Animal feed, livestock and greenhouse gas emissions: What are the issues?

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This paper examines the contribution that livestock make to greenhouse gas emissions, and the options for emissions reduction, focusing mainly on emissions from beef and dairy systems.

The paper represents a contribution to the annual proceedings of the Society of Animal Feed Technologists. As such it considers the importance of animal feed production and transport animal feed relative to overall livestock related greenhouse gas emissions.

1. Introduction

The earth's climate is warming. This is caused by increasing concentrations of carbon dioxide (CO_2)and other gases in the atmosphere, which have a warming effect on the earth's climate. It is generally accepted[1] that human beings are contributing to the increases in these gaseous emissions and hence to the rise in temperatures.

At present, the global concentration of CO_2 in the atmosphere stands at 383 parts per million (ppm).[2] Recent research suggests that we need to keep emissions to below 450 parts per million[3] since, at a concentration higher than this, we are likely to experience an average warming of 2ºC above pre industrial levels. An emerging scientific consensus suggests that an increase in average global temperatures above this could well tip us into the likelihood of 'dangerous climate change' – a situation when the earth's climatic mechanisms spiral out of control leading to potentially catastrophic consequences.[4] Increased concentrations may have irrevocable effects on the capacity of the world's forests and oceans to store carbon, leading to runaway climate change. Furthermore the melting of icecaps will lead to major rises in sea levels, with very severe implications for low lying countries.

The existing concentration of gases in the atmosphere, combined with time-lags in the earth's climate mechanisms, mean that we are already 'committed' to a temperature rise: if no more fossil fuels were burned and no more greenhouse gases emitted into the atmosphere as from this moment, the world would still continue to warm by at least 1°C above the 2000 average.[5]

[1] Climate Change 2001: The Scientific Basis: Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) Cambridge University Press, UK, 2001
[2] **^** http://www.cmdl.noaa.gov/ccgg/trends/
[3] *Avoiding Dangerous Climate Change*, edited by Joachim Schellnhuber et alia, Cambridge University Press, January 2006
[4] *Avoiding Dangerous Climate Change*, ed. Hans Joachim Schellnhuber, Cambridge University Press, 2006
[5] Wigley, T.M.L., 2005: "The climate change commitment", *Science*, 307: 1766–1769

We will also see climate change affecting world agricultural systems; how significant these impacts will be will vary depending on the level and pace of climate change. Changes include an increase in the likelihood of extreme weather events, such as drought and flooding, changes in crop suitability for different geographic growing regions, changes in the distribution of rainfall (with already dry areas likely to become drier) as well as changes in the types and spread of crop, livestock and foodborne diseases.[6] Food processing and distribution structures may also be affected. As ever, the poor are likely to suffer the most.

Notwithstanding worldwide high level political recognition of the urgent need to tackle climate change, we are not actually seeing emission reductions. CO_2 levels in the UK have actually risen slightly in recent years, and have risen more substantially still for the EU as a whole. Forecasts by the International Energy Agency suggest that if nothing is done to tackle climate change, global CO_2 emissions are likely to be 50% higher in 2030 than they are today.[7] This makes 'dangerous climate change' a distinct probability.

2. Food and greenhouse gases: an overview

The food system as a whole, from production in the field through to consumption and disposal via processing, distribution and retailing, makes a very substantial contribution to greenhouse gas emissions. It is important to recognise that for biotic systems – which include agriculture and forestry – one needs to consider not just the global warming potential of CO_2 emissions but also of other gases such as methane (CH_4) and nitrous oxide (N_20) which have, relatively speaking, an even more powerful global warming potential than CO_2.[8]

The emissions contribution of the food chain will differ from country to country, reflecting not only the scale and type of agricultural production but also the importance of other industrial and domestic sectors relative to total emissions. According to one EU level analysis, the food chain – from plough to plate – accounts for up to 31% of the EU's total greenhouse gas emissions.[9] Current, cautious estimates suggest that for the UK the contribution is around 20%,[10] a figure similar to estimates made in other Northern European countries.[11]

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[6] 31st Session of the Committee on World Food Security, Special Event on Impact of Climate Change, Pests and Diseases on Food Security and Poverty Reduction, *Background Document, FAO*23-26 May 2005

[7] Fatih Birol, *World Energy Outlook: Key Trends - Strategic Challenges*, International Energy Agency, 13 June 2006
http://www.iea.org/textbase/speech/2006/whec.pdf

[8] According to the IPCC, while carbon dioxide has a global warming potential of one, for methane it is 21 and for nitrous oxide higher still at 310.

