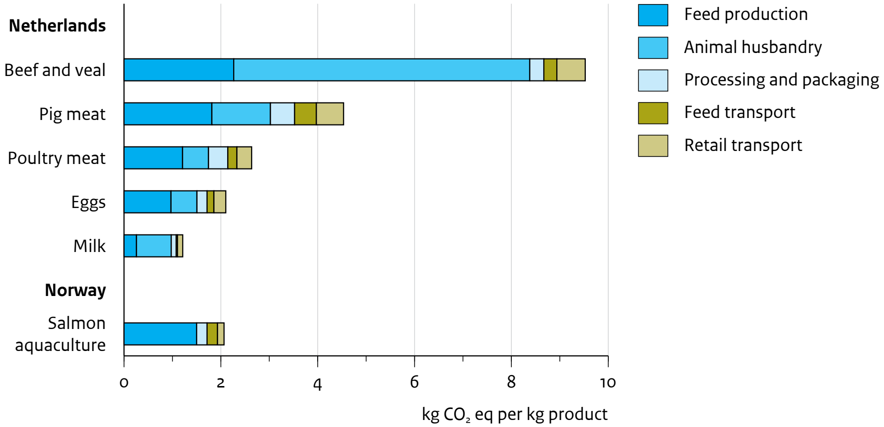
7.6 Environmental impacts of European consumption

Emissions from the consumption of animal products make up 10% of total greenhouse gases due to consumption

As stated, the production of animal products has serious impacts on the environment. These products, however, also form important elements of the European diet. The environmental impact of consumption in the EU27, therefore, partly is related to the diets containing these animal products.

In the EU27, the consumption of meat and dairy produce led to a greenhouse gas emission of 539 Mt CO_2 eq in 2007 (calculated from MRIO; Wilting 2008). This corresponds to 10% of the total emissions due to consumption. The consumption of beef and dairy each caused around a third of these emissions. The rest may be attributed to consumption of pig meat and poultry combined.

Figure 7.3
Greenhouse gas emissions related to animal products, 2006



Source: Blonk et al. (2008)

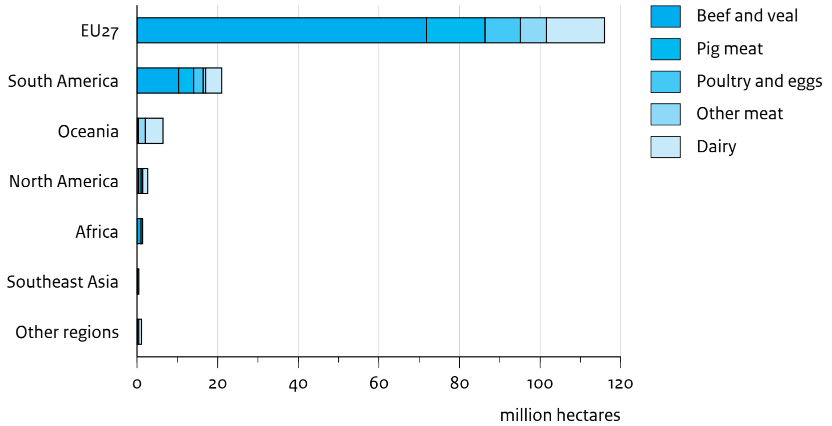
Transport makes a modest contribution to greenhouse gas emissions related to animal products consumed in the Netherlands.

Consumption in EU27 also related to land use outside Europe

Land use related to EU27 consumption of meat and dairy produce was almost 150 million hectares in 2007. This represented about one third of the total land use related to household consumption. Land use was calculated on the basis of consumed volumes and land use per product category as described in the previous section (see the annex for more details). Beef required the most land; its land use was more than 55% of total land use for meat and dairy produce. Half of the remaining land use was related to dairy produce.

About 20% of the land use that is related to the European consumption of meat and dairy products lies outside EU borders (figure 7.4). This land use is needed for the production of imported meat and intermediates, such as feed. Just over half of this land outside the EU27 is used for the production of soy meal[2] for animal feed. The importation of beef from South America and dairy produce and lamb from Oceania also requires land outside Europe. This is largely due to the fact that, in these regions, the land is used in extensive production systems (small number of animals per hectare).

Figure 7.4
Land use related to the consumption of livestock products in EU27, 2009



Source: PBL, based on FAO (210b); EC (2010a,b,c)
European consumption requires land both inside and outside Europe.

7.7 Life-cycle assessments and intervention prospects

The outcomes of life-cycle assessment (LCA) studies may be used in efforts to reduce to environmental impacts of products or to shift consumption towards products with lower environmental impacts. Further improvement to yields and feed efficiencies will result in less land use and emissions, although this may have rebound effects as increased intensification may lead to higher energy inputs, and impacts on biodiversity and animal welfare. An optimum amount of fertiliser, balanced animal feed and accommodation, and good manure management may reduce these emissions. According to Weidema et al. (2008), a reduction of 25% in greenhouse gas emissions may be achieved by implementing several existing improvement options.

Dietary shifts may have large environmental benefits, by moving from sources of protein with high environmental impacts to les detrimental sources (figures 7.1 and 7.2). Diets containing less meat, white meat (poultry) instead of red meat, vegetal proteins (e.g. meat substitutes and soy) or sustainably farmed fish, usually have less detrimental consequences for climate and biodiversity. Furthermore, diet compositions can be rearranged using products from the same product category. See, for example, the wide variation in impacts of products within the product category beef.

A transition from wild fish towards more herbivorous farmed fish may lead to water quality problems and increased land use. A large-scale transition towards a vegetal diet could result in a shortage of pet food grade by-products and to a surplus of by-products from the human food industry, which could otherwise be used as animal feed.

However, it must be stressed that large-scale shifts from one product to another may change the outcomes of the LCAs. For example, a full transition from red to white meat may lead to expansion of arable land and consequent conversion of grasslands, as well as to the abandonment of extensive meadows with high natural and landscape qualities.

A straightforward extrapolation of LCA results could overestimate or overlook the effects of large-scale shifts. An LCA alone, therefore, would not be enough for analysing the effects of large-scale shifts in meat demand. Since global economic equilibrium models can account for limited production factors, changes in prices, feedbacks and rebound effects, these models provide more accurate scenarios, compared to LCAs, for the effects of shifts at a global level (see chapter 8).

7.8 Summary and conclusions

Within the European diet, the consumption of meat, fish and dairy produce has a significant effect on the environmental impact. The European consumption of meat and dairy produce represents about 10% of greenhouse gas emissions from consumption and about one third of the total land use for European household consumption. The land use of about 150 million hectares is mainly in Europe, but also occurs overseas for imported products such as beef and dairy produce and feed used in European meat production. Some of the greenhouse gases are also emitted outside Europe.

Not all animal products have the same environmental impact. Ruminant meats – such as beef and sheep meat – exert the highest environmental pressure (both in terms of greenhouse gas and land use). Beef generally has a higher land use than other types of meats; however, this land concerns largely grasslands, especially in extensive systems. Some grassland regions are not suitable for arable farming, and beef is the only possible production system (see also chapter 5). Furthermore, the impact of land use on biodiversity differs strongly between extensively produced beef –which demands mainly grasslands – and pig meat and poultry, which demands arable land with an usually higher impact on biodiversity.

Poultry generally has the lowest impact in terms of land use and greenhouse gas emissions, due to its higher feed conversion. The impact of pig meat is between that of beef and poultry. Beef from dairy cows is also in this range. Expressed per kilogram, milk protein is in the same range as pig meat and poultry.

Land use and greenhouse gas emissions related to farmed fish are usually in the same order of magnitude as those of poultry. The impact on marine biodiversity depends on the use of forage fish in feed; this is relatively high for predator fish such as salmon, but low for species such as tilapia. Bottom-trawled shellfish generally has high greenhouse gas emissions due to high energy use. Wild-caught fish involves no land use but does have an impact on marine biodiversity.

Furthermore, differences exist within a single category, such as beef or pig meat. These differences are mainly related to production systems, although transportation is also an important element for some products, especially air transport.

Meat substitutes generally have lower impacts than meat. However, meat substitutes enriched with animal (milk or egg) protein have higher greenhouse gas emissions than pure vegetal meat substitutes, whereas usually there is not much difference in land use. Compared to poultry – meat with the lowest impact – meat substitutes including pulses generally involve lower land use and greenhouse gas emissions, although for some substitutes these are comparable to poultry.

The differences in environmental impact – both between and within the various product categories – offer chances for lowering the environmental impact of the European diet and for mitigating climate change. Most important are improving production chains and encouraging a shift in consumption from red meats and bottom-trawled shellfish towards vegetal sources of protein, poultry and sustainable shellfish. Furthermore, a reduction in consumption, as well as some of these shifts, are also beneficial to human health in the EU (chapter 3).

The impacts from these shifts and improvements could be analysed using straightforward extrapolations of LCA results or global economic equilibrium models. In the case of large-scale changes, such as changing the whole European diet in particular, the dynamic approach will provide more accurate scenarios than the straightforward extrapolation of LCA results, as these models are dynamic and take into account changes in price due to changing demand and supply, limited production factors and rebound effects (see chapter 8).

Notes

1 The annex to this report can be viewed online or downloaded from www.pbl.nl/en.

2 Allocation of land use for soy is 60% for soy cake and 40% for the oil (allocated on the basis of economic value).

EIGHT

Modelling the effects of options towards a sustainable protein supply

8.1 Introduction

The previous chapters have demonstrated that the present European consumption of livestock products and fish leads to various environmental and health problems (chapters 3, 5 and 6). Many of the environmental issues are related to feed production and consequent land use (chapters 2, 4 and 5). Expressed per kilogram of protein, there are marked differences in environmental pressure between various livestock products and also when compared to vegetable alternatives (chapter 7). At a global level, the expected increases in population and wealth are projected to lead to strong growth in food demand, leading to higher nitrogen and greenhouse gas emissions and additional biodiversity loss. In spite of the strong increase in food production, a large number of people are expected to continue to suffer from malnutrition (chapter 2).

