# Meat Production & Consumption (in Europe) and Public Health

An exploration

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# Executive summary

The **role of meat production and consumption** features prominently in debates about the future of food. Health is also increasingly central in thinking about food and food systems reform. This paper offers an attempt to disentangle the most distinctive connections between current levels of meat production (animal farming) and consumption in Europe and public health. In doing so, it intends to foster debate and contribute to a richer understanding about the links between food systems and health.

The connections between meat and health are explored on the basis of **eight 'food-health' dimensions**. While focusing on health impacts in Europe, global health implications will be referred to as well. This exploration draws on a collection of reputable sources, but is not a systematic literature review and not exhaustive.

- **Nutrition**. Good nutrition is key for health and well-being. Meat, both red and white, is highly nutritious and can provide an important contribution to adequate nutrient intake, which is especially consequential during sensitive stages of life, such as early childhood, youth and pregnancy.

  At the same time, high consumption of red, and especially processed meat, has been associated with a range of negative health impacts. According to estimates, high red and processed meat consumption may contribute to 2.7% of the burden of disease, and 3.8% of all premature deaths in the European Union (EU) in 2019. A reduction in average meat intake in high-consuming regions, such as Europe, when achieved as part of a diverse and nutritious diet, can lead to health and environmental benefits, and may support global health and food security.

- **Zoonotic diseases**. Zoonotic diseases are infectious diseases transferred from non-human animals to humans. 75% of new or emerging infectious diseases are of zoonotic origin. Animal foods are responsible for most food safety outbreaks in Europe. At the same time, high-density animal farming systems can act as 'laboratories' for new non-food borne zoonotic diseases and increase the risk of severe contamination events. Agricultural drivers, such as biodiversity loss, have been associated with over 50% of zoonotic infectious diseases in humans globally since 1940.

- **Antimicrobial resistance** (AMR). AMR, or drug resistance, arises when microorganisms, such as bacteria, change over time and stop responding to medicines. AMR threatens the effective treatment of infections and endangers critical healthcare interventions, from surgeries to chemotherapy. Resistance to antibiotics is becoming more widespread, currently killing at least 33,000 people in Europe each year. Left unaddressed, 10 million people may die of AMR globally by 2050. Antibiotics overuse in human medicine, which is probably the main cause, and in high-density animal farming systems are main contributors to drug resistance.

- **Air pollution**. Air pollution is Europe's leading environmental health risk. Among pollutants, Particulate Matter ($PM_{2.5}$) pollution stands out, with nearly 380,000 premature deaths attributed in Europe in 2018. Ammonia (NH3) contributes to the formation of $PM_{2.5}$. Over 90% of NH3 in Europe is emitted by agriculture, with animal farming responsible for the main share. Estimates vary, but some find NH3 to be the largest relative contributor to $PM_{2.5}$ formation in Europe.

- **Climate change**. Climate change is already impacting Europe and contributing to its burden of disease, including through heat-related deaths, floods, infectious diseases, allergies and mental ill-health. Dependent on the extent of further warming and the adaptation measures taken, future impacts may be incomparably greater, deeply affecting natural conditions and social dynamics, with major repercussions for health and well-being.

  Global food systems account for 21-37% of total greenhouse gas emissions. The impact of meat and other animal foods stands out, being responsible for 14.5% of all emissions. It was found that even if all non–food system greenhouse gas emissions were immediately ended, emissions from the current global food system alone would probably exceed 1.5°C warming.

- **Nature and biodiversity**. The concept of 'planetary health' is based on the realisation that human health and human civilisation depend on flourishing natural systems. Nature and biodiversity shape numerous critical ecosystem services, including the availability and quality of water, food security, climate regulation, flood defence, the incidence of (non-)communicable diseases, availability of medicinal products and mental health.

  Today, both Europe and the world are experiencing an enormous decline in biodiversity. Agriculture, with a considerable role for animal farming, is likely the single largest driver of global biodiversity loss and degradation. Agriculture is, for instance, responsible for 75% of global deforestation, while the import of animal feed is a main source of Europe's imported deforestation. Animal production was found to be the main contributor to agriculture's role in terrestrial biodiversity loss in Europe, and the main source of nitrogen emissions to water bodies. Nitrates in drinking water continue to pose health risks. At the same time, extensively managed permanent grasslands with grazing ruminants can contribute to biodiversity benefits in Europe, including pollination.

- **Occupational conditions**. Work in food and agriculture can be highly satisfying and part of a cherished socio-cultural identity and 'way of life'. It is also a hazardous set of professions with significant risks related to the exposure to agrochemicals, musculoskeletal disorders, respiratory disease, exposure to infectious agents, risk of AMR, mental ill-health and with often precarious conditions for food workers. While agriculture is one of the professions most prone to non-communicable diseases, growing-up on a farm is also associated with lower asthma and allergies.

- **Socio-economic factors**. The 'social determinants of health' encompass a wide range of socio-economic factors, such as levels of income, social protection, education, employment, housing, gender and socio-cultural status. Social factors strongly influence health outcomes: people exposed to socio-economic vulnerabilities are disproportionately burdened by ill-health.

  In the EU today, 20% of people are at risk of poverty or social exclusion, and 11% unable to afford a nutritious meal every second day. Differences in socio-economic status have been linked to differences in consumption patterns of animal source foods. Meat consumption is furthermore deeply interwoven with a complex set of cultural contexts and identities.

  Work in agriculture and the food chain supports millions of livelihoods in Europe, providing employment, income and social status. Animal production represents around 40% of the European food economy. However, income and socio-economic inequalities, declining employment and farm numbers, occupational risks and mental ill-health impair the full contribution that animal farming-related professions can make to social well-being. Moreover, low wages and unattractive working conditions have been reported in slaughterhouses.

The comprehensive understanding of the links between food and health explored in this paper, lends further force to the perspective that **significant public health benefits** can be had, including globally, from a reconfiguration of the European animal food production and meat consumption system.

At the same time, this exploration also suggests that strategies to enhance the healthfulness of food systems should formulate an answer to different 'food-health' dimensions. This involves designing pathways that maximise multiple health benefits at once. Such pathways can be inspired by the rich literature describing possible **'co-benefits' of a sustainable food systems transition**. While focused on maximising benefits, trade-offs need to be recognised and adequately dealt with.

Despite improvements in the understanding of health risk factors and the availability of a fair amount of data, attributing health impacts and burdens of disease to food systems remains difficult. **Health metrics** tend to have a narrow focus on morbidity, mortality and disability and may fail to capture the full breadth of complex interlinkages. Better data, metrics and ways to communicate (potential) health risks and benefits are needed. Otherwise, both current and future health impacts linked to food systems may remain underappreciated.

# Introduction and aim

There is increasing consensus that the European food system is not sustainable and needs a transformation.[1] The role of **meat production and consumption** has become a central feature of this debate. While there are many facets to a sustainable transition, the 'meat production and consumption nexus' stands out as a sub-component of the food system that disproportionality affects multiple sustainability dimensions.[2] It is also among the most contested topics in debates about the future of food.

**Health** is also increasingly prominent in thinking about food and food systems reform. People often perceive their personal relationship with food in health-terms.[3] Frequently however, the connection between food and health is rather narrowly understood with a focus on nutrition and food safety. This while food systems also impact public health in many other ways.[4] [5]

While concepts such as 'One Health' and 'Planetary Health' have helped widen the understanding of the links between food and health, a need remains to further explore these connections and unpack them in both a comprehensive and user-friendly way. This paper aims to contribute to a **richer and more compelling understanding** of the links between animal farming, meat consumption and human well-being.

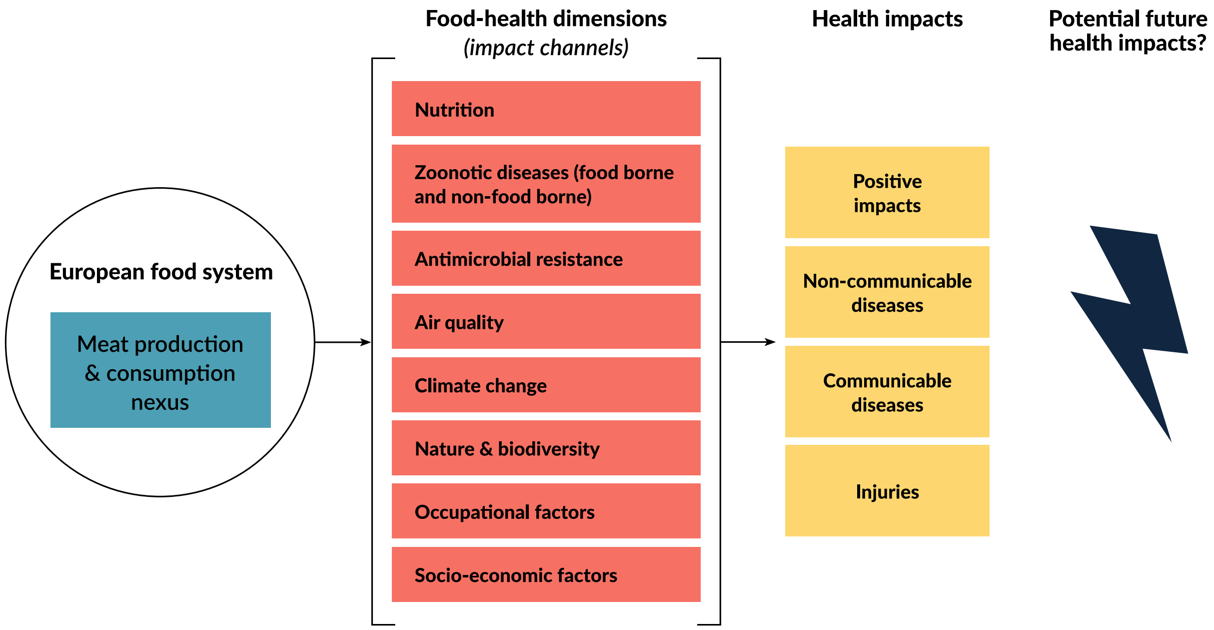
More specifically, this paper offers an attempt to **disentangle the most distinctive links between current levels of meat production (animal farming) and consumption in Europe and public health**. In doing so, it reflects on related health impacts where data is available.

This paper is by no means exhaustive and **not a systematic literature review**. While aiming to be balanced, it **sets out a vision on the topic** drawing on a collection of reputable sources, especially academic papers, systematic reviews, modelling studies, as well as reports by national, European and international agencies. In doing so, it **intends to inform, foster debate** and to empower new perspectives and actors to contribute to a sustainable food systems transition.

# Conceptual framework & limitations

For the purposes of this paper, the relationships between the **European 'meat production and consumption nexus'** – understood as the interactions within food systems that relate to the production (animal agriculture) and consumption of meat – and health are conceptualised in the following figure.

*Figure 1: Conceptual framework of the links between meat production and consumption in Europe and public health.*




*The relation between health and the meat production and consumption nexus, which is seen as a sub-system of the wider European food system, is described on the basis of eight 'food-health' dimensions. These dimensions act as the 'impact channels' on health. Health impacts are seen to manifest either as positive, or as non-communicable diseases (NCDs), communicable diseases and injuries. The paper also reflects on potential future health impacts where any indications are found in the literature. The future health impacts section is mainly meant to reflect on whether a change in the magnitude of health impacts could be expected in the future.*

This paper focuses on the **European food system**, referring to the overall context and data covering the European Union (EU) and the United Kingdom (UK). Most of the data presented for the EU covers the UK as well. However, given the UK is no longer part of the EU, the wider term 'Europe' will be used in most instances. If the data refers to the World Health Organization (WHO) European Region, which includes 53 countries in Europe and Central Asia, or the European Economic Area (EEA) this will be pointed out. Where possible and relevant, the paper also seeks to provide illustrations for three priority countries individually, namely France, Germany and the UK.

Depending on the food-health dimension, **different stages of the food system** will be covered, mainly reflecting on the stage of the food system (from production to disposal) where the role of meat especially stands out in terms of health relevance. In the course of the discussion, the paper will point out specifically which stage(s) of the food system is described to ensure transparency. Likewise, it is often unfeasible to single out the contribution of meat specifically. Therefore, in most cases production data will cover animal farming as a whole, including dairy and eggs.

In presenting descriptions and quantifications, the paper refers to current aggregate impacts of meat production and consumption in Europe. It does **not distinguish between different production models or different modes of consumption**. It also does not refer to possible alternative production and consumption scenarios, while recognising that these can produce very different impacts. While focusing on health impacts in Europe, global health implications will be highlighted as well.

This paper does **not provide a quantified assessment of the overall health impact of meat production and consumption**. Many uncertainties remain about the exact contribution of animal production and consumption to different dimensions of health, burden of disease data may be missiong, and questions about association and causality can be raised.[6] Furthermore, while this paper follows a broad definition of health as being a 'state of complete physical, mental and social well-being', most studies focus on more narrow health impacts only, for instance related to cardiovascular health, or injury, or cancer risk reduction. Attempts to overcome these barriers are useful, but outside the scope of the current exercise.

## Key terms and definitions

- **Health**: a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.[7]

- **Risk factor**: risk factors are any attribute, characteristic or exposure of an individual that increases the likelihood of developing a disease or incurring an injury.[8]

- **Burden of disease**: the burden of disease is a measure of the gap between current health status and an ideal situation in which everyone lives into old age, free from disease and disability. The disease burden tends to be expressed in disability-adjusted life-years (DALYs).[9]

- **Disability-adjusted life-years (DALYs)**: one DALY represents the loss of the equivalent of one year of full health. DALYs for a disease or health condition are the sum of the years of life lost to due to premature mortality (YLLs) and the years lived with a disability (YLDs) due to prevalent cases of the disease or health condition in a population.[10]

- **Premature deaths**: deaths that occur before a person reaches an expected age. This expected age is typically the life expectancy for a country, stratified by sex. Premature deaths are considered preventable if their cause can be eliminated.[9]

- **Noncommunicable diseases (NCDs)**: also known as chronic diseases, tend to be of long duration and are the result of a combination of genetic, physiological, environmental and behaviours factors. NCDs are not passed from person to person.[11] In the EU, NCDs are responsible for over 90% of mortality and over 85% of the burden of disease.[12]

  The main types of NCDs are cardiovascular diseases (like heart attacks and stroke), cancers, chronic respiratory diseases (such as chronic obstructive pulmonary disease and asthma) and diabetes. They also include a wide range of other conditions, for instance related to the liver, kidneys and mental health issues.

  Overweight and obesity are usually described as risk factors to NCDs, although obesity is increasingly recognised as an NCD itself.

- **Injuries**: include a range of harms caused by occurrences such as road traffic accidents, poisonings, falls, fire, heat, drownings, violence and self-harm.[13]

- **Communicable diseases**: a communicable (or infectious) disease is an illness due to the transmission of a specific infectious agent (or its toxic products) from an infected person, animal or inanimate source to a susceptible host, either directly or indirectly.[14] These include diseases such as cholera, hepatitis, influenza, malaria, measles, or tuberculosis.

- **Association** (in epidemiology): a statistical relationship between two or more events, characteristics or other variables, such as an association between exposure to X and a health effect Y, which may not imply cause and effect.[15]

- **Causality**: the relating of causes to the effects they produce.[16]

- **Food system**: the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal and natural environments in which they are embedded.[17]

- **Red meat**: refers to unprocessed mammalian muscle meat, including beef, veal, pork, lamb, mutton, horse or goat meat, including minced or frozen meat. [18]

- **White meat**: refers to poultry, including chicken, hen, turkey, duck, goose, unclassified poultry, and rabbit.[18]

- **Processed meat**: refers to meat that has been transformed through salting, curing, fermentation, smoking or other processes to enhance flavour or improve preservation- processed meat can consist of beef, pork, poultry, offal or meat by-products such as blood.[18] Products include sausages, bacon, ham, salami, pâtés, canned meat such as corned beef, sliced luncheon meats.[19]

- **Ruminant**: an herbivorous, even-toed, hoofed mammal that has a complex 3- or 4-chambered stomach, including bovines, sheep and goats.[20]

- **Granivore** (in agriculture): farm animals that eat seeds as the main part of the diet, including poultry and pigs.

# 1. Meat production and consumption in Europe and public health

## I. Nutrition

This section explores some of the key relationships between nutrition, diet, health and meat consumption. Recognising the complex and multi-dimensional nature of interactions, this section does not pretend to solve any of the outstanding questions, but to point at relevant considerations. The discussion focuses on the food systems dimension of consumption.

### Nutrition, diet and health

**Nutrition** is the process of taking in food and using it for growth, metabolism, and repair.[21] A **diet** refers to the kinds of food that a person habitually eats. A **healthy diet** helps protect against malnutrition in all its forms.[22]

- A healthy diet has been **defined** as being "of adequate quantity and quality to achieve optimal growth and development of all individuals and support functioning and physical, mental and social wellbeing at all life stages and physiological needs. Healthy diets are safe, diverse, balanced, and based on nutritious foods."[23]

**Malnutrition** refers to deficiencies, excesses, or imbalances in a person's intake of energy and/or nutrients. The term malnutrition addresses three broad groups of conditions:[24]

- Undernutrition – which includes wasting, stunting and underweight;
- Micronutrient-related malnutrition – which includes micronutrient deficiencies or micronutrient excess;
- Overweight, obesity and diet-related non-communicable diseases (NCDs).

While the exact make-up of a **healthy diet** can vary, it should include at least:

- Appropriate energy intake – dependent on age, sex, activity levels and body mass;
- Balanced macronutrient intake – including proteins, carbohydrates (such as sugars, starches and fibres) and fats;
- Adequate micronutrient intake – vitamins and minerals.

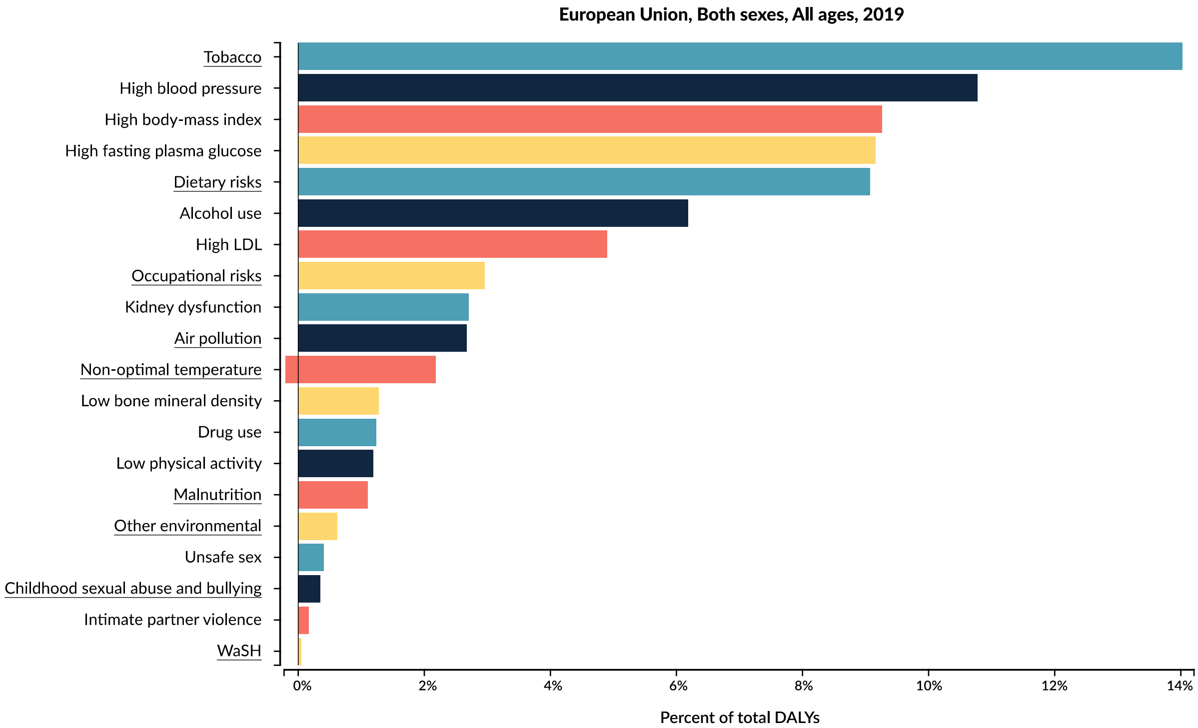
The World Health Organisation (WHO), based on recommendations by the Nutrition Guidance Expert Advisory Group (NUGAG),[25] describes the **building blocks for a healthy diet**,[22] which include:

- At least 400g of fruit and vegetables per day;
- Less than 30% of total energy intake from fats (saturated fat intake should be less than 10% of total energy intake, and intake of trans-fats less than 1% of total energy intake, with a preferrable shift in fat intake towards unsaturated fats and the goal of eliminating intake of industrially-produced trans-fats);
- Less than 10% of total energy intake from free sugars, with a further reduction to less than 5% of total energy intake suggested for additional health benefits;
- Less than 5g of salt per day.

