

CHAPTER ONE

The Consumption of Animal Products and the Human Right to Health Care

1.1 Introduction

As human beings cannot stay healthy for long without adequate food, many people may agree that the human right to health care should include a right to adequate food. Having sufficient food that is adequate is a very basic human need, which is why the human interest in food is an excellent candidate for grounding a human right. This right has been defended by many, including the United Nations (UN CESCR 1999; De Schutter 2011).

If we accept that every human being's right to health care includes a right to food, it might be argued that there are situations where this right can only be protected by using other animals for food. As many animal products are relatively dense in nutrients compared to other foods, some groups of people who might particularly benefit from the consumption of animal products are very young children with limited stomach capacities relative to their energy demands and people living with the human immunodeficiency virus (HIV) or acquired immunodeficiency syndrome (AIDS), who may have increased nutritional requirements but reduced appetites (Randolph et al. 2007; Roubenoff 2000). These are just some examples of groups of people who might be more vulnerable in situations where they were denied the option of consuming animal products. Some populations would also be vulnerable, for example some Inuit who live at high northern latitudes and who may lack not only sufficient plant foods to feed themselves, but also the means to acquire them from elsewhere. The consumption of animal products may also be vitally important to many people who live in Asia, where much human population growth in the near future is expected to occur. To meet the challenge of feeding this growing population, it has been argued that, in many areas with relatively adverse environmental conditions, using animals may be indispensable (Devendra 2007;

How to cite this book chapter:

Deckers, J 2016 *Animal (De)liberation: Should the Consumption of Animal Products Be Banned?* Pp. 13–50. London: Ubiquity Press. DOI: <http://dx.doi.org/10.5334/bay.b>. License: CC-BY 4.0

Sharma et al. 2012). Some significant advantages that are conferred by the use of animals for human food are that some animals can eat plants, such as grass, that human beings cannot digest, and that some animals are better able to cope with drought compared to plants, for example due to their greater mobility (Morton and Kerven 2013).

In addition, animals can be used to provide food not only directly, but also indirectly, by providing important services, for example by producing excrements that can be used as manure or fuel or by providing draught power and means of transportation that could save on human labour and fossil fuel consumption. In India, for example, over 55% of the total land that was cultivated in 2009 used animals for draught power (Phaniraja and Panchasara 2009). Research in Africa by Iannotti et al. has also shown that the acquisition and use of chickens to produce eggs is 'one of the few and first mechanisms for asset accumulation in poor households' (2014, 355). The authors add that programmes aimed at stimulating the keeping of chickens by poor people may be 'an uncracked part of the solution' to 'undernutrition ... in many parts of the world' (Iannotti et al. 2014, 366). Accordingly, any strategy that considers reducing the human use of other animals must be careful not to undermine some people's rights to food, an issue that I shall return to in section 3.5.2.

Although the stipulation of a right to food is not free from problems—including the problem of what the correlative duties are of those who must ensure that every human being is able to obtain sufficient food—many ethical theories accept that any personal liberties that may be possessed by some individuals ought to be restricted by the (negative) duty to avoid significant harm to some other individuals (Mill 1859; Raz 2010). In this light, some scholars have questioned the consumption of animal products, claiming that the fact that some people consume animal products causes hunger for other human beings (Rifkin 1993; Lewis 1994; Popkin and Du 2003; Webb 2010). Singer, for example, has claimed that the fact that a lot of food that could be eaten by humans is fed to farmed animals is the primary cause of 'the food crisis' (2009, 122), and Weis has similarly claimed that 'the meatification of diets' is 'a vector of global inequality, environmental degradation, and climate injustice' (2013, 81–82). Whereas the authors of an influential report—the LEAD study—entitled 'Livestock's Long Shadow', published by the Livestock, Environment, and Development Initiative (LEAD), a group co-ordinated by the Food and Agriculture Organization of the United Nations (FAO), grant that the farmed animals' sector is a major cause of environmental degradation, they cautiously reject the idea that this might be associated with injustice towards those who lack adequate food, writing: 'it is probably true that livestock do not detract food from those who currently go hungry' (Steinfeld et al. 2006, 270). What is undisputed, however, is that the increase in the human consumption of animal products over the last 50 years has been unprecedented. Most notably, the consumption of animals' body parts has increased by more than fourfold. Rather than speak of the number of animals whose bodies are being used for human

consumption, dominant metrics refer to this rise in terms of an increase in tonnage, lumping the bodies of different animals together in a common unit. According to the FAO (2014), tonnage increased from 71,357,169 tonnes in 1961 to 262,919,740 tonnes in 2006 and to 302,390,507 tonnes in 2012, the latest year for which data are available at the time of writing.

About 30% of all animal-flesh consumption occurs in countries that account for no more than 12% of the world population. Ranked from higher to lower levels of total consumption, these are: the USA, Australia, New Zealand, Argentina, Canada, and Western European countries (where consumption data are combined) (Weis 2013). Although the consumption of animal products has now stagnated at high levels in many relatively rich countries, in many less affluent countries it has risen and is continuing to rise rapidly (Steinfeld et al. 2006, 15–16). China and Brazil in particular have seen rapid increases over the last 50 years, the former having seen a 15-fold and a 31-fold and the latter a 2.5-fold and an 11-fold increase in, respectively, total consumption and production of animal flesh (Weis 2013). A nutrition transition towards diets that are relatively rich in animal products has been and is taking place, which has been claimed to have contributed to recent food price increases (Popkin 2009). This transition is associated with an unprecedented rise in what has been called ‘domesticated zoomass’—the weight of domesticated animals, which is estimated to have grown from 180 million tonnes in 1900 to 620 million tonnes in 2000, with what has been referred to as ‘bovine biomass’ having the largest share, with a share of 450 million tonnes (Smil 2002, 618).

Lipton (2001) has reported that, as demand for animal products frequently comes mainly from those who are relatively affluent, rising levels of affluence in relatively poor countries have led to an increasing amount of grain and land being used to feed farmed animals. Consequently, relatively poor people may suffer not only from the fact that the farmed animals’ sector displaces parts of other food sectors, but also from being displaced themselves. This risk of being displaced has increased in recent times due to what Webster (2013, 10) has referred to as ‘the second industrial revolution’ in the farmed animals’ sector’s recent history—the first one being the capitalist transition from common to enclosed land. This second revolution, which started around 70 years ago, has resulted in the farm no longer depending on the land it occupies for its inputs. Rather, these can now be sourced from an increasingly globalised world where inputs are merely confined by capital and by the farm’s ability to process them.

Consequently, many indigenous communities, for example in Australia and in the Cerrado of Brazil, have been displaced by land appropriation for the expansion of the farmed animals’ sector (Aldrich et al. 2012; White et al. 2012; MacDonald and Simon 2011, 11–14; Stoll-Kleemann and O’Riordan 2015, 41). What Australia and Brazil also have in common is that their farmed animals’ sectors are increasingly owned by a small number of large corporations with high levels of vertical integration (concentration of different stages of the production process) that allow these corporations to exercise a very high degree of

control over the food system (MacDonald and Simon 2011; Loughnan 2012). These centralising tendencies are by no means absent in other nations. Many people who work for these large corporations, for example in slaughterhouses and in other settings where the farmed animals' sector relies on labour that is modelled on the repetitive, monotonous, and highly specialised work that is typical of many factories, belong to the lowest strata of society, and many are paid badly (Joy 2010, 85). Dillard (2008), for example, reports that in the USA most slaughterhouse workers are paid relatively poorly to work in conditions where they are likely to endure both physical and psychological harm. Many studies report similar concerns. A study in Denmark, for example, reported high levels of physical and mental problems amongst slaughterhouse workers (Kristensen 1991), whilst a study in Turkey identified increased psychological problems amongst butchers compared to office workers (Emhan et al. 2012). In many countries, large farms ('megafarms') and slaughterhouses are also situated in relatively deprived areas, creating significant health concerns caused by localised pollution (Fitzgerald 2010).

Against this backdrop, the objectives of this chapter are: firstly, to explore whether there are situations where the consumption of animal products jeopardises human rights to health care unjustifiably; and secondly, to address how human diets might be changed to address situations where it does so. As I shall argue in the appendix to this book, some people who consume particular animal products jeopardise their own health in some situations where they eat (too many) foods that are unhealthy, which imposes negative impacts on others, for example on taxpayers who pay for public health services. However, these are by no means the only ways in which human others are affected. In the preceding paragraph I have already reported facts that may trigger the question whether those who consume animal products impose unacceptable health risks on relatively poor people who may have little choice in deciding whether or not to work in conditions that are likely to compromise their physical and mental health. The same question might be asked when we consider the causal links between the human consumption of animal products and the creation and spread of zoonoses. Unlike diseases that may be caused directly by the consumption of animal products, many zoonoses also impact upon those who abstain from consuming animals.

After having described common zoonoses that have been associated with the consumption of animal products, this chapter will then consider whether the large quantities of resources that are used in the process of feeding the vast and increasing number of animals on the planet pose human health concerns. The land, water, and energy that are used to produce such a large quantity of animal products could frequently be used more efficiently if it was used to grow foods for direct human consumption. Even if the land, water, and energy requirements of different diets vary from place to place, depending (amongst other factors) on climate, water cycles, and the quality of the land, of the water, and of the technologies that are available, diets that include animal products

generally require more resources. Some of the key issues that will be considered are the impacts on human health associated with land use and degradation, water use and pollution, and fossil fuel use and atmospheric pollution. Though these issues are interconnected, they will be separated for analytic reasons. A meta-analysis of different studies on these impacts has pointed out that studies have focused predominantly on global impacts that are relatively easy to quantify, such as emissions of greenhouse gases, and that localised impacts have been neglected because they are frequently much more difficult to quantify (Pluimers and Blonk 2011). This explains why this overview is biased towards issues that are of global concern.

Whereas it will become clear in chapter two that the consumption of animal products produces many other negative GHIs apart from those that are discussed here and that it therefore presents other concerns related to the human right to health care, the overview that will be provided in this chapter may be sufficient to raise serious concern even amongst those who fail to recognise the (moral importance of the) interests discussed in chapter two.

1.2 Zoonoses

The vast majority of human diseases spread between different species of animals (Woolhouse and Gowtage-Sequeria 2005; Torres-Vélez and Brown 2004; Grace 2015). Whereas some of these, for example tapeworms, primarily affect the bodies of those who consume animal products, others can affect everyone, regardless of whether or not they consume animal products themselves. The causes underlying the emergence and the re-emergence of zoonoses are complex. Whereas a detailed overview of these is provided by Ka-Wai Hui (2006), at least four reasons show that the consumption of animal products poses a significant concern. Firstly, the scale of the farmed animals' sector is unprecedented, increasing risk due to the sheer size of the animal population. Secondly, many animals display a high level of genetic uniformity as breeders select for a small number of traits, for example large muscle mass, resulting in a loss of resilience amongst populations and an increased susceptibility to infection. Thirdly, the vast majority of farmed animals are kept in confined spaces, increasing the risks of various infections due to increased contact, stress, and exposure to pathogens. Fourthly, animals are transported faster and over greater distances than ever before, increasing the spread of pathogens and reducing our ability to control it.