This chapter explores the effects of different options for reducing the environmental impact of the global food system, with special attention paid to the human protein supply and livestock production. The rationale for analysing these options is discussed in section 8.2. The focus is on those environmental challenges, as indicated in the previous chapters, which would require a response at EU or global level. The effects of the options were calculated using two alternative agro-economic models: LEITAP (Van Meijl et al. 2006) and IMPACT (Rosegrant et al. 2008), coupled to PBL's integrated assessment model IMAGE. These models are described in more detail in the online annex to this report.[1] A parallel assessment of the different options was carried out using the two agro-economic models. The results were quite similar for some options, but for others there were striking differences. In most cases, only the LEITAP results are presented in this chapter, for reasons of conciseness and simplicity. Woltjer (2011) provides more information on these results. An overview of IMPACT results is given in table 8.3. A more in-depth comparison of the IMPACT and LEITAP results in this study is provided by Stehfest et al. (2011), who also provide more technical-scientific background.

An analysis of the options is presented in section 8.3; and their effects on consumption, production and the environment are described in section 8.4 (for options at EU level) and section 8.5 (for options at global level). Section 8.6 pays attention to the effects on poverty (food prices) and production sectors. Section 8.7 discusses the plausibility and robustness of the results. A summary of the findings and the conclusions are presented in section 8.8.

This chapter only looks at the options from a 'what-if' point of view and makes no evaluation of the feasibility of the assessed options or how they could be put into practice. These questions are addressed, in a general sense, in chapter 9. The options do not include changes in fish consumption, fisheries or aquaculture. However, the PBL study *Rethinking Global Biodiversity Strategies* includes an option of reducing marine fishing (PBL 2010).

The options were implemented in the models as variants to the *Reference Scenario* or 'business as usual' projection, presented in chapter 2. The study has a time horizon up to 2030. Effects of these options include the consumption and production of different crop and livestock commodities, land use, greenhouse gas emissions, terrestrial biodiversity as indicated by the Mean Species Abundance indicator, and nitrogen emissions. In addition, we also looked at commodity prices and self-sufficiency as proxies for food security and food sovereignty, respectively.

8.2 Rationale for options

The following strategies, theoretically, could lead to a reduction in environmental pressures or improvements in animal welfare:

- increasing resource use efficiency, which could be producing more efficiently (e.g. more crop products per ha per year; better feed conversion) or reducing supply chain wastes and losses with consequent decrease in demand and production;
- developing more robust systems with higher animal welfare, such as changing to free-range or organic production, or reducing local environmental pressures by changing to less intensive production (e.g. organic production);
- changing consumption patterns, for example, switching within a food category, such as meat, to products with less environmental impact, or (in affluent regions) to less consumption of animal products.

Table 8.1
Overview of the consumption and production options analysed

Scenario	Description
Options at EU level	
Healthier diet	EU diets in 2020 in accordance with health recommendations
Substitution of red meat	Preference shift from red meat to white meat in the EU, with 40% lower red meat consumption in 2020 compared to the *Reference Scenario*
Reduced consumption of animal products (10%, 20% and 50% less)	Reduction in the consumption of livestock products in the EU, by 10%, 20% and 50%
Animal friendly	All livestock production in the EU according to animal-friendly standards by 2020
Organic	50% of EU livestock production and 20% of EU arable land managed according to organic agriculture standards by 2020
Options at global level	
Low wastage	Reduction in food losses worldwide, from 20% to 5% by 2020 (-15%)
High crop yield increase	Worldwide, yields increase 40% faster than in the *Reference Scenario* (i.e. a 10% yield increase in the *Reference Scenario* would become 14%)
Livestock efficiency increase	Worldwide, livestock efficiency 15% higher than in the *Reference Scenario* by 2020 (i.e. 15% less feed needed per unit of product)

Rebound and leakage effects limit potential of options

A number of similar options have been analysed in previous studies. For example, Stehfest et al. (2009) looked into the effects of a global shift in diets towards less animal products, demonstrating such shifts' large theoretical potential for reducing the costs of climate change mitigation. That study might have overestimated the effects, however, by ignoring feedbacks in the agro-economic system. Such feedbacks are often referred to as rebound effects and leakage. These appear to be particularly relevant when changes are assumed to occur in specific regions only. For example, a decrease in meat and dairy consumption in Europe may lead to decreasing crop and meat prices globally, and in turn to higher consumption elsewhere (leakage). Likewise, decreasing commodity prices and less area requirements may lead to a decrease in land prices and lower yields (rebound), partly offsetting the theoretical land savings of reduced consumption. Accounting for such effects in the analysis requires the combination of a global agro-economic model and an integrated environmental impact model. It has to be noted that the rebound effects described may induce positive effects, such as lower food prices.

8.3 Options analysed

An overview of the options is presented in table 8.1. These options either refer to changes in the EU or are assumed to be implemented on a global scale. Globally, only options regarding more efficient production and a reduction in food losses were evaluated. At EU level, mainly options regarding consumption shifts were evaluated, as these options currently are under discussion in the EU, motivated from environmental and human health perspectives. Some of the evaluated consumption options are aimed human health (*Healthier diet* and *Substitution red meat*), while the options that focus on lower consumption of animal products are assumed to relate to the environmental perspective. In addition to the options that target global environmental pressures, those targeting a shift towards animal-friendly and organic production were also included.

8.4 Options at EU level

8.4.1 Description of options

Healthier diet

Current food consumption levels in the EU and most other affluent regions are considered unhealthy (see section 2.6) as well as harmful to the environment (see chapter 4). It is therefore often suggested that a healthier diet would be favourable to the environment (Friel et al. 2009; SDC 2009; Tukker et al. 2009). To explore this hypothesis, an option was constructed to assess the effect of a shift towards a healthier diet according to the following criteria inspired by WHO recommendations (WHO 2002, 2003) concerning the intake of proteins and saturated fats. An additional criterion regarding the intake of red meat is further motivated under the option *Substitution of red meat*:

- a maximum consumption of red meat of 300 grams per week;
- a minimum consumption of fish of 200 grams per week;
- a daily consumption of milk of 400 grams;
- a maximum consumption of fat of 30% of total caloric intake;
- a maximum consumption of saturated fat of 10% of total caloric intake.

If application of these criteria were to lead to a more than 5% reduction in total caloric intake, the models would compensate for this with an extra intake of crop products (see Stehfest et al. (2011) for further details on how these criteria were implemented in the model chain).

Substitution of red meat

During the past decades, there has been a shift in European diets from red to white meats (chapter 3).[2] This trend can be partly related to the increasing evidence that red meat is associated with increased risks of vascular diseases and certain types of

Table 8.2
Assumptions for the options Animal friendly and Organic

Animal friendly	Organic
All EU livestock production complies with animal-friendly standards by 2020	By 2020, 50% of EU livestock production and 20% of EU arable land comply with organic agriculture standards
Per unit of product, 10% more feed required for pig meat, 27% for poultry and 10% for eggs	Per unit of product, 20% more feed required for pig meat, 54% for poultry and 10% for eggs
No change in crop yields	Crop yields 25% lower

cancer (Ding & Mozaffarian 2006; Li et al. 2005; WCRF & AICR 2007). Here, we assume a further shift from red to white meats in the EU, resulting in a 40% reduction in red meat consumption, compared to that in the *Reference Scenario*, which is compensated for with equal quantities of poultry. This reduction level represents about half of the reduction necessary to achieve supposedly healthy levels of red meat consumption according to Willet (2001).

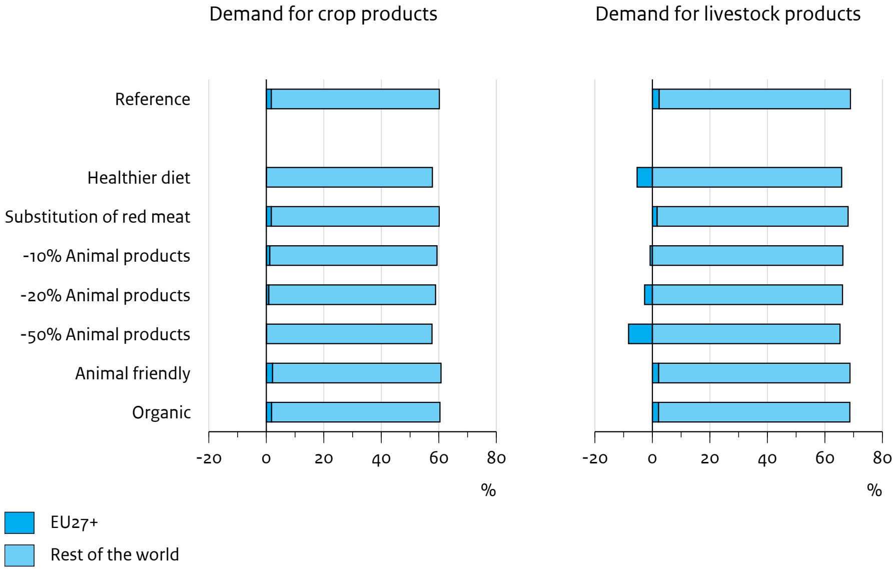
Reduced consumption of animal products
Three options were considered that assume a general reduction in EU consumption of livestock products (meat, dairy, eggs), of 10%, 20% and 50%, respectively.[3] Additional consumption of crop products is not prescribed, but is a result of model elasticity and spending in the food sector.

Animal friendly and Organic
In Europe and elsewhere, there is a growing concern about animal well-being in the livestock sector, as well as about the implications for human health and the environment that are attributed to food produced with synthetic fertilisers, genetically modified (GM) crops and biocides. The result has been an increasing demand for more animal-friendly produced livestock products as well as organic food. Compared to 'conventional farming', however, animal-friendly and organic production systems tend to be associated with lower feed efficiency (see chapter 4) and, in the case of organic production, lower crop yields. To analyse these effects, we applied the assumptions presented in table 8.2. The animal-friendly option only applies to poultry and pig production. For both options, we assumed no additional feed requirements for cattle and sheep, and no change in grassland yields.

8.4.2 Overall results from the EU options

The results from the *Reference Scenario* and the effects of the different EU options are presented in figures 8.1 to 8.3, as well as in tables 8.3 and 8.4. The results are shown relative to the situation as it was in the year 2000. Since these EU options also have an effect outside the EU, all the data presented refer to the global situation. The results from the EU options may therefore appear quite marginal in some cases, while in fact they are substantial.

