BEYOND FACTORY FARMING

Sustainable Solutions for Animals, People and the Planet

A Report by Compassion in World Farming - 2009

COMPASSION in world farming

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UNITS USED IN THE TEXT

1 hectare = 2.47 acres

1 square kilometre (km^2) = 100 hectares = 247 acres

1 tonne (metric tonne) = 1000 kg = 0.98 ton

1 cubic metre (m^3) = 1000 litres

1 kilocalorie (kcal) = 1000 calories

1 gigajoule (GJ) = 1 billion joules = 278 kilowatt hours (KW hr) = 0.278 megawatt hours (MW hr)

EXECUTIVE SUMMARY

'Well before 2050, the world will need farming systems capable of feeding 8 –11 billion people within a resource-light, low-carbon economy. '

Factory farming of animals for food is resource-hungry and carbon-intensive. A creation of the second half of the 20th century in the developed world, it depends on high inputs of global natural resources – energy, water and land. Sixty billion animals (poultry and mammals) are used to produce food annually[1] and over 50% of pigmeat and 70% of chickenmeat is already industrially produced.[2, 3] Industrial systems have been increasing at six times the rate of traditional mixed farming systems.[4] Policymakers now predict that meat production will double by 2050, potentially doubling the number of animals used to 120 billion a year. The planet will not be able to sustain these huge numbers of livestock nor these methods.

Industrial livestock production is a highly inefficient use of global resources of land, water and fossil fuel energy when compared to plant crops such as cereals and vegetables. Every kilogramme of factory farmed meat requires several kilogrammes of grains for animal feed. Around 40% of the world's grain harvest is already used as livestock feed, and that proportion is around 70% in most rich countries.[5] Much of the land, energy and water used to grow feedcrops for intensively produced animals could be more efficiently used to grow food that is directly consumed by people. The United Nations Intergovernmental Panel on Climate Change (IPCC) in 2001 noted, 'A shift from meat towards plant production for human food purposes, where feasible, could increase energy efficiency and decrease GHG [greenhouse gas] emissions.'[6]

A number of economic pressures are now forcing a re-evaluation of how we use global resources: forecast population growth to more than nine billion by 2050, rapid industrialisation of developing economies, Peak Oil, higher energy prices, the demand for biofuel alternatives to oil, the impact of climate change on the availability of land and water for agriculture, people and industry, and the urgent need to reduce greenhouse gas emissions, starting now.

Livestock production globally is currently responsible for 18% of human-induced greenhouse gas emissions,[2] a higher proportion than all global transport (14%).[7]

Climate change could fundamentally change the conditions under which livestock can be produced in future, by reducing the availability of feedcrops, water and land. High temperatures may drastically reduce crop yields.[9] Large areas of the world's current cropland may become unusable or unproductive due to coastal flooding or drought. A rise in sea level of one metre is possible by the end of this century; this would flood one-fifth of Bangladesh and 2 million km^2 of land globally. As many as 150-200 million people could be permanently displaced by 2050 due to rising sea levels, floods and droughts and forced to settle on previously farmed land.[10] As we approach 2050, the huge resources of land, water and energy that our current intensive livestock production is based on may simply not be available. Factory farming would become both economically and ethically unsustainable.

With its high demand for resources and its high impacts, factory farming is the wrong model for feeding the world in 2050. In the next decades, we need to halve the environmental footprint of food production and free-up grain to feed people. A reduction in animal production, combined with lower-input, extensive farming, is the most effective response that farmers and policymakers in developed countries can make to achieve this goal. A reduction in consumption of animal products is also one of the most rapid and effective responses that an individual can make to the global problems of climate change, over-exploitation of the global environment and to free up natural resources for the use of the world's poor.

FACTORY FARMING'S IMPACT ON RESOURCES

Resource inefficiency: Factory farming gives a poor return on inputs of energy, land and water.

Livestock feed consumes nearly 43% of the food energy (kilocalories) produced by the world's total harvest of edible crops,[5, 11] after post-harvest losses. To produce 1 kg of edible meat by typical industrial methods requires 20 kg of feed for beef, 7.3 kg of feed for pigmeat and 4.5 kg of feed for chickenmeat.[11] On average, to produce 1 kg of high quality animal protein, livestock are fed nearly 6 kg of plant protein.[12] The production of just 1 kg of beef, as a global average, consumes nearly 15,500 litres of water,[13] the equivalent of 90 full bathtubs. This is nearly 12 times the quantity needed to produce 1 kg of wheat.[13]

One kcal of food energy from beef requires 40 kcal of fossil fuel energy input to produce.[14] Soya is 65 times as energy efficient as grain-fed beef and 73 times as energy efficient as farmed salmon, per unit of food energy (calories) consumed.[15] The production of 1 kg of beef requires 15 times as much land as the production of 1 kg of cereals and 70 times as much land as the production of 1 kg of vegetables. One kilogramme of pigmeat uses over six times as much land as 1 kg of cereals and 30 times as much land as 1 kg of vegetables.[16] Per cubic metre of water used in production, lentils and wheat produce up to 17 and 19 times more food calories respectively and up to five times more edible protein, compared to beef.[17]

The world's cereal harvest cannot support the world's population of 6.5 billion on a high-meat diet, let alone the 9.2 billion people who are forecast to be alive in 2050. At the level of the United States' consumption of animal products, we could feed only 2.5 billion people; at the level of Italy's consumption, only 5 billion people; but at India's current level of grain and meat consumption we could feed up to 10 billion people.[18]

Resource scarcity: Factory farming consumes large quantities of resources that will be scarce and costly by 2050.

Harvests

To feed people and livestock, the world will need to produce an additional 1 billion tonnes of cereals annually in the next decades, a 50% increase. A significant part of this increase will be used for animal feed.[19] Increasing food output will not be easy. The rate of growth in crop yields is slowing sharply, partly due to soil degradation and the over-use of agrichemicals[20] and climate change will almost certainly affect global food security. Heat stress could reduce crop yields in tropical and subtropical regions by 2.5% to 16% for every 1°C increase in temperature in the growing season, potentially destabilising world food markets.[9]

Biofuels are now adding to the competition between livestock producers and others for resources. These competing claims could reduce the calorie intake of the world's poorest. Biofuel expansion could decrease food calorie consumption by 5% or more in some regions such as Sub-Saharan Africa.[21]

Land

The demand for feedcrops for livestock will put intensive animal production in direct competition for land with people, biofuel production and forests.

For food production alone, an additional 2 million km^2 of land will be needed by 2030.[22] At the same time, over-exploitation of arable land and soil damage is causing the loss of millions of hectares of once-productive cropland.[23] The demand for land for feed grain is increasing the pressure on already scarce grazing land. Grazing is moving into marginal land, where it leads to desertification, and into forests or other ecologically valuable areas.[24]

Sea level rise and loss of land

Sea level rise will impact the world's harvest due to salination or total flooding of good low-lying agricultural land. Currently, 200 million people live in coastal floodplains, including 35 million people in Bangladesh and the inhabitants of 22 of the world's largest cities. Two million km^2 of land could be flooded if sea levels rise by one metre, a possibility during this century.[10] This is the same area as that of the extra farmland that the world needs to find by 2030. The doubling of livestock production by mid-century is therefore projected to take place at a time when crop production is actually decreasing due to climate-related losses.

Water

Up to 2 billion people currently suffer from water scarcity and this number is likely to increase to between 4 and nearly 7 billion by 2050, more than half the world's population.[25] Competition for water is already intense.

Water use for livestock production is projected to increase by 50% to 2025 and already uses 15% of all irrigation water.[26] The UN's Food and Agriculture Organization (FAO) has concluded: 'It is clear that feed production consumes large amounts of critically important water resources and competes with other usages and users.'[26] Increasing meat consumption has been identified as the main cause of the worsening water scarcity in China.[27] Reducing the proportion of animal-based food and increasing the proportion of plant-based food in the diet can almost halve an individual's water footprint.[28]

Peak Oil and the energy crisis

Peak Oil, the point at which world oil production reaches a maximum and then begins to decline, is likely to arrive between 2010 and 2020, signifying the end of the era of cheap and reliable energy supplies.[29a]

By 2050, oil and gas production may be half what it was at its peak.[29b] Intensive agriculture is based on cheap fuel, with two-thirds of agriculture's energy costs used for fertilisers and agrichemicals.[30] In developed countries, half of the total use of nitrogen fertiliser is used for growing animal feed.[26] Cutting meat and fish consumption by 50% and milk consumption by 40% in developed countries would make a major contribution to halving energy use in the food system.[23]

THE COSTS OF FACTORY FARMING: CLIMATE, ENVIRONMENT AND HEALTH

Factory farming produces 'cheap' meat, milk and eggs for retail sale but the hidden external costs of production are high. The costs include damage to the environment and climate, to animal and human health, and to animal welfare. If we want to create a livestock production system with lower external costs, it is essential that the true costs of production are reflected in prices. According to the FAO, 'A top priority is to achieve prices and fees that reflect the full environmental costs [of livestock], including all externalities.'[31] Lower-input animal farming can more than halve external costs per kilogramme of product.[52]

Climate change

Global greenhouse gas (GHG) emissions in 2050 need to be 85% below those of 2000 if we are to have a reasonable chance of limiting temperature rise to around 2°C. To achieve this, global emissions must peak no later than 2015 and get down to the level of 2000 emissions by 2030.[32] The livestock sector is responsible for a large proportion (18%) of total global GHG emissions and therefore needs to make substantial reductions within a short timeframe.

Livestock production is responsible for 37% of global methane (CH_4) emissions, 65% of global nitrous oxide (N_2O) emissions and 9% of global carbon dioxide (CO_2) emissions. In addition, 64% of ammonia emissions originate in livestock production and contribute to air, soil and water pollution, acid rain and damage to the ozone layer.[2] Globally, the most important sources of livestock-related GHGs are enteric fermentation (methane produced by digestion), animal manure and fertilisers used for feed production. A major driver of deforestation in South America is soybean production for factory farms in Europe and elsewhere.

The predicted global doubling of animal production by 2050 will generate large increases in livestock-related GHG emissions in the next decades. Nitrous oxide emissions are projected to increase by up to 35-60% by 2030 due to increased manure production by animals and increases in nitrogen fertiliser, much of which will be used to grow feed.[33] The expansion of large-scale commercial production of pigs and poultry is predicted to raise global emissions of methane from pig slurry and nitrous oxide from poultry manure.[34] Some developing regions will have very steep increases in livestock-related GHG emissions, making it even more essential that developed countries cut their own emissions rapidly.

Instead of seeking alternative solutions, many official responses to livestock-related GHG emissions have been to advocate further intensification of animal production. This would merely increase the waste of global resources devoted to animal feed production, with its associated problems of resource demand, alongside increased suffering of farmed animals. The most effective and fairest solution for reducing global livestock-related GHG emissions is to reduce the consumption of factory farmed products.

Biodiversity

Animal production-induced damage to wildlife habitats is one of the major threats to biodiversity globally. According to the FAO, 'Livestock play an important role in the current biodiversity crisis, as they contribute directly or indirectly to all these drivers of biodiversity loss, at the local and global level' through habitat change, climate change, overexploitation and pollution and 'over 70% of globally threatened birds are said to be impacted by agricultural activities'.[35a]

The impacts of intensive farming on biodiversity contribute to an already precipitous situation. The International Union for Conservation of Nature (IUCN), which monitors endangered species, believes that we are currently living through an extinction crisis. Current extinction rates are estimated to be at least 100 – 1000 times higher than natural background extinction rates.[35b] Global warming of 2°C could result in the extinction of 15% to 40% of land species and an eventual rise of 3°C or more, which is now thought to be likely, could see the extinction of up to half of all land species.[1]

Water and air pollution

Factory farming depends on crowding animals together in a relatively small space, often indoors. This breaks the link between livestock and the carrying capacity of the land and thus its ability to recycle wastes. Long before there was widespread concern over climate change, environmentalists and policymakers have been struggling to prevent pollution due to agricultural emissions of nitrogen and phosphorus globally. In water, these pollutants cause eutrophication and oxygen depletion, damaging biodiversity and killing fish. Around 30% of the nitrogen that pollutes water in the EU and the US is due to livestock (72% in China).[26, 37]

Nitrogen pollution is caused by both animal manure and the use of excessive quantities of fertilisers to produce animal feed. Two hundred dairy cows can produce as much manure as a town of 10,000 people.[38] Cattle and pig slurry and silage effluent are even more polluting to water than raw domestic sewage from human wastes.[39] Livestock production additionally pollutes freshwater by sediments (through soil erosion), pesticides, antibiotics, heavy metals and pathogens such as *Salmonella, Campylobacter and Escherichia coli (E. coli)* (all of which can cause foodborne disease in people).[26] Factory farms are sources of aerial pollutants that can damage the health of workers and those living near them. A chicken shed holding 100,000 broiler meat birds can emit up to 77 kg of polluting dust per day.[40]

Risks to human and animal health

Intensive livestock production methods, where large numbers of animals are kept together in confined spaces, increase the potential for infections to be spread between animals and from animals to humans. The stresses of factory farming and their reduced genetic diversity damage animals' natural capacity to resist infection and maintain health.[41a-c]

Factory farms commonly use antibiotics to prevent the spread of diseases that would otherwise occur among animals kept in unnaturally crowded conditions. It has been estimated that half of all antibiotics produced in the world are used for food animals, often for preventing disease rather than for curing sick animals.[45a] Over-use of antibiotics in intensive animal production is a major cause of the resistance of many common pathogens to the antibiotics used to treat humans.[45b] Factory farm use of antibiotics is also implicated in the spread of superbugs such as Methicillin-Resistant Staphylococcus Aureus (MRSA).[46a-b]

Factory farming has been implicated in the development of several significant human health challenges in the last 20 years. Bovine spongiform encephalopathy (BSE) emerged out of the intensification of the dairy industry. Highly pathogenic avian influenza, or bird flu, which now poses the threat of a global pandemic among people, emerged during a boom and rapid intensification in the global chicken industry. In 2006, the costs of controlling bird flu were estimated at 1 billion US dollars.[43] Reducing the size of the global-intensive chickenmeat industry would be one essential step towards controlling the disease. The 2009 human swine flu pandemic has also raised questions as to the role of factory farming in its origin and spread.

Of the new or currently emerging animal diseases, it has been estimated that 73% are transmissible to humans (zoonotic).[42] Global warming and global trade and transport can be expected to increase the rate at which animal diseases are spread and make infections in factory farms more difficult to control.

Food quality, nutrition and dietary choices

Factory farmed chicken has become a cheap meat, but at a cost in quality. Factory farmed meat chickens contain around one-third more fat than free-range organic chickens, and thus provide inferior nutrition.[44] Poultry are a common cause of food poisoning by bacteria such as *Salmonella* and *Campylobacter*. A diet lower in animal products would benefit public health in countries where meat consumption is high. The World Health Organization European Anti-Obesity Charter of 2006 reported that 50% of Europe's adults and 20% of children are overweight.[47a] In the US, there are 'dramatic increases' in the number of overweight children (now at 16%), according to the United States Department of Agriculture (USDA). 65% of adults are overweight and 30% are classified as obese.[47b]

A 60% reduction in meat consumption, down to 90 g per person per day, would reduce the risk of colorectal cancer, breast cancer and heart disease, as well as the risk of becoming overweight or obese.[48] The World Cancer Research Fund's 2nd Expert Report recommends a diet composed mostly of 'foods of plant origin' and a public health goal of consumption of no more than 43 g red meat per day (300 g per week).[49]

In the interests of global equity, and in order not to disadvantage people in poorer countries who currently eat very little meat, Compassion in World Farming supports a strategy of 'contraction and convergence' in meat consumption.[48] A reduction of meat consumption in rich countries would allow poorer countries to increase their consumption according to their dietary needs.

SUSTAINABLE ALTERNATIVES TO FACTORY FARMING FOR 2050

Dramatic global benefits would be derived from reducing meat consumption and ending factory farming. The most effective way to reduce the impact of the livestock industry on the climate, environment, natural resources and health is to reorient the world's animal production towards lower-input, more extensive systems. At a time when land, energy and water are scarce and costly, lower-input farming would be more environmentally efficient than intensive farming and is capable of providing adequate nutrition for the nine billion people of 2050.[50]

Extensive animal farming can significantly reduce inputs of mineral fertilisers and other agrichemicals and save energy. Reducing meat consumption would enable many developed countries to reduce their intensive cereal production in favour of rotations that benefit the soil, and so end their dependence on energy-intensive and polluting synthetic nitrogen fertilisers.[51] Water resources could be used more efficiently, as animals reared on natural rain-fed pasture have a much lower impact on water resources.[5] Organic production can reduce the (normally hidden) external costs of pigmeat by 70% and the external costs of poultrymeat by 66% compared to the external costs of intensive production.[52]

A transition to a global low-meat diet would make an important contribution to reducing GHG emissions. In addition to reducing emissions of methane and nitrous oxide, it would act immediately to discourage deforestation for animal feed production. Pastureland and arable land released from intensive feedcrop production could be used to absorb large quantities of carbon dioxide. Studies have shown that a global low-meat diet implemented in the period 2010 to 2030 would reduce by 50% the expected costs of mitigating climate change up to 2050.[53]

A transition to a global low-meat diet has the potential to immensely improve the welfare of farmed animals. Free-range, organic and good semi-intensive indoor systems provide the animals with a number of very important welfare advantages that they are denied in intensive and industrial systems. These include: sufficient space for exercise; access to daylight and fresh air; opportunity for natural behaviour such as foraging, exploration and nesting; and reduction in the frustration, stress and injuries that result from overcrowding in sheds or feedlots or from close confinement in cages and crates. Animals that are under less pressure to grow rapidly and produce the highest yields are also likely to be more robust and to have longer productive lifetimes.

THE FUTURE OF FOOD: FOR ANIMALS, PEOPLE AND THE PLANET

In the near future, food will need to be produced within constraints of less water, less land, less energy, conflicts over land policy, decreasing biodiversity and a changing climate.

We still have the choice: to continue on the path of high meat consumption and evermore intensified factory farming - or we could choose now to move to a food production system that is sustainable for people and the environment and that respects animal welfare. However, the global circumstances of population growth, Peak Oil and climate change are likely to make factory farming unviable by 2050, if not earlier, and thus make the choice for us. This could leave the world food system disrupted and struggling to adjust to the new circumstances, with drastic consequences for animals, people and the planet.

The situation is urgent – but the benefits of reducing meat consumption and moving beyond factory farming are profound:

Food supply: A reduction in meat consumption in developed countries, starting within the next 10 years, will make an important contribution to freeing up global resources of land and water, reducing global food prices and increasing the world supply of food energy available for human use.

Climate change: The most effective way to start to bring global livestock-related emissions under control within the next 10 years is a managed reduction in the production and consumption of meat and dairy products in developed countries.

Peak Oil: A reduction in the volume of meat production and consumption in rich countries over the next 10 to 20 years would enable farmers to move to more extensive, low-input animal farming and would make a significant contribution to reducing agrichemical and energy use in agriculture.

Deforestation: A reduction in the size and intensification of the livestock industry in developed countries, starting within a decade, would make an immediate impact on discouraging deforestation.

Biodiversity: The transition to a low meat diet in developed countries would reduce pressure on land and start to reverse damage to habitats and species globally. Well-managed extensive systems can be beneficial to maintaining biodiversity.

Public health: An increase in the proportion of plant-based foods and a corresponding reduction in the proportion of animal products in the diet of people in rich countries would make an immediate contribution to improving the health of current and future generations.

Food inequality: A more equitable global food system, including a proportionate reduction in meat consumption in developed countries, needs to be developed within the next 10 years.

Animal welfare: A reduction in the production and consumption of animal products in rich countries, such as those of the EU, would enable farmers to switch to a range of less intensive, more welfare-friendly production systems and develop world-leading animal welfare standards.

TOWARD A HUMANE AND SUSTAINABLE FUTURE

Compassion in World Farming recommends that the following approaches adopted in developed countries would enable us to create a sustainable, fair and humane animal production system by 2050:

- The production and consumption of livestock in developed countries needs to be reduced. A realistic target for reduction by 2020 would be 30% below current levels. A realistic reduction by 2050 would be 60-80% below current levels. These proposed reductions are in line with EU and UK greenhouse gas reduction targets up to 2020 and are also in line with dietary targets. These steps should be taken in addition to other essential livestock-related climate mitigation measures, such as halting deforestation, better fertiliser and manure management and switching to renewable energy sources on farm. These will help to meet the total UK climate target applicable to livestock by 2050 (a reduction to 80% below 2005 levels).

- Governmental and intergovernmental targets and incentives for both farmers and consumers are needed to support the transition to sustainable livestock production. These would include the agreement of international standards for the welfare of farmed animals and protection for the purchasing power of low-income consumers. Imported products would need to meet the welfare standards of the importing country.

- A recognition is needed that meat and milk are currently underpriced in relation to their real environmental and carbon costs and their impact on public health. Fiscal disincentives to over-production and factory farming need to be introduced, according to the ‘polluter pays’ principle. These could include green taxes and the pricing of factory farmed products to take full account of all external costs such as greenhouse gas emissions, deforestation, land and water use, pollution, soil damage and public health.

- A government-supported meat reduction strategy is needed which would enable farmers to reduce animal stocking densities and move from intensive to more extensive methods. Farmers need to be supported in raising animal welfare standards to the best free-range and organic farming standards of today, while protecting rural livelihoods.

- Encouragement is needed for food manufacturers, retailers and caterers in the food industry to support extensive high-welfare animal farming, to educate consumers about saturated fat in animal products and to partially substitute for meat in processed foods and undertake other meat-reduction strategies.

- All proposed climate mitigation measures should be screened for their impact on animal health and welfare. These measures include the various interventions intended to reduce digestive methane emissions (such as feeding more concentrates, feed additives, antibiotics, vaccinations and genetic engineering) and the intensification of animal breeding and management. It is unacceptable to make animals pay with their welfare for the climate impact of factory farming and the over-production of livestock products. The acceptable and more effective alternative is to reduce the volume and intensity of animal production.

EXECUTIVE SUMMARY REFERENCES

[1] FAOSTAT. Online database. Food and Agriculture Organisation of the United Nations (FAO). http://faostat.fao.org/default.aspx

[2] Steinfeld, H. *et al.*, 2006. *Livestock's Long Shadow: environmental issues and options.* Food and Agriculture Organisation of the United Nations. Rome. http://www.fao.org/docrep/010/a0701e/a0701e00.htm

[3] WorldWatch Institute, 2004. *State of the World 2004: The Consumer Society*. http://www.worldwatch.org/node/1785

[4] FAO, n.d. Protecting Animal Genetic Diversity for Food and Agriculture. Time for Action. Animal genetic resources group, Food and Agriculture Organisation (FAO), Rome.

[5] Lundqvist, J., de Fraiture, C., Molden, D., 2008. *Saving Water: From Field to Fork – Curbing Losses and Wastage in the Food Chain*. SIWI Policy Brief. SIWI. http://www.siwi.org/documents/Resources/Policy_Briefs/PB_From_Filed_to_Fork_2008.pdf

[6] IPCC, 2001. *Climate Change 2001: Mitigation of climate change. Technical summary*. A report of Working Group III of the Intergovernmental Panel on Climate Change. Section 3.3.4. www.ipcc.ch/pub/un/syreng/wg3ts.pdf

[7] Stern Review: the economics of climate change. HM Treasury and Cabinet Office. 2006. Part III, chapter 7. http://www.hm-treasury.gov.uk/sternreview_index.htm

[8] Pachauri, R. K., 2007. *IPCC 4th Assessment: key findings*. Presentation to UN, New York City, 24 September. http://www.ipcc.ch/pdf/ presentations/pachauriun_nyc_2007-09-07.pdf

[9] Battisti, D. S. Naylor, R. L. Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat. *Science 323*:240 – 244. DOI: 10.1126/science.1164363.

[10] Stern Review: the economics of climate change. HM Treasury and Cabinet Office. 2006. Part II, chapters 3 and 4. http://www.hm-treasury.gov.uk/sternreview_index.htm

[11] Smil, V., 2000. *Feeding the world: a challenge for the twenty-first century*. MIT Press.

[12] International Assessment of Agricultural Science and Technology for Development (IAASTD), 2008. Global summary for decision makers. http://www.agassessment.org/docs/Global_SDM_060608_English.pdf

[13] Hoekstra, A. Y. and Chapagain, A. K., 2007. Water footprints of nations: Water use by people as a function of their consumption pattern. *Water Resources Management*, 21:35–48. DOI 10.1007/s11269-006-9039-x.

[14] Pimentel, D., 2006. Impacts of Organic Farming on the Efficiency of Energy Use in Agriculture: An Organic Center State of Science Review. *The Organic Center*. http://www.organic-center.org/ reportfiles/ENERGY_SSR.pdf and http://www.organic-center.org/science.pest.php?action=view&report_id=59

[15] Eshel, G. and Martin, P. A., 2006. Diet, energy and global warming. *Earth Interactions*, 10: 1-17. http://geosci.uchicago.edu/~gidon/papers/nutri/nutriEI.pdf and http://geosci.uchicago.edu/~gidon/papers/nutri/nutri.html

[16] Gerbens-Leenes, W. and Nonhebel S., 2005. Food and land use. The influence of consumption patterns on the use of agricultural resources. *Appetite* 45:24-31. doi:10.1016/j.appet.2005.01.011.

[17] Molden, D. et al., 2007. Pathways for increasing agricultural water productivity. International. *Water for Food, Water for Life. A Comprehensive Assessment of Water Management in Agriculture*. Water Management Institute Summary, ed. Molden D. Chapter 7. http://www.iwmi.cgiar.org/assessment/Water%20for%20Food%20Water%20for%20Life/Chapters/Chapter%207%20Water%20Productivity.pdf and http://www.iwmi.cgiar.org/assessment/Publications/books.htm

[18] Brown, L. R., 2008. Plan B 3.0: *Mobilizing to Save Civilization*. New York: W.W. Norton and Company, Earth Policy Institute. chapter 9. Feeding Eight Billion Well. http://www.earthpolicy.org/Books/PB3/PB3ch9_ss5.htm

[19] FAO, 2006. Global Perspective Studies Unit. *World agriculture: towards 2030/2050*. Interim report. http://www.fao.org/es/esd/AT2050web.pdf

[20] FAO, 2009. Farming must change to feed the world. Press release 4 February 2009. http://www.fao.org/news/story/en/item/9962/icode/

[21] von Braun, J., 2008. *Food prices, biofuels and climate change*. Presentation. IFPRI. http://www.ifpri.org/presentations/200802jvbbiofuels.pdf

[22] The Rights and Resources Initiative (RRI), 2008. *Seeing people through the trees*. RRI Washington DC. http://www.rightsandresources.org/documents/files/doc_737.pdf ; *Science Daily*, 2008. Record land grab predicted. 15 July. http://www.sciencedaily.com/releases/2008/07/080714092746.htm

[23] Pimentel, D. *et al.*, 2008. Reducing energy inputs in the US food system. *Human Ecology* 36:459-471. DOI 10.1007/s10745-008-9184-3.

[24] Steinfeld, H. *et al.*, 2006. *Livestock's Long Shadow: environmental issues and options*. Food and Agriculture Organisation of the United Nations. Rome. Chapter 2. http://www.fao.org/docrep/010/a0701e/a0701e00.htm

[25] Bates, B. *et al.*, 2008. *Climate Change and Water*. IPCC Technical paper VI. IPCC, WMO and UNEP. http://www.ipcc.ch/pdf/technical-papers/climatechange-water-en.pdf

[26] Steinfeld, H. *et al.*, 2006. *Livestock's Long Shadow: environmental issues and options*. Chapter 4. Food and Agriculture Organisation of the United Nations. Rome. http://www.fao.org/docrep/010/a0701e/a0701e00.htm

[27] Liu, J., Yang, H., Saveniji, H. H. G., 2008. China's move to high-meat diet hits water security. *Nature* 454:397.

[28] Liu, J., Yang, H., Saveniji, H. H. G., 2008. Food consumption patterns and their effect on water requirement in China. *Hydrology and Earth Systems Science* 12:887-898. 2008. www.hydrol-earth-syst-sci.net/12/887/2008

[29a] Association for the Study of Peak Oil (ASPO), 2008. http://www.peakoil.net/ *Newsletter 91*, July 2008. http://www.energiekrise.de/e/aspo_news/aspo.html

[29b] UK Industry Taskforce on Peak Oil & Energy Security (ITPOES), 2008. *The Oil Crunch. Securing the UK's Energy Future*. http://peakoil.solarcentury.com/wpcontent/uploads/2008/10/oil-report-final.pdf

[30] World Bank, 2007. *World Development Report 2008. Agriculture for Development*. Chapter 2. http://siteresources.worldbank.org/INTWDR2008/Resources/2795087-1192112387976/WDR08_04_ch02.pdf

[31] Steinfeld, H. *et al.*, 2006. *Livestock's Long Shadow: environmental issues and options*. Executive Summary. Food and Agriculture Organisation of the United Nations. Rome. http://www.fao.org/docrep/010/a0701e/a0701e00.htm

[32] Pachauri, R. K., 2007. *IPCC 4th Assessment: key findings*. Presentation to UN, New York City, 24 September. http://www.ipcc.ch/pdf/presentations/pachauriun_nyc_2007-09-07.pdf

[33] IPCC, 2007. *Climate Change 2007: Mitigation of Climate Change*. IPCC 4th Assessment report, Working Group III. Chapter 8, Agriculture. Final Draft pre-copy edit version. http://www.mnp.nl/ipcc/pages_media/FAR4docs/chapters/CH8_Agriculture.pdf

[34] United States Environmental Protection Agency (US-EPA), 2006. *Global Anthropogenic non- CO_2 Greenhouse Gas Emissions: 1990 – 2020*. http://www.epa.gov/nonco2/econinv/international.html

[35a] Steinfeld, H. *et al.*, 2006. *Livestock's Long Shadow: environmental issues and options*. Food and Agriculture Organisation of the United Nations. Rome. Chapter 5. http://www.fao.org/docrep/010/a0701e/a0701e00.htm

[35b] IUCN News Release, 2007. Extinction crisis escalates: Red List shows apes, corals, vultures, dolphins all in danger. 12 Sept. http://cms.iucn.org/search.cfm?uNewsID=81

[36] Sahney, S., Benton, M. J., 2007. Recovery from the most profound mass extinction of all time. *Proceedings of the Royal Society B*. Biological Sciences. 275:759-765. 2008. doi:10.1098/rspb.1370.