Many zoonoses stem from the ways in which farmed animals are treated by human beings. Cows are herbivorous animals, but many cows used to be fed with ground-up remains of slaughtered sheep and other cows, which led to bovine spongiform encephalopathy (BSE), which has also been called—ironically and derogatorily—‘mad cow disease’. The causal agent of BSE, a prion, was subsequently transmitted to humans, causing new variant Creutzfeldt-Jakob Disease (nvCJD). Problems also stem from the ways in which human beings manage

animal manure, of which there is no shortage. Manure provides a great vehicle for the spread of many pathogens which could subsequently present human health hazards (Kanaly et al. 2009, 23), for example *Cryptosporidium parvum*, *Vibrio cholerae*, *Enterococcus* spp., *Escherichia coli* serotype O157:H7 (or other faecal coliform bacteria that are pathogenic), staphylococci, and streptococci.

To fight disease, the farmed animals' sector uses a large quantity of different kinds of drugs. Particular concerns have been expressed over the large-scale use of antibiotics (Graham et al. 2016). Many antibiotics are used not because the animals are ill, but simply to prevent disease, or the spread of it, as well as to promote growth (by changing the bacteria in the animals' digestive systems so that more nutrients are absorbed) (Anomaly 2009; Price et al. 2015; Meek et al. 2015). The Union of Concerned Scientists (UCS), a non-profit organisation based in the USA, has estimated that the amount of antibiotics that are used by the farmed animals' sector in the USA merely to prevent disease is eight times greater than that of antibiotics used to treat human disease (UCS 2001). Globally, it has been estimated that about half of all antibiotics that are produced are given to farmed animals (Steinfeld et al. 2006, xx, 273). This promotes the development of drug resistant strains of pathogenic bacteria, of which box 1 provides some examples.

Antibiotic-resistant strains of *Salmonella*—the main pathogen involved in food-related deaths in humans—and of *E. coli* and *Campylobacter* have been found in many farmed animal products (Marshall and Levy 2011). Other zoonotic pathogens that are resistant to a whole array of drugs are quinolone-resistant *Campylobacter jejuni* and various tetracycline-resistant bacteria (Levy et al. 1976; K. Smith et al. 1999; Hermans et al. 2012); quinolone-resistant *Salmonella enterica* (Chiu et al. 2002; Mølbak et al. 1999; Dechet et al. 2006); and ceftriaxone-resistant *Salmonella enterica* (Fey et al. 2000).

As many people's bowels contain vancomycin-resistant *Enterococcus*, which can cause a range of infections in humans, this pathogen in particular presents a very serious health concern. It developed its resistance by the use of avoparcin on chicken farms (Bates et al. 1994; Aarestrup et al. 2000; Garcia-Migura et al. 2005; Sørensen et al. 2001). Vancomycin-resistant genes have also spread to some populations of the more common and more troublesome methicillin-resistant *Staphylococcus aureus* (MRSA). *Staphylococcus aureus* is a bacterium that can either transiently or permanently colonise the nasal cavity wherefrom it can migrate to infect other body parts, causing necrotising fasciitis, a severe infection of the skin (Bonten et al. 2001; Ferber 2002). Many strains of MRSA are actually multi-drug resistant, as about 90% of *Staphylococcus aureus*

strains are resistant to penicillin and other penicillin-related antibiotics. MRSA is a very serious human health concern as about half of all nosocomial (hospital-acquired) infections have been reported to be MRSA infections (Aiello et al. 2006). Until recently, MRSA was only known to be a nosocomial pathogen, but in recent years the incidence of community-acquired MRSA has been increasing and transmission from farmed animals has been documented, for example in Dutch slaughterhouse workers (Gilbert et al. 2012; Huijsdens et al. 2006; Voss et al. 2005; Armand-Lefevre et al. 2005; van Belkum et al. 2008; Marshall and Levy 2011). In light of these connections, some scholars have started to speak of 'livestock-associated MRSA' (T. Smith and Pearson 2011). A Dutch study found that MRSA was carried by nearly 27% of pig farmers, while only 0.19% of individuals without contact with farmed animals were found to be carriers (van Cleef et al. 2010). A different study found that many veterinarians in Denmark and Belgium also carry the pathogen (Garcia-Graells et al. 2012).

Box 1: Examples of drug resistant bacteria in relation to the use of antibiotics in the farmed animals' sector

Vector-borne illnesses are diseases that are caused by infections that are transmitted to people by arthropods (insects and arachnids). Many vector-borne diseases, as well as viral diseases, have either emerged or become more severe because of human environmental changes, including deforestation and the reduction of biodiversity. The farmed animals' sector is a major contributor to these changes, and box 2 provides some examples of how some diseases may have either emerged or increased in prevalence because of it.

Examples of vector-borne diseases that have become more prevalent due to human deforestation are malaria and leishmaniasis (GECHH 2007, 50). Deforestation may open up new windows of opportunity for some of these vectors if what is known as the 'dilution effect' applies (Ostfeld 2009). This effect relates to the fact that vectors feed from a wider range of species in areas that are relatively rich in biodiversity, where some hosts are less likely to transmit the disease compared to the host that may be dominant in a more impoverished ecosystem.

A good example of a zoonotic viral disease that may have emerged for similar reasons is the Machupo virus. In the early 1960s, many forests were cleared in Bolivia to create agricultural land, and this was accompanied

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by the spraying of DDT to control the malaria mosquito. Forest clearance led to the migration of *Calomys* mice to arable land, while the DDT poisoned cats, their predators. The consequent increase in the mouse population was accompanied by an increase in the viruses they carried, resulting in the emergence of a new zoonotic viral fever, the Bolivian (Machupo) haemorrhagic fever, which killed around one seventh of the population who lived in the town of San Joaquín in northern Bolivia (GECHH 2007). Similar causal mechanisms underlie the emergence of Argentine haemorrhagic fever and Lassa fever (Ka-Wai Hui 2006).

Box 2: Examples of vector-borne and viral diseases that may have become more prevalent because of environmental changes caused in part by the farmed animals' sector

Concerns with the emergence of zoonoses are not limited to the farmed animals' sector, but extend also to other animal products that are consumed by human beings. One of the most well-known zoonoses is HIV/AIDS: HIV-1 is thought to have emerged from SIVcpz, a simian immunodeficiency virus (SIV) found in a sub-species of chimpanzee (*Pan troglodytes troglodytes*) (Peeters et al. 1989); HIV-2 is thought to stem from SIVsmm, an SIV found in the sooty mangabey (*Cercocebus atys*) (Marx et al. 1991; Ka-Wai Hui 2006). Both HIV strains are likely to have emerged from human contact with the blood of infected chimpanzees and sooty mangabeys, possibly through butchering practices (Chitnis et al. 2000).

Finally, influenzas (flus) are viral diseases that have regained prominence in recent years. Flu viruses are categorised in A, B, and C types. B and C types are relatively mild and undergo changes through antigenic drift, the normal process of flu viruses' genetic mutation. The A type flu viruses, however, also undergo changes through antigenic shift, which involves a rapid change caused by genetic mixing between different subtypes, resulting in the creation of flus that can be relatively severe as human beings may not have come into contact with these new strains before. Though not many people have been killed by recent outbreaks, flus have had a devastating effect on many people in the 20th century through three pandemics: the 1918 ('Spanish influenza') H1N1 virus, the 1957 ('Asian influenza') H2N2 virus, and the 1968 ('Hong Kong influenza') H3N2 virus pandemics. The first one of these was particularly memorable, as it has been estimated to have killed up to 40 million people in 1918–20, or about 3% of the world population. Research has shown that the emergence of these flus stemmed from human interactions with other animals (Taubenberger et al. 2005; Belshe 2005), raising the question whether viral diseases that have emerged

more recently in close connection with animal farming practices might trigger disease in large numbers of people. Box 3 provides some prominent examples of such viral diseases directly associated with the farmed animals' sector.

One example of a recently emerged zoonotic virus is the Nipah virus, a new paramyxovirus that emerged in Malaysia in 1998, affecting a number of pig farmers and slaughterhouse workers, causing encephalitis and death. This virus was proven to be caused by the presence of flying foxes (*Pteropus*, or fruit bats) on a large pig farm in Malaysia (Daszak et al. 2006). Forced by habitat loss, the bats in question arrived *en masse* to eat from the fruit trees that grew in an orchard near to the farm, passing on infection to the pigs by dropping half-eaten fruit that had been infected into the pigs' pens (Torres-Vélez and Brown 2004; Ka-Wai Hui 2006). The haemorrhagic virus outbreak of 1994–1995 in Queensland, Australia, is thought to have had similar origins, with horses rather than bats being the intermediate hosts (Ka-Wai Hui 2006).

Many animals are sold in live-animal markets (also called 'wet markets'), where they come into close contact with many other animals of various species. The capture and sale of bats in markets is thought to have caused the outbreak of severe acute respiratory syndrome (SARS) coronavirus in China in 2002, which infected people in Singapore, Vietnam, and Canada after some people from these countries had visited Hong Kong in March 2003 (Weiss and McMichael 2004; Ka-Wai Hui 2006). Another example of a disease that may have developed because of the crowded conditions in which animals are kept and sold is H5N1, an avian (bird) influenza that emerged in South East Asia in 2003 (Sims et al. 2005). By the end of December 2012, over 600 laboratory-confirmed human cases of H5N1, causing 360 deaths, had been reported to the World Health Organization (WHO 2012).

Pigs are considered to be good mixing vessels for the development of new zoonotic viruses as they are susceptible to both bird and human viruses, which is why pigs who enter into contact with both host species are particularly good virus creators (Ka-Wai Hui 2006). In 2009, a new influenza virus, the swine-origin influenza A H1N1 virus, started to infect human beings. Though there is much debate about the precise origins of this virus, there is a high level of agreement over a causal link with the farming of pigs (Escalera-Zamudio et al. 2012). By 1 August 2010, the virus had killed over 18,000 people (WHO 2010).

Box 3: Examples of zoonotic viral diseases directly associated with the farmed animals' sector

As high populations of farmed animals are maintained only because of human demand for their products, many consumers of animal products are more likely to impose diseases upon other human beings compared to those who refrain from such consumption: the probability that those who consume animal products will facilitate the emergence of a zoonotic disease that would cause illness and kill a large number of people is much higher than the probability that those who consume plant products will do so (B. Chen et al. 2009). An additional concern is that people who are relatively rich are more likely to consume animal products, whereas people who are relatively poor are more likely to suffer from zoonoses (Gunderson 2012; Karesh et al. 2012; Grace 2015).