Figure 8.1
Effects of EU options regarding demand, 2000 – 2030



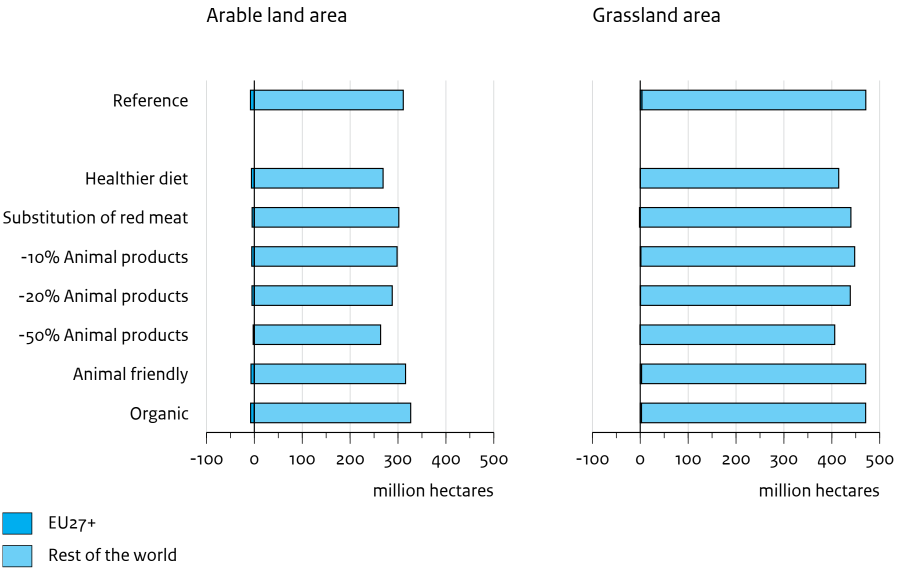
The global demand for crop and livestock products increases in all options, but in the options 'Healthier diet' and '-50% Animal products' a global effect of these EU options can be noticed.

Significant effects at global level from a reduction in the EU consumption of meat and dairy

In the *Reference Scenario*, the global demand for livestock products increases by almost 69% compared to that in the year 2000 (figure 8.1). In the EU options with the highest reductions in livestock production, the global increase is limited to 57% in the option *-50% Animal products* and 60.5% in the option *Healthier diet*. Given the fact that the EU population of 2030 will only account for approximately 6% of the global population, this is a significant reduction in the demand for livestock products. It also indicates that, by 2030 in the EU, people will still be eating more livestock products than the global average.

The global demand for crop products in the *Reference Scenario* rises by over 60%, while the demand in the options *-50% Animal products* and *Healthier diet* increases by 57.5% (figure 8.1, left). This indicates that, although the reduction in EU consumption of livestock products leads to an increase in direct human consumption of crop products, the reduction in feed demand is larger. The demand for crop products is higher in the *Organic* and *Animal friendly* options due to a less efficient feed conversion.

Figure 8.2
Effects of EU options regarding agricultural land use, 2000 – 2030

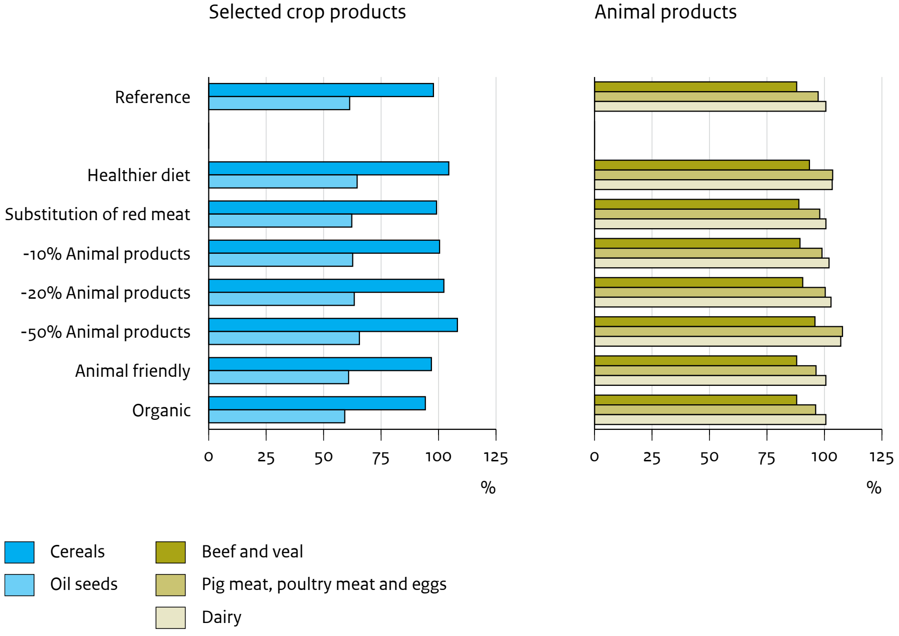


The EU options mainly result in changes in land use (compared to the Reference Scenario) outside the EU27+. Effects within the EU27+ are hardly noticeable in this graph.

Marked effects of EU options on cropland and grassland areas outside Europe
The changes in demand for livestock and crop products are partially reflected in the areas of arable land and grassland. The global arable land area increases by just over 300 million hectares in the *Reference Scenario*, which is 2.5 times the size of the EU arable land area (figure 8.2; table 8.4). In the options -50% *Animal products* and *Healthier diet*, around 40 million hectares less arable land are needed worldwide; this is roughly equivalent to one third of the total EU arable land area. It is projected, however, that this reduction in arable land area (or more correctly said: the smaller expansion compared to that in the *Reference Scenario*) will take place outside the EU, because of increased cereal exports (that would otherwise be used for animal feed) from the EU, in addition to a decline in the import of protein-rich feed into the EU. In the options *Organic* and *Animal friendly*, an additional 6 to 16 million hectares of arable land area is needed.

The global grassland area is projected to increase by 470 million hectares in the *Reference Scenario*. In the options -50% *Animal products* and *Healthier diet*, around 60 million hectares less grasslands would be needed, which is roughly equivalent to the total EU grassland area.

Figure 8.3
Effects of EU options regarding EU27+ self-sufficiency, 2030



The reduction in the EU consumption of animal products is only slightly reflected in an increase in EU self-sufficiency in crop and animal products, due to different feedbacks, including an increased use of crop products for biofuel production.

EU self-sufficiency improves (slightly) when domestic feed demand is reduced
Reduction in the EU demand for livestock products and, consequently, in the demand for feed, would contribute to improved self-sufficiency. According to LEITAP model results, this would be particularly the case for sectors for which the EU is most competitive, such as cereals and pig meat (figure 8.3). For other sectors, however, differences between the options and the *Reference Scenario* would be rather small, because of market adaptation on the supply side. For most key commodities, self-sufficiency will remain around 100%. At first glance, most surprising are the results for oil seeds – the main source for protein rich feed, for which the EU will remain strongly dependent on imports. One would expect that a strong reduction in the consumption of animal products, such as that in the options -50% *Animal products* and *Healthier diet*, would result in a strong improvement in self-sufficiency in oil seeds. However, the model projections only suggested a minor response, as the demand for biofuels would become the main driving force behind oil-seed imports, rather than the demand for protein-rich feed. Although the model results for the *Animal friendly* and *Organic* options showed a small general decline in EU self-sufficiency.

8.4.3 Results per EU option

Healthier diet

- The option *Healthier diet* would result in a reduction in the overall EU demand for livestock products (on a dry mass basis) of 34%, compared to that in the *Reference Scenario*. Globally, this reduction would be 5% (figure 8.1).[4]
- The reduced consumption also implies less agricultural land use than in the *Reference Scenario*. Globally, the difference is -40 million hectares (2.3%) for arable land (figure 8.2, left) and -56 million hectares (1.5%) for grassland (figure 8.2, right). Combined, these areas correspond to an area larger than half the EU agricultural area.
- Interestingly, however, these reductions are most pronounced outside the EU.[5] The area of arable land in the EU even shows an increase of 2 million hectares, compared to that in the *Reference Scenario*.
- The decrease in grassland area outside the EU mainly relates to the reduced export of beef (and to a lesser degree of sheep and goat) to the EU. Within the EU, however, rather than abandoning the land, the model projected that farmers would prefer to keep the land in production – albeit much less intensively – in order to meet cross-compliance criteria for receiving CAP subsidies. As a consequence, the decrease in EU grassland area is only 3.3 million hectares (ca 4% of total EU grassland), compared to that in the *Reference Scenario*.
- A relatively small part of the reduction in EU demand for livestock products 'leaks away' in the form of exports of these products to other parts of the world (and then only with respect to pig meat, poultry and eggs), because of the high production costs in the EU, and its relatively strongly shielded market.
- Given the reduced feed requirement in the EU, more cereals are exported (figure 8.3). Some EU grassland is converted to arable land (figure 8.2).

Substitution of red meat

- Overall, consumption of livestock products is hardly affected under this option (figure 8.1), but the effects on land use would be considerable (figure 8.2) because of the shift in demand; from mainly pasture-based cattle, sheep and goats to mainly grain-fed poultry. In addition, the feed conversion of poultry is more efficient than that of red meat livestock (see chapter 4).
- Compared with the situation in the *Healthier diet* option, a larger share of the differences are compensated within the EU, although most changes in land use and other impacts still occurs outside the EU.

Reduced consumption of livestock products (minus 10%, 20% and 50%)

The mechanisms and effects of this option are largely similar to those of the *Healthier diet* option. For all indicators, the step-by step reduction in the EU consumption of animal products is mirrored by a step-by-step reduction in impacts, mainly outside the EU, with results from the *Healthier diet* option being in between the results from the options *-20% and -50% consumption of livestock products*.

Animal friendly and Organic
The model results suggested that these options would have relatively little effect on overall land use. Demand for livestock products initially would contract as products become more expensive due to increased production costs. By 2030, however, the market would have adapted and differences would have become insignificant (figure 8.1). Crop demand would be slightly higher than in the *Reference Scenario,* because of increases in the amounts of feed needed (figure 8.1).
For the *Animal friendly* option, the effects on land use would be even somewhat smaller than on production, as higher price levels would stimulate an improvement in production efficiency. An additional 6 million hectares of arable land would be needed, equal to 5% of the EU arable area. In the *Organic* option, this effect would be mostly negated, as EU crop yields would be inherently lower, leading to a more pronounced expansion of arable land (of 16 million hectares). Again, these changes would mostly occur outside the EU, suggesting that increasing the share of organic agriculture in the EU – at the same level of production – would push conventional farmers to purchase more feed from outside the EU.