[37] WHO and European Commission, 2002. *Eutrophication and Health*. http://ec.europa.eu/environment/water/water-nitrates/pdf/eutrophication.pdf

[38] *Animal waste pollution in America: an emerging national problem, 1997. Environmental risks of livestock and poultry production*. A report by the Minority Staff of the US Senate Committee on Agriculture, Nutrition and Forestry for Senator Tom Harkin.

[39] Archer, J. R., Nicholson, R. J. 1992. Liquid wastes from animal enterprises. *Farm animals and the environment*, ed. Phillips C and Piggins D. CAB International. 1992.

[40] Wathes, C. M. *et al.*, 1997. Concentrations and emission rates of aerial ammonia, nitrous oxide, methane, carbon dioxide, dust and endotoxin in UK broiler and layer houses. *British Poultry Science* 38:14-28.

[41a] Rauw, W. M. *et al.*, 1998. Undesirable side effects of selection for high production efficiency in farm animals: a review. *Livestock Production Science* 56: 15- 33.

[41b] Sørensen, A. C. *et al.*, 2006. Udder Health Shows Inbreeding Depression in Danish Holsteins *Journal of Dairy Science* 89:4077–4082.

[41c] Yunis, R. *et al.*, 2002. Antibody responses and morbidity following infection with infectious bronchitis virus and challenge with Escherichia coli, in lines divergently selected on antibody response. *Poultry Science* 81: 149-159.

[42] Greger, M., 2007. The Human/Animal Interface: Emergence and Resurgence of Zoonotic Infectious Diseases. *Critical Reviews in Microbiology*, 33:243–299. DOI: 10.1080/10408410701647594.

[43] MacKenzie, D., 2006. Time to stamp out bird flu at source. *New Scientist*, 14 January 2006, p6-7.

[44] Wang, Y. Q. *et al.*, 2005. Changes in protein and fat balance of some primary foods: implications for obesity. Presented at the 6th Congress of the International Society for the Study of Fatty Acids and Lipids. 27 June – July 2004, Brighton.

[45a] Nathan, C., 2004. Antibiotics at the crossroads. *Nature* 431:899-902.

[45b] Shea, K. M., 2003. Antibiotic resistance: what is the impact of agricultural uses of antibiotics on children's health? *Pediatrics* 112(1):253-258.

[46a] MRSA found in US pigs, 2008. *Pig Progress*. July 14. http://www.pigprogress.net/news/ id1602-59602/mrsa_found_in_us_pigs.html

[46b] Smith, T. C. *et al*., 2009. Methicillin-Resistant Staphylococcus Aureus (MRSA) Strain ST398 Is Present in Midwestern U.S. Swine and Swine Workers. PLoS ONE 4(1): e4258. 2009. doi:10.1371/journal.pone.0004258.

[47a] WHO Europe, 2006. *Draft European Charter on counteracting obesity*. EUR/06/5062700/8. 18 September. http://www.nepho.org.uk/view_file.php?c=1777

[47b] Dietary Guidelines for Americans 2005. US Department of Health and Human Services and US Department of Agriculture. http://www.health.gov/dietaryguidelines/dga2005/document/pdf/DGA2005.pdf

[48] McMichael, A. J., Powles, J. W., Butler, C., Uauy, R., 2007. Food, livestock production, energy, climate change, and health. *The Lancet*. Published online13 September. DOI:10.1015/S0140-6736(07)61256-2.

[49] World Cancer Research Fund and the American Institute for Cancer Research, 2007. *Food, Nutrition, Physical Activity, and the Prevention of Cancer: a global perspective*. Chapter 12. www.dietandcancerreport.org

[50] Badgley, C. *et al*., 2007. Organic agriculture and the global food supply. *Renewable agriculture and food systems* 22(2):86-108. 2007.

[51] Crews, T. E., Peoples, M. B., 2004. Legume versus fertilizer sources of nitrogen: ecological tradeoffs and human needs. *Agriculture, Ecosystems and Environment* 102:279-297.

[52] Pretty, J. N. et al., 2005. Farm costs and food miles: An assessment of the full cost of the UK weekly food basket. *Food Policy* 30(1):1-19. doi:10.1016/j.foodpol.2005.02.001. http://www.essex.ac.uk/BS/staff/pretty/Pretty%20et%20al%20Food%20Policy%202005%20%20vol%2030%20%20pp1-20.pdf

[53] Stehfest, E. *et al*., 2009. Climate benefits of changing diet. *Earth and Environmental Science*. Published online 4 February. DOI:10.1007/s10584-008-9534-6.


REPORT

INTRODUCTION

Feeding the world in 2050

Factory farming was a creation of the second half of the 20th century in the industrial world. During those 50 years more low-priced meat, milk and eggs were produced than ever before in the history of agriculture. A diet high in animal protein and animal fat became available to everyone in rich countries and the 'dietary transition' to energy-dense foods began to develop rapidly worldwide.

The basis for much of this transformation is the grain feeding of billions of poultry, pigs, dairy cows and, to some extent, beef cattle, selectively bred for speed of growth, uniformity, high feed conversion efficiency and high yield and kept concentrated in large numbers, often indoors. By the end of the 20th century factory farming was becoming globalised and agricultural policymakers typically viewed industrial animal production as an unquestioned necessity and as a normal part of economic development. However, at the end of the first decade of the 21st century, our changed circumstances are forcing a total re-assessment of this view.

This report aims to set out the economic and environmental factors that will impact global animal production up to 2050 and will combine to make factory farming obsolete. These factors include rising populations and food demand; the availability of land and water for growing feed crops; climate change; the environmental impact of intensive animal production; increasing oil scarcity and high prices after 'peak oil'; the impact of animal diseases on both animal and human health; and the needs of human nutrition (the abolition of hunger, undernutrition and over-nutrition).

Animal production and global resources

The intensive production of meat is known to be one of the most resource-inefficient methods of producing food for people.

Farmers need to grow several kilogrammes of animal feed to produce one kilogramme of meat. One kilogramme of edible boneless beef requires around 20 kg of animal feed and 15500 litres of water to produce[1, 2]; 15000 litres is equivalent to filling up 100 average-sized bathtubs. One kilogramme of beef requires 12 times the quantity of water needed to produce 1 kg of wheat and five times the quantity of water needed to produce 1 kg of rice.[2] Beef production consumes 17 times more water than wheat in order to supply the same amount of food energy.[3] One calorie of food energy obtained from beef requires inputs of 9 calories of food energy from plants[4] and 40 calories of fossil fuel energy.[5]

One-third of the world's current cropland is used for animal feedcrops.[6] Around 40% of the world's cereal harvest is used as livestock feed, and that proportion is 70% in most rich countries.[7] Much of the land, energy and water used to grow feed crops for intensively produced animals could have been more efficiently used to grow food that is directly consumed by people.

For many of the world's poorest, livestock may be their only capital asset and essential for providing draught power, fertiliser and fuel from dung as well as food. Rich countries are in a completely different situation however, because they both over-produce and over-consume livestock products. The excessive production and consumption of animal products in rich countries, wasting large quantities of grain in animal feed, is one of the main drivers of global food price rises that harm poor people.

Reducing our consumption of animal products, particularly meat, would significantly reduce the resources needed to feed the rapidly growing human population of the planet. In 2001 the Intergovernmental Panel on Climate Change (IPCC) noted, 'A shift from meat towards plant production for human food purposes, where feasible, could increase energy efficiency and decrease greenhouse gas emissions.'[8] Studies show that removing meat from an individual's diet could halve the total quantity of water used for that individual's food production.[3] A 50% reduction in the consumption of meat in the United States, in combination with other changes in technology and production methods, could cut by half the energy inputs to the United States food system.[5] A 60% reduction in meat consumption in all developed countries could prevent the predicted steep increase in livestock-related greenhouse gas emissions between now and 2050.[9] Livestock production globally is responsible for 18% of human-induced greenhouse gas emissions, a higher proportion than global transport.[6, 7]

Animal production and climate change

Factory farming of animals for food is highly carbon intensive. Currently around 60 billion animals (poultry and mammals) are used to produce food annually.[10] It has been widely predicted by policymakers that global meat production will double by 2050. This would potentially increase the number of livestock to 120 billion and double the quantity of the world's resources of land, energy and water needed to grow the crops to feed them.

The projected doubling in animal production comes at a time when climate change may make large areas of the world's existing cropland unusable or seriously reduce crop yields due to coastal flooding, drought and an increase in crop pests. A sea level rise of one metre or more is possible by the end of this century; this would flood one-fifth of Bangladesh and 2 million km^2 of land globally. As many as 150-200 million people could be permanently displaced by 2050 due to rising sea levels, floods and droughts.[11] These people may need to re-build their towns and cities on what was previously farmland. Already millions of hectares of cropland are being lost annually to erosion and salinisation.[5] Water resources could become so stretched as to cause armed conflicts in some areas.[12, 13] At some time between 2010 and 2020 the world will reach 'Peak Oil' - the point at which the maximum production of oil and natural gas has been reached, resulting in the end of cheap energy.

It is clear that the huge resources of land, water and energy needed to produce animal feed for factory farms may not be there to use as we approach 2050. Factory farmed meat production will be in competition with both people and the biofuel industry for essential resources. At the very least, factory farming will become extremely costly, and it could well become impossible. It is even more likely to be seen as environmentally indefensible.

Why factory farming must end by 2050

A few years ago this question would not have been even asked, since it was taken as a given that industrialisation was the future of animal production. However today it is clear that the economic and environmental conditions for animal farming in the decades leading to 2050 could be entirely different from those of the past.

The reality of climate change and the ongoing resource crisis present developed countries such as those of the European Union (EU) with the need to re-orient and re-structure their animal farming systems. We need a food production system for the future that is much less wasteful of land, energy and water and produces a much lower level of environmental pollution.

This report shows that an essential aspect of a sustainable food system is an end to the wasteful over-production of meat and other animal products by factory farming. This would mean that fewer animals would be reared but they would be reared in more extensive conditions such as in good free-range and organic farms, using slower growing and hardy animals that require lower inputs of concentrated feed and energy.

Scaling down livestock production in the rich countries of the world is the fastest and most effective response that we can make to reduce the environmental footprint of food production and to free up grain for people. A reduction in the consumption of animal products is also one of the most rapid and effective responses that an individual can make to the global problems caused by climate change and environmental damage and to free up natural resources for the use of the world's poor.

PART 1: FACTORY FARMING, RESOURCE USE AND CLIMATE CHANGE

1. Global economics and resources

Today a number of economic and resource pressures are combining to force a re-evaluation of how we use global resources. These pressures include: population growth and rapid industrialisation of developing economies; peak oil and high energy prices; the urgent need to reduce greenhouse gas emissions; the biodiversity crisis; the demand for biofuel alternatives to oil; and the impact of climate change on the availability of land and water for agriculture, people and industry.

According to agricultural experts, these 'new driving forces', will redefine the world food situation.[14,15] The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) concludes that these driving forces 'are affecting local and global food security and putting pressure on productive capacity and ecosystems. Hence there are unprecedented challenges ahead in providing food within a global trading system where there are other competing uses for agricultural and other natural resources.'[14]

1.1 New resource pressures

By 2050 there is forecast to be an additional 2.5 billion people alive, bringing the population to 9.2 billion, compared to 6.7 billion today. 86% of our population will be in less developed regions, where demand for better diets is increasing rapidly.[16] If we are not able to find ways to use global resources more carefully, we may find that by 2050 or even sooner the global food system is unable to meet demand; in that case the poorer regions of the world that are unable to pay higher prices will be the worst losers.

Intensive animal production is resource-hungry in every respect, at a time when we should be reducing our resource use. As the UK Government's Cabinet Office has pointed out, 'Well before 2050, the world will need farming systems capable of feeding 8–11 billion people within a resource-light, low-carbon economy.'[17]

With a 'business as usual' model of agriculture, animal production will take an increasing share of global resources. Meat production, if demand is not modified, is predicted to increase by between 70% and 160% by 2050 compared to 2007.[7, 18] Milk consumption in developing countries could double by 2030.[18] Agriculture as a whole will need to take over another 2–5 million km^2 of land in the next two to three decades.[19, 20] Water use in agriculture (for food and fibre) will increase by 70-90% as a result of population increase and changes in diet.[14] China's oil imports increased over seven-fold between 1996 and 2006.[21] All these will put severe pressure on the world's resources. But one of the severest constraints on intensive agriculture will be energy – its availability and cost.

Chatham House, the London think-tank, argued that policymakers need to plan now for the 'oil supply crunch' and the 'food crunch' that seem likely when the current world economic recession ends and prices continue to rise.[22, 23] The 'long-term resource scarcity trends' including climate change, energy supply and cost, falling water availability and competition for land make it likely that the global number of undernourished and hungry people will continue to rise.[23]

1.2 Peak Oil and the coming energy crunch

Intensive animal production (factory farming) is highly dependent on cheap fossil fuel energy, mainly because of the huge quantities of feedstuffs, particularly grains, that it consumes. This fact alone would make it the wrong system for the era of unpredictable, scarce or costly energy supplies that we are now entering.

Oil and natural gas are finite resources and the 20th century has used up the best of them. Between 1930 and 2009 the global production of oil and gas per year increased over 19-fold as populations and economic activity grew over the 20th century.[24] However, between now and 2050 oil and natural gas supplies may fall to approximately half of current levels, according to the Association for the Study of Peak Oil, a network of independent energy experts.[24] Expert discussions held by the National Petroleum Council in the United States heard evidence in 2007 that 28% of existing oil fields were in decline by 2005 and 40% of existing oil fields will be in decline by 2008-2009. United States, Norwegian and UK production is already in decline.[25]

'Peak Oil' is the term used to refer to the point at which the maximum production of oil and natural gas has been reached and the amount that can be produced starts to decrease. Most experts believe that this production peak will happen any time between 2008 and 2040, with the most common estimates being between 2010 and 2020.[24-30] This would mean that after 2010 or 2020 the amount of oil and natural gas available for use will inevitably and continuously decrease. Peak Oil could be followed by a relatively orderly 'descent', but possibly by a 'collapse' in the availability of oil and gas.[26]

Output from existing oilfields is already falling. To compensate for this, new production capacity equal to four times the current production of Saudi Arabia needs to be built by 2030, even without any increase in demand. But global primary energy demand is forecast to increase by 45% between 2006 and 2030 and demand for oil is forecast to increase by 25%.[29] As demand for oil and gas continues to rise over the next decades, there will be a 'supply-crunch' unless massive investment equivalent to US$ 1 trillion a year is made in time.[29]

Almost all energy experts, whether independent or from the oil industry, agree that the era of cheap or 'easy' oil is over.[22] A group of high-profile British companies, the Peak Oil Group, has concluded that we have under 20 years or fewer to respond to the decline in supply, or under 10 years if supplies collapse rapidly.[26] In the UK, this would require a reduction in oil consumption by 46% relative to 2007, coal consumption by 79% and natural gas consumption by 26%.[26]

1.3 A combination of risks

In 2007 the World Bank reported on the world food outlook, and listed three primary risks to the global food system:

- 'High energy prices combined with more biofuels production from food crops could lead to large food crop price increases through effects on both supply and demand';
- 'Global warming could occur faster than expected and add to water shortages, hitting irrigated agriculture with lower yields and increasing risk in rain fed agriculture'; and
- 'Rapid income growth in Asian countries with limited land and water resources could lead to a surge in food imports that, combined with higher energy and fertiliser prices, drive up food prices…Or, all three could happen together.'[31]

In 2007-2008 at least two of these predictions came true. Both peaceful and violent protests over high food and commodity prices occurred in more than 20 mostly low income countries in Asia, Africa and Latin America.[21] A study from the University of Washington, Seattle, and Stanford University in 2009 concluded that there is an over 90% probability that temperatures in the tropics and subtropics by 2100 will be higher than the most extreme temperatures that have occurred up to 2006[32a]. Food crops would be severely affected and by 2100 half the world's population could be short of food.[32b]

The potential for human suffering and social dislocation due to climate change in this century was summarised by the Stern Review in 2006 as follows: 'Millions of people could be compelled to move between countries and regions, to seek new sources of water and food if these fall below critical thresholds. Rising sea levels may force others to move out of low-lying coastal zones… Worldwide, nearly 200 million people today live in coastal flood zones that are at risk; in South Asia alone, the number exceeds 60 million people. In addition, there are potentially between 30 to 200 million people at risk of hunger with temperature rises of 2-3°C – rising to 250 to 550 million people with a 3°C warming; and between 0.7 to 4.4 billion people who will experience growing water shortages with a temperature rise of 2°C.'[33]

2. The 20th-century revolution in livestock production

2.1 Changing diets and the globalisation of industrial livestock production

Since the middle of the 20th century there has been an unprecedented global increase in the number of farmed animals used to produce meat, milk, eggs and, more lately, fish, and in the yield extracted from each animal. Currently around 4.3 billion mammals and 58.4 billion poultry (mainly meat chickens) are used globally to produce the main meats, milks and hens' eggs, according to the United Nations Food and Agriculture Organisation's (FAO) statistics.[10] This represents a doubling of the number of pigs, a 3.5-fold increase in the number of poultry and an increase of 65% in the number of ruminants (cattle, sheep and goats) used for meat compared to 30 years ago. The world average supply of meat per person per year increased between 1961 and 2000 from 23 kg to about 40 kg on average and to about 80 kg a year in developed countries.[34] In China, consumption of meat increased 3.7 times between 1980 and 2003 and milk consumption increased three-fold between 1990 and 2005.[3,35]

The majority (around 85%) of the increase in the number of animals used to produce these huge increases in output took place in developing countries, particularly in large and rapidly developing countries such as China, India and Brazil.[10] In the case of fish farming (aquaculture), Asia and the Pacific region (mainly China) account for nearly 92% of aquaculture tonnage, with double-digit annual growth since the mid-20th century.[36] Diets are changing across the developing world wherever incomes are rising – away from a grain-based diet towards a diet rich in animal protein and animal fat (meat, fish, eggs and milk).

The expansion in terrestrial animal production has come mainly from non-grazing animals (pigs and poultry) that can be kept indoors in huge numbers. Between 1980 and 2004, pigs and poultry accounted for 77% of the increase in production in developing countries and they now account for 70% of all meat.[6,34] The production of pigs and poultry over the last few decades has increased four-fold while the production of cattle, sheep and goats (ruminants) has approximately doubled.[6]

These statistics signal the march of globalised factory farming across the world during the last several decades. Pig and poultry farming in particular can be relatively easily scaled up or integrated into industrial production systems. These are often in the hands of a few large companies that supply inputs such as breeding animals, chicks and feed to small farmers and organise centralised slaughtering and marketing of products.

The appearance of these large companies often results in the disappearance of small farmers who use local breeds of animal. In developing countries, industrial systems are often run in association with multinational food, feed and genetics companies based in Europe and North America. Industrialised systems have taken over, or are currently taking over, from backyard or peasant

Table 1. Increase in number of food animals (excluding fish) used annually in developed and developing countries, over 10 years comparing 1996 and 2006. Source: FAO, 2007[10]

Absolute change in number of animals used in 2006 compared to 1996 for each product

	Human population in 2005	Pigmeat	Chickenmeat	Cattlemeat	Hen eggs	Cow milk
Developed countries	1.21 billion	+10.3 million	+2.1 billion	-22.9 million	+135.4 million	-16.2 million
Developing countries	5.25 billion	+305.8 million	+11.5 billion	+52.8 million	+1.2 billion	+32.9 million

animal keeping, pastoralism or small commercial farmers around the world. Industrial production now accounts for at least 74% of poultrymeat, 55% of pigmeat production, 68% of eggs and 43% of beef globally.[6, 37] The result of this is that the large majority (72%) of the animal feed grown on cropland is fed to pigs and poultry,[34] typically kept in intensive farming systems. The FAO reports that industrial animal production systems have been increasing at six times the rate of traditional mixed farming systems.[38]

2.2 Another livestock revolution?

A second 'livestock revolution' is now predicted in response to globally rising incomes and industrialisation. Agencies such as the World Bank, the UN's Food and Agriculture Organisation (FAO) and the International Water Management Institute expect that meat production will approximately double in the decades up to 2050,[7, 18, 39] reaching between 465 million tonnes and 570 million tonnes annually.[7, 40] World demand for milk could accelerate even faster than demand for meat.[40]

Such a massive scale of animal production, carried out by factory farming, could mean that in 2050 the world has not today's 60 billion but 120 billion livestock to feed, mainly on cereals and soya. This could have devastating consequences for the world's resources of land, water and energy, for biodiversity and for greenhouse gas emissions, as this report will show. It would inevitably have severe consequences for the welfare of the world's farmed animals.

2.3 The animal welfare impact of factory farming

A doubling of meat production up to 2050 would mean a huge increase in factory farming, mainly of pigs and chickens, but also of dairy cows and feedlot beef cattle.

Intensive or industrial animal production is designed to be a high-input, high-output system. In this system the animals are treated as production machines rather than as individual sentient beings with individual needs for physical and psychological wellbeing. Maximising productivity involves encouraging over-fast growth and excessively high yields by selecting for these traits and by feeding the animals with nutrient-dense cereal and soya based concentrate feed.

Antibiotics or other growth promoting treatments or feed additives are often used in many countries to encourage high yield.

Good animal welfare implies that the animal is protected from suffering, hunger, thirst, weather, injury, disease, pain, distress and fear and also that the animal is free from the frustration caused by being unable to carry out the natural behaviour of its species. The objective of 'intensive' animal farming is to maximise the output and cost-effectiveness of each animal, even when this conflicts with the animal's welfare needs.

Intensive animal production conflicts with animal welfare in a number of ways. It is characterised by the use of close confinement (in cages and crates), overcrowded sheds or barren outdoor feedlots. Factory farmed poultry and pigs may never see daylight. Typically, fast-growing or high-producing breeds are used, where the animals are more at risk of often painful production-related disorders. The health problems that are related to intensive breeding and management include high levels of painful lameness and also heart failure in fast-growing meat chickens, lameness and mastitis in high-yielding dairy cows, and lameness and heart disease in pigs bred for fast growth and large muscles. Laying hens suffer from brittle bones due to calcium deficiency because of their very high output of eggs.[41, 42a-g]

Factory farmed animals that are crowded indoors in barren sheds are unable to perform many of their natural behaviours, such as nest-building, foraging for food, exploration of the environment or taking normal amounts of exercise. Hens in battery cages cannot stretch their wings, sows in gestation crates and farrowing crates and calves in veal crates are not even able to turn round. Instead, animals develop a number of abnormal and often injurious behaviours, which are the result of boredom, frustration and social stress; these include feather-pecking and body-pecking, cannibalism, tail-biting, vulva-biting, bar-biting, air-chewing, belly-nosing, fighting, mounting and harassing other animals who are unable to move away as they would do in natural conditions. In an attempt to minimise injuries, hens have part of their beaks cut off and a large proportion of all piglets have their tails cut off and their teeth clipped, all usually without pain relief.

Intensive animal production systems can be characterised as having a low welfare potential. This is because these systems fail to meet the behavioural and physical needs of the animal and because they have the potential to cause pain or suffering. The classic example of a farming system with low welfare potential is the barren battery cage for egg laying hens, still the commonest system for keeping commercial hens worldwide. The cramped and barren cage denies many of the hen's physical and behavioural needs, causing her to suffer as a result. The restrictive nature of the cage is an inherent part of the system. The battery cage is, therefore, a system with low welfare potential. Even if the attention given to the hens is good in terms of preventing infection, maintaining hygiene and providing food and water, their welfare is likely to remain poor.

If the world were to attempt to double meat and milk production in the next 40 years, billions more animals would be subjected to these factory farming methods.

2.3.1 Loss of farm animal genetic diversity

The huge increase in factory farming that would be necessary in order to double the current level of livestock production is a threat to the genetic diversity of farmed animals globally. As intensive production systems spread rapidly, the multiplicity of local, regional and traditional livestock breeds in developing countries are already being replaced by what the FAO terms 'a narrow range of breeds…that are most profitably utilised in industrial production systems.'[43] This is bad for the welfare of both the animals and their owners.

The International Livestock Research Institute (ILRI) has warned of the dangers of replacing traditional low-input breeds of animal in developing countries by supposedly higher-yielding breeds imported from industrial countries. High-yielding farm animals were usually developed for use in temperate climates and in relatively high-input systems, whereas native breeds in developing countries are adapted to cope with the local conditions of heat, drought, disease and parasites (such as ticks) and lower quality feed. These conditions can increase the risks of production failure and can cause severe suffering to animal breeds that are not well adapted to survive them. ILRI gave an example of Ugandan farmers who had switched from indigenous Ankole cattle to higher-yielding Western cows, then lost nearly all the cows during a drought when the animals were not robust enough to walk long distances to water.[43, 44] Studies in South Africa have shown that cattle from imported Western breeds lose 15% of their weight when they have no water for 24 hours, whereas the weight of local cattle is hardly affected.[45]

The uniform, highly-selected commercial strains of livestock have a low genetic diversity, even though there may be millions or billions of such individuals globally. Research by a team of American, Chinese, Canadian and Dutch scientists published in 2008 showed that strains of commercial chicken have lost on average half the genes that used to be present in the chicken species as a whole (some strains have lost 90% of their ancestral genes)[46a]. Animal scientists believe it is important to continue farming the less commercial and indigenous breeds as these may be carrying essential genes associated with resistance to disease or to changing environmental conditions.[46b]

2.3.2 Selective breeding and animal health

The drive to high production has meant that commercial farm animals such as very fast-growing meat chickens and high-yielding dairy cows have been genetically selected for high yield rather than for good health. There is abundant scientific evidence that highly selected animals are more likely to suffer from ill health than more robust traditional breeds[47] and because genetic diversity has been reduced by extreme selection and inbreeding, there is less natural variation between the animals in their ability to resist disease.

Studies of dairy cows have shown that inbreeding is linked to increased risk of mastitis, reduced fertility, shorter productive lifetime and an increased risk of having stillborn calves.[48] Experiments have found that chickens from commercial strains selected for rapid growth are less able to withstand infections than chickens from more traditional and slower-growing breeds and consequently that 'rapid growth rate substantially reduces broiler [chicken] viability'.[49]

2.3.3 Cloning and genetic engineering of farm animals

An attempt to double animal production up to 2050, and the intensification that would go along with it, make it increasingly likely that animal breeders will turn to genetic engineering and cloning in order to produce ever higher-yielding farm animals. Already both the United States Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA) have given their opinion that food from healthy clones or their offspring is as safe to eat as non-cloned products.[50, 51] The United States Food and Drug Administration has gone so far as to issue regulatory guidelines for industry on the commercialisation of genetically engineered animals.[52]

One of the main aims of genetic engineering experiments on farm animal species over more than 20 years has been to increase the animals' rate of growth. Pigs, salmon, sheep and other animals have been genetically engineered with extra growth hormone genes in numerous experiments, the new genes sometimes taken from another species. Currently breeders are aiming to replicate particular animals that are already known to be well above average in productivity, for example high-yielding Holstein dairy cows. The offspring of such clones have been sold both in the United States and to the UK.[53]

Even those who believe that genetic engineering and cloning are a good approach to increasing food production from animals concede that the animal suffering caused so far has been considerable.[54a] While some cloned and genetically modified (GM) animals are born, grow up and breed without health problems, cloning and genetic engineering typically create considerably more health and welfare problems than does normal reproduction. Pigs, sheep and salmon engineered with growth hormone genes have been born with gross skeletal deformities and enlarged organs.[54b] A large proportion (often 50%) of cloned offspring die shortly before or after birth, often due to their inability to breathe due to poorly developed heart and lungs or immune system. A greater proportion require caesarean section and there is a higher than normal death rate of the surrogate mother animals compared to normal reproduction. Problems include the large number of adult animals used in order to produce relatively few live and healthy clones (or GM animals), the physical defects and ill health of clones (and GM animals) and the welfare risks associated with the genetic changes made to GM animals (for example excessive muscle or skeletal growth).[55]

EFSA's official opinion in 2008 confirmed that cloning leads to additional health and welfare problems compared to normal reproduction. EFSA stated that 'Mortality and morbidity of clones are higher than in sexually produced animals' and that 'The health and welfare of a significant proportion of clones has been found to be adversely affected.'[50] The United States FDA also confirmed increased health problems in cloning. The FDA concluded that the success rate 'is very low' and animals are 'at increased risk of adverse health outcomes.'[56]

The European Group on Ethics (EGE) reported to the European Commission in January 2008: 'Considering the current level of suffering and health problems of surrogate dams and animal clones, the Group has doubts as to whether cloning for food is justified.
At present, the EGE does not see convincing arguments to justify the production of food from clones and their offspring.'[57]

From the point of view of both animal welfare and human welfare, the use of genetically engineered and cloned farm animals cannot be justified. It has no useful role in providing the world with a sustainable food system. It is banned in organic farming. Even the few genetic engineering experiments that aim to reduce animal disease are much less likely to be effective than the use of normal cross-breeding, the use of good husbandry methods and appropriate veterinary advice.