**Dietary reference values** provide recommendations on the amounts of energy and different macro- and micro nutrients that should be regularly consumed by healthy individuals to maintain health. Reference values are adopted at global,[26] [27] European,[28] and national levels.[29] [30] [31]

Suboptimal diet, or **unhealthy diet**, is the leading driver for global morbidity and mortality.[32] It is also a main underlying cause for Europe's burden of disease, contributing to 950,000 deaths and over 16 million disability adjusted live years (DALYs) in the European Union in 2017.[33]

*Figure 2: Risk factors for the global burden of disease, European Union, all ages, 2019, in DALYs.*




*Source: Institute for Health Metrics and Evaluation.[34] Unhealthy diet is a main risk factor for the burden of disease in the EU. It should be noted that unhealthy diet as risk factor is present in several of the top 10 risk factors, not only in 'Dietary risks'. This including 'High blood pressure', 'High body-mass index', 'High fasting plasma glucose', 'High LDL', Kidney disfunction'. Used with permission. All rights reserved. (image re-drawn from original)*

The excessive consumption of energy, saturated fats, trans fats, sugar and salt, as well as low consumption of vegetables, fruits and whole grains are **leading risk factors for the burden of diet-related conditions** in Europe.[35]

**Foods and drinks high in fat, sugar and salt** (HFSS), or so-called 'energy-dense, nutrient-poor' foods, have for many years been the focus of attention in nutrition policies. **Ultra-processed foods** (UPFs) are an emerging category of potential concern. UPFs are highly processed foods that may pose health concerns related to the type and extent of processing, potentially independent of their nutrient composition.[36 37]

There is common agreement in public health literature that food choices and nutritional outcomes are shaped by **food environments**, which are the "physical, economic, political and socio-cultural context in which consumers engage with the food system to make their decisions about acquiring, preparing and consuming food".[38]

- Current food environments are considered to be unhealthy and to "exploit people's biological, psychological, social, and economic vulnerabilities, making it easier for them to eat unhealthy foods".[39] This in turn reinforces preferences and demands for foods of poor nutritional quality, furthering the unhealthy food environments.

Across Europe there is significant evidence of **lower intakes of various micronutrients than the recommended levels**.[40] These include vitamins C, D and B12, calcium, folate, iron, iodine and anti-oxidants. Deficiencies **may or may not have adverse health effects**, depending on the importance of the micronutrient not adequately supplied at a certain stage of the life cycle.[41] Overall, there is insufficient research on the effects of lower than recommended micronutrient intake before the occurrence of clinical symptoms.

As further discussed in section VIII below, the burden of ill-health in Europe tends to fall disproportionately on people exposed to **socio-economic vulnerabilities**. Consumption patterns associated with poor diet, as well as diet-related NCDs are far more prevalent among people from lower socio-economic status groups.

Globally, according to the recent State of Food Security and Nutrition in the World (SOFI) report, the **world is not on track to end hunger and malnutrition** in all its forms by 2030. This trend has been further exacerbated by the disruptions brought by the COVID-19 pandemic. In 2020, 118 million more people were suffering from hunger than in 2019.[42] Conflict, climate change and economic factors are identified as the main drivers negatively affecting food and nutrition security. These drivers are often interrelated and tend to be on the increase in both frequency and severity.

At the same time as hunger is on the rise, a **'nutrition transition'** is taking place across many regions of the world. The nutrition transition is characterised by the fast uptake of highly processed foods, breastmilk substitutes and animal source foods, coupled with an insufficient increases in the consumption of vegetables, fruits and nuts.[43] The nutrition transition is associated with a shift from undernutrition-related diseases, towards non-communicable diseases such as cardiovascular disease, type 2 diabetes and obesity.

The creation of enabling food environments that promote healthy and environmentally-friendly diets is often identified as one of the answers to global food systems challenges.[42] However, for many people living in poverty or on low incomes, such diets may not be **affordable**, posing a major barrier for their uptake.

- One global study estimated that the most affordable nutritionally adequate diet still **costs 2.66 times more** than a diet which is adequate in energy alone.[44]
- Another similar study finds that while a planetary healthy diet may be accessible for many people in high income countries, its cost was found to **exceed household per capita income for at least 1.58 billion people** across the globe. To address this, the study recommends a combination of measures to increase incomes, provide nutritional assistance and lower the prices of nutritious foods.[45]

## The role of meat in nutrition

The relationship between meat, and other animal foods, and healthy nutrition is **complex and multi-dimensional**. It is moreover closely linked to the context in which the relation is embedded.[46]

Meat, both red and white, including organs such as the liver, is **highly nutritious**.[47] Furthermore, and importantly, meat provides a **bioavailable** source of nutrients, meaning that a high fraction of the nutrients contained are absorbed and utilised.[48] [49] Both red and white meat are **included as part of dietary guidelines** of all EU countries and the UK.[50]

- Meat is a good source of **macronutrients**, providing **high quality protein** and a variety of fats (including omega-3 polyunsaturated fatty acids), and is rich in energy.
- Meat also provides a wide range of **micronutrients**, such as iron, zinc, selenium, phosphorus, vitamin A and B-complex vitamins, including thiamine, riboflavin, niacin, biotin, vitamins B6 and B12, pantothenic acid and folacin. A number of these nutrients have been identified as being in short supply in the diets of some population groups.[49]
- Different animal feeding regimes have been linked to differences in the **nutritional profiles of meat** and dairy products. Products from grass-fed ruminants and wild animals are generally associated

with better profiles.[5 51 52 53 54] At the same time, the health effects of such differences on overall nutrition remain unclear.

While meat is an excellent source of nutrients, evidence strongly suggests that the **diet of an average adult does not *have* to contain meat to provide healthy nutrition**. The nutritional importance of any particular food in the diet will depend upon what else is, or is not eaten. As long as available and accessible, there are, in principle, ample opportunities in Europe to provide the necessary nutrients through a combination of plant and other animal source foods.[55] This potentially with the help of supplementation, although its effects can be ambiguous.[56]

- For instance, despite the lower protein quality of individual plant-based foods, combinations of different plant proteins can ensure a **high dietary protein quality**.[57 58]
- There is significant evidence about the overall adequacy and, for different health indicators, benefits associated with **vegetarian diets**.[59 60 61]
- Research on **vegan diets**, which exclude all animal source foods, is more recent. It is often argued that more research may be required on longer-term effects. While a number of potential protective qualities have been described for different health indicators,[62 63] findings also suggest that avoiding nutritional inadequacies can be a challenge and that careful planning is required.[64 65]

**Infants, children and adolescents**, **pregnant and breastfeeding women and women of child bearing age,** as well as **seniors** are among the population groups with special nutritional needs, often requiring increased intakes of different macro- and micro nutrients. Poor nutrition during childhood can lead to long-term consequences for development and health.[46] There is strong evidence that suboptimal maternal nutrition can have **transgenerational effects**, increasing the susceptibility to chronic diseases in offspring.[41]

The implications of these findings for the levels of intake of meat and other animal foods in sensitive population groups are described differently across sources.[49 66 67 68 69 70] A **precautionary approach** may be required while further research is pending.

Moreover, several areas relevant to the discussion about animal foods and health remain underexplored, such as the effects of diets without meat or animal products on the **brain and cognitive functions**.[71]

## High meat consumption and health

Considering the widespread availability and consumption of meat and meat products in Europe and their high nutrient content, it can be considered that these products have made, and are making, an important **contribution to the nutritional sufficiency** of European diets.

At the same time, a significant and growing body of evidence associates the **long-term, high intake of red meat, and especially processed meat, with a range of negative health outcomes**.[72 73 74 75 76 77 78]

- The strongest associations suggest that high intakes of red and processed meat increase the risk of **all-cause mortality**, **cardiovascular disease**, **colorectal cancer** and **type 2 diabetes**. This both for men and women.[72 79]
- Adverse health outcomes have been most consistently associated with **processed meat**, but not always for red meat.[80]
- The International Agency for Research on Cancer (IARC) has classified processed meat as a Group 1 **carcinogen** to humans, and red meat as a Group 2A **probably carcinogen**, based on their associations with colorectal cancer.[18] Equivalent classifications have been made by the World Cancer Research Fund (WCRF)/American Institute for Cancer Research (AICR).[81]
- Associations have also been found for a range of other health effects, including other cancers, obesity, non-alcoholic fatty liver disease, progression of kidney disease and dementia (for processed meat).[82 83 84 85 86 87 88 89 90 91 92]
- Overall, epidemiological evidence describes **associations without establishing direct causality**. It also includes a wide range of studies of different quality.[72]

- For unprocessed **white meat**, evidence tends to show an inverse relation between mortality risk and intake. This implies that substituting red and processed meat with white meat, especially when minimally processed, may reduce risks.[74 79]

Based on this mounting evidence, estimates have been made of the potential health effects of high red and processed meat consumption. In 2017, **3.4% of premature deaths** (over 300,000 deaths) in the WHO European region (Europe and Central Asia) were attributed to high red meat consumption.[93]

Table 1 below presents the estimated contribution of **high red and processed meat consumption to the burden of disease** in the EU and for France, Germany and the UK in 2019.

- For the EU, it was estimated that high red and processed meat consumption may contribute to **2.7% of all DALYs and 3.8% of all premature deaths**. For France this is 2.1% of DALYs and 3.3% of premature deaths; for Germany 3.0% of DALY's and 4.0% of premature deaths; for the UK 2.2% of DALYs and 2.7% of premature deaths.
- In comparison, tobacco use as risk factor contributed to nearly 14% of all DALYs in the EU that same year.

*Table 1: Diets high in processed and red meat as risk factor for the burden of disease in Europe*

| Geography | Diet high in processed meat | | | Diet high in red meat | | |
|---|---|---|---|---|---|---|
| | **Premature deaths** | **YLD** | **DALY** | **Premature deaths** | **YLD** | **DALY** |
| **EU** | 13.31 | 109.87 | 337.18 | 23.73 | 120.86 | 507.47 |
| | **1.50%** | **0.79%** | **1.04%** | **2.28%** | **0.86%** | **1.66%** |
| **France** | 10.32 (5.43-15.13) | 53.27 (32.05 - 79.7) | 202.57 (124.32-281.46) | 19.71 (13.34-26.6) | 76.74 (52.23-106.28) | 375.33 (277.49-473.55) |
| | **1.13%** | **0.40%** | **0.75%** | **2.17%** | **0.57%** | **1.37%** |
| **Germany** | 19.46 (8.43-29.48) | 148.88 (89.1-227.6) | 431.56 (261.2-607.6) | 25.15 (13.99- 36.75) | 144.03 (92.26-207.77) | 532.62 (349.3-715.3) |
| | **1.72%** | **1.01%** | **1.34%** | **2.23%** | **0.97%** | **1.66%** |
| **UK** | 11.73 (4.67-18.32) | 134.44 (81.91-201.57) | 331.78 (202.1-465.3) | 13.29 (7.03-20.13) | 89.77 (55.37-133.3) | 311.57 (195.2-430.4) |
| | **1.43%** | **0.94%** | **1.13%** | **1.28%** | **0.62%** | **1.07%** |

*Source: Institute for Health Metrics and Evaluation.[34] Note: These findings are modelled based on the Global Burden of Disease study. Data refers to European Union, both sexes, all ages, year 2019, sub-category: "Dietary risks". Numbers refer to risk per 100,000 persons. Percentages to share of total burden. YLD: Years lived with disability, DALY: Disability adjusted life years. The confidence interval (between brackets) indicates significant uncertainty.*

While evidence about the negative health effects of red and processed meat consumption tends to coalesce around a notion of 'high' levels of intake, there is no common definition of what **high red meat consumption** is. Several existing recommended levels of intake include:

- German Society for Nutrition: total meat consumption (including red, white and processed meat) should be limited to **300g-600g** per week.[94]
- French dietary guidelines: limit red meat consumption to **500g** per week, with no more than 150g of processed meat per week.[50]
- UK dietary guidelines: limit red and processed meat intake to 70g per day (or **490g** per week) based on cooked weight.[95]

- World Cancer Research Fund International: limit red meat consumption to no more than **350–500g** per week cooked weight. Processed meat should be avoided or only rarely consumed.[96]
- EAT-Lancet Commission: proposes different intake ranges for a 'planetary health diet', which includes environmental considerations alongside nutrition. The recommended intake for beef, lamb and pork is between **0-196g** per week (average 98g), and for poultry **0-406g** per week (average 203g).[97]

It should be noted that certain authors **question the recommendation to limit red meat consumption** on nutritional grounds.[98] [99] [100] Criticism includes the following considerations, which may themselves be contested:

- Findings from observational studies should be interpreted with care. They should serve to produce hypotheses rather than be the basis for recommendations;
- Epidemiological data has not been able to demonstrate consistent causal links based on mechanistic evidence between red meat intake and health harms;
- Dietary advice tends to cherry-pick studies, overlooking conflicting data and perspectives;
- Meat is highly nutritious and has been an integral part of human history;
- Meat avoidance may be able to be supplemented by well-planned diets, but this is usually not realistic in practical settings.

## Current levels of meat intake and trends

It has been estimated that **50% of protein intake in the EU in 2007 was of animal origin**. Half of that intake was from meat and around 35% from dairy. The same assessment also found that, on average, people in the EU consumed 70% more protein than required and 40% more saturated fat. Overall, red meat consumption was found to be twice as high than the recommended levels.[101]

Like for most other foods, it is **not easy to measure meat consumption**. Different methodologies and approaches are used to provide a measure of consumption, which is why different values may be observed across sources.[102] The methodology according to which meat consumption is represented is important when reflecting on the relationship between actual levels of consumption and recommended levels.

- The most used methods are based on 'food balance sheets' and do not actually assess direct consumption. What is presented is a measure of **availability for consumption**, calculated as the difference between production, imports and exports within a country. Such calculations, which can also vary by source, show useful trends over time, but usually end-up overestimating actual consumption. Such data is often used as a proxy for consumption.
- **Consumption surveys**, such as diet records and 24-hour recalls, have the potential to reflect actual consumption levels, but are not always precise. They also rely on population samples of self-selected volunteers, which may not be representative of entire populations.

Table 2 below provides the current levels of **meat available for consumption** in France, Germany and the UK based on data by the United Nations Food and Agricultural Organization (FAO).

*Table 2: Meat available for consumption per kg/ per capita for France, Germany, UK in 2018.*

| | Poultry | Red meat (Pig, Bovine, Mutton, Goat) | Other meat | Total per capita |
|---|---|---|---|---|
| France | 22.99 | 54.88 | 1.11 | 78.98 |
| Germany | 18.15 | 53.2 | 1.79 | 73.14 |
| UK | 30.21 | 46.17 | 0.87 | 77.25 |

*Source: FAOSTAT.[103] Note: Food supply is defined as food available for human consumption. At country level, it is calculated as the food remaining for human use after deduction of all non-food utilizations (i.e. food = production + imports + stock withdrawals − exports − industrial use − animal feed – seed – wastage − additions to stock). Wastage includes losses of usable products occurring along distribution chains from farm gate (or port of import) up to the retail level. However, such values do not include consumption-level waste (i.e. retail, restaurant and household waste) and therefore overestimates the average amount of food actually consumed.*

To illustrate the differences in calculations, table 3 below provides a similar estimate for Germany, using national methodology. It shows lower overall meat availability for consumption than with FAO data. Except for poultry, which increased, availability of meat for consumption **decreased between 2010 and 2020**. At 57.3 kilograms per person, meat availability, used as a proxy for consumption, was lower than at any time since these records started to be tracked in 1989.

*Table 3: Levels of meat available for consumption in kg/per capita in Germany, national data.*

| Year | Poultry | Red meat | Other meat | Total per capita |
|---|---|---|---|---|
| 2020 | 13.26 | 42.65 | 0.64 | 57.33 kg |
| 2010 | 11.36 | 49.99 | 1.07 | 62.42kg |

*Source: German Federal Office for Agriculture and Food.[104]*

According to European Commission estimates, presented in table 4 below, **meat consumption** across the EU is expected to slightly **decline from an average 69.8kg per capita to 68.7kg**, amounting to a 1.6% decrease between 2020 and 2030.[105]

- Especially beef and pork consumption are expected to decline while poultry intake will increase, partly replacing the former;
- Processed meat consumption is set to increase compared to fresh meat;
- Lab-grown meat could become a competitor for meat, though consumer acceptance and the environmental footprint are still debated.

*Table 4: Estimate of meat available for consumption in kg/per capita in the EU up to 2030.*

| EU | Beef | Pig | Poultry | Sheep | Total per capita |
|---|---|---|---|---|---|
| 2000 | 11.8 | 32.5 | 17.6 | 2.6 | 64.5 |
| 2010 | 11.3 | 32.6 | 20.6 | 2.0 | 66.5 |
| 2020 | 10.8 | 31.3 | 25.6 | 1.8 | 69.8 |
| 2030 | 10.0 | 30.2 | 26.6 | 1.8 | 68.7 |

*Source: European Commission.[105]*

At a global level, **meat consumption is projected to increase** by 1kg per person between 2019 and 2030, reaching 35.7kg per capita, or 374 million tons in total. This mainly due to population and economic growth in emerging economies.[106] While the consumption of all meats is set to grow, **poultry** will constitute the largest share of additional per capita consumption at the global level, expected to account for 50% of the additional meat consumed.

## Outlook: potential future impacts

The projections for EU meat consumption towards 2030, referred to above, show a marginal 1.6% overall decline, with shifts between different types of meat. It can be hypothesised that the projected replacement of beef and pork (red meats) in favour of poultry (white meat) **could lead to some dietary health gains**. At the same time, the expected replacement of fresh meat by processed meat could result in **more negative effects**.

Other predictions are bolder, claiming that every tenth portion of meat, dairy and eggs across the globe will be alternative by 2035, implying a much steeper decrease in animal food intake.[107] The nutritional health gains of **replacing meat with plant-based alternatives** are, however, quite uncertain. While a **'health halo' exists around plant-based products**, their nutritional impacts are not yet well-understood. Plant-based alternatives are often highly processed products and may contain significant amounts of nutrients which are currently over-consumed, such as saturated fat, sugar and salt.[108] A recent study found significant differences in metabolite composition between plant-based and grass-fed meat, concluding that these products should not be seen as nutritionally interchangeable, although without concluding on the relative healthfulness of one over the other.[109]

Apart from plant-based meat and dairy substitutes, active discussions are ongoing about **other sources of protein and micronutrients**, including edible insects such as termites, grasshoppers and caterpillars.[110] The potential usages of marine algae and seaweeds are also increasingly explored.[111] There is also considerable focus on rethinking the role of seafoods as part of sustainable and healthy diets.[112]

The discussion above suggests that when considering the potential nutritional effects of changes in meat intake, **focus should not go to the meat component alone**. Central is how the overall diet evolves, and more specifically, by which products the meat is replaced. To ensure that meat reduction strategies in high income countries **deliver real nutritional benefits, or at least do not result in adverse effects**, the overall food environment should be re-designed in a way to enable diets that are both nutritionally healthy and sustainable. And crucially, people should have the means to access such diets too.[113]

In addition to the direct nutritional effects of different meat futures, the indirect effects of meat production on shaping **food security risks** associated with drivers such as **climate change and biodiversity loss** should also be considered (as further addressed in sections V and VI below). Over three quarter of global diet-related greenhouse gas emissions are currently associated with animal source foods. Reducing the intake of animal products in high consuming regions and implementing 'plant-forward' dietary strategies in transition countries, can significantly reduce the hidden diet-related and climate change costs of current food systems.[113] Such dietary strategies have also often been associated with reduced land use. One could hypothesise that lower pressure on agricultural land could help reduce the cost of production, increasing **food affordability**.