8.4.4 Effects of EU options on biodiversity and greenhouse gas emissions
The IMAGE model spatially allocates crop and livestock production and calculates the resulting environmental impacts, land use, land-use changes and related greenhouse gas emissions, according to a certain scenario. These greenhouse gas emissions include those related to livestock production (see chapter 5) and land use and land conversion (e.g. from forest to grassland). By entering the results from the IMAGE model into the GLOBIO-3 model, the effects on terrestrial biodiversity can be quantified, using Mean Species Abundance (MSA) as an indicator. The PBL study *Rethinking Global Biodiversity Strategies* gives more details on biodiversity indicators (PBL 2010).

In the *Reference Scenario,* the greenhouse gas emissions related to global agricultural activities are projected to increase from 228 Pg CO_2 eq, aggregated for the 1990-2010 period, to 286 Pg CO_2 eq, aggregated for the 2010-2030 period (table 8.4), which is an increase of over 25%. Most of this increase would come from CH_4, mainly from ruminant livestock, followed by CO_2 from the conversion of nature to agriculture and from grassland to cropland. Please note that these results are presented as cumulative values for a longer time period because carbon emissions from land-use changes have a particular tendency to vary strongly between years (both in reality and in model results). The greenhouse gas emissions in figure 8.4 represent the change in greenhouse gas emissions from 2000 (2000 figure represents average emissions over the 1990-2010 period) to 2020 (2020 figure represents average emissions over the 2010-2030 period).

Global terrestrial biodiversity, as measured by the MSA indicator, would decline by just over 7%[6] up to 2030. This is equivalent to a loss of biodiversity from a pristine state to zero in an area over twice as large as the EU. In reality, it means that the quality of biodiversity would be lost over a much larger area. This is not only caused by agriculture, but also by other pressures, including climate change, fragmentation and encroachment

(PBL 2010). Yet, almost two thirds of the MSA losses up to 2030 will occur in regions where agricultural expansion is greatest: in Sub-Saharan Africa, Central and South America, as well as some OECD countries other than those in the EU. Only 3% of global MSA losses over this period will occur within the EU.

The environmental effects of the *Healthier diet* option largely mirror the changes in land use:

- Compared with the situation in the *Reference Scenario*, greenhouse gas emissions (figure 8.4) in the *Healthier diet* option show a small decrease for the EU (mainly of CH_4 and N_2O, as a result of less livestock production), and a fairly large reduction worldwide, mainly of CO_2 as a result of less land conversion.
- In terms of MSA, some additional biodiversity loss will occur in the EU, compared to the situation in the *Reference Scenario,* due to the conversion of some pastures into arable land. At the global level, MSA losses are avoided, especially in those regions where they are the greatest in the Reference Scenario, because less natural and semi-natural areas are converted to agriculture.

The net environmental benefits of the *Substitution of red meat* option – in terms of greenhouse gas emissions and biodiversity (figure 8.4) – amount to roughly half the benefits of the *Healthier diet* option. This is not surprising, because in this option the reduced environmental pressure from red meat production is partly negated by the increased feed requirements for poultry production.

In the *Organic* and *Animal friendly* options the larger area requirements per unit of produce, combined with lower yields and contracted demand, lead to higher greenhouse gas emissions. Therefore, the net change in these emissions, compared to those in the *Reference Scenario,* is very small and appears to be within the error margin of the analysis. The effects on the MSA biodiversity indicator – mainly as a consequence of the larger area requirements – are slightly negative in both options. However, it must be noted that the *Organic* option will have other positive environmental effects that cannot be modelled. These include the reduced use of pesticides and related emissions, and positive effects on biodiversity in rural areas.

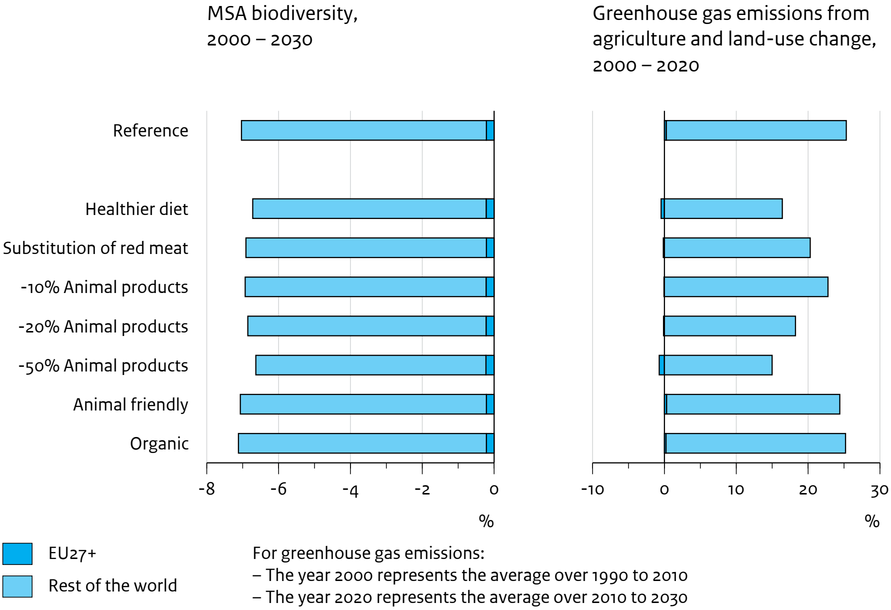
8.5 Options implemented at the global scale

8.5.1 Description of options

Low wastage

This option assumes a reduction in waste and losses of 15% of total production, resulting in 15% less food production required to meet the same level of nutrition. Presently, large amounts of agricultural products are lost along the supply chain from ‘field to fork’. These losses are caused by numerous factors, such as harvest inefficiencies (e.g. due to poor timing), poor harvest conditions (e.g. too wet), losses

Figure 8.4
Effects of EU options regarding the environment

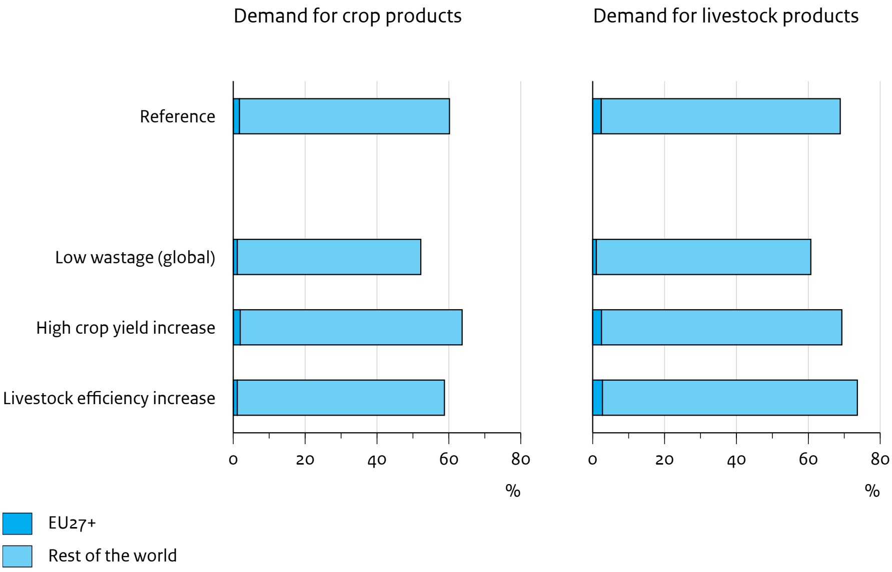


during transport, or deterioration during storage on-farm, on-market, or after consumer purchase. On-farm losses tend to be more prominent in developing countries, whereas losses in high-income countries mostly occur further down the supply chain. The fraction of food lost or thrown away as waste is very difficult to estimate, and numbers vary from 25% and 30% (Kantor 1997; UNEP 2009) to 50% (Lundqvist 2009).

High crop yield increase

In the option *High crop yield increase* it is assumed that improved practices would result in a crop productivity increase of 40% higher than that in the *Reference Scenario*, based on IAASTD (2009). Between 1970 and 2000, agricultural yields, on average, increased by about 1% per year (Bruinsma 2003). Differences between estimated potential yields and actual yields suggest that there is still considerable room for improvement. Such yield gaps are particularly wide in Sub-Saharan Africa (IAC 2004; IAATSD 2009; PBL 2009). Reasons for very large yield gaps include low agricultural inputs, lack of location-specific technologies and inappropriate agronomic practices, in general, which are often caused by social, economic, infrastructural and institutional constraints (Bruinsma 2003; IAASTD 2009; IAC 2004; Koning et al. 2008; Lobell et al. 2009; Neumann et al. 2010; Van der Ploeg 2010). Even in developed countries, where actual yields are already close to current potential, it is expected that plant breeding will allow yield increases

Figure 8.5
Effects of global options regarding demand, 2000 – 2030



to continue, albeit at a slower rate (FAO 2006). It is assumed that these practices would also entail more efficient resource use than in the *Reference Scenario* (see the annex).