3. Climate change: livestock's impact on greenhouse gas (GHG) emissions

From a global perspective, livestock production is now known to be a major contributor to climate change. The FAO estimates that livestock contribute 18% of the total human-induced (anthropogenic) greenhouse gas emissions. Globally, this is higher than the share of all transport (14%), including road, rail, air and shipping.[6, 58]

The livestock sector is responsible for significant proportions of several greenhouse gas (GHG) emissions: 37% of total methane (CH_4) emissions, 65% of total nitrous oxide (N_2O) emissions and 9% of total carbon dioxide (CO_2) emissions. In addition, 64% of ammonia emissions originate in livestock production and contribute to air, soil and water pollution, acid rain and damage to the ozone layer.[6]

A large proportion of these livestock-related GHG emissions are a result of the natural biological requirements of the animals themselves, i.e. feeding, digesting and excreting.

3.1 GHG emissions from animal production

Globally, the most important individual contributions to livestock-related GHGs are deforestation (34% of total) followed by CH_4 from enteric fermentation and manure-related N_2O (each around 25% of total).[6] It is notable that livestock manure and enteric fermentation alone account for 10% of all anthropogenic GHG emissions,[6] five times the proportion of global emissions due to air transport.[58]

In developed countries, emissions of carbon dioxide (as opposed to methane and nitrous oxide) from livestock production are relatively higher than in developing countries, because more energy is used in industrialised farming.

A large proportion of emissions from animal production in developed countries are of methane and nitrous oxide and come from enteric fermentation, manure and fertilisers used for feed production. Therefore it is clear that the most rapid reductions in GHG emissions in the livestock sector in developed countries, such as those of the EU, would be achieved by reducing the scale of livestock production.

3.2 Deforestation for soybean plantations

There is a clear link between the production of factory farmed meat and other animal food products and the destruction of the world's rainforests. Deforestation is responsible for 75% of Brazil's total GHG emissions.[59] Factory farming is one of the main drivers behind the destruction of the Amazon rainforest and the savannah lands of South America. Forests and savannahs are being cleared and ploughed up for soya plantations to provide livestock feed for the intensive farms of rich countries. In response to demand for animal feed, world soybean production has tripled since the mid-1980s.[60] The steep rise in world prices of soya and other grains since 2007 has led to an acceleration in the rate of deforestation in

Globally, the major causes of livestock-related GHGs are:

- Animal manure that is deposited in fields or in animal housing by the animals, stored on farm and then disposed of by being spread on fields or pastureland. Manure releases both methane (CH_4) and nitrous oxide (N_2O). All manure-related emissions account for 30% of livestock-related emissions and over 5% of total anthropogenic GHGs.[6]
- The digestive processes of the animals, particularly ruminants such as cattle, sheep and goats. The 'enteric fermentation' process by which ruminant animals digest fibrous feed releases large amounts of methane (CH_4). Enteric fermentation emissions account for about 25% of livestock-related emissions and about 4.5% of all anthropogenic GHG emissions.[6]
- The production of animal feed (crops and grassland). Around one-third of the world's total cereal crop and over 90% of the world's soya crop is used for animal feed. Feed crops require the use of land, fertilisers, machinery and transport. Carbon dioxide and nitrous oxide are emitted during the manufacture of mineral (N) fertiliser and nitrous oxide is emitted from mineral fertiliser used on land. The manufacture and use of fertiliser for producing animal feed accounts for over 6% of all livestock-related GHG emissions.[6] (Fertiliser and pesticide manufacture also uses large amounts of costly fossil fuels, as discussed later in this report.)
- Deforestation for cattle grazing and/or for the production of soybeans or cereals for animal feed (mainly in South America). Deforestation releases large amounts of CO_2 previously stored in vegetation and soil. Deforestation for animal production accounts for 34% of all livestock-related GHG emissions and over 6% of all human-induced GHG emissions.[6]

the Amazon region.[61] Under a 'business as usual' scenario, WWF expects soya expansion to result in the loss of 16 million hectares of savannah and six million hectares of tropical forest by 2020.[62]

Imports of soya to the EU27 countries account for a large proportion of the total soya production in South America. According to Greenpeace in 2006, Europe buys half of the soya exported from the Brazilian Amazon state of Mato Grosso, where 90% of rainforest soya is grown.[59] The EU takes 32% of total soya production of Brazil, 25% of total soya production of Argentina and 17% of total soya production of Paraguay. Brazil and Argentina are the second and third largest suppliers of soya imports to the EU27, after the United States, supplying annually around 59 million tonnes and 49 million tonnes respectively.[63]

The CO_2 emissions from deforestation and lost carbon storage in ploughed up areas of forests and savannahs may be 'very significant' contributions to the total carbon footprint of animal products, according to the Food Climate Research Network.[64] Compassion in World Farming believes that these indirect CO_2 emissions need to be quantified accurately as part of the total livestock-related GHGs emitted from the UK and Europe. If these emissions were properly included in the carbon footprint of the countries that import the soya as livestock feed, factory farming in developed countries might look even less climate-friendly.

3.3 Climate impact of doubling meat production

The predicted global doubling of animal production by 2050 would lead to a massive increase in livestock-related GHG emissions in the next decades, even allowing for increases in energy efficiency and other mitigation measures. These emissions would increase the likelihood that the world will fail to limit the global temperature rise to 2ºC, necessary to prevent dangerous climate change.

The expected increases in methane and nitrous oxide emissions have been set out by the IPCC and the United States Environmental Protection Agency. The EPA considered that: 'The key factors influencing both methane and nitrous oxide emissions in this category [from storage and disposal of manure] are expected to be the growth in livestock populations necessary to meet the expected worldwide demand for dairy and meat products and the trend toward larger, more commercialised livestock management operations.'[65]

If methane emissions grow in proportion to animal numbers, livestock-related methane production from enteric fermentation and slurry is expected to increase by 60% to 2030.[66] Agricultural N_2O emissions are projected to increase by up to 35-60% by 2030 due to increased manure production by the animals and increased nitrogen (N) fertiliser use, much of it used to grow animal feed.[66] Currently in most developed countries, over 50% of N fertiliser is used for feed crops (as a world average the proportion is estimated at 25-40%).[34, 67]

Some developing regions will have very high increases in emissions: East Asia, including China and India, is predicted to increase methane emissions from enteric fermentation by 153% and from manure slurry by 86% by 2020 relative to 1990.[66] Africa, Latin America (mainly Brazil and Argentina) and the Middle East are predicted to increase nitrous oxide emissions from soil (due to animal manure and use of synthetic fertiliser) by over 100%.[65] Demand for high-quality grain for feed crops for 'advanced' livestock operations will be a significant reason for the predicted increase in the use of synthetic fertiliser.[65] Emissions from North America are also expected to increase by nearly one-fifth between 1990 and 2020, mainly due to manure from poultry, pigs and cattle.[66]

3.4 The reductions needed in livestock-related GHG emissions

These large increases in livestock-related emissions are expected at the very time that the world is attempting to cut GHG emissions urgently. With the aim of limiting the temperature rise to 2ºC within this century, the EU Heads of Government agreed a European target of reducing 'overall emissions' by 20–30% compared to 1990 levels by 2020.[68] In 2008 the UK agreed that cuts of 42% relative to 1990 should be made by 2020 (31% relative to 2005). Until a global agreement can be reached, the target cuts for 2020 are lower (34% relative to 1990 or 21% relative to 2005).[69, 70] By the end of 2009 there is likely to be a global agreement on GHG reductions similar to those agreed in the EU and the UK.

Importantly, the UK targets apply to all sectors of the economy and apply to emissions of methane and nitrous oxide as well as carbon dioxide.[69, 70] This means that the livestock sector is included in the 2020 and 2050 reduction targets.

At a time when the world has recognised that we have a climate crisis, a continuing increase in global livestock-related emissions cannot be allowed to happen. The very large increases in GHG emissions expected in developing regions are unlikely to be easily controlled. This makes it all the more essential that developed countries take urgent steps to scale down their intensive livestock industries in order to reduce the global total of livestock-related GHG emissions.

4. Diet and greenhouse gas emissions

Our choice of diet has important implications for climate change. The production of animal-based foods nearly always generates more GHG emissions than the production of plant-based foods. According to the University of Surrey's Food Climate Research Network, 'meat and dairy products are by far and away the most GHG-intensive foods'.[71]

The European Commission is also aware of the link between meat and GHG emissions. The Commission's Climate Change Campaign website for consumers recommended in their 2008 Climate Protection Calendar: 'Consider decreasing your meat consumption. Producing meat is both CO_2 and CH_4 intensive and requires large amounts of water.'[72] Meat requires higher inputs of fossil fuel energy than plant-based foods and is much less energy efficient (see Section 6.4).

It is estimated by the Food Climate Research Network that the emissions due to meat and dairy production and consumption account for around 8% of total anthropogenic GHG emissions in the UK, although this is likely to be higher if emissions from land-use change are taken into account.[64, 73] The large majority of these emissions are related to production on-farm, rather than to transport, processing, storage or distribution after the animals leave the farm. Meat and dairy production and consumption account for about 13.5% of total EU25 emissions, according to the European Commission's 2006 Environmental Impacts of Products (EIPRO) assessment and around half of all food-related emissions.[73, 74] In the Netherlands it has been calculated similarly that meat, fish and dairy products contribute just over half of the total GHG emissions from food (Table 2).[75]

Studies of particular food items and diets from different countries have confirmed that a diet high in meat has a high global warming potential, compared to a diet high in plant-based products. In Sweden, a locally produced vegetarian meal produced only one-ninth the level of greenhouse gas emissions compared with a meal that contained pork and an imported food item. The 'domestic' vegetarian meal produced the lowest level of GHG emissions for the highest level of nutrients (protein, calories and beta-carotene).[76a-b]

The average American diet is high in meat. A study at the University of Chicago concluded that the differences in energy efficiency between the average American diet and an entirely plant-based diet, with the same

Table 2. Contribution of different foods to total Dutch food-related GHG emissions.
Source: Kramer *et al.*, 1999[75] and Garnett, 2007[64, 73]

Food group	Proportion of total food-related GHG emissions (%)
Meat, meat products and fish	28.2
Dairy products	22.9
Beverages and products containing sugar	14.9
Potatoes, fruit and vegetables	14.6
Bread, pastry and flour	13.3
Oils and fats	3
Other foods	3

protein and calorific content, are equivalent to emissions of 701 kg CO_2 per person per year. This means that a diet high in meat is equivalent to roughly one-third of the annual GHG costs of a person's use of a standard car for personal transportation.[77] Overall the researchers found that increasing the proportion of animal-products in the diet decreases the energy efficiency of the diet and increases the methane and nitrous oxide emissions from its production.[77]

A 2008 calculation published in the *New York Times* estimated the fossil fuel inputs needed to produce 170 g (6 ounces) of beef steak to be 16 times greater than the fossil fuel inputs needed to produce a meal consisting of vegetables and rice. The GHG emissions to produce the meat were 25 times as much as to produce the vegetables and rice.[78]

These facts have implications for governmental GHG reduction strategies and targets and for the choices made by any individual consumer in order to reduce his or her carbon footprint. Diets high in animal products increase GHG emissions and increase an individual's carbon footprint. Diets high in plant products save fossil fuel energy and reduce an individual's carbon footprint.

5. Climate mitigation strategies and animal welfare

Various methods have been suggested by policymakers for reducing the greenhouse gases emitted from livestock production. A number of these, such as reforestation, prevention of deforestation, better land-tilling practices, better storage and disposal of manure and use of renewable energy sources, are obviously essential, although it is doubtful if they alone could make sufficiently large cuts in emissions in the short time span that is needed.

Certain other methods that have been suggested could have serious animal welfare implications and are not acceptable on animal welfare grounds. Compassion in World Farming believes that no mitigation measures that involve interventions at the level of animal management or breeding should be considered before they have been thoroughly screened for their impact on animal health and welfare. Climate scientists may well be unaware that some of the measures they propose could damage welfare.

5.1 Manipulating the animals' digestion

To try to reduce the amount of methane produced by the digestive processes of cattle and sheep, some have proposed feeding cattle a high concentrate diet that is lower in fibre and higher in grains, as well as various chemical interventions such as feed additives (propionate precursors) that make the cows' guts emit hydrogen rather than methane, antibiotic growth promoters (such as ionophores, currently banned in the EU) or even vaccination to reduce methane production in the gut and the excretion of nitrogen and phosphate in manure.[79] Some of these interventions could alter the animals' feed or their digestive systems in ways that cause discomfort, pain or ill-health.

Chemical treatments and high-concentrate feedstuffs are unlikely to be affordable for small farmers globally and they have clear disadvantages for animal welfare. High-concentrate feed is inappropriate for ruminant animals whose digestive systems are designed for fibrous food. Feeding cattle excessive levels of concentrates is known to cause discomfort, inflammation[80] or in severe cases acidosis leading to lameness and other disorders. For this reason, organic farming cattle standards require that at least 60% of the dry matter in cattle diet is in the form of fibrous foods (such as grass and silage).[81]

Even if these manipulations were acceptable on animal welfare grounds, they would be unlikely to make sufficiently large cuts in emissions to offset the possible doubling of animal production predicted up to 2050. According to a 2007 assessment by an international group of scientists, 'Available technologies for reduction of emissions from livestock production, applied universally at realistic costs, would reduce non-carbon dioxide emissions by less than 20%.'[9]

5.2 Intensification

A second approach advocated by some agricultural policymakers and farm animal geneticists has been to expand and increase the intensification of animal production. The proposed intensification would be done by selectively breeding animals for higher output (which might include genetic engineering or cloning) and by more intensive management. It would aim to increase the output per individual animal and thus reduce the GHG emissions per kilogramme of product (kg of meat, litre of milk).

For example, the Scottish Agricultural College believes that the milk yield of dairy cows in the UK could be increased by 30% by 2022, as part of a climate change mitigation strategy.[79] The suggestion has even been made that more dairy cows should be injected with the growth hormone BST (bovine somatotrophin) to increase milk production.[79, 82] BST has been banned in the EU because of its risks to animal welfare, although it is quite commonly used in United States dairy production.

Intensification would be a serious threat to animal welfare. In many cases intensively bred and managed animals are already worked at the limit of their physical capacity. The European Food Safety Authority's 2009 opinion on the overall effects of farming systems on dairy cow welfare and disease concludes that: 'Long term genetic selection for high milk yield is the major factor causing poor welfare, in particular health problems, in dairy cows'.[207] Additional production pressures would be likely to result in even more breakdowns in their health and hence reduce their output or their working lifetimes. High milk-yielding Holstein dairy cows typically last for only three complete lactations,[83] and often fewer, before they are culled due to ill health or productive failure.

Meat chickens are often claimed to be the most 'efficient' animals used for meat production. An extensive survey by Bristol University scientists of commercial meat chickens found that nearly 30% of the chickens were suffering from painful lameness before they were six weeks old.[41] The primary reason for this very high level of leg disorders is that factory farmed meat chickens are bred and fed to grow excessively fast in order to get to slaughter weight in the shortest possible time. Their skeletal development cannot keep up with the excessive daily increase in their body weight. For this reason, the 'Freedom Food' welfare assurance standard for meat chickens explicitly puts a limit on daily weight gain and legal standards for free-range and organic meat chickens specify a minimum age for slaughter that is up to twice the age for factory farmed chickens, so that the chickens have to be grown more slowly.[84a-c]

Intensification of animal production has a negative impact on the environment (increased use of resources for cereal and soya feed production, increased use of synthetic fertiliser, pollution from manure). It also has a negative impact on small farmers through increased costs of feed and the likelihood of being out-competed or controlled by large food and feed companies that operate on an industrial scale.

Nearly all the climate change mitigation methods put forward by the proponents of intensive livestock production have serious side effects, either for the animals, for the environment, for rural livelihoods, or for all of these. The quickest and most effective method of reducing livestock-related GHG emissions in developed countries is to reduce the consumption of factory farmed products and scale down the livestock industry.

Sections of the animal production industry agree that reducing the number of animals that are used is an effective way to cut GHG emissions, but at the same time they recommend intensification to extract a higher output from each animal so that the industry's total output remains the same, from fewer animals.[79] This strategy is a recipe for animal suffering, dressed up as a 'green' solution to climate change. A much better strategy is to reduce our consumption and production of animal-based foods, allowing farmers to keep fewer animals in more extensive and welfare-friendly conditions, without pushing the animals to their physiological limits or beyond.

6. Climate change and global resources: The inefficiency of factory farming

At a time of rising population and changing climate, intensive animal farming is a wasteful way of trying to feed the world. Factory farming consumes high levels of resources, but consumes them very inefficiently. The factory farm route to feeding the world would not only add an enormous burden of animal suffering but would be counterproductive to the aim of using scarce natural resources efficiently and sustainably.

Factory farming depends on converting good quality plant food into the meat, milk and eggs of animals. The plant food is produced using resources of arable land, water and energy. It would usually be much more efficient to use these resources to produce grains, pulses and vegetables for direct consumption by people. On average, to produce 1 kg of high quality animal protein for consumption, livestock are fed nearly 6 kg of plant protein.[5]

The Earth Policy Institute has estimated that if the whole world population consumed meat at the current level of Italy (about 80% of the consumption in the United States), current world grain supplies would be adequate to feed five billion people (compared to the current 6.7 billion population). At the United States, level of use of grain per person per year of 800 kg, the current world harvest would feed only 2.5 billion people. In the United States, only 100 kg of the 800 kg total is eaten directly as cereal products (such as bread) and the rest is consumed indirectly as livestock products. With a diet more similar to the average person in India, where most grain is consumed directly by people, the world could feed 10 billion people,[85] even more than the nine billion expected to be alive in 2050.[86]

Intensively produced animal products do not deliver a good return on the inputs of natural resources we use to produce them. This is true whether we consider the quantity of crops fed to the animals, the quantity of land used to grow the crops, the food energy provided by the crops compared to the food energy provided by animal products, or amount of water needed to produce the food energy from animal products. The following section considers these inefficiencies in turn.

6.1 Feed crop efficiency

According to the FAO and the International Water Management Institute, an estimated 33-40% of the world's entire cereal harvest is used as livestock feed,[6, 7] and that proportion is typically around 70% in rich developed countries.[7]

Every one kilogramme of meat produced requires an input of several kilogrammes of animal feed. Even when the animals are bred, fed and managed to grow the most rapidly and to be the most efficient converters of feed into flesh, animal production is inefficient.

According to the United States Department of Agriculture (USDA) it takes up to 2.6 kg of feed to produce 1 kg of chickenmeat, 6.5 kg of feed to produce 1 kg of pigmeat and 7 kg of feed to produce 1 kg of beef, using typical intensive animal rearing methods.[87] In reality, the conversion of feed to edible meat is even more wasteful than this.

The usual feed conversion calculations used by the livestock industry are either based on the weight of the live animal or of the animal's carcass. However, animals contain a considerable weight of material that is not normally eaten, such as bone and hide. According to calculations from the University of Manitoba in the United States, if we consider the amount of feed required to produce 1 kg of genuinely edible meat, the amount of feed required nearly triples for beef and increases by 80% for chickenmeat. It turns out that producing 1 kg of edible meat in the United States by industrial methods requires 20 kg of feed for beef, 7.3 kg of feed for pigmeat and 4.5 kg of feed for chickenmeat (Table 3).[1]

Table 3. The feed inefficiency of factory farming. Source: Smil, 2000.[1]

Product	Feed input required to produce 1 kg of edible product (kg)
Beef	20
Pigmeat	7.3
Chickenmeat	4.5
Eggs	2.8
Milk (liquid)	1.1

Meat contains a large proportion of water. If we consider the typical water content of meat (around 65-70% water[88]) and of feed grains (14-19% water[89]), the amount of feed grain required per kilogramme of meat turns out to be even greater. Considering only the dry content, we can estimate that 1 kg of raw edible pigmeat requires at least 18 kg of grain and 1 kg of raw edible chickenmeat requires at least 11 kg of grain.

6.2 Land efficiency

One-third of the world's entire cropland is used for growing animal feed. This does not include pasture land, which takes up around 26% of the world's land area.[6] Because every kilogramme of factory farmed meat requires land for growing several kilogrammes of feed crops, factory farming is a wasteful use of land.

Very much more land is needed to produce 1 kg of intensively-produced animal-based food than to produce 1 kg of cereals, vegetables or fruit. Calculations made in the Netherlands, a country that uses significant intensive farming, have shown that 1 kg of beef requires 15 times as much land as the production of 1 kg of cereals and 70 times as much land as the production of 1 kg of vegetables. The production of 1 kg of pigmeat uses over six times as much land as 1 kg of cereals and 30 times as much land as 1 kg of vegetables (Table 4).[90]

6.3 Water efficiency

Food crops typically require quite large quantities of water to grow. Agriculture as a whole accounts for around 86% of all human use of water, including both rainwater in soil and irrigation water.[2] Animal feed consumes a significant proportion of that water.

In the Netherlands, a typical industrial country, livestock account for 46% of all water use related to the consumption of agricultural products (including food, cotton, tobacco and other products).[91a] Globally, livestock production accounts for around 23% of all the water used in agriculture, according to calculations by WWF, including both the rainwater in soil and the freshwater used for irrigation.[91b] Irrigation of livestock feed consumes about 15% of all irrigation water,[92] often a very scarce resource. The world's use of water for livestock production is equivalent to 1150 litres of water per person per day.[91b] This is more than 20 times what is considered the basic minimum of water that an individual requires daily for personal use, or about eight times the daily average household use of water per person in the UK.[93]

Table 4. Area of land required in a typical industrial country (The Netherlands) to produce 1 kg of either animal products or staple plant products. Source: Gerbens-Leenes and Nonhebel, 2005.[90]

Product	Land area required per kg of product in the Netherlands (square metres per year)
Animal products	
Beef	20.9
Pigmeat	8.9
Chickenmeat (fillet)	7.3
Butter	13.8
Cheese	10.2
Eggs	3.5
Plant products	
Cereals	1.4
Potatoes	0.2
Vegetables (average)	0.3
Fruits (average)	0.5

Intensive animal production is an inefficient use of water. The large majority of all the water used in livestock production is used to produce animal feed (90% in the case of beef production[2]). Because each kilogramme of animal product requires several kilogrammes of feed crops, much more water is consumed by animal products than is consumed by an equal quantity of staple plant foods. For this reason, livestock products typically have a very large 'water footprint' compared to plant foods.

Water management scientists have quantified the water needed to produce 1 kg of a number of products across a number of countries. The production of just one kilogramme of beef, as a global average, consumes nearly 15500 litres of water.[2] Depending on growing and rearing conditions, 1 kg of meat can take up to 20000 litres of water to produce.[7] The quantities of water needed to produce 1 kg of chickenmeat and 1 kg of pigmeat are 3900 litres per kg and 4900 litres per kg respectively, as a global average. This compares with around 900 litres of water per kg of maize and 1300 litres per kg of wheat.[2]

Whether we look at the world average or the more technologically efficient production in the United States, grains have a smaller water footprint than meat and are therefore the more efficient choice for feeding people. The plant product that has the highest water footprint is soybean, over 90% of which is grown primarily for feed for intensively farmed animals.

As a world average, the quantity of water required to produce 1 kg of beef is nearly 12 times the quantity needed to produce 1 kg of wheat. In the United States, 1 kg of beef consumes nearly 16 times the quantity of water needed to produce 1 kg of wheat.[2] The quantity of water used to produce 1 kg of beef in California is equivalent to nearly three-quarters of the annual recommended basic requirement for an individual's domestic water use (drinking, food preparation and hygiene) of 50 litres per person per day.[3] Table 5 shows the 'virtual water' content of selected food products. This is defined as the volume of water required to produce any given commodity.

'Water productivity' (or 'water efficiency') indicates the quantity of food calories

Table 5. **Water used to produce selected products: 'virtual' water content.**
Source: Hoekstra and Chapagain 2007, Table 1[2]

	Virtual water content of product (litres of water used to produce 1 kg of product)		
Product	World average	USA (industrial)	China
Livestock products			
Beef (boneless)	15497	13193	12560
Pigmeat	4856	3946	2211
Sheepmeat	6143	5977	5202
Chickenmeat	3918	2389	3652
Leather (from cattle)	16656	14191	13513
Eggs	3340	1510	3550
Milk (powder, i.e. solids)	4602	3234	4648
Plant products			
Rice (paddy)	2291	1275	1321
Wheat	1334	849	690
Maize (corn)	909	489	801
Soy beans	1789	1869	2617
Barley	1388	702	848

produced per unit of water used in production. Studies have found that the water productivity of meat is very low compared to that of plant crops. For the use of one cubic metre of water, plant crops provide several times more food calories.

According to the International Water Management Institute in 2007, lentils and wheat produce up to 17 and 19 times more food calories respectively per cubic metre of water used, compared to beef. Maize (corn) and rice produce up to 33 and 10 times more food calories respectively per cubic metre of water, compared to beef.[94] Lentils and wheat produce up to five times the quantity of edible protein per cubic metre of water used, compared to beef.[94]

In China, wheat produces nearly 3000 kcal of food energy per cubic metre of water used in production. Pigmeat produces only 785 kcal of food energy per cubic metre of water used in production. This makes wheat over three times more efficient in producing food energy than pigmeat in China, per unit of water used in production (Table 6).[3]

One of the world's most prominent experts on the world's food supply has concluded that 'overwhelmingly vegetarian' diets can be produced using only 900 – 1200 cubic metres (m^3) of water per person per year. This is to be compared with twice as much water (well over 2000 m^3) per person per year to produce the meat-based diet typical of rich countries.[1] Up to 90% of the water that an individual uses (his or her 'water footprint') is used to produce food. Calculations have shown that reducing the proportion of animal-based food and increasing the proportion of plant-based food in the diet can almost halve an individual's water footprint.[3]

6.4 Fuel energy efficiency

Factory farming requires large inputs of fossil fuel energy, in particular for the manufacture of synthetic fertiliser and pesticide to grow feed crops. As international concern about the use of fossil fuel energy increases, several studies have shown that factory farmed food is an inefficient use of the energy that is used in its production.

Studies at Cornell University have shown that it takes 40 kcal of fossil fuel energy to produce 1 kcal of food energy from beef. Pigmeat requires 14 kcal of fossil fuel energy input to get out 1 kcal of food energy. Even factory farmed chickenmeat, claimed to be the most energy-efficient type of meat, requires 4 kcals of fossil fuel energy input to get out 1 kcal of food energy[95] – which is not 'efficient' by any normal standard. Beef produced in an intensive feedlot requires twice as much energy input as beef produced from cattle raised entirely on grass (Table 7).[95]

Table 6. Comparative efficiency of water to produce food energy in China for selected products. Source: Liu & Saveniji, 2008, Table1[3]

Product	Food energy efficiency of water use (kcal of food energy produced per cubic metre of water used)
Plant foods	
Rice	2770
Wheat	2701
Maize (corn)	3403
Soy beans	1035
Livestock foods	
Beef	161
Pigmeat	785
Chickenmeat	715
Eggs	410
Milk	670

Table 7. Energy inputs per unit output of animal product, from industrial production methods in the United States. Source: Pimentel, 2006[95]

	Fossil fuel energy input required to produce 1 kcal of food energy output from product (kcal)
Beef	[1] 40
Pigmeat	14
Chickenmeat	4
Milk (liquid)	14
Eggs	39
Turkeys	10

[1]. Feedlot-produced beef compared with energy input for grass-fed beef, which is 20 kcal energy input to produce 1 kcal of food energy.[95]

Calculations on a wide range of foods in Sweden showed large differences between the inputs of energy (usually fossil fuel energy) needed to produce portions of different food items. Portions of meat and animal products are nearly always more energy demanding than plant-based products such as pulses, grains, pasta, vegetables and fruit. The highest energy input is required by portions of beef, cod and farmed salmon. The energy input for a portion of domestically produced cooked pork is over three times the energy input for imported cooked soya beans and 5.5 times the energy input for domestically grown cooked potatoes.[96] Soya is a significant component of commercial pig feed, illustrating the inefficiency of our animal food system. The energy input for a portion of beef is nearly 10 times that for a portion of potatoes (both cooked).[96]

Research from the University of Chicago has looked at the energy efficiency of various diets (that is, the amount of food energy the diet provides per unit of energy to produce it). The results showed that in the United States the energy efficiency of vegetable foods is very much greater than the energy efficiency of animal products; for example, soya is 65 times as energy efficient as grain-fed beef and 73 times as energy efficient as farmed salmon, per unit of food energy (calories) consumed.[77]

Reducing the proportion of intensively produced meat and milk in an individual's diet can significantly reduce that person's fossil fuel energy footprint. In the United States, half the total energy input to an individual's diet goes to produce the animal products in the diet, while only 20% of the total energy input goes to produce the part of the diet that consists of staples such as rice, potatoes and vegetables.[5] Scientists from Cornell University have calculated that to reduce the energy use in the United States food system by half, one necessary action would be a 50% reduction in meat and fish consumption and a 40% reduction in milk consumption.[5]

6.5 Food energy efficiency

Intensive animal production is an inefficient use of the food energy produced by the world's crop harvest. Animal feed takes a large proportion of all the food energy produced by the world's total harvest, and does not deliver an equal amount of food energy back in the form of meat, milk and eggs.