1.3 Land use and degradation

Agriculture occupies about 38% of the earth's ice-free land, with 26% of ice-free land occupied by grazing and 12% by arable land (Foley et al. 2011). As the land that is used to farm animals includes both grazing and arable land, it has been estimated that the farmed animals' sector occupies about 70–75% of all agricultural land (Steinfeld et al. 2006; Foley et al. 2011). About one third of the earth's soil surface is unsuitable for arable production, though it either is or could be used for grazing or browsing (Penning de Vries et al. 1995). Provided that farmed animals eat plants that are not suitable for human consumption and do not rely (heavily) on feed, diets that include animal products need not necessarily use more land than could be used to feed the human population directly. In recognition of this fact, the opinion has been expressed that the ability of some farmed animals to turn plants that humans cannot eat into foods that people can eat 'may become increasingly important in terms of global food security' (Gill et al. 2010, 330). In reality, however, it is known that a lot of arable land is used to feed farmed animals; this is known principally by the fact that about 35% of the global harvest of cereals has been fed to farmed animals in recent years (Alexandratos and Bruinsma 2012, 71; Foley et al. 2011). In a study carried out in 2006, it was found that the area dedicated to this land use amounted to 400 million hectares (ha), or 4 million square kilometres, an area that is equivalent to the surface area of the 27 countries that then constituted the European Union (Aiking et al. 2006, 171).

The fact that a lot of arable land is used globally to feed farmed animals does not imply that this is the case right across the world. In many poorer countries most grain is consumed directly by people. Most nations in Africa and Asia allocate more than 80% of their arable land to the purpose of feeding people. Accordingly, it has been argued that in countries such as Kenya and Egypt, the current mixed agricultural system provides more human food compared to what a vegan system might provide, as the farmed animals in these countries rely mainly on resources that could not be used for direct human consumption

(CAST 1999). For a similar reason and because the significant unpredictability of rainfall limits arable farming, it has been argued that 'milking animals ... are crucial for maintaining human nutritional welfare in the drylands' of people living in Djibouti, Eritrea, Somalia, and Ethiopia, the countries that make up the Horn of Africa (Morton and Kerven 2013, 25).

In many more affluent countries, by contrast, large quantities of grain are fed to farmed animals. In North America and Europe, for example, only about 40% of all arable land is used to feed people. In addition, some affluent nations also use some of the land of less prosperous nations to feed their farmed animals: as land and labour costs are lower in poorer nations, the large agribusinesses that control a significant part of the farmed animals' sector benefit from sourcing some of their feed from poorer nations, in spite of the costs associated with transportation (Smil 2005). Some of this feed is grown on land that might have (had) more value by not being cultivated (for example, some rainforests) or by growing food crops. This is a growing concern as the amount of arable land that is being used to feed farmed animals is increasing rapidly. This is caused by the following factors: the explosion in the consumption of animal products; the fact that the greatest growth is not seen in the consumption of ruminants, but in the consumption of products from pigs and chickens ('monogastrics') who depend almost exclusively on feed in dominant farming systems; and the fact that a growing number of ruminants are being fed arable crops as substantial components of their diets (Weis 2013).

The use of arable land to feed farmed animals is very inefficient. This inefficiency varies between different areas and farming systems, depending on social and ecological conditions. In the context of farming in the USA at the dawn of this millennium, Smil (2002) calculated that 4.5 kg of feed is required to produce 1 kg of flesh from chickens, 9.4 kg of feed for 1 kg of flesh from pigs, and 25 kg of feed for 1 kg of flesh from feedlot-fed cows. Though chickens are the best converters of plant-to-animal-protein of all the main animals reared for their flesh, about 78% of all the plant protein that was fed to a chicken in the USA about a decade ago was not converted to protein that is eaten by human beings.

Accordingly, several studies (see box 4) have concluded that there are significant differences in the land requirements of different diets, depending on both the amount and the kinds of animal products that they include, with diets that include animal products generally requiring more land compared to diets that exclude them (Baroni et al. 2007; Reijnders and Soret 2003; Peters et al. 2007).

A study from the USA has claimed that 'an overwhelmingly vegetarian diet produced by modern high-intensity cropping' requires five times less arable land than 'the typical Western diet', which is calculated to use 'up to 4,000 m²/capita' (Smil 2002, 619).

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A lower estimate is provided by a Dutch study, which concluded that the land used by an average Dutch household comprising 2.41 persons in 1990 to provide for a typical Dutch diet of 1990 equals 3,490 m² (Gerbens-Leenes et al. 2002). The authors add that this exceeds the land area of 444 m² calculated by another study (Penning de Vries et al. 1995) to feed a household at subsistence level by a factor of eight, largely because the former diet includes a much larger quantity of animal products.

A final example is a UK study which showed that a 50% reduction in the consumption of animal products in the UK, under a specific dietary scenario that provides other health-benefiting changes, including a reduction in the consumption of sugar, would—assuming that the proportion of food imports remained the same—reduce arable land usage by 265,000 ha in the UK and by 311,000 ha outside the UK, as well as release millions of hectares of grassland in the process (Audsley et al. 2011).

Box 4: Evidence that diets that include animal products generally use more land

In general, diets that include farmed animal products also contribute more to land degradation than diets that exclude them. The authors of the LEAD study claim that about 20% of the world's pastures and rangelands are degraded through overgrazing, compaction, and erosion caused by farmed animals (Steinfeld et al. 2006). What is ignored by the authors of this study is what may well turn into the most important issue associated with future strategies to counter land degradation: the loss of phosphorus obtained from mined rock phosphate, a key ingredient in most mineral fertilisers. Although the quality of reserves of rock phosphate is declining and mining costs are increasing, a recent study has estimated that the reserves that remain could be used up by the end of the century and that they could reach a peak (maximum rate) of use by 2033 (Cordell et al. 2009). The continent with the greatest food insecurities at the present time, Africa, exports more phosphate rock than any other continent, and a large and increasing percentage of phosphate rock is devoted to the farmed animals' sector, either through the cultivation of crops for feed or through feed supplementation. The production of fertilisers from phosphate rock yields large quantities of phosphogypsum, a toxic by-product that contains radionuclides of uranium and thorium. Some of these, as well as cadmium, end up in the soil when crushed rock phosphate is applied directly to it, as well as when processed phosphate fertilisers are applied that contain smaller

quantities of these elements. Furthermore, although phosphorus can, unlike oil, be recovered and reused, large quantities of phosphorus leak from agricultural land. Long-term food security is therefore jeopardised both by soil pollution from phosphate rock and by the fact that remaining reserves are dwindling (Cordell et al. 2009; Wallis 2014).

Other than being undermined by the toxic components of mineral rock phosphates, soil fertility can also be compromised by other practices associated with the farming of animals. Apart from cadmium, some soils are polluted by other metals used in the farming of animals, for example by the zinc, copper, and arsenicals used as feed additives, as well as by veterinary medicines. The fertility of some soils is also jeopardised by nutrient loading—the accumulation of nutrients in the soil—caused by the application of excessive quantities of manure and fertilisers. Nutrient excesses have been documented to be particularly large in China, Northern India, the USA, and Western Europe (Foley et al. 2011). Over the long term, the soil is acidified by such excesses, resulting in reduced plant growth. Ammonia (NH_3) emissions also contribute to soil acidification, and about two thirds of anthropogenic ammonia emissions have been estimated to be produced by the farming of animals (Steinfeld et al. 2006). Ammonia acidifies the soil by combining with oxygen to form nitrogen oxide (NO_x) and nitrogen dioxide (NO_2), which can then combine with water and oxygen to produce nitric acid (HNO_3) and deposit as acid rain; as many ecosystems comprise organisms that cannot cope with the surplus nitrogen, this process also contributes to biodiversity losses. Nutrient loading, mentioned above, is a problem that is growing as more farmed animals are reared further away from their feed sources. An increasing number of animals are also reared in crowded facilities, which have been associated with relatively poor waste management practices due to their high concentrations of waste (Garnett 2009). Some soils are also waterlogged by a range of irrigation methods that are used by the farmed animals' sector to produce animal feed. Irrigation also contributes to salinisation, the mobilisation and accumulation of salts that are naturally occurring in soils. The salt scalds that are thus formed on top of the ground undermine soil productivity, restricting plant growth (Trout 2000).

A large amount of land also degrades through deforestation. Deforestation causes many land problems, including those associated with salinisation—the removal of trees allows ground water to rise, thus mobilising salt. Deforestation also leads to the erosion of fertile topsoil as most of the fertility of the soil that is found in rainforests is due to the soil being held together by trees. In 2000, Goodland and Pimentel (2000) estimated that about 60% of deforestation took place to make room for animal farming. Current expansion of agricultural farm land is mainly taking place in tropical areas. Tropical forests are very rich in biodiversity and provide many important ecosystem services. It has been estimated that about 80% of all new croplands in the tropics are situated in areas that used to be forests (Gibbs et al. 2010).

A large number of these are devoted to the production of animal feed, mainly in the shape of soybeans, the cultivation of which doubled to 22 million ha in the decade leading up to 2004 (Elferink et al. 2007) and then increased further, up to more than 111 million ha (yielding just over 276 million tonnes of beans) in 2013, a year in which more than 1 billion tonnes of maize was also grown, a large percentage of which, again, was used to feed animals (FAO 2015). Whereas the area that is devoted to growing maize has not increased as much as that used to grow soybeans, it has been estimated that it has grown by around 50% in the last 50 years (Weis 2013). The increases in yields of these two main animal feeds do not simply reflect increases in acreage—the former in fact surpass the latter increases, as global yield increases of soybeans and maize have, respectively, octupled and quadrupled over this same period of the last 50 years (Weis 2013). Most of the soybeans that are grown worldwide are crushed, producing 18.6% soy oil and 78.7% soy meal (as well as some waste), and—although the oil is used in a wide range of products (including biofuels)—almost all the meal is currently used to feed farmed animals (van Gelder et al. 2008). It has been estimated that only about 6% of all soybeans that are grown are directly consumed by people (Oliveira 2015). Though soybeans stimulate rapid growth of farmed animals because of their high protein content, by current yields they require more land relative to other crops that are grown to feed animals per unit of animal product (Elferink and Nonhebel 2007). In 2013, for example, about twice as much land was needed to produce soybeans as was needed to produce a similar mass of maize (FAO 2015). Brazil is a major producer of soybeans and a growing producer of animal flesh, and box 5 provides a good illustration of how the farmed animals' sector affects deforestation in a country with such large areas of remaining forests.

The country with the third largest production of body parts from land animals (with a production exceeding 20 million tonnes annually in recent years) and the second largest production of soybeans (with a production of 82 million tonnes in 2013), Brazil provides an interesting case study of the impact of the farmed animals' sector upon deforestation (Oliveira 2015; Weis 2013). The sector's expansion is the main cause of deforestation in the world's largest tropical rainforest, the Brazilian Amazon (Nepstad et al. 2006). Though the Amazon spreads out over eight countries in Latin America, the majority of it is located in Brazil. The LEAD study claims that the farmed animals' sector uses about 70% of the land in the Amazon that was previously forested as pastures, and most of the remainder of that land to produce animal feed (Steinfeld et al. 2006). To meet the high global demand for soybeans, some of the forest that had originally been cleared to expand grazing

has been converted to soybean cultivation, leaving ranchers with large profits that some have invested in the acquisition of new forested land that either has been or is being deforested to increase grazing land. Increasingly, it is not only in the Amazon, but also in the *cerrado*—the Brazilian savannah, which equals the size of Mexico and occupies about 21% of Brazil's land—that soybean plantations spring up (MacDonald and Simon 2011, 10). The associated loss in biodiversity is huge, as both the Amazon and the *cerrado* used to be—and to some extent still are—very rich in biodiversity.