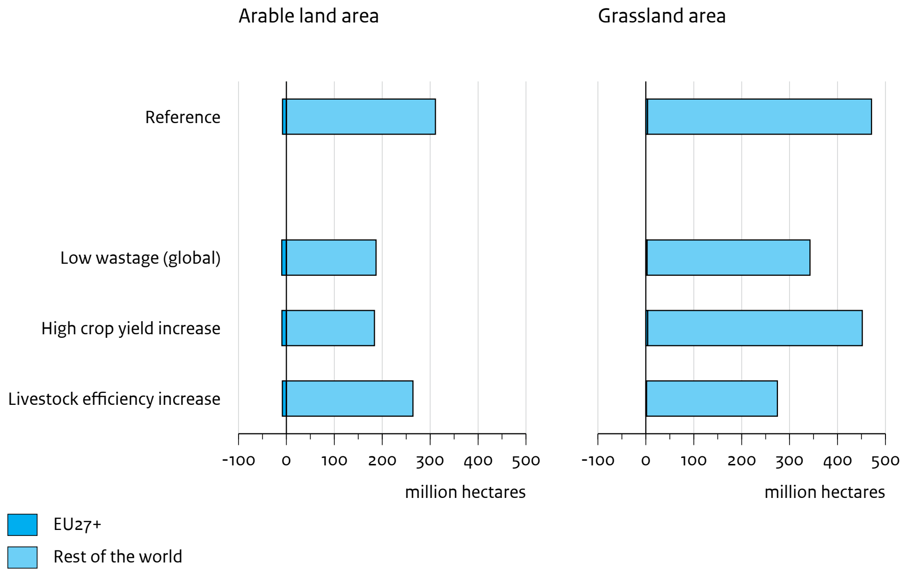
Livestock efficiency increase
Livestock systems differ strongly around the world, and there is still a large potential to increase their efficiency (Bouwman et al. 2005), for example, in terms of production per unit of feed. We assessed the effects of improving this ratio globally by 15% above the level assumed in the *Reference Scenario*. This is a realistic estimate according to Oenema (personal communication, 2010), considering the large share of energy in feed that is currently being used in the animals' maintenance energy requirement (Oenema & Tamminga 2005), the large variation in feed conversion between countries (Lesschen et al. 2011) and the efficiency improvements that have been achieved in intensive livestock systems. The 15% value was applied for all feed and fodder, including grass.

8.5.2 Results

Low wastage option leads to lower production levels, but also to rebound effect from higher consumption
The results for the *Low wastage* option demonstrate that a 15% supply-chain efficiency increase would result in a decrease in the demand for livestock products of only 4.8%, globally (figure 8.5). The remaining 10.2% in supply-chain efficiency gains are used as additional consumption. The demand for crop products would also be reduced by 5%.

Figure 8.6

Effects of global options regarding agricultural land use, 2000 – 2030



Human consumption of these products would be reduced much more: by almost 12%; indicating a shift in diets towards more animal products. Compared to the *Reference Scenario*, the total agricultural area would be reduced by some 250 million hectares (4.5% of the global agricultural area), with about equal shares of arable land and grassland (figure 8.6). Compared to the year 2000, however, there would still be an increase of 520 million hectares (table 8.4).

In the *High crop yield increase* option, too, some of the potential benefits would leak away as a result of higher consumption, but to a far lesser degree than in the *Low wastage* option. An increase in demand for crop products of just over 2% is projected, as well as a minor increase in the demand for livestock products (figure 8.5). The expansion of arable land would be 129 million hectares smaller than in the *Reference Scenario* (figure 8.6), corresponding to almost 7% of the global arable land area. For grassland, an
In the *Livestock efficiency increase* option, agricultural expansion would be similar to that in the *Low wastage* option, but with a much smaller contribution from arable land and a much greater share in grassland (figure 8.6). Similarly to the *Low wastage* option, the decrease in agricultural land use (2.6% of global arable land and 5.1% of global grassland) would be rather modest, compared to the 15% improvement in feed conversion efficiency, because of the following rebound effects:

– a decrease in production costs in the livestock sector, partly passed on to consumers, would result in an increase in the demand for livestock products of almost 3% (figure 8.5);

- an increase in the demand for crop products for human consumption, due to lower prices of crop commodities, would partly compensate the reduction in the demand for feed crops;
- more extensive use of grassland than in the *Reference Scenario*, due to lower land prices.

For the same reason as discussed above for the EU-level options (farmers preferring to keep the land in production in order to meet cross-compliance criteria for receiving CAP subsidies), the environmental effects found in Europe are very small.

8.5.3 Effects of global options on biodiversity, greenhouse gas emissions and nitrogen surplus

Significant reductions in greenhouse gas emissions and biodiversity loss in Low wastage option

The average greenhouse gas emissions under the *Low wastage* option would increase by almost 8% over the 2000-2020 period, whereas in the *Reference Scenario* this increase is 25%. (figure 8.4). This reduction is much stronger than that in consumption and production, because land-use change (rather than land use *per se*) is such a dominant factor in greenhouse gas emissions, and, under this option, much less natural land would be converted to agriculture than in the *Reference Scenario*. The MSA biodiversity indicator is 1% greater than in the *Reference Scenario*. This is equivalent to avoiding biodiversity loss from a pristine state to zero in an area of 130 million hectares, that is the size of a quarter of the EU27. Most of these environmental benefits would occur outside the EU27, particularly in Sub-Saharan Africa, Latin America and some other OECD countries. In the EU27, the effects on MSA would be very small, proportionally, because the main effect would be agricultural extensification rather than sparing land for nature.

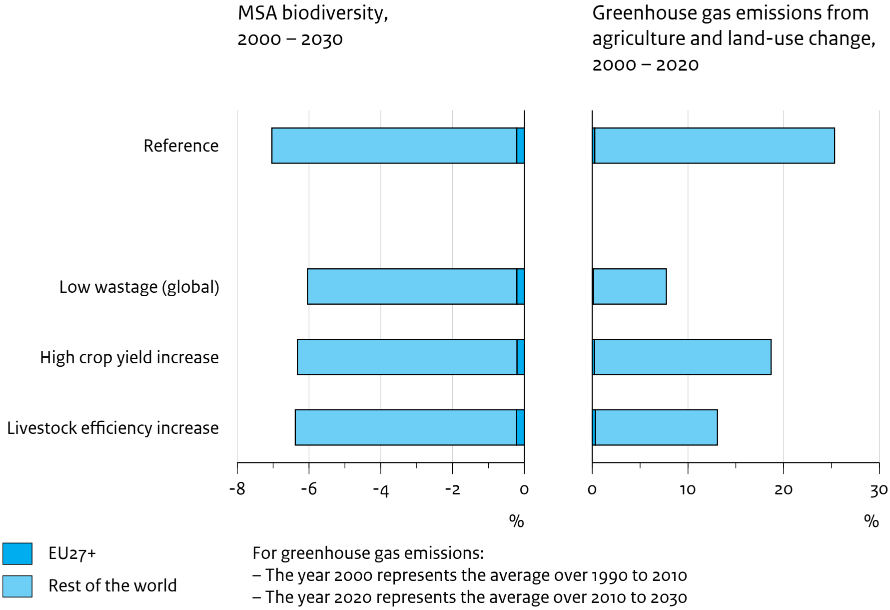
The environmental effects of the options *High crop yield increase* and *Livestock efficiency increase*, although less pronounced than those of the *Low wastage* option, would still be considerable. *High crop yield increase* would result in a 19% increase in greenhouse gas emissions, and for *Livestock efficiency increase* this would be over 13%, whereas in the *Reference Scenario* the increase would be 25% (figure 8.7; table 8.4). The avoided MSA loss for both options would be around 0.7%.

Nitrogen emissions

The annual soil N budgets were calculated for 0.5 by 0.5 degree grid cells, following the methodology described by Bouwman et al. (2009). Nitrogen inputs include biological N fixation, atmospheric N deposition, application of synthetic N fertiliser and animal manure. Outputs include N withdrawal from the field through crop harvesting, hay and grass cutting, and animal grazing. Option-specific assumptions were made concerning the development of the fertiliser N use efficiency (NUE), which represents the production in kilograms of dry matter per kilogram of fertiliser N.

Figure 8.7

Effects of global options regarding the environment



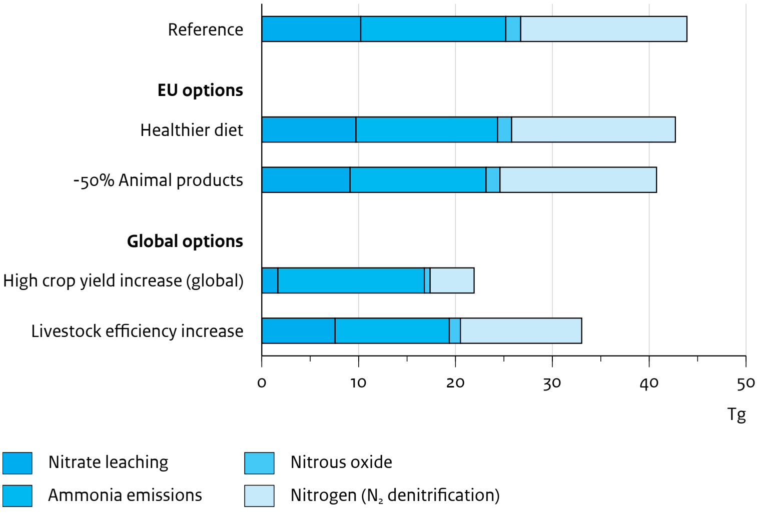
Globally, nitrogen losses are projected to increase from 45 Tg (+30%), to 198 Tg by 2030 (figure 8.8). In the EU, nitrogen losses in the *Reference Scenario* are projected to decrease by 3.5%, mainly as a consequence of more efficient use.

The EU options -50% *Animal products* and *Healthier diet* would only have a limited effect on global nitrogen losses. For the global options *High crop yield increase* and *Livestock efficiency increase*, this effect would be much stronger; partly because of the smaller agricultural land area, and partly because better nutrient management practices are assumed to be used in these options. In the option *High crop yield increase*, the increase in surplus would be cut by almost 50% compared to that in the *Reference Scenario*. And nitrate emissions would reduce even more strongly. Compared to the situation in the *Reference Scenario*, EU nitrogen emissions would reduce by 6% to 12%, depending on the option.

