Agricultural Statistics and Climate Change

10th Edition
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Department for Environment Food & Rural Affairs

Enquiries:
Agri.EnvironmentStatistics@defra.gov.uk

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Further information on National Statistics can be found on the UK Statistics Authority website.

Introduction

This is the tenth edition of Agricultural Statistics and Climate Change. This edition includes links to the results from the 2020 Farm Practices Survey, the 2019 British Survey of Fertiliser Practice and updates the indicator framework monitoring greenhouse gas emissions from agriculture. Other charts and tables have also been updated where new data are available. The tenth edition follows on from publication of the 9th edition in 2019.

In line with the requirements set out in the Climate Change Act 2008 and as part of international obligations, the UK Government is committed to adopting policies that will reduce greenhouse gas (GHG) emissions across the economy by at least 80%, from 1990 levels, by 2050. Agriculture will need to play its part in this reduction, but faces unique challenges in that action to reduce GHG emissions has to be considered in the context of long-term policy debates around food security, land use and natural resources. A decline in agricultural activity in the UK may well lead to a decline in domestic GHG emissions (or vice versa), but such activity is also driven by a complex interaction of subsidies, regulation, and international markets, as well as by producer, retailer and consumer preferences. As in other sectors, it would not make sense to drive down emissions from UK agriculture by relying more on the import of products that are at least as GHG intensive: this would effectively export the emissions resulting from food consumption, causing "carbon leakage".

However, there are measures that farmers can implement now that would lower GHG emissions at minimal or no extra cost and indeed would also be positive from a farm business case. The Government believes that it is right for the agricultural industry to take responsibility for reducing its emissions and so has encouraged an industry partnership to lead in tackling the challenge. The Agriculture Industry GHG Action Plan: Framework for Action (published in February 2010) outlined how reductions could be made through greater resource efficiency, generally involving changes in farming practice which are also good in terms of business operations. Examples include nutrient management (through efficient use of fertilisers or slurry / manures) and feed efficiency as part of good animal husbandry. The GHG Action Plan is now one of several industry led initiatives working within Championing the Farmed Environment (CFE). For more details visit the CFE home page.

The individual sector-bodies are also taking action to reduce emissions through environmental product roadmaps[1]. The Dairy, Beef and Lamb, and Pig meat product roadmaps all encourage farmers to employ better management techniques and farming practices. While work by the Agricultural and Horticultural Development Board on the Farm Scale Resource Use Efficiency Calculator[2] looks to build awareness on the way farm management decisions can impact on the environment and the economy.

During 2012, Defra, working collaboratively with a range of stakeholders, carried out a review of progress in reducing GHG emissions from agriculture. The final report[3], acknowledged the progress made by the industry so far and concluded that the overall ambition of reducing annual GHG emissions from agriculture by 3 Mt carbon dioxide equivalent by the third carbon budget was achievable, subject to continued focus and effort by the industry.

The 2016 review[4], published in March 2017, assesses the performance of the GHG Action Plan during the period 2012 through to the end of 2015. The review draws on evidence from a range of government and industry sources to illustrate the activities undertaken as part of the action plan and examine their effectiveness. It recognises that the GHG Action Plan has helped to drive the uptake of mitigation methods that have delivered just under a third of the target reduction in emissions. To achieve the target of 3 Mt CO_2e by 2022 the GHG Action Plan has to drive further uptake of mitigation methods already proving effective. Going forward Defra will continue to work in collaboration with industry to identify how they can most effectively support them in achieving this target.

Government continues to improve the science base: in partnership with the Devolved Administrations, the Government has invested over £12 million, over a four and half year period, to strengthen our understanding of on-farm emissions. A revised agricultural GHG Inventory model was implemented in 2017. The model introduced new emissions factors based on UK specific measurements, and better reflects the structure and practices typical of UK agricultural systems. Critically the new model allows us to better reflect efficiency gains achieved by farmers and to capture their impact on emissions.

Purpose of this publication

This publication brings together existing statistics on agriculture in order to help understand the link between agricultural practices and GHG emissions. It summarises available statistics that relate directly and indirectly to emissions and links to statistics on farmer attitudes to climate change mitigation and uptake of mitigation measures. It also incorporates information on developing research and provides some international comparisons.

Data sources

Data sources are shown on charts/referenced in footnotes. The Glossary provides links to methodology details of the original data sources.

Geographic coverage

Climate change mitigation in agriculture is a devolved issue, and Defra has policy responsibility for England. This publication aims to provide measures based on England, however this is not always possible and in some instances measures are GB or UK based.

Comparisons over time

Data series are shown from 1990 onwards wherever possible. In some instances comparable data are not available from 1990, and in these cases the closest available year is shown. In summarising the data ‘long term’ and ‘short term’ comparisons are made[5].

Summary: greenhouse gas emissions from agriculture - a framework of leading indicators

The indicator framework aims to assess progress in reducing greenhouse gas (GHG) emissions whilst research is undertaken to improve the UK agricultural GHG inventory.

The framework, initially developed as part of the 2012 review of progress in reducing GHG emissions from English agriculture[6], consists of ten key indicators covering farmer attitudes and knowledge, the uptake of mitigation methods and the GHG emission intensity of production[7] in key agricultural sectors. As far as possible, it reflects the farm practices which are aligned to the Industry's Greenhouse Gas Action Plan[8] and acknowledges the indicators set out in the Committee on Climate Change annual progress reports[9].

A brief overview of the revised methodology used from 2013 onwards for indicators 2, 9 and 10 is available at the end of this summary. Detailed indicator assessments which include more information on data sources, methodology and statistical background can be found here.

Overview

For some indicators (such as farmer attitudes) there are limited data currently available to assess long term trends and the short term suggests little change. Where longer term data are available, a current assessment shows the overall picture to be mixed. Over the last 10 years there is a positive long term trend for the soil nitrogen balance (a high level indicator of environmental pressure) and for the derived manufactured nitrogen use efficiency[10] for barley, oilseed rape and sugar beet. For intermediate outcomes relating to GHG emission intensity[10] for the livestock sector there has been either little overall change in the longer term trend (e.g. feed conversion ratios for poultry) or some deterioration (e.g. feed conversion ratios for the pig finishing herd). However, when assessed over the most recent 2 years, the indicators suggest positive trends in the case of intermediate outcomes relating to pigs, beef, lamb and some key crops.