A lot of soybeans that are grown in Brazil are exported to distant places, particularly to China and the European Union. Most is exported to the former, and China is the country that has produced the largest annual share of flesh from land animals since 1990 (van Gelder et al. 2008; FAO 2015). The European Union, which banned the feeding of a range of animal products, including offal, to farmed animals (Regulation (EC) 999/2001), increased its importation of soybeans significantly after the BSE crisis. About 10 million ha of the soybeans that are grown in non-European countries are imported by the European Union annually, representing an area that corresponds to 10% of the arable land of the European Union (Elferink et al. 2007, 468). In the last decade, at least 20 million tonnes of soybean meal has been imported by the European Union annually, primarily from Brazil, to feed farmed animals (EC 2011; de Visser et al. 2014; van Gelder et al. 2008).

Box 5: The farmed animals' sector and deforestation in Brazil

To obtain a good picture of how much protein is used by the farmed animals' sector, I have calculated how many human beings could be nourished from the soybean meal that is fed to farmed animals if they consumed this meal directly, using the facts that roughly 20 kg of protein is recommended per human being annually and that 44% of the content of soybean meal is protein (Wallis 2014). In the European Union, 440 million people could satisfy all their annual protein requirements if we use a conservative estimate of the amount of soybean meal (20 million tonnes) that is imported annually by the European Union to feed farmed animals. This is almost 90% of the number of people living in the European Union. In the case of Australia, 11 million people could satisfy all their annual protein needs merely by the amount of soybean meal that it imports annually (at least half a million tonnes), which equates to about half of its human population.

In this survey I have shown that, on average, the farmed animals' sector uses more land to produce a unit of food than other agricultural sectors require to

produce a similar quantity of food. In many situations, the sector also degrades more land than other agricultural sectors either are or would be degrading to produce a fixed unit of food. Finally, the case study of Brazil shows that a large proportion of the recent expansion of the farmed animals' sector has occurred in areas that are relatively rich in biodiversity.

1.4 Water use and pollution

The virtual water content of an entity is the amount of water that is required to produce it, which is captured by its water footprint (Hoekstra and Chapagain 2007). When talking about water, it is useful to distinguish between 'blue', 'grey', and 'green' water. The 'blue water' footprint of an entity refers to the volume of surface water and groundwater that is used—measured in terms of the surface water or groundwater that is lost—in its production; the 'green water' footprint stands for the rainwater that is consumed (excluding runoff) by the entity; and the 'grey water' footprint refers to the volume of freshwater that is required to assimilate the pollutants of the entity in question, based on existing ambient water quality standards (Mekonnen and Hoekstra 2012, 402). These distinctions are useful to highlight the fact that not all uses of water are equally problematic in terms of their negative GHIs.

Problems associated with water scarcity have particularly led to greater scrutiny of sectors that use large amounts of blue water. As many water sources are being emptied faster than the rate by which the hydrological cycle can refill them, a lot of blue water is used at unsustainable rates. Deforestation can also have a major impact upon the availability of water, as the loss of canopies reduces the soil's humus content and reduces local precipitation, resulting in reduced infiltration and water storage. Deforestation also makes the land more susceptible to fire, thereby increasing greenhouse gas emissions as well. It therefore contributes to climate change and its associated problems, including the loss of water from mountains that are losing snow and ice because of global warming.

The LEAD study estimates that the farmed animals' sector accounts for more than 8% of global human water use (Steinfeld et al. 2006). Not only does the sector use water to hydrate animals, to manage manure, and to clean animal housing, but—as soil compaction reduces infiltration rates—grazing animals and the use of heavy agricultural machinery also reduce the replenishment of freshwater sources by lowering water tables (Kirchmann and Thorvaldsson 2000). Though water usage in the sector varies between animals, their feed, the technologies that are used to obtain their products, and the ecosystems in which they live, are killed, and are prepared for human consumption, the production of farmed animal products generally requires more water compared to the production of other foods with similar nutritional content (Hoekstra and Chapagain 2007; Marlow et al. 2009; WWAP 2009). The sector accounts

for 29% of the total water footprint from agriculture, which stems in large part (98%) from the water it uses to feed the animals: 1,463 Gm³/year for crops, and 913 Gm³/year for feed from grazing (Mekonnen and Hoekstra 2012). The total footprint for feed from crops amounts to 20% of the total water footprint of all crop production in the world, or 12% of the total blue water footprint of all crops (Mekonnen and Hoekstra 2012).

Mekonnen and Hoekstra (2012, 405) also reveal that the annual production of animal flesh, in tonnes, requires the following global averages of water: 4,300 m³/tonne for the flesh from chickens; 5,500 m³/tonne for the flesh from goats; 6,000 m³/tonne for the flesh from pigs; 10,400 m³/tonne for the flesh from sheep; and 15,400 m³/tonne for the flesh from cows, bulls, and steers. Per gram of protein, the water footprint of cows' milk, of eggs, and of chickens' bodies was estimated to be about 1.5 times larger than that of pulses, whereas for the flesh from cows, bulls, and steers, it was 6 times larger than the latter (Mekonnen and Hoekstra 2012, 410). The authors add that, with the exception of chickens, who rely heavily on feed regardless of whether they are kept in more extensive or more intensive systems, blue and green water usage increases hand in hand with intensification (in 'industrial systems'), as intensive systems rely more on the use of arable crops to feed animals. Where animals use grazing land that could not be used more efficiently for other purposes without substantial difficulties, the fact that they use a lot of water may not be such a problem, particularly if they rely mainly on green water. However, water scarcity is a growing concern, which is why the increasing usage of blue and grey water is particularly problematic.

Importantly, the global averages calculated by Mekonnen and Hoekstra (2012) exclude the grey water footprint associated with the treatment of a range of pollutants, including animal waste, pesticides, fertilisers other than nitrogen fertilisers, and other agrochemicals. One source of the farmed animals' sector's pollution is the soil that ends up in water through the erosion and sedimentation caused by farmed animals, either indirectly, through the deforestation that takes place for the expansion of the farmed animals' sector, or directly. Another problem is the creation of 'dead zones': the nitrogen compounds and the phosphorus excreted by animals, together with the application of excessive quantities of fertilisers to grow their feed, overfertilise rivers and seas and cause the algae that live in them to grow rapidly, a process known as eutrophication. When these short-lived algae die, they decompose; because any biological decomposition consumes oxygen, this causes oxygen depletion (hypoxia) of rivers and seas, leading to the suffocation of aquatic ecosystems (Eshel and Martin 2009). Eutrophication also causes human health concerns, for example by contributing to the development of *Pfiesteria piscicida*, an aquatic organism that not only kills fish but can also cause human health problems (Burkholder and Glasgow 2001). As an increasing number of animals are kept in confined systems that are far removed from nutrient-deficient fields that might benefit from the nutrients provided by their manure and urine, eutrophication is increasing (Smil 2002).

A further problem is the formation of nitrates from manure and artificial fertilisers. These nitrates can leach into drinking water supplies and filter through into the groundwater. The health effects of nitrate ingestion are the subject of considerable debate, as some studies have linked the human ingestion of nitrates with the occurrence of cancers and methaemoglobinaemia (Powlson et al. 2008; Katan 2009). Since many animals are fed from crops grown on arable land, of which large parts are devoted to monocultures, many methods used to farm animals increase the spread of pests and plant diseases, a well-documented problem associated with monocultures. This frequently leads farmers to use large quantities of pesticides—some of which are known to be harmful to human health—thus contributing to the development of pesticide resistance and to the presence of harmful pesticide residues in water and food (Koller et al. 2012; Matthews 2006).

Water is also polluted by the use of antibiotics and hormones, the latter of which are used to promote growth. Recombinant bovine somatotropin (rBST) is a hormone used in the USA, where it is administered to some dairy cows. It is unclear whether the use of these types of hormones might pose human health risks, but disruptions in the endocrine systems of several species of other animals have been associated with their use (Hotchkiss et al. 2008). Though its use is prohibited in the European Union and in many other countries, some other nations have allowed rBST. Other pollutants are the detergents, disinfectants, and antiparasitic agents that are used by the farmed animals' sector. Whereas some pathogens are undermined by some pollutants, others, for example *Cryptosporidium*, thrive in water polluted by the farmed animals' sector (Duffy and Moriarty 2003; Burkholder et al. 2007).

Though this is not intended to be a complete survey of all the water issues raised by the consumption of animal products, the negative water impacts associated with some forms of aquaculture must not be forgotten either, especially as about half of all fish who are currently consumed by human beings are produced in aquaculture systems (Bergqvist and Gunnarson 2013, 76). Some methods used to farm fish can be associated with relatively small negative water impacts; this is the case, for example, of the use of herbivorous species such as the common carp (*Cyprinus carpio*) or species of tilapia in small ponds (Bergqvist and Gunnarson 2013, 95). Others, however, have been associated with relatively large negative water impacts because of their use of algicides, fertilisers, pesticides, nutrients that cause eutrophication, (prophylactic) antibiotics, and other drugs that these methods use to raise fish (D. Cole et al. 2009; Bergqvist and Gunnarson 2013). The destruction of ecosystems associated with some forms of aquaculture also presents a growing concern. An example that has received some attention from academic scholars is the destruction of mangrove swamps in South East Asia that is taking place to meet the increasing demand—mainly from Western consumers—for shrimps, and its effects on coral reefs (Hendrickson et al. 2008, 320).

This survey shows that the farmed animals' sector uses a relatively large proportion of freshwater compared to other agricultural sectors and that it contributes significantly to water pollution. Though diets that include products from pasture-fed animals may save water if they rely mainly on rainwater, dietary shifts towards vegan diets could also save large volumes of water and reduce water pollution in many situations.

1.5 The use of fossil fuels and atmospheric pollution

Diets that include animal products generally require more fossil fuels than diets that exclude them. The reason for this stems in part from the fact that a large proportion of the plants that are eaten by animals are not converted into food that people can or want to eat, but are merely used to keep the animals alive, as well as to produce manure and urine. Whereas the proportion of an animal that is actually consumed varies depending on the nature of the animal in question, one example of this inefficiency is provided by Loughnan (2012, 106), who estimates that 65% of the weight of a steer may not be consumed.

The explosion in the consumption of animal products that has occurred over the last century was facilitated to a large extent by the invention of the Haber–Bosch process, which is crucial in the production of artificial fertilisers. This process, which uses energy to capture nitrogen from the air, has been identified as the key factor in the exponential growth of the world population since its commercialisation in 1913 (Smil 2001). In addition, crop losses have been reduced significantly through the development and application of pesticides. What artificial fertilisers and most pesticides have in common is that their production uses large quantities of oil and gas (Hanlon and McCartney 2008).

