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Emissions from Livestock

Livestock farming results in the emission of the greenhouse gases (GHG) methane and nitrous oxide. Such emissions are difficult to accurately quantify and control. This POSTnote examines current policy and prospects for further reductions in emissions.

Overview

- Around 8% of the UK's GHG emissions are methane and nitrous oxide from agriculture.
- Agricultural emissions are hard to measure.
- Emissions from livestock farming can be reduced by improving efficiency. The agricultural sector will voluntarily reduce emissions by 11% by 2020.
- Agricultural emissions stem from biological processes and are difficult to eliminate. It is likely that an increasing proportion of UK emissions will come from agriculture if production remains stable while projected reductions are achieved in other sectors.
- Emissions can be reduced through breeding, diet or behaviour change.

Background

Agriculture accounts for an estimated 9% of total UK greenhouse gas (GHG) emissions. The major GHG emissions from UK agriculture are shown in Figure 1; the main gases emitted are nitrous oxide, methane and to a lesser extent carbon dioxide (CO_2). Sources of nitrous oxide emissions include:

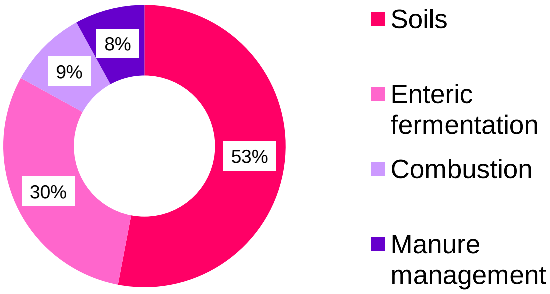
- nitrogen compounds found in fertilisers or manures applied to farmland which are converted to nitrous oxide by microbes in soil (soils account for 53% of UK agricultural GHG emissions, see Figure 1)
- dung and urine from grazing animals
- management of livestock manure (8% of emissions).[1]

Among the main sources of methane are:

- fermentation by livestock digestive systems, predominantly from ruminant animals (Box 1) such as cattle and sheep (30% of emissions)[2]
- the anaerobic break down of stored manures and slurries.

CO_2 emissions are mainly from the use of on-farm machinery and heating (combustion in Figure 1) and account for 9% of UK agricultural GHG emissions. This POSTnote focuses on on-farm emissions of nitrous oxide and methane from farming livestock. Over the full production lifecycle there are several other emission sources associated with rearing livestock, such as fertiliser production or land use change for growing feed; these are beyond the scope of this note.

Figure 1. Sources of UK Agricultural GHG Emissions



Box 1. Ruminants

Ruminants digest fibrous plant materials such as grass by fermenting them in their rumen, an organ that sits above the stomach and contains a complex mix of microbes. It includes microbes called methanogens which produce methane as a by-product that is then expelled in the breath through eructation (burping). Monogastric animals such as pigs and poultry (and humans) produce much less methane than ruminants. It is estimated that a Western European dairy cow can produce around 117 kg of methane each year, which is roughly equivalent to driving 12,000 km in the average petrol car.[3,4]

Methane production captures the hydrogen produced during fermentation. There are however competing fermentation pathways in the rumen that do not produce methane. A variety of dietary and other possible approaches to promote alternative fermentation pathways to reduce methane emissions are discussed later (page 3).

Box 2. Quantifying GHG Emissions
The UK is obligated to provide an inventory of its GHG emissions to the United Nations Framework Convention on Climate Change (UNFCCC) and the European Monitoring Mechanism (EUMM). GHG emissions are calculated from activity data such as livestock numbers or the amount of fertiliser applied. This is then multiplied by an emissions factor, giving the amount of GHG emitted into the atmosphere from this activity. Different GHGs have varying atmospheric lifetimes from around 9-15 years (methane) to 100 years or more (CO$_2$ and nitrous oxide). They also vary in the extent to which they contribute to the greenhouse warming effect. These global warming potentials are assigned relative to CO$_2$ and are usually expressed over a period of 100 years. CO$_2$ is given a global warming potential of 1, methane has a global warming potential of 21 and nitrous oxide of 310. GHG emissions may be calculated in tonnes of carbon dioxide equivalent (CO$_2$e) by multiplying the gasses' global warming potential by the weight emitted.