Indicators 2, 9 and 10 focus on the uptake of particular mitigation methods (including those relating to organic fertiliser management and application) and provide a measure of progress towards achieving the industry's ambition to reduce agricultural production emissions by 3 Mt CO_2 equivalent by 2020 compared to a 2007 baseline. Together these indicators suggest that, by early 2020, a 1.3 Mt CO_2 equivalent reduction in GHG had been achieved, around 28% of the estimated maximum technical potential[11,12]. A key component has been the uptake of practices relating to nutrient management, such as the use of fertiliser recommendation systems. The current status of each of the individual indicators has been summarised below. Symbols have been used to provide an indication of progress:

Clear improvement	✓	Little or no change	≈
Clear deterioration	✗	Insufficient or no comparable data	…

Methodology 2013 onwards

Indicators 2, 9 and 10 use estimates of potential and achieved GHG emission reductions that have been calculated using the FARMSCOPER tool developed by ADAS for Defra[13]. The data feeding into this model are drawn from a variety of sources including land use and livestock population data from the June Agricultural Survey. The majority of the data relating to the uptake of the mitigation methods within these indicators are from Defra's Farm Practices Survey and the British Survey of Fertiliser Practice. In 2013, in order to gain a more refined picture of the level of uptake of mitigation measures, responses from these surveys have, wherever possible, been divided into those from farms within and outside Nitrate Vulnerable Zones. This was not done for the initial assessment in November 2012 and changes seen here reflect this improved method rather than any marked variation in uptake.

Livestock indicators

The indicators focused on livestock give an insight into the efficiency of production where this can impact on GHG emissions and are intended to be viewed within the context of animal welfare regulations and legislation. To examine the wider potential implications of GHG mitigation measures, including animal health and welfare, Defra commissioned research project AC0226 - Quantifying, monitoring and minimising wider impacts of GHG mitigation measures[14].

Indicator summaries

Overarching indicators

1 Attitudes & knowledge

Assessment: behaviour change can be a long process. Measuring awareness of the sources of emissions and intentions to change practice can provide a leading indicator of uptake of mitigation methods and help to highlight motivations and barriers. However, changing attitudes are not the only driver for the adoption of mitigation methods; research suggests that business sustainability and financial implications are important drivers for change.

- 18% of farmers reported that it was “very important” to consider GHGs when making decisions relating to their land, crops and livestock and a further 46% thought it “fairly important”. These were increases of 5% and 4% respectively when compared to 2019 responses. 30% of respondents placed little or no importance on considering GHGs when making decisions or thought their farm did not produce GHG emissions.
- Overall, 66% of farmers were taking actions to reduce emissions, a 5% increase on the previous year. Of these, larger farms were more likely to be taking action than smaller farms.
- For those farmers not undertaking any actions to reduce GHG emissions, informational barriers were important, with both lack of information (35%) and lack of clarity about what to do (39%) cited as barriers by this group. 42% did not believe any action was necessary, a decrease from 47% in 2019.

More details on farmer attitudes can be found in Section 3.1.

Current Status	Long term (last 10 years) …	Short term (last 2 years) ✓

2 Uptake of mitigation methods

Assessment: there are a wide range of farm practices that can reduce GHG emissions from agriculture. Monitoring the uptake of these mitigation methods provides an indicator of progress towards achieving the industry’s ambition to reduce agricultural production emissions by 3 M tCO_2 equivalent (e) by 2020 compared to a 2007 baseline.

- By February 2020, approximately 0.9 Mt CO_2e reduction in GHG emissions had been achieved from the uptake of the key mitigation methods within this indicator. This compares to an estimated maximum technical potential[15] reduction of 2.8 Mt CO_2e were all of these methods to be fully implemented on relevant farms.

- Mitigation methods related to nutrient management (e.g. fertiliser spreader calibration) collectively provide the greatest potential emissions reduction (0.9 Mt CO_2e). By 2020, uptake of these methods has been assessed to have delivered an estimated GHG reduction of 0.4 Mt CO_2e, around 40% of the maximum technical potential reduction.

More details on uptake of mitigation methods can be found in Section 3.2.

Current Status	Long term (last 10 years) …	Short term (last 2 years) ≈

3 Soil nitrogen balance

Assessment: the soil nitrogen balance is a high level indicator of potential environmental pressure providing a measure of the total loading of nitrogen on agricultural soils. Whilst a shortage of nutrients can limit the productivity of agricultural soils, a surplus of these nutrients poses a serious environmental risk. The balances do not estimate the actual losses of nutrients to the environment (e.g. to water or to air) but significant nutrient surpluses are directly linked with losses to the environment.

- The nitrogen surplus (kg/ha) in England has fallen by 30% since 2000. The main drivers have been reductions in the application of inorganic (manufactured) fertilisers (particularly to grass) and manure production (due to lower livestock numbers), partially offset by a reduction in the nitrogen offtake (particularly forage).
- Provisional figures show that the nitrogen balance decreased by 12% between 2018 and 2019. This was driven by an 8.7% increase in overall offtake (mainly via harvested crops) which more than offset a 0.8% decrease in inputs. The increase in offtake reflects a significant increase in overall harvested production compared to 2018. For more details of the soil nitrogen balance see Section 2.9.1.

Current Status	Long term (last 10 years) ✓	Short term (last 2 years) ✓

Sector specific indicators

4 Pig sector: feed conversion ratio for finishing herd (GB)

Assessment: the feed conversion ratio is a measure of the amount of feed required to produce 1 kilogramme of pig live weight. More efficient use of feed has the potential to reduce GHG emissions intensity[16] and improve productivity (see **Livestock indicators** note at the beginning of summary).

- The feed conversion ratio (FCR) for the pig finishing herd deteriorated from around 1995 to 2009, albeit with some fluctuations, an indication that more feed has been required to produce 1 kg of pig live weight. This suggests higher levels of GHG emissions from the GB finishing herd over this period.

- Several factors could explain this including the trend towards heavier finishing weights, changes in production systems and disease. As the FCR is a broad indicator of feed use efficiency and GHG emissions, it is not possible to separate the effects of different factors (such as type of feed) on GHG emissions from the finishing herd.

- From 2007 to 2019 there have been many fluctuations in the FCR, more recently the FCR is at a higher level meaning more feed was used to produce 1 kg of pig live weight. The clean pig average carcase weight also rises steadily over this time period.

More details on the on the pig sector can be found in Section 2.7.