[9] *Environmental impact of products (EIPRO): Analysis of the life cycle environmental impacts related to the total final consumption of the EU25*, European Science and Technology Observatory and Institute for Prospective Technological studies, main report, May 2006

[10] Tara Garnett , Food Climate Research Network, unpublished

[11] Uhlin, S-E. (1997). Energiflöden i livsmedelskedjan (Energy flows in the food chain). Report No. 4732. Stockholm: The Swedish Environmental Protection Agency.

There are various ways of viewing the greenhouse gas contribution of the food chain. One is to take a 'life cycle' perspective, examining the contribution made by agricultural production, by processing and manufacturing, by transport and distribution and so on. By this reckoning, the agricultural stage is responsible for around half of total food related greenhouse gas emissions, with the remaining 50% shared out among the other life cycle stages.

Another way of examining impacts is to look at particular food categories – at meat and dairy products, fruit and vegetables, cereals and carbohydrates, oils and fats and at beverages. Viewed in this way, research suggests that meat and dairy products are responsible for over half of total food chain greenhouse gas emissions.[12] [13]

3. Greenhouse gas emissions and livestock products

A recent report published by the Food and Agriculture Organisation (FAO) concludes that globally, livestock generate around 18% of global greenhouse gas emissions.

Why should this be and what is the contribution of animal feed production and transport to the total? Since the remit of this paper is to consider specifically the production of animal feed, we consider here both the more direct 'first order' contributions of the livestock feed sector to climate changing emissions and the indirect 'second order' effects.

First order greenhouse gas impacts

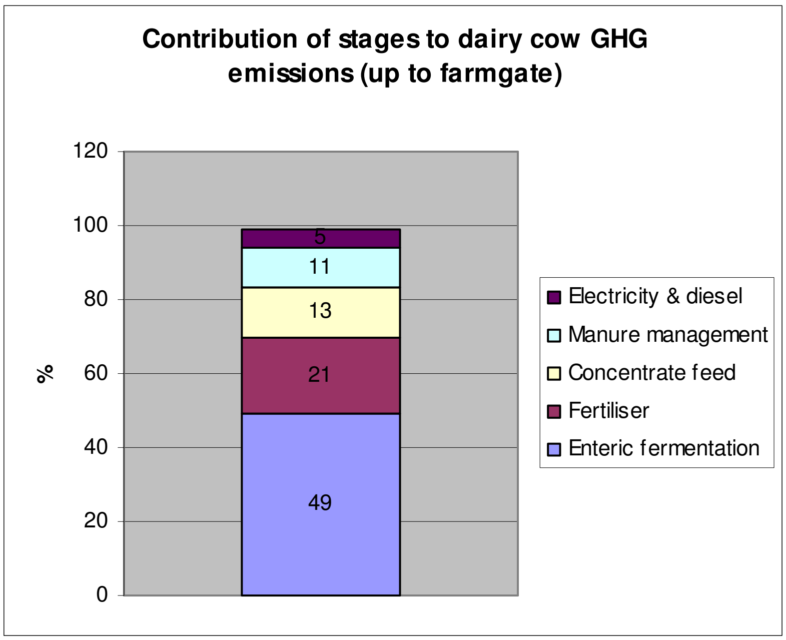
Livestock related impacts occur at every stage of the production system. Some of the impacts result from the use of CO_2 emitting fossil fuels while others are linked to basic metabolic processes in soil and livestock. These stages, and the main gases associated with them include:

- Fertiliser production and transport for feed crops and pasture (CO_2 and N_2O)
- Feed manufacture and transport (CO_2)
- Livestock (enteric fermentation) (CH_4)
- Manure and urine (CH_4 and N_2O)
- Slaughtering, processing, refrigeration, transport, cooking (CO_2 and refrigerant gases)

One study[14] of dairy farming in Ireland gives a breakdown of the relative importance of different lifecycle stages for livestock rearing, up to the farmgate (Figure one).