Regulation and Targets

Measuring Emissions from Agriculture

Methane and nitrous oxide are more powerful GHGs than CO$_2$.(See Box 2). There is a high degree of uncertainty in estimating their emission from agriculture. Nitrous oxide emissions from land have a particularly high degree of uncertainty (see Table 1). This is due to the effect of factors such as climatic conditions, soil type, drainage and uneven localised concentrations of nitrogen, such as urine patches.

Table 1 Uncertainty in annual UK agricultural emissions

GHG Source	Estimated emission (MTCO$_2$e)$^{\sim}$	Range (MTCO$_2$e)*
Soils (N$_2$O)$^{+}$	26,400	1,850-92,100
Enteric (CH$_4$)$^{@}$	15,200	12,800-17,600
Manure (N$_2$O and CH$_4$)	4,320	3,240-5,400

$^{\sim}$MTCO$_2$e megatonnes CO$_2$ equivalent; *95% probability that the actual emission falls within the range[5]; +N$_2$0 nitrous oxide; @CH$_4$ methane

Methane emissions from grazing livestock may be measured experimentally by fitting animals with a tube near the nose that collects a known proportion of exhaled gas into a canister worn around the animal's head. More accurate measurements require an animal to be enclosed within a respiration chamber. Nitrous oxide from soil can be measured by placing chambers on the ground and measuring the flow of gas emitted. However, the variability referred to above means that many such measurements are needed to obtain accurate estimates. The Department for Environment and Rural Affairs (Defra) and the devolved administrations have commissioned research to provide improved, UK-specific, emission factors for nitrous oxide and methane emissions from agriculture, in order to reduce the uncertainty in reported GHG emissions. The programme also aims to improve understanding of factors contributing to emissions. It is due to report in 2014.

Mitigation Targets

Agricultural GHG emissions have fallen since 1990. Reasons for this include Common Agricultural Policy reforms that have decoupled subsidy from production and the impacts of epidemics such as foot and mouth disease, both of which resulted in a fall in livestock numbers and changes to the way the inventory is calculated. The UK is committed to reducing GHG emissions by 80% of 1990 levels by 2050. The 2008 Climate Change Act mandates a series of legally binding emissions targets for the UK. Emissions in the 3rd carbon budgeting period (2018-2022) are to be 18% lower than in 2008.[6]

So far a voluntary approach has been adopted to deliver agricultural emission reductions. Organisations from the agricultural sector in England, such as the National Farmers Union and the Agriculture and Horticulture Development Board (AHDB) have developed the Agricultural Industry GHG Action Plan. This is a voluntary commitment to reduce emissions by 3 megatonnes (MT) CO$_2$e compared to a 2007 baseline, a reduction of about 11%.[7] The lower reduction target for agriculture, compared to the UK economy as a whole, is partly due to uncertainty surrounding agricultural emissions and the options for their management.

Within the Action Plan, individual farming sectors have developed and published their own plans to minimise environmental impacts. The overall emphasis of the Action Plan is to encourage farmers to adopt resource efficiency measures that can both save money and reduce GHG emissions. Forecasts from economic projections of livestock numbers and fertiliser use indicate that the 3 MT CO$_2$e reduction target will be met. Agriculture is a devolved policy area and the devolved administrations have adopted broadly similar voluntary approaches to those in England. The Committee on Climate Change estimates that overall UK reductions will be around 4.5 MT CO$_2$e.[8]

It is estimated that a further reduction of between 5 and 12 MT CO$_2$e in annual UK emissions will be possible by 2020 at zero or negative cost to farmers. Lack of precise knowledge about current emissions, as well as of future technical possibilities (discussed on page 4) and EU regulations render the exact figure uncertain.[9]

Reducing Emissions

There are three main approaches to reducing emissions from livestock farming:

- enhancing livestock efficiency through selective breeding, better livestock management and optimising diets
- reducing agricultural emissions associated with fertiliser use and manure management
- behaviour changes that alter demand for livestock products.