Current Status	Long term (last 10 years) ≈	Short term (last 2 years) ×

5 Grazing livestock sector: beef and sheep breeding regimes

Assessment: the selection of useful traits can help improve herd and flock productivity and efficiency which can in turn influence GHG emissions intensity. The Estimated Breeding Value (EBV) is an estimate of the genetic merit an animal possesses for a given trait or characteristic. The EBV is used here as a proxy measure for on-farm GHG emissions intensity (see **Livestock indicators** note at the beginning of summary).

- Overall in 2020, bulls and rams with a high EBV were used either “always” or “most of the time” on 35% of farms breeding beef cattle and 19% of those breeding lambs. When compared to 2019 this is an increase of 2% on farms breeding cattle and a 2% decrease on those breeding lambs.
- For farms breeding lambs, uptake on lowland farms was greater than those in Less Favoured Areas (LFA) (20% and 15% respectively). For farms breeding beef cattle the uptake was lower on LFA’s which were at 30% compared to 33% on lowland farms.
- There are differences between farm sizes, with uptake greatest on larger farms.

For more details on the beef and sheep sectors see Section 2.5 and Section 2.6.

Current Status	Long term (last 10 years) …	Short term (last 2 years) ✓

6 Dairy sector: ratio of dairy cow feed production to milk production

Assessment: using milk yields in conjunction with trends in inputs (such as feed) provides an indication of GHG emissions intensity in the dairy sector. The ratio of dairy cow compound and blended feed production to milk production is used here as proxy measure for on-farm GHG emissions intensity (see **Livestock indicators** note at the beginning of summary). It is recognised that the picture is complex and this indicator is not ideal. Firstly, it considers production of feed rather than overall dry matter consumption but perhaps more importantly it does not attempt to assess the consumption of concentrates produced by on-farm mixing, or of grazed or conserved forage. We will continue to investigate other data sources to improve this indicator.

- Although there have been some fluctuations over the period since 2005 the rate of increase of compound and blended feed production has outstripped that of average milk yields suggesting an increase in GHG emissions intensity.
- In the shorter term the ratio has decreased which has been mainly driven by an decrease in feed use

More details on the dairy sector can be found in Section 2.4.

Current Status	Long term (last 10 years) ✓	Short term (last 2 years) ✗

7 Poultry sector: feed conversion ratio for table birds

Assessment: more efficient use of feed has the potential to increase productivity and reduce GHG emissions intensity. The feed conversion ratio (FCR) is a measure of the amount of feed required (kg) to produce 1 kilogramme of poultry meat (dressed carcase weight). The indicator provides an overall measure of feed efficiency. Within this there are differences between production systems and species. It is used here as a proxy measure for on-farm GHG emissions intensity (see **Livestock indicators** note at the beginning of summary).

- There was a slight upward trend in the overall FCR for table birds between 2001 and 2008, suggesting a possible increase in GHG emissions intensity.
- There was some improvement in the FCR between 2010 and 2013 have seen an overall improving (downward) trend. Over the last two years the FCR has remained at around the same figure with very slight fluctuations.

For more details on the poultry sector see Section 2.8.

Current Status	Long term (last 10 years) ✓	Short term (last 2 years) ≈

8 Cereals and other crops: manufactured fertiliser application

Assessment: more efficient use of nitrogen fertilisers has the potential to increase productivity and reduce risks to the environment. The ratio of the weight of crops produced to the weight of manufactured nitrogen fertiliser applied provides a proxy measure for the intensity of GHG emissions[20].

- From 2000 to 2014, there has been little overall change in the apparent nitrogen use efficiency of wheat. However, over the last three years yields have improved which has led to more wheat being produced per tonne of nitrogen applied. A significant increase in wheat yields for the 2019 harvest has driven the most recent increase in nitrogen use efficiency of wheat.
- Trends for winter and spring barley are similar to those for wheat. Over the last 10 years the intensity measure for winter oilseed rape has seen a light upward trend peaking in 2016.

More details on crop production can be found in Section 2.3 and Section 2.9.

Current Status	Long term (last 10 years)	Short term (last 2 years)
Wheat	✓	✓
Winter barley	✓	✓
Spring barley	✓	✓
Winter oilseed rape	✓	≈
Sugar beet	✓	≈

9 Slurry and manure

Assessment: systems for the management of manure and slurry are relevant to the control of environmental risks to air and water including GHGs. Monitoring uptake of relevant mitigation methods provides an indicator of progress towards achieving the industry's ambition to reduce agricultural production GHG emissions by 3 Mt CO_2 equivalent (e) by 2020 compared to a 2007 baseline.

- Estimates indicate that the maximum technical potential[21] GHG reduction from uptake of mitigation methods relating to slurry and manure (which include types of storage, the use of liquid/solid manure separation techniques and anaerobic digestion (AD) systems) is approximately 1.5 Mt CO_2e.
- Uptake of these mitigation methods by February 2020 suggests that the GHG reduction achieved has been approximately 0.04 Mt CO_2e which is a similar level to 2017 and 2018.
- Estimates from the Farmscoper tool suggest that the use of manures and slurries for anaerobic digestion has a GHG reduction potential outweighing that from improved storage of slurries and manures. However, significant start-up and running costs are barriers to uptake. In 2020, survey data indicated that 3% of all farms processed slurries for AD; the same proportion as 2018.

For more details on slurry and manure see Section 2.9.2 and Section 3.2.

Current Status	Long term (last 10 years) ...	Short term (last 2 years) ≈

10 Organic fertiliser application

Assessment: the form, method and timing of application for organic fertilisers can influence GHG emissions. Monitoring these factors provides an indicator of progress towards achieving the industry's ambition to reduce agricultural production emissions by 3 Mt CO_2 equivalent (e) by 2020 compared to a 2007 baseline.

- By February 2020, approximately 0.34 Mt CO_2e reduction in GHG emissions had been achieved from the uptake of the mitigation methods (which include the timing of applications and application methods) within this indicator[17]. This compares to an estimated maximum technical potential[18] reduction of 0.46 Mt CO_2e were all of these methods to be fully implemented on relevant farms.