8.6 Effects on commodity prices, food affordability and production sectors

At the global level, several options addressed in this report would entail decreasing land and food prices (figure 8.9) and, hence, improved food availability. This also holds true

Figure 8.8
Effects of EU and global options regarding nitrogen losses, 2000 – 2030



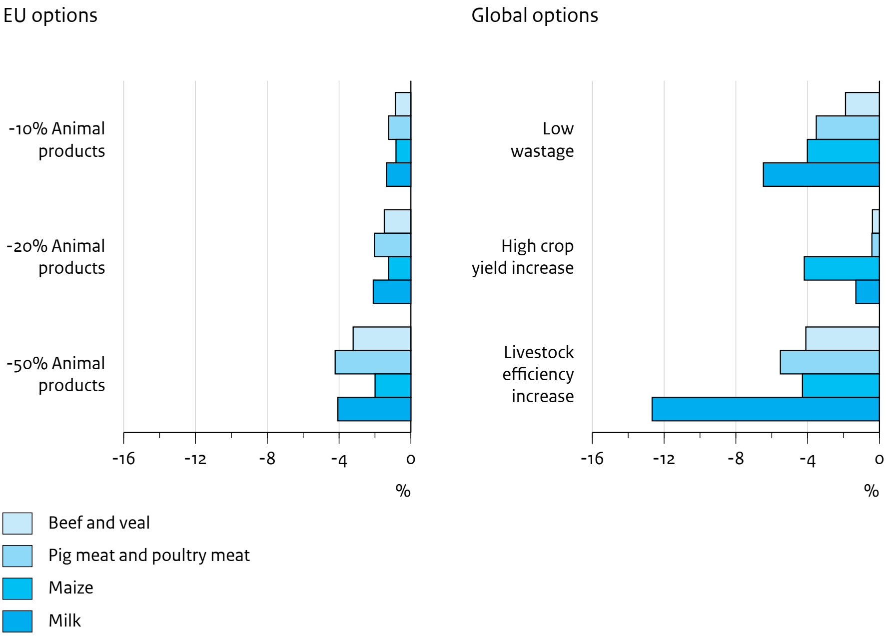
All reviewed options would lead to lower nitrogen losses, compared to the Reference Scenario. However, these losses would all be higher than those of the year 2000, due to the large increase in global agricultural production.

for reductions in food losses, shifts in diets away from meat consumption, and increases in agricultural productivity. However, a major shift to organic or animal-friendly production would increase land and food prices, and decrease food availability. But these are crude, net, global effects, which will play out differently for different regions, and rural and urban populations. The effects would depend strongly on socio-economic and institutional factors, such as access to markets and the manner in which the options are introduced. Most poor and undernourished people live in rural areas and depend on farming for their livelihoods (Cervantes-Godoy & Dewbre 2010). These farmers are mainly subsistence farmers who earn additional income by selling part of their produce. In general, these farmers are negatively affected by decreasing food prices and this holds true even more for commercial farmers. Landless agricultural workers do not automatically benefit from increasing food prices, but when prices are decreasing they could be more vulnerable to losing their income. The urban poor are generally fully dependent on the market for their food and therefore benefit from decreasing food prices. This would also indirectly benefit the numerous rural households in developing countries that partly depend on financial remittances from their urban relatives.

The list below provides an indication of the main effects of the options on different groups of producers and consumers, compared to the situation in the baseline scenario.

Figure 8.9

Effects of options regarding commodity prices compared to reference scenario, 2030



Changes in selected world market commodity prices by 2030 (% difference with the Reference Scenario) according to LEITAP. Prices in the Reference Scenario change to -37% for beef, poultry and pig meat, and -44% for maize, between 2001 and 2030.

As the models used were unable to address any poverty impacts in detail, only a qualitative, rough indication has been given, which by definition is incomplete.

– A reduction in the consumption of livestock products in the EU would lead to a decline in the demand for feed and land, which eventually would result in lower food prices and increased food availability. Overall, producers would see their incomes decline. The effect would be particularly strong in the EU. However, effects will probably be small in the rural areas of the poorest nations that are shielded from world market effects by logistic barriers.
– Improving the productivity of farmland or the feed conversion efficiency of livestock through the introduction and outreach of better management practices and novel technologies would also decrease food prices and increase food availability, especially in regions where the gaps between actual and attainable yield levels are the widest. How farmers would be affected would greatly depend on their access to new technologies and on how strongly they are connected to the market. More technologically advanced farmers and their employees may benefit, while other

Table 8.3
Overview of environmental effects of the options, analysed by IMPACT-IMAGE

IMPACT-IMAGE	Area of food crops (million hectares)		Grassland / fodder (million hectares)		GHG emissions (Pg CO_2 eq)		Biodiversity (MSA,%[1])	
	EU27+	RoW	EU27+	RoW	EU27+	RoW	EU27+	RoW
Base year (2000) value	139	1,401	80	3,257	11.6[2]	182[2]	1.52	67.3
Reference Scenario (change 2000-2030)	-0.4	198	15.3	-47	2.1[3]	18[3]	-0.23	-5.0
Option results (change compared to reference)								
Global options								
Low wastage (global)	-1.9	-37	-4.2	-79	-0,9	-15	0.01	0.44
High crop yield increase	-5.6	-49	0.4	51	0,0	5	0.01	0.19
Livestock efficiency increase	-1.8	-42	-12.0	-241	-0,5	-21	0.03	0.89
EU options								
Healthier diet	0.2	-6	-1.4	-36	-0,4	-8	0.00	0.18
Substitution of red meat	-0.1	-6	-1.3	-26	-0,4	-5	0.00	0.14
Animal friendly	0.3	-2	-0.4	-5	0,2	-1	0.00	-0.02
Organic	2.2	-1	0.1	-11	-0,6	-4	-0.01	0.09

[1] *Expressed in percentage, in relation to MSA, of the global land surface excluding Greenland and Antarctica.*
[2] *Cumulative CH_4, N_2O and CO_2 emissions from livestock, land use and land-use change between 1990 and 2010.*
[3] *Cumulative CH_4, N_2O and CO_2 emissions from livestock, land use and land-use change between 2010 and 2030.*

farmers and farm workers may be driven further into poverty as a consequence of lower product prices and perhaps fewer on-farm jobs.

– Reducing losses in the food supply chain would decrease food prices and increase food availability. The impacts of reduced losses in the food supply chain would depend greatly on where this reduction would take place (on-farm or further down the supply chain) and whether a region is a net importer or exporter of food. Reducing on-farm losses will have similar effects to improving yields. The potential for reducing on-farm losses is particularly large in developing countries dominated by small-scale farming. Reducing losses further down the supply chain would benefit retailers and/or consumers, while producers would face lower prices for their produce.

It should be stressed that, at the global level, these effects refer to less expansion of production or land use compared to that in the *Reference Scenario*, and not to an actual decrease from that of the current situation.

Table 8.4
Overview of environmental effects of the options analysed by LEITAP-IMAGE

LEITAP-IMAGE	Area of food crops (million hectares)		Grassland / fodder (million hectares)		GHG emissions (Pg CO_2 eq)		Biodiversity (MSA,%[1])	
	EU27+	RoW	EU27+	RoW	EU27+	RoW	EU27+	RoW
Base year (2000) value	139	1,401	80	3,257	13.8[2]	214[2]	1.56	67.7
Reference Scenario (change 2000-2030)	-8.1	308	1.1	501	0.6[3]	57[3]	-0.21	-6.8
Option results (change compared to Reference Scenario)								
Global options								
Low wastage	-1.6	-124	-0.9	-127	-0.3	-40	0.00	0.99
High crop yield increases	-1.3	-127	0.3	-19	0.0	-15	0.01	0.70
Livestock efficiency increases	-0.3	-47	-2.1	-194	0.2	-28	0.00	0.65
EU options								
Healthier diet	2.0	-42	-3.3	-53	-1.7	-20	-0.01	0.32
Substitution of red meat	3.4	-9	-5.2	-28	-1.0	-11	0.00	0.12
Animal friendly	1.1	5	-0.8	1	0.1	-2	0.00	-0.03
Organic	0.3	16	-0.9	1	-0.1	0	0.00	-0.09
-10% animal products	2.6	-13	-2.2	-21	-0.8	-5	-0.01	0.11
-20% animal products	3.1	-23	-3.0	-29	-0.9	-16	-0.01	0.18
-50% animal products	5.7	-47	-4.2	-61	-2.3	-23	-0.01	0.41

[1] *Expressed in percentage, in relation to MSA, of the global land surface excluding Greenland and Antarctica.*
[2] *Cumulative CH_4, N_2O and CO_2 emissions from livestock, land use and land-use change between 1990 and 2010.*
[3] *Cumulative CH_4, N_2O and CO_2 emissions from livestock, land use and land-use change between 2010 and 2030.*

The diversity in effects implies that measures to halt biodiversity loss, enhance access to food and alleviate poverty require a concerted approach. Region-specific accompanying measures would be needed to avoid partial failure in any of these areas, which would eventually undermine progress in the others. For example, substantial reduction in deforestation and expansion of protected areas seems only viable if food availability is enhanced through increased yields and reduced losses. The reverse is also true: there is no incentive to reduce food losses and close yield gaps when land for agriculture is available in abundance (Lobell et al. 2009).

8.7 Plausibility and robustness of results

Limitations of this modelling exercise

The evaluation of the different options has shown that the effects of these options on consumption and production cannot easily be computed, since the whole system is very complex, with many feedbacks. This analysis is helpful to improve our understanding of effects and trade-offs, and for supporting discussions between scientists and policymakers, but uncertainties in models and results need to be kept in mind. This is illustrated to some extent by the differences between the results, using the two agro-economic models (table 8.3 vs table 8.4 and Stehfest et al. 2011). While most of the findings and conclusions as discussed above are supported by both models, significant differences exist between the IMPACT and LEITAP models, in terms of effect sizes and their geographic distribution. Effects of the options relative to the 2000 situation tend to be larger in IMPACT, because changes in the *Reference Scenario* tend to be smaller. For example, the effects on land use in the option *Livestock efficiency increase* in LEITAP (table 8.4) are similar to those in IMPACT (table 8.3), but in IMPACT this results in a decrease in agricultural land use, from the 2000 situation, whereas in LEITAP it means a smaller increase. Other differences are related to how regional markets are connected in the models. For example, according to the IMPACT results from the *Healthier diet* option, much of the reduction in meat and dairy consumption within the EU would be compensated by a larger consumption in other regions. Such leakage effects are much smaller in LEITAP, because LEITAP has calculated that price decreases in the EU Common Market would be insufficient to lead to a substantial decrease in world market prices from which it is shielded. As a consequence, most of the reduction in livestock production would also occur within the EU. Furthermore, the effects of the options depend on the context of the *Reference Scenario* in which they were implemented. For example, effects may change as a consequence of future reform of the EU Common Agricultural Policy (CAP) and conclusion of the WTO Doha round. Future, more in-depth analyses could address both such possible developments as well as intra-European effects by combining the models used in this study with more detailed EU-level models, such as CAPRI (Britz & Witzke 2008).