Enhancing Livestock Sector Efficiency

More efficient farming results in lower GHG emissions. For instance, improving the fertility of breeding stock reduces GHG emissions because fewer animals are needed to populate that stock. Similarly, increasing feed efficiency in animals raised for their meat reduces the time taken for an animal to reach the required weight and thus also limits the scope for emissions. Work for the English beef and lamb executive (EBLEX) estimates that increasing the fertility of beef cattle by 0.05 calves/cow/year combined with an increased live-weight gain of 0.32kg/cow/day would reduce emissions by the desired 11% from the sector, with similar results for lamb.[10]

Selective Breeding

Selective Breeding is a powerful tool to improve livestock performance and its benefits accumulate over successive generations (POSTnote 393). An animal's genetic merit can be estimated by measuring a number of different traits and using data from its pedigree and progeny to assign it an Estimated Breeding Value (EBV, see Box 3). In sectors where selective breeding is widely used – pork, poultry and dairy – research shows the resulting increased productivity has reduced GHG emissions by around 1% a year.[11]

In the dairy sector, a combination of breeding and changes in management have increased average annual milk yields per cow from 6,346 litres in 2001 to 7,533 litres in 2011.[12] Fewer cows producing the same amount of milk results in lower emissions. But trade-offs may have to be made in the traits selected for. For instance selecting for optimum milk yield in the past has resulted in reduced fertility. In 2004 it was estimated that restoring dairy cow fertility to 1995 levels would reduce GHG emissions by 10%, as fewer cows would be needed to replace those culled for failing to calve. Since 2007, breeders have increased the weighting placed on health and fertility traits in dairy cattle.

Increasing the use of animals with high EBVs for breeding is a key part of EBLEX's strategy for the beef and lamb sector. In a 2013 survey, 34% of beef farmers and 27% of sheep farmers reported that they usually use high EBV animals for breeding.[13] A possible reason for this low uptake is that farmers are not convinced that they will receive a return on their investment on high EBV animals in challenging settings such as upland farms. Large market fluctuations in carcass prices from week to week may also undermine incentives to use high EBV animals.[14]

Improved Livestock Management

Efficiencies can be made by improved management of animals, often through comparatively low-tech means. Improving animal health results in less waste and reduces GHG emissions per unit of produce. The levy board for pork producers (BPEX) emphasises management for better health and welfare as part of its GHG strategy. For instance, it has called for updated farm buildings as there has been an historic lack of investment due to low profitability.[15] Ensuring that livestock have optimal nutrition for their stage of development can enhance growth rates, yields and fertility. GHG emissions are also affected by the diet and nutrients fed to livestock (see next section).

Optimising Diets for Low GHG Emissions

Researchers also aim to reduce GHG emissions through adjusting livestock diets. As with selective breeding, there may be trade-offs that have to be made between reducing emissions and factors such as animal welfare and cost. Some of the main approaches are discussed below.

Box 3. Estimated Breeding Values (EBVs)

An Estimated Breeding Value (EBV) is an approximation of an animal's breeding worth for a particular set of traits, based on the performance of the individual and its relatives. The EBV of an animal will influence its economic worth (animals with an EBV in the top 1% of the range may fetch a considerable premium) and the price paid for breeding services.

An animal's EBV can be identified by profiling its genome. This enhances the accuracy of the assigned EBV and allows high genetic merit animals to be identified early, without having to wait for them to have mature progeny. It also enables selection for traits which are difficult or expensive to measure. Genomic selection is increasingly used commercially in the Dairy Sector (see POSTnote 393).

There is considerable variation in methane output between individual animals, so it may be possible to select for low methane emissions. Results so far have been mixed.[16] Researchers have shown animals selected for feed efficiency have lower methane emissions.[17,18] In practice low methane emission, or traits associated with it such as feed efficiency, are difficult and expensive to measure. Genome selection could make such options commercially viable in the future.

- **High protein**. Livestock fed on high protein diets excrete high levels of nitrogen thus increasing nitrous oxide emissions. Defra is currently funding research looking at the effects of reduced protein diets on milk yields and animal welfare in dairy cows. [19]
- **High sugar**. Cattle grazed on grasses with a high sugar content have been shown to excrete less nitrogen, reducing nitrous oxide emissions. [20] ASDA supermarket is encouraging its supplier farmers to plant high sugar grasses.
- **High quality forage diets**. Diets where more of the intake is digestible to ruminants have been shown to result in lower methane emissions. Finer chopping of forages has also shown similar effects.[17]
- **High starch**. Feeding ruminants a high starch diet alters ruminal fermentation pathways and can reduce methane emissions. US beef cattle are often fed high cereal content diets to promote rapid growth. In the UK, forage maize is now often used in place of grass to make silage fed to dairy cows, increasing the starch content in their diet.
- **Oils and fats**. Supplementing the diets of ruminants with oils and fats reduces methane output without adversely affecting milk yield. While pure oils and fats are expensive, by-products such as the dried grains from brewing or distillation are an inexpensive source of fat in the diet. They are increasingly widely used and can reduce methane emissions. Feeding oil seeds direct to cattle has also been shown to have similar benefits.[21]
- **Supplements**. Researchers have been investigating dietary supplements in the hope of stimulating the fermentation pathways in the rumen that do not produce methane while inhibiting those that do. Among the approaches being looked at are: naturally occurring plant products; essential oils; probiotic bacteria; vaccination against methane-producing bacteria; and chemical feed additives, such as nitrates that combine with hydrogen. None of these approaches are currently viable.