[12] Klaas Jan Kramer, Henri C Moll, Sanderine Nonhebel, Harry C Wilting, Greenhouse gas emissions related to Dutch food consumption, *Energy Policy* 27 (1999) 203-216
[13] *Environmental impact of products (EIPRO): Analysis of the life cycle environmental impacts related to the total final consumption of the EU25*, European Science and Technology Observatory and Institute for Prospective Technological studies, main report, May 2006
[14] Casey JW and Holden NM. Analysis of greenhouse gas emissions from the average Irish milk production system, Agricultural Systems 86 (2005) 97–114

Figure one



Source: Casey JW and Holden NM. Analysis of greenhouse gas emissions from the average Irish milk production system, *Agricultural Systems* 86 (2005) 97–114

Almost half of total emissions result from enteric fermentation, with a further 11% attributable to manure. While enteric fermentation and manure will be similarly significant for other ruminants, such as beef cattle and sheep, for monogastric livestock the proportions will be different.

Concentrate feed production (including associated transport) accounts for 13% of total emissions up to the farm gate. The more intensive the livestock rearing system, the more significant a contribution the feed production stage makes to total emissions. There may, however be declines in other areas – ruminants fed on a diet high in concentrates tend to produce fewer methane emissions per kg of meat or milk output.

So far the analysis has focused on impacts up to the farmgate. Beyond this stage, there will also be greenhouse gas emissions which result from the processing and distribution of animal products into milk, other dairy products and various kinds of meat products. However, as a rule, by far the greatest impacts are associated with primary production. One study shows that the livestock rearing stage accounts for 95% of emissions associated with a kilogram of cheese, with the remaining 5% attributable to pasteurisation, refrigeration, transport and so forth.[15] Another study which examined a ready meal comprising meat balls, potatoes, vegetables and milk found that the meat and dairy element of the meal accounted for the majority of greenhouse gas emissions, and as such was far more important than the distribution of the ingredients or the manufacture of packaging.[16]

Second order impacts: greenhouse gases and lost carbon sequestration potential

On the face of it then, for ruminants at least, the production of animal feed is less significant than other stages in the farming process.

As for the transport of feed, this appears to be less significant still. Casey estimates that of the 13% of total emissions attributable to animal feed production, 91% are associated with the actual production of the feed and only 9% with its distribution. In another study Casey examines various feeding options for suckler beef, and finds that a switch to more local feed inputs for concentrates will have a negligible effect on total emissions.[17] The transport saved by more local sourcing is outweighed by the fact that greater quantities of concentrate need to be feed. Data presented in the FAO livestock report[18] confirms the relative insignificance of 'feed miles.' The import of soy feed into the EU generates 4979.6 million tonnes CO_2. This equates to only 0.000643% of total EU GHG emissions. Even if this figure were increased to account for the transport of other feed inputs, the significance of transport would not increase dramatically.

However, while the first order impacts of buying in overseas soya and other crops for feed production may seem trivial, the second order impacts are very substantial indeed.

At a global level, changes in land use brought about by livestock farming include deforestation for pasture land and the ploughing of grass land for feed crops. This has serious consequences for the planet's natural capacity to store carbon; indeed the FAO estimates that livestock related land use change leads to the release of 2.4 billion tonnes of CO_2 a year, equivalent to approximately 7% of global greenhouse gas emissions.

Soy cultivation represents particular cause for concern. While soy is grown for its oil as well as its value as an animal feed, it is generally accepted that the rapid growth in soybean cultivation over the last decades has been heavily driven by the demand for meat.

There are particular impacts associated with the farming of soya in South America, and especially in Brazil.

The Brazilian government estimates that, since 1978, roughly 60 million hectares of forest land have been cleared from the Legal Amazon region, the result of logging,

[15] Berlin J (2002). Environmental life cycle assessment (LCA) of Swedish semi-hard cheese, *International Dairy Journal* 12 939–953
[16] Sonesson U, Mattson B, Nybrant T and Ohlsson T. (2002). Industrial processing vs home cooking: an environmental comparison between three ways to prepare a meal. *Ambio*. Vo. 34 vol 4-5
[17] Casey JW and Holden NM. Quantification of GHG emissions from suckler-beef production in Ireland *Agricultural Systems* 86 (2005) 97–114
[18] *Livestock's Long Shadow –Environmental Issues and Options*, FAO, December 2006

mining, human settlement, construction of transport infrastructure, and the establishment of both subsistence and large-scale commercial agricultural enterprises.[19] This level of deforestation represents a loss of over 13% of the original ecosystem, as well as the fragmentation of a much larger portion of the rainforest.[20] In Brazil as a whole the land area under soybean cultivation nearly doubled between 1994 and 2003. Some of the highest growth rates were, and continue to be seen in the frontier states encompassing the Legal Amazon.[21]