8.8 Summary and conclusions

- All the options that were expected to reduce agricultural land use as well as greenhouse gas emissions actually did so, according to the model calculations. Global implementation of increased livestock efficiency, and a reduction in food waste, resulted in the largest environmental gains. Of the European options, a shift towards a healthier diet and a reduction in the consumption of animal products had the largest effects.
- Interestingly, for all options implemented at the European level, the environmental benefits outside Europe appeared to be much larger than those within Europe, because EU policies discourage the retraction of agricultural land use, and because

some potentially abandoned grasslands would be used for crop production (including biofuels), according to the model.

- All options that would lead to a reduction in land use also showed a decrease in agricultural commodity prices, with the largest effects for the global options. It should be noted that large investments among other things in infrastructure, innovation and education would be needed to achieve a more efficient crop and livestock production.
- The model results suggest that less than 50% of the theoretical environmental gains would actually be achieved, due to feedbacks in consumption and production. For example, price decreases would lead to an additional increase in consumption on the one hand, and to less efficient production, especially land use, on the other.
- To some extent, these rebounds and leakage effects may benefit other policy targets: lower food prices would mean a better affordability of food and, hence, potentially reduce malnutrition. Extensification of production may also improve local environmental quality.
- However, if such strong rebound effects are to be avoided, additional measures should be taken in parallel.
- This suggests the need for strong potential synergies between the options and more 'classical' measures to prevent the conversion of natural and semi-natural land, and/or to promote the creation of natural and semi-natural conservation areas, including high nature value farmlands.
- While most of the findings and conclusions presented above are supported by both models, significant differences exist between IMPACT and LEITAP, in terms of effect sizes and their geographic distribution. For example, according to the IMPACT results, much of the reduction in meat and dairy consumption within the EU would be compensated by a larger consumption in other regions. Such leakage effects are much smaller in LEITAP, because LEITAP calculated that price decreases in the EU Common Market would be insufficient to lead to a substantial decrease in world market prices from which it is shielded. As a consequence, most of the reduction in livestock production would also occur within the EU.
- Such large differences between results from the two models, which were both employed to develop scenario projections on global land use, show that more extensive model comparisons are useful to gain more insight. In fact, as far as we are aware, this study is the first consistent model comparison of two global agro-economic models.

Notes

1 The annex to this report can be viewed online or downloaded from www.pbl.nl/en.
2 Red meat: beef, sheep, goat, pig and horse. White meat: poultry.
3 Calculations for this option were performed using the LEITAP model only.
4 The net decrease in consumption in non-EU countries shown in figure 8.1 for this option refers to non-food livestock products.
5 The reductions in arable land occur mostly in other OECD countries, the Former Soviet Union and Central and South America; whereas most of the reduction in grassland occurs in Central and South America.
6 A 1% MSA loss is equivalent to a biodiversity loss from a pristine state to zero (100% to 0% quality) in 1% of the global land surface, excluding Greenland and Antarctica, i.e. 1.3 million km2.

NINE

Assembling the pieces of the puzzle

9.1 Introduction

Livestock production and fisheries are currently causing a number of negative effects, such as loss of biodiversity, greenhouse gas emissions, animal welfare issues and human health risks. As a result of the expected increase in global livestock and aquaculture production, global biodiversity loss and emissions of nitrogen and greenhouse gas are projected to increase. A number of opportunities for intervention are identified in chapters 3 to 7 and assessed quantitatively in chapter 8. This chapter focuses on opportunities for reducing adverse impacts that result from the consumption and production of livestock products. Possible improvements in fisheries and aquaculture are also briefly discussed in chapter 6.

This chapter starts with a summary of the points in the food chain for which intervention may be possible, in order to reduce the negative impacts of EU consumption of livestock products, including a number of opportunities per point of intervention (section 9.2). The opportunities have been consequently arranged into three broad strategies (section 9.3). Section 9.4 briefly discusses opportunities and barriers around the implementation of these strategies. Finally, section 9.5 looks into the role that different actors could play in addressing the various challenges. Given the complexity of the 'protein puzzle', this chapter should be regarded as a first exploration of the possible role of actors and institutions.

9.2 Points of intervention and opportunities

The previous chapters have shown that there are many opportunities for reducing biodiversity loss, nitrogen and greenhouse gas emissions, and human health risks, and for improving animal welfare. These opportunities relate to different points of intervention in the causal relationship between consumption, production and negative impacts (see causal diagram in figure 9.1). These opportunities, listed in table 9.1, are presented in the form of possible technical, behavioural or management measures.

All the measures indicated in table 9.1 relate to interventions for reducing the pressures on biodiversity and other environmental and human health impacts. This chapter focuses on a reduction in pressures indicated in figure 9.1. Not included are options for reducing impacts directly, such as the physical protection of natural areas (see PBL 2010) or 'end of pipe' solutions such as purification of drinking water.

9.3 Three strategies to reduce impacts

What would be needed to convert these opportunities into actions? Why is this not happening yet, or not everywhere? Grouping the opportunities into three strategies provides a structure for answering these questions:

1. Consuming less or different animal products.
2. Increasing resource efficiency.
3. Producing with fewer local impacts.

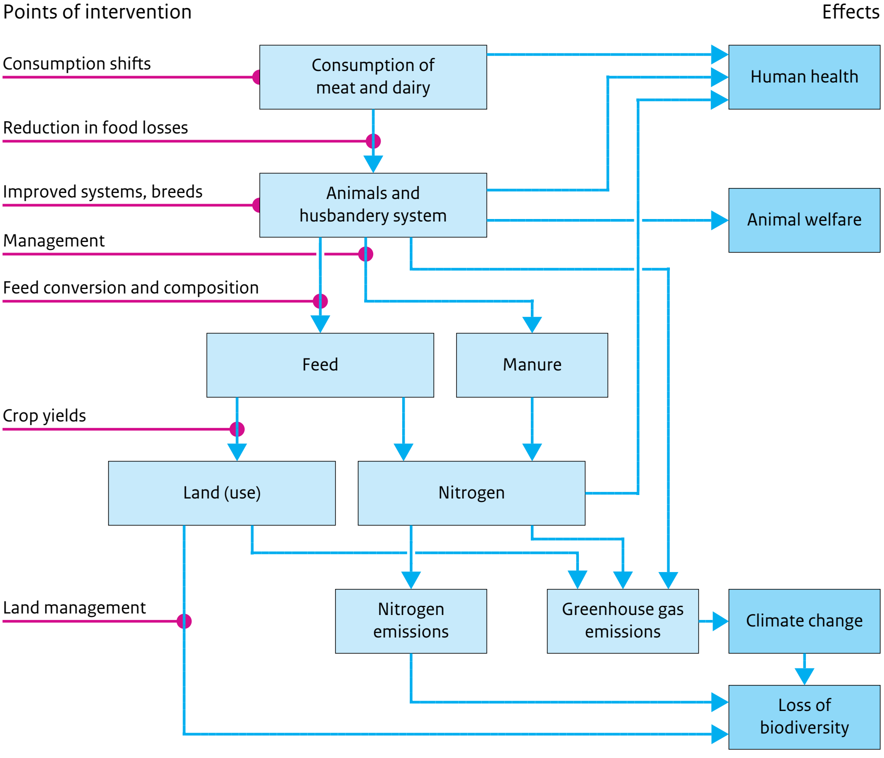
Table 9.1 shows the link between the different opportunities and the strategies they could be part of. It should be emphasised that these strategies are not mutually exclusive. In fact, they largely complement each another.

Consuming less or different animal products
Consuming less animal products would reduce the size of livestock production, which in turn would lead to lower environmental pressure. This strategy also includes a shift towards products that are produced in a more animal-friendly manner or that are less environmentally harmful. In general, this strategy would lead to human health benefits, since many animal products also contain high levels of saturated fats.

Increasing resource efficiency
More efficient use of various resources such as land and water, and inputs such as nitrogen and phosphate, generally would lead to a reduction in emissions and in land area needed. Examples of opportunities that fall within this strategy are higher yields per hectare, higher feed efficiency, improved management of manure and fertilisers and reduced losses in the food chain.

Figure 9.1

Causal diagram of effects of meat and dairy consumption and points of intervention



Causal diagram, showing how consumption of meat and dairy products results in various negative effects, and points of intervention for reducing these effects.

Producing with fewer local impacts

This strategy focuses on mitigating local impacts. Main objectives are animal welfare, achieving robust livestock farming, reducing local environmental impacts and reducing animal and human health risks. Examples of opportunities that fall within this strategy are improved animal housing systems, improved breeds and improved land management. Organic farming also falls within this strategy, as do many other farming systems.

Relations between the strategies

The strategy for reducing meat and dairy consumption would consequentially lead to an increase in resource efficiency, as well as to a reduction in local environmental impacts. It is therefore a robust strategy for reducing these impacts.

Table 9.1

Examples of opportunities for mitigating negative impacts associated with livestock

Point of intervention (chapter)	Examples of opportunities	Related to strategy
Consumption shifts (3, 8)	- Reduction in the consumption of meat, dairy and fish; - Shift towards animal products with lower impacts, such as from red meats to poultry.	*Consuming less*
Reduction in food losses (3, 4, 8)	- Reduction in post-harvest, transport and storage losses, processing losses and losses relating to retail, catering and domestic uses; - Using certain types of bone meal as feed.	*Increase resource efficiency*
Improved animal husbandry systems; improved breeds (5)	- Adapting housing systems, either by modifying existing housing systems or by developing innovative housing systems; - Developing and introducing more robust and more 'amiable' breeds; - Reducing the use of antibiotics and implementing preventive measures.	*Reduce local impacts*
Improved feed conversion and animal diets (5, 8)	- Reducing feed use per kilogram of product through better management; - Optimising feed or digestion, especially for ruminants; - Enhancing the use of by-products and wastes; - Reducing the protein content of animal feed; - Measures to improve animal health.	*Increase resource efficiency*
Higher crop yields (8)	- Better crop management, such as weed and pest control, and the use of local manure and compost; - Developing higher yielding varieties, especially of legumes; - Higher inputs of fertilisers, pesticides and labour; - Improving pest management and nutrient management; - Increasing yields of protein-rich crops in Europe.	*Increase resource efficiency*
Improved land management (5)	- Preventing the conversion of grasslands into arable land, reducing emissions from draining peatland; - Increasing landscape quality and species diversity; - Restoring degraded land (due to erosion or overgrazing); - Mitigating the environmental and socio-economic effects of soy cultivation.	*Reduce local impacts*
Improved management of nutrients from animal manure and artificial fertilisers (5)	- Improving management of manure application (quantity, timing and spreading method); - Improving management of total nitrogen supply (combination of manure and fertilisers); - Soil and water conservation measures; - Improving management to enhance soil health, and maximise soil volume explored by plant roots; - Prevention of high regional concentrations of livestock.	*Increase resource efficiency, Reduce local impacts*

The examples are given at the different points of intervention (see figure 9.1), indicating the chapter that discusses the intervention, and the strategy to which the opportunities are related (section 9.3).