The world's total edible crop harvest, before post-harvest losses, could supply 4600 kcal per person per day.[1, 7] As Table 8 shows, livestock production consumes food energy equivalent to 1700 kcal per person per day and the resultant meat and dairy products yield only 500 kcal per person per day.[1, 7]

Thus livestock feed consumes nearly 43% of the world's food energy that is available after post-harvest losses and animal products return only 29% of the food energy taken out of the world supply by livestock feed.[1, 7]

Table 8. Losses in the world's food energy supply from feed conversion and waste at different stages of production. Source: SIWI, 2008[1, 7]

Stage of production	Energy losses, conversions and wastage (kcal/capita/day)
World edible crop harvest	+4600
Minus: Post-harvest losses	-600
Minus: Animal feed	-1700
Meat and dairy products	+500
Total before distribution	2800
Minus: Food wasted	-800
Net available for consumption	2000

7. Food production at a time of climate change

7.1 Land demand and availability

Over the next decades there will be a global shortage of good agricultural land because of population pressure and the effects of climate change. Food and agriculture experts predict that 5 million km² of additional land will be needed for agricultural expansion in the next few decades.[19, 20] At least an additional 2 million km² will be needed for food production alone by 2030.[19] This is without taking into account the strong likelihood of falling crop yields and loss of arable land due to climate-related temperature rise, drought and flooding.

According to the agricultural scientists of the International Assessment of Agricultural Science and Technology for Development (IAASTD) in 2008, 'Rapid growth in demand for meat and milk is projected to increase competition for land with crop production and to put pressure on the price for maize and other grains and meals'.[4] A further expansion of factory farming is almost guaranteed to make these pressures worse.

The World Bank has concluded that the global production of cereals needs to increase by 50% by 2030[17] to meet the expected increase in the human and the livestock population of the world, as meat consumption continues to grow. The FAO predicts we need an additional one billion tonnes of cereals in 2050 compared to production in 2005.[40] Cereal production already takes up 700 million hectares.[97] The World Bank's prediction means that, unless yields per hectare are greatly increased, the world will need an additional 350 million hectares of land (3.5 million km²) for cereal production by 2030. This is a land area six times the size of Ukraine.[97]

The increased demand for cereals and soya will be in large part due to the increased consumption of animal products. According to the FAO, 'a good part of' the increase in cereals will be for animal feed in developing countries 'to support the expansion of their livestock production'.[40]

Even with increases in the yield of feed crops on existing cropland, the FAO foresees a need for a continuing expansion of the land used for animal feed.[6] This will put animal production in increasing competition for land with people, biofuel production and forests. It has been estimated by the Rights and Resources Institute (RRI) that the world could find an additional 250-300 million hectares (up to 3 million km²) for the production of food, fuel and wood products - but the projected increase in demand is much greater than this. The total additional land that RRI estimates will be needed for food, fuel and wood production by 2030 is at least 515 million hectares, almost twice what could be available.[19]

Agricultural land demand has ecological as well as economic effects. Over the last four decades, agricultural land gained almost 500 million hectares (5 million km²) from forests and other land uses.[20] This is an area over nine times the size of France.[97] The FAO estimated in 2006 that around 70% of the Amazonian area that had been deforested was used for animal grazing and most of the rest for feed crops such as soya.[1(6)] More than half of the Brazilian Cerrado (savannah and dry woodland) has been replaced by crops and pasture in the last 35 years and it is now one of the world's main regions of soya and beef production.[98]

The demand for land for feed grain for intensively produced animals increases the pressure on grazing land. Feed crops are taking over land that was previously pasture and this is expected to continue in many developing countries. Pasture land is already under pressure and there is essentially no more grazing land available. According to the FAO, the world's pastures already have their 'backs against the wall'. Grazing is already moving into marginal areas where it has 'reached the limit allowed by climate and soil'.[67] Any expansion of grazing is likely to be into forests or other ecologically valuable areas.[99]

There are already signs that potentially high food prices and the expectation of future scarcity may be starting a global scramble for farmland. Arable or other fertile land is being bought up by West European investors in Poland, Hungary, Romania and the Czech Republic. Food importing countries such as Saudi Arabia or the United Arab Emirates are buying up land in Africa and central Asia for farming.[100]

The growth of meat production that is predicted up to 2050 will be a major cause of agricultural land shortage and ecological damage, because of its high demand for feedgrains. Developed countries could make an important contribution to reducing these pressures by reducing their meat consumption and moving their livestock production to more extensive, lower-input systems.

7.2 Climate-induced sea level rise

Currently 200 million people live in coastal flood plains (including 35 million people in Bangladesh) and 2 million km^2 of land are within one metre of sea level.[11] At the same time as the world's food production is demanding more agricultural land, our usable land area is likely to be reduced by rising sea levels over the next decades.

Agricultural land could be impacted in two ways by climate-induced sea level rise. Good low-lying agricultural land could be temporarily or permanently flooded or made unusable by salt in invading sea water.

Even a small increase in sea level could cause salt to invade low-lying rice and other crop producing areas such as in Bangladesh, Jiangsu province in China and in Egypt,[1] damaging plant growth and forcing farmers to look for alternative land. Alternatively, agricultural land may be taken over by people retreating from coastal settlements and cities.

Coastal flooding could affect very large numbers of people. According to the Stern Review, a 2°C temperature rise, which is now thought to be inevitable, would subject 10 million more people yearly to coastal flooding. A 3°C rise would subject up to 170 million more people to flooding each year. A temperature rise of 3-4°C, which could occur this century if climate change is not checked, would result in up to 300 million additional people suffering flooding each year.[11]

Coastal cities will be particularly vulnerable to flooding, potentially leading to mass retreat of human populations on to previously agricultural land. By 2025 three-quarters of the world's population is expected to live within 50 miles of a coastline, compared to the two-thirds of the world's population today.[101] Twenty-two out of the world's top 50 cities are at risk from flood surges and these include Tokyo, Shanghai, Hong Kong, Mumbai, Calcutta, Karachi, Buenos Aires, St Petersburg, New York, Miami and London. Even if protected, these cities would be at risk of flooding similar to that seen in New Orleans in 2005.[11] According to the Tyndall Centre for Climate Change Research, rapid sea-level rise of more than one metre per century 'would overwhelm the capacity of coastal societies to respond and lead to large losses and a widespread forced coastal retreat.'[102]

Areas particularly at risk are the large coastal areas and populations of South and East Asia, West Africa, the Nile Delta in North Africa, Indian and Pacific islands and the Caribbean (where more than half the population lives within 1.5 km of the coast).[11] The collapse and melting of Antarctic ice sheets, which scientists now fear may happen, would result in a sea level rise of at least five metres and would largely inundate Washington DC.[103a-b] A five-metre rise in sea level would mean that South and East Asia would lose 15% of its land area and many major cities would have to be abandoned or very expensively protected. The world would lose 4 million km^2 of land and 5% of the world's population (270 million people) would be affected.[11]

Sea level rise is already occurring because of global warming that has taken place during the 20th century. The extent of sea level rise by the end of the present century is still uncertain. In 2007 the IPCC predicted sea levels to rise by over half a metre by the end of the century,[104] while the rise could be much greater if GHG emissions are not reduced. A December 2008 report on *Abrupt Climate Change* by the United States Climate Change Science Program concluded that the IPCC's predictions were too low. This is because the rate of melting of ice sheets and glaciers in Greenland and the Antarctic has been faster than expected. These United States scientists believe that sea level rise by 2100 could be 1.5 metres.[105a-b]

A global sea-level rise of one metre could occur well before the end of the present century. If this happens, up to 2 million km^2 of land within one metre of sea level could be lost to the sea.[11] This potentially lost land area is the same size as the area of new agricultural land that will be needed in the next two decades just for food production. In such circumstances, the continued use of one-third of the world's cropland for producing livestock feed would become entirely unviable.

7.3 Crop yields during climate change

Climate change will almost certainly make it harder to produce enough grains to meet the growing demand for food and, increasingly, for animal feed. Developing countries, where the growth in population and in animal production will be greatest, are expected to increase their net cereal imports 2.7-fold during the first 50 years of the century.[40] The FAO has warned that our ability to produce the 50% increase in cereals that will be required for both food and animal feed 'should not be taken for granted' in view of slower growth in yields and stretched resources of land and water. [40]

The rate of increase in the yield of the world's major crops (wheat, maize (corn) and rice) have slowed 'sharply' in developing countries since the 1980s, according to the World Bank. Apart from in Africa, all the 'easy' gains in yield have already been made,[31] and the growth of yield per year by 2050 will be less than half what it is now.[15] World cereal stocks in 2006 were at their lowest since the mid-1980s, according to the International Food Policy Research Institute.[15] Yields per hectare and the total output of crops could be increased today by ploughing up more land and by increasing the use of fertilisers, pesticides and irrigation, but these measures have costs in terms of energy, climate and environmental damage. One reason for the slowing in rate of growth of yields is probably soil degradation, due to over-exploitation. The FAO believes growth has been the 'over-reliance by farmers on increasing levels of inputs to raise production, which harms soils and ecosystems and brings diminishing returns.'[15]

Climate scientists consider that, if no action is taken to reduce GHG emissions, an average global temperature rise of 2–3°C could occur by around 2050.[11] Agricultural yields are most likely to suffer in developing countries, which is also where the biggest increases in demand for food and animal feed are forecast. An increase of 2°C or more is expected to sharply reduce crop yields in tropical regions, especially in Africa, leaving millions of people unable to produce or buy enough food.[11] The International Food Policy Research Institute (IFPRI) expects climate change-related droughts and floods to reduce average cereal yields by about 15% by 2080 in over 40 developing countries, mostly in Africa.[15] This reduction will be even more serious because it will be at a time of rapidly rising population.

According to evidence cited in the 2006 Stern Review on climate change, global wheat yields could decrease by 22% for a temperature rise of 3-4°C. The worst affected areas would be Africa and Western Asia (including the Middle East), where the reductions could be as much as 30%.[106]

In the United States, if temperatures rise above 3°C, agricultural output could fall by between 5% and 16% even with effective adaptation, because of summer drought and high temperatures.[106] In Australia the 2002 drought reduced agricultural output by 30% and a 2°C temperature rise could reduce the water flow in the agriculturally crucial Murray-Darling river system by a quarter. The Murray-Darling river is in Australia's main food-growing region and is used for irrigation. It has already dried up in some parts, due to both over-extraction for agriculture and drought. Dairy farmers have been forced out of business because of a lack of either irrigation water or rainfall.[107a-b]

China is the world's most populous country and by 2050 will be the world's largest economy. Climate change is predicted to cause a net decrease in agricultural output, with the north and northwest particularly vulnerable.[12] By 2050, the yields of rain-fed wheat, maize and rice could be reduced by as much as 20%, 22% and 14% respectively. For irrigated crops the reductions would be as much as 7%, 11% and 12% for wheat, maize and rice respectively. Hotter temperatures will mean that 28% more water will be required for growing winter wheat and up to 18% more water for growing summer maize in North China. The additional demand for irrigation water will exacerbate the existing water shortage in that area.[108] In India and South Asia the yield of irrigated wheat and rice could be down by as much as 22% and 34% respectively. In India, 62% of the cropped area is dependent on rainfall, meaning that the impacts of climate change on agriculture are critical.[109]

A changing climate brings unstable and less predictable weather, which is usually bad for agricultural production. By the 2080s temperatures are predicted to fluctuate from year to year by up to half the total expected temperature rise.[106] North America is the world's major producer of maize (corn), wheat and soya, the main components of concentrate livestock feeds. In 2008 the United States Climate Change Science Program and the Subcommittee on Global Change Research predicted that extreme events such as droughts, heavy rains, excessive heat and intense hurricanes are likely to become more frequent in North America as global GHG emissions increase.[110]

Climate change will take its toll on the world's food supply. Heat stress will affect both crop and livestock production. In the tropics and sub-tropics, studies predict that crop yields will fall by between 2.5% and 16% for every 1°C increase in temperature in the growing season. Local disruptions in supply can easily become global and destabilise world food prices. The possible result by the end of the 21st century is that 'global food security will be severely jeopardised' according to United States scientists writing in the international journal *Science* in 2009.[32]

The projected doubling of livestock production by mid-century would therefore take place at a time when there is a grave risk of *decreasing* crop production due to climate-related losses. Every additional kilogramme of meat produced will require several kilogrammes of these decreasing grains and other crops for animal feeds.

A food strategy based on expanding intensive livestock production at a time of climate change would be contrary to all our aims for sustainability, at the very least. At the worst it could be a road to disaster. We can prepare for the effects of future climate change on agriculture by investing in technological measures such as plant breeding and improvements in sustainable cultivation methods. However, it is clear that a major contribution could be made by reducing meat consumption, particularly in developed countries, which would free up land and crops for human consumption.

7.4 Water scarcity

Climate change is forcing us to make choices about the priorities for using water. Fresh water is scarce in many regions of the world; up to two billion people currently suffer from water scarcity. Competition for water is already intense in regions where supplies are inadequate to meet all the demands of households, agriculture and industry.[111, 112] The UN Secretary General has warned that water should be a top environmental priority in order to avoid future conflicts over water supplies.[13]

The International Water Management Institute (IWMI) Comprehensive Assessment of 2007 was made over five years of study by 700 scientists from around the world. Their assessment asked the question: will there be enough water to produce food for a growing population in the next 50 years? The answer was: 'It is possible to produce the food – but it is probable that today's food production and environmental trends, if continued, will lead to crises in many parts of the world.'[112] In 2008 the IWMI concluded that, 'Considering water scarcity constraints, it's vitally important to consider what are realistic levels of food production and the desirable levels and composition of food consumption.'[7]

Intensive animal production is wasteful of water, for the same reason that it is wasteful of good cropland. Water has to be used to grow several kilogrammes of feed in order to produce just 1 kg of meat.

Increasing populations, increasing incomes and higher consumption of calories and of meat have resulted in the human population taking three times more from rivers than we did 50 years ago.[112] The level of water in aquifers is 'declining rapidly in densely populated areas of North Africa, North China, India, and Mexico because of overexploitation' according to the International Water Management Institute. Some rivers no longer have enough water to reach the sea.[112]

Rising global temperatures are expected to increase water stress by 2050. According to a technical report for the IPCC on water and climate change, the number of people in water-stressed river basins (already over two billion) is likely to increase to between four and nearly seven billion by 2050, more than half the world's population.[111] By the 2050s, the area of land subject to *increasing* water stress due to climate change is projected to be more than double the area that will experience decreasing water stress.[111] In these circumstances, livestock production will be a likely contributor to human conflict over water resources.

The projected doubling of livestock production by mid-century is likely to impact water use severely, even in the absence of climate change. Water use for all crops (food, feed and fibre) could almost double on present trends by 2050, from 7000 km^3 a year to 13,000 km^3, according to the International Water Management Institute.[7] The use of water for livestock production is projected to increase by 50% up to 2025 alone.[92]

Although feed accounts for most of the water used, animals also need large quantities of drinking water and their requirement rises considerably at higher temperature. At a temperature of 35ºC a lactating sow requires nearly 47 litres a day (approximately the same as the daily minimum need of a person), and a lactating cow requires nearly 127 litres a day.[92]

Water management scientists are well aware of the role of intensive animal production in increasing the demand for water. According to a 2008 report from the International Water Management Institute on saving water, 'The production of meat from animals fed on irrigated crops has a direct impact on water resources, much more so than if the meat is derived from grazing animals and animals fed on [crop] residues.'[7] Researchers at UNESCO and the University of Twente have concluded that a high level of meat consumption is one of the main factors in increasing the water footprint of any individual country.[2]

Research on water use and food in China has concluded that the increase in meat consumption is a major cause of the water shortages that exist in that country. Increased consumption of meat has resulted in a 3.4-fold increase in the amount of water needed per person for food in China since the early 1960s. Writing in the journal *Nature* in 2008, researchers in water science institutes in Switzerland and the Netherlands conclude that: 'In China, changing food-consumption patterns are the main cause of the worsening water scarcity. If other developing countries follow China's trend towards protein-rich Western diets, the global water shortage will become still more severe.'[113]

In arid areas of the world where rainfall or soil moisture is inadequate, freshwater is used for irrigation of food, feed and other crops. Agriculture (mostly irrigation) accounts for about 70% of all human uses of freshwater.[92] On the basis of our present population growth, human demand for freshwater by 2050 will be more than two-thirds of the world's total freshwater resources that are accessible today.[1] This means that in 2050 agriculture as a whole could be using nearly half of the world's entire freshwater resources. Livestock feed consumes around 15% of the world's irrigation water and in areas of water scarcity the use of freshwater on feed crops can have a severe impact on water resources. The FAO has concluded: 'It is clear that feed production consumes large amounts of critically important water resources and competes with other usages and users.'[92]

Intensive animal production is a much less efficient use of water than extensive animal production on rain-fed natural pasture. In a time of water scarcity it becomes increasingly difficult to justify using either good rain-fed arable land or scarce irrigation water for growing feed crops for factory farms. Large amounts of water could be saved globally by moving away from intensive livestock production.

7.5 Energy use to produce animal feed

Intensive livestock production is highly dependent on inputs of fossil fuel energy for nearly all its operations. These include the production of feed, with associated manufacture of mineral fertiliser and pesticides, transport of feed and animals, heating and ventilation of animal sheds, disposal of manure, and slaughter.

Modern intensive agriculture as a whole is based on a ready supply of cheap energy and this dependence threatens the future of the food production industry. Energy costs are 16% of total agricultural production costs in the United States; about one-third of this cost is for fuel and electricity and two-thirds is used indirectly for the energy needed to manufacture fertiliser and other agrichemicals.[31] In the United States nearly 6000 megajoules (million joules) of energy is used per tonne of maize produced, nearly 33 times the energy input per tonne of maize grown in Mexico.[114] 6000 megajoules is equivalent to 160 litres of oil.[31]

On average, agrichemical inputs of fertiliser, insecticide, herbicide and fungicide in modern agriculture typically represent an energy content of 12,000 megajoules (MJ) per hectare,[114] according to calculations by the FAO in 2000 (Table 9). Fertiliser costs are reported by the World Bank to be 18% of the production costs of irrigated wheat in the Punjab and 34% of the costs of soybeans in Mato Grosso, Brazil.[31]

Modern farming's dependence on synthetic nitrogen fertiliser is one of the main reasons why the input of fossil fuel energy is so high. It has been estimated that 40% of the world's population is dependent on the extra calories produced by synthetic nitrogen fertiliser, and the proportion could reach 60% by 2050.[115] The FAO has predicted that the world will be using 118 million tonnes of synthetic nitrogen per year by 2030 (baseline scenario), an increase of 48% in annual use compared to the mid-1990s.[116]

The global use of all mineral fertiliser (of which the majority is nitrogen), increased at a rate of 2.9 million tonnes per year between the early 1960s and the end of the 20th century, by which time the industrialised countries were applying as much as they usefully could.[116] In 2000 the FAO predicted as a baseline scenario that all fertiliser use would increase to a total of nearly 200 million tonnes per year by 2030, representing almost a 50% increase in annual use since 1995-1997. Most of the increase is expected to be in Asia, Africa and Latin America.[116] These predictions did not take into account either climate change or soil degradation due to intensification, both of which are likely to increase dependence on synthetic fertiliser yet further.

Our dependence on synthetic nitrogen will become increasingly unaffordable in a future when energy prices will be high or volatile and energy supply will be uncertain. The energy used for synthetic nitrogen manufacture usually comes from natural gas, although in China coal is typically used.[6] Natural gas is a dwindling resource and coal is a major risk to the global climate. In most countries, including the United States, Brazil and European countries, one tonne of nitrogen fertiliser takes around 40 gigajoules (billion joules) of energy to produce; in China

Table 9. Average energy utilised for chemical inputs for crops.
Source: FAO, The Energy and Agriculture Nexus, 2000, Table 2.7[114]

Input	Energy utilised for chemical inputs per hectare of crop produced (MJ/ha)
Nitrogen (fertiliser)	9750
Phosphate (fertiliser)	540
Potash (fertiliser)	360
Insecticide	28
Herbicide	1200
Fungicide	276

Table 10. Proportion of all mineral fertiliser used for feed crops and pasture.
Source: Steinfeld *et al.*, 2006, Table 3.3 (data from 2002 and 2003).[67]

	Proportion of total N fertiliser used for feed crops and grassland for animal production, rather than for food crops for direct human consumption (%) (* indicates countries with significant grassland fertiliser use)
UK	70 *
Germany	62 *
Canada	55
France	52 *
USA	51
Spain	42
Brazil	40

it takes 50 gigajoules of energy.[67] It has been estimated that the quantity of natural gas needed to manufacture one tonne of nitrogen fertiliser is sufficient to generate nearly 10,000 kilowatts of electricity, enough to run the average United States home for 10.5 months.[117] Manufacture of synthetic nitrogen fertiliser currently accounts for around 1% of the world's total energy use.[67]

Livestock production is a major reason why the world is so dependent on synthetic fertiliser. As Table 10 shows, typically over half of all nitrogen fertiliser use in developed countries is for animal feed crops (globally the proportion is up to 40%).[34, 67]

The world's over-dependence on synthetic nitrogen fertiliser has major implications for the world's use of energy, as well as for the climate and the environment. We could reduce our dependence on synthetic nitrogen by reducing meat production and consumption. Meat reduction would in turn reduce the need for cereal feed crops and hence the need for synthetic nitrogen. It has been calculated that food production in the United States could be run without synthetic nitrogen, instead using legume crops that fix nitrogen from the air. However, this could only be done if the population reduced their consumption of meat to around one-eighth of the current level and obtained most of their protein requirements from plant-based foods.[117]

7.6 Biofuels in competition for land

The facts of climate change and energy scarcity are likely to make biofuels production a significant use of land in the future. This will tend to increase cereal prices and reduce the availability of land for food and feed crops. Between 2000 and 2007 there was a 25% increase in the global use of cereals for biofuel production. In the same period, the use of cereals for food and for animal feed increased by 4% and 7% respectively.[15] In the United States, the use of maize (corn) for ethanol production increased 2.5-fold in the same period[15] and 24% of the maize crop was expected to go into ethanol production in the 2007/2008 crop year.[87] Factory farming now competes with cars as well as with people for a share of the world's limited land and food resources.

As demand for biofuels drives up cereal prices, concentrate animal feed may become so costly that factory farming becomes uneconomic. High cereal prices may also put staple foods out of reach of the world's poor. The International Food Policy Research Institute (IFPRI) has predicted that biofuel expansion will result in a decrease in food calorie consumption in some regions of the world. This reduction in calorie consumption could be at least 2% and possibly up to 5% or more in some regions such as Sub-Saharan Africa.[35]

Increased demand for biofuels will also reduce the amount of cropland that is available for food and feed production. Cropland is already scarce: according to the United States agricultural consultancy FarmEcon LLC, the United States policy of encouraging biofuels is unsustainable because, 'There simply is no significant reserve of fertile, productive, farm land in the United States (or in the world) that can be brought into production to satisfy major demand increases.'[118]

Both biofuels and animal feed consume cereals and land that could otherwise be used to grow food for direct consumption by people. This has already resulted in human hunger and suffering. The strong possibility that biofuels will be in permanent competition for land and crops in the decades up to 2050 makes it all the more urgent to limit the proportion of the world's harvest that is used inefficiently to produce animal products.

7.7 Conclusions on resource use for factory farming

Factory farming of animals is probably the most resource-intensive method of food production that has yet been invented. Unless we change direction, by 2050 the world will be trying to produce twice the quantity of livestock products from a depleted or unpredictable resource base of land, crops, water and energy that is considerably lower than today's. The high level of resource use demanded by intensive animal production might be overlooked in a time of plenty, when pressures of population and resources were not as apparent as they are today. At a time of crisis in the planet's climate and in light of increasing competition for scarce resources, the over-production of factory-farmed food by rich countries will be either unacceptably wasteful or economically unviable.

PART 2: THE COSTS OF FACTORY FARMING

Factory farming imposes costs on society because of its impacts on the environment and the health of both people and animals. These hidden external costs are not paid in full by the animal production industry and so they are not included in the retail price of cheap meat, milk and eggs paid by the consumer.

The external costs of factory farming include livestock's contribution to the contamination of water by excess nitrogen, phosphorus, pesticide and pathogens; air pollution, including GHG emissions; damage to wildlife and habitats; damage to soil; animal production diseases; food poisoning; human diet-related illness; and damage to animal welfare.

Some of these costs can be quantified in financial terms. In 2004 economists at Iowa State University estimated the external cost of livestock production in the United States to be up to US$ 739 million annually and the external cost of all crop production (including animal feed crops) to be up to US$ 16 billion annually.[119] In 2005 agriculture and food policy experts calculated that the total external costs of UK agriculture up to the farm gate are £1.5 billion annually.[120] Livestock products were found to generate the highest external costs per kilogramme: the external costs for beef, for example, are 38 times as much as for cereals and 106 times as much as for vegetables. The external costs for pork are over seven times as those of cereals and 21 times as those for vegetables. The external costs for poultrymeat are more than three times those of cereals and over nine times as those of vegetables.[120]

8. Factory farming's impact on the environment

Factory farming is not only an inefficient use of resources and a threat to the climate. It is also a major cause of environmental pollution, habitat damage and loss of biodiversity. The FAO published in 2006 probably the most detailed study ever made of the environmental impact of livestock and concluded that this impact was so great that 'business as usual' was not an option for the future. The authors considered that, '[T]he livestock sector has such deep and wide ranging impacts that it should rank as one of the leading focuses for environmental policy.'[121] One of the main recommendations of the FAO's study was that the 'polluter pays' principle should be extended to livestock production. According to the FAO, 'A top priority is to achieve prices and fees that reflect the full environmental costs [of livestock], including all externalities.'[121]

8.1 Soil degradation and desertification

Soil degradation is already a serious problem globally, due to over-exploitation of farmland and deforestation. Factory farming contributes to land degradation both directly and indirectly. The direct effects come from the intensive exploitation of land to produce animal feed. The indirect effects arise when small farmers and pastoralists are forced to move into more marginal land or forest, sometimes because they are displaced by large-scale feed production operations.

The projected doubling of livestock production up to 2050 would immensely increase pressure on already fragile soil resources. The over-production of livestock and their feed means that available land is used more intensively and relatively more land has to be put into continuous cereal production. Factory farming of livestock encourages the expansion and intensification of cereal and soya production, the over-use of synthetic fertilisers and pesticides, over-exploitation of soil and the abandonment of crop rotations that would maintain soil fertility.

By the beginning of the 1990s, the FAO was concerned that: 'A critical challenge facing most countries is to halt and reverse the present extent of environmental degradation resulting from excessive exploitation of natural resources, especially those manifested in desertification, soil erosion, water logging, and soil and water salinisation, in order to ensure the needs of future generations.'[122] The FAO explained that: 'Environmental stress is often the result of the excessive demand for scarce natural resources and the related pollution of the land and water generated by over-development and by poverty', for example when the poor are forced to over-use marginal lands for agriculture.[123]

Degradation of soil quality and desertification result in the loss of millions of hectares of once-productive cropland. It has been estimated that the amount of cropland available per person in the world has been reduced by 20% in the last decade.[5] Soil damage is one of several reasons for this. Wind or water erosion is estimated to have caused the loss of 10 million hectares of cropland per year[5] and the FAO estimates that 10 million hectares are abandoned per year due to soil degradation (waterlogging, salinisation, erosion).[122] Estimates of cropland damage in China in the mid-1990s were that soil erosion, salinisation and losses of farmland may have cost China six million tonnes of grain a year, with agricultural losses possibly amounting to 2% of national GDP at that time.[1]

Worldwide, irrigation is the most common cause of the salinisation and waterlogging of agricultural soils. Some degree of salinisation is an almost inevitable result of irrigation.[123] Nearly all natural freshwater sources used for irrigation, such as rivers and aquifers, contain some salts and these accumulate on repeatedly-irrigated soils when the irrigation water evaporates. Few crops can grow well in saline soils and in the worst cases the salt is deposited on the soil surface like a layer of snow. Between 25% and 50% of the world's irrigated land is affected by some degree of salinisation.[123]

Already, 20% of the world's total pasture land, including 73% of the world's dry rangelands, are degraded to some extent due to overgrazing, erosion and compaction.[121] A study published in *Nature* commented in September 2007: 'Arid ecosystems are among the most sensitive ecosystems to global climate change. High grazing pressure pushes arid ecosystems towards the edge of extinction. Increased aridity can then lead to desertification in a discontinuous way, where the possibility of recovery will be low.'[124] According to the Millennium Ecosystem Assessment, desertification affects the livelihoods of more than 25% of the world's population.[124]

Over one-third of the world's cereal crop and over 90% of the world's soya crop is grown for animal feed. Abandoning factory farming would free up land for less intensive cropping and grazing and help to stop the continuing degradation of soil globally.