Soybean cultivation not only makes use of land in its own right (currently 4% of the Legal Amazon and set to double)[22] but is also an important 'push' factor for deforestation by other industries. In other words, although the area under soy production may not be enormous (at present) and may not occur directly on virgin rainforest, it takes land away from other uses, such as smallholder cultivation and cattle rearing, pushing these enterprises into the rainforest. As a highly profitable industry it also provides income to purchase land for other purposes, including logging.[23] Hence, soybean cultivation represents a serious threat to the Amazon environment, as an important driver of deforestation in the region.[24] [25]

This has serious consequences for CO_2 emissions. Evidence suggests that changes in tropical land use (*not* total land use) since the 1980s may account for 25% of all anthropogenic carbon emissions, with the other three quarters resulting from fossil fuel use.[26] Soy as a driver of land use change in the tropics should therefore take on a share of the resulting CO_2 emissions. And a proportion of this should be allocated to the livestock sector since growth in soybean cultivation is heavily driven by demand for meat.

The UK feed industry is responsible for a share of these emissions. Non EU soya imports (mainly from South America) account for 75% of the UK's oilcake imports and

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[19] Production Estimates and Crop Assessment Division Foreign Agricultural Service, USDA, January 2004 http://www.fas.usda.gov/pecad2/highlights/2004/01/Amazon/Amazon_soybeans.htm accessed 26 May 2005

[20] *Production Estimates and Crop Assessment Division Foreign Agricultural Service*, USDA, January 2004 http://www.fas.usda.gov/pecad2/highlights/2004/01/Amazon/Amazon_soybeans.htm accessed 26 May 2005

[21] *Production Estimates and Crop Assessment Division Foreign Agricultural Service*, USDA, January 2004

[22] *Production Estimates and Crop Assessment Division Foreign Agricultural Service*, USDA, January 2004 http://www.fas.usda.gov/pecad2/highlights/2004/01/Amazon/Amazon_soybeans.htm

[23] ISTA Mielke, Oil World Annual 2004, Hamburg, May 2004 cited in Jan Maarten Dros, *Managing the Soy Boom: Two scenarios of soy production expansion in South America*, WWF, June 2004 http://www.panda.org/downloads/forests/managingthesoyboomenglish_nbvt.pdf

[24] Woods Hole Research Centre http://www.whrc.org/southamerica/agric_expans.htm

[25] ISTA Mielke, Oil World Annual 2004, Hamburg, May 2004 cited in Jan Maarten Dros, *Managing the Soy Boom: Two scenarios of soy production expansion in South America*, WWF, June 2004 http://www.panda.org/downloads/forests/managingthesoyboomenglish_nbvt.pdf

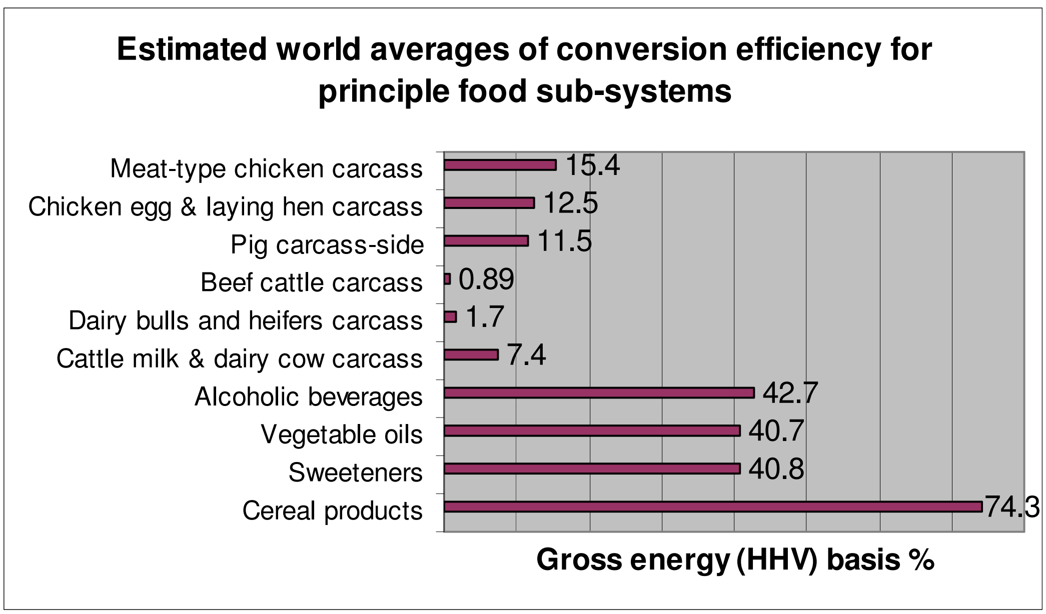
[26] Houghton, R.A. 1999. The annual net flux of carbon to the atmosphere from changes in land use, 1850-1990. *Tellues Series B – Chemical and physical meteorology*, 51(2): 298-313