A strategy aimed at increasing resource efficiency, but biased to only one or a few resources, might lead to adverse local impacts, for instance, it may lead to biodiversity loss and high emissions of nitrate in regions with high production levels. The benefit of this strategy, however, is that less land and resources would be required, globally, so other areas might be saved from being converted into agricultural land (chapter 8).

Although the *Producing with fewer local impacts* strategy would lead to a better local environment, and improved animal welfare and better health conditions, this might be at the expense of a less efficient use of resources, both at the European and the global level. Examples would be poorer feed efficiencies associated with increased animal welfare, lower yields per hectare if nitrogen losses would be greatly reduced or when a large area of land were to be reserved for ecological set-aside.

Within the constraints of the 'fewer local impacts' strategy, farmers tend to strive for optimum efficiency, but this would never reach the level of the most efficient systems.

9.4 From strategy to practice

How can the strategies described above be implemented in practice? What are the incentives for farmers and consumers? What are the barriers? These questions have been addressed for each strategy.

Consuming less or different animal products
A shift in consumption in the EU to less or other animal products depends very much on the willingness of consumers. Dietary and consumption patterns are often deep-rooted and partly culturally determined. However, consumer patterns can change significantly over a longer period of time (chapter 3). There are indications that an increasingly large group of consumers is prepared to eat less or no meat for one or more days per week (De Bakker & Dagevos 2010). In addition to consumer demand, the range of products on offer also plays an important role. This implies that retailers are in a position to influence consumer choice with an animal- and environment-friendly assortment in their shops.

In case of animal-friendly products or those produced with less local impact, the large price difference with conventional products may form a barrier. Consumers often experience the 'social dilemma' of knowing that if they buy such a 'better' product – which is more expensive than its 'not so friendly' counterpart – this will only be effective if many other consumers do the same.

Increasing resource efficiency
Increasing resource efficiency contributes to the underlying principles of the availability of sufficient food and at a reasonable price, being two of the objectives of the Common Agricultural Policy. The success of this EU policy has enabled the EU to be more or less

self-sufficient since the 1980s (chapter 4), and in fact many agricultural products are now over-produced. The European food market is a saturated market and competition takes place mainly on prices. Farmers need to keep their cost price low if they are to maintain a reasonable income. Cost price reduction is also a ‘natural’ incentive for farmers to improve resource efficiency.

Resource efficiency, in general, has greatly improved in the EU over recent decades. For example, crop yields have increased markedly in many regions, and feed conversion has also much improved. Opportunities for further increases in resource efficiency are limited in many EU countries and on many farms. Actual yields of wheat, for example, are already close to current potential (chapter 8). However, there are still opportunities for increasing resource efficiency in some Member States, and certainly also on farm level. The ability to exploit this potential requires access to modern production resources (machinery, modern housing systems and improved breeds) as well as to knowledge and management skills.

At the global level there is more scope to increase resource efficiency. As indicated by the model results (chapter 8), options for improving resource use on a global scale, by improving yields and feed conversion, would lead to a significant reduction in additional land area for agricultural use, in reductions in greenhouse gas and nitrogen emissions, and less biodiversity loss. Commodity prices would also be lower compared to the *Reference Scenario*. Therefore, implementing these options, at least in theory, would not only reduce negative environmental impacts, but also improve food security.

There are also risks associated with improved efficiency. In particular, because it tends to be biased towards private resources, such as land, labour and capital, whereas there are few incentives for the efficient use of public resources, such as air, surface water and biological diversity. In addition, breeding from a small genetic base may make the livestock population susceptible to epidemics. The same applies to strong specialisation in certain crops. More generally, a disproportionate focus on continued resource efficiency would result in a system that is increasingly susceptible to external influences, whether price increases of inputs, competition over land related to biofuels, animal disease outbreaks, or stagnating soy imports from South America due to poor harvests or geopolitical considerations (LIS 2011).

Producing with fewer local impacts

An unbalanced focus on resource efficiency would results not only in a more vulnerable system, which eventually undermines its productivity, but also in negative external effects, such as decreasing animal welfare and loss of biodiversity and landscape qualities. There are therefore several reasons for trying to achieve a more robust livestock production system with a wider focus than economic efficiency alone (e.g. see Star et al. 2009; Van der Veen 2009). This focus, however, for the large part is deeply ingrained in the current food production system (Van der Ploeg 2001).

Agreements made in the Common Agricultural Policy and within the framework of global trade agreements (WTO) encourage competition over cost price, while the incentives to reduce the negative external effects are rather limited because of the weak structure of multilateral environmental agreements (WTO 1999). Improvements in animal welfare, local biodiversity and landscape qualities generally result in higher costs for farmers. In some cases related to, for instance, local produce or organic products, farmers do succeed in receiving higher prices for their products. In most cases, however, consumers are not prepared to pay more if cheaper alternatives remain available. Therefore, often it is not in farmers' own interest to reduce non-price-related effects and to shift to more robust production methods. A vital question is how conditions could be created to change this setting.

9.5 Addressing the challenges

How could the negative environmental impacts of the EU consumption of livestock products be reduced, and animal welfare be improved, taking into account the global context of the EU food system and effects of changes within the EU on other regions? How could food availability be improved on a global scale, while limiting the additional biodiversity loss and emissions of greenhouse gases and nitrogen?

Pivotal role of EU policies in EU production and consumption of food
On both the global and European scale, many opportunities exist for reducing the impacts from livestock farming and fisheries. The three strategies and relations between these strategies have been discussed above. In general, EU policies such as the CAP have led to a strong increase in food production and lower food prices. WTO agreements have further encouraged this competition in order to reduce production costs. By and large, EU and WTO policies have been focused on the second strategy, being the efficient use of resources whether on a European or a global scale. With regard to the first strategy (*Consuming less or different animal products*), national, European and global policies are practically non-existent. With regard to the third strategy (*Producing with fewer local impacts*) policies do exist, but are mostly secondary to free market policies.

With regard to the first and third strategy, the question is whether the EU and WTO will eventually play their pivotal roles as they do with regard to the second strategy. Given the large influence of EU policies on EU agricultural and fisheries sectors, the EU could play a key role. The current reform of both the Common Agricultural Policy and the Common Fisheries Policy creates opportunities. The production and consumption of food could also play an important part in the Flagship Initiative Resource Efficient Europe. The various ways in which EU policies could influence the production and consumption of meat, dairy and fish include the internalisation of externalities ('getting the prices right'). This would not only involve taxing resources or emissions, but also targeted payments for the delivery of public goods. Other policy instruments are legislation (with respect to environment, food quality and animal welfare) and the encouragement of innovations and behavioural changes. The latter may also include engagement with stakeholder initiatives, as discussed below.

Actors in the food chain may act independently from governments

Actors in the food chain, such as farmers, retailers and consumers, have many opportunities to put these strategies into practice, independently from EU and national policy efforts. Consumers could shift to purchasing products with lower impacts on environmental or animal welfare, while maintaining a balanced diet. However, consumers will only do so when they are well informed by food companies and retailers, and when there are real choices to be made. The fact that 'sustainable' diets are generally healthier as well, may serve as a convincing selling point. Retailers could enlarge their product range, and include animal products that are produced under higher standards, and products to substitute meat and fish. In addition, retailers could cooperate with farmers and food suppliers to develop new labels and improve production techniques. Actors in the food chain could initiate and implement changes ahead of the international institutional changes.

At global scale much to be gained through improved resource use, but targeted approach needed

At the global scale, especially in developing countries, there is the major challenge of improving food security, while limiting local and global environmental impacts. The development of agriculture is vital to reduce poverty in rural areas (IAASTD 2009; World Bank 2007). Food security and the global environment, in theory, could benefit from improved efficiency, such as higher yields. However, increased food production alone will not guarantee improved food security. To reduce hunger and malnutrition, a more targeted, pro-poor approach would be needed, based on the local physical and socio-economic conditions. In support of such an approach, investments in rural infrastructure, education, inputs and agricultural innovations would be necessary (IAASTD 2009). Institutional changes would also be essential, partly at a global level and at a national or regional levels, including equal access to production factors.

Scope for increasing food and protein availability while limiting impacts

The 'protein puzzle' is not easy to solve, and many question remain unanswered; with respect to more technical issues as well as regarding changes in the institutional setting. Human consumption will always have an impact on the environment, but there is considerable scope for increasing food and protein availability while limiting impacts on biodiversity, climate, animal welfare, and animal and human health.

Farmers and other actors in the food chain, to date, have largely been driven in the direction of cost price reduction and production increases. This direction has generally resulted in an efficient livestock production, but often with negative impacts on non-priced aspects, such as the environment and animal welfare. Current policies and institutional settings hardly support other strategies, such as those to reduce consumption of meat, dairy and fish, or to reduce local impacts.

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The choices we make in what we eat do not only influence our own health, they also have a large impact on the environment. The present European consumption of meat, dairy and fish leads to various environmental and health problems. At a global level, the expected increases in population and wealth lead to strong growth in food demand, leading to higher nitrogen and greenhouse gas emissions and additional biodiversity loss.

This report analyses the current situation in the EU. Furthermore, it presents the effects of various options and strategies to reduce the environmental impacts of consumption and production of meat, dairy and fish. These strategies range from reducing consumption, via increasing efficiency to improving animal welfare and reducing local environmental impacts.

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