8.2 Water pollution and depletion

Factory farms keep unnaturally large numbers of animals crowded together in relatively little space. These systems break the link between livestock and the carrying capacity of the land and its ability to recycle wastes.

Animal manure has a high nitrogen (N) and phosphorus (P) content. Nitrogen and phosphorus are essential to plant and animal life and growth, but excessive quantities of N and P causes serious environmental pollution. Intensive agriculture, especially livestock farming, is a major source of nitrogen pollution worldwide. The main livestock-related causes of water pollution are the large quantities of animal manure generated and the use of excessive quantities of fertilisers to produce animal feed. Globally, an estimated eight million tonnes of nitrogen and nearly 15 million tonnes of phosphorus contaminate freshwater courses from livestock manure.[92]

The problem of how to dispose of livestock manure from factory farms occurs worldwide. A United States Senate Committee report of 1997 calculated that large livestock operations are the waste equivalent of towns or even cities. 200 dairy cows can produce as much manure as a town of 10,000 people. A pig operation producing 2.5 million pigs a year would have a waste output greater than the urban area of Los Angeles.[125]

Eutrophication of waters (either freshwater or seas) occurs when the water is over-enriched by nitrogen and phosphorus. This is caused most often by run-off from agricultural land, leaching of fertiliser through soil to waterways, human sewage and industrial wastes, and nitrogen deposition from the atmosphere.[126] The resulting environmental damage reduces biodiversity as the faster-growing species take over. The damage also includes pollution of drinking water sources, algal blooms ('red tides'), large-scale fish kills as the algae absorb all the available oxygen, and toxicity in shellfish.

The EU reported in 2000 that, 'more than 20% of EU groundwaters are facing excessive nitrates concentrations, with a continuous increasing trend in the most intensive areas of livestock breeding and fertiliser consumption. At least 30-40% of rivers and lakes show eutrophication symptoms or bring high nitrogen fluxes to coastal waters and seas. The agricultural origin of these N fluxes accounts for 50 - 80% of total N inputs to EU waters', varying between countries and conditions.[127]

Livestock manure is estimated to contribute 39.5% of this nitrogen in the countries of the EU15 and N fertilisers contribute 48.9%.[126] (Probably around half of that N fertiliser had been used to grow animal feed crops.) In 1997, 9 million tonnes of nitrogen were generated by the EU15 alone directly from livestock husbandry, in other words from manure and other wastes. This is despite the adoption in 1991 of the Nitrates Directive to limit the amount of manure and N fertiliser that can be applied to land and thus reduce run-off to water bodies.[126] In regions of the world where health and environmental regulation is inadequate to the task, livestock-related pollution is likely to be even higher.

In China's Guangdong Province, pig waste has been found to be the source of 72% of the nitrogen and 94% of the phosphorus pollution of water systems.[92] In the United States livestock have been found to be responsible for 55% of sediments eroded from agricultural land into water, for 33% of water pollution by nitrogen and for 32% of water pollution by phosphorus.[92] Globally, the contamination of water due to mineral fertiliser used to produce animal feed and forage is lower but still significant, amounting to over 200 thousand tonnes of nitrogen and over 20 thousand tonnes of phosphorus annually.[92] Livestock are also responsible for a considerable percentage of the pollution of freshwater by sediments (erosion), pesticides, antibiotics and heavy metals. Watercourses are also polluted by pathogens from livestock such as *Salmonella, Campylobacter* and *Escherichia coli* (E. coli) (all of which can cause foodborne disease in people). Slaughterhouses, processing plants, dairies and tanneries also have the potential to cause serious pollution in their local area.[92]

Cattle and pig slurry and silage effluent are very much more polluting in water than raw domestic sewage from human wastes because they have a much higher biological oxygen demand (BOD: This is the quantity of oxygen that is taken from the water in the process of degrading a material). The huge lagoons full of pig slurry that is collected in large intensive pig farms, such as in North Carolina, are considered a 'major environmental and health concern.'[128] Pig slurry has a 75-fold higher biological oxygen demand than raw domestic sewage and silage effluent has a 200 times higher BOD than domestic sewage.[129]

If excessive amounts of water are withdrawn or polluted, the result is ongoing depletion of renewable water resources. According to the FAO, water use for agriculture as a whole, including livestock, is responsible for 93% of water depletion globally.[92] It is clear that we could make a very significant contribution to protecting water quality by reducing the scale of livestock production and by moving away from factory farming methods.

8.3 Loss of habitat, biodiversity and extinctions

'Growth in agriculture has been responsible for much of the loss of biodiversity and habitats and of regulating ecosystem services.' (International Water Management Institute, 2007)[112]

The expansion of intensive livestock production is closely implicated in biodiversity loss in both developed and developing regions of the world. The causes include pollution of soil and freshwater through acidification and eutrophication; deliberate destruction of natural habitats, including rainforest and savannah, linked to production of livestock feed; acidification of the oceans due to emissions of carbon dioxide; overfishing in order to provide fishmeal for carnivorous farmed fish species; and climate change. Intensive livestock production also leads to pressure on arable land to produce ever more feed crops as well as food for direct human use, leading to the intensification of arable farming and loss of natural grasslands. In addition to encroaching on previously unfarmed land, intensive animal production acts to reduce biodiversity in farmed habitats.

Animal production-induced damage to wildlife habitats is one of the major threats to biodiversity globally. According to the FAO, 'livestock play an important role in the current biodiversity crisis, as they contribute directly or indirectly to all these drivers of biodiversity loss, at the local and global level' through habitat change, climate change, overexploitation and pollution and 'over 70% of globally threatened birds are said to be impacted by agricultural activities'.[130]

Land use changes up to 2010 are likely to increase deforestation still further in protected areas of Central and South America. These threatened countries and areas include Guatemala (mainly Laguna del Tigre National Park), the eastern Venezuelan Amazon, the Colombian National Park Sierra de la Macarena and the Cuyabeno reserve in north-eastern Ecuador. The majority of this expected deforestation is linked to providing pasture for animal production.[130]

Research by conservation organisations has highlighted the threat from the expansion of animal production. WWF reports that livestock production is a current threat to 306 of 825 identified terrestrial ecoregions. Conservation International reports that 23 of 35 identified global biodiversity hotspots are 'affected by livestock production.' (Hotspots are those ecoregions identified by conservationists as the most biologically valuable and the most threatened.) The World Conservation Union (IUCN) Red List of Threatened Species shows that 'most of these are suffering habitat loss where livestock production is a factor.'[121] Birdlife International in its 2008 *State of the World's Birds* report notes that 'agriculture destroys and degrades more habitat than any other factor', particularly by the intensification of farming practices.[131]

Agricultural intensification is a global cause of habitat loss, often driven by increased production of livestock and of biofuels. The area of land Brazil used for soya production, for livestock feed, has more than doubled since the beginning of the 1990s.[131] The Cerrado (savannah) area of Brazil, which contains over 900 species of birds and 10,000 species of plant, has been reduced to half its original size, mainly due to planting of soya (for animal feed) and sugarcane (for biofuel).[131] The loss of rangeland (lightly-grazed grasslands) in the United States is believed to be an important cause of decline in the numbers of Red-winged Blackbirds.[132] The populations of 45% of Europe's common bird species have declined across 20 countries between 1980 and 2005, with farmland birds particularly badly affected; Birdlife International says that, 'It is widely accepted that these declines have been driven by agricultural intensification and the resulting deterioration of farmland habitats.'[132]

The most serious threat to present and future biodiversity is climate change caused by past and continuing emissions of carbon dioxide and other GHGs. A rise of 2ºC in global temperatures could result in the extinction of 15-40% of land species and the destruction of coral reefs and tropical mountain habitats. Up to 60% of South African mammal species could be lost. A rise of 3ºC or more, which is now thought to be possible this century, could see the extinction of up to half of all land species. Biodiversity hotspots could lose thousands of species.[11]

The acidity of the oceans is already increasing, as CO_2 in the atmosphere dissolves in their waters, and could result in a three-fold increase in acidity by 2100. The acidity is already damaging the fertility of some species and is potentially lethal for the animals with chalky skeletons that make up more than a third of marine life.[133] Since a temperature rise of 2ºC is the current climate target for most governments of the developed world, future large-scale extinctions related to climate change now look hard to avoid.

The IUCN, which monitors endangered species, believes that we are living through an extinction crisis. The 2007 Red List of Threatened Species included over 41,000 species, with over 16,000 of these in danger of extinction. Current extinction rates are estimated to be at least 100 – 1000 times higher than natural background extinction rates.[134]

We know that ecosystems and species have recovered in the past from the most catastrophic mass extinctions, such as the end-Permian extinction of 251 million years ago. During that mass extinction, 'on land and sea, life was nearly extinguished, ecosystems were devastated and many long-lived lineages disappeared.'[135] Recovery from mass extinctions does happen, but scientists at Bristol University who have studied patterns of recovery have concluded that recovery of complex ecosystems and biodiversity takes a very long time – in the region of 30 million years.[135]

Scaling down the animal production industry in developed countries could make an important contribution to protecting biodiversity globally. It would drastically reduce the demand for animal feed, particularly soya, which is grown in South America for export to Europe and thus would reduce the pressure on land. In developed countries it would enable farmers to produce crops and animals less intensively, saving on the use of energy, fertiliser and pesticide.

Most importantly, it would take the lead in making meaningful reductions in livestock-related greenhouse gas emissions and help to limit global temperature rise.

9. Factory farming and health

Factory farming has become a global risk to both animal and human health. There are risks to both animals and people from infectious disease and from the pollution that arises when very large numbers of animals are kept crowded together in a relatively small area, often indoors. Other health risks relate to the diets that we choose to eat. It is now clear that the production of large quantities of low-priced meat and dairy products has encouraged overconsumption of animal protein and animal fat in developed countries, to the detriment of public health. Apart from the individual suffering involved, these health problems of animals and people can incur very high costs to taxpayers in terms of prevention, clean-up, compensation, and the economic and medical costs of illness.

The Pro-Poor Livestock Policy Initiative report of 2007 *Industrial Livestock Production and Global Health Risks*, recognised that: 'Concentration of food animal production and the unregulated 'evolution' of densely populated livestock production areas not only result in major environmental burdens, but also generate significant animal and public health risks.'[136]

9.1 Pollution hazards to farm workers and the public

Factory farms, where hundreds to thousands of animals are confined in a small space, are sources of pollutants that can damage the health of the people who work in them. Slurry pits under livestock sheds produce toxic gases. These include sulphur dioxide, which can cause loss of consciousness after a few breaths, together with carbon dioxide, methane and ammonia, all of which can displace oxygen in and over slurry pits and can lead to the asphyxiation of workers. When the slurry is stirred, the levels of hydrogen sulphide can rise to lethal concentrations very rapidly. An average of 92 fatal accidents in confined agricultural spaces occur per year in the United States, many of them caused by asphyxiation.[137]

Studies in Europe at the end of the 20th century showed that the levels of ammonia and inhalable dust in broiler sheds in some European countries were close to or above the eight-hour exposure level for stockpeople (and often greatly exceeded the guideline limit for the animals).[138a]

The levels of endotoxins (airborne particles of bacteria, insects, manure, etc) were considered high enough to induce toxin fever in humans given prolonged occupational exposure. An industry publication warned in 1999 that 'The air of a poultry house seethes with a health-threatening mixture of gases, dusts and microoganisms' and that a poultry house is a 'large source of aerial pollutants.'[138b]

Toxic dust and gases can cause chronic respiratory problems for agricultural workers, especially those in pig production units and in buildings with high levels of dust and gases.[139] People living near factory farms may also experience lower but significant levels of air pollution which can affect especially children and the elderly. A survey of Iowa families found a high prevalence of asthma among children who lived on family pig farms, especially if antibiotics were added to the pig feed.[139] Over 100 chemical species of odorants have been identified in animal housing, which can be carried on dust and smelled up to 2 km away. A Silsoe Research Institute study found the rate of emission of dust to be 8 g per hour per 500 kg weight of animals.[138c] This would amount to around 3.2 kg emitted per hour (or 77 kg emitted per day) from a broiler house holding 100,000 chickens at their typical slaughter weight. Researchers at the Johns Hopkins Bloomberg School of Public Health have found that disease-causing bacteria, some of them antibiotic-resistant, are emitted from trucks taking poultry to slaughter and that these bacteria collect on surfaces and in the air inside cars travelling behind the poultry trucks.[140a-b]

9.2 Increased risk of animal diseases

There is increasing awareness that factory farming has the potential to increase disease risks to people and to generate economically-damaging production diseases on farms on a massive scale. Many respiratory viruses need a threshold density of a susceptible host population in order to spread, persist and cause large disease outbreaks.[141] Large-scale intensive farming provides pathogens with just such a host animal population.

It has been estimated that 64% of all known pathogens that affect humans (bacteria, viruses, etc) are zoonotic (that is, they originate from pathogens in animals, even if thousands of years ago).[139, 141] Intensive livestock production methods, where large numbers of animals are kept together in confined spaces, greatly increase the potential for infections to be spread between animals and thus from animals to humans. Pathogens can be transferred to farm workers who are in contact with up to potentially thousands of animals per day or to the general public through food. These increased risks occur in spite of the higher levels of disease control from biosecurity measures and the use of vaccines and antimicrobials that are often found in intensive farming compared to traditional farming. In fact, high levels of biosecurity and medication are necessary in intensive farming exactly because factory farm conditions favour the spread of disease among the animals.

The 2008 report of the Pew Commission on industrial livestock production explained why pathogens in factory farms can become more transmissible between animals or more transmissible to people and more virulent than they would be in more extensive conditions. Factory farms provide the pathogen with a large number of hosts in close proximity and conditions in which different strains of pathogen can co-infect one host and facilitate genetic mutation and recombination.[139, 142] Because of the rapid turnover of animals such as pigs and poultry in factory farms, this factory system continually provides pathogens with new hosts to infect. Factory farmed animals are typically stressed and therefore more susceptible to infections.

9.2.1 Impact of climate change on animal disease and food safety

Global warming can be expected to increase the rate of global spread of animal diseases as pathogens that were once considered 'tropical' are able to spread to more northerly regions. The Bluetongue virus, transmitted by midges that were previously found only as far north as southern Europe, has already spread to large areas of northern Europe. The whole of England was declared a Bluetongue 'restricted zone' in September 2008.[143] Many of the infections in England were caused by the import of infected live animals.

Climate change will almost certainly make the control of livestock diseases in factory farms more difficult and could increase the likelihood of transmission of animal diseases to people. A FAO study of how climate change is likely to increase the risk of food borne and other diseases related to livestock considered the possible effects for transmission of disease from livestock to people by increasing the range and the breeding season of disease-causing agents, the number of animals acting as natural reservoirs of these agents, and the possible establishment of new diseases in some areas. Higher temperatures and extreme weather events (droughts, floods, and hurricanes) could increase disease risk; for example, *Salmonella* and *Campylobacter* infections are found to increase after a period of higher temperatures. Animals and people tend to become more susceptible to infection when stressed by environmental factors such as heat or drought.[144]

Some of the infectious agents that can be transmitted to people and are thought likely to become more problematic as a result of climate change include Rift Valley fever (which affects a number of species of livestock and wildlife), Nipah virus (which affects pigs and presents a serious risk to farm and slaughterhouse workers), Hepatitis E virus (a possible source of infection is pig manure), Yersinia, which is a class of bacteria causing bubonic plague (pigs are a major livestock reservoir and slaughtermen are at risk), Leptospirosis (affects all livestock), *Cryptosporidium* (a gut parasite, shed in cattle and sheep manure and a risk to animal handlers), as well as the food-poisoning pathogens *Salmonella, Campylobacter, E. coli* 0157, and *Listeria*.[144] *Listeria* infection is particularly dangerous to pregnant women and has a high mortality rate.[145]

9.2.2 Highly pathogenic avian influenza (bird flu)

Highly Pathogenic Avian Influenza (HPAI) first came to attention in 1997 in Hong Kong's live bird markets and chicken farms, when six people died from the disease. From 2003 the H5N1 strain of the Influenza A virus spread across East Asia, during a period of unprecedented increase in the poultry population and intensification of poultry production in the region. China reared three times as many meat chickens in 2005 as in 1990.[11] Over 50 billion meat chickens are now reared globally each year.

The H5N1 virus has since spread across countries in Asia, the Middle East, Eastern Europe (2005), Western Europe (2006) and to Africa. It has been found in chicken, goose and turkey farms and in some wild birds, mainly swans, chicks and geese. It has by now been detected in poultry and/or wild birds in most European countries.

Intensification and the global poultry meat trade are implicated in this rapid spread. As *The Lancet* has explained, 'Over the years, large concentrations of birds have facilitated an increased affinity of the virus to chickens and other domestic poultry, with an increase in pathogenicity.'[146] According to a FAO-endorsed report from the Pro-Poor Livestock Initiative in 2007, 'around 40% of the HPAI H5N1 outbreaks in domestic poultry reported to the OIE [The World Organisation for Animal Health] between late 2005 and early 2007 occurred in poultry units of 10,000 birds or more (more than 25% occurred in units of more than 10,000 birds).'[136]

The FAO has confirmed that 'the disease is spread through the human activities of poultry production, improper hygiene and uncontrolled commercialisation.'[147] In England, Highly Pathogenic H5N1 infected the Bernard Matthews intensive turkey operations in Suffolk in January/February 2007. International meat transport was suspected as the cause of the outbreak. Investigations by the food safety and animal health authorities indicated that the virus was probably transmitted in turkey meat imported for processing from Hungary.[148]

Up to January 2009 the WHO recorded 393 people known to have been infected by the H5N1 virus, of whom 248 have died (a 63% death rate). Nearly half of the recorded deaths were in Indonesia.[149]

In some cases it seems very likely that H5N1 was transmitted between people. The much greater longer-term risk to public health is that every time another person is infected the virus is given an opportunity to mutate to become much more easily transmitted between humans, potentially leading to an influenza pandemic (a global epidemic). Public health scientists writing in the *Lancet* estimated that such an influenza pandemic could kill 62 million people, the vast majority in developing countries.[150]

Most of the people who have been infected by H5N1 lived in close proximity with their household chickens or were involved in killing infected birds. However, the possibility exists that H5N1 could be transmitted to the general public in retail meat. This could happen if birds are slaughtered before the disease becomes obvious but when they are carrying high levels of the virus, at the end of the incubation period.[151] According to the WHO, the H5N1 avian influenza virus spreads to virtually all parts of an infected bird, including blood, meat and bones.[152]

Avian influenza viruses survive in contaminated raw poultrymeat and therefore can be spread through the marketing and distribution of contaminated food products, such as fresh or frozen meat. Although the virus is killed by thorough cooking, it survives for days or weeks in bird faeces or on surfaces, particularly at low temperatures such as those used in chilled meat storage.[152] From the investigation of the H5N1 infection in an intensive turkey unit in England in 2007, it appeared that the H5N1 virus survived in turkey meat for around 13 days before it is suspected to have caused a disease outbreak.[148]

Highly pathogenic bird flu can also be transmitted from poultry workers to their families, as shown during the Netherlands outbreak of the H7N7 strain of the virus in 2003 (when one veterinarian died). Testing found that 86 poultry industry workers and three family contacts were infected by H7N7 during the outbreak and around 30 more family contacts were infected with virus of the H7 type.[153] According to the Pro-Poor Livestock Policy Initiative report of 2007, 'An unrecognised aspect of industrial food animal production concerns worker exposures to zoonotic diseases…[W]hen CAFO workers comprise more than 15% of a community they may act as [influenza A virus] amplifiers for the community as a whole.'[136] The term 'CAFO' refers to a Concentrated Animal Feeding Operation or factory farm.

The explosive growth of the globalised chickenmeat industry has driven the development and spread of the disease, providing the virus with a continuous supply of new hosts to infect. While it continues, HPAI is a risk to the whole human population and has devastating economic effects on households and small farmers in developing countries. In 2006 the World Bank estimated that the costs of controlling the virus would be US$ 1 billion, including US$ 500 million needed for the development of vaccines to protect people.[154] Reducing the size of the global intensive chickenmeat industry would be one essential step towards controlling the disease.

9.2.3 Swine influenza

Classical swine influenza was first discovered in 1931. It was an H1N1 virus, related to the virus that caused the 1918 pandemic in which approximately 50 million people died worldwide. In 1998, a new virulent form of the virus was discovered on a pig farm in North Carolina. The virus was a "triple reassortment" – a mixture of pig, bird and human viruses, which soon became the dominant pig flu virus in North America.[209] The virus behind the 2009 swine flu pandemic is also known to have originated in pigs; its genetic components show it to be related to the virus behind the 1998 North Carolina outbreak and to similar Asian and North American swine flu viruses.[210]

Scientists have been warning for years that these types of viruses pose a real risk to human health as they are capable of making a "species jump" to humans. Pigs are susceptible to both human and bird influenza viruses and they can therefore function as intermediate hosts or "mixing vessels" in which new influenza viruses can arise through replication, recombination and reassortment.[211] The recent emergence of swine flu viruses has been attributed to the global growth and intensification of pig production. The United States Council for Agriculture, Science and Technology has warned that a major consequence of modern industrial livestock production systems is that they potentially allow the rapid selection and amplification of pathogens.[212]

In the last fifty years, pig farms have changed from small-scale farms to industrial-scale operations in which thousands of animals of similar genotypes are raised for food production.[213] Around 1.3 billion pigs are slaughtered annually for meat worldwide and at least half of these are raised in intensive systems. The majority of pig production takes place in East Asia, particularly China, which rears half of the world's pigs. This is followed by the European Union, North America and Brazil. Between 1994 and 2001, the market share of pigs produced in industrial production units in the United States increased from 10% to 72%.[214] A similar expansion occurred in Asia; for example, in China, pork production increased from 41 million tonnes to 51 million tonnes between 2001 and 2006 alone.[214]

A large-scale industrial farm is a perfect breeding ground for the emergence and spread of influenza viruses. The sheer numbers of animals on industrial farms results in the rapid transmission and mixing of viruses.[215, 216, 217] The conditions in which animals are kept also play a key role in the emergence of new viruses. Pigs on many farms are severely overcrowded, and have significantly less space than recommended by welfare scientists.[218] Influenza in pigs is closely correlated with pig density as overcrowding results in more opportunities for direct nose-to-nose contact between pigs and in greater spread of pathogens in aerosol form between pigs in the same unit.[217, 219] Overcrowding also results in stress which weakens pigs' immune systems and makes them more susceptible to disease.[217]

Biosecurity is not necessarily higher on intensive farms. The large volumes of waste produced by intensive pig farms are difficult to dispose of and may pollute surface and ground waters.[216] Manure lagoons can result in the transmission of pathogens through the air and through flies which may visit the lagoons.[216] In addition, the geographic concentration of many pig farms results in a higher risk of transmission between farms.[217] Several studies have shown that risk of disease spread is higher in areas of high pig concentration because the microviral load can be high in these areas and there is also a higher risk of viruses spreading from herd to herd.[220, 221]

The geographic distribution of pig and poultry production has become more clustered over the last 60 years, resulting in highly concentrated populations of pigs and poultry often in relatively close proximity of each other.[213] The proximity of intensive pig farms and intensive poultry farms increases the risks of viral recombination and the emergence of new virulent flu strains. For example, interactions between poultry flocks and swine herds were documented during a study of the 1997-1998 swine fever outbreak in the Netherlands.[214]

According to one swine flu expert "[T]he United States pig population of 60 million is an "increasingly important reservoir of viruses with human pandemic potential". [215] In 2008, the Pew Commission concluded that industrialised animal agriculture posed "unacceptable" public health risks.[222] It is clear that a reduction in the size of the intensive pig industry and a switch to less intensive practices are necessary steps towards decreasing the risk posed to humans by factory farming.

9.2.4 Foot and mouth disease (FMD) and animal production viruses

Animal disease outbreaks can be very damaging to farmers and extremely costly to taxpayers, even when they are not transmissible to humans. The FMD epidemic in the UK in 2001 resulted in the recorded slaughter of at least six million farmed animals,[155] probably nearer 10 million if the unrecorded deaths of piglets and lambs are included. The National Audit Office estimated that the cost to the UK economy was £8 billion, including killing and disposing of the animals, financial compensation to farmers, loss of farm exports and even larger losses to local businesses and tourism.[156]

In the last decades several 'production viruses' have emerged in the intensifying global pig industry, which tend to weaken the pigs' immune systems and increase their susceptibility to other pathogens, including multi-pathogen diseases such as Porcine Respiratory Disease Complex.[157] There is evidence that stress caused by intensification is likely to be an important factor in the spread of such diseases.[139, 158]

A highly-damaging viral production disease that has spread worldwide since the mid-1980s is Porcine Reproductive and Respiratory Syndrome (PRRS or 'blue ear'). Pigs with PRRS stop eating or growing, develop fever and often die. The syndrome causes sows to abort (up to 6% of sows), piglets to be stillborn (up to 30%) and results in high death rates in her piglets (up to 70% of infected piglets in the first month of infection).[159] Mortality of weaned and growing pigs may be up to 15%, although some infected herds show no symptoms.[159]

The main route of infection is from other live pigs and workers' clothes and equipment. Live transport of pigs is a major infection route. Studies have found that the infection is more likely to persist in large pig herds in pig-dense regions where the virus is repeatedly reintroduced by bringing in new infected pigs.[160]

Losses to US pig farmers have been estimated in 2005 at US$ 560 million, but as feed prices have increased since 2005 so will the losses.[161] Losses to pig farming in Europe, where 35% of farms were infected by December 2008, have been estimated at 420 million Euros.[162] Losses from PRRS in China, the world's largest pig producer, are estimated by some observers to be in the range of 50-100 million pigs over 12 months during 2007-2008, at unknown cost. In 2007 Chinese scientists reported 'unparalleled large-scale outbreaks' of a previously unknown highly pathogenic and 'high fever' strain of the PRRS virus.[163]

Many intensively farmed pigs are likely to be highly stressed by overcrowding, inadequate ventilation, lack of opportunity for natural behaviour, rough handling, moving and mixing with unfamiliar pigs, as well as close confinement in gestation and farrowing crates in the case of breeding sows. In pig factory farms, piglets are weaned and removed from their mother as young as 3–4 weeks old, making them very prone to infections. Another recently emerged 'production virus', Porcine Circovirus 2 (PCV2), can cause very high mortality among weaned piglets from Postweaning Multisystemic Wasting Syndrome (PMWS). Trials of vaccines against PCV2 in pig farms in Korea, where intensive production methods are common, found that mortality among unvaccinated pigs after weaning was on average 31% and could be as high as 48%.[164]

9.2.5 Emerging zoonotic diseases

Of the new or currently emerging diseases that affect humans it has been estimated that 73% are zoonotic, meaning that they originated in animals and were transmitted to humans.[141] An important factor in this transmission is the destruction of animal habitats by humans. An example is the deforestation in Asia that has been linked to an exodus of flying foxes (fruit bats) carrying the Nipah virus, which causes encephalitis. The virus subsequently infected large numbers of domestic pigs, killed around 100 people at the turn of the century in Malaysia and was exported to Singapore by the transport of live pigs.[141, 165] The 'index' pig farm where the outbreak started was the largest in Malaysia, holding 30,000 pigs, and investigators believe its size and density of pigs may have helped the virus to adapt and multiply.[141]

Other animal viruses that have spread to people include the Ebola-Reston virus, which was first found in pigs in the Philippines in 2008. By early 2009 several pig workers were found to be infected by the virus. While the Reston strain of the Ebola virus is currently harmless to people (whereas the Zaire strain is often lethal), there is concern that the virus could mutate in pigs or other animals to become more virulent to humans.[166]

Hepatitis E virus (HEV) is a common cause of hepatitis among people in developing countries and kills up to 20% of pregnant women in developing countries who are infected by it. Recently HEV has started to emerge in people in other countries who have not recently travelled to a region where the virus is endemic and it is possible that the virus is being transmitted to people from pigs. In such countries the virus that is found in people is very close to the HEV that is already endemic in pigs (including in United States, Spain, New Zealand, UK), and is also found in pig slurry. Surveys of UK pigs have found that over 20% of pigs may be excreting the virus at any one time and that 'slurry constitutes a large burden of potentially infective HEV released into the environment from indoor pig units'.[167]

9.3 Food quality and nutrition

Factory farming has produced ever larger quantities of lower cost meat and other animal products but this has often been at a cost of quality, safety and nutritional value. This is in spite of the considerable advances in understanding of animal and human health and the availability of veterinary medicines in the 20th century. Farming methods that keep animals in more extensive conditions and aim to promote their positive health and robustness are more likely to produce better food for consumers, as well as giving the animals a higher quality of life.