24% of total feed imports.[27] The European Compound Feed Manufacturers' Federation (FEFAC) now recognises the major problems associated with unsustainable soy production in the developing world, and as a result is now formally a member of the Round Table for Responsible Soy production (RTRS), a body set up to engage a range of stakeholders in the promotion of viable, equitable and environmentally sustainable soybean production. It remains to be seen to what extent the initiative will have tangible positive effects.

Second order impacts: opportunity costs of animal feed inputs
There are additional 'second order impacts' resulting from animal feed production which also need to be considered. The first concerns the relative merits of feeding food to animals instead of directly feeding them to humans.

As figure two shows, the energy conversion efficiency of livestock products is poor compared with plant foods.

Figure 2



Source: Wirsenius S. Efficiencies and biomass appropriation of food commodities on global and regional levels, *Agricultural Systems* 77 (2003) 219–255
Note: HHV: higher heating value. Conversion efficiency' is defined as product generated in a sub-system divided by the feed intake (animal commodities) or feedstock use (processed vegetable commodities) of the sub-system. Thus, it reflects the efficiency of the processes of converting phytomass into animal and processed vegetable food

Hence one might argue that greenhouse gas emissions from our increasingly meat-based food system are far higher than they 'need' be to ensure adequate nutrition for all.

[27] H M Revenue and Customs Data prepared by Trade statistics, Agricultural Statistics and Analysis Division, DEFRA

Comparing conversion efficiencies is a somewhat simplistic approach since it ignores several issues. The first is that some of the cereal crops grown are not suitable for human consumption but are the only crop varieties which the soil type in question can sustain. For example feed wheat cannot be used to make bread -although it can be used for biscuits, for brewing and so forth. Second, it has been argued that animal feed production acts as a important 'buffer' against variations in world food output. In years where harvests are good, cereal prices fall and so the surplus can be fed to animals; in years when yields are lower the prices are higher and more grain is used directly to feed humans.[28]

These arguments are only valid up to a point; on the whole the fact remains that crops which are suitable for human consumption are currently used to feed animals, and this is an inefficient process. A shift away from livestock based production is likely to lead to a reduction in food related greenhouse gas emissions.

It is also argued that some livestock, in particular ruminants, can be reared on land which is unsuitable for other agricultural purposes. As such livestock rearing turns the inedible – grass – into the edible – meat. The argument is undermined somewhat by the fact that in the UK grazing land tends to receive applications of nitrogen fertilisers (which themselves entail the use of energy and emit greenhouse gases). Approximately 64% of nitrogen fertiliser used in the UK is applied to feed crops and grazing land[29] - the FAO report puts the figure higher still at 70%. [30]

One might also consider the 'opportunity cost' of that grazing land. Could it instead be used for other purposes, such as the production of biomass for fuel? Such biomass could for example be used for fuel in combined heat and power plants, thereby reducing the need for fossil fuel inputs.

Clearly the conversion of traditional pasture land to biomass crops such as willow would mean major changes in the appearance of our landscape but it is also the case that climate change requires of us substantial responses. It is important to note too that overgrazing is a major problem in many parts of the UK and at a global level the issue is more serious still. Hence a reduction in livestock grazing would lead to improvements in the appearance (not to mention the sustainability) of the land.

Future years are likely see major growth in the production of biofuels, spurred on by EU policy.[31] In theory, biofuels production offers two benefits for the price of one, as it were, since residues from the biofuels process (such as oilseed cake) can be used for livestock feed. However the cultivation of biofuel crops raises similar concerns to those of existing soybean cultivation. Moreover, the production of biodiesel[32] is by no means carbon neutral and some question its value as a strategy for curbing greenhouse gas

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[28] Rosegrant MW, Leach N and Gerpacio RV. (1999) Meat or wheat for the next millennium? Plenary lecture: Alternative futures for world cereal and meat consumption *Proceedings of the Nutrition Society* 58, 219–234

[29] Tara Garnett , calculations based on Defra AUK 2005 and AIC Fertiliser statistics 2005 report http://www.agindustries.org.uk/document.aspx?fn=load&media_id=1988&publicationId=350

[30] *Livestock's Long Shadow –Environmental Issues and Options*, FAO, December 2006

[31] EU biofuels directive (directive 2003/30)

[32] As distinct from biomass for heat generation

emissions.[33] As such, livestock rearing renders economically viable a system of fuel production which is, from a greenhouse gas (and wider environmental) perspective, flawed.