# II. Zoonotic diseases

This section explores different types of zoonotic diseases, the role of animal agriculture in the development and spread of zoonotic diseases and health impacts from zoonoses. The discussion touches on different points across the food systems, including production, supply chain and consumption.

## Different types of zoonoses

A zoonosis, or zoonotic disease, is an **infectious disease transferred from non-human animals to humans**. Zoonotic pathogens are usually bacterial, viral or parasitic. Zoonoses can spread to humans through direct contact with animals, through food and water, or the environment.[114] The severity of zoonotic diseases ranges from mild to deadly.

**Zoonotic diseases** are commonly divided into:[115]

1. food borne diseases;
2. non-food borne diseases.

**Food borne diseases** are caused by consumption of food or water contaminated by pathogenic microorganisms. The most **common food borne zoonotic diseases** monitored in the EU are caused by Campylobacter (70% of reported cases), Salmonella, Yersinia, Escherichia coli (STEC) and Listeria (most deadly among the diseases with a 90% hospitalisation and 17% fatality rate).[116]

**Contamination** can occur at many points along the food chain, including at farm-level, slaughter, during processing and at preparation. Different stages of the food chain have different sources of contamination.[115]

- **Farm level**: sources of contamination include contaminated animal feed; parasites infecting farm animals; milk or animal skin contaminated through contact with faeces or environmental factors.
- **Slaughter**: sources of contamination include contamination by intestinal contents.
- **Processing**: sources of contamination include contamination by microorganisms in other raw agricultural products or on food contact surfaces; food handling by infected personnel.
- **Preparation**: sources of contamination include spread of bacteria through improper use of utensils or kitchen surfaces. The safe and hygienic handling and thorough cooking of raw meat and other raw foods can prevent or reduce the risk posed by such microorganisms.

**Non–food borne diseases** have several routes of transmission.[117]

- These include **vector borne** where pathogens are transmitted through bites by ticks, mosquitos, or fleas. Examples of associated diseases include Lyme disease, Malaria or West Nile virus.
- Transmission can also occur through **direct contact or close proximity**. For instance, when coming into contact with the saliva, blood, urine, mucous, faeces or other bodily fluids of an infected animal. Transmission can also occur through areas where animals live and roam, or through objects or surfaces that have been contaminated with germs. Examples include Avian influenza and Q fever.

## Zoonotic diseases and animal agriculture

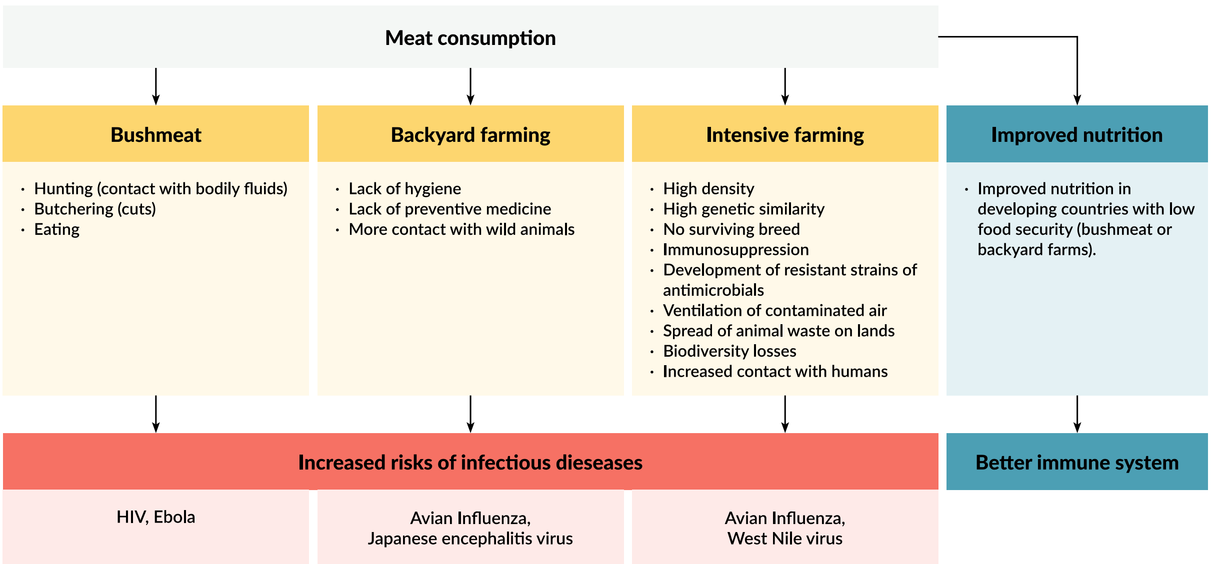
According to estimates, around **60% of known infectious diseases** and up to **75% of new or emerging infectious diseases** are of zoonotic origin.[118] [119] Agriculture plays a major role in the **risk of zoonotic disease** outbreaks globally. Agricultural drivers have been associated with more than **25% of all**, and more than **50% of zoonotic infectious diseases in humans** since 1940.[120] These proportions may increase as agriculture expands and intensifies.[121]

The exact contribution of European animal farming and meat consumption to the global incidence of zoonoses is hard to isolate. However, current production and consumption **contribute to global land use change and the conversion of natural habits**, which are recognised risk factors for zoonotic diseases emergence and spread.[119 122 123] This occurs, for instance, through demand for animal feed and imports of meat products for consumption.

Moreover, intensive animal agriculture could be seen as a potential **'laboratory' for the generation of new zoonotic diseases**. A recent survey of over 2,500 European pig farms, collecting over 18,000 samples, found high prevalence of swine influenza viruses. Around half the farms were found to host strains with the potential for zoonotic transmission to humans. The study concluded that European swine populations can be reservoirs for emerging influenza strains with zoonotic and, possibly, pre-pandemic potential.[124]

Three main pathways have been identified through which animal farming and meat consumption may shape zoonotic disease risk, presented in figure 3 below. First, the **consumption of wild animals**, which is an important driver for zoonoses globally. Second, through farming models that result in **contacts between farmed and wild animals**. Third, from **intensive livestock operations**, where genetically similar animals are kept confined in high densities, escalating the risk of severe outbreaks. Such systems also exert pressure on land resources for feed production.[121]

*Figure 3: Model of how animal farming and meat consumption can increase the risk of infectious diseases.*




*Source: Springer Nature, Environ Resource Econ 76, 1019–1044. Infectious Diseases and Meat Production. Espinosa, R., Tago, D. & Treich, N., Copyright (2020). Reprinted by permission from Copyright Clearance Center (image re-drawn from original).*[121]

## Health impacts from zoonotic diseases in Europe

**Most food safety issues** (food borne diseases) in Europe are of zoonotic origin. In the EU, foods of animal origin such as meat, egg, dairy and fish products are associated with most of the recorded food borne outbreaks.[116]

Based on reporting by the European Centre for Disease Prevention and Control (ECDC) and the European Food Safety Agency (EFSA), outbreaks of the **six main zoonoses** related to animal food production in the EU resulted in over **326.000 reported cases**, more than **40.000 hospitalisations** and just over **500 deaths** in 2019.[116]

Table 5 below provides an **overview of confirmed cases** of the main food borne zoonoses in Europe. These figures cover outbreaks involving two or more individuals, not individual cases.

*Table 5: Confirmed cases of five types of food borne zoonotic disease outbreaks in Europe in 2019.*

| Disease | EU | France | Germany | UK |
|---|---|---|---|---|
| Campylobacteriosis | 220,682 | 7,712 | 61,254 | 58,718 |
| Salmonellosis | 87,923 | 8,935 | 13,495 | 9,718 |
| E. coli (STEC) | 7,775 | 335 | 1,907 | 1,587 |
| Yersiniosis | 6,961 | 1,135 | 2,154 | 163 |
| Listeriosis | 2,621 | 373 | 570 | 154 |

*Source: EU One Health Zoonoses report.[116] Note: these are reported outbreaks involving two or more individuals and are probably underestimates. Numbers presented in the table may differ from national reports due to differences in case definitions used at EU and national level or to different dates of data submission and extraction.*

The main **non-food borne zoonoses** prevalent in Europe include Avian influenza (highly contagious and prevalent, but with only sporadic human infection),[125] Lyme disease (approximately 650,000-850,000 people contract Lyme disease in Europe every year),[126] Q fever (mostly transmitted through inhalation of infected aerosols in contaminated locations) and Escherichia coli.[117] These zoonoses are not necessarily directly related to agriculture.

Furthermore, specific **agriculture-related disesae outbreaks** have occured, including the 2009 swine flue pandemic that killed over 2,000 people.[127] Another example of a non-food borne zoonotic outbreak in Europe includes the **Q fever epidemic** in the Netherlands between 2007-2010. The epidemic appears to have been caused by airborne transmission of contaminated dust particles from dairy goat farms. Mainly people living in an area of 5km from such farms were affected, resulting in over 4,000 notified cases and 95 officially estimated deaths.[128] [129]

## Other health effects of living near or on animal farms

Other health effects of living near, or on animal farms that do not necessarily relate to known zoonotic diseases **provide a mixed picture**.

A study in the Netherlands investigated the **health impacts of living near animal farms** in an area of the country with high animal densities.[130]

- It found residents having less asthma, fewer allergies and fewer people with COPD (a chronic lung disease). However, those who did have COPD often showed more serious complications of the disease.
- A connection was found to reduced lung function, especially when exposed to high concentrations of ammonia.
- A higher risk of pneumonia was found, including in close vicinity to poultry farms.
- Also, inhabitants were slightly more likely to be carrying the MRSA bacterium.

Growing-up on a farm has been associated with **lower asthma and allergies in children**. While this 'farm effect' has been widely documented, the exact reasons have not been established. Hypotheses include that exposure to microbiological diversity in farm environments could activate the immune system and provide protection.[131]

**Odour annoyance** related to living nearby animal farms has been associated with reduced general health and increased reporting of respiratory, gastrointestinal, neurological and stress symptoms. The numbers of animals near homes was associated with annoyance.[129]

## Outlook: potential future impacts

Zoonotic disease outbreaks have increased over the past several decades. Between 2011 and 2018, the WHO identified 1,483 epidemic events in 172 countries.[132] As experience shows, zoonoses are not always easily localised and **the health and societal impacts of non-food borne outbreaks may be off-the-charts** compared to the impacts of the regularly monitored zoonotic diseases presented above. While characterised by high degrees of uncertainty, the risks involved are quite significant.

The health, social and economic effects and societal disruptions brought by the **COVID-19 pandemic** has significantly increased attention to zoonotic diseases and the conditions for their emergence and spread.[133] While the origin of COVID-19 has not been established with full certitude, and the state of current evidence does not in any way allow to link COVID-19 directly to agriculture, the risks for the future occurrence of similar pandemics is exacerbated by drivers in which animal agriculture and meat consumption play an important role.

The projected **expansion of animal agriculture and animal food consumption globally** is most likely to **exacerbate existing infectious disease risks**. This including through increased biodiversity loss, climate change and the creation of reservoirs for the generation and spread of new zoonoses. Notably, a positive correlation was found between increasing numbers of cattle and outbreaks of zoonotic diseases.[134]

While **Europe's animal production and consumption** are not expanding, they remain at very high levels and continue to put pressure on global biodiversity through imports and by contributing to climate change. Inside Europe, the increased consolidation and intensification of the animal farming sector may allow for enhanced biosecurity. At the same time, intensive systems may involve larger-scale pandemic risks.[121]

Moreover, responses to major zoonotic disease outbreaks, such as Avian influenza or Swine flu, have often seen the culling of entire flocks to stem disease spread, which may be seen as a **vulnerability from the perspective of food security**.[121]

# III. Antimicrobial resistance

This section explores some of the key relationships between antibiotics use in animal agriculture, antimicrobial resistance and human health. The discussion touches on different points across the food systems, including production, supply chain and consumption.

## Antimicrobial resistance (AMR) and health

Antimicrobial resistance (AMR) arises when **microorganisms**, such as bacteria, viruses, fungi and parasites, **change over time and stop responding to medicines**. AMR is not a disease itself, but an occurrence that makes different infections hard, or impossible to treat.[135]

**Antimicrobials**, including antibiotics, antivirals, antifungals and antiprotozoals, are active substances of synthetic or natural origin, which kill or inhibit the growth of microorganisms. Antimicrobials are used in every-day medicine, including for treating infections, such as pneumonia or tuberculosis, in routine surgeries, for chemotherapy and the care for premature babies. They are **vital for preventing and treating infections**.

Due to AMR, also called **drug resistance**, antimicrobial medicines lose their effectiveness and infections become more difficult or impossible to treat. This increases their risk of spreading, of severe illness and of death. Microorganisms that have developed resistance to multiple antimicrobials are sometimes referred to as '**superbugs**'.

The development of resistance involves an **evolutionary process via natural selection**. Bacteria can **acquire resistance in two main ways** 1) through random mutations, 2) by receiving resistance genes from other bacteria. The latter is also called **horizontal gene transfer** and is considered the most important pathway of acquiring resistance.[136]

- The process of natural selection implies that if a bacterium acquires resistance and this resistance confers it an advantage, the feature may be maintained and passed on. When a bacterial population is treated with an antibiotic, the antibiotic applies selective pressure: bacteria that acquired resistance will stay alive and be able to multiply, leading to a population of mostly resistant bacteria. In this way, the **large scale use of antimicrobials, such as antibiotics, speeds-up the process of natural selection** and greatly increases the rate at which resistance develops and spreads.[137]

The overuse of antimicrobials occurs primarily in **human medicine** and **animal farming**, both in agriculture and aquaculture. The development and spread of AMR involve a highly interrelated set of interactions, involving prescription practices, contamination in healthcare settings, human, animal and manufacturing waste, direct transmission between people and transmission from animals to people, food consumption, exposure to resistant microorganisms in the environment, travel and so on.

Today AMR, with a special focus on **antibiotic resistance**, threatens the effective prevention and treatment of an ever-increasing range of infections across Europe.[55] For instance, recent data finds that a large proportion of Salmonella bacteria in the EU are multidrug-resistant. Campylobacter in many countries has high, to very high resistance to the most common antibiotic used for its treatment.[138] Globally, AMR is now so widespread that it has been included into the **top 10 list of public health threats** facing humanity.[139] In the EU alone, it is estimated that AMR **costs 1.5 billion EUR annually** in healthcare costs and productivity losses.[140]

According to the best available estimate, presented in table 6 below, more than **33,000 people die each year in the EU/EEA as a direct consequence of an infection with bacteria resistant to antibiotics**. This health burden is similar to the cumulative burden of influenza, tuberculosis, and HIV. Worryingly, nearly 40% of this burden was caused by bacteria resistant to 'last-line' antibiotics, which are antibiotics preserved to serve as a final treatment option. A clear increase has been reported between 2007 and 2015.[141]

The study estimates that around three-quarter of these infections were **associated with healthcare settings**.[142] While this is the best available study it is probably not complete and does not allow to fully evaluate the role of antibiotics overuse in animal agriculture in producing human health impacts.

*Table 6: Country- specific burden of antimicrobial resistance, 2007-2015.*

| | YLD | YLL | DALY | Cases per year | Deaths per year |
|---|---|---|---|---|---|
| France | 23,539 | 123,505 | 147,045 | 125,011 | 5,552 |
| Germany | 7,841 | 44,422 | 52,263 | 54,469 | 2,370 |
| UK | 7,205 | 44,695 | 51,901 | 52,992 | 2,177 |
| EU/EEA | 130,108 | 745,541 | 875,650 | 672,440 | 33,227 |

*Source: Cassini et al. (2018).[142] Estimates are based on the incidence of infections with 16 antibiotic resistance–bacterium combinations from European Antimicrobial Resistance Surveillance Network. Note: YLD: Years lived with disability, YLL: Years of life lost; DALY: Disability adjusted life years. All information can be extracted from Lancet "Attributable deaths and disability-adjusted life-years caused by infections with antibiotic-resistant bacteria in the EU and the European Economic Area in 2015"; country-specific data in the supplementary material.*

## The role of agriculture in antibiotic resistance

There is sufficient evidence to link the **use of antibiotics in animal agriculture to antibiotic resistant infections in humans**. For instance, a 2015 literature review of 139 peer-reviewed studies found 72% of them showing sufficient evidence of a link, while only 5% of the studies argued against one.[143] A similar conclusion was reached in 2003 by three key UN agencies.[144]

**Resistance is transmitted between animals and humans** in three main ways:[145]

1. through direct contact;
2. the food chain;
3. the environment.

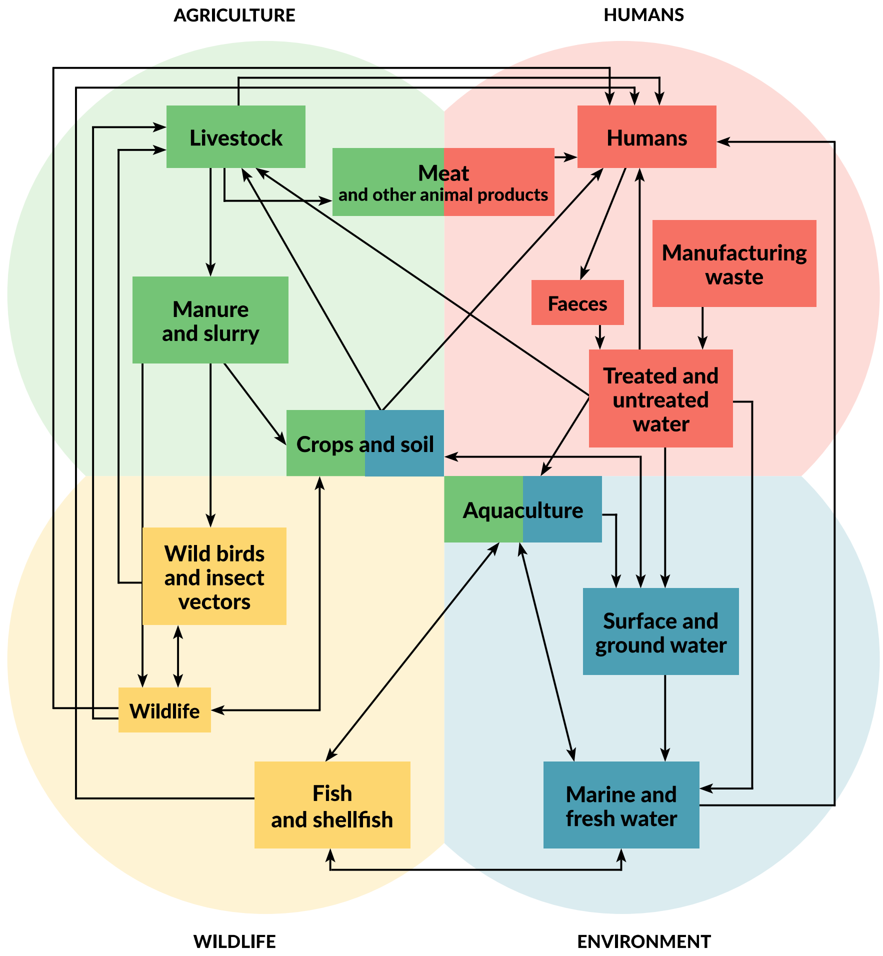
Drug-resistant strains can be passed on through **direct contact between humans and animals**. Examples exist of resistant bacteria that circulate in animal populations being transferred onto farmers and their families, as well as veterinarians. Those, in turn, can pass the bacteria onto the wider population. In the same way, bacteria can also be passed from humans to animals.