The nutritional quality of factory farmed modern meat chickens is very different from that of meat chickens nearly 40 years ago. Research from the Institute of Brain Chemistry and Human Nutrition at London Metropolitan University has found that intensively reared chicken today contains proportionately 2.7 times as much fat as in 1970 (8.6 g per 100 g in 1970 compared with 22.8 g today). Today's intensively reared chicken also contains around 30% less protein than in 1970 (24.3 g per 100 g compared with 6.5 g today). Factory farmed chicken thus contains nearly 40% more fat than protein. In contrast, organic free-range chickens contain more protein than fat and have 25% less fat then factory farmed chickens (17.1 g per 100 g for organic compared with 22.8 g for factory farmed).[168]

The drive to produce more meat more quickly also affects food quality in the beef industry, where in some parts of the world feedlot cattle are treated with steroid hormones. This practice is illegal in the EU, but scientists who work on detecting drugs in livestock believe that up to 10% of European beef cattle are illegally treated with growth-enhancing drugs, including steroid hormones that have been linked to cancer risk.[169]

9.4 Food safety and food poisoning

Intensively farmed ('broiler') meat chickens are a good example of the negative impacts of factory farming on food and health. Factory farmed poultry are a common cause of food poisoning by bacteria such as *Salmonella* and *Campylobacter* in the birds' intestines and faeces that contaminate the poultrymeat during slaughter and processing.

Campylobacter infection annually causes around 2.5 million cases of illness in the United States and over 340,000 cases in the UK.[170] The European Food Safety Authority (EFSA) reported over 160,500 foodborne *Salmonella* infections in Europe in 2006, but the real number of cases is likely to be several times higher than this, because most people do not report the infection. An average 5.6% of all raw broiler meat samples were reported to be infected with *Salmonella* in the EU and in some instances the levels of *Salmonella* positive samples were as high as 67%.[171] An average of 35% of all raw broiler meat samples in the EU tested positive for *Campylobacter.*[171] Tests in Maryland, USA, in 2005 found that 74% of retail chickens were contaminated with *Campylobacter* and 44% with *Salmonella*.[172] *Salmonella* can also infect people through pigmeat. In 2008 the European Food Safety Authority reported that an average of 10% of pigs slaughtered for consumption in the EU25 carried *Salmonella*.[173] The great majority of all poultry and pigmeat in these countries is factory farmed.

Good extensive farming methods can reduce infectious disease at the same time as improving animal welfare. A survey by the UK Veterinary Laboratories Agency published in 2007 found that while the prevalence of Salmonella infection was around 23% for caged hens, it was only 6.5% in free-range hens. The highest *Salmonella* prevalence was found in the largest egg production units holding 30,000 hens or more.[174] A separate survey by Bristol University scientists, published in 2008, found that the prevalence of *Campylobacter* among free-range meat chickens on farm was no higher than among intensive broiler chickens,[170] even though proponents of factory farming often claim that animals confined indoors are better protected from infection.

9.5 Antibiotic resistance and factory farming

Factory farms commonly use antibiotics to prevent the spread of infections that would otherwise occur among the animals kept in unnaturally crowded conditions. Low doses of antibiotics are also used in some countries as additives in pig and poultry feed because they have the effect of increasing growth rate. The over-use of antibiotics in intensive animal production is known to be an important factor in the development of resistance to antibiotics that are used to treat humans. Because of this danger, the use of antibiotic feed additives for growth promotion is illegal in the EU, although the use of antibiotics for disease prevention is still legal.

Bacteria in farmed animals that are over-treated with antibiotics become resistant to the drugs and the resistant bacteria are passed from the animals to humans, either in food or via the environment. Antibiotics used for people and animals are often closely related, even if they are not identical. This means that when a person suffers from a serious foodborne infection (food poisoning), the antibiotics that doctors use to treat the infection may fail. Factory farm use of antibiotics is also implicated in the spread of superbugs (multi-drug resistant bacteria) in the human population, which are a serious threat to human medicine. The rapid growth of resistance at the end of the 20th century has been described by a United States paediatrician as at 'a crisis stage in human medicine' with 'the prospect of untreatable infections.'[175]

The European Food Safety Authority (EFSA) and European Centre for Disease Control wrote in their 2007 report on foodborne infections: 'An alarming fact highlighted in the 2006 report is that zoonotic bacteria found in animals and in humans are becoming increasingly resistant to commonly used antibiotics. This trend should be of concern for all those working with animal and human health issues.'[171]

Resistance to the relatively new antibiotic ciprofloxacin used in human medicine has been of particular concern. EFSA reported in 2007 that, 'In human *Campylobacter* cases, high levels of resistance to ciprofloxacin was reported in 2006 (up to 45%), thereby causing severe problems in treating these infections… This resistance is also common in *Campylobacter* from poultry meat and live poultry, pigs and cattle.'[171] The resistance to ciprofloxacin developed in poultry because they were treated with an antibiotic (enrofloxacin) that is similar to ciprofloxacin. The use of this type of antibiotic in poultry farms has been banned in the United States for this reason.[175]

It has been estimated that half of all antibiotics produced in the world are used for food animals.[176] Only a small minority (around 10-20%) of these antibiotics are actually used to treat sick animals, according to estimates made by the United States Institute of Medicine and the United States Union of Concerned Scientists. Most of the use is for non-therapeutic purposes, either to prevent infection that might occur or as growth promoters and as much as 70% of the antibiotics sold in the USA are used as animal feed additives.[174, 177]

Pathogens that are resistant to antibiotics are also found in farm workers as well as in their animals. In the Netherlands, chicken farmers and slaughterers, as well as the chickens themselves, have been found to be resistant to several antibiotics, including two which are used to treat superbugs. The humans were somewhat less resistant than the chickens, indicating that the resistance had been transmitted from chickens to people.[178] In 2008 tests in the United States found that in one large corporate pig production system 70% of the pigs and 64% of the farm workers carried the superbug methicillin-resistant staphylococcus aureus (MRSA).[179a-b] MRSA has also been found in pigs and farm workers in the Netherlands, Germany and Canada.[180]

Tests in both Europe and the United States have shown that organic or premium free-range chickens that are not routinely treated with antibiotics are much less likely to carry resistant pathogens. Tests on *Salmonella* samples from standard retail chickens in Maryland (United States), showed that all the *Salmonella typhimurium* samples were resistant to five or more antibiotics. However, *Salmonella typhimurium* samples from organic chickens, where routine antibiotics are not used, showed no risistance, being mostly susceptible to 17 antimicrobials.[172]

The achievements of well managed free-range and organic farms show that animal husbandry without routine use of antibiotics is entirely viable when animal stocking densities are lower and with skilled and knowledgeable management. Factory farms where animals are unnaturally crowded, even with careful management, are more likely to need drugs to keep infections at bay.

9.6 'Downer' cows and BSE

During the 1980s meat and bone meal derived from slaughtered dairy cows was fed back to intensively farmed dairy cows as a cheap source of protein to increase the cows' milk production. This feeding practice caused the emergence of the degenerative brain disease BSE (bovine spongiform encephalopathy) among cows and its tragic transmission to humans as new variant Creutzfeldt-Jakob Disease (vCJD), confirmed in England in 1996. Cows that were suffering from the neurological symptoms of the disease went into the human food chain in the UK, apparently unnoticed by the authorities.

In 2008 the United States public were made aware that sick or injured dairy cows unable to stand ('downer' cows) were being dragged, shoved and carried to slaughter, at a probable rate of nearly half a million per year,[181a] raising the possibility that some of these cows might be suffering from BSE or other transmissible diseases. An exposé by The Humane Society of the United States (HSUS) resulted in the USDA recalling 65 thousand tonnes (143 million lbs) of beef supplied by the Hallmark/Westland slaughterhouse,[181b] a company that was a major supplier of beef to the national school lunch programme. Since the recall dated back to 2006, much of that beef could already have been eaten.

Recently a new ('atypical') variant of BSE in older cattle showing no disease symptoms has been identified at slaughterhouses in Europe and North America. The findings suggest that this disease, created by factory farming, has not left the food animal population, although the level of classical BSE is decreasing. Studies have shown that the atypical BSE (known as BASE) can be transmitted to monkeys and kills them faster than does classical BSE.[182]

9.7 Human nutrition, health and disease prevention

In order to achieve an effective, equitable and sustainable food system by 2050, the world has to solve the linked problems of poverty, under-nutrition and over-consumption. There are an estimated one billion people in the world who are chronically hungry[208] while in rich countries, such as the UK, one-third of food purchased is wasted.[17] 35% of the deaths of children and 11% of the world's burden of disease are caused by under-nutrition.[183] At the same time, another one billion people are overweight, 300 million of them obese.[17]

The WHO's European Anti-Obesity Charter of 2006 reported that 50% of Europe's adults and 20% of children are overweight. 16.5% of adults and 7% of children are classified as obese.[184] More than one million deaths annually can be attributed to overweight, often related to chronic diseases such as diabetes, heart disease, hypertension and some cancers. Adult obesity and overweight is responsible for up to 6% of the entire health care costs in the European region.[184] Official estimates for the cost of obesity in the UK are £1 billion annually to the National Health Service and from £2.6 billion to £3.6

billion annually to the economy as a whole, due to lost productivity.[185]

In the United States, rates of overweight and obesity are apparently going up rather than down, in spite of USDA guidelines on healthy eating. There are 'dramatic increases' in the number of overweight children (now at 16%), according to the USDA.[186] 65% of adults are overweight (up 56%) and 30% are classified as obese (up 23%, both compared to 10 years earlier) and 90 million Americans are affected by chronic and weight-related diseases.[186] Obesity is also increasing in developing countries where people are adopting a 'western' style of diet.[187]

9.7.1 Obesity and diet

The current epidemic of overweight and obesity in developed countries (and among higher-income people in developing countries) has a number of causes related to diet and lifestyle, but a substantial cause is the overconsumption of saturated fat from animal products (meat and dairy) and underconsumption of vegetables and fruits.

According to a World Health Organisation (WHO) paper on social inequalities and food-related ill-health, 'An energy-dense diet high in saturated fat and low in foods of plant origin, together with a sedentary lifestyle, is the major cause of the pan-European epidemic in obesity and overweight, with increased risk of non-communicable diseases including cardiovascular diseases, certain cancers and diabetes.'[188] A research report in the *Bulletin of the World Health Organisation* suggests that the consumption of full-fat dairy products in Europe is an important source of cholesterol and risk of cardiovascular disease, and may be responsible for at least 9800 deaths from coronary heart disease and 3000 deaths from stroke annually, based on 'very conservative estimates.'[189]

The average meat consumption in rich countries is estimated by public health experts to be around 200–250 g per person per day,[9] considerably more than the world's resources could provide for the global population. Recent research from the public health departments of the Australian National University, Cambridge University, The London School of Hygiene and the University of Chile has confirmed the essential role of reducing meat consumption in high-income, developed countries both to improve health and in order to avoid increasing GHG emissions and wider environmental damage due to livestock production. The scientists suggest limiting global meat consumption per person to 90 g per day, which in rich countries would require a reduction in meat consumption of around 60% compared to current levels of consumption.[9] For poorer and developing countries, where average per capita meat consumption is one-tenth of that in developed countries, the target of 90 g per person per day would allow continued growth in consumption.[9]

Public health scientists consider that limiting meat consumption to 90 g per person per day would offer 'important gains to health' for people who currently consume more than the 90 g per day. The benefits would include a likely reduction in risk of colorectal cancer, breast cancer and heart disease, as well as the risk of becoming overweight or obese. The likely reductions in heart disease would be mainly due to reducing the consumption of saturated fat in meat.[9]

9.7.2 Diet-related disease risks

In late 2007 the World Cancer Research Fund and the American Institute for Cancer Research jointly published their second Expert Report on nutrition and cancer prevention, involving 100 scientists from 30 countries. The report reviewed all relevant research and made a series of recommendations for both public health goals and personal actions on diet. The report cited both red meat (i.e. meat from cattle, pigs, sheep and goats) and processed meat (meats preserved by salting, smoking, curing or the addition of preservatives, such as ham, salami, bacon and sausages) as 'a convincing cause of colorectal cancer' and asserted that there is limited evidence linking both to a range of other cancers, such as pancreatic cancer.[190] Although milk may be a 'probable' protector against colorectal cancer, the report stated that there is limited evidence suggesting that both milk and dairy products are a cause of prostate cancer and that cheese is a cause of colorectal cancer. Diets high in calcium are a probable cause of prostate cancer.[191] The report cites 'a limited amount of fairly consistent evidence' suggesting that animal fats are a cause of colorectal cancer.[192]

The World Cancer Research Fund report recommends a public health goal of consumption of no more than 43 g of red meat per day (300 g per week), with a personal goal of less than 71 g per day (500 g per week), 'very little if any to be processed.'[193] It recommends a diet composed mostly of 'foods of plant origin' with a public health goal of 600 g non-starchy vegetables and fruit daily and a personal recommendation of at least 400 g daily.[193]

Evidence on the link between meat and chronic disease (particularly cancer) is increasing annually. An expert review on cancer prevention from the University of Texas Anderson Cancer Center in 2008 concluded that 30-35% of all cancers are diet related and that three of the most important factors in cancer prevention are increased consumption of fruit and vegetables, 'minimal' meat consumption and use of whole grains. The title of the review gives the message: 'Cancer is a preventable disease that requires major lifestyle changes.'[194] Research from the San Diego School of Medicine published in late 2008 found additional evidence that consumption of red meat and milk can encourage the growth of tumours. This occurs through an inflammatory mechanism caused by a specific molecule that is found in meat and milk products.[195]

Factory farming has led to the situation where people in rich countries are encouraged to eat excessive quantities of animal protein and animal fat, often greater than the real dietary requirement. This situation needs to be reversed by a planned reduction in the proportion of animal-based foods and an increase in the proportion of plant-based foods in the diet, combined with other measures such as public education and food labelling.

PART 3. SUSTAINABLE ALTERNATIVES TO FACTORY FARMING FOR 2050

This report has shown that factory farming is an inefficient use of land, water and energy and imposes a large number of costs. These include costs to the environment from the emission of greenhouse gases, water pollution and depletion, soil damage and loss of biodiversity; costs to public health through foodborne infections, pollution and diet related disease; and costs to animal health and welfare.

For these two reasons – unsustainable resource use and unsustainable costs to the environment, public health and animal welfare – it is urgent that we develop resource-light alternatives to factory farming that will be in place well before 2050.

The essential first step towards a sustainable system of animal production is for populations in developed countries to lead the way by reducing their consumption of meat and dairy products. A 2009 report on *The Feeding of the Nine Billion* from Chatham House, the London think-tank, has concluded: 'People in developed countries need to recognise the huge impact that their lifestyles have on the rest of the world, especially in the context of global food markets. In addition to the growing use of biofuels, western diets – full of meat and dairy products – are massively inefficient in terms of water, energy and grain use, and produce more CO_2 as well…Fundamental questions of fairness are at stake.'[23]

10. The global benefits of ending factory farming

The world can make important savings in resources and can start to reverse the damage done by factory farming by taking action from today. When developed countries start to reduce their over-production and over-consumption of animal products and move to more extensive animal production systems, the world as a whole will be able to make large energy savings, use water resources more sustainably, improve soil quality and carbon storage, mitigate climate change, reduce dependence on synthetic fertilisers, reduce pollution, better protect biodiversity, improve human health and greatly improve the welfare of farmed animals. The following are examples of some of the benefits that would result from this action.

10.1 Savings in energy and water use

Organic farming provides considerable energy savings per kilogramme of product compared to conventional high-input farming (Table 11).[196]

Table 11. Change in energy use for selected products as a result of organic farming, compared to non-organic farming in the UK. Source: Soil Association, 2007[196]

Product	Percent change in energy use in organic farming, compared to non-organic farming (MJ/t)
Milk	38% less
Beef	35% less
Lamb	20% less
Pigmeat	13% less
Wheat	29% less
Oilseed rape	25% less

Organic production of eggs and chickenmeat uses somewhat more energy than in conventional industrial poultry production (eggs 14% more, chickenmeat 32% more), but this is because factory-farmed hens and meat chickens are kept in conditions that most consumers find unacceptable in terms of animal welfare. Factory farmed laying hens are often confined in barren battery cages and factory farmed meat chickens are crowded into broiler sheds and fast-grown to their slaughter weight in half the lifetime of organic chickens. These factory-style methods may reduce the energy input required in production but cause immense animal suffering. They cannot therefore have any place in a sustainable food system.

Industrial farming is dependent on inputs of energy-intensive and costly fertiliser and pesticides to grow animal feed. Low-input and extensive farming systems are likely to be more economically viable, as well as more sustainable, in the era of high commodity prices that the world has now entered. The Soil Association has calculated that if energy prices are high, the profits per hectare of non-organic agriculture are affected more than the profits of organic agriculture. With an oil price of £200 per barrel, UK organic farmers would make more profit per hectare than non-organic farmers, because of their lower energy consumption.[197] Low-input, extensive animal production is also more profitable at a time of high commodity prices as feed costs may be lower and the health and robustness of the animals would be improved.

Reducing factory-farmed animal production would help to conserve global water resources. Extensive production of livestock on rain-fed natural pasture can be a sustainable method of food production, provided that the carrying capacity of the pasture-land is not exceeded and that the pasture is not the result of deforestation. The International Water Management Institute (IWMI) has concluded that low-input animal farming is a more sustainable user of water than meat production systems that rely on growing animal feed. According to the IWMI, 'From a water perspective grazing is probably the best option.'[112]

10.2 Protecting soil and climate

There is increasing evidence that a switch to extensive farming would help protect against climate change. The Food Climate Research Network has pointed out that grazing land has a greater ability to store carbon (carbon sequestration), and hence reduce GHG emissions, than has land ploughed for feedcrops.[64] The world's pasture and rangeland has the potential to store almost as much carbon as is stored in the world's forests. Improved pasture management (such as planting trees and avoiding overgrazing) could be an important contribution to reducing GHG emissions via carbon storage.[198ab] Keeping fewer and lower-yielding animals on well-managed pasture can be more 'efficient' from an environmental point of view than growing feed crops in order to produce higher yields from the animals.

Calculations in 2009 by climate scientists in the Netherlands have shown that reducing global meat consumption could free up 1 million km^2 of cropland and 27 million km^2 of pasture that could be used to store large amounts of carbon as the vegetation regrows. The scientists estimated that if the world made a global transition to a healthy low-meat diet during the period 2010–2030, this would reduce by 50% the cost of the climate mitigation measures that we need to undertake in the period up to 2050. The low-meat diet was based on healthy eating guidelines from Harvard Medical School and would therefore also have significant global health benefits.[198c]

Lower-input farming systems using manure or legumes rather than synthetic fertiliser, maintain the quality of soil and improve its long-term fertility.[198d] Factory farming, with its high demand for animal feed grains, is a major factor in the continuous intensive use of arable land for cereal production and the abandonment of crop rotations that maintain soil quality.[199] The over use of arable land for cereals can lead to even greater dependence on mineral fertilisers and pesticides in order to maintain yields on degraded soil.

10.3 Reduced dependence on synthetic fertilisers

Livestock feedgrain production is responsible for heavy global use of synthetic nitrogen fertiliser. Synthetic nitrogen demands large quantities of fossil fuel energy to produce; the manufacture and use of nitrogen fertiliser is a cause of GHG emissions (nitrous oxide and carbon dioxide); its use results in pollution of soil and water. Australian crop and environmental scientists have demonstrated how a reduction in the amount of meat in diets would free up large amounts of land from continuous grain production and allow more land-expensive but more sustainable legume/grain rotations. On the basis of their calculations, if meat consumption were reduced to 10% of the total protein requirements in human diets, a large number of European countries, including France, Germany, Ireland, Italy, probably the UK, and the United States could eliminate their dependence on N fertiliser for grain production, and many other countries could significantly reduce their fertiliser dependence.[199]

Conventional intensive crop production is also dangerously dependent on phosphorus fertiliser, which is a finite resource. Phosphorus is likely to run out later this century, seriously reducing crop yields even without the impact of climate change. At the current rate of consumption alone, the known deposits of phosphorus will be used up in around 64 years from now. Research by the University of Newcastle, UK, under the EU's Quality Low Input Food Programme, shows that as phosphorus becomes less available and finally runs out, the yield of intensively produced wheat could halve by the end of the century.[200] The yield of organic wheat, which does not use mineral fertiliser, would not be reduced.

10.4 Better animal welfare

A planned and well-managed reduction in the size of the animal production industries in developed countries would lead to immense improvements in the welfare of farmed animals. This is because it would enable farmers to use more extensive animal production systems that have a much higher potential for good animal welfare.

Organic, free-range and well-managed semi-intensive indoor systems provide the animals with a number of very important welfare advantages that they are denied in intensive and industrial systems. These include sufficient space for exercise; access to daylight and fresh air; opportunity for natural behaviour such as foraging, exploration and nesting; and reduction in the frustration, stress and injuries that result from overcrowding in sheds or feedlots or from close confinement in cages and crates. Animals that are under less pressure to grow rapidly and produce the highest yields are also likely to be more robust and have longer productive lifetimes. Successful small scale and extensive animal farming systems also have social and economic benefits to human society in terms of maintaining rural employment, personal autonomy and local communities.

Agricultural policymakers are increasingly seeing the value of non-industrial and higher-welfare animal production. The 2008 Pew Commission report on United States meat production, *Putting Meat on the Table*, was highly critical of the impact of factory farming on the environment, the social fabric of rural America, human health and animal welfare and concluded that, 'confined animal production systems in common use today fall short of current ethical and societal standards.'[139] The Pew Commission recommended phasing out 'the most intensive and inhumane production practices within a decade,' including gestation crates (sow stalls), farrowing crates, battery cages and the individual housing of calves for veal production (as in veal crates).[139]

The International Finance Corporation (IFC) in 2006 issued a *Good Practice Note: Animal Welfare in Livestock Operations* that linked better animal welfare with better food production. The IFC stated: 'Animal welfare is gaining increased recognition as an important element of commercial livestock operations around the world…Animal welfare is just as important to humans for reasons of food security and nutrition.
Better management of and care for livestock can improve productivity and food quality, thereby helping to address nutritional deficiencies and food shortages as well as ensuring food safety.'[201]

10.5 Better allocation of resources and lower external costs

Up to now, livestock production in much of the world has not had to pay the full costs of its activities, such as the costs resulting from its impacts on the environment and on human health. As a result of ignoring these external costs, factory farmed products have appeared to be 'low cost' food. As this report has shown, factory farmed products are actually very costly in both resources and impacts and their price to the consumer should reflect this fact. Smaller-scale, extensive animal farming would be able to provide adequate quantities of meat, milk and eggs from a lower use of resources and generate lower external costs.

Table 12. Reduction in external costs achievable by organic production.
Source: Pretty *et al.*, 2005.[120]

Product	External costs of organic production as a percentage of external costs of conventional production per kg (%)
Beef	18.7
Pigmeat	29.6
Poultrymeat	33.6
Eggs	36.4
Milk	42.6

Agriculture and food policy scientists have calculated that organic farming could achieve very large reductions in the external costs of meat, milk and eggs, compared to conventional intensive production. For pig and poultrymeat, the external costs of organic production are only 30-34% as much as the external costs of conventional (intensive) production (Table 12).[120]

10.6 Checklist for a sustainable food system

A sustainable global food system for the period up to 2050 needs to meet several conditions that have been discussed in this report. Such a system needs to:

- Provide a nutritionally adequate food supply for all of the 6.7 billion people alive today and for the 9.2 billion people who will be alive in 2050
- Reduce greenhouse gas emissions in rich countries by 30% compared to 2005 by 2020 and by at least 80% by 2050
- Minimise the use of natural resources of land, water and energy and avoid over-exploitation or degradation of these resources
- Protect wildlife habitats and biodiversity
- Ensure that the economic costs of food production, including the price of animal products, include the full cost of resources used (land, water, energy and waste sinks)
- Ensure that the economic costs of food production, including the price of animal products, include the full external costs of production to society, environment and animals (climate, pollution, land degradation, deforestation for soya feed production, damage to biodiversity, human health and animal welfare)
- Be equitable and remove the present gross disparities in the food supply available to rich countries compared to the poorest countries
- Support employment and the local economy in rural communities
- Provide a diet that promotes human health and prevents the diseases associated with undernutrition, overnutrition and pathogens transmitted from livestock
- Promote the positive physical and mental well-being of farmed animals and avoid animal suffering

A food system that produces meat, milk and eggs from low-input, extensive farming systems would be capable of meeting all of these goals. A food system based on factory farming will be unable to meet the majority of these goals.

11. The choice ahead

In April 2008 the International Assessment of Agricultural Science and Technology for Development concluded: ***'The way the world grows its food will have to change radically to better serve the poor and hungry if the world is to cope with a growing population and climate change while avoiding social breakdown and environmental collapse.'***[203a-b]

Food will need to be produced within constraints of less water, less land, scarcer energy supplies, conflicts over land policy, decreasing biodiversity, a changing climate and an urgent need to reduce greenhouse gas emissions.

In the next decade we still have the choice of whether to continue on the path of high meat consumption and factory farming. Alternatively we could choose to move to a food production system that is sustainable for people and the environment and that respects animal welfare. As we have seen, to continue on the factory farming path will involve huge waste of resources, increasing greenhouse gas emissions, undernutrition and overnutrition, with their attendant diseases, and a devastation of biodiversity.

On the other hand, the circumstances of population growth, Peak Oil and climate change are likely to make factory farming unviable by 2050, if not earlier, and thus make the choice for us. This could leave the world food system disrupted and struggling to adjust to the new circumstances.

We need to reduce the pressure on natural resources and the environment globally. Factory farming and the over-production of livestock in developed countries are a major cause, directly and indirectly, of the current over-exploitation of resources. Starting within a decade, a planned and government-supported move to a smaller and more extensively managed animal production industry in developed countries will allow us to maximise our sustainable use of natural resources for food production. It will also allow us to minimise the economic, social and environmental disruption that climate change scientists and economists now believe is inevitable. A reduction in the size of the livestock industry would enable farmers to produce fewer livestock but to keep them at a lower stocking density with access to the outdoors and would greatly reduce the quantity of land, water and energy needed to produce their feed.

In the interests of global equity, and in order not to disadvantage people in poorer countries who currently eat very little meat, Compassion in World Farming supports a strategy of 'contraction and convergence.'[9] Rich countries need to reduce their consumption of animal products by around 60%, allowing poorer countries to increase their consumption to meet their dietary needs.

The reorientation of our food production system needs to be achieved urgently, to stabilise and then reduce food prices in poorer countries, to meet climate change targets, to prevent possibly irreversible damage to the world's environment and biodiversity in the coming decades and to reverse the damage done to public health by overconsumption of animal protein and animal fats.

CONCLUSIONS AND RECOMMENDATIONS

Why change is urgent: a summary

Food supply

Over one billion people are short of food, while developed countries use up to 70% of their cereal harvest for animal feed and waste around one-third of food produced. The world population is predicted to be 7.7 billion in 2020, around one billion more than today, and 9.2 billion in 2050. Within the next 10-20 years we need to have put a farming system in place that is capable of feeding 7-9 billion people effectively from fewer resources.

Climate change is very likely to disrupt food production during this century. We can expect that crop yields will be reduced and farmland will be damaged or lost due to flooding or rising sea levels. The use of up to 40% of the world's cereal harvest[7] and 15%[92] of the world's irrigation water to produce livestock feed is not a sustainable food strategy. **A reduction in meat consumption in developed countries, starting within the next 10 years, would make an important contribution to freeing up global resources of land and water, reducing global food prices and increasing the world supply of food energy available for human use.**

Climate change

We need to start cutting greenhouse gas emissions from today in order to prevent catastrophic levels of global warming later this century. Global emissions need to peak by 2016 and then be reduced by 5% per year.[204] A continued expansion of factory farming up to 2050 will greatly increase rather than reduce GHG emissions. Reducing meat consumption is equivalent in carbon savings to an individual cutting out hundreds of kilometres of car travel[205] or switching to a carbon-efficient hybrid car[77] and could reduce climate mitigation costs up to 2050 by 50%.[198] **The most effective way to start to bring global livestock-related emissions under control within the next 10 years is a managed reduction in the production and consumption of meat and dairy products in developed countries.**

Peak Oil

There is an urgent need to reduce energy use. Oil and gas output will peak in the period 2010 to 2020 and by 2050 output may be half of what it is today.[24] Fossil fuel dependence in rich countries needs to be ended within a timescale of less than 20 years.[26] Intensive agricultural production uses very much larger amounts of energy than low-input farming. In addition, the energy needed to produce meat is disproportionately high compared to the energy needed to produce plant crops. **A reduction in meat production and consumption in rich countries over the next 10 to 20 years would enable farmers to move to more extensive, low-input animal farming and would make a significant contribution to reducing global energy use.**

Deforestation

Deforestation is an important cause of global warming. Livestock-related deforestation is mainly occurring in South America, where the demand for animal feed for intensive farms will continue to be a driving factor in forest destruction. **A reduction in the size and intensification of the livestock industry in developed countries, starting within a decade, would make an immediate impact to discourage deforestation.**

Biodiversity

The world is living through an extinction crisis as a result of human activities. Livestock production is one of the main global threats to biodiversity through its associated changes in land use, intensification of arable production for animal feed, pollution of soil and water and impact on climate change. **The transition to a low meat diet and a scaled-down and more extensive livestock industry in developed countries would make a major contribution to reducing damage to habitats and species globally.**

Public health

The world is experiencing a very costly epidemic of overweight and obesity, leading to an increased burden of chronic disease such as diabetes, heart disease, cancer, and consequent human suffering. Consumption of energy-dense foods containing saturated fats, such as meat and dairy products, is known to be an important factor in this epidemic. **An increase in the proportion of plant-based foods and a corresponding reduction in the proportion of animal products in the diet of people in rich countries would make an immediate contribution to improving the future health of the generation of children born today.**

Food inequality

Inequalities in food supply between rich and poor countries are likely to exacerbate the social tensions that are expected as a result of population growth and climate change. According to the UN Secretary General: 'Hunger, especially when man-made…breeds anger, social disintegration, ill-health and economic decline.'[206] Factory farming and the overconsumption of animal products in rich countries are man-made contributions to the world's food inequalities. The supply of animal products in the diet accounts for more than 1000 kcal per person per day in the United States and only 96 kcal per person per day in Ethiopia (based on 2003 statistics)[10] **A more equitable global food system, including a proportionate reduction in meat consumption in developed countries, needs to be developed within the next 10 years.**

Animal welfare

The predicted doubling of animal production up to 2050 would subject billions of additional animals to suffering in factory farms. Protecting farm animal welfare is nominally a public policy goal in most developed countries, notably the countries of the European Union. This ambition to improve animal welfare is incompatible with the continuation or expansion of factory farming. **A reduction in the production and consumption of animal products in rich countries within the next 10 years would enable farmers to switch to a range of less intensive, more welfare-friendly production systems and to give a lead in improving animal welfare to the rest of the world.**

Milestones for change

Animal production methods that respect both the environment and the welfare needs of animals can provide adequate nutrition for the growing human population and sustainable incomes for the world's farmers. This can be done while avoiding the very large costs (inputs and externalities) associated with factory farming. A reduction in meat production and consumption in developed countries, where there is already considerable overconsumption of meat and animal products, would enable us to make this essential change in farming practice. Meat reduction is one of the quickest and most effective measures that individuals or policymakers in developed countries can take, in order to tackle some of the world's most urgent problems related to food production, climate, the environment and public health.