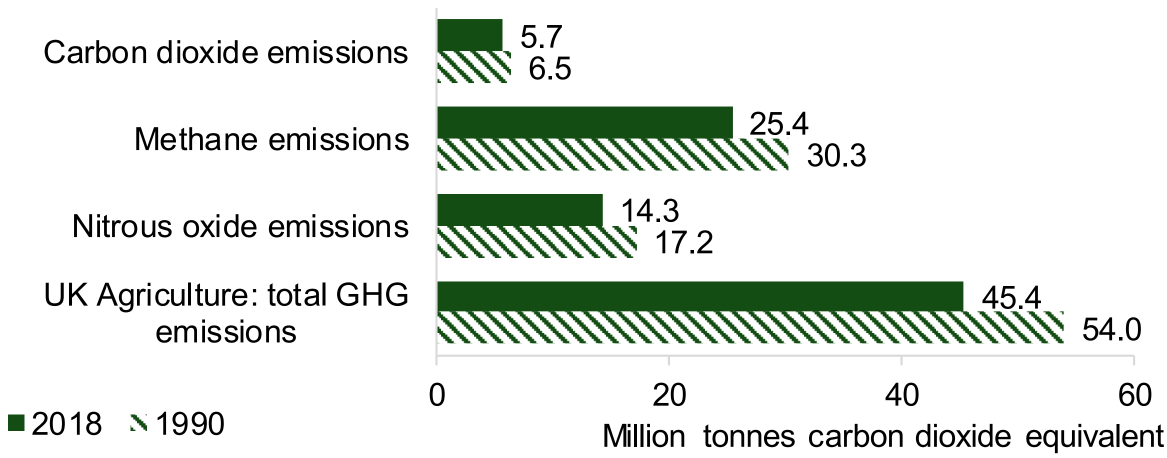
For more details on organic fertiliser application see Section 2.9.2 and Section 3.2.

Current Status	Long term (last 10 years) ...	Short term (last 2 years) ≈

Section 1: Emissions from agriculture

UK agriculture estimated greenhouse gas emissions

Figure 1.1 UK estimated greenhouse gas emissions for agriculture, 1990 and 2018 [19]



Source: Department for Business, Energy & Industrial Strategy

Drivers of emissions

Drivers of recorded sector emissions: The methodology used to report agricultural emissions has been predominantly based on the number of livestock animals and the amount of nitrogen-based fertiliser applied to land. A variety of important factors influence emissions which are not captured by this methodology (see "Other drivers of emissions" below for details); research[20] has been undertaken to better reflect the position. The results of this research have been incorporated into an upgraded greenhouse gas (GHG) inventory for agriculture, implemented since 2017.

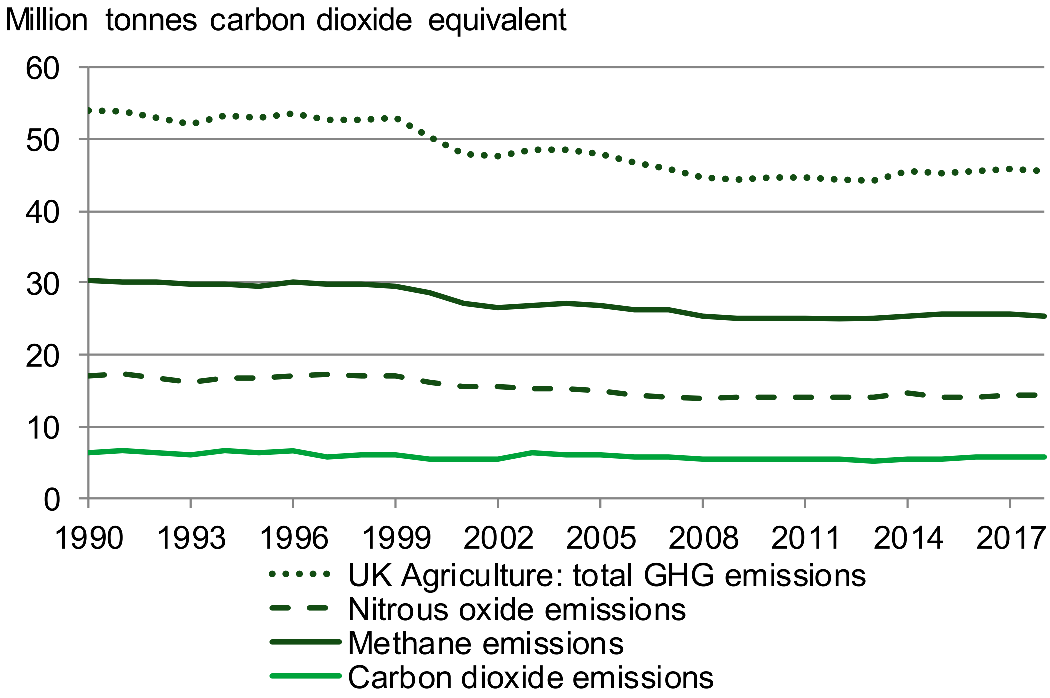
Other drivers of emissions: There are other factors which are not captured in estimated emissions, but which are likely to affect the true level of emissions. For example, some areas of farming practice will have an impact, e.g. timing of fertiliser application, efficiency of fertiliser use, feed conversion ratios, genetic improvements. Some of these relate to efficiency: there have been productivity gains in the sector, through more efficient use of inputs over the last twenty years and some of these gains will have had a positive impact, though some may have had a negative impact on emissions. Soil moisture and pH are also highly important to soil emissions. On a national basis these drivers are expected to have a subtle, but significant impact, rather than a dramatic impact on the true level of emissions over the period. On a regional basis, the drivers of soil emissions are likely to have a more dramatic impact for some land use types.

1.1 Total emissions

The chart below provides an overall picture of the level of estimated greenhouse gas (GHG) emissions from agriculture. In 2018, when compared to total emissions from all sectors, agriculture was the source of:

- 10% of total GHG emissions in the UK,
- 70% of total nitrous oxide emissions,
- 49% of total methane emissions,
- 1.6% of total carbon dioxide emissions.