Drug-resistant strains can be passed onto humans **through the food chain**. Resistant bacteria can be transferred to food products and food workers at slaughter and during packaging or processing (see section above on food borne infections). When the animal product is consumed without careful treatment the bacteria can spill-over. Bacteria can also be passed on through other food products, such as vegetables that have been irrigated or fertilised with contaminated water or manure. Spraying antibiotics as a pesticide is a widely used practice around the world and is receiving increasing attention. While this practice is prohibited in the EU, imported products could presumably be affected.[146]

Drug-resistant strains can develop and be passed onto humans **through the environment**, including through water and soils. A large share of the antibiotics consumed by animals, often with the active ingredient unmetabolised, are excreted and released into the natural environment. This creates additional selective pressure that can lead to the development of drug resistance. Resistant bacteria themselves can also be released into the environment, creating reservoirs of resistance. The extent to which and through which mechanisms the environment contributes to the problem of resistance is under active investigation.[147]

Figure 4 below represents the main **transmission pathways** of resistance involving agriculture, environment and wildlife are represented.[148]

*Figure 4: Development and transmission pathways of antibiotic resistant genes.*




*Source: Food and Agriculture Organization of the United Nations. 2016. Wall, B. A., et al. Drivers, dynamics and epidemiology of antimicrobial resistance in animal production. http://www.fao.org/3/i6209e/i6209e.pdf. Reproduced with permission. (image re-drawn from original).*[148]

The contribution of antibiotics overuse in agriculture to resistance in humans is hardly disputed. What is disputed is the **degree to which agriculture contributes to resistance in humans,** compared to antibiotics use in human medicine. While there is no clear answer to the relative contribution of each source, and possibly such answer is elusive, a number of considerations can be made.

- A study looking at the health burden of five types of common infections suggests that the health effects of antibiotic-resistant bacteria predominantly – in the range of 75% – occur in **hospitals and other health-care settings**.[142]
- Similarly, it is suggested that the emergence of resistance in humans mostly **originates from antimicrobial use in humans**, while most resistance among farm animals originates from antimicrobial use in animal production.[145] This does not, however, deny the possibilities for spill-over of resistance between animal and human populations of bacteria.
- At the same time, there is general consensus that the **level of antibiotics use is a main factor in driving the development and spread of resistance**.[145] Globally, antibiotics use in animal agriculture

tends to considerably exceed human use. While humans and animals use comparable amounts of antibiotics, the total biomass of farm animals exceeds humans by far, resulting in larger total use.[149] Use in animal agriculture is, on average, also higher in the EU.[138] Considering that most antibiotics used in animals are also medically important for humans, this suggests a risk of resistance transfer.[143]

- Also, agriculture is a main contributor to the **exposure of ecosystems to antibiotics** and the creation of reservoirs for the development and (horizontal) dissemination of resistance genes. The study of resistance transfer through microbial ecosystems is an active field of research.[150]

There are different ways to reduce the risk of AMR in humans. These include shifting use towards antimicrobials that are not medically important, either now or in the future, and that are different enough not to allow resistance to develop to human drugs.[143] However, the most **long-term secure way of reducing the risk of AMR seems to be to reduce the use of antibiotics**.

Progress is being made in the EU and the UK towards reducing farm antibiotics use. As presented in table 7 below, between 2011 and 2018 the **sales of veterinary antibiotics decreased by more than 34%**. This includes noticeable drops in sales of those classes of antibiotics considered critically important for human medicine.[151]

*Table 7: Antibiotics sales for animal production in France, Germany and UK, 2012 and 2018.*

| | Antibiotic use in livestock in year 2012 | Antibiotic use in livestock in year 2018 |
|---|---|---|
| France | 101.2 mg/PCU | 64.2 mg/PCU |
| Germany | 204.8 mg/ PCU | 88.4 mg/PCU |
| United Kingdom | 66.3 mg/ PCU | 29.5 mg/PCU |
| *Sweden* | 13.5 mg/PCU | 12.5 mg/PCU |
| *Poland* | 134.0 mg/PCU | 167.4 mg/PCU |
| *Spain* | 302.4 mg/PCU | 219.2 mg/PCU |
| Median EEA | | 57.0 mg/PCU |

*Source: European Medicines Agency (2020).[151] Note: The 'population-corrected unit' (PCU) is a proxy for the size of the food-producing animal population. The amounts of veterinary antimicrobial agents sold in the different countries are normalised by the animal population that could potentially be treated with antimicrobials in each country. Sales is expressed in milligrams of active ingredient sold per PCU – mg/PCU.*

While these are positive developments, several considerations **suggest significant scope for further improvement**.

- Very **large differences in antibiotics sales** remain across European countries, ranging from 2.9 to 466.3 mg/PCU, indicating potential for further progress.[151]
- Over 85% of antibiotics sold are of the type used primarily in **group treatment**.[151] This implies that much further gains could be had from a move towards more individualised application and non-routine uses.
- As the use of medically important antibiotics is reduced, there is concern that they can be **replaced by other classes of antibiotics**, such as ionophores. Ionophores are not currently used in human medicine and their application in agriculture tends to be less regulated. Such substances could, however, be used in a way to reduce the imperative for improvements in animal husbandry conditions. Also their relation to the development of resistance in humans may require further scrutiny.[152] Moreover, recent research suggests ionophores could become adapted for use in humans, possibly making them medically important in the future.[153]
- Large scale antibiotics use has enabled and been accompanied by intensive animal production. It can be considered that a key strategy to minimise antibiotics use is to induce a **transition in**

**production models**. For instance, organic agriculture is associated with lower antibiotics use, especially in poultry and pig production, and can serve as inspiration for a transition in production practices.[51 154 155]

## Outlook: potential future impacts

AMR has the potential to result in a **significantly larger health burden in the future than current data suggests**. Today, according to low estimates, around 700,000 annual deaths globally can be attributed to drug resistance. Without significant action to tackle AMR this can increase to **10 million global deaths per year by 2050**, which could mean **390,000 deaths per year in Europe** by the same year.[137]

While predictions are hard to make, several trends in the area of food production are a cause of concern. This includes the growing global demand for animal products, linked to a projected increase in farm antimicrobials use worldwide. As low- and middle income countries are expected to shift to more intensive production practices, **total antibiotics use in animal agriculture is set to increase** from over 93,000 tonnes in 2017 to just over 104,000 tonnes in 2030.[156]

The overuse of antibiotics in animal production may also result in **global food security** and farmers' profitability challenges, for instance if rising resistance among animals results in higher mortality and morbidity. In the case of severe untreatable infections, entire flocks or herds may need to be culled.[143]

At the same time, **progress is also being made in tackling antibiotics use**. For instance, EU legislation will come into force in early 2022 that will set a framework to limit routine preventative use of antibiotics, establish a list of medically critical antibiotics that cannot be used in animal agriculture, expand use data collection and enforce higher import standards.[157 158] Furthermore, the EU Farm to Fork Strategy, a policy initiative, has set a target to reduce the sales of farm antimicrobials by 50% by 2030.[159] Such legislative and policy initiatives have the potential to set a standard and act as a catalyst for more ambitious action worldwide.

As an additional consideration, the **risk of higher prevalence of infectious diseases in Europe** (see sections on Zoonotic diseases and Climate change) may endanger antibiotic stewardship. For instance, during the COVID-19 pandemic a rise in antibiotic prescriptions has been reported for mild disease cases or even prophylactic purposes.[160] Rising temperatures may also increase disease proneness of farmed animals, with similar consequences.

# IV. Air quality

This section explores the impacts of air pollution on health and the role of animal agriculture in contributing to air pollution. The discussion relates to the agricultural production side of the food system.

## Air pollution and human health

Air pollution is the result of a **complex mix of gases and particles in the air**. Outdoor air pollution is currently the leading environmental health risk in Europe and globally.[161] While air pollution affects everyone, certain groups are more susceptible to its effects on health, such as children, elderly people, pregnant women and those with pre-existing health conditions.[162]

**Air pollutants** can be categorised into:[163]

1. primary pollutants;
2. secondary pollutants.

**Primary air pollutants** are directly emitted to the atmosphere and include particulate matter (PM), black carbon (BC), sulphur oxides (SOX), nitrogen oxides (NOX) (which include both nitrogen monoxide, (NO), and nitrogen dioxide, (NO2)), ammonia (NH3), carbon monoxide (CO), methane (CH4), non-methane volatile organic compounds (NMVOCs), including benzene (C6H6) (15), and certain metals and polycyclic aromatic hydrocarbons (PAHs), including benzo[*a*]pyrene (BaP).

**Secondary air pollutants** are formed in the atmosphere from precursor pollutants through chemical reactions and microphysical processes. Key secondary air pollutants are PM, ozone (O3), NO2 and several oxidised volatile organic compounds (VOCs).

Europe's **most serious pollutants in terms of harm to human health**, are particulate matter (PM), nitrogen dioxide (NO2) and ground-level ozone (O3).[163] PM is usually divided into $PM_{10}$ and $PM_{2.5}$, reflecting the size of the particles of which it is composed. $PM_{2.5}$ can penetrate both into the lungs and directly enter the blood stream, and is considered the most harmful of the two.[161]

Air pollution is a **risk factor for a wide range of health issues.**

- Air pollution has been classified as **carcinogenic** by the International Agency for research on Cancer.[164] It has been associated with different cancers, including lung cancer,[165] kidney cancer and bladder cancer.[166] [167]
- The respiratory tract is the main organ affected by air pollution and the most studied. Air pollution contributes to a wide range of **respiratory diseases**, including Asthma and COPD.[161] [166]
- Between 40-80% of air pollution-related excess mortality is linked to **cardiovascular diseases**, such as hypertension, stroke and heart failure.[165]
- Long-term exposure to high levels of air pollutants has been associated with an elevated risk of **type 2 diabetes.**[168]
- A growing body of literature links air pollution to **diverse neurological disorders**, including impairments in cognitive function and increased risk of dementia.[169] [170] Prenatal and early childhood exposure to $PM_{2.5}$ is associated with delayed psychomotor development.[171]
- Exposure to air pollution during pregnancy has been associated with **adverse pregnancy outcomes** and reduced foetal growth.[172]
- A **potential role** has been suggested for air pollution in contributing to obesity and non-alcoholic fatty liver disease, but further evidence is required.[173]
- Furthermore, evidence suggests that air pollution may be contributing significantly to higher rates of **COVID-19** related mortalities.[174]

Despite a **steady overall decrease in pollutant emissions and concentration levels**, exposure to air pollution in Europe often exceeds WHO guidelines.[161 163] This while compliance with WHO recommendations **could prevent over 50,000 deaths in European cities each year**.[175]

As presented in table 8 below, the total health burden attributed to $PM_{2.5}$, NO2 and O3 pollution in the EU27 and UK amounted to over **450,000 premature deaths, or over 5 million years of life lost** in 2018.[163]

*Table 8: Premature deaths in Europe attributed to three air pollutants, 2018.*

| | $PM_{2.5}$ | | NO2 | | O3 | |
|---|---|---|---|---|---|---|
| Country | Premature deaths | YLL | Premature deaths | YLL | Premature deaths | YLL |
| France | 33,100 | 424,700 (659*) | 5,900 | 76,400 (119*) | 2,300 | 30,400 (47*) |
| Germany | 63,100 | 710,900 (859*) | 9,200 | 103,500 (125*) | 4,000 | 46,600 (56*) |
| UK | 32,900 | 373,300 (563*) | 6,000 | 67,900 (102*) | 1,000 | 12,500 (19*) |
| EU27 and UK | 379,000 | 4,381,000 (863*) | 54,000 | 610,000 (120*) | 19,400 | 232,000 (46*) |

*Source: European Environment Agency (2020).[163] Note: YLL = Years of life lost. *per 100.000 inhabitants.*

Other calculations, presented in table 9 below, suggest that these results **need to be revised upward** significantly, reporting **659,000 excess deaths** in the EU27 and UK from $PM_{2.5}$ in 2015. Cardiovascular disease mortality alone was held responsible for 264,000 excess deaths in the same year.[165]

*Table 9: Estimated annual excess mortality from cardiovascular disease attributed to PM2.5 in 2015.*

| | Disease | | |
|---|---|---|---|
| Country | CEV | IHD | CVD |
| France | 3,000 | 13,000 | 16,000 |
| Germany | 7,000 | 42,000 | 49,000 |
| UK | 3,000 | 14,000 | 17,000 |
| EU-28 | 48,000 | 216,000 | 264,000 |
| Europe | 64,000 | 313,000 | 377,000 |

*Source: Lelieveld et al. (2019).[165] Note: CEV is cerebrovascular disease, IHD is ischaemic heart disease, CVD are total cardiovascular diseases (CEV + IHD). Estimates differ from EEA calculations.*

## The contribution of animal agriculture to air pollution

There are **six key sectors** that contribute to air pollution in Europe: transport, buildings (residential, commercial, institutional), energy generation, manufacturing, agriculture and waste.[163]

The **agricultural sector** contributes mainly to the following **primary air pollutants**:[163]

- 93% of ammonia ($NH_3$) emissions;
- 54% of methane ($CH_4$) emissions;
- 20% of non-methane volatile organic compounds (NMVOC);
- 18% of primary $PM_{10}$ emissions;

- 15% of nitrogen oxides (NOX) emissions;
- 12% of benzopyrene (BaP) emissions;
- 7% of primary $PM_{2.5}$ emissions.

Approximately 75% of ammonia emissions[176] and 2/3 of methane emissions (mainly enteric fermentation and manure management)[177] can be attributed to animal agriculture. Compared to other sectors, **agriculture showed the lowest reductions in emissions** of direct air pollutants between 2000-2018. An increase in ammonia emissions was observed since 2012/2015.[163]

Agriculture also contributes to the formation of **secondary air pollutants**.[163]

- Methane is a **precursor to the formation of ground level ozone (O3)** an important secondary air pollutant responsible for significant health and biodiversity impacts.
- Ammonia, alongside sulphur dioxide (SO2), NOX, and VOCs, is a known **precursor for secondary PM**.

Given the importance of $PM_{2.5}$ as a risk factor for air pollution-related harm, there has been some attention to the **contribution of ammonia to $PM_{2.5}$ formation**. Although estimates vary, research in this area suggests a significant role for agriculture, and animal farming in particular.

- A recent study in the US found **agriculture to be a major contributor to air pollution**. It estimated that of the 15,900 annual premature deaths from food-related $PM_{2.5}$ emissions, 80% could be attributed to animal production.[178]
- A study using a global atmospheric chemistry model to investigate the link between premature mortality and seven emission source categories, found agriculture having a large impact on $PM_{2.5}$ formation. As presented in table 10 below, under the assumption that all PM particles are equally toxic, **agricultural emissions were found to make the largest relative contribution to $PM_{2.5}$ formation and associated health harms in Europe**.[179]

*Table 10: Drivers of premature mortality from PM2.5 and O3 in Europe.*

| | Agriculture | Traffic | Energy generation | Industry | Residential | Biomass burning | Natural |
|---|---|---|---|---|---|---|---|
| France | **41%** | 18% | 12% | 14% | 14% | 1% | 0% |
| Germany | **45%** | 20% | 13% | 13% | 8% | 1% | 0% |
| UK | **48%** | 20% | 16% | 11% | 6% | 0% | 0% |

*Source: Lelieveld et al. (2015).[179] Note: There are suggestions, though not conclusive, that not all types of PM particles are equally toxic. While agricultural emissions mostly form inorganic PM2.5, carbonaceous particles could be more toxic. Should such differential effect exist, agriculture's impact on mortality would diminish significantly, under the assumption that carbonaceous PM2.5 is five times more toxic. For Germany, agriculture's contribution would be closer to 26%, which however remains significant.*

- Another study estimated the contribution of ammonia to $PM_{2.5}$ formation in Europe in the range of **5–15%**.[180]

Studies looking at options to reduce $PM_{2.5}$ pollution all point to the importance of tackling precursor substances. As presented in table 11 below, **reducing ammonia emissions from agriculture is found to be a highly effective and cost-effective measure.**[181] [182]

*Table 11: Modelled health and economic benefits of a 6% NH3 emissions reduction in Europe.*

| | Modelled reduction in percentage of premature mortality of a 6% NH3 emissions reduction | Modelled annual economic benefit of a 6% NH3 emissions reduction, in million Euros |
|---|---|---|
| France | 1–2% | 848 |
| Germany | 2–5% | 3,652 |
| UK | 2–5% | 3,416 |
| EU27 + UK | | 13,488 |

*Source: Giannakis et al. (2016).[182] Note: The NH3 emissions reduction target relates to the EU obligation of reducing NH3 emissions by 6% by 2020, relative to 2005.*

- Certain studies suggest ammonia emission reduction to be the **most effective strategy for $PM_{2.5}$ reduction** in Europe in both summer and winter.[183]
- Others find the sensitivity of $PM_{2.5}$ to NOx reduction to be stronger than to NH3 reduction.[184] It is for instance suggested that while NOx reduction is always effective, NH3 reduction is only effective under certain temperature conditions.[184]
- It is also suggested that $PM_{2.5}$ reduction is a non-linear process, with NH3 reductions especially effective when ammonia availability is the limiting factor for PM formation. In those circumstances a 50% decrease in NH3 could lead to a $PM_{2.5}$ drop of up to 34%. **NH3 reduction appears especially effective when emissions are systematically abated**.[181]

Although the extent to which ammonia contributes to $PM_{2.5}$ and under which circumstances are debated, tackling ammonia can produce co-benefits for climate mitigation and biodiversity quality as it would simultaneously **reduce levels of other reactive nitrogen (Nr) compounds** next to ammonia, such as nitrous oxide (N2O),a greenhouse gas, and nitrate (NO3-), associated with eutrophication and water contamination.[184]

## Outlook: potential future impacts

Europe currently suffers from high levels of air pollution and related health harms. While there is no expectation of increased pollution due to increased emissions, the **effects of climate change may exacerbate the effects of air pollution.** A synergistic effect has been reported between higher temperatures and increased premature mortality from ozone and particulate matter.[185] Also, the possible effects of an ageing population should be considered, given higher vulnerability to air pollution in these age groups.

Several expected developments can lead to improvements in air quality, but the extent of benefits will greatly depend on the levels of ambition.

- A full switch from fossil fuels to clean renewable energy sources could **decrease air pollution-related mortality by about 55%.**[165]
- Modest **NH3 emission reduction efforts** are currently ongoing under EU legislation, although a significant number of countries are still exceeding their allocated ceilings.[182] This while a large-scale reduction in NH3 emissions in the EU27 and UK by 50% could reduce associated premature mortality by 18%, resulting in economic gains of 89 billion USD annually.[181]

Considering the projected expansion of animal agriculture globally, **higher ammonia emissions can be expected with potential negative health impacts**. However, if NOx emissions from combustion are sufficiently reduced this impact may be (partly) mitigated.[184]

Another aspect to consider is that high ground-level ozone concentrations can **lower agricultural yields and damage vegetation**, with potential implications for food security and other ecosystem services.[163]

# V. Climate change

This section explores the links between food systems, animal foods and climate change, as well as the impacts of climate change on health. The exploration relates to food systems as a whole, but especially to production, which is the biggest source of climate impact.

## Food systems, animal products and greenhouse gas emissions

Food systems are responsible for emitting **three main greenhouse gasses**: Methane ($CH_4$), Nitrous oxide ($N_2O$) and Carbon dioxide ($CO_2$).[186] Agriculture emits over 55% of non-$CO_2$ greenhouse gas emissions.[187]

- **Methane** is the most powerful greenhouse gas among the three. It is however relatively short-lived in the atmosphere, breaking-down after about 12 years.[188]
- **Nitrous oxide** is both powerful, with a global warming potential around 265 times greater than carbon dioxide, and long-lived, though not emitted in very high quantities.
- **Carbon dioxide** is the 'primary' global greenhouse gas. Unless sequestrated, it accumulates in the atmosphere where it can stay for hundreds of years.[189]

Three clusters of **emission sources from food systems** are usually identified.[186] When interpreting data, it is always important to consider which food systems activities are, and which are not included into calculations. When data refers to food systems emissions, all these aspects should, in principle, be included.