Reducing Other Emissions

Fertiliser Use on Grazing Pasture

Optimising the timing and reducing the amount of nitrogen fertiliser or manure applied to land reduces nitrous oxide emissions and farmers' costs. Increasingly, farmers are more carefully planning nutrient application, partly driven by recent sharp rises in fertiliser costs. For instance, 73% of dairy farmers have a grassland nutrient management plan, on course for an industry target of 90% by 2015.[12,22] Growing clover, a plant that can fix nitrogen into the soil, is a strategy that reduces fertiliser inputs on pasture. It is suitable for fields with low to moderate stock densities and livestock grow well on diets including clover.[9,23]

Use of Low Nitrogen Crops as Animal Feed

Some cereal crops require less nitrogen from fertilisers than others and may also be grown on more marginal land. Examples include triticale, a cross between rye and wheat that is often grown as an animal feed, and oats. A breeding program is currently underway to improve oat productivity for human consumption and animal feed. Oats may also reduce methane emissions due to their high oil content.

Nitrification Inhibitors

Some chemicals inhibit nitrification, a bacterial process that causes nitrous oxide formation. These have been shown to reduce nitrous oxide emissions by up to 80%. Nitrification inhibitors can be incorporated into fertilisers or even conceivably fed to animals, in which case they are excreted unchanged in urine.[17] Nitrification inhibitors are now being investigated in UK conditions and may prove to be a tool for reducing nitrous oxide emissions. They offer no agronomic benefit to farmers, raising the issue of who pays for them.

Manure Management

Emissions of nitrous oxide and methane from manures depend on the way they are managed.[1] There are numerous strategies to reduce GHG emissions from manures, however not all are presently regarded as cost effective. For instance, allowing a crust to develop on slurry tanks can reduce methane emissions.

Anaerobic Digestion (AD) is a technology in which methane from the breakdown of manures, agricultural or food waste, is captured and used as an energy source (see POSTnote 387). The remaining digestate can be used as a fertiliser. Widespread use of AD would significantly reduce methane emissions from manure storage. The Government provides support for small scale AD plants on farms.

Behaviour Change

The Committee on Climate Change has discussed potential emissions savings from behaviour and dietary changes:[8]

- Reduction in food waste. Halving food waste would save around 3.2 MT CO_2e of agricultural emissions and 1. 2 MT CO2e from avoidance of landfill.
- Changes in consumption patterns. A 50% reduction of livestock products could save 13 MT CO_2e, a switch from red to white meat consumption 6 MT CO_2e and a 50% reduction in consumption of white meat 3 MT CO_2e.

This analysis includes on-farm emissions and emissions associated with fertiliser production. The research noted that reductions in UK livestock production could increase production (and thus emissions) abroad to meet rising UK demand. In all cases the model predicts that these changes would free up land, both in the UK and overseas.

Wider Sustainability Issues

Emissions and Global Markets

Livestock products are traded internationally. Policies that lower UK livestock production may not impact net global emissions if demand for livestock products in the UK stays constant, as more produce will be imported from abroad. Conversely, reduction in consumption of livestock products in the UK would not necessarily result in a reduction in emissions from UK farms, if more produce is then exported abroad. EBLEX argues that global meat demand is set to increase and suggests that the UK should aim to be an exporter of livestock products to make best use of available farmland that is not suitable for arable farming.

Farming Efficiency: Costs and Benefits

Improving farming efficiency to reduce GHG emissions can bring other benefits. For instance, improving animal health can result in better productivity and animal welfare. Furthermore, improved efficiency could reduce the amount of pastureland needed for livestock farming thus allowing more land to be left for nature, potentially increasing biodiversity. On the other hand, intensification to increase productivity from livestock may also have undesirable consequences, such as reduced biodiversity.

Endnotes

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POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Dave Parker for researching this briefing, to the Royal Society of Chemistry for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Pete Border.