Figure 1.2 Greenhouse gas emissions from UK agriculture

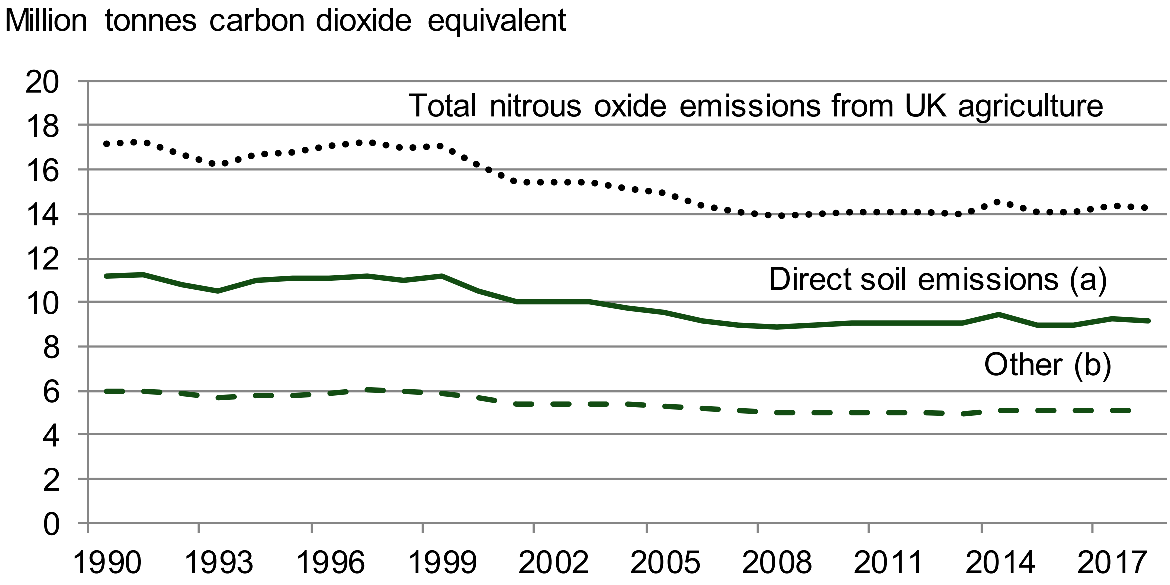


Source: Department for Business, Energy & Industrial Strategy

1.2 Nitrous oxide emissions

Direct emissions of nitrous oxide (N_2O) from agricultural soils are estimated for the following: use of inorganic fertiliser, biological fixation of nitrogen by crops, ploughing in crop residues, cultivation of histosols (organic soils), spreading animal manures on land and manures dropped by animals grazing in the field. In addition to these, the following indirect emission sources are estimated: emission of nitrous oxide from atmospheric deposition of agricultural nitric oxide (NOx) and ammonia (NH_3) and the emission of nitrous oxide from leaching of agricultural nitrate and runoff. Also, nitrous oxide emissions from manures during storage are calculated for a number of animal waste management systems.

Figure 1.3 Emissions of nitrous oxide from UK agriculture by source



(a) Direct soil emissions consists of leaching/ runoff, synthetic fertiliser, manure as an organic fertiliser, atmospheric deposition, improved grassland soils, crop residues, cultivation of organic soils, N-fix crops, deposited manure on pasture (unmanaged).
(b) Other includes: stationary and mobile combustion, wastes and field burning of agricultural wastes.

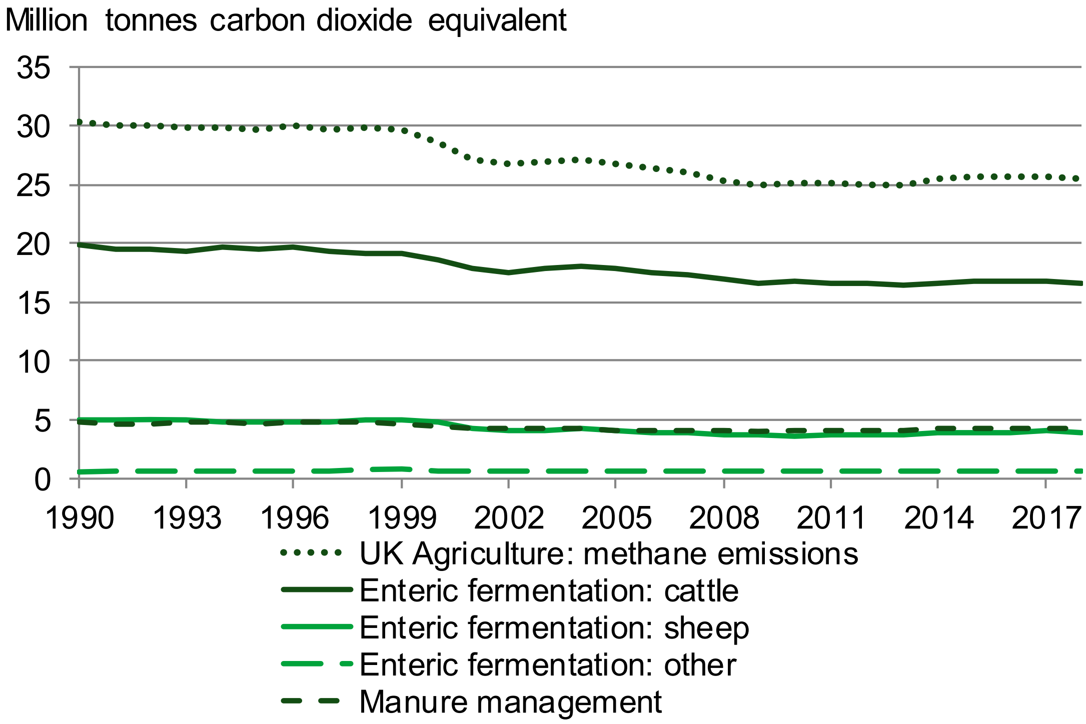
Source: Department for Business, Energy & Industrial Strategy

The fall in estimated nitrous oxide emissions over the last twenty years has been driven by substantial reductions in the overall application rate for nitrogen fertilisers, particularly to grassland; whilst arable application rates have remained relatively stable, grassland application rates have reduced. Over this period, wheat yields have increased, suggesting that the UK is producing more wheat for the same amount of nitrogen. Further measures relating to the intensity of emissions are covered in Section 2.

1.3 Methane emissions

Agriculture is estimated to have been the source of 49% of the UK's methane (CH_4) emissions in 2018. Methane is produced as a by-product of enteric fermentation and from the decomposition of manure under anaerobic conditions. Enteric fermentation is a digestive process whereby feed constituents are broken down by micro-organisms into simple molecules. Both ruminant animals (e.g. cattle and sheep), and non-ruminant animals (e.g. pigs and horses) produce methane, although ruminants are the largest source per unit of feed intake. When manure is stored or treated as a liquid in a lagoon, pond or tank it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid or when it is deposited on pastures, it tends to decompose aerobically and little or no methane is produced. Hence the system of manure management used affects emission rates.