- **Agricultural activities** cover emissions from enteric fermentation, manure application and management, synthetic fertilisers, rice cultivation, crop residues and biomass burning. Agricultural activities also involve energy use and transport, but emissions from these activities are often not included in statistics as part of agricultural sector emissions. Certain supply chain assessment methods do include such other sources of emissions.
- **Land use and land use change** relate to how food systems activities affect the land's status as either a source of emissions or a sink. For instance, the conversion of forests into croplands will lead to emissions, while well-managed grasslands can store carbon.
- **Supply chain and consumption**, including activities such as transport, processing, packaging, retail, cooking, wastage and so on.

According to current estimates, **food systems contribute to a very high** share of global anthropogenic greenhouse gas emissions.

- The Intergovernmental Panel on Climate Change (IPCC) attributes between **21–37%** of total greenhouse gas emissions to the food system.[186]
- A recent study estimates the global food system's contribution at 18 Gt $CO_2$ equivalent per year, or **34% of total emissions** (range of 25-42%).[190]

Among food groups, the **contribution of animal products** stands out. They are responsible for approximately **14.5% of total global anthropogenic greenhouse gas emissions**, or more than half of food systems emissions.[191]

A global study that attributed **emissions shares to different parts of the food system** showed, among others, the outsized role of production-related emissions. As presented in table 12 below, supply chain activities contribute to only 18% of emissions. The table also highlights the significant role of animal production and related activities.[192]

*Table 12: GHG emissions from global food systems.*

| Food emission source | Gigaton CO-eq | Share |
|---|---|---|
| *Total land use change* | *2.38* | *18%* |
| *Savannah Burning* | *0.29* | *2%* |
| *Cultivated organic soils* | *0.55* | *4%* |
| | Crop production | |
| *Food* | *2.87* | *21%* |
| *Feed* | *0.81* | *6%* |
| Livestock and Fisheries | | |
| *Livestock/Agriculture* | *4.14* | *30%* |
| *Capture Fisheries* | *0.18* | *1%* |
| | Supply Chain | |
| *Processing* | *0.60* | *4%* |
| *Transport* | *0.80* | *6%* |
| *Packaging* | *0.63* | *5%* |
| *Retail* | *0.39* | *3%* |
| Total | 13.64 | 100% |

*Source: Poore & Nemecek (2018).[192]*

As presented in table 13 below, among animal products, **meat from ruminants is particularly emissions intensive**, primarily due to enteric fermentation, a process linked to the animal's digestive system.[191]

- At the same time, there is increasing attention to the potential that well-managed **grasslands with grazing ruminants** may have in terms of combining food production, carbon sequestration, and contributing to biodiversity and agronomic benefits. To date, there is however no firm evidence that such systems, on the whole, can achieve net emissions reductions where sequestration outweigh emissions.[189]
- However, should it become widely possible to **reduce emissions from enteric fermentation**, for instance through feed supplementation with seaweed, which one long-term study found to reduce enteric fermentation by 80%,[193] that balance could be positively affected. The question of what constitutes the best use of land will, however, remain debated.

*Table 13: Global average GHG emissions of food products.*

| Food product | kgCO2-eq/ per kg of food product across the whole supply chain | *from which kgCO2-eq land use change | *from which kgCO2-eq for farm processes |
|---|---|---|---|
| Beef | 60 | 16.3 | 39.4 |
| Lamb & Mutton | 24 | 0.5 | 19.5 |
| Cheese | 21 | 4.5 | 13.1 |
| Chocolate | 19 | 14.3 | 3.7 |
| Coffee | 17 | 3.7 | 10.4 |
| Prawns | 12 | 0.2 | 8.4 |
| Palm oil | 8 | 3.1 | 2.1 |
| Pig meat | 7 | 1.5 | 1.7 |
| Poultry | 6 | 2.5 | 0.7 |
| Olive oil | 6 | -0.4* | 4.3 |

| | | | |
|---|---|---|---|
| Fish (farmed) | 5 | 0.5 | 3.6 |
| Eggs | 4.5 | 0.7 | 1.3 |
| Milk | 3 | 0.5 | 1.5 |
| Soymilk | 0.9 | 0.2 | 0.1 |

*Source: Poore & Nemecek (2018).[192] * Negative because carbon is stored in the trees.*

According to EU accounting, **agriculture** is responsible for around **10% of total EU greenhouse gas emissions**. Emissions have declined by 20% between 1990-2015, but started to rise again between 2012 and 2015. Trends in emissions are largely explained by fertiliser use and fluctuations in farm animal numbers.[194]

EU statistical accounting does not include emissions from land-use change, such as for feed production, or energy use and therefore does not represent a full picture of agriculture's contribution to emissions. Other methodologies, that do take into account land use change and several other dimensions, estimate a **higher contribution to EU emissions from food**, both from the food system as a whole and from agriculture alone.

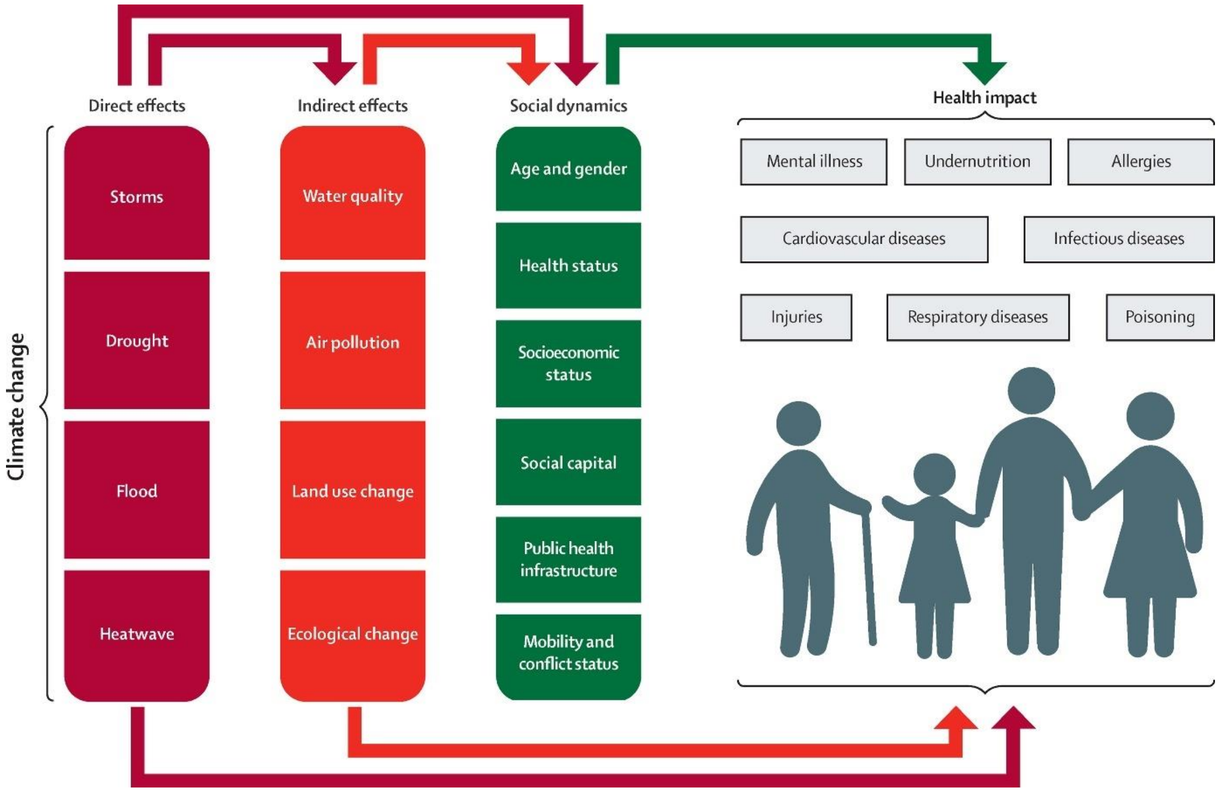
- Taking a food chain approach, the EU Joint Research Centre estimated that **animal agriculture** alone was responsible for **12.8% of total EU emissions** for the year 2004.[195]
- Taking a **food systems** life cycle approach, it was estimated that **animal products** were responsible for **12–17%** of EU emissions in 2007.[196]
- A life-cycle assessment from 2003 estimated that **food** as a final consumer good was responsible for around **30%** of the EU's total contribution to global warming, with the contribution of meat products estimated at 4-12% of the total.[197]

## Climate change and health

The **effects of climate change are pervasive, impacting on natural conditions and social dynamics** that go the heart of the functioning of societies. Current impacts extend across every region of the world and affect every population group, although the effects disproportionally fall on vulnerable populations.[198]

Climate change **interacts with health in a multitude of both direct and indirect ways**. Figure 5 below aims to capture these interactions.

*Figure 5: Climate change and health impacts.*




*Source: The Lancet, Vol. 386, Issue 10006, Watts, N., Adger, W. N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., ... & Costello, A. Health and climate change: policy responses to protect public health. P1861-1914, Copyright (2015), Reprinted with permission from Elsevier.*[199]

In its latest report, The Lancet Countdown describes the global **health impacts of climate change** based on the following five dimensions.[93]

- **Heat, including heat waves**. Exposure to high temperatures and heatwaves are linked to a variety of negative health impacts, from morbidity and mortality due to heat stress and heatstroke, to higher rates of cardiovascular and respiratory diseases. In 2019, a record of 475 million additional exposures to heatwaves were observed among vulnerable populations. Europe is among the world's regions that is most vulnerable to extreme heat events.

- **Extreme weather events, including wildfires, floods and drought**. Extreme weather events affect human health in many ways. These include death and injury as a direct consequence of an extreme event. Such direct effects are often strengthened by effects mediated through the environment, like respiratory impacts from wildfire smoke or the spread of infectious diseases following a flood. Impacts are also mediated through the disruption of social systems, like health services. Traumatic events can affect mental health. There has been a significant increase in the number weather-related disasters worldwide.

  Climate change also changes hydrological cycles, with a tendency to make dry areas drier and wet areas wetter. It affects the intensity, duration and frequency of droughts and can threaten drinking water supplies, sanitation and agricultural production, enhance the risk of wildfires, and lead to migration and risk of conflict.

- **Infectious diseases**. Changes in climatic conditions are increasing the risk of spread of infectious diseases, including vector borne, food borne, and water borne. From 1950 to 2018, the climate suitability for disease transmission has increased globally for all diseases tracked.

- **Food security and undernutrition, both terrestrial and marine**. Rising temperatures, extreme weather events and ground level ozone affect crop yields. The yield potential of the main staple crops, such as maize, winter wheat, soybean and rice, is in continued decline putting global food production at risk. Moreover, higher CO2 levels have been found to lower the nutritional quality of crops. Experiments have shown that crops grown under elevated CO2 emissions had 3-17% lower concentrations of important nutrients (iron, zinc, and protein) than those grown under ambient CO2 levels.[200]

  Compounding these risks is that much of global food security is underpinned by trade in a limited number of staple crops – maize, rice and wheat account for 60% of global food energy intake. With trade in these commodities highly dependent on a number 'breadbasket' regions and trade routes, climate change is increasing the risk for harvest failures in key regions and for disrupting physical trade flows. When several such risks manifest at the same time, this could result in vast implications for global food security.[201] [202]

  Climate change also affects oceans in many ways, including through the rise in sea surface temperatures and coral bleaching, affecting fish stocks. This puts population groups who are especially dependent on marine foods at risk of food insecurity.

- **Migration, displacement and rising sea levels**. Climate change has been widely connected to migration, with associated impacts on health and well-being. Rising sea levels are expected to impact health in multiple ways, including through changes in water and soil quality, livelihood security, disease vector ecology, flooding and saltwater intrusion.

While the key impact areas are well-identified and described, the report highlights the limited extent to which formal statistical studies are currently used to **systematically attribute burdens of disease to climate change**. It argues for a further development of such body of literature to improve understanding of current impacts and future risks on lives and livelihoods.

- In this light, linking climate change to mental health is one of the challenges mentioned. Despite the indications of strong links, mental health is significantly under-reported and there are cultural variations across the world in how well-being is understood.

## Health impacts of climate change in Europe

**Climate change is already impacting Europe**, contributing to its burden of disease and premature deaths.[203] Climate change has increased the frequency and severity of health-related events, which is expected to continue into the future. This especially as Europe is warming faster than the rest of the world.[204] Health burdens are predicted to increase significantly, with southern Europe especially impacted due to greater exposure to heat-related events, water stress, habitat loss, and forest fires.

The European Environment Agency describes the following main drivers of **climate change attributable health burdens**.[9]

- **Exposure to high temperatures**. Exposure to hot weather that lasts for several days can cause fatigue, heat stroke or heat stress. It can also worsen existing health issues, such as respiratory and cardiovascular diseases and kidney problems. The effects of hot weather are further aggravated by air pollution.

  Over the period 1980-2017 there were **77,637 additional deaths attributed to heatwaves** in the EEA. Without mitigation measures, there could be an additional 132,000 deaths per year due to heatwaves in Europe by the end of the century. Under a 2°C scenario, 58,000 additional deaths per year are projected for the period 2025 to 2055.

The Lancet estimates **104,000 heat-related deaths** for the European region in 2018, with 20,200 deaths in Germany alone that year.[93] Climate change is also projected to increase **hospital admissions for heat-related respiratory diseases** from 11,000 admissions between 1981-2010, to 26,000 during 2021-2050. At the same time, deaths from cold weather will likely have decreased by 2080.

Long dry weather increases the risk of **forest fires**. The length and severity of forest fire seasons are already increasing, especially in the Mediterranean region. The total burnt area in Europe may double by the end of the 21st century.[205]

Increased temperatures may also release toxic chemicals, such as mercury, and may accelerate the bioaccumulation of chemicals in fish. The spread of unknown infectious diseases from melting permafrost is another risk.

- **Drought**. Between 2006-2010, on average 15% of the EU territory and **17% of the EU population** were affected by droughts each year. Severe droughts may impact public water supply and food production. Large increases in the frequency, duration and severity of droughts are predicted, especially in southern European countries. Especially after 2070, the whole European continent may be affected by the risk of more frequent and severe extreme droughts. Effects on animal health are also expected, considering increased susceptibility to diseases.[206]

- **Floods**. Floods led to over **8.000 deaths** in the EEA between 1980-2016 due to drowning or injuries. Floods also generate indirect health risks by disrupting the delivery of services, such as healthcare, safe drinking water, sanitation and transport. Floods can also increase the risk of infections and increase exposure to chemicals. Moreover, up to three quarters of people affected by a flood have experienced mental health effects.

- **Vector borne diseases**. Vector borne diseases are infectious diseases transmitted by carriers, such as insects and rodents. Climate change has already impacted on a wide range of vector borne diseases and is projected to **further expand infectious diseases** in Europe.[207] Shifts in climatic conditions could enable the establishment of diseases that have not been present on the continent. Cases of dengue, malaria, chikungunya and Zika have already been reported.

  Lyme disease, transferred by ticks, is a well-studied example of how human-induced environmental change, especially climate change and biodiversity loss, can lead to increased disease risk. Ticks have increased in abundance over the last years, shifting their geographical range accompanied by changes in disease incidence.[126] [208]

- **Water- and food borne diseases**. While difficult to attribute specific disease outbreaks to climate change, increased air and water temperatures do **accelerate the growth rates of pathogens**, including bacteria, viruses and parasites. Pathogens including Vibrio, Campylobacter, Salmonella, Norovirus and Cryptosporidium have all been found to respond to climatic factors.

  For instance, the proportion of coastline suitable for the transmission of water- and food borne Vibrio bacteria in the Baltic region, covering areas of Germany, Poland, Estonia, Lithuania and Sweden, has increased by 61% by 2019 compared to a 1980s baseline.[93]

Furthermore, climate change is also expected to **exacerbate allergies**. Changes in maximum or minimum temperatures have been significantly correlated with both increased airborne pollen loads and longer pollen seasonality across the northern hemisphere.[209] The amount of allergenic proteins in pollen may increase, enhancing allergies and complications for people suffering from allergies.[210]

There are clear indications that climate change and environmental degradation are taking their toll on people's mental well-being. **Mental health effects**, including depression and post-traumatic stress, have been documented following natural disasters.[211] However, psychological effects related to the climate crisis and the threat of environmental disaster more generally have been less studies. Nonetheless, there are clear indications that so-called **'climate anxiety' or 'eco-anxiety'** could lead to new psychological conditions and worsen existing mental illnesses, especially among young people. Associated symptoms include panic attacks, insomnia and obsessive thinking, potentially leading to stress and depression.[212]

Evidence also points to **decreasing agricultural yields for key crops** due to climate change. Yields for key non-tropical crops like barley, wheat, sorghum, maize and rapeseed have declined in western and southern Europe by between 6.3–21.2%.[213] While no direct health burden can be attributed to this yet, it may indicate a potential future food security risk.

Climate change may help **exacerbate existing health inequalities** as environmental risks disproportionally affect socially disadvantaged and vulnerable population groups in Europe. Although everyone in Europe will be affected by climate change, certain people in society are more vulnerable to health impacts, especially linked to their age, health status or level of social deprivation. For instance, while older people are more vulnerable to heat stress, children are more vulnerable to respiratory diseases and allergies. Poorer people will be less able to protect themselves from climate related-risks.

Table 14 below summarises **fatalities and economic loss due to extreme weather and climate-related events** throughout the period 1980-2019. For the EU, total economic losses were calculated at 446 billion EUR and total fatalities reached **90,325 deaths** in the period 1980-2017.

*Table 14: Economic losses due to extreme weather and climate related events between 1980- 2019.*

| Country | Losses (million euros) | Loss per sq. km (euros) | Loss per capita (euros) | Insured losses (million euros) | Insured losses (%) | Fatalities |
|---|---|---|---|---|---|---|
| France | 67,524 | 106,642 | 1,099 | 33,503 | 50 | 23,491 |
| Germany | 107,445 | 300,649 | 1,329 | 51,235 | 48 | 11,110 |
| UK | 53,605 | 215,683 | 894 | 37,278 | 70 | 3,546 |

*Source: European Environment Agency.*[214]

Some of the data available for Europe allows to **quantify the burdens of disease related to climate change**. At the same time, many gaps remain and future endeavours should help to better illustrate, and where possible to project and quantify,[215] the direct and especially indirect impacts associated with this fundamental global threat.[216]

## Outlook: potential future impacts

Climate change poses a severe threat to human health and well-being across the world. The future **impact of climate change may be incomparably greater than current impacts suggest**. For instance, climate change may risk pushing 1/3 of global food production outside safe climatic limits.[217] There is also a risk that potential 'tipping points' will be reached that could lead to abrupt disruptions in the climate system, with severe societal consequences as a result.[218] Overall, the degree to which health risks will manifest depends on the rate, peak and duration of warming, and on the adaptation measures implemented.[219]

At the same time, **health could be greatly improved** from co-benefits-oriented strategies to achieve the Paris goal of keeping warming 'well below 2°C'. It has been estimated that an annual reduction of 1.18 million air pollution-related deaths, 5.86 million diet-related deaths, and 1.15 million deaths due to physical inactivity could be achieved across nine countries in the world by 2040. A more ambitious scenario could achieve even further health gains.[220]

The latest projections by the UN point to the world currently being **on course for a 3.2°C warming by 2100**, which is well-above the Paris Agreement.[221] Although it is hard to describe such a world precisely, it is likely to look quite different from now and far more menacing.[222]

The future of food systems, and the role of animal production therein, will be a significant determinant of the climate trajectory. It has been calculated that even if all non–food system greenhouse gas emissions were immediately ended and would be net zero from 2020 to 2100, **emissions from the current food system alone** would likely exceed the 1.5°C warming limit between 2051 and 2063.[223]

While a small decline in meat production of 8% by 2030 is predicted for the EU, only a 5% emissions reduction is projected compared to 2012.[105] Global projections are worrying. **Global meat production is projected to expand** by nearly 40 Mt by 2029, reaching 366 Mt. The bulk of meat production growth is attributed to emerging economies, which will account for 80% of the additional output. Brazil, China, EU and the United States are projected to produce nearly 60% of global meat output by 2029.[106]

# VI. Nature and biodiversity

This section explores the links between nature and biodiversity and health, and how animal production influences the state of nature. Nature is the fabric underpinning and co-shaping the dynamics of most other health dimensions addressed in this paper. This section best exemplifies the deep interrelation between the various food-health dimensions.