Apart from relying on large quantities of fossil fuels, the farmed animals' sector contributes significantly to a wide range of problems caused by atmospheric pollution, particularly because of the sector's rapidly increasing greenhouse gas emissions. The LEAD study calculated the relative share of emissions produced by the farmed animals' sector, claiming that the sector produced 18% of all anthropogenic greenhouse gas emissions in CO₂-equivalents (CO₂e) in 2002 (Steinfeld et al. 2006). The CO₂e of a substance measures its radiative forcing (or, less technically, its global warming) potential in units of carbon dioxide (CO₂). It stands for the amount of heat trapped by a quantity of gas as a factor of the heat trapped by one unit of a similar mass of CO₂.

Whereas a later, more detailed FAO study found that the total estimate provided by the LEAD study was 'in line with' the total estimate for the year 2005 (Gerber et al. 2013, 15), the former estimate has also been challenged: one study claims that the farmed animals' sector emitted 51% of all emissions in CO₂e in 2009 (Goodland and Anhang 2009). The main reasons for

this significant difference from the LEAD study are attributed to the following issues: that the LEAD study did not include respiration as a source of emissions; that it undercounted the number of farmed animals (for example, by excluding farmed fish); that it overlooked some emissions produced by the production, distribution, and disposal of animal products, their by-products, and their packaging; that it ignored the emissions produced by the medical and pharmaceutical industries in their fight against diseases associated with the farmed animals' sector; and that an inappropriate CO₂e of 23, rather than the more appropriate figure of 72, was used for methane. With regard to this last reason, the authors justify their figure by pointing out that a 20-year timeframe (with CO₂e of 72) must be used for calculation rather than a 100-year timeframe, 'because of both the large effect that methane reductions can have within 20 years and the serious climate disruption expected within 20 years if no significant reduction of greenhouse gases is achieved' (Goodland and Anhang 2009, 13). The authors of the study also point out that the LEAD study ignored the opportunity costs associated with the fact that a lot of land (26% of grassland and 33% of arable land) that is used by the farmed animals' sector could regenerate as forest and capture much more carbon through photosynthesis (Goodland and Anhang 2009, 13).

The 51% figure provided by Goodland and Anhang (2009) has been contested. One study claims that respiration should not be included within the count as the CO₂ that farmed animals produce by respiring would have ended up in the atmosphere anyway by the decay of the plants that would not have been consumed by farmed animals anymore (Herrero et al. 2011). Goodland and Anhang (2012) have retorted by saying that this ignores that the earth's photosynthetic capacity cannot balance out all the carbon that is respired by farmed animals; the problem lies in the fact that the sector contributes to a loss in photosynthetic capacity through deforestation and forest burning, thus reducing the earth's ability to absorb carbon from the atmosphere. Goodland and Anhang (2012) do not explain, however, how they determined that respiration exceeds photosynthesis, resulting in a carbon loss. A second point made by the Herrero et al. (2011) study is that Goodland and Anhang (2009) factored in the opportunity costs of the farmed animals' sector, but not of other human activities that reduce carbon capture opportunities, for example urban development. This criticism is entirely justified. Goodland and Anhang (2012, 254) have also responded to this point, stating that they 'used a minimal figure for foregone carbon absorption in land set aside for livestock and feed production when the true figure would be much higher'. The problem with this is that they neither explain what this claim is based on nor how it would compare with the true figures for other domains of human activity.

In light of this lack of clarity, box 6 relies on data provided by the LEAD study and the later FAO study to provide a more detailed sketch of the most prominent contributing factors of the farmed animals' sector to climate change (Steinfeld et al. 2006; Gerber et al. 2013).

Firstly, the sector produces carbon dioxide. Animals respire, producing CO_2 . Though some of the carbon that animals send up in the air when their lungs combine carbon with oxygen would also end up in the air through plants breaking down and through soils releasing gases had the animals not existed, some of the carbon released in the latter case would remain out of the atmosphere for longer by being locked either inside plants that live for a long time, such as trees, or inside soils that in the former case may not only release carbon, but also lose some of their potential to absorb carbon by being used to farm animals. In addition, fossil fuels are used to operate agricultural machinery, and most synthetic fertilisers and pesticides are derived from oil. This implies that carbon dioxide is released into the atmosphere through their production and use. About 25% of all synthetic fertilisers and pesticides are used to produce animal feeds (Steinfeld et al. 2006). Animal feeds are often grown far from where animals are kept and therefore require transportation. Animals are also often reared far from where they are killed, turned into products, and consumed. Energy is also required to house animals, as well as to transport and store the products that are derived from them. If the environmental costs of animal farming are included, they have been estimated to contribute to. Pimentel and Pimentel (2008) have calculated that, in the USA, the energy input from fossil fuels is more than 10 times greater for a unit of animal protein than for a unit of plant protein, although they add that the nutritional value of a unit of animal protein as human food is 1.4 times greater than that of a unit of plant protein. Though products derived from the bodies of animals are produced in different ways in the USA compared to how they are produced elsewhere, there is no doubt that the production of many animal products emits more carbon dioxide than the production of many other food products does. In total, the LEAD study estimates that the farmed animals' sector accounts for 9% of anthropogenic CO_2 emissions (Steinfeld et al. 2006), whilst the later FAO study estimates that it accounted for 5% of such emissions in 2005 (Gerber et al. 2013, 15).

The sector also produces methane (CH_4), mainly from enteric fermentation by ruminants and from stored manures, especially where these are stored in liquid form, as for example in lagoons. The full contribution of methane to climate change has been estimated to be more than half that of carbon dioxide (Shine and Sturges 2007). The LEAD study estimates that the farmed animals' sector accounted for about 37% of all anthropogenic methane emissions in 2002 (Steinfeld et al. 2006), whilst the later FAO study estimated that its share was 44% in 2005 (Gerber et al. 2013, 15). Though methane does not remain in the atmosphere

(Box continued from previous page)

for as long as CO₂, its CO₂e is 72 over 20 years, and 23 over 100 years (Forster et al. 2007). The fact that the farmed animals' sector produces a large amount of methane is primarily associated with the large number of ruminants that are used.

Chemical and organic nitrogen fertilisation also produces emissions of nitrogen oxide (NO_x), nitrous oxide (N₂O), and ammonia (NH₃). The creation of nitrous oxide in particular is a problem. The microbial production of nitrous oxide from soil nitrogen is promoted where the available nitrogen exceeds plant requirements. The LEAD study estimates that the farmed animals' sector is responsible for 65% of anthropogenic emissions of this gas, which has a CO₂e of 289 over 20 years (and a CO₂e of 298 over 100 years) and which also contributes to the hole in the ozone layer (Steinfeld et al. 2006; Forster et al. 2007); the figure given in the later FAO study is lower, at 53% for the year 2005 (Gerber et al. 2013, 15). In addition, the sector also accounts for almost two thirds of anthropogenic ammonia emissions (mainly from manure), which contribute not only to global climate change, but also to acid rain and the problems caused by soil acidification mentioned in section 1.3 (Steinfeld et al. 2006).

Box 6: How does the farmed animals' sector contribute to climate change?

Whereas my focus has been on the farmed animals' sector, we must not ignore the fact that many human diets also include products derived from animals who have not been farmed, particularly fish. Many diets that include fish who have been caught in the wild are associated with relatively high emissions compared to plant-based diets. Eshel and Martin (2006) estimate that typical Western diets, which include fish, are more inefficient compared to plant-based diets, especially since long-distance boat journeys are associated with the catching of fish preferred by Western customers. This long travelling distance is the reason for the high emissions of cod fishing calculated by Carlsson-Kanyama and González (2009, 1707S). A more general study was carried out by Reijnders and Soret (2003, 667S), who claim that, in Western Europe, trawler fishing—the prevailing fishing method in the area—uses 14 times more fossil fuels than would be used to produce an equal amount of plant protein. This figure excludes the high emissions that are frequently produced to process fish, for example the emissions produced by canning and refrigeration (Basurko et al. 2013).

The consumption of some fish, such as herbivorous fish kept in ponds that are situated close to consumers, can be associated with relatively small quantities of emissions. Many forms of aquaculture, however, are associated with serious concerns because of the emissions associated with their use of pesticides, prophylactic antibiotics, and nutrients that contribute to eutrophication, particularly their use of other fish as feed (D. Cole et al. 2009; Naylor et al. 2009). More generally, about one third of all the fish who are caught has been estimated to be used to feed farmed animals, which is why many diets that include the latter are associated with large emissions (Goldburg and Naylor 2005, 23).

Though figures on the magnitude of its contribution vary between different studies, it is clear that current human consumption of animal products contributes a great deal to climate change. The extent to which this might be mitigated will vary greatly with the alternatives that are envisaged.

One alternative that has been proposed is to reduce methane emissions by dietary or pharmaceutical interventions, but Webster (2013, 41–43) mentions that these interventions raise health concerns for the animals who might be affected. Rather than modify ruminant fermentation, a better strategy might be to reduce the number of ruminants. At the same time, however, it must be borne in mind that any reduction in the number of farmed animals is likely to trigger an increase in wild and feral animals who would occupy some of the freed-up space. However, though some of these would also produce methane, a reduction in the number of farmed animals is still likely to be accompanied by a decrease in methane emissions.

This is so for various reasons. Firstly, populations of wild and feral animals tend to be less dense compared to those of farmed animals. Secondly, the metabolic rates of these animals would be slower compared to those of many farmed animals—for example compared to cows (such as the Holstein-Friesian breed) who have been bred to produce large quantities of milk—thus reducing methane emissions. And thirdly, many ruminants would be replaced by animals who do not ruminate. In Australia, for example, reductions in the populations of sheep and cows would be likely to be accompanied by a growth in the number of kangaroos, who produce far fewer greenhouse gas emissions (Hoedt et al. 2015). Drastic reductions may not be achieved everywhere, however, depending on which animals might replace farmed animals. In the USA, for example, methane emissions might still be high if farmed animals are replaced by the animals who roamed across the land before the arrival of European colonisers. One study calculates that, if it is assumed that there were about 50 million bison before the arrival of European colonisers, methane emissions from bison, elk, and deer may have been about 86% of current methane emissions from farmed ruminants (Hristov 2012). This is in line with another study, which argues that current ruminant methane production in the USA is probably no more than 20% greater than what it was 300 years ago (when the author estimates there may have been 60 million bison), which is partly attributable to the fact that

ruminants kept in feedlots—also known as feed yards—produce less methane (Webster 2013, 43).

Webster (2013, 43) adds the valid point that a focus on mere emissions of methane or of other gases is inadequate in light of the fact that the total impact of the animals concerned on the quantities of detrimental gases in the atmosphere must be considered. In this regard, Webster (2013, 195) points at recent research into the potentially positive role played by grazers, who ingest silica which is then excreted to end up in rivers and eventually in the sea to feed diatoms, a particular type of algae, which take up carbon dioxide by photosynthesis (Mike Packer 2009). The idea is that greater numbers of grazers lead to greater quantities of silica in the sea, which in turn triggers an increase in the number of diatoms and a greater capture of carbon dioxide (Carey and Fulweiler 2015; Vandevenne et al. 2013). Whereas Webster (2013, 43)'s claim that 'well-managed grasslands constitute a significant carbon sink' is contested as a necessary condition for this to be the case is that they must have been managed relatively badly beforehand (see e.g. P. Smith 2014), to assess the real potential of grasslands to reduce negative climate change impacts more research is needed to compare this type of management with how other ways in which the land could be managed might affect the concentration of different gases in the atmosphere.