Figure 1.4 Emissions of methane from UK agriculture by source



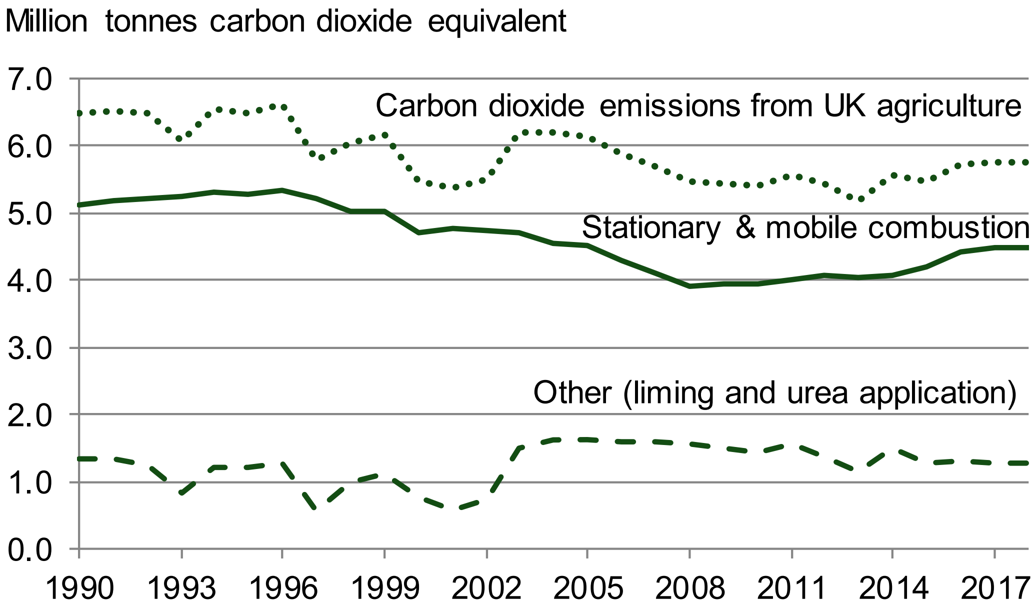
Source: Department for Business, Energy & Industrial Strategy

The majority of the fall in estimated methane emissions since 1990 is due to reductions in the numbers of cattle and sheep in the UK. Measures relating to the greenhouse gas (GHG) emissions intensity of agriculture are explored in Section 2.

1.4 Carbon dioxide emissions

1.6% of carbon dioxide (CO_2) emissions in the UK are attributed to agriculture, these relate mainly to fuel use. Since 1990 there has been an overall decline in estimated carbon dioxide emissions from agriculture.

Figure 1.5 Emissions of carbon dioxide from UK agriculture by source



Source: Department for Business, Energy & Industrial Strategy

1.5 Uncertainty in emissions

There are relatively large uncertainties in estimating agricultural emissions as they are generated by heterogeneous natural systems for which we do not have precise measures. Uncertainties around N_2O emissions are particularly large; they incorporate spatial and temporal variation in emissions factors (e.g. soil texture variations etc), and more structural uncertainties relating to the way the farming industry and biological processes are represented in the current model. Some of these uncertainties are already understood to some extent, whilst others have undergone further research as part of the recent inventory improvement programme.

The table below shows typical uncertainties (for 2018 estimates) in the current methodology and reflects recent improvements in the analysis [21] although, it will not be possible to remove all uncertainty.

Table 2: Emissions uncertainty

IPCC Category	Gas	2018 emissions (Gg CO2e)	Combined activity and emission factor uncertainty (%)
3A Enteric fermentation	Methane	21,173.79	13.7%
3B Manure management	Methane	4,201.12	8.4%
	Nitrous oxide	2,802.04	9.5%
3D Agricultural soils	Nitrous oxide	11,393.74	11.2%

Source: UK National Inventory Report Annex 2[22]

Section 2 summarises a range of statistics which provide an indication of changes in the intensity of emissions from agriculture in terms of the quantity of GHGs per unit of output.

Section 2: Intermediate outcomes & context

This section provides statistics and commentary on some of the key intermediate outcomes and, where possible, proxy measures for greenhouse gas (GHG) intensity, i.e. GHG emissions per tonne of crop or litre of milk or kilogramme of meat produced (Sections 2.1, 2.2 and 2.4 to 2.10). Some examples of the intermediate outcomes covered are productivity, animal longevity and fertility, application rates of manufactured nitrogen and soil nitrogen balances.

The section also covers some of the main contextual factors, such as crop areas, numbers of breeding livestock, prices of agricultural inputs (i.e. animal feed and fertiliser) and prices of agricultural products received by farmers (Sections 2.3, 2.11 and 2.12). Crop areas and the number of breeding livestock indicate overall levels of activity, whilst prices help to explain some of the drivers for changes in this activity.

Background information

By applying best practice, farmers can reduce their GHG intensity (GHG produced per tonne of crop or litre of milk or kilogramme of meat produced) and make a positive contribution to climate change mitigation by:

- improving the efficiency and effectiveness of nitrogen use in cropping systems,
- improving the efficiency of feed conversion in livestock systems,
- storing manures in ways that reduce emissions, and
- protecting and enhancing carbon stores in soils and trees.

It is important to recognise that reducing the GHG intensity of production may not necessarily reduce total UK GHG emissions. All other things being equal, this would increase the competitiveness of the sector, making it more able to compete in international markets. This in turn could encourage an increase in the numbers of livestock or area under crops, which in some circumstances might result in an overall increase in UK agricultural emissions, even where unit intensity has decreased. However, as noted in the introduction, agricultural activity in UK emissions has to be viewed in the broader policy context, including the demand for food. Failure to take action to reduce emissions in the UK could result in “carbon leakage”, where production moves abroad. This would not reduce overall global GHG emissions and could put pressure on sensitive landscapes or habitats overseas.

Improved nitrogen use efficiency in cropping systems can be achieved through improved crop nutrient management; for example by:

- ensuring that all nutrients are in balance to ensure maximum uptake by the crop,
- ensuring that the correct quantity of nitrogen (manufactured and organic) is applied to match crop growth needs,
- ensuring that nutrients are applied to the crop at the right time and in a manner most likely to ensure uptake (e.g. using band spreaders),
- minimising nutrient requirements through selecting the right crop, cultivar and nutrient regime for its intended end use.