## Nature, biodiversity and health

**Nature** embodies different concepts for different people, covering frames like biodiversity, ecosystems, Mother Earth and the living world. Nature is essential for human existence and a good quality of life. It provides people with multiple basic services, including those related to the production of food, energy, medicines and genetic resources. It sustains the quality of water, soil and air, and regulates the climate. It moreover contributes to cultural and social identities, and spiritual and mental well-being. Nature is also a source of dangers, such as from wild animals, pathogens and toxic plants. **Much of what nature provides is hard, and sometimes impossible, to replace**. Maintaining the diversity of nature can be seen as an important safety net.[224]

Biological diversity, or **biodiversity**, is defined as "the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems".[225]

**Planetary health** is the leading concept exploring and describing the interlinkages between nature and health. It is the study of "the health of human civilization and the state of the natural systems on which it depends".[226] The concept is based on the understanding that **human health and human civilisation depend on flourishing natural systems**, as well as the wise stewardship of those natural systems.

The World Health Organization and the Secretariat of the UN Convention on Biological Diversity describe the **links between heath and biodiversity** based on the following thematic areas.[227]

- **Freshwater**. Water is critical for human life. It is used both for direct consumption and other uses, such as industrial, domestic, agricultural, fishing and recreational. Freshwater ecosystems, forests, wetlands, soil and mountains all play a role in regulating water quantity and quality, including nutrient cycling and flood risk. The ecosystems sustaining water supply are complex, and harm to such systems can be linked to public health outcomes.

  Such ecosystems, for instance, play a crucial role in purifying water. Nearly 800 million people globally rely on an unimproved water supply which can be highly contaminated. Mountain ecosystems contribute on average between 32%-63% to rivers, and supply some 95% of the total annual river discharge in certain arid areas. Wetlands can provide sources of fish and space for rice planting.

  A wide range of human-induced activities can hinder the ability of ecosystems to provide these services. These include water pollution, such as by chemicals, sewage discharge and pharmaceuticals; eutrophication; excessive water extraction; invasive alien species; biodiversity degradation; and the alteration of waterways, including through dams and irrigation canals.

  For instance, nature loss and soil degradation can impair water purification capacity. While poor quality water can result in vast health burdens, water treatment plants are costly to install and operate. Likewise, eutrophication, to which over half of European lakes are exposed, can create toxic algal blooms affecting aquatic life and human health directly. Moreover, freshwater surface alterations coupled with biodiversity loss have been linked to increased incidence of a wide range of water borne infectious diseases.

- Marine ecosystems[174] Oceans, seas and human health are interlinked in many ways. Marine environments provide many services to humans, including food, capturing carbon and economic activity such as fisheries, aquaculture and navigation. Also, there are benefits from tourism, culture, biomedicine, recreational activities and renewable energy.

  At the same time, human activities are increasing cumulative pressures on oceans and seas, producing negative impacts, such as pollution, habitat destruction, overfishing and ocean acidification. These, in turn, can have significant negative impacts on human health, including through infectious diseases, the acquisition of drug resistant bacteria, or toxic effects from algal blooms. Plastics pollution and the associated spread of microplastics is another potential health threat.

- Air quality. The major impacts of air pollution on health have already been described above. Vegetation has an overall positive effect on different air quality dimensions, although in certain circumstances it can also be a source of chemicals contributing to air pollution. Air pollution, in turn, can affect the health of trees, vegetation and ecosystems.

  Plants are associated with a range of impacts on air quality: vegetation removes air pollutants; certain species emit volatile organic compounds (VOCs); vegetation produces pollen, either linked or not to allergic reactions; vegetation reduces air temperatures; adjacent trees can enhance the energy efficiency of buildings.

- Climate regulation.[228] Nature and biodiversity influence climate both locally and globally. Ecosystems can affect the climate in several main ways: as drivers of warming, for instance through the emission of greenhouse gases; as drivers of cooling, for instance as sinks of greenhouse gas, or as sources of aerosols and of transpiration that reflects solar radiation; and by altering regional rainfall patterns and water distribution.

  At the moment, approximately 20% of CO2 emissions are absorbed by terrestrial ecosystems, while oceans have absorbed nearly 40% of all emission.[229] Land use change and changes in the ocean's chemistry may lower their sink capacity. While higher CO2 concentration could be expected to enhance plant productivity and its role as carbon sink, this is not necessarily the case due to a variety of other factors, especially temperature increase.

- Food security and nutrition. Good nutrition is at the heart of health and well-being. The availability of a sufficient and reliable supply of nutritious food is one of the preconditions for food security. Agricultural biodiversity refers to the components of nature and biodiversity relevant to food and agricultural production. Agrobiodiversity is crucial for the productivity and resilience of agroecosystems. The sustainability of agroecosystems, in turn, is dependent on the conservation and enhancement of biodiversity.

  Biodiversity is a key source of food diversity. The development and maintenance of different crop varieties, animal breeds and aquatic species is key for a varied food supply, in which diverse foods provide a natural richness of nutrients. Diversity however may not only matter between food types, but also between different varieties of the same crop, as significant difference in nutritional composition may exist.

  Genetic diversity is also important for productivity and ensuring the adaptability of production to new conditions. Continued improvements in animal breeds and crop varieties have been at the basis of meeting increased food demands. Diversity is also important in other areas. For instance, soil health is improved when it houses a higher diversity of soil biota, which makes it better able to support productivity.[230] More genetically diverse animals are also less susceptible to mass outbreaks of zoonotic diseases.

Insect pollination is another key ecosystem service related to food supply. Many of the crops for which pollination is essential, including fruits and vegetables, are important sources of micronutrients and vitamins. Around a third of the human diet comes from plants pollinated by insects. Many forage crops for animals are dependent on pollination too. Pollinators themselves thrive in rich biodiversity.

Pest control is also linked to agrobiodiversity. The value of species diversity and the importance of maintaining natural prey-predator relations for pest control have been demonstrated in many crops. Moreover, genetic diversity within crops can also contribute to pest and disease control, as well as practices such as plant intercropping.

Moreover, and although frequently overlooked, between 1-5% of food globally is produced in natural forests, underlining the importance of forest conservation.[231] A review also recorded the important of wild foods in the EU, with 38 species of game, 81 species of plants and 27 species of mushrooms collected and consumed.

- Infectious diseases. Infectious diseases are a major risk for human health. At the same time, the richness and diversity of microorganisms is an important feature of biodiversity: one microorganism may be harmful for one host, but beneficial for another. While the needs of biodiversity and human health may not always align, key human-induced drivers, such as deforestation, are driving both infectious diseases and biodiversity loss.[232]

  Infectious diseases are responsible for over one billion human disease cases per year, leading to millions of deaths annually. The increased encroachment of human activity into the environment is enabling pathogen spill-over. While the links between biodiversity and infectious disease is complex, disturbance and biodiversity loss have been strongly linked to the increased prevalence and risk for a variety of zoonotic diseases. At the same time, certain evidence, though less conclusive, has suggested that biodiversity richness with its larger pools of pathogens may be linked to increased disease emergence.

- Non-communicable diseases. Chronic inflammatory disorders such as allergies, autoimmune diseases and certain other NCDs have increased in urbanised settings. There are suggestions that a range of factors in modern life that have reduced exposure to microbial diversity and have affected diversity of the gut microbiome may be linked to some of these afflictions.[233]

- Medicine. Plants and natural organisms have been, and still are, widely used in both traditional and modern medicine. The diversity of life on earth has been an engine of biomedical discovery, contributing to countless medical advances. Most antibiotics are, for instance, of natural origin. Despite great advances in science, much about the natural world remains unknown. Preserving biodiversity means maintaining a vast pool of organisms that may be crucial for life-saving cures in the future.

- Mental, physical and cultural health. Contact with nature is not only associated with positive mental health benefits, but can also promote physical activity and contribute to cultural and spiritual well-being. A body of literature links green spaces in urban settings to mental benefits such as stress reduction. There are strong benefits from interaction with nature for treating depression, anxiety and behavioural problems, particularly in children and teenagers. The existence of a 'nature-deficit disorder' has also been suggested among children in high income countries due to reduced time playing outdoors.

  Moreover, the quality and depth of green spaces in terms of species richness and heterogeneity seems to matter as well. Positive associations have been demonstrated between species richness and aspects of psychological well-being. Environmental decline on the contrary, including loss of biodiversity, has been shown to have adverse mental health effects.

Access to green spaces within high income urban countries are an important conduit for better physical activity. The specific role of biodiversity in this has however not been clearly established. Some studies show that the use of, and exposure to the natural environment is associated with better health. Living in green spaces has been found to have positive health effects for people of low socio-economic status. At a global scale, on the contrary, there is evidence that more biodiverse settings correlate with poorer health outcomes.

The central role of nature and biodiversity have also been described in multiple cultural and spiritual contexts. For many indigenous peoples they are an inseparable component of well-being and health.

The quality and quantity of **nature and biodiversity worldwide have been heavily affected by human activities**.[234] A few highlights are presented.[224]

- **75% of the global land surface has been significantly altered** and natural ecosystems have declined by 47%. Over 85% of wetlands have been lost and while the overall rate of deforestation has slowed, this is not true for all areas: 32 million hectares of primary forest were lost between 2010 and 2015. A large part of the Amazon rainforest seems to be nearing a tipping point where it could move into an altered, savannah-like state.
- 66% of **oceans are experiencing cumulative negative impacts** from human activities, while only 3% of oceans are free from human pressure. Since 1870, half the corals have been lost, with losses accelerating in the last decades driven among others by climate impact. At a warming of 2°C, 99% of corals are expected to be lost.[219] 33% of fish stocks are classified as overexploited and more than 55% of the ocean area is subject to industrial fishing.
- Around 25% of species in assessed animal and plant groups are threatened. Wild mammals have declined by 80%. Habitat loss and deterioration, largely caused by human actions, have reduced terrestrial habitats by 30% relative to an unimpacted state. **One million species face extinction within decades**, a trend that will further accelerate without action. The current global rate of species extinction is hundreds of times higher than over the past 10 million years.
- The **genetic variety of domesticated animals and plants are also decreasing**. By 2016, over 9% of domesticated breeds of animals had become extinct (559 of the 6,190), and at least 1,000 are threatened. Increased genetic uniformity of plants and animals threatens the resilience of agricultural systems against climate change, pests and pathogens.
- Human drivers are speeding-up evolutionary processes with uncertain consequences. Overall, **uniformity in biological communities is on the rise** across the world.

In the EU, the latest report on **trends in the state of nature** between 2013-2018 paints a following picture.[235]

- Around half the **EU's bird species** assessed show a good conservations status, representing a decline by 5%. The proportion of species with poor or bad status has increased by 7%, reaching 39%. Among the species where conservation status is improving, farmland birds are least represented.
- Only 15% of the **natural habitats** assessed have a good conservation status. 81% have a poor or bad status. Just 9% of the habitats with poor or bad conservation status show improvements, while 36% continue to worsen. Habitats important for pollinators have worse than average conservation status and trends. Marine habitats tend to fare worse than terrestrial ones.
- Approximately 27% of **non-bird animal species** have a good conservation status, an increase by 4%. For one third of species, trends are unknown.

In the EU27 and the UK, **630,000 deaths were attributed to the environment** in 2012. 90% of these deaths result from non-communicable diseases, including cancers, cardiovascular diseases, mental, behavioural and neurological disorders, musculoskeletal disorders and asthma.[9]

Air pollution has by far the most significant health impact, followed by noise pollution, exposure to chemicals, climate change, indoor air pollution and radiation. Both air pollution and climate change have been **addressed in previous sections**. Infectious disease risk and AMR are also closely interlinked with dynamics in the environment and have been discussed as well. **Despite the numerous interlinkages between nature and health, very few other burden of disease estimates** seem to have been produced across European countries.

The **quality of water** is an important dimension and the European Environment Agency reports on water quality in the EU.[9]

- The **drinking water supply** serving the majority of the population complies nearly 100% with Europe's quality standards. Some of the smaller private wells, which nonetheless serve around 65 million people achieved much lower compliance rates.
- Despite the overall good reported status, **nitrates in drinking water remain a risk to health**. Increased risks have been observed with the ingestion of water nitrate levels below regulatory limits.[236 237]
- Both **bathing water** and **groundwater** are overall in good status. The status of **surface waters** is, however, of great concern, with only 40 % found to be in good ecological status and 38% found to be in good chemical status.

At the global level, 2.7 % of the burden of disease and 1.7 % of total premature deaths are attributed to **chemicals**, which is likely an underestimate.[9]

- Of the 314 million tonnes of chemicals consumed in the EU in 2018, 71% were classified as hazardous to health, including various agrochemicals. The **intensive use of pesticides** in agriculture applied at landscape levels has led to widespread exposure to agrochemicals, and there are mounting concerns about the impacts of long-term, low-dose exposure to pesticides.[238 239]
- There is special concern about **endocrine disrupting effects** of certain chemicals, especially for young people. Approximately 800 chemicals are known or suspected to be endocrine disruptors, including various pesticides. Diseases and dysfunctions caused by exposure to endocrine-disrupting chemicals have been estimated to cause 157 billion EUR in annual healthcare costs across the EU.[9]
- Concern also extends to the fact that people in their everyday lives are exposed to **mixtures of chemicals**, while safety thresholds are set for chemicals individually. A combination of chemicals can produce effects that are larger than the effects of a single chemical.
- Despite these indications, **no comprehensive burden of disease estimates** have been produced on this theme in Europe.[240]

## Agriculture, animal farming and biodiversity

**Agriculture occupies around 38% of the global land surface**. About one-third of this land is used for crop production and two-thirds consist of meadows and pastures for grazing.[241] Of the cropland, around a third is used for producing animal feed. In sum, approximately **77% of global agricultural land is used for animal agriculture**.[242]

Agriculture is one of humanity's largest impacts on the environment.[243] Across a range of key metrics, it can be seen as a major, if not **single largest driver of global biodiversity loss and degradation**, with animal agriculture playing a major role.

- For instance, agricultural expansion drives **75% of global deforestation**. Deforestation predominantly occurs in the tropics, and nearly half of tropical deforestation takes place in Brazil and Indonesia. Beef, soy and palm oil are responsible for 60% of tropical deforestation. Expansion of pasture land for raising cattle is the main driver, responsible for 40%, while deforestation linked to animal feed production is another important driver.[242 244]
- The **habitat loss of terrestrial vertebrates** is to a large extent driven by agricultural expansion. About 80% of all threatened terrestrial bird and mammal species globally are threatened by agriculturally driven habitat loss. Of the 28,000 species evaluated to be at risk of extinction on the International

Union for Conservation of Nature´s (IUCN) Red List of Threatened Species, agriculture is listed as a threat for 24,000 of them. In Europe many species are threatened by agriculture also.[245]

As presented in table 15 below, a **global land use comparison** of different food products linked to different measures of nutrient density, suggests that meat, aquaculture, eggs and dairy use approximately 80% of the world's farmland and contribute 56-58% of food's different emissions.[192]

*Table 15: Land use footprint of different food products.*

| Food | Land use per kilogram | Land use Per 1000kcal | Land use per 100gram protein |
|---|---|---|---|
| Lamb & Mutton | 369.81 m² | 116.66 m² | 184.8 m² |
| Beef (beef herd) | 326.21 m² | 119.49 m² | 163.6 m² |
| Cheese | 87.79 m² | 22.68 m² | 39.8 m² |
| Dark Chocolate | 68.96 m² | 13.34 m² | 137.9 m² |
| Beef (dairy herd) | 43.24 m² | 15.84 m² | 21.9 m² |
| Olive Oil | 26.31 m² | 2.98 m² | - |
| Coffee | 21.62 m² | 38.61 m² | 27.0 m² |
| Sunflower Oil | 17.66 m² | 2.00 m² | - |
| Pig Meat | 17.36 m² | 7.26 m² | 10.7 m² |
| Other Pulses | 15.57 m² | 4.57 m² | - |
| Nuts | 12.96 m² | 2.11 m² | 7.9 m² |
| Poultry Meat | 12.22 m² | 6.61 m² | 7.1 m² |
| Rapeseed Oil | 10.63 m² | 1.20 m² | - |
| Soybean Oil | 10.52 m² | - | - |
| Groundnuts | 9.11 m² | 1.57 m² | 3.5 m² |
| Milk | 8.95 m² | 14.92 m² | 27.1 m² |
| Fish (farmed) | 8.41 m² | 4.70 m² | 3.7 m² |
| Oatmeal | 7.60 m² | 2.90 m² | 5.8 m² |
| Peas | 7.46 m² | 2.16 m² | 3.4 m² |
| Eggs | 6.27 m² | 4.35 m² | 5.7 m² |
| Wheat & Rye | 3.85 m² | 1.44 m² | 3.2 m² |
| Tofu (soybeans) | 3.52 m² | 1.30 m² | 2.2 m² |
| Prawns (farmed) | 2.97 m² | 2.88 m² | 2.0 m² |
| Maize | 2.94 m² | 0.65 m² | 3.1 m² |
| Rice | 2.80 m² | 0.76 m² | 3.9 m² |

*Source: Poore & Nemeczek (2018).[192] Note: Data is from a meta-analysis with global data.*

In the EU, similarly, around **38% of the land area is used for agriculture**. More than 60% of that is used as cropland, around 31% as grassland and the rest for permanent crops, such as fruit and olive trees and grapes.[246] According to estimates, a large share of this cropland is used for animal feed, meaning that approximately **65-70% of EU agricultural land could be dedicated to animal agriculture**.[180]

In the EU, **animal production** was found to contribute **78% to agriculture's role in terrestrial biodiversity loss**.[180] Agriculture overall was the main sector contributing to air, water and soil pollution in the EU.[235] At the same time, permanent grasslands with grazing ruminants can also contribute to biodiversity, as further highlighted below.

A life cycle assessment of 35 food products in Europe shows **meat as having the main impact on biodiversity across the majority of impact categories**, followed by other animal products, such as milk, cheese, butter and eggs.[247]

- The study assessed products on the basis of **16 impact categories**, including climate change, ozone depletion, human toxicity, particulate matter, eutrophication, land use, water use and fossil fuel use.
- Eight products (pork, poultry and beef meat, cheese, eggs, butter, milk and sunflower oil) contribute to **75% of total damage to biodiversity**. Loss of species is mainly driven by meat, specifically pork and beef, which together contribute to 43% of total species loss over a year. Poultry meat 8-13%, Cheese 7%, eggs 4-5%. The reason behind the relevant role of meat is twofold, namely the intensity of the impacts of a certain food type per kg and its amount consumed in the EU and the UK.

While a **wide range of metrics is used to assess biodiversity**, this section will further highlight the following considerations:

1. eutrophication;
2. land use change;
3. agrochemicals use; and
4. positive biodiversity effects.

**Eutrophication** is caused by the enrichment of surface waters and coastal zones with nutrients, leading to excessive plant and algal growth. It is a major threat to both water ecosystems and human health, with risks including toxic poisoning, loss of species diversity, oxygen depletion, fish deaths and challenges with water purification.[227]

- While eutrophication is a slow naturally occurring process, it can be greatly accelerated by human activity. Nutrient pollution from human activity is caused especially by phosphorus and nitrogen. **Agriculture is a major source of reactive nitrogen**, both through fertiliser use and animal manure. Reactive nitrogen (Nr) covers a group of compounds, including ammonia (NH3), nitrogen oxides (NOx) and nitrous oxide (N2O).
- Agriculture represents one-third of human nitrogen emissions globally.[248] In the EU, animal production was found to represent **73% of all agricultural nitrogen emissions to water bodies**.[180] While the gross nitrogen balance from agriculture has improved since 2000, the decline in nitrogen surplus has stalled since 2010. Nitrogen input into natural systems still substantially exceeds acceptable inputs.[249]

**Land use change** is the conversion of land, such as natural ecosystems, for agricultural purposes. It is one of the most important drivers of biodiversity loss. Animal production affects terrestrial biodiversity through the need for grazing land and for cropland to grow animal feed. The impact of the European food system on land use change is almost entirely due to imports.