Some have also suggested that the numbers of current populations of some farmed animals could be reduced by the replacement of some animal products that are associated with high emissions by other foods that have been derived from animals and production chains that produce fewer emissions, for example grasshoppers and other insects (Vogel 2010). Meyers (2013, 119), for example, has argued that 'we ought to engage in and encourage *entomophagy*, the practice of eating insects'. He arrives at this conclusion in light of the claim that 'ten kilograms of plant food yields only three kilograms of pork and only one kilogram of beef', but to 'about nine kilograms of insect meat', which is partly because 'insects are cold-blooded' and 'do not waste fuel keeping their bodies warm' (Meyers 2013, 124). To this he adds that many insects produce far fewer emissions and can eat things that human beings cannot eat. Before sharing in Meyers' excitement, however, we would need not only more precise ecological impact assessments of how different insect-rearing practices affect the environment, but also to address whether grasshoppers and other insects should be valued instrumentally for human consumption, a question that will be addressed in chapter two.

Many scholars have argued that radical changes in human diets are required in light of the significant contributions of the farmed animals' sector to problems caused by climate change (Macdiarmid et al. 2012; Scarborough et al. 2012b; McMichael et al. 2007). More generally, I shall argue in section 1.6 that such changes are required in light of all the negative GHIs that have been described. A range of websites now exist that provide people with the tools to calculate some of the environmental impacts associated with their food choices, such as the Agri-footprint website (<http://agri-footprint.com>) and

the UNS website (<http://www.ulme.ethz.ch>, in German). Without wishing to endorse any of these, the usage of this type of websites may help readers to calculate the environmental impacts of their dietary choices, as well as guide dietary policy-making.

1.6 The moral imperative to reduce negative GHIs

The question of what counts as a good diet should be considered in light of the question of what counts as a diet that minimises negative GHIs (or maximises positive GHIs). In light of the dietary impacts that have been described previously, individuals and governments that take seriously the imperative to safeguard the right of all human beings to health care must encourage citizens to minimise dietary negative GHIs. Many negative GHIs should be allowed to be produced provided that positive GHIs are maximised. For example, in the case of the cultivation of rice, the fact that rice requires much more water than many other crops may be outweighed by the greater nutritional benefits of its consumption relative to other crops that could be grown, by local soil and climatic conditions, by the greater cultural meaning of rice, or by a combination of any of these factors. This example also shows that negative and positive GHIs that are difficult to quantify should not be excluded from our moral evaluations—for example the amount of pleasure that people derive from eating particular foods, the degrees of importance that they give to particular risks and uncertainties (for example those related to zoonotic diseases), the benefits that some people derive from the traction power or from the aesthetic values that some animals may provide, or any deontological constraints that should be accepted to safeguard moral agents' duties to strive for holistic health, for example those related to any duties that we may have towards other animals.

People may disagree about whether moral agents have a duty to prioritise more important over less important interests (or a duty to maximise positive GHIs) and about which impacts should count as positive or negative GHIs. However, in my view, there is overwhelming evidence to substantiate the view that many people, particularly those who live in relatively affluent countries, produce negative GHIs that ought to be avoided. In earlier work I suggested that those who contribute to the emergence and spread of zoonoses by consuming a wide range of animal products produce negative GHIs that ought to be avoided (Deckers 2011b). Elsewhere I provided a positive answer to the question whether the consumption of some animal products contributes to the existence of human hunger (Deckers 2011c). This is borne out at least partly by the fact that the consumption of many animal products contributes to the increase in human hunger that is triggered by one domain of human activity that is being taken increasingly seriously: anthropogenic climate change.

The evidence that can be provided to support the view that many people produce merely through their contributions to climate change negative GHIs that

ought to be reduced is overwhelming. Climate change is expected to become more and more dangerous if the average global surface temperature increases by more than 2°C relative to pre-industrial times. According to a study by the Intergovernmental Panel on Climate Change (IPCC), the atmospheric concentration of greenhouse gases was about 375 ppm (parts per million) in CO₂e in 2005, and concentrations will have to stabilise at or below that level to avoid a more than 2°C warming relative to the pre-industrial age (IPCC 2007a, 20). If this is the case, global anthropogenic emissions must be cut by 50–85% relative to the 2000 level by 2050 (Shellnhuber et al. 2006; European Commission 2007). The IPCC claims with ‘high confidence’—which is defined in terms of an 8 out of 10 chance—that, if we continue with a business-as-usual emissions policy, millions of people will suffer from negative health impacts associated with climate change (IPCC 2007b, 48). In Southern Asia, for example, the health status of millions of people has already been compromised through flooding, which has been reported to happen ‘more frequently and more severely than before’ (Douglas 2009, 127). The more the agricultural sector contributes to climate change, the more agriculture itself will be jeopardised by the adverse effects that have been associated with climate change, including increased droughts and floods. Several studies indicate that these problems will manifest themselves more in countries where people currently are relatively poor, thereby increasing the risks of their rights to health care being jeopardised (P. Smith et al. 2007; Lang and Heasman 2004; Parry et al. 2007; Stern 2006).

In light of these concerns, many governments have recognised the moral case for radical reductions in greenhouse gas emissions. By passing the Climate Change Act 2008, the UK Parliament, for example, has committed to reducing emissions by 80% by 2050, relative to emission levels in 1990 (Climate Change Act 2008). Similarly, the Australian Government has expressed the view that an 80% reduction in greenhouse gas emissions by 2050 relative to emission levels in 2000 would represent ‘a fair contribution from Australia’ (DCCEE 2011, xi).

Greenhouse gas emissions, however, are not the only things that matter morally. The development of a broader understanding of the negative GHIs associated with many human activities is facilitated by the notion of ‘ecological footprint’ (Wackernagel and Rees 1996). This concept was coined by Wackernagel and Rees (1996) to represent the ‘amount of biologically productive land and water area an individual, a city, a country, a region, or all of humanity uses to produce the resources it consumes and to absorb the waste it generates under current technology and resource management practices’ (Kitzes and Wackernagel 2009, 813; Rees 2003, 898). Though materials that are neither created nor absorbed by biological processes, such as plastics, are not represented, ‘ecological footprinting’ does include the effects that such materials have on biological systems (Kitzes and Wackernagel 2009, 814). Carbon dioxide emissions are included within ecological footprints by calculating the area of forest that would be required to assimilate those emissions, an approach that has been criticised not only because there are other ways in which these emissions could

be sequestered, but also because the used conversion rates are debatable (Van den Bergh and Verbruggen 1999). A similar problem underlies the calculation of the ecological footprint associated with the use of nuclear energy, which has been equalised with the amount of forest that would be required to offset the CO₂-equivalent of nuclear energy (Moran et al. 2009, 1943).

In spite of these limitations, the ecological footprint provides useful information to assess the magnitudes of some of our negative GHIs because of its inclusion of a broad range of ecological parameters. Whereas the GHI concept measures the impact of human actions on the health of all biological organisms in one common unit, the concept of ecological footprint measures the impact of human activities on the nonhuman environment in one common unit: the use of 'bio-productive' (biologically productive) space, or the quantity of biological resources that is used to provide for any particular human activity. This is usually expressed in terms of 'global hectares' ('gha'), the amount of land that is needed to produce any particular thing that is consumed and to deal with its waste using currently available technologies at average global productivity. Whilst health is affected by much more than by the use of bio-productive space, it has nevertheless been claimed that the ecological footprint is 'the most comprehensive and most widely adopted overall measure of threats to environmental sustainability', and this indicator has been understood as one of the most important ways to measure the impact of 'environmental stressors' on human health (Dietz et al. 2009, 118; Dwyer 2009). As such stressors also affect the health of nonhuman organisms, the ecological footprint of humans is also concerning for those who question our impact on the nonhuman world.

The fact that our collective ecological footprint is large provides a very strong indication that our negative GHIs are substantial. In 2008, 2.7 gha was the ecological footprint of the average person, but the amount of biologically productive water and land that was available in that year per person was calculated to be no more than 1.8 gha (WWF 2012, 44, 48). On this basis, Rees (2006a) has used Catton (1980)'s concept of 'overshoot' to refer to the fact that resources derived from biological organisms are consumed faster than the rate by which they are replenished. Great differences between different people's ecological footprints can be observed. In 2008, the average Bangladeshi used less than 1 gha, whereas the average person from many more affluent countries, such as Denmark, the USA, the UK, or Australia, used more than 4 gha (WWF 2012, 43). In addition, the USA combines a very large national ecological footprint with a significant increase in population (Ehrlich and Ehrlich 1997, 1198).

Both our collective ecological footprint and the existence of large differences between people's individual footprints are morally questionable. The problem with the former is that future generations will have to try to secure their rights to health care whilst reducing their ecological footprints substantially. Future generations might well be able to find novel ways to safeguard their rights, even if their 'earth capacity' will be much reduced. However, the probability that the rights of many future people will be compromised is great as the odds

are stacked against many of our future fellows. Take for example the people of Bangladesh: no clear answer has as yet been provided in relation to the question of how they will be protected from the likelihood of the large-scale flooding of coastal zones that is either caused or increased by anthropogenic climate change. Similarly, the health status of many Bangladeshis who are alive today has already been affected negatively by the November 2007 floods, which are likely to have been caused wholly or partially by anthropogenic climate change (Afjal Hossain et al. 2012). The fact that some people satisfy many desires that are not strictly necessary to enjoy a decent standard of health and thereby accumulate large ecological footprints causes severe problems for other people whose rights to health care are undermined.

We must therefore address not only what overshooting countries should do to reduce their ecological deficit, but also how many resources and how much waste each of us should be allowed to, respectively, consume and produce, and how many children we should have, without jeopardising the rights to health care of others unfairly. To help with this task, ecological footprint calculators that gauge individuals' footprints are useful. However, it must be recognised that the ecological footprint is no more than an aid, rather than the ultimate criterion to determine the morality of human actions. Clearly, some activities may be detrimental to the health of biological organisms, even if they use relatively few resources and produce little waste. An example would be killing someone, which might be considered positive if our sole aim was to reduce the ecological footprint of the entire human population. This example shows that a relatively large negative GHI (such as that of killing someone) need not be associated with a relatively large ecological footprint. The reverse also holds true. A relatively large ecological footprint need not be associated with a relatively large negative GHI. Compare, for example, the ecological footprint of a factory that produces shoes at a greater ecological footprint per shoe than a factory that produces shoes at a smaller ecological footprint. Should the former produce shoes that are significantly better for human health, for example by reducing bacterial infections, its average GHI per produced shoe might be more positive than the latter's. In spite of these considerations, the ecological footprint provides an important indicator of ecological stresses that may jeopardise human rights to health care.