There is also the byproducts question to consider. The animal feed industry makes use of a huge range of food system byproducts, from oilseed cake (which is a co-product rather than a byproduct) through to citrus pulp and spent brewers' grains. While livestock farming currently performs a useful role in turning these inedible products into edible meat and milk, there may be alternative uses for such byproducts. One option is anaerobic digestion (AD) or the production of methane as a fuel. Marks & Spencer[34] and Tesco[35] are currently trialling AD systems as a way of dealing with the food waste from their stores.

4. Reducing livestock emissions

What are the options for reducing livestock related emissions?

For livestock systems, there are three different gases at play: carbon dioxide, methane and nitrous oxide. The relative importance of each gas varies by livestock type and indeed by farming system. According to Schils et al (2005) , for a dairy system methane accounts for 49% of total emissions, nitrous oxide 27% and carbon dioxide 24%. Gibbons et al[36] find the following relative split for a mixed dairy and beef farm: methane, 54.4% nitrous oxide 36.5% and carbon dioxide. 9.2%. Either way, clearly nitrous oxide and methane are significantly more important than carbon dioxide. However, it is important to note that land use change (particularly that associated with soybean production) is excluded from these analyses;[37] its inclusion would increase the relative importance of CO_2 substantially.

The following paragraphs summarise the measures that have been widely reported as offering potential for reducing livestock related greenhouse gas emissions. There is a risk that measures to reduce one type of emission can lead to increases in emissions of the other gases.[38] As such an integrated approach in needed, to minimise trade offs that may occur.

Reducing CO_2

Most studies, by ignoring issues of land use change, underestimate the contribution of CO_2 to livestock related greenhouse gas emissions. As highlighted above, the conversion of forest or other non-agricultural land to pasture or feed crop production, leads to a release of carbon dioxide into the atmosphere and hence contributes to

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[33] Clift R. *Biofuels – a positition paper*, Draft working paper, Centre for Environmental Strategy, University of Surrey, 2006

[34] http://www2.marksandspencer.com/thecompany/mediacentre/pressreleases/2007/com2007-01-15-00.shtml

[35] http://www.tesco.com/climatechange/speech.asp

[36] Gibbons JM, Ramsden SJ, Blake A. (2006). Modelling uncertainty in greenhouse gas emissions from UK agriculture at the farm level, *Agriculture, Ecosystems and Environment* 112 (2006) 347–355

[37] Schils RLM, Verhagen A Aarts HFM and Šebek LBJ. A farm level approach to define successful mitigation strategies for GHG emissions from ruminant livestock systems, *Nutrient Cycling in Agroecosystems* 71. 163-175, 2005

[38] Monteney G-J, Bannink A and Chadwick D. (2006) Greenhouse gas abatement strategies for animal husbandry, *Agriculture, Ecosystems and Environment* 112 63–170

climate change. While major land use change tends not to occur in the UK itself, at the global levels the issue is a major one. The overseas production of feedstuffs for UK livestock must take on a share of the responsibility. One way of reducing CO_2 emissions is thus to halt the use of unfarmed land for livestock rearing and feed production.

The other, quantified sources of CO_2 in livestock farming include synthetic fertiliser production and use. Lower applications will have potential to reduce CO_2 emissions as well as N_20, as discussed below.

On-farm machinery use is another CO_2 emitting activity. Energy use here depends on the intensity of the farming system as well as the lifespans of the animals in question. Hence, organic dairy systems tend to use less energy than conventional systems. This said, overall greenhouse gas emissions can often be greater owing to lower milk yields in organic systems - methane emissions tend to be higher per litre of milk produced.[39]

Conventional poultry rearing systems use less energy than free range and organic systems, simply because the fattening period and lifespans of caged birds are shorter than those freerange birds.[40] Clearly there will be important issues of animal welfare to consider as well here.