- Today, European agriculture has a **negligible impact on land use change inside the EU**. Towards 2030 EU agricultural land is actually predicted to shrink by 1%. However, in some areas of southern and south-eastern Europe agricultural land expansion in the range of 15% is foreseen. Some land expansion in northern Europe, including in the UK, has also been foreseen driven by climate change.[105]
- Over the period 1990-2008, the EU27 has been the largest net **importer of deforestation** globally, importing almost 36% of all deforestation embodied in crop and animal products traded between regions. Approximately 61% of embodied deforestation has been associated with the livestock sector. This should be put in perspective that worldwide 33% of deforestation embodied in crops is traded, and only 8% of deforestation embodied animal products. All in all, the import of embodied deforestation occurred mainly through the import of **crop products, such as soy used for animal feed**.[250]

- More recent estimates show a decline in imports of deforestation, with the EU taking the second place after China. The EU was still held to be **responsible for 16% of deforestation associated with international trade**, with soy, palm oil and beef the commodities with most embedded deforestation.[251]
- Also, research suggests that around 20% of soy exports and at least 17% of beef exports from both Brazil's Amazon and Cerrado to the EU may be contaminated with illegal deforestation.[252]
- Likewise, the assessment of the biodiversity impacts of different food products consumed in the EU, referred to above, showed that the high impact of animal-based products on biodiversity was mainly due to the **production of animal feeds**, such as the cultivation of barley and soybean.[247]

**Agrochemicals, such as pesticides and synthetic fertilisers** are widely used in Europe, including for animal feed production, which likely covers at least half of EU cropland.

- **Pesticides** use in the EU has remained stable over the period 2011-2018 with 360 million kg sold.[194] The large-scale use of pesticides has been widely associated with biodiversity loss and ecosystem degradation.[253] [235] Pesticide use has contributed to reducing populations of birds, insects, amphibians and aquatic and soil communities,[254] either through direct exposure or reduction in food and habitat availability.[238] The impact of pesticides on pollinators, in combination with other human-induced pressures, has been especially well-explored.[224] [255] Vast **declines in insects** have been reported across Europe over the last decades,[256] raising significant concern about the future of pollination services.[257]
- The excessive use of **fertilisers** releases nitrogen and phosphorus into the environment. The main impacts include direct toxicity to organisms, soil and water acidification, eutrophication, groundwater and air pollution and contribution to climate change.[240] Overuse of fertilisers is also one of the drivers of **soil degradation and erosion**, which poses a significant risk for future food security.[258]

**Positive biodiversity impacts** have especially been linked to the role of ruminants in maintaining **permanent grasslands**. Grasslands have the potential to supply multiple ecosystem services, including food production, nutrient cycling, water supply and flow regulation, carbon storage, erosion control, pollination and cultural services.[259]

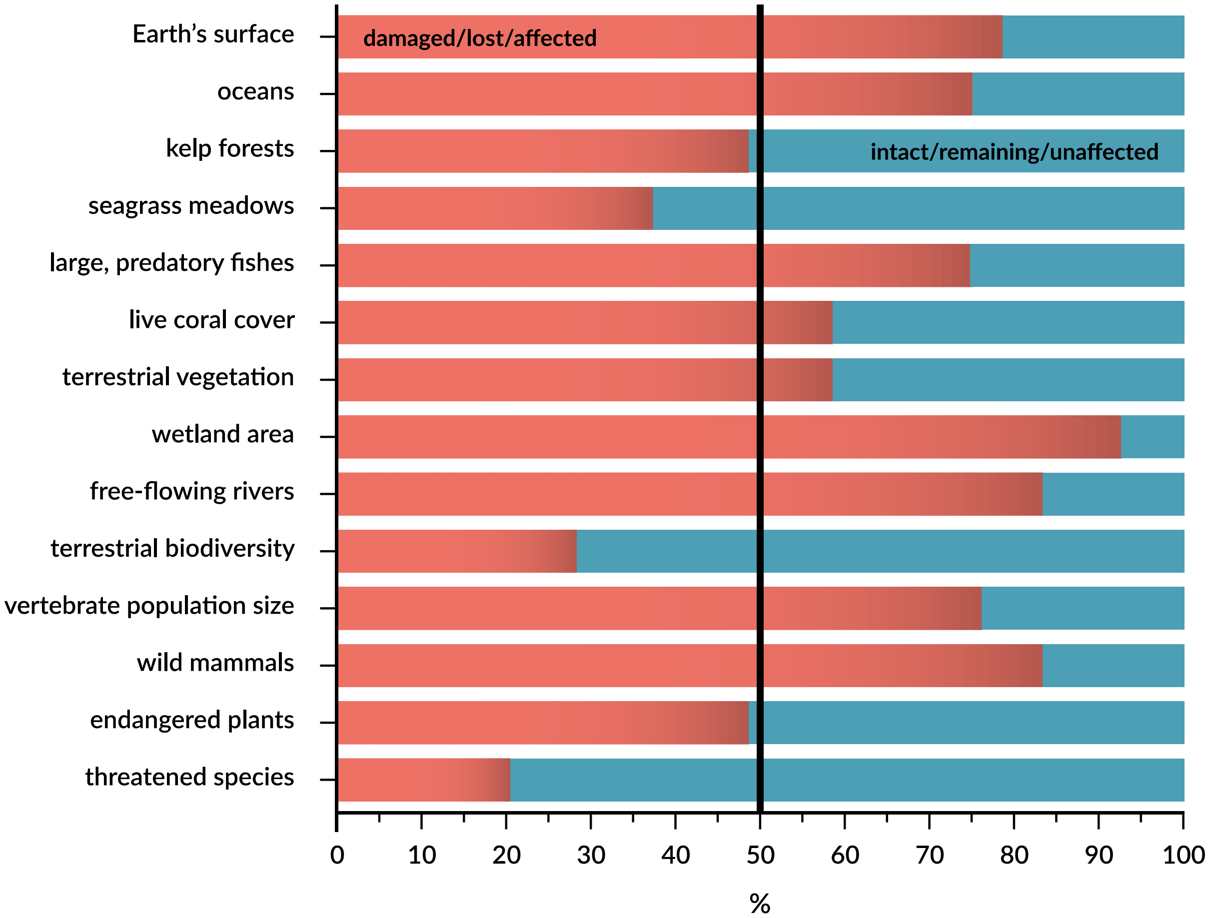
- About half of the endemic plant species in Europe are dependent on the **grassland biotope**. Likewise, half of bird species depend on grassland habitats for food and reproduction. Grasslands provide a home for invertebrate species and soil under permanent grassland tends to have high levels of biodiversity. Bees and other pollinators benefit from grasslands and associated features, such as hedges.
- Permanent grasslands also function as **stores and sinks of carbon**. The contribution of livestock manure, unless in excessive quantities, improves soil organic matter content, soil macroflora, such as earthworms, and soil microbial diversity.
- However, the **benefits of grasslands**, including carbon sequestration and diversity, **decrease significantly with increased intensity of use**. This suggests that better ways should be found to maximise the potential of grasslands to contribute to functional landscapes, biodiversity, food security and sustainable livelihoods.[260]

## Outlook: potential future impacts

The global outlook for biodiversity is worrying. If **current trends in agricultural continue, pressures on biodiversity will increase substantially**. The global cropland under a 'business-as-usual' scenario, involving a transition towards higher calorie and higher animal-based food diets, has been projected to increase by a total of 26% between 2010 to 2050. Under this scenario it is projected that 87.7% of species would lose some degree of habitat by 2050.[261] Nitrogen emissions from animal farming too will continue to increase, given the projected global expansion of animal production in the coming decade.[248]

A paper reviewing the evidence about potential future environmental conditions argues that the scale of the **threat facing the global biosphere is far greater than currently acknowledged**, including for humanity. Figure 6 below summarises the current state of key ecosystem indicators, while projecting further deterioration in the years to come in the absence of strong measures.[262]

*Figure 6: Summary of major environmental-change categories expressed as a percentage change relative to the baseline.*




*Source: Bradshaw CJA, Ehrlich PR, Beattie A, Ceballos G, Crist E, Diamond J, Dirzo R, Ehrlich AH, Harte J, Harte ME, Pyke G, Raven PH, Ripple WJ, Saltré F, Turnbull C, Wackernagel M and Blumstein DT (2021) Underestimating the Challenges of Avoiding a Ghastly Future. Front. Conserv. Sci. 1:615419. doi: 10.3389/fcosc.2020.615419. Reproduced with permission. Copyright (2021), with permission from Frontiers. (image re-drawn from original).[262] Note: Red indicates the percentage of the category that is damaged, lost, or otherwise affected, whereas blue indicates the percentage that is intact, remaining, or otherwise unaffected.*

The EU's contribution to global deforestation seems to have decreased somewhat over the years, but is still high. Should the EU take strong action to move towards deforestation-free supply chains, should it become more self-sufficient in animal feed and cut agriculture-related greenhouse gas emissions, its **pressure on global biodiversity and related global health impacts can be significantly reduced**. As for biodiversity impacts within the EU, significant action will have to be taken, especially to improve the nitrogen balance and reduce agrochemicals use. Furthermore, the importance of improving soil biodiversity for tackling soil erosion and supporting food security cannot be underestimated.[263 258]

It seems fair to suggest that the **environmental threats to human health and human civilisation will be characterised by surprise and uncertainty**. While some of the ecosystem-linked impacts are well-described and quantified, especially the impact of air pollution and increasingly that of climate change, the impacts of many other indicators are much less specific and probably underestimates.

There appears to be a big gap between, on the one hand, the evidence about the importance of nature and biodiversity for health, linked to the strong evidence about biodiversity decline and, on the other, a **lack of convincing metrics showing population-wide health impacts**. It remains hard to put a finger on what exactly the health impacts may be of, for instance, the disappearance of species, or loss of corals, or ecosystems that have shifted beyond their tipping points.

Similar to climate change, some of the health impacts of biodiversity loss can be mitigated or cushioned through **adaptation measures**, such as for instance, by installing water purification systems, or working on flood defence. However, such measures may be costly and may crowd-out investments in other health-relevant areas. Also, while individually these could be seen as problems that could be fixed or overcome, taken together they may fundamentally affect the life and life chances of large shares of the global population. This risk is further exacerbated by the, sometimes, irreversible nature of biodiversity loss.

# VII. Occupational conditions

This section explores current occupational risk factors in animal farming and animal-related professions. The discussion deals with the agricultural production and processing sides of food systems.

## Occupational risks and farming

Agriculture and forestry are among the **top most dangerous professions in Europe**. As presented in table 16 below, agriculture and forestry register an average of 500 deaths and 150,000 non-fatal accidents per year, which is likely to be a significant underreporting.[264]

- While forestry has a higher rate of accidents, agriculture comes fourth in Europe with a fatal accidents rate of 4.1 out of 100,000 and a non-fatal accidents rate of 2,019 out of 100,000.[264]

*Table 16: Fatal and non-fatal accidents in the agriculture, forestry and fishing sector in year 2018.*

| | Non-fatal accidents | | Fatal accidents | |
|---|---|---|---|---|
| | Total number | Incidence rate/ 100,000 people employed | Total number | Incidence rate/ 100,000 people employed |
| *France* | 15,025 | 2,259 | 25 | 3.76 |
| *Germany* | 47,652 | 1,637 | 76 | 2.61 |
| *UK* | 6,695 | 1,912 | 49 | 14.08 |
| *EU-28* | 150,654 | 1,961 | 485 | 6.31 |

*Source: European Agency for Safety and Health at Work, 2020) based on Eurostat.[264] Note: No detailed overview of agriculture on its own is available. Many occupational accidents and work-related diseases are not recorded consistently leading to significant under-reporting of workplace accidents and ill-health. A full and transparent picture of the safety and health situation of farmers is not available today. Underreporting in some instances may be as high as 90%.*

The **top eight killers** in agriculture and forestry include the following: transport accidents; falls from heights; being struck by falling or moving objects, including machinery; drowning, including in water reservoirs, slurry tanks; handling livestock, such as being attacked or crushed by animals and zoonotic diseases; contact with machinery; entrapments under collapsed structures; electrocutions.[264]

Despite the very limited availability of comparable data across Europe, it appears that **over 60% of agricultural workers report having a limiting NCD**, which brings it to a second place in Europe among NCD-prone occupations. A similar number of respondents in the sector report their work is affecting their health.[264] The **exploitation of migrant workers in agriculture** has been widely documented across Europe.[265] [266]

The following key **health and well-being related risks** of agricultural work have been identified in a review by the European Agency for Safety and Health at Work.[264]

- Farmers and workers are exposed to **pesticides, fertilisers and other hazardous chemicals**. Exposure occurs, among others, through working in fields where pesticides have been applied, breathing-in pesticide 'drift', working without appropriate personal protective equipment (PPE), eating with pesticide-contaminated hands and so on. Effects can range from mild to lethal, and from acute to long-term with cumulative effects. The most common effects are allergies, skin diseases, cancers, reproductive problems and birth defects, respiratory diseases and poisoning. Documenting long-term health effects of exposure is considered a significant challenge, with limited data available. A number of studies in France point to a higher rate of prostate cancer and Parkinson's disease among farmers.

- The various manual tasks performed in farming, like bending, lifting heavy weights, weeding, picking, handling machinery, pushing and pulling very often result in a variety of **musculoskeletal disorders**. Musculoskeletal disorders are the most serious work-related health issue in farming, with over 55% of agricultural workers reporting backache and upper limb pain and 45% lower limb pain. It has been estimated that over 80% of agricultural workers will have a musculoskeletal disorder at some time in their life.
- **Hearing loss due to noise exposure** is another important risk factor. It appears that over 20% of agricultural workers suffer from noise exposure.
- Exposure to **high levels of dust** from preparing soils or mixing of animal feed is also a substantial health risk. It is associated with respiratory diseases, such as occupational asthma and pneumonitis and potentially chronic lung disease and lung cancer. High levels of chronic bronchitis have been reported in many studies of farmers.
- Farmers and farm workers are also highly exposed to the **risk of zoonotic diseases**, both spread by farm animals and insects, such as Lyme disease. Farmers and veterinarians are on the frontline of human-animal interactions and susceptible to zoonotic infections, including by drug resistant microorganisms.
- Moreover, **mental ill-health** is one of the major current and upcoming issues confronting the agricultural profession.[267] [268] [269] Long working hours, isolation, financial uncertainty and administrative demands put lots of stress on farmers. In the UK, 84 % farmers under 40 years-old believe that mental health is the biggest challenge facing the sector.[270] Both financial and non-financial stress result in mental distress, leading to a predisposition to injury, anxiety and depression. Farmers in many countries, both in Europe and beyond, experience high rates of suicides.[271] French data suggest higher suicide rates among farmers between 45 and 54 years of age compared to population averages.[272] Likewise, suicide rates of male Swiss farmers may be 37% higher than of the average male.[273]

Farming is often discussed as a 'way of life' rather than purely a profession. A survey of farmers across nine European countries found 58% of farm managers having a medium **quality of life satisfaction rate**, 22% a low satisfaction rate and 20% a high satisfaction rate.[274]

Lack of physical activity is an important risk factor for NCDs. The **levels of physical activity involved in farming** could be health-promoting,[275] although increased mechanisation may reduce potential benefits.

## Occupational risks and animal-related professions

A number of **specific occupational risks linked to animal-related professions** in Europe have been described for different types of workers.[276]

- **Slaughterhouse workers** are exposed to infectious agents through contact with infected animals, their blood, body fluids or their tissues. This leads to a large range of health risks including leptospirosis, brucellosis, Q fever, tuberculosis, influenza-like illnesses, West Nile virus and hepatitis B and E. AMR transfer has also been reported with slaughterhouse workers.[277]
- **Animal farmers and workers on animal farms** can be exposed to animal hair, fluids (blood, urine, milk), manure, animal feed, animal-related parasites and the microorganisms found in these sources. This leads to exposure to a wide range of health risks, including infectious outbreaks of zoonoses such as Q fever and different influenzas, health problems resulting from the inhalation of organic dust, such as lung function decline, COPD and other respiratory diseases, hepatitis E and MRSA. Exposure to drug resistant microorganisms is a significant risk.[278]
- **Veterinarians** due to their frequent exposure to sick animals are at risk of a broad spectrum of diseases.

Such findings are confirmed by other studies **describing zoonotic, AMR, respiratory, chemical and physical risks, but also some positive exposures** related to animal farming professions.[131]

Recently, meat processing facilities across Europe, including in France, Germany[279] and the UK, have turned into COVID-19 hotspots, raising significant attention to the **precarious labour conditions of slaughterhouse workers**, many of whom are migrants and cross-border workers both from inside the EU and third countries.[280]

- The issues involved include **abusive employment contracts**, often signed as subcontracts or as independent worker contracts, with low pay and low sickness allowances leading some workers not to report their health status in fear of losing their job or income; overcrowded and unsafe accommodations, sometimes owned by the employer; lack of social distancing at work; and overall stressful working conditions with long hours and few breaks.
- Moreover, employees in the slaughtering sector more likely to face **injuries** than the average person at work.[281]

In addition to the **mental health issues affecting farmers** more generally, there are voices highlighting that animal farmers may be especially affected as they feel **vilified by a perceived 'anti-meat' agenda**. Being labelled as the problem and not part of the solution has been described as taking an additional toll on mental well-being.[282] [283] [284]

**No comparative burden of disease data** is available to quantify these health impacts.

## Outlook: potential future impacts

If the current trend of reduced employment in agriculture persists and if technologies can in practice alleviate some of the occupational risk factors, one **may expect a reduction in the absolute rate of occupational injuries** in the future.

At the same time, **higher occupational risks** are expected due to a number of developments.[264]

- **Climate change** is expected to impact on a wide range of occupational factors, including increased exposure to extreme weather events and heat and sun, increased risks of infectious diseases, higher dust exposure, increased use of pesticides to combat higher incidence of insect pests, fire risks and more. It will furthermore increase the unpredictability of production, increasing financial risk and stress.
- **Emerging biological risks** have been highlighted, especially with a view on the role of farmed animals acting as a reservoir for the development and spread of zoonotic diseases, potentially resulting in new epidemics. Their further role in the development of AMR and the risks of direct exposure to animals is also highlighted as especially relevant to animal-related occupations.[285]

Moreover, the role of **mental health risks may become bigger in the future**, especially if meaningful frameworks and incentives are not established to embed agriculture, and animal agriculture especially, into a pathway that increases economic resilience while contributing to food systems sustainability.[264]

# VIII. Socio-economic influences

This section explores the links between socio-economic status and health. It reflects on social determinants from both production and consumption perspectives. The discussion touches on the agricultural production and processing sides of food systems as well as consumption.

## Social determinants and health

The 'social determinants of health' encompass a **wide range of non-medical socio-economic factors that influence health outcomes**. They are defined as the "conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life".[286]

**Examples of the social determinants of health**, which can influence health in both positive and negative ways, include levels of income; systems of social protection; education; employment status; occupational conditions; levels of food security; housing quality; early childhood development; social inclusion; gender; ethnicity; exposure to discrimination; exposure to structural conflict; levels of access to affordable and quality health services.

Social, or socio-economic, determinants are largely responsible for health inequities, which are systematic differences in the health status of different population groups. While health inequalities refer to observed differences in health status, **health inequities are avoidable and therefore deemed unfair or unjust**.[287]

The WHO identifies actions in **five main policy domains to tackle health inequities**.[288]

- Health services;
- Income security and social protection;
- Living conditions;
- Social and human capital;
- Employment and working conditions.