In light of the magnitude of our ecological footprint, some ethicists have claimed that the occurrence of 'more hunger' is a certainty (Gjerris et al. 2011, 346). Rather than adopt such a pessimistic stance, I argue that negative GHIs that are not needed to fulfil our duties must be eliminated.

1.7 Reducing negative GHIs through dietary changes

A small but increasing number of studies have argued that dietary changes are required to reduce a wide range of negative GHIs associated with our dietary choices (Reijnders and Soret 2003; Carlsson-Kanyama and González 2009;

Baroni et al. 2007; Peters et al. 2007; Compassion 2007; Eshel and Martin 2009; Macdiarmid et al. 2012; Scarborough et al. 2012b). Some studies compare vegan with omnivorous diets (Eshel and Martin 2006; Carlsson-Kanyama and González 2009; J. Davis et al. 2010; Berners-Lee et al. 2012). Readers who wish to engage with these studies in detail are referred to box 7. A systematic analysis of peer-reviewed studies that report the land requirements and the emissions of 49 dietary options provides some indication that a transition to vegan diets in the European Union might reduce total greenhouse gas emissions by up to 20% and the demand for land needed to fulfil human dietary requirements by up to 60%, but the authors are rightly cautious about these claims as the review does not consider how non-diet related environmental impacts, for example those associated with leather replacements or the associated changes in health care costs, might be affected by such a transition (Hallström et al. 2015). A further reason why caution is needed is that most studies that compare different dietary scenarios consider vegan diets that are relatively unprocessed, where more emissions are likely to be produced by more processed vegan diets. A more general reason to be cautious is that there is a great deal of uncertainty associated with the impacts of a radically transformed agricultural system. In spite of this need for caution, it is clear that many people who consume animal products produce many more negative GHIs by doing so compared to those who abstain from doing so, and that dietary shifts towards vegan diets could reduce negative GHIs considerably.

A study from the USA revealed that the mean diet of a USA citizen, which includes 27.7% of calories from animal sources (comprising 41% from dairy, 5% from eggs, and 54% from a range of animal bodies), produces at least 1.5 tonnes more emissions in CO₂e per year than the emissions produced by a vegan USA citizen (Eshel and Martin 2006, 13). To obtain some idea of how this compares with the emissions produced by personal transportation, the authors point out that the average number of miles travelled by a USA citizen in 2003 was 8,332 miles, producing between 1.19 and 4.76 tonnes of CO₂ emissions, depending on which vehicle was used (Eshel and Martin 2006, 2–3). Drawing on their knowledge of the emissions produced by different car models, the authors make an interesting analogy. If we imagine that a person adopting the mean USA diet drove an averagely efficient car, the Toyota Camry, and that a vegan compatriot drove one of the most energy-efficient hybrid vehicles on the USA market in 2006, the Prius, the difference in diet-related emissions (for a given quantity of food with equal caloric intake) would amount to the difference in emissions produced by the former driving 143 miles in the less efficient car and the latter driving 100 miles in the more efficient car (Eshel and Martin 2006, 2–3). To understand

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the magnitude of this difference, a different analogy could also be used: the difference in emissions between the person adopting the mean USA diet and the person adopting the vegan diet corresponds to the difference in emissions between driving 8,332 miles in one of the most efficient cars and not driving at all.

A UK study measured the greenhouse gas emissions associated with 61 food categories that are sold in a mid-sized UK supermarket chain and used FAO 2010 statistical data to calculate the amount of food that is currently used in the UK (Berners-Lee et al. 2012). The calculation yielded a total of 3,458 kilocalories (kcal) per person per day, which is significantly more than what is actually consumed, revealing that a large amount of food is wasted. Subsequently, they described six dietary scenarios—each providing 3,458 kcal per day—and calculated the emissions that would be associated with each of them. Greenhouse gas emissions were reduced most significantly in the three vegan dietary scenarios. The vegan diet that produced the fewest emissions was not particularly healthy, and will not be discussed further. The two remaining vegan scenarios provide interesting food for thought. One of them embodied emissions that were 23% lower than the UK average diet. This scenario was based on scaling up the self-reported diets of vegans in the USA (Haddad et al. 1999) to the kilocalories associated with current UK usage levels, including both actual consumption and wastage. The other diet, described as the ‘thoughtful’ vegan diet, contained the highest level of carbohydrates, the lowest of added sugar, and the lowest of fat. It embodied 5.6 kg emissions in CO₂e per day, which is 25% less than the average UK diet’s emissions per day. Interestingly, its annual cost was also found to be £380 cheaper than the average UK diet (Berners-Lee et al. 2012). In this study, it was assumed that an equal amount of food would be wasted for all 61 food categories. The problem with this is that it may well misrepresent vegan diets, for at least two reasons. Firstly, as foods derived from animal products are likely to go off more quickly and to be discarded more quickly because of their greater risks of causing food-borne illnesses, it is highly likely that omnivorous diets contribute more to food waste. There is some evidence for this in the literature, as research found that more than half of all the flesh that is available for consumption in the UK is wasted (Aston et al. 2012). Secondly, research has found that many people who adopt vegan diets do so at least in part for environmental reasons, which may indicate that they are more

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averse to wasting food than people who adopt different diets (Fox and Ward 2008). Accordingly, it is likely that the reductions in emissions for the vegan dietary scenarios would be greater than those reported here.

Different dietary scenarios were also discussed in a Swedish study, which compared the greenhouse gas emissions of three Swedish meal options. Depending on which kinds of animal products were chosen, the difference between the hypothetical vegan meal and the two hypothetical meals that included animal products varied between a factor of three and a factor of eight, in spite of the fact that the former included soy imported from Brazil (Carlsson-Kanyama and González 2009, 1708S). A different study by the same authors, published with an additional co-author, compared the energy costs and greenhouse gas emissions from 84 common foods up to their point of import in a Swedish port, revealing that the importation of vegan protein used much less energy and emitted far fewer emissions than protein derived from animal products (González et al. 2011). The same study found that animal products produced more emissions when they contained more protein, whereas the reverse applied for plant products and protein levels.

A wider range of impacts was explored in a study that estimated the environmental impacts of four different meals with roughly similar nutritional content by means of the life cycle assessment methodology, which aims to measure the 'cradle-to-grave' impacts of products (J. Davis et al. 2010). The four meals that were compared for hypothetical consumption in both Spain and Sweden were the following: 1/ a meal consisting of chopped pieces of pigs who had been fed with cereals and with soy meal imported to Europe from American countries, with potatoes, raw tomatoes, wheat bread, and water; 2/ a meal consisting of chopped pieces of pigs who had been fed with a feed based on peas, rapeseed, mostly European-grown cereals, and some imported soy meal from American countries, with potatoes, raw tomatoes, wheat bread, and water; 3/ a meal consisting of chopped pieces of pigs who had been fed in the same way as in the second scenario that were turned into a sausage that also contained 10% of peas, with potatoes, raw tomatoes, wheat bread, and water; 4/ a meal consisting of a burger made from peas grown in Europe, with potatoes, raw tomatoes, wheat bread, and water. In the Swedish scenario, it was assumed that all foods would be produced in Germany, except for the potatoes, which would be produced in Sweden, and the tomatoes, which would be produced in Spain. In the Spanish scenario, it was assumed that all foods consumed by people were produced in Spain.

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It was found that the energy use of the fourth option would be almost as high as the energy required for the other options as the assumption was made that these burgers would be sold and stored as frozen and that slightly more frying would be required because of the higher volume of the burgers compared to the fried items in the other meal options. The authors point out, however, that the study assumed that the pieces of pigs had been bought fresh, but that energy use would be much different had the assumption been made that these had been frozen. It was also found that the global warming contribution of the fourth option would be about half that of each of the other three options—which all had similar global warming contribution levels—in Sweden, but about two thirds of that of the meals that contained animal products for Spain, largely because the pea burger requires significant amounts of energy at the pea burger factory, the retailer, and the household level. The discrepancy between Spain and Sweden for the global warming contribution of the fourth scenario is attributed to the fact that the latter nation generates much more energy from nuclear power plants and water. Regarding the contribution to eutrophication, it would be less than half for the fourth option than the high levels associated with the other options, which is due primarily to the high quantities of nitrates and ammonia that are produced by pig farms. The contribution of the fourth option to acidification would be even lower compared to the other options. The authors did not calculate differences in land use, but point out that the fourth option would use considerably less land. Finally, rather than rely on processed pea burgers, many people in Sweden and Spain might actually prefer to eat raw or cooked peas, which can reasonably be expected to reduce energy costs quite considerably.

Other studies at European and global levels also report significant differences between diets that include and diets that exclude animal products, in favour of the latter (Tukker et al. 2006; Tukker et al. 2011; Stehfest et al. 2009; Foley et al. 2011). One study revealed that the farmed animals' sector contributes no more than 6% of all economic value in the European Union, but that it produces about 24% of all monetarised environmental impacts from the consumption of all goods (Weidema et al. 2008, 6). This finding suggests that the sector produces relatively large quantities of negative GHIs, even if the exact quantification of this will vary depending on which and how environmental impacts are measured.

Box 7: Comparing the negative GHIs associated with omnivorous and vegan diets

1.8 The case for a radical transformation of agriculture

Though some vegan diets produce fewer negative GHIs than other diets, two obstacles manifest themselves when the results of the studies that I have discussed in the previous section are used to stimulate dietary change towards veganism. The first is that they measure a limited number of negative GHIs that are associated with current production systems, rather than the negative GHIs that might be produced by very different agricultural systems. Future vegan diets would be very different from those that are adopted by vegans living today if they were accompanied by a shift—whether more or less radical—from our current mixed agricultural farming system towards a vegan system. Such a system would, for example, require very different methods to maintain or improve soil fertility, including a much greater reliance on the use of green manures (plants that are grown to provide manure for other plants) and human manure and urine, the latter of which are now frequently wasted, causing losses of nitrogen and—more importantly—phosphorus. The use of green manure could also be accompanied by the use of plant-based anaerobic digestion, which would produce digestate that is rich in nitrogen to stimulate plant growth and methane that could be used for energy purposes. It has also been remarked that such a system would need to rely more on chemical fertilisers (Korthals 2012); whereas this need not be the case if both green and human manures are used, there is no doubt that a radical shift to a vegan-organic system would pose a significant challenge in relation to the goal of maintaining and boosting soil fertility (Darlington 2010).

Reliable studies of how shifts to vegan diets might reduce negative GHIs must therefore incorporate estimates of the negative GHIs that might be produced by very different agricultural systems, where relatively little may as yet be known about how such systems might perform. Such estimates, however, would be highly relevant. For example, to determine whether sufficient fruits and vegetables would be available to provide for healthy diets in a particular location, it is important to know what kinds of foods could be grown in that area and how much they might yield. This does not imply that locally sourced diets will always produce the least negative GHIs, particularly as it has been shown that current transportation of foods accounts for a relatively small percentage of their greenhouse gas emissions (Weber and Matthews 2008; González et al. 2011).