Reducing CH_4

Enteric fermentation accounts for about 80% of methane emissions from ruminant livestock, with the remainder attributable to manure.[41] For non-ruminants, manure is the most important source of CH_4 but overall methane emissions are much smaller.

The choice of feed will influence the output of methane emissions. Many studies conclude that ruminants fed on higher proportions of concentrates tend to produce lower methane emissions than those fed on fibrous by-products and those at pasture.[42] [43] More specifically, feeds with increased levels of soluble starch or rapidly fermentable carbohydrates reduce methane from enteric fermentation. In most cases the production of concentrates will require fertiliser and other fossil-fuel based inputs. While the CH_4 savings tend to outweigh the 'first order' CO_2 impacts arising from increases in fossil fuel use for concentrate production, there will also be the very significant and currently unquantified 'second order' implications for land use change and associated emissions, as highlighted above. Hence there will be trade offs to consider.

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[39] Williams, A.G., Audsley, E. and 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. Available on www.silsoe.cranfield.ac.uk, and www.defra.gov.uk

[40] Williams, A.G., Audsley, E. and 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. Available on www.silsoe.cranfield.ac.uk, and www.defra.gov.uk

[41] Monteney G-J, Bannink A and Chadwick D. (2006) Greenhouse gas abatement strategies for animal husbandry, *Agriculture, Ecosystems and Environment* 112 163–170

[42] Monteney G-J, Bannink A and Chadwick D. (2006) Greenhouse gas abatement strategies for animal husbandry, *Agriculture, Ecosystems and Environment* 112 163–170

[43] Gibbons JM, Ramsden SJ, Blake A. (2006). Modelling uncertainty in greenhouse gas emissions from UK agriculture at the farm level, *Agriculture, Ecosystems and Environment* 112 (2006) 347–355

On the whole, research suggests that for dairy cows, faster growth, the use of higher-yield breeds and shorter dry periods between lactations will lower CH_4 emissions. Likewise, an increase in the average longevity of dairy cows (meaning a greater number of lactations per lifetime) relative to the period from birth to first calving will reduce methane loss per unit of milk yield.[44] These multiple objectives are not necessarily easy to achieve since higher yielding cows tend to manage fewer lactations and have shorter lifespans than lower yielding animals.

While manure is a less significant source of methane in ruminants, it is more manageable. Manure related CH_4 can be reduced by minimizing uncontrolled storage. Controlled storage also offers possibilities for using methane as a biogas, thus offsetting the need for fossil fuel inputs.[45]

Reducing N_2O

Fluxes of N_20 emissions vary hugely according to climate, soil quality and other variables[46] and hence the global warming contribution of agricultural processes and specifically livestock production may be considerably underestimated. Reductions in manure and synthetic fertiliser applications will also reduce N_20 (and for synthetic fertiliser, CO_2 emissions) although this may be offset slightly by lower yields and hence the requirement to farm more land for a given quantity of feed or pasture. Where artificial nitrogen fertilisers are applied, research suggests[47] that urea leads to lower N_20 emissions than ammonium nitrate although under some conditions, ammonia emissions may increase.[48] Nitrification inhibitors will also lead to reductions in emissions.

Optimising the nitrogen content in feed (balancing the need to maximise yields and to minimise the nitrogen content of the urine), as well as better urine and manure management will all reduce N_20 emissions. [49][50]

Conclusions

Ultimately systems using fewer cows which produce more milk and meat at lower stocking densities, which live longer and undertake more lactations will tend to produce milk and meat with lower GHG burdens. Both first and second order greenhouse gas impacts, need to be considered when looking at mitigation strategies, as well as the sometimes conflicting relationships among the different greenhouse gases.

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[44] Monteney G-J, Bannink A and Chadwick D. (2006) Greenhouse gas abatement strategies for animal husbandry, *Agriculture, Ecosystems and Environment* 112 63–170

[45] Monteney G-J, Bannink A and Chadwick D. (2006) Greenhouse gas abatement strategies for animal husbandry, *Agriculture, Ecosystems and Environment* 112 63–170

[46] Conen, F., Dobbie, K.E. and Smith, K.A. (2000). Predicting N_2O emissions from agricultural land through related soil parameters. *Global Change Biology*, 6, 417-426.