The importance of social determinants cuts across the entire spectrum of public health. The 'rule of thumb' is that people who are **exposed to socio-economic vulnerabilities are disproportionately burdened by ill-health** across a wide range, if not all, health dimensions.[289 290]

## Social determinants and animal production

**Employment and income, and the social status they provide, are important social determinants of health**. This section will present several considerations on how animal farming-related economies and professions may relate to social well-being. While partly overlapping with the chapter on Occupation factors, this section discusses socio-economic aspects beyond occupational safety.

Animal agriculture **contributes substantially to the agricultural economy** of Europe.[246 259]

- Europe, including the EU27 and UK, is the world´s second largest producer of meat after China.[145] It is a **net animal foods exporter** as well, especially of dairy and pork products.
- For the EU27 in 2019, Germany produced 23% of pigs, 11.9% of poultry, 17.9% of beef and 22.7% of milk. France produced 20.8% of beef, 12.8% of poultry, 9.7% of pigs and 17.9% of milk.
- Animal farming represents around **40% of the total economic activity in agriculture**.
- The value of animal output in France was 26.6 billion EUR and in Germany 27.3 billion EUR in 2019. In some European regions there is special reliance on the animal farming economy.
- Animal agriculture **employs around 4 million people** in the EU27 and UK. The estimated total employment in agriculture and related services was 9.2 million in the EU27, or 4.4% of total

employment in 2018. Agriculture in France employed 726,000 work units and Germany 940 000 work units in 2019 [291] In the UK, currently around 472,000 people work on agricultural holdings.[292]

- Approximately **25% of EU farms are specialised animal farms**. Mixed farms account for just over 20% of agricultural holdings. At the same time, mixed crop-and-animal farms account for the largest share of jobs in animal agriculture. Over 55% of European farms hold animals.
- Family farms, which are holdings where 50% or more of the employment is provided by family workers, reared 62.5% of all farmed animals. Only 5% of all farms in the EU are not family farms, but they cultivated 37% of the agricultural area.[293]
- Of the 289,000 food and beverage manufacturers in the EU27 in 2018, 11.9% specialised in meat and meat products, and 4.4% in dairy products. **5 of the top 10 most valuable products sold were meat products**. Cheese was the highest valued product.
- Various input industries, including animal health and feed, and services, such as veterinary, are closely interrelated with animal food production and form part of that economy.

While agriculture and related services play an important economic role, and while the share of animal production therein is significant, **employment in agriculture is on the decline** and structural challenges in the sector impede generational renewal.[246 294]

- The **number of farms in Europe have been in steep decline** over the past decades. Between 2005 and 2016 there were over 4 million farms less in the EU27, or a decline of nearly 30%. The vast majority of those were farms under 5 hectares.
- The **share of people employed in agriculture fell** from 6.4% of total employment in the EU27 in 2005, to 4.4% in 2018. Likewise, the volume of work carried out in the agricultural sector fell by 25% between 2005 and 2016.
- Nearly 55% of farm managers are 55 years-old or more. Only 10% of farmers are under the age of 40. Also, the share of young farmers under age 35 has declined from 6.9% in 2005, to 5.1% in 2016.
- A process of **consolidation** is ongoing with a growth in the number of large holdings and a growth in the land area they hold.

A sector's influence on well-being is not only shaped by the numbers of jobs it provides, but by their quality too. The degree to which agriculture **provides for a fair standard of living** cannot be answered in a straightforward way. It is moreover made difficult by a lack of good statistics. Several relevant considerations are presented below.[295]

- Over the long-term, there is evidence of a **general downward pressure on profits and incomes in farming**. Agriculture in economically developed countries seems to be caught in a 'squeeze' where production costs increase relative to the prices received.
- Shorter-term instability, such as natural disasters or political events that interrupt supply or demand, add to this pressure.
- The entrepreneurial income for farmers has, on average, been found to be **just above 45% of the average wages in the economy**.[296]
- At same time, again on average, **farmers do not seem to be a particularly low-income population group** judged on the basis of household disposable incomes. Many farmers or members of their household also have other gainful activities. The entrepreneurial income therefore does not show the full picture, although it could be seen as an indicator of the economic attractiveness of the profession.
- A key feature of the farming landscape are the very **large disparities** in both incomes, and especially, in wealth. Only 20% of the labour force in generates nearly 80% of the income.
- A strong relationship exists between the **economic size of farm business and the average levels of income** generated. While different factors add to inequality, including regional differences and whether a holding is in a Less Favoured Area or not, the relationship between farm size and income levels cuts across all other differences.
- In terms of sub-sectors, farms rearing **granivores** (grain eating animals like pigs and poultry) tend to have the highest incomes, while **mixed farms and grazing livestock** the lowest.

An exploration of the **quality of employment in the meat processing industry** in four European countries paints a picture of an increasingly unattractive industry with low wages and repetitive work at a high pace involving significant risk of injury.[281]

- In Germany and the UK, meat processing is a **low-wage industry** that increasingly employs workers on temporary contracts, which endangers income stability, job security, work-life balance and unionisation.
- Due to pressure from market forces, the profession moved from one dominated by skilled butchers, towards an increasingly concentrated **mass production operation requiring low- or semi-skilled operations**. A parallel development with greater focus on small-scale production, quality, locality and animal welfare is also visible, but remains niche. Automation may enhance the skill level of workers and reduce work-related risks, but is moving slowly due to a high availability of cheap labour.

## Social determinants and food consumption

Socio-economic conditions not only **mediate between food systems and health outcomes**, they also shape the possibilities for achieving food systems change. The interaction between socio-economic status, dietary patterns, health outcomes and socio-cultural influences raises a large number of complex questions.

Lower socio-economic status has been widely **associated with less healthy dietary patterns**, especially in relation to consuming less fruit and vegetables and more energy-dense foods.[297 298 299 300 301] Lower socio-economic status has also been widely associated with a **higher risk of developing NCDs**, including obesity.[302,303]

Differences in **consumption patterns of animal-based** foods in Europe have also been linked to differences in socio-economic status.

- Higher consumption of **red and processed meat** has been associated with lower socio-economic status.[304–306]
- Higher **cheese** consumption has been associated with higher socio-economic groups.[307]
- A German national cohort study found that the prevalence of **vegetarianism** is highest among people in high socio-economic groups.[308]

**Significant levels of social deprivation** are found in the EU27 and the UK, as presented in table 17 below.

- Over 20% of people are at **risk of poverty or social exclusion**.[309]
- An estimated 11% of the population (49 million people, EU-27) is **unable to afford a quality meal every second day**.[310]

*Table 17: Percentage of people at risk of poverty and social exclusion, and unable to afford a meal with meat, chicken, fish (or vegetarian equivalent).*

| | Percentage of the population at risk of poverty or social exclusion, 2019 | Percentage of the population unable to afford a meal with meat, chicken, fish (or vegetarian equivalent), 2019 |
|---|---|---|
| France | 17.9% | 12.1% |
| Germany | 17.4% | 11.6% |
| UK | 23.1% (2018) | 7.7% (2018) |
| EU27 + UK | 21.4% | 10.9% |

*Source: Eurostat (2021), People at risk of poverty and social exclusion.[309] & Eurostat (2021), Inability to afford a meal with meat, chicken, fish (or vegetarian equivalent).[310]*

In the EU27 and the UK, on average, **13% of total consumer expenditure was spent on food** in 2019. For France this was 13.1%, Germany 10.8% and the UK 7.9%.[311] When including catering, restaurants and alcoholic beverages the total average expenditure is closer to 21%. Meat accounted for the largest share of consumer expenditure.[246]

- In France, 38% of total consumer expenditure on food (excluding alcoholic and non-alcoholic drinks) was in the categories of meat (25%) and milk, cheese and eggs (14%).[312]
- In Germany in 2013, 14% of total expenditures by private households were in the category of food and beverages, including tobacco. Meat and meat products took 17% of this share and dairy products and eggs 12%.[313]

Assessing the **cost of meat in relation to its nutrient density**, a study in the US found that, although meat is an excellent source of nutrients, it was not necessarily cheaper than other products in protein-density per cost.[47]

Moreover, it is often held that the price of foods, and animal products especially, does not reflect their **'true cost' to society**. A life-cycle assessment for Germany found that external greenhouse gas costs are highest for animal-based products and lowest for plant-based products. Internalising such costs could lead to a relative price increase for meat.[314]

**Taste, cost and safety** are reported to be the top three factors influencing consumer food decisions in the EU. Other factors such as origin, nutritional quality, shelf-life, levels of processing, environmental impact, ethical alignment and convenience are also often mentioned.[3]

Seen from the point of view of a low-income consumer, the **affordability of food and the accessibility of a healthy diet involve a set of complex considerations and judgments**. Actual price of a food is one important factor, but not the only one. Other considerations include whether a food provides sufficient satiety, whether the package size meets needs, whether it is consumed too quickly and whether it generates food waste. Prices are also perceived in relative terms, benchmarked against other 'reference' foods.[315]

Although still under-researched, there is an emerging appreciation of how **socio-cultural factors shape health and well-being**. Cultural contexts orient our lives and shape how we accord meaning, which in turn influences the experience of well-being.[316] While culture and identity are not immutable, pathways for change need to be better understood.[317]

- Meat consumption is deeply interwoven with a wide range of **cultural contexts and identities**, such as gender, communal, racial, national and class.[318] Moreover, a link may exist between meat consumption and the personal appreciation of social status.[305]
- It has been argued that in the area of food policy, the question of *why* we eat as we do has largely been overshadowed by a 'nutrionist' approach focused on the question *what* to eat. It has been alleged that messaging drawing nutrient-based recommendations will fail to transform food choices if it does not engage with the **social meaning of eating and food**.[316]

Illustrating the challenges, but also possibilities, of overcoming food preferences, traditions and cultural habits, a 2020 consumer survey across several EU countries found **low willingness among consumers to cut down on meat and dairy**.[319]

- On average, only 1 in 3 respondents said they were willing to cut down on red meat, while 1 in 5 was undecided. Respondents from Italy, Germany and Austria were the most willing among surveyed countries.
- More than half the respondents were unwilling to cut down on dairy. Only 20% were willing to do so, with 20% undecided.

## Outlook: potential future impacts

**Socio-economic inequality has been on the rise** in Europe over the last decades.[320] It is widely predicted that the economic consequences of the COVID-19 crisis could create a **further surge in inequalities**.[321] This could have serious implications for food-related health outcomes, and the ramifications for achieving food systems change. At the same time, the predicted social challenges could also provide momentum for more decisive policy action in the field.

There may be **some momentum to address food workers' rights** and mend at least the acute occupational issues in meat processing. For instance, a new occupational health and safety law in Germany will improve conditions for slaughterhouse workers, including a prohibition on subcontracts, a restriction on temporary contracts and improved accommodation requirements.[322]

The EU Common Agricultural Policy (CAP) plays a central role in shaping **farmers' incomes**. Although the policy has failed to address inequalities in the past, and spending under the CAP has arguably even exacerbated income inequality in agriculture,[323] much will depend how the reformed policy is implemented. Much uncertainty also exists in the UK post-Brexit.

Not only agricultural policy, but market forces too play a key role in shaping farm incomes. Projections by the European Commission indicate that the expected (slight) decrease in meat consumption by 2030 would exert **downward pressure on domestic meat prices**, which would drop by 18%. This would increase net exports of meat and reduce imports and lead to a decline in meat production by 8%.[105] Without policy interventions, reduced producer prices would likely result in further consolidation in animal farming and further push the trend towards lower farm numbers.

# 2. Co-benefits

'Co-benefits' refer to the **additional benefits of tackling multiple issues simultaneously**.[324] Achieving co-benefits in food systems is possible because many **food systems dimensions** are closely interconnected and often **share similar drivers and solutions**.[325 326 327 328 329]

There is a large body of literature describing how the **adoption of more sustainable dietary patterns**, which involve the reduction of meat consumption and associated production, either as a main driver of change or a necessary component, can deliver a range of **essential sustainability co-benefits**.[330]

- The co-benefits that may manifest include improved nutrition and reduced diet- related mortality and morbidity, reduced health risks from air pollution, reduced health-related costs, climate mitigation, increased land availability, forest and biodiversity conservation and lower antibiotics use.[149 165 192 220 329 331 332 333 334 335 336 337] At the same time, increased water use and international trade have been signalled as potential trade-offs of sustainable diets.[330]
- Although imaginable, the potential socio-economic co-benefits of such transition scenarios for both producers, workers and consumers are usually not described. This is an important area requiring further attention.

Adopting a co-benefits approach will involve conceptualising **'co-benefits pathways'**. Such pathways can be seen as strategic combinations of mutually reinforcing measures that maximise benefits across as many food systems dimensions as possible. While focused on co-benefits, designing such pathways will also involve prioritisation, for instance in view of the urgency or scale of societal impact. This will lead to **trade-offs**, which, in turn, need to be understood and adequately managed.[330]

The **'less and better' meat and animal products** approach is an example of such a co-benefits framing. 'Less and better' rests on two inseparable pillars: one being a reduction in animal source food consumption and production, the other being better production methods implying benefits for farm added value, environment and animal welfare.[338]

While having great potential, **several challenges remain unsolved** when applying the principle. This includes the challenges of estimating appropriate amounts of meat and animal products in different regions and population groups. Applying 'better' also requires threshold values for classifying one animal product as more sustainable than another, which have not yet been defined and which may be in constant flux given dependence on underlying sustainability indicators.[339]

Three examples below of different co-benefits approaches to food systems change show that the selection of change pathways can lead to several **nuances in how 'less and better' is defined**, and which food systems benefits are prioritised.

- The EAT-Lancet Commission is notable in its unprecedented breadth of scope and ambition. It proposes a **'planetary health' diet** which is meant to be both nutritionally healthy and able to feed 10 billion people by 2050 without transgressing planetary boundaries. For people in high income countries, a key feature of this broad dietary pattern is a much lower intake of meat and other animal products. It especially emphasises reduced ruminant meat intake considering their high greenhouse gas emissions.[97]

- A similarly systemic exercise, but focused on Europe, was conducted by IDDRI starting from an **agroecological approach to food production**. It showed, among others, that the generalised application of agroecology by 2050 could feed Europeans healthily, significantly cut agricultural greenhouse gas emissions, restore biodiversity and protect natural resources. The reduction in animal-based foods was also central to the achievements of this model, but here the reduction in ruminant meat was much lower compared to poultry. More emphasis was placed on the agronomic role ruminants play in, for instance, nutrient cycling.[340]

- Another approach to 'less and better', points to an additional conceptualisation of a safe operating space for animal agriculture. It takes the need to **avoid food-feed competition** as a starting point and assumes farmed animals will only consume leftovers from arable land, grass and food waste streams. This approach would still produce a fair part of human protein needs from animal-based foods, while reducing its environmental (though to a lesser extent climate) footprint.[341]

Expressing the **'nutrient density' of foods in relation to their environmental impacts** is another parallel way of conceptualising co-benefits, which is increasingly explored today. This approach seeks to combine nutritional quality and environmental (usually climate) impact to assess the performance of individual foods on both metrics.[342] While this could in principle allow for a more holistic evaluation of a product's contribution to sustainable diets, it is also fraught with difficulties.

- For instance, the term **'nutrient density' is not yet well-defined** and it is not necessarily understood which nutrients should be used as markers for healthfulness. This especially considering that a healthy diet is meant to consist of a variety of different foods and nutrients.[343] [344]
- In addition, it remains unclear on which basis nutritional and environmental effects are to be weighed against each other. For instance, it may not be obvious at which point a food's higher carbon footprint can be **'offset'** by its higher nutritional value.[345]
- Moreover, a composite index to rank foods may be open to **arbitrariness** in the choice of threshold.[346]

From a political perspective, while systems and co-benefits thinking is gradually being introduced into European (health) policy, **food systems are not always part of that picture**, as shown in the box below.

### A 'European Health Union': without the essential co-benefits of food systems change?

As the COVID-19 crisis took its toll on Europe and the world, calls emerged for a stronger and more active role for the EU in protecting people's health. In 2020, the President of the European Commission kicked-off the process of building a "European Health Union". While still being defined, the Health Union's underlying purpose is to better equip the EU and its member countries to prevent, prepare and manage cross-border health crises.

The basic Commission document outlining the first principles behind the initiative recognises that long-term trends such as climate change and biodiversity loss will significantly increase the risk of infectious disease pandemics, and that AMR and an ageing population will likely enhance the severity of the impacts on health.[347]

The document proposes first building blocks for a Health Union, covering items such as enforced EU-level response to health threats, improved preparedness and response planning and reporting, reinforced epidemiological surveillance and enhanced international cooperation.

Two further policy initiatives are incorporated into the scope of the Health Union,[348] namely the "Pharmaceutical Strategy", which aims to modernise pharmaceuticals legislation, and "Europe's Beating Cancer Plan", which aims to tackle cancer from prevention to treatment to care.

Strikingly absent from the line-up of policy initiatives however, is the "EU Farm to Fork Strategy", which aims to create a fair, healthy and environmentally-friendly food system. The strategy recognises the "inextricable links between healthy people, healthy societies and a healthy planet", and provides for a large number of initiatives in this area, covering most stages of the food system.[349] The absence of this initiative is all the more striking given that the European Commission's Directorate-General for health is in the driving seat of implementing Strategy.

# 3. Conclusions

This paper attempts to disentangle the most distinctive links between current levels of meat production (animal farming) and consumption in Europe and public health.

The resulting broad understanding of the links between food and health lends further force to the perspective that **significant public health benefits can be had from a reconfiguration of the European animal food production and meat consumption system**.

Meat, and other animal products, impact health in many, and often significant ways. For a considerable number of these impacts, meat production and consumption act as part of a wider set of underlying drivers. Despite being indirect, such impacts are real and can be substantial.

While the understanding of health risk factors is improving, **attributing health impacts and burdens of disease to food systems** remains a daunting task. This both for impacts inside Europe, as well as for the global health impacts linked to the drivers that European food systems externalise to other countries, such as climate change and land use change.

- For instance, some of the described health impacts remain hard to quantify and it is often difficult to fully isolate the contribution of meat consumption and production to specific outcomes. This in part reflects the inherent **difficulty of attributing disease burdens to underlying causes**. Overcoming this will probably require more and better data and further research.[350] Further experimentation may also be needed with methods of attributing disease burdens to different food systems drivers.[129]
- Some of the health risks described appear to be cumulative and non-linear, and future health impacts may be magnitudes beyond those seen today. This, for instance, applies to the dimensions of climate, biodiversity, AMR and zoonotic diseases. **Health metrics** tend to have a narrow focus on morbidity, mortality and disability and **may fail to capture the full breadth of interlinkages**. Without better metrics and ways to communicate future risks, health threats and impacts may remain underappreciated and underemphasised.

When considering **pathways for food systems change**, taking a 'co-benefits' approach seems to be the most satisfying way forward. This means designing pathways that maximise benefits in as many food-health dimensions as possible, while at the same time acknowledging and managing trade-offs. While this paper has not discussed change pathways in any detail, a few considerations can be made.

- '**One Health**', which highlights the deep interconnections between the health and well-being of people, animals and planet,[351 352] can provide a good guiding principle for designing co-benefits pathways. The health and welfare of farmed animals should be seen as a core pillar of such a solutions-oriented transition agenda.
- Despite the multiple health impacts of meat, which extend beyond food safety and nutrition, leveraging dietary change with a **single focus on reducing red and processed meat consumption**, or even animal products more widely, **is not a suitable strategy within a holistic approach to health**. Shifting down on meat in European countries must therefore go hand-in-hand with shifting up in overall dietary quality.
- Furthermore, while designing change strategies, it is important to keep in mind that the most efficient and effective way of addressing an individual health issue will not necessarily deliver **optimal outcomes for health and well-being** overall. The multidimensional nature of health and its multiple connections to meat production and consumption should warn against staring blind on any single metric.
- Considering the **societal significance of meat and animal products**, it seems unlikely that a sustainable transition can be achieved without a strong engagement with the socio-economic and cultural factors that shape people's livelihoods, positions in life and outlooks to the future.

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