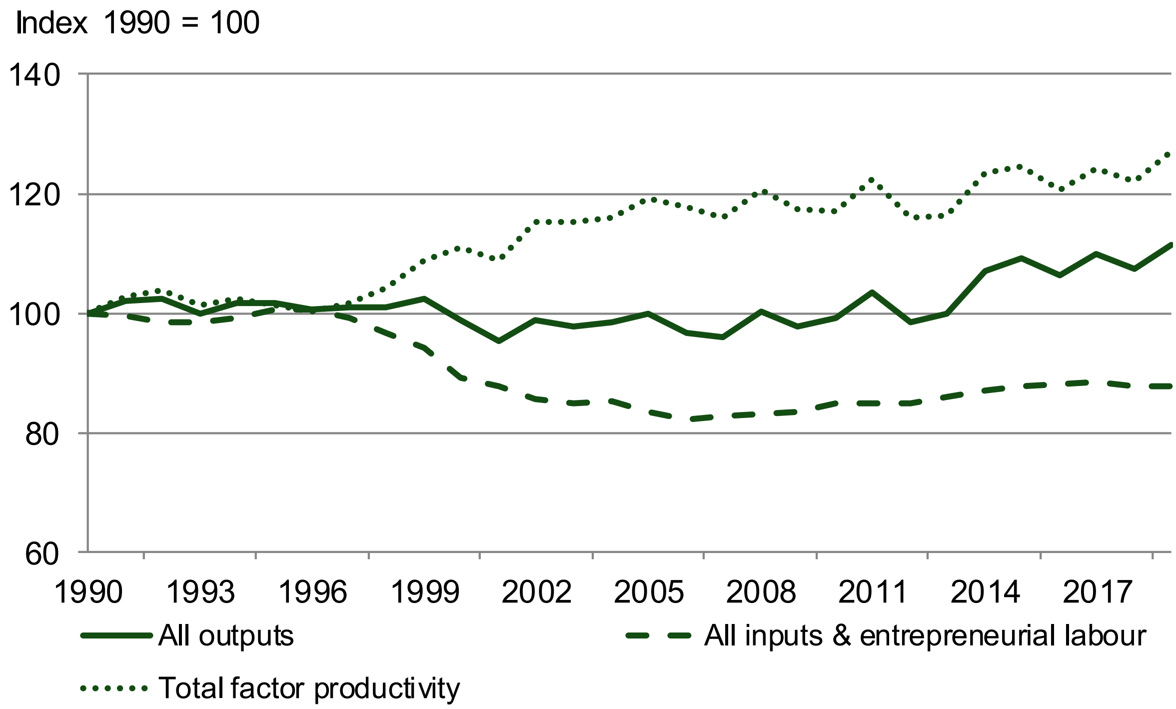
Improved feed conversion can be achieved in livestock systems by:

- ensuring that livestock diets are well-matched to animal needs,
- providing better quality diets,
- breeding animals that produce more offspring or milk and that are less likely to suffer from lameness or mastitis,
- ensuring all animals are healthy (e.g. not subject to endemic diseases which reduce yields and conditions such as Bovine Viral Diarrhoea, liver fluke, mastitis or lameness).

2.1 Headline measures of agricultural input, output and productivity

This section provides a brief summary of how efficiently the agricultural industry uses resources based on headline measures of input, output and productivity. Total factor productivity measures the volume of agricultural output per unit of input, where the input measure includes intermediate consumption, fixed capital, labour and land and covers all businesses engaged in farming activities, including specialist contractors.

Figure 2.1 Total factor Productivity, UK



Source: Defra Statistics

Trends

Total factor productivity has risen over the period with reduced inputs a driving factor since the late 1990s. Since 2005 total factor productivity has remained relatively level with some year to year variations. In the shorter term, total factor productivity is estimated to have increased by 4.0% between 2018 and 2019. This was driven by an increase in overall levels of production combined with static volumes of inputs. Some of the change in productivity, although not all of it, will have a bearing on greenhouse gas intensity, and this is explored in the following section.

2.2 Drivers of change in productivity in the context of greenhouse gas emissions

Table 4a contains the main agricultural outputs and inputs based on volume indices. This broadly illustrates the main drivers of change in the headline measures.

Animal feed forms the greatest contribution to inputs; with the figure remaining similar to the 17% approximate contribution to inputs in 2018. Some inputs, such as animal feed, fertiliser, energy, are more closely related to greenhouse gas (GHG) intensity than others (maintenance, equipment), whilst others are unlikely to be associated with emissions (other goods and services).

This information provides an aggregate picture of the productivity of the industry. However, in the context of emissions it can help inform understanding when used together with information from the rest of this publication. Productivity gains may be related to overall improved GHG intensity given that fertiliser and energy inputs have decreased since 1990, however the increase in animal feed is likely to have offset some of this improvement.

Table 4a: Main drivers of change in productivity

Volume indices 1990=100

	1990	2000	2010	2015	2019
Headline measures					
Output	100.0	98.9	99.1	109.1	111.4
Input	100.0	89.3	84.8	87.7	87.7
Total Factor Productivity	100.0	110.8	116.9	124.4	127.0
Main outputs					
Output of cereals	100.0	111.4	97.5	117.7	117.7
Output of vegetables & horticultural products	100.0	93.8	85.9	86.2	84.4
Livestock output primarily for meat	100.0	94.6	91.8	97.1	102.8
Milk	100.0	93.6	89.8	100.9	102.4
Main inputs					
Energy	100.0	88.8	75.5	74.0	70.7
Fertiliser	100.0	77.7	56.8	57.3	50.2
Animal feed	100.0	100.5	114.5	118.7	123.5
Maintenance	100.0	77.4	73.0	78.3	80.3
Equipment	100.0	93.0	89.5	104.5	113.4
Other goods and services	100.0	96.4	94.9	94.2	95.1

Source: Defra statistics

Table 4b: Contribution to output

	Approx. contribution to output (based on 1990 - 2019 average)
Main outputs	
Output of cereals	12%
Output of vegetables & horticultural products	10%
Livestock output primarily for meat	29%
Milk	17%
Main inputs	
Energy	5%
Fertiliser	5%
Animal feed	18%
Maintenance	6%
Equipment	7%
Other goods and services	12%