The second problem is that we should not ignore the possibility that a reduction of negative GHIs in one domain of human activity might increase negative GHIs in another domain, or even overall. What we eat affects many other things. Accordingly, the negative GHIs of human diets should not be isolated from the negative GHIs of other human activities, for example the production of footwear. Should the adoption of a predominantly vegan agricultural system be associated with a decline in the supply of leather, for example, people

would need to increase their production of non-leather shoes. Any uncertainties related to what kinds of shoes might be produced and how this might be done result in difficulties to estimate these shoes' potential negative GHIs.

The existence of these uncertainties might persuade some to favour conservative strategies that support (the development of) production systems that reduce the negative GHIs associated with the consumption of animal products, rather than to support strategies that aim to reduce their consumption as such. Many strategies could be adopted to reduce the negative GHIs associated with the consumption of animal products, including better manure management, changing from warm-blooded to more efficient cold-blooded animals, reducing negative GHIs associated with the slaughtering of animals and the distribution of their products, improving breeds of farmed animals and of plants used for their feed (for example through the genetic engineering of animals and plants), and developing lab-grown (also known as cultured, synthetic, or in-vitro) flesh. In a study funded by New Harvest, an organisation that supports this last technology, it is claimed that in-vitro flesh that is assumed to be able to be cultivated by using cyanobacteria as a growth medium might lower energy use, greenhouse gas emissions, and land and water usage very substantially compared to conventionally produced flesh in Europe, but the authors also point out that its public acceptance may be marred by public concerns over its unnaturalness (Tuomisto and de Mattos 2011), a theme that will be explored in section 2.12. Empirical research, however, has found that this is not the only thing that people are concerned about regarding in-vitro flesh, and that their concerns include issues of safety and taste (Hocquette et al. 2015; Laestadius and Caldwell 2015).

Whereas some of these technologies may reduce some negative GHIs considerably, the LEAD study has claimed that 'the environmental impact of livestock production will worsen dramatically ... in the absence of major corrective features' (Steinfeld et al. 2006, 275). If this is so, it must be doubted whether approaches that merely aim at changing production will be sufficient, particularly since many studies estimate that reducing the sector's environmental impacts may turn out to be rather difficult (Weidema et al. 2008; Wirsenius and Hedenus 2010; McMichael et al. 2007). With regard to the sector's greenhouse gas emissions, for example, it has been claimed that a 20–25% reduction per unit of product derived from the bodies of animals might be possible (Weidema et al. 2008; DeAngelo et al. 2006). However, it must be doubted whether even modest reductions could be achieved, at least in the short term. A working group on agriculture for the IPCC concluded that 'little progress has been made in the implementation of mitigation measures at the global scale' (P. Smith et al. 2007, 500). Though the past may not be an accurate basis from which to predict the future, reducing the negative GHIs associated with the consumption of animal products significantly per unit of product may be difficult. Any technological progress that may be achieved must be situated within the context of future agriculture, which will be compromised by the negative impacts that have been

produced in the past, including the decline in reserves of rock phosphate and fossil fuels, loss of soil fertility, land degradation, and water scarcity and pollution, as well as the negative impacts associated with atmospheric pollution. Any technological advances that might be made also rely on investments in science and its infrastructure, thus increasing emissions in the short term.

Even if significant reductions per unit of product might be achievable, the rapid adoption of diets that include (a greater quantity of) animal products is problematic in light of the fact that the human population is growing at an unprecedented rate, resulting in an increased demand for food (World Bank 2008; Royal Society 2009). On the basis of recent demographic and consumption trends, the LEAD study predicts that global demand for farmed animals' products will double by 2050 relative to the production level in 2000 (Steinfeld et al. 2006, 275). If this demand materialises, significant reductions in negative GHIs per unit of product may fail to bring about an overall reduction of negative GHIs. The argument has been made, however, that there is limited potential for further expansion of agricultural land, and that food increases will therefore have to come mainly from land that is in production already (Lal 2009). This may be difficult, especially because the gap between actual yields and maximum yields under ideal growing conditions is rather small in many countries (J. Huang et al. 2002). Whilst crop yields increased by 56% between 1965 and 1985, Foley et al. (2011) found that they only increased by 20% between 1985 and 2005. Indeed, serious questions have been raised over whether higher yields could be obtained without compromising long-term sustainability, particularly because these even higher yields are likely to be associated with large losses of phosphates and nitrogen (Smil 2011).

A further reason why merely reducing negative GHIs per unit of animal product does not go far enough relates to the fact that human beings need other things apart from food, for example energy. To replace fossil fuels, it is likely that an increasing amount of land will be required to provide energy in the future. The World Bank (2009) predicts that by 2030 even as much as 40% of our global grain production could be used as biofuels. Though this prediction may be wrong, the increase in pressure on agricultural resources from the energy sector provides further evidence to suggest that many diets that include relatively large quantities of animal products are highly problematic.

Clearly, conservative attempts to reduce dietary negative GHIs merely by altering production methods are grossly insufficient. I mentioned before that the UK Parliament, for example, has committed to reducing greenhouse gas emissions by 80% relative to its emissions in 1990 (Climate Change Act 2008). To obtain a better understanding of how drastic this reduction is, it must be borne in mind that it has been calculated that current dietary emissions in the UK are as high as 2.7 tonnes CO₂e per person per year, and that those who adopt a vegan diet sourced from within the current food production system have been estimated to reduce their emissions by no more than about 25% (Berners-Lee et al. 2012, 190). Given that total consumption-related emissions

have been estimated to exceed a UK average of 14 tonnes CO₂e per year per person (Aston et al. 2012) and that they should total around 2.8 tonnes CO₂e to reach the 2050 target of an 80% reduction, it is extremely unlikely that this target could be reached if the average person's allocated quota was to be filled almost entirely by their dietary emissions alone.

Unless dietary changes are made, it would leave the average UK citizen with no more than an allowance of 0.1 tonnes CO₂e annually for non-diet related sources. The same applies to other citizens who live in countries with similar levels of emissions that may be committed to similar reductions. As such drastic reductions in non-diet related emissions seem totally unrealistic I would like to imagine what the world might look like if everyone who could adopt a diet that did not include animal products without compromising the right to health care of any human being would adopt such a diet. Though the answer to this question will vary between different areas, depending on social and ecological factors, I have selected the example of the United Kingdom, partly because Simon Fairlie (2010) has envisaged what 'a vegan permaculture' system might look like if it were adopted in the UK. This system would not only avoid synthetic fertilisers and pesticides, but also produce some biofuels, as well as some flax and hemp to produce 7.25 kg in textiles per person per year (replacing the wool and leather that is used for these purposes under the current system).

Fairlie (2010) estimates that such a system would be able to feed about eight people from one hectare of land. As there are currently about 61 million people in the country, approximately 7.7 million ha of the approximately 22 million ha of non-urban land that is available in the UK would be required to feed this population. Each person would be provided with 2,767 kcal of food per day, which is more than the recommended daily intake values (FAO/WHO/UNU 2001), thus allowing for some food waste. However, it can be expected that bodily energy needs would be higher than what they are today, as more people would carry out harder physical work under such a scenario than within the current agricultural system, which relies heavily on fossil fuels through the use of machinery, pesticides, and synthetic fertilisers, thus saving on human labour. More than 14 million ha of non-urban land would be left for non-arable purposes. Though there is no doubt that some of this land would need to be used for human purposes unrelated to food production, including the production of timber and firewood (Heaton et al. 1999), some land that would not be used for arable purposes could nevertheless still be used to produce food, for example by being cropped with fruit trees.

Fairlie's proposal is modelled largely on the kinds of foods that are currently produced in the UK, that is, cereals, potatoes, sugar, rapeseed oil, dried peas, vegetables, fruit, and nuts, where he envisages that over half of all the arable land would be occupied by cereals, potatoes, and rapeseed (for oil). These crops are currently frequently grown in large monocrops, which are notoriously poor in biodiversity. It is therefore likely that any vegan agricultural system that is more sustainable might look very different from the scenario depicted by Fairlie

(2010). Out of a concern for biodiversity, even if it were valued only to sustain a rather narrow conception of human health, we must move away from the large monocrops that now dominate world food markets, and seek new ways to increase variety through a renewed emphasis on growing (a broader range of) fruits and vegetables. Our current agricultural system jeopardises food security by focusing on a very narrow range of plant foods. The FAO has estimated that 75% of the plant varieties that were cultivated on farms in the beginning of the 20th century were no longer cultivated by its end; that human beings obtain about 60% of their calories from only three plants (rice, maize, and wheat); and that only about 200 of the 250,000 to 300,000 known edible plant species are consumed by us (FAO 2004). Whatever the precise form might be of a UK vegan agricultural system, such a system should increase the range of plants that are consumed and be accompanied by a move away from the few food crops that now dominate the UK, as well as the global, food market.

The negative GHIs that would be associated with such a system would be much smaller than those that are associated with the current UK agricultural system. Some of the benefits of a modified version of the system envisaged by Fairlie (2010) include: the avoidance of pesticides and synthetic fertilisers and a reduction in the use of fossil fuels; a greater diversity of plants grown for food, resulting in more varied diets and greater long-term food security; a reduction in the loss of phosphates and nitrogen and in the eutrophication process associated with such a loss; a reduction in acidification; and greater availability of land that can be reforested to produce timber and firewood. Fairlie's scenario would also eliminate food imports and must therefore also be amended where a good case exists for the importation of some vegetables and fruits with relatively small negative GHIs.

As omnivorous diets are associated with more negative GHIs than vegan diets in many locations, similar benefits can be expected if the global agricultural system was transformed into a predominantly vegan agricultural system. However, in light of what has been described in the introduction to this chapter, namely that the lives of some people currently depend on using animals, an exclusively vegan agricultural system would not be optimal to minimise negative GHIs unless it could be shown that removing their dependency would decrease negative GHIs. To assess this issue fully, as well as to assess comprehensively whether my case for a radical transformation of agriculture survives further scrutiny, the GHIs associated with any duties we may have towards the nonhuman world must be explored, an issue that will be addressed in chapter two.

1.9 Conclusion

Many human moral agents produce negative GHIs that ought to be avoided, jeopardising the rights to health care that are possessed by all human beings. Although not all diets that include animal products result in relatively large

negative GHIs, I have shown that, in many eco-social settings, diets that include animal products produce more negative GHIs than vegan diets. Using the UK as an example, I argued that a wide range of diet-related negative GHIs could be reduced significantly if current agriculture was transformed into a predominantly vegan agricultural system. As I have ignored the GHIs of different human diets on the entities that make up the nonhuman world, it might be possible that the greater negative GHIs associated with many omnivorous diets are outweighed by the greater positive GHIs that such diets produce on the nonhuman world. The chapter that follows aims to document the GHIs that have so far been ignored to provide a holistic picture of the GHIs associated with human diets. Without this picture, it is not possible to assess which diets compromise each moral agent's duty to safeguard their holistic health. The conclusions that have been drawn here, however, stand firm in light of an assessment of all the interests that must be tended to in order to fulfil one's holistic health care duty.