For the reasons set out in this report, Compassion in World Farming believes that the transition to a more extensive animal production industry in developed countries needs to begin now and to become part of mainstream public policy during the next five to 15 years.

RECOMMENDATIONS FOR A SUSTAINABLE FUTURE

Compassion in World Farming recommends that the following approaches adopted in developed countries would enable us to create a sustainable, fair and humane animal production system by 2050:

- The production and consumption of livestock in developed countries needs to be reduced. A realistic target for reduction by 2020 would be 30% below current levels. A realistic reduction by 2050 would be 60-80% below current levels. These proposed reductions are in line with EU and UK greenhouse gas reduction targets up to 2020 and are also in line with dietary targets. These steps should be taken in addition to other essential livestock-related climate mitigation measures, such as halting deforestation, better fertiliser and manure management and switching to renewable energy sources on farm. These will help to meet the total UK climate target applicable to livestock by 2050 (a reduction to 80% below 2005 levels).
- Governmental and intergovernmental targets and incentives for both farmers and consumers are needed to support the transition to sustainable livestock production. These would include the agreement of international standards for the welfare of farmed animals and protection for the purchasing power of low-income consumers. Imported products would need to meet the welfare standards of the importing country.
- A recognition is needed that meat and milk are currently underpriced in relation to their real environmental and carbon costs and their impact on public health. Fiscal disincentives to over-production and factory farming need to be introduced, according to the 'polluter pays' principle. These could include green taxes and the pricing of factory farmed products to take full account of all external costs such as greenhouse gas emissions, deforestation, land and water use, pollution, soil damage and public health.
- A government-supported meat reduction strategy is needed which would enable farmers to reduce animal stocking densities and move from intensive to more extensive methods. Farmers need to be supported in raising animal welfare standards to the best free-range and organic farming standards of today, while protecting rural livelihoods.
- Encouragement is needed for food manufacturers, retailers and caterers in the food industry to support extensive high-welfare animal farming, to educate consumers about saturated fat in animal products and to partially substitute for meat in processed foods and undertake other meat-reduction strategies.
- All proposed climate mitigation measures should be screened for their impact on animal health and welfare. These measures include the various interventions intended to reduce digestive methane emissions (such as feeding more concentrates, feed additives, antibiotics, vaccinations and genetic engineering) and the intensification of animal breeding and management. It is unacceptable to make animals pay with their welfare for the climate impact of factory farming and the over-production of livestock products. The acceptable and more effective alternative is to reduce the volume and intensity of animal production.

REFERENCES

[1] Smil, V., 2000. *Feeding the world: a challenge for the twenty-first century.* MIT Press.

[2] Hoekstra, A. Y., Chapagain, A. K., 2007. Water footprints of nations: Water use by people as a function of their consumption pattern. *Water Resources Management*, 21:35–48. DOI 10.1007/s11269-006-9039-x.

[3] Liu, J. Savenije, H. H. G., 2008. Food consumption patterns and their effect on water requirement in China. *Hydrol. Earth Syst Sci* 12:887-898. www.hydrol-earth-syst-sci.net/12/887/2008

[4] IAASTD, 2008. Global summary for decision makers. http://www.agassessment.org/docs/Global_SDM_060608_English.pdf

[5] Pimentel, D. *et al.*, 2008. Reducing energy inputs in the United States food system. *Human Ecology* 36:459-471. DOI 10.1007/s10745-008-9184-3.

[6] Steinfeld, H. *et al.*, 2006. *Livestock's Long Shadow: environmental issues and options.*
Food and Agriculture Organisation of the United Nations. Rome.
http://www.fao.org/docrep/010/a0701e/a0701e00.htm

[7] Lundqvist, J., de Fraiture, C. Molden, D., 2008. Saving Water: From Field to Fork – Curbing Losses and Wastage in the Food Chain.
SIWI Policy Brief. SIWI.
http://www.siwi.org/documents/Resources/Policy_Briefs/PB_From_Filed_to_Fork_2008.pdf

[8] IPCC.: *Climate Change 2001:. Mitigation of climate change. Technical summary.* A report of Working Group III of the Intergovernmental Panel on Climate Change. Section 3.3.4.
www.ipcc.ch/pub/un/syreng/wg3ts.pdf

[9] McMichael, A. J., Powles, J. W., Butler, C., Uauy, R., 2007. Food, livestock production, energy, climate change, and health. The Lancet. Published online 13 September 2007. DOI:10.1015/S0140-6736(07)61256-2.

[10] FAOSTAT. Online database. Food and Agriculture Organisation of the United Nations (FAO).
http://faostat.fao.org/default.aspx

[11] Stern review: the economics of climate change. HM Treasury and Cabinet Office. 2006. Part II, chapters 3 and 4.
http://www.hm-treasury.gov.uk/sternreview_index.htm

[12] Stern review: the economics of climate change. HM Treasury and Cabinet Office. 2006. Part II, chapter 5.
http://www.hm-treasury.gov.uk/sternreview_index.htm

[13] Chenoweth, J., 2008. Looming water crisis is simply a management problem. New Scientist 20 August 2008, 28-32.

[14] IAASTD, 2008. Global summary for decision makers.
http://www.agassessment.org/docs/Global_SDM_060608_English.pdf

[15] von Braun, J., 2009. The world food situation: new driving forces and required actions. IFPRI, Washington DC, December 2007.
http://www.ifpri.org/pubs/fpr/pr18.pdf
FAO. Farming must change to feed the world. Press release 4 February 2009.
http://www.fao.org/news/story/en/item/9962/icode/

[16] Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, *World Population Prospects: The 2006 Revision and World Urbanization Prospects: The 2005 Revision*.
http://esa.un.org/unpp

[17] Cabinet Office, 2008. The Strategy Unit. *Food Matters: towards a strategy for the 21st century.* Executive Summary.
http://www.cabinetoffice.gov.uk/strategy/work_areas/food_policy.aspx

[18] Steinfeld, H. *et al.*, 2006. Livestock's Long Shadow: environmental issues and options. Food and Agriculture Organisation of the United Nations. Rome. Pages iii and 15.
http://www.fao.org/docrep/010/a0701e/a0701e00.htm

[19] The Rights and Resources Initiative (RRI), 2008. *Seeing people through the trees.* RRI Washington DC.
http://www.rightsandresources.org/documents/files/doc_737.pdf
Science Daily. Record land grab predicted. 15 July 2008.
http://www.sciencedaily.com/releases/2008/07/080714092746.htm

[20] Pachauri, R. K., 2008. Global warning! *The impact of meat production and consumption on climate change.* CIWF Peter Roberts Memorial Lecture. London, 8 September 2008.
http://www.ciwf.org.uk/includes/documents/cm_docs/2008/l/1_london_08sept08.pps

[21] Trostle, R., 2008. *Global agricultural supply and demand: factors contributing to the recent increase in food commodity prices.* USDA ERS May/July 2008.
http://www.ers.usda.gov/Publications/WRS0801/WRS0801.pdf

[22] Stevens P., 2008. *The coming oil supply crunch*, Royal Institute of International Affairs, Chatham House.
http://www.chathamhouse.org.uk/files/11937_0808oilcrunch.pdf

[23] Evans, A., 2009. *The feeding of the 9 billion: global food security for the 21st century.* Chatham House.
http://www.chathamhouse.org.uk/files/13179_r0109food.pdf

[24] Association for the Study of Peak Oil (ASPO) (http://www.peakoil.net/). *Newsletter 91*, July 2008.
http://www.energiekrise.de/e/aspo_news/aspo.html

[25] National Petroleum Council, 2007. *Summary discussions on peak oil*. Working document of the NPC Global Oil & Gas Study. Topic Paper #15.
http://downloadcenter.connectlive.com/events/npc071807/pdf-downloads/Study_Topic_Papers/15-STG-Peak-Oil-Discussions.pdf

[26] UK Industry Taskforce on Peak Oil & Energy Security (ITPOES), 2008. *The Oil Crunch. Securing the UK's Energy Future*.
http://peakoil.solarcentury.com/wp-content/uploads/2008/10/oil-report-final.pdf

[27] Peak Oil Task Force, Office of Sustainable Development, City of Portland, Oregon, 2007. *Descending the Oil Peak: Managing the Transition from Oil and Natural Gas.*
http://www.portlandonline.com/osd/index.cfm?c=42894&a=150016

[28] Porter, A., 2005. "Peak oil" enters mainstream debate.' *BBC News online*. 10 June.
http://news.bbc.co.uk/1/hi/business/4077802.stm

[29a] International Energy Agency (IEA), 2008. *World Energy Outlook*. Factsheets.
http://www.worldenergyoutlook.org/docs/weo2008/fact_sheets_08.pdf

[29b] International Energy Agency (IEA). New Energy Realities - WEO Calls for Global Energy Revolution Despite Economic Crisis. Press release, 12 November 2008.
http://www.iea.org/Textbase/press/pressdetail.asp?PRESS_REL_ID=275

[30] Macalister, T., Monbiot, G., 2008. Global oil supply will peak in 2020, says energy agency. *Guardian*, 15 December.
http://www.guardian.co.uk/business/2008/dec/15/global-oil-supply-peak-2020-prediction

[31] World Bank, 2007. *World Development Report 2008. Agriculture for Development*, Chpt. 2.
http://siteresources.worldbank.org/INTWDR2008/Resources/2795087-1192112387976/WDR08_04_ch02.pdf

[32a] Battisti, D. S.,Naylor, R. L., 2009. Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat. *Science* 323:240 – 244. DOI: 10.1126/science.1164363.

[32b] Half Of World's Population Could Face Climate-induced Food Crisis By 2100. *Science Daily*. 9 January 2009.
http://www.sciencedaily.com/releases/2009/01/090108144745.htm

[33] Stern review: the economics of climate change. HM Treasury and Cabinet Office. 2006. Part II, chapter 4.
http://www.hm-treasury.gov.uk/sternreview_index.htm

[34] Galloway, J. N. *et al.*, 2007. International trade in meat: the tip of the pork chop. *Ambio* 36(8):622-629. DOI: 10.1579/00447447(2007)36[622:ITIMTT]2.0.CO;2.

[35] von Braun, J., 2008. Food prices, biofuels and climate change. Presentation. IFPRI.
http://www.ifpri.org/presentations/200802jvbbiofuels.pdf

[36] FAO, 2006. *State of World Fisheries and Aquaculture*.
http://www.fao.org/docrep/009/a0699e/A0699E00.htm

[37] WorldWatch Institute, 2004. *State of the World 2004*.

[38] FAO. *Protecting Animal Genetic Diversity for Food and Agriculture. Time for Action*. Animal genetic resources group, FAO, Rome. n.d. http://dad.fao.org/cgibin/getblob.cgi?sid=230b173a68b7f2af6efeca2d4a86b12e,1

[39] World Bank, 2007. *World Development Report 2008*. Agriculture for Development. Overview. http://siteresources.worldbank.org/INTWDR2008/Resources/27950871192112387976/WDR08_01_Overview.pdf

[40a] FAO, 2006. Global Perspective Studies Unit. World agriculture: towards 2030/2050. Interim report. http://www.fao.org/es/esd/AT2050web.pdf

[40b] Halweil B. *Vital signs update: meat production continues to rise*. World Watch Institute. 20 August 2008. http://www.worldwatch.org/node/5443?emc=el&m=136135&l=5&v=33ac6ed814

[41] Knowles, T.G. *et al.*, 2008. Leg disorders in broiler chickens: prevalence, risk factors and prevention. *PLoS ONE* 3(2): e1545. doi:10.1371/journal.pone.0001545.

[42a] Weeks, C. Butterworth, A., eds., 2004. *Measuring and Auditing Broiler Welfare.* Oxford University Press.

[42b] Scientific Committee on Animal Health and Animal Welfare, 2000. *The Welfare of Chickens Kept for Meat Production (Broilers*). European Commission.

[42c] Whitehead, C. C. *et al.*, 2003. Skeletal problems associated with selection for increased production. *Poultry Genetics, Breeding and Biotechnology*, Muir, W. M. and Aggrey, S. E. eds. CABI Publishing.

[42d] Whay, H. R. *et al.*, 2003. Assessment of dairy cattle welfare using animal-based measurements. *Veterinary Record*, 153:197-202.

[42e] Bradley, A. J. *et al.*, 2007. Survey of the incidence and aetiology of mastitis on dairy farms in England and Wales. *Veterinary Record*, 160:253-258.

[42f] Scientific Panel on Animal Health and Welfare, EFSA, 2007. Opinion and Report related to animal health and welfare in fattening pigs in relation to housing and husbandry. Annex to the EFSA Journal 564:1-14. http://www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1178654659432.htm

[42g] Pickett, H., 2007. *Alternatives to the barren battery cage for the housing of laying hens in the European Union.* Compassion in World Farming. http://www.ciwf.org.uk/includes/documents/cm_docs/2008/a/alternatives_to_the_barren_battery_cage_in_the_eu.pdf

[43] FAO, 2007. *The State of the World's Animal Genetic Resources for Food and Agriculture*. Rischkowsky, B. and Pilling, D. eds. Rome. http://www.fao.org/docrep/010/a1250e/a1250e00.htm

[44] BBC News, 2007. Livestock breeds face 'meltdown.' 2 September. http://news.bbc.co.uk/1/hi/sci/tech/6976322.stm

[45] Hoffman, I., 2008. Livestock genetic diversity and climate change adaptation. Presentation at Livestock & Global Climate Change Conference Hammamet, Tunisia, 17-20 May. http://www.bsas.org.uk/downloads/pp/LGCC_08_22_Hoffmann.pdf

[46a] Muir, W. M. *et al.*, 2008. Genome-wide assessment of worldwide chicken SNP genetic diversity indicates significant absence of rare alleles in commercial breeds. *Proceedings of the National Academy of Sciences (PNAS)* 105(45): 17312–17317.

[46b] McKenzie, D., 2008. Chicken genome plucked bare by inbreeding. *New Scientist* online 4th November (Print edition 8th November 2008, p7). http://www.newscientist.com/article/dn15122-chicken-genome-plucked-bare-byinbreeding.html?DCMP=ILC-hmts&nsref=news4_head_dn15122

[47] Rauw, W. M. *et al.*, 1998. Undesirable side effects of selection for high production efficiency infarm animals: a review. *Livestock Production Science* 56: 15-33.

[48] Sørensen, A. C., *et al.*, 2006. Udder Health Shows Inbreeding Depression in Danish Holsteins *Journal of. Dairy Science* 89:4077-4082.

[49] Yunis, R. *et al.*, 2002. Antibody responses and morbidity following infection with infectious bronchitis virus and challenge with Escherichia coli, in lines divergently selected on antibody response. *Poultry Science* 81:149-159.

[50] European Food Safety Authority (EFSA), 2007. *DRAFT Scientific Opinion on Food Safety, Animal Health and Welfare and Environmental Impact of Animals x 1 derived from Cloning by Somatic Cell Nucleus Transfer (SCNT) and their Offspring and Products Obtained from those Animals*. Endorsed for consultation 19 December 2007. http://www.efsa.europa.eu/cs/BlobServer/DocumentSet/sc_opinion_clon_public_consultation.pdf

[51] United States Food and Drug Administration (FDA), 2008. Animal cloning: a Risk Assessment – Final. January 2008.
http://www.fda.gov/cvm/CloneRiskAssessment_Final.htm

[52] United States Food and Drug Administration, 2009. FDA Issues Final Guidance on Regulating Genetically Engineered Animals. 15 January 2009.
http://www.fda.gov/bbs/topics/news/2009/new01944.html

[53] Poulter, S., 2008. Eight 'clone farm' cows born in Britain - and their meat could be on sale in months. *Daily Mail*, June 6.
http://www.mailonsunday.co.uk/news/article-1024578/Eight-clone-farm-cows-born-Britain--meat-sale-months.html

[54a] The Royal Society, 2001. The use of genetically modified animals.
http://royalsociety.org/displaypagedoc.asp?id=11513

[54b] Compassion in World Farming, 2002. *The gene and the stable door: genetic engineering and farm animals*.
http://www.ciwf.org.uk/includes/documents/cm_docs/2008/t/the_gene_and_the_stable_door_2002.pdf

[55] D'Silva, J., 2007. Animal Welfare Perspectives on the Ethics of Cloning Farm Animals for Food. European Group on Ethics in Science and New Technologies Roundtable on the ethical aspects of Animal cloning for food supply. 24-25 September 2007. Brussels.
http://www.ciwf.org/publications/reports/animal-welfare-perspectives-ethics-of-cloning-for-food.pdf

[56] United States Food and Drug Administration (FDA), 2008. Animal cloning: a Risk Assessment – Final. Chap 1 Exec Summary.
http://www.fda.gov/cvm/CloneRiskAssessment_Final.htm

[57] European Group on Ethics in Science and New Technologies to the European Commission, 2008. Ethical aspects of animal cloning for food supply. Opinion no. 23.
http://ec.europa.eu/european_group_ethics/activities/docs/opinion23_en.pdf

[58] Stern Review: the economics of climate change, 2006. HM Treasury and Cabinet Office. Part III, chapter 7.
http://www.hm-treasury.gov.uk/sternreview_index.htm

[59] Greenpeace, 2006. *Eating up the Amazon*.
http://www.greenpeace.org.uk/files/pdfs/migrated/MultimediaFiles/Live/FullReport/7555.pdf

[60] Steinfeld, H. *et al.*, Livestock's Long Shadow: environmental issues and options. Chapter 2. Food and Agriculture Organisation of the United Nations. Rome. 2006.
http://www.fao.org/docrep/010/a0701e/a0701e00.htm

[61] BBC Television, 2008. *Panorama. Can Money Grow on Trees?* 8 September.

[62] Dros, M. J., 2004 *Managing the soy boom*. WWF.
http://assets.panda.org/downloads/managingthesoyboomenglish_nbvt.pdf

[63] van Gelder, J. W., Kammeraat, K.,Kroes, H., 2008. *Soy consumption for feed and fuel in the European Union*. Friends of the Earth Netherlands.
http://www.foeeurope.org/agrofuels/index.html and http://www.foeeurope.org/agrofuels/FFE/Profundo%20report%20final.pdf

[64] Garnett, T., 2007. *Meat and dairy production and consumption*. Working paper for the Food Climate Research Network, Centre for Environmental Strategy, University of Surrey.
http://www.fcrn.org.uk/frcnResearch/publications/PDFs/TG%20FCRN%20livestock%20final%206%20Nov%20.pdf

[65] United States Environmental Protection Agency (US-EPA), 2006. *Global Anthropogenic Greenhouse Gas Emissions: 1990 – 2020*.
http://www.epa.gov/nonco2/econinv/international.html

[66] IPCC, 2007. *Climate Change 2007: Mitigation of Climate Change*. IPCC 4th Assessment report, Working Group III. Chapter 8, Agriculture. Final Draft pre-copy edit version (for revision).
http://www.mnp.nl/ipcc/pages_media/FAR4docs/chapters/CH8_Agriculture.pdf

[67] Steinfeld H *et al.*, *Livestock's Long Shadow: environmental issues and options*. Chapter 3. Food and Agriculture Organisation of the United Nations. Rome. 2006.
http://www.fao.org/docrep/010/a0701e/a0701e00.htm

[68] Draft Climate Change Bill, 2007. Consultation document. Department of Food and Rural Affairs (Defra).

[69a] Department of Energy and Climate Change, 2008. UK leads world with commitment to cut emissions by 80% by 2050. Press release 16 October.
http://nds.coi.gov.uk/environment/fullDetail.asp?ReleaseID=381477&NewsAreaID=2&NavigatedFromDepartment=False

[69b] Committee on Climate Change, 2009. *Carbon budgets*. http://www.theccc.org.uk/carbon-budgets/ Accessed 8 January 2009.

[70] Committee on Climate Change, 2008. *Building a low-carbon economy – the UK's contribution to tackling climate change*. http://www.theccc.org.uk/reports/

[71] Garnett, T., 2008. *Cooking up a Storm: Food, Greenhouse Gas Emissions and our Changing Climate*. Food Climate Research Network, Centre for Environmental Strategy, University of Surrey. http://www.fcrn.org.uk/frcnPubs/publications/PDFs/CuaS_web.pdf

[72] European Commission. Climate Change Campaign. Climate Protection Calendar. Week 47. http://ec.europa.eu/environment/climat/campaign/index_en.htm Accessed 21 November 2008.

[73] Garnett, T., 2007. *Food and Climate Change: the world on a plate*. Food Climate Research Network, University of Surrey. http://www.fcrn.org.uk/frcnresearch/presentations/PDFs/FCRN%20generic%20ppt.ppt

[74] EIPRO, 2006. European Commission. *Environmental impact of products* (EIPRO). Analysis of the life cycle environmental impacts related to the final consumption of the EU-25. http://ec.europa.eu/environment/ipp/pdf/eipro_report.pdf

[75] Kramer, K. J. *et al.*, 1999. Greenhouse gas emissions related to Dutch food consumption, *Energy Policy* 27: 203-216, Elsevier Publications. Cited in Garnett, T., 2007, as references 64 and 73 listed above.

[76a] Garnett, T., 2007. *Food and Climate Change: the world on a plate*. Food Climate Research Network, University of Surrey, and FCRN website information. www.fcrn.org.uk

[76b] Carlsson-Kanyama, A., 1998. Climate change and dietary choices - how can emissions of greenhouse gases from food consumption be reduced? Food Policy, 23(3/4): 277-293. http://www.fcrn.org.uk/frcnresearch/presentations/PDFs/FCRN%20generic%20ppt.ppt

[77] Eshel, G. Martin, P. A., 2006. Diet, energy and global warming. *Earth Interactions*, 10: 1-17. http://geosci.uchicago.edu/~gidon/papers/nutri/nutriEI.pdf and http://geosci.uchicago.edu/~gidon/papers/nutri/nutri.html

[78] Bittman, M., 2008. Re-thinking the meat-guzzler. *New York Times*, 27 January. http://www.nytimes.com/2008/01/27/weekinreview/27bittman.html?_r=1&oref=slogin

[79] Moran, D. *et al.*, 2008. *UK Marginal Abatement Cost Curves for the Agriculture and Land Use, Land-Use Change and Forestry Sectors out to 2022, with Qualitative Analysis of Options to 2050. Final report to Committee on Climate Change*. http://www.theccc.org.uk/reports/ (supporting research) and http://hmccc.s3.amazonaws.com/pdfs/SAC-CCC;%20UK%20MACC%20for%20ALULUCF;%20Final%20Report%202008-11.pdf

[80] Ametaj, B. N. *et al.*, 2008. Backgrounding and finishing diets are associated with inflammatory responses in feedlot steers. *Journal of Animal Science*. Published online first on December 19. doi:10.2527/jas.2008-1196.

[81] Soil Association, 2005. *Soil Association Organic Standards*. Chapter 11.

[82] IPCC, 2007. *Climate Change 2007: Mitigation of Climate Change*. IPCC 4th Assessment report, Working Group III. Chapter 8, Agriculture. Final Draft pre-copy edit version (for revision). http://www.mnp.nl/ipcc/pages_media/FAR4docs/chapters/CH8_Agriculture.pdf

[83] Williams, A.G., Audsley, E. Sandars, D.L., 2006. *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*. Main Report. Defra Research Project IS0205. Bedford. Cranfield University and Defra. www.silsoe.cranfield.ac.uk and www.defra.gov.uk

[84a] RSPCA, 2008. Welfare standards for chickens. http://www.rspca.org.uk/servlet/Satellite?pagename=RSPCA/RSPCARedirect&pg=broilerchickenresourcepage

[84b] EU poultrymeat marketing standards 1993. Commission Regulation (EEC) No 2891/93. L 263/22. Annex IV.

[84c] Soil Association, 2005. *Soil Association Organic Standards*. Chapter 20, Poultry.

[85] Brown, L. R., 2008. *Plan B 3.0: Mobilizing to Save Civilization*. New York: W.W. Norton and Company, Earth Policy Institute. chapter 9. Feeding Eight Billion Well. http://www.earthpolicy.org/Books/PB3/PB3ch9_ss5.htm

[86] Roberts, P., 2008 The End of Food: the coming crisis in the world food industry. Bloomsbury. Citing calculations by the Earth Policy Institute, Ref 85.

[87] Trostle, R., 2008. *Global agricultural supply and demand: factors contributing to the recent increase in food commodity prices*. USDA ERS. http://www.ers.usda.gov/Publications/WRS0801/WRS0801.pdf

[88] USDA, 2007. Food Safety and Inspection Service (FSIS) *Meat Preparation. Water in meat and poultry*. Factsheet. http://www.fsis.usda.gov/Factsheets/Water_in_Meats/index.asp
See also Lymbery, P., 1992. The welfare of farmed fish. Compassion in World Farming. Annex 1.

[89] Alberta Agriculture and Rural Development. Cereal grain drying and storage. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/crop1204
Accessed January 2009.

[90] Gerbens-Leenes, W., Nonhebel, S., 2005. Food and land use. The influence of consumption patterns on the use of agricultural resources. Appetite 45:24-31. doi:10.1016/j.appet.2005.01.011.

[91a] van Oel P R, Mekonnen M M and Hoekstra A Y. *The external water footprint of the Netherlands. Quantification and impact assessment.* UNESCO-Water Education Institute.

[91b] WWF, 2008. Living Planet Report 2008. http://assets.wwf.org.uk/downloads/lpr_2008.pdf

[92] Steinfeld, H. *et al.*, 2006. *Livestock's Long Shadow: environmental issues and options*. Chapter 4. Food and Agriculture Organisation of the United Nations. Rome. http://www.fao.org/docrep/010/a0701e/a0701e00.htm

[93] Chapagain, A., Orr, S., 2008. *UK Water Footprint: the impact of the UK's food and fibre consumption on global water resources*. Volume 2, Appendices. http://assets.wwf.org.uk/downloads/uk_waterfootprint_v2.pdf

[94] Molden, D. *et al.*, 2007. Pathways for increasing agricultural water productivity. International. *Water for Food, Water for Life. A Comprehensive Assessment of Water Management in Agriculture*. Water Management Institute Summary, ed. Molden D. Chapter 7. http://www.iwmi.cgiar.org/assessment/Water%20for%20Food%20Water%20for%20Life/Chapters/Chapter%207%20Water%20Productivity.pdf and http://www.iwmi.cgiar.org/assessment/Publications/books.htm

[95] Pimentel, D., 2006. Impacts of Organic Farming on the Efficiency of Energy Use in Agriculture: An Organic Center State of Science Review. *The Organic Center*. http://www.organic-center.org/reportfiles/ENERGY_SSR.pdf and http://www.organic-center.org/science.pest.php?action=view&report_id=59

[96] Carlsson-Kanyama, A., Pipping Ekström, M., Shanahan, H., 2003. Food and life cycle energy inputs: Consequences of diet and ways to increase efficiency. *Ecological Economic*, 44:293-307, 2003.

[97] FAOSTAT. ProdSTAT database. Primary crops. FAO 2008. http://faostat.fao.org/site/526/default.aspx
ResourceSTAT database. Land. FAO. 2005. http://faostat.fao.org/site/405/default.aspx

[98] Marris, E., 2005. The forgotten ecosystem. *Nature* 437:944-945. doi: 10.1038/437944a.