[47] Smith K, Smith J and Smith P (2004) Review of the contribution to climate change through greenhouse gas emissions of fertiliser use on different soil types and through different application methods, Scottish Executive 2004

[48] Give ref

[49] C. A. Rotz, C A. (2004) Management to reduce nitrogen losses in animal production1
J. Anim. Sci. 82(E. Suppl.):E119–E137

[50] Monteney G-J, Bannink A and Chadwick D. (2006) Greenhouse gas abatement strategies for animal husbandry, *Agriculture, Ecosystems and Environment* 112 63–170

'Multipurpose' breeding – that is rearing dairy cattle with good 'eating' characteristics will also lead to fewer emissions at a more systemic level.[51]

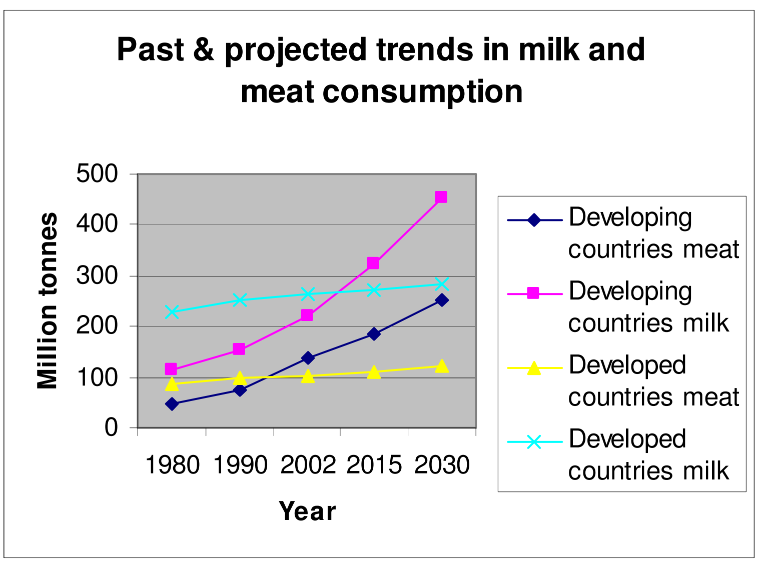
Attempts to reduce greenhouse gas emissions from livestock production will also need to consider animal welfare objectives. From a policy perspective it may be preferable to ask not which the most greenhouse gas 'efficient' system of production might be, but what level of meat consumption (and hence production) is sustainable given certain defined standards of animal welfare. In order to achieve both emissions reductions and improved animal welfare standards we are likely to need to reduce substantially the number of livestock being reared and our consumption of meat and dairy products.

5. Future implications

Clearly a reduction in meat and dairy production and consumption is likely to raise many difficult questions. In the UK, livestock farming not only provides jobs (both directly and indirectly) but it also has huge popular symbolic importance. Ruminant farming systems in particular have shaped our landscape and our notion of what the countryside 'should' look like. And at a global level, livestock farming is essential to people's survival even while its practice undermines the viability of the soil on which it depends.

Although from an environmental perspective, a reduction in livestock production can lead to important greenhouse gas reductions, the trends suggest that production is set to increase substantially. Globally we are likely to see huge increases in consumption, fuelled by the growing economies of China, India and other rapidly industrialising countries.

Figure 3



Source: Source: Livestock's Long Shadow –Environmental Issues and Options, FAO, December 2006

[51] Casey JW and Holden NM. Quantification of GHG emissions from suckler-beef production in Ireland *Agricultural Systems* 86 (2005) 97–114

Clearly this is a problem that demands a global response and one that is very clearly lacking at present.

As regards the UK, however, it is worth pointing out that in recent years, the public has become increasingly aware of the environmental impacts of food production and consumption. The food miles issue (however misrepresented) is now widely reported and discussed in the media. Air freight now appears to be the concern of the moment, with both Tesco and Marks & Spencer announcing that they will label all their air freighted food as such. In coming months, as concerns about climate change grow, it is entirely possible that meat and dairy consumption could become the next big food issue.

6. The Food Climate Research Network

The Food Climate Research Network (FCRN) is a UK research council-funded project based at the University of Surrey's Centre for Environmental Strategy.

Its purpose is to highlight the significant contribution that the food chain in its entirety makes to the UK's greenhouse gas emissions; to quantify more accurately what that contribution might be and where the key impacts lie; to research and promote ways of reducing food emissions; and to bring people together to work on areas of mutual concern.

The FCRN's approach is interdisciplinary: it explores not just the scope for technological improvements but also the more fundamental behavioural and societal context within which our food system has developed, and the options for shifting behaviour in more sustainable directions.

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