[99] Steinfeld, H. *et al.*, 2006. *Livestock's Long Shadow: environmental issues and options*. Food and Agriculture Organisation of the United Nations. Rome. Chapter 2. http://www.fao.org/docrep/010/a0701e/a0701e00.html

[100] Blas, J., 2008. Farmland fund to exploit food price boom. *Financial Times*, 14 September. http://www.ft.com/cms/s/0/8521d7ae-8285-11dd-a019-000077b07658.html

[101] Swing, J. T., 2003. What future for the oceans? *Foreign Affairs* 82(5):139-152.

[102] Anthoff, D. *et al.*, 2006. Global and regional exposure to large rises in sea-level: a sensitivity analysis. Supporting research paper for Stern Review. Tyndall Centre for Climate Change Research. http://www.tyndall.ac.uk/publications/working_papers/twp96.pdf

[103a] University of Toronto, 2009. Collapse Of Antarctic Ice Sheet Would Likely Put Washington, D.C. Largely Underwater. *Science Daily*, February 6. http://www.sciencedaily.com/releases/2009/02/090205142132.htm

[103b] Mitrovica J X, Gomez N and Clark P U. The Sea-Level Fingerprint of West Antarctic Collapse. *Science* 323:753. DOI: 10.1126/science. 1166510.

[104] Pachauri, R. J., 2007. *IPCC 4th Assessment. Synthesis report*. Press presentation, Valencia, 17 November. http://www.ipcc.ch/pdf/presentations/valencia-2007-11/pachauri-17-november-2007.pdf

[105a] Clark, P. U., 2008. United States Climate Change Science Program. *Abrupt Climate Change*. Final report, synthesis and assessment product 3.4. Executive Summary and Chapter 2.
http://downloads.climatescience.gov/sap/sap3-4/sap3-4-final-report-exec-sum.pdf
http://www.climatescience.gov/Library/sap/sap3-4/final-report/default.htm#finalreport

[105b] Randerson, J., 2008. Sea level could rise by 150cm, United States scientists warn. *Guardian*, 16 December.
http://www.guardian.co.uk/environment/2008/dec/16/climatechange-scienceofclimatechange

[106] Warren, R. *et al.*, 2006. *Understanding the regional impacts of climate change*. Paper prepared for the Stern Review. Tyndall Centre for Climate Change Research.
http://www.tyndall.ac.uk/publications/working_papers/twp90.pdf

[107a] BBC News online, 2008. South Australia drought worsens. 10 July.
http://news.bbc.co.uk/1/hi/world/asia-pacific/7499036.stm

[107b] Australian farmer, 2008. Our river is dying.
http://news.bbc.co.uk/1/hi/world/asia-pacific/7499739.stm

[108] Lin, E., Zou, J., 2006. Climate change impacts and its economics in China. Stern Review supporting research report.
http://www.hm-treasury.gov.uk/media/8/1/stern_review_china_impacts.pdf

[109] Roy, J. *The economics of climate change. A Review of Studies in the Context of South Asia with a Special Focus on India*. Stern Review supporting research paper. N.d.
http://www.hm-treasury.gov.uk/media/5/0/roy.pdf

[110] *Science Daily*. Expect More Droughts, Heavy Downpours, Excessive Heat, And Intense Hurricanes Due To Global Warming, NOAA. 20 June.
http://www.sciencedaily.com/releases/2008/06/080619175522.htm

[111] Bates, B., *et al.*, 2008. Climate Change and Water. IPCC Technical paper VI. IPCC, WMO and UNEP.
http://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf

[112] International Water Management Institute, 2007. *Water for Food, Water for Life*. A Comprehensive Assessment of Water Management in Agriculture. Summary, ed. Molden, D.
http://www.iwmi.cgiar.org/Assessment/files_new/synthesis/Summary_SynthesisBook.pdf

[113] Liu, J., Yang, H.,Saveniji, H. H. G., 2008. China's move to high-meat diet hits water security. *Nature*, 454:397.

[114] FAO, 2000. *The energy and agriculture nexus*. Environment and natural resources working paper 4. Rome, 2000. Chapter 2. Energy for agriculture.
http://www.fao.org/DOCREP/003/X8054E/x8054e05.htm#P361_53876

[115] Smil, V., 2005. Do we need higher farm yields during the first half of the 21st century? *Yields of Farmed Species*, ed. Sylvester-Bradley R and Wiseman J. Nottingham University Press. Chapter 1, 1-14.

[116] FAO, 2000. F*ertilizer requirements in 2015 and 2030*. Rome 2000.
ftp://ftp.fao.org/agl/agll/docs/barfinal.pdf

[117] Roberts, P., 2008. *The End of Food: the coming crisis in the world food industry*. Bloomsbury.

[118] Elam, T. E., 2008. Biofuels support policy costs to the United States economy. FarmEcon LLC.
http://farmecon.com/Documents/Biofuel%20policy%20cost%20to%20U.S.%20economy%20FarmEcon%20LLC.pdf

[119] Tegtmeier, E. M., Duffy, M. D., 2004. External Costs of Agricultural Production in the United States. *International Journal of Agricultural Sustainability* 2(1):1-20.

[120] Pretty, J. N. *et al.*, 2005. Farm costs and food miles: An assessment of the full cost of the UK weekly food basket. *Food Policy*, 30(1):1-19. doi:10.1016/j.foodpol.2005.02.001.
http://www.essex.ac.uk/BS/staff/pretty/Pretty%20et%20al%20Food%20Policy%202005%20%20vol%2030%20%20pp1-20.pdf

[121] Steinfeld, H. *et al.*, 2006. Livestock's Long Shadow: environmental issues and options. Executive Summary. Food and Agriculture Organisation of the United Nations. Rome.
http://www.fao.org/docrep/010/a0701e/a0701e00.HTM

[122] Rhoades, J. D., Kandiah, A.,Mashali, A. M., 1992. *The use of saline waters for crop production* - FAO irrigation and drainage paper 48. FAO. Chapter 1.
http://www.fao.org/docrep/t0667e/t0667e04.htm#chapter%201%20%20%20introduction

[123] Rhoades, J. D., Kandiah, A. Mashali, A. M., 1992. *The use of saline waters for crop production* - FAO irrigation and drainage paper 48. FAO. Chapter 5.
http://www.fao.org/docrep/t0667e/t0667e0a.htm#nature%20and%20causes%20of%20environmental%20problems

[124] Kéfi, S. *et al.*, 2007. Spatial vegetation patterns and imminent desertification in Mediterranean arid ecosystems. *Nature*, 449: 213-217. Also cites: Millennium Ecosystem Assessment. *Ecosystems and Human Well-Being: Desertification Synthesis* (World Resources Institute, Washington DC, 2005.

[125] *Animal waste pollution in America: an emerging national problem. Environmental risks of livestock and poultry production*. A report by the Minority Staff of the United States Senate Committee on Agriculture, Nutrition and Forestry for Senator Tom Harkin, December 1997.

[126.] WHO and European Commission, 2002. Eutrophication and Health. http://ec.europa.eu/environment/water/water-nitrates/pdf/eutrophication.pdf

[127] European Commission, 2002. The Implementation of Council Directive 91/676/EEC concerning the Protection of Waters against Pollution caused by Nitrates from Agricultural Sources. Report COM(2002)407. Synthesis from year 2000 member States reports. http://ec.europa.eu/environment/water/water-nitrates/report.html

[128] Anon, 2008. EDF working towards cleaner hog farms. *Pig Progress*, 11 September. http://www.pigprogress.net/home/id160266404/edf_working_towards_cleaner_hog_farms.html

[129] Archer, J. R.,Nicholson, R. J., 1992. Liquid wastes from farm animal enterprises. *Farm Animals and the Environment*, Phillips, C. and Piggins, D. eds. CAB International. pp. 325-343.

[130] Steinfeld, H. *et al.*, 2006. Livestock's Long Shadow: environmental issues and options. Chapter 5. Food and Agriculture Organisation of the United Nations. Rome. http://www.fao.org/docrep/010/a0701e/a0701e00.htm

[131] BirdLife International, 2008. *State of the world's birds: indicators for our changing world*. Cambridge, UK: BirdLife International. www.birdlife.org/sowb

[132] Birdlife International, 2008. State of the world's birds. Accessed January 2009. http://www.biodiversityinfo.org/sowb/default.php?r=sowbhome

[133a] *Science Daily*, 2008. Acidifying Oceans Add Urgency To Carbon Dioxide Cuts. 6 July. http://www.sciencedaily.com/releases/2008/07/080703140716.htm

[133b] *Science Daily*, 2007. Acid Oceans From Carbon Dioxide Will Endanger One Third Of Marine Life, Scientists Predict. 19 October 2007. http://www.sciencedaily.com/releases/2007/10/071017102133.htm

[134] IUCN, 2007. News Release. Extinction crisis escalates: Red List shows apes, corals, vultures, dolphins all in danger. 12 Sept. http://cms.iucn.org/search.cfm?uNewsID=81

[135] Sahney, S., Benton, M. J., 2008. Recovery from the most profound mass extinction of all time. *Proceedings of the Royal Society B*. Biological Sciences. 275:759-765. doi:10.1098/rspb.2007.1370.

[136] Otte, J., *et al.*, 2007. *Industrial Livestock Production and Global Health Risks*. Pro-Poor Livestock Initiative. www.fao.org/ag/AGAinfo/projects/en/pplpi/docarc/rep-hpai_industrialisationrisks.pdf

[137] Anon, 2008. Pumping pits – you need a safety plan. The PigSite August 2008. http://www.thepigsite.com/articles/4/waste-and-odor/2360/pumping-pits-you-need-a-safety-plan

[138a] Wathes, C. M. *et al.*, 1997. Concentrations and emission rates of aerial ammonia, nitrous oxide, methane, carbon dioxide, dust and endotoxin in UK broiler and layer houses. *British Poultry Science* 38:14-28.

[138b] Wathes, C. M., 1999. Strive for clean air in your poultry house. *World Poultry* 15:17-19.

[138c] Groot Koerkamp, P. W. G. *et al.*, 1998. Concentrations and emissions of ammonia in livestock buildings in Northern Europe. *Journal of Agricultural Engineering Research* 70:79-95.

[139] Pew Commission on Industrial Farm Animal Production, 2008. *Putting meat on the table: industrial farm animal production in America*. http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Industrial_Agriculture/PCIFAP_FINAL.pdf

[140a] Rule, A. M., Evans, S. L. Silbergeld, E. K., 2008. Food animal transport: A potential source of community exposures to health hazards from industrial farming (CAFOs). *Journal of Infection and Public Health*, 1 (1): 33 DOI:10.1016/j.jiph.2008.08.001.

[140a] Anon, 2008. Transporting broilers spreads bacteria to humans. *World Poultry*, 26 November. http://www.worldpoultry.net/news/transporting-broilers-spreads-bacteria-to-humans-3347.html

[141] Greger, M., 2007. The Human/Animal Interface: Emergence and Resurgence of Zoonotic Infectious Diseases. Critical Reviews in Microbiology, 33:243–299. DOI: 10.1080/10408410701647594.

[142] Greger, M., 2006. *Bird flu: a virus of our own hatching*. Lantern Books. Available online at http://birdflubook.com/g.php?id=5

[143] Defra, 2008. Bluetongue Regulations 2008. Declaration of a Protection Zone. http://www.defra.gov.uk/animalh/diseases/notifiable/bluetongue/pdf/declaration-bt-pz-080901.pdf

[144] Jaykus, L-A. *et al.*, 2008. Climate change: implications for food safety. FAO. http://www.fao.org/ag/agn/agns/files/HLC1_Climate_Change_and_Food_Safety.pdf

[145] European Food Safety Authority and European Centre for Disease Control, 2007. News release on Report on Trends and Sources of Zoonoses, Zoonotic Agents, Antimicrobial resistance and Foodborne outbreaks in the European Union in 2006. 19 December. http://www.efsa.eu.int/EFSA/efsa_locale1178620753812_1178671313012.htm

[146] Anon, 2006. Avian influenza goes global, but don't blame the birds. Leading Edge (editorial). *The Lancet Infectious Diseases*, 6:185.

[147] FAO News, 2006. *Avian flu: Don't place all the blame on wild birds. Human activities not birds more likely to spread the virus.* 22nd May. http://www.fao.org/docs/eims/upload//214442/Dontplaceallblameonwildbirds.pdf

[148] Department for Environment, Food and Rural Affairs (Defra), 2007. *Summary of initial epidemiological and virological investigations to determine the source and means of introduction of highly pathogenic H5N1 vian influenza virus into a turkey finishing unit in Suffolk, as at 14 February 2007*. http://www.defra.gov.uk/animalh/diseases/notifiable/disease/ai/pdf/epidemiological160207.pdf

[149] WHO, 2009. Cumulative numbers of H5N1 human infections and deaths. WHO cumulative numbers, as at 7 January 2009. http://www.who.int/csr/disease/avian_influenza/country/cases_table_2009_01_07/en/index.html

[150] Murray, C. J. L. *et al.*, 2006. Estimation of potential global pandemic infl uenza mortality on the basis of vital registry data from the 1918–20 pandemic: a quantitative analysis. *Lancet* 368:2211-2218.

[151] European Food Safety Authority, 2006. Scientific Report of the Scientific Panel on Biological Hazards on: *Food as a possible source of infection with highly pathogenic avian influenza viruses for humans and other mammals. EFSA Journal*. 74, 1–29. http://www.efsa.europa.eu/EFSA/Scientific_Document/biohaz_report_ej74_avian_influenza_en2.pdf

[152] WHO, 2007. Food safety information and frequently asked questions on avian influenza. http://www.who.int/csr/disease/avian_influenza/en/ Accessed November 2007, items dated 2005 to 2007.

[153] van Beest Holle, M Du R., 2005. Human-to-human transmission of avian influenza A/H7N7, The Netherlands, 2003. *Euro Surveill*: 10(12):264-8. 2005. http://www.eurosurveillance.org/em/v10n12/1012-222.asp

[154] MacKenzie, D., 2006. Time to stamp out bird flu at source. *New Scientist*, 14 January, p6-7.

[155] Defra (2009). Statistics on foot and mouth disease. http://www.defra.gov.uk/footandmouth/cases/statistics/breakdownstats.htm

[156] National Audit Office, 2002. *The 2001 Outbreak of Foot and Mouth Disease. Stationery Office*. Executive Summary. http://www.nao.org.uk/publications/nao_reports/01-02/0102939.pdf

[157] Waddilove, J., 2008. Production Viruses - A Global Challenge That's Costing a Fortune. *The PigSite*. http://www.thepigsite.com/articles/8/biosecurity-disinfection/2183/production-viruses-a-global-challenge-thats-costing-a-fortune

[158] Gadd, J., 2008. PRRS – the disease that keeps bugging us. *Pig Progress*. 1 September. http://www.pigprogress.net/blogs/id170265307/action/showDetails/prrs__the_disease_which_keeps_bugging_us.html

[159] Anon, n.d. Porcine Reproductive & Respiratory Syndrome (PRRS). *The PigSite.* http://www.thepigsite.com/diseaseinfo/97/porcine-reproductive-respiratory-syndrome-prrs Accessed September 2008.

[160] Evans, C. M., Medley, G. F. Green, L. E., 2008. Porcine reproductive and respiratory syndrome virus (PRRSV) in GB pig herds: farm characteristics associated with heterogeneity in seroprevalence. *BMC Veterinary Research*, 4:48. 2008 doi:10.1186/1746-6148-4-48. http://www.biomedcentral.com/1746-6148/4/48

[161] Zimmerman, J., 2008. PRRSV - The Disease That Keeps Bugging Us. Presentation at the London Swine Conference 2008. *The PigSite*. http://www.thepigsite.com/articles/1/health-and-welfare/2286/prrsv-the-disease-that-keeps-bugging-us

[162] Burch, D.,2008. PRRS infections – where are we post PCV2? *The PigSite*. http://www.pigprogress.net/news/weblog/pig-health/prrs-infections-%E2%80%93-where-are-we-post-pcv2%3F-id2402.html

[163] Tian, K. *et al.*, 2007. Emergence of Fatal PRRSV Variants: Unparalleled Outbreaks of Atypical PRRS in China and Molecular Dissection of the Unique Hallmark. *PLoS ONE* 2(6): e526. doi:10.1371/journal.pone.0000526.

[164] Burch, D., 2008. Tying up some loose ends. *Pig Progess*. September 9. http://www.pigprogress.net/blogs/id1702-66108/action/showDetails/tidying_up_some_loose_ends.html

[165] Center for Infectious Disease Research and Policy, n.d. Nipah Virus. University of Minnesota. http://www.cidrap.umn.edu/cidrap/content/biosecurity/ag-biosec/anim-disease/nipah.html Accessed September 2008.

[166] Anon, 2009. Ebola virus hits more pig farmers in the Philippines. *Nature* 457:648. 4th February. http://www.nature.com/news/2009/090204/full/457648b.html doi:10.1038/457648b.

[167] McCreary, C. *et al.*, 2008. Excretion of hepatitis E virus by pigs of different ages and its presence in slurry stores in the United Kingdom. *Veterinary Record* 163:261-265.

[168] Wang, Y. Q. *et al.*, 2005. Changes in protein and fat balance of some primary foods: implications for obesity. Presented at the 6th Congress of the International Society for the Study of Fatty Acids and Lipids. 27 June – July 2004, Brighton.

[169] Queen's University, Belfast. Improved Test To Detect Steroid Abuse In Cattle. *Science Daily*. 9 February 2009. http://www.sciencedaily.com/releases/2009/02/090202140211.htm

[170] Colles, F. M. *et al.*, 2008. Campylobacter infection of broiler chickens in a free-range environment *Environmental Microbiology* 10(8), 2042–2050. doi:10.1111/j.1462-2920.2008.01623.x.

[171] EFSA, 2007. EFSA-ECDC report on animal infections transmissible to humans. News release 19 December. http://www.efsa.europa.eu/EFSA/efsa_locale1178620753812_1178671313012.htm

[172] Cui, S. *et al.*, 2005. Prevalence and antimicrobial resistance of Campylobacter spp. and Salmonella Serovars in Organic Chickens from Maryland retail stores. *Applied Environmental Microbiology*, 71(7):4108-4111.

[173] European Food Safety Authority, 2008. EFSA publishes EU-wide survey on Salmonella levels in slaughtered pigs. 9th June. http://www.efsa.europa.eu/EFSA/efsa_locale1178620753812_1178713190137.htm

[174] Snow, L. C. *et al.*, 2007. Survey of the prevalence of *Salmonella* species on commercial laying farms in the United Kingdom. *Veterinary Record*, 161:471-476.

[175] Shea, K. M., 2003. Antibiotic resistance: what is the impact of agricultural uses of antibiotics on children's health? *Pediatrics*, 112(1):253-258; CVM Update, 2000. *FDA/CVM proposes to withdraw poultry fluoroquinolones approval*. FDA 26.10.

[176] Nathan, C., 2004. Antibiotics at the crossroads. *Nature* 431:899-902.

[177] Mellon, M., C. Benrook, C. Benbrook, K. L., 2001. Hogging It. Estimates of Antimicrobial Abuse in Livestock. Union of Concerned Scientists.

[178] van den Bogaard, A. E. *et al.*, 2002. Antibiotic resistance of faecal enterococci in poultry, poultry farmers and poultry slaughterers. *Journal of Antimicrobial Chemotherapy*, 49(3):497-505.

[179a] Anon, 2008. MRSA found in United States pigs. *Pig Progress*. July 14th. http://www.pigprogress.net/news/id160259602/mrsa_found_in_us_pigs.html

[179b] Smith, T. C. *et al.*, 2009. Methicillin-Resistant Staphylococcus aureus (MRSA) Strain ST398 Is Present in Midwestern United States Swine and Swine Workers. PLoS ONE 4(1): e4258. Doi:10.1371/journal.pone.0004258.

[180] Anon, 2008. Tests find MRSA bacteria in German piggeries. *Pig Progress*. May 6th. http://www.pigprogress.net/home/id1602-52106/tests_find_mrsa_bacteria_in_german_piggeries.html

[181a] Hallmark Update, 2008. *Farmed Animal Watch* Number 8, Volume 8. 7 March. www.farmedanimal.net

[181b] Becker, G. S., 2008. *USDA meat inspection and the humane methods of slaughter* Act. CRS report for Congress. 26 February.

[182] Comroy, E. E. *et al.* n.d. Atypical BSE (BASE) Transmitted from Asymptomatic Ageing Cattle to a Primate. PLoS ONE 3(8): e3017. doi:10.1371/journal.pone.0003017.

[183] Anon, 2008. Feasting and fasting. *Nature* 454:1.

[184] WHO Europe, 2006. *Draft European Charter on counteracting obesity*. EUR/06/5062700/8. 18 September. http://www.nepho.org.uk/view_file.php?c=1777

[185] National Audit Office, Health Care Commission and Audit Commission, 2006. *Tackling Child Obesity – First Steps. Executive Summary*. Stationery Office. http://www.nao.org.uk/publications/0506/tackling_child_obesity.aspx

[186] Dietary Guidelines for Americans, 2005. United States Department of Health and Human Services and United States Department of Agriculture. http://www.health.gov/dietaryguidelines/dga2005/document/pdf/DGA2005.pdf

[187] Lang, T., 2006. Achieving access to ethical food: animal and human health come together in: Turner, J. and D'Silva, J. eds. *Animals, ethics and trade: the challenge of animal sentience*. Earthscan 2006, chapter 4, p 260-272.

[188] Robertson, A., 2001. Social inequalities and the burden of food-related ill-health. *Public Health Nutrition*, 4(6A):1371-1373.

[189] Lloyd-Williams, F. *et al.* Estimating the cardiovascular mortality burden attributable to the European Common Agricultural Policy on dietary saturated fats. *Bulletin of the World Health Organisation* 86(7): 497-576. 2008.

[190] World Cancer Research Fund and the American Institute for Cancer Research, 2007. *Food, Nutrition, Physical Activity, and the Prevention of Cancer: a global perspective*. Chapter 4.3. www.dietandcancerreport.org

[191] World Cancer Research Fund and the American Institute for Cancer Research, 2007. *Food, Nutrition, Physical Activity, and the Prevention of Cancer: a global perspective*. Chapter 4.4. www.dietandcancerreport.org

[192] World Cancer Research Fund and the American Institute for Cancer Research, 2007. *Food, Nutrition, Physical Activity, and the Prevention of Cancer: a global perspective*. Chapter 4.5. www.dietandcancerreport.org

[193] World Cancer Research Fund and the American Institute for Cancer Research, 2007. *Food, Nutrition, Physical Activity, and the Prevention of Cancer: a global perspective*. 2007. Chapter 12. www.dietandcancerreport.org

[194] Anand, P. *et al.*, 2008. Cancer is a preventable disease that requires major lifestyle changes. *Pharmaceutical Research*, 25(9): 2097-2116. DOI: 10.1007/s11095-008-9661-9.

[195] Hedlund, M. *et al.*, 2008. Evidence for a human-specific mechanism for diet and antibody-mediated inflammation in carcinoma progression. *Proceedings of the National Academy of Sciences of the United States* (PNAS). Published online before print November 18, 2008, doi:10.1073/pnas.0803943105.

[196] Soil Association, 2007. *Energy Efficiency of Organic Farming*. Analysis of data from existing MAFF/Defra studies.

[197] Andersons, 2008. *The impact of rising oil prices on organic and non-organic farm profitability – a study by Andersons for the Soil Association*. Soil Association. http://www.soilassociation.org/web/sa/saweb.nsf/librarytitles/27C46.HTMl/$file/Andersons%20oil%20price%20comparison%20FINAL,%20lo%20res.pdf

[198a] Appleby, M. C., 2008. *Eating our future: the environmental impact of industrial animal agriculture.* World Society for the Protection of Animals (WSPA). http://www.wspa.org.uk/Images/WSPA_ESR_small_tcm9-5754.pdf#false

[198b] Drinkwater, L. E., Wagoner, P., Sarrantonio, M., 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature*, 396:262-265.

[198c] Stehfest, E. *et al.*, 2009. Climate benefits of changing diet. *Earth and Environmental Science*. Published online 4 February. DOI:10.1007/s10584-008-9534-6.

[198d] Tilman, D., 1998. The greening of the green revolution. *Nature*, 396: 211-212.

[199] Crews, T. E. and Peoples, M. B., 2004. Legume versus fertilizer sources of nitrogen: ecological tradeoffs and human needs. *Agriculture, Ecosystems and Environment*, 102:279-297.

[200] Soil Association, 2008. Wheat yields could halve says scientist. Press release 19 November 2008. http://www.soilassociation.org/web/sa/saweb.nsf/848d689047cb466780256a6b00298980/a04b105694fedd4f80257506003070e4!OpenDocument

[201] International Finance Corporation, 2006. Good Practice Note. Number 6. *Animal welfare in livestock operations*. http://www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/p_AnimalWelfare_GPN/$FILE/AnimalWelfare_GPN.pdf

[202] Invitro Meat Consortium, 2008. Preliminary Economics Study, project 29071, V5. http://invitromeat.org/images/Papers/invitro%20meat%20economics%20study%20v5%20%20march%2008.pdf

[203a] IAASTD, 2008. Agriculture – the need for change. Press release 15 April 2008. http://www.agassessment.org/docs/Global_Press_Release_final.doc

[203b] Watson B *et al. International Assessment of Agricultural Science and Technology for Development*. Presentation, London 15 April 2008. IAASTD. 2008.

[204] Stern Review: the economics of climate change. HM Treasury and Cabinet Office. 2006. Executive Summary; Postscript. http://www.hm-treasury.gov.uk/sternreview_index.htm

[205] Fanelli, D., 2007. Meat is murder on the environment. *New Scientist*, 18 July, p15.

[206] Ban Ki-Moon. Address to UN High-Level Conference on world food security, 3 June 2008. http://www.un.org/apps/news/infocus/sgspeeches/statments_full.asp?statID=255

[207] EFSA, 2009. Scientific Opinion on the overall effects of farming systems on dairy cow welfare and disease. Question number: EFSA-Q-2006-113. The EFSA Journal (2009) 1143, 1-38. http://www.efsa.europa.eu/cs/BlobServer/Scientific_Opinion/ahaw_op_ej1143_overalldairycowwelfare_en,0.pdf?ssbinary=true

[208] FAO, 2009. 1.02 billion people in hunger - one sixth of humanity undernourished - more than ever before. http://www.fao.org/news/story/en/item/20568/icode/

[209] Mackenzie, D, 2009. Pork industry is blurring the science of swine flu. *New Scientist*, 30 April 2009. http://www.newscientist.com/blogs/shortsharpscience/2009/04/why-the-pork-industry-hates-th.html

[210] Greger, 2009. *CDC Confirms Ties to Virus First Discovered in United States Pig Factories*. Available at: http://www.hsus.org/farm/news/ournews/swine_flu_virus_origin_1998_042909.html

[211] Brown I.H., 2000. The epidemiology and evolution of influenza viruses in pigs. *Veterinary Medicine* 74:29-46. http://BirdFluBook.org/resources/Brown29.pdf

[212] CAST. Animal Agriculture and the Global Food Supply. *Task Force Report 135,* 1999; 92pp.

[213] Otte, J., Roland-Holst, D., Pfeiffer, D., Soares-Magalhaes, R., Rushton, J., Graham, J., Silbergeld, E., 2007. *Industrial Livestock Production and Global Health Risks*. Pro-Poor Livestock Policy Initiative. A Living from Livestock Research Report.

[214] Graham *et al.*, 2008. The Animal-Human interface and Infectious Disease in Industrial Food Animal Production: Rethinking biosecurity and Biocontainment. *Public Health Reports* 123: 282.

[215] Wuerthe, B., 2003. Chasing the fickle swine flu. Science 299:1502-5. http://birdflubook.org/resources/WUETHRICH1502.pdf

[216] Gilchrist *et al.*, 2007. The Potential Role of Concentrated Animal Feeding Operations in Infectious Disease Epidemics and Antibiotic Resistance. *Environmental Health Perspectives* 115: 313-316.

[217] Fablet C., 2009. An overview of the impact of the environment on enzootic respiratory diseases in pigs. In: Aland A, Madec F (eds.). *Sustainable Animal Production*. Wageningen Academic Publishers.

[218] AHAW, 2005. Welfare aspects of weaners and rearing pigs: effects of different space allowances and floor types. Scientific Opinion of the Panel on Animal Health and Welfare. Question no. EFSA-Q-2004-077. European Food Safety Authority. *The EFSA Journal*, 268: 1-19.

[219] MacKenzie, D., 1998. This little piggy fell ill. *New Scientist*, September 12, p. 1818.

[220] Maes, *et al.*, 2000. Herd factors associated with the seropravalances of four major respiratory pathogens in slaughter pigs from farrow-to-finish pig herds. *Veterinary Research* 31: 313-327.

[221] Rose, N., Madec, F., 2002. Occurrence of respiratory disease outbreaks in fattening pigs: relation with the features of a densely and a sparsely populated pig area in France. *Veterinary Research* 33: 179-190.

[222] Pew Commission on Industrial Farm Animal Production, 2008. *Putting meat on the table: industrial farm animal production in America*. Executive summary, p. 13.
http://www.ncifap.org/_images/PCIFAPSmry.pdf
Accessed August 26, 2008.

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CONTACT US

Compassion in World Farming
River Court
Mill Lane
Godalming
Surrey
GU7 1EZ
UK
Tel: +44 (0) 1483 521 950
Email: compassion@ciwf.org.uk

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