Source: Defra statistics

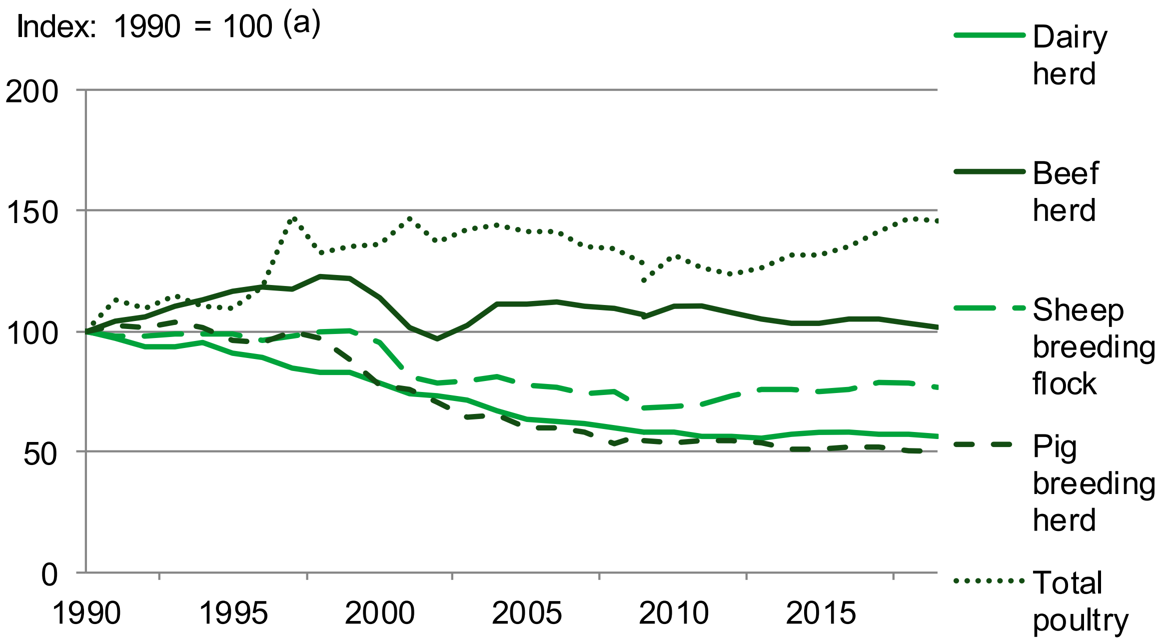
2.3 Contextual factor: livestock numbers and areas of key crops and grasses

Indices of breeding livestock

Rationale

Livestock, particularly cattle[23], are a major source of greenhouse gas (GHG) emissions. They emit methane as a result of enteric fermentation[24] and their manures release nitrous oxide. Trends in livestock populations are presented to illustrate changes in the basic drivers of emissions. GHG intensity[25] is explored in the sections which follow.

Figure 2.2 Changes in selected livestock populations, England



(a) Break in time series in 2009

Source: June Agricultural Survey, Cattle Tracing System

Notes: Cattle population changes are based on the June Agricultural Survey up to 2004 and Cattle Tracing System data from 2005 onwards. Dairy and beef herds are defined as cows and heifers that have calved.

Estimates for 2009 onwards are not directly comparable to earlier years due to a large number of inactive holdings being removed from the survey register following the 2010 census and the introduction of a survey threshold. Further details can be found in the [June Survey methodology report]

Trends

There has been a long term downward trend in the number of dairy cows since the introduction of milk quotas in 1984. The beef (or suckler) herd increased during the 1990s linked to headage based payments for suckler cows and switches from milk production. Changes to subsidy schemes in 2000 and the 2001 Foot and Mouth (FMD) outbreak led to substantial reductions in the number of beef cows. However, numbers recovered to some extent and have remained relatively stable since.

There was little overall change in the size of the sheep breeding flock during the 1990s, largely due to quota limits. As for the beef herd, changes to subsidy schemes in 2000 and the FMD outbreak in 2001 resulted in a substantial reduction in ewe numbers. There was a further decline following the last CAP reforms in 2004 but ewe numbers have seen an increase in more recent in years.

The breeding pig population shows an overall downward trend, particularly since the mid-1990s. This is due to a number of factors including problems with disease and high feed prices, however numbers have remained relatively stable over the last 5 years.

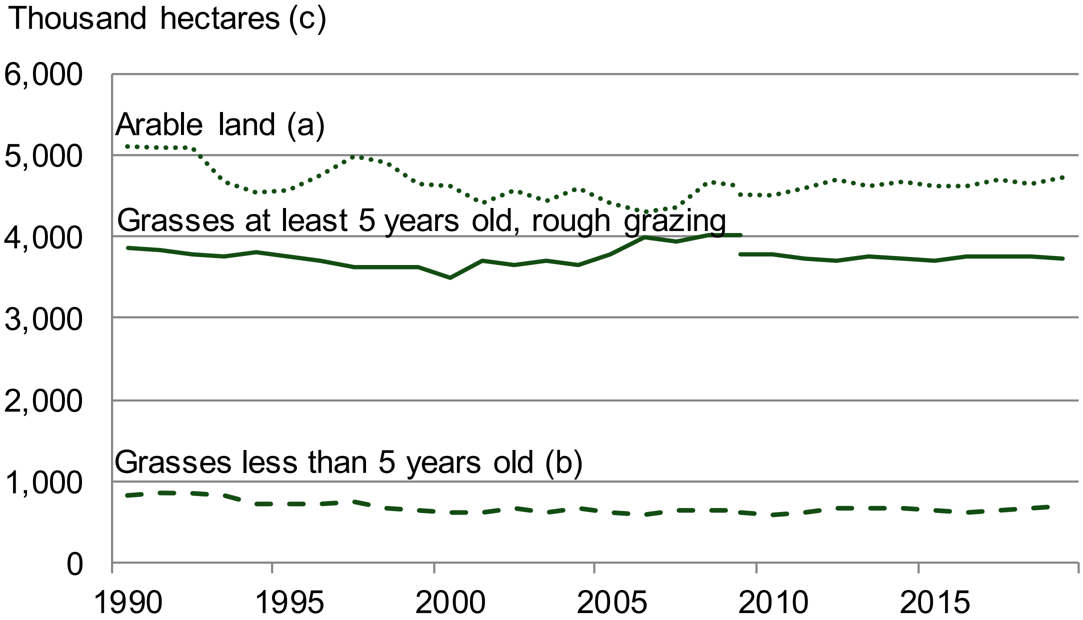
Poultry numbers generally increased between 1990 and 2004. This was followed, until recently, by an overall declining trend. Several factors influenced this; rising input costs (particularly for feed but also lighting, heating and labour) led to reduced profit margins or even losses with some producers leaving the industry. The introduction of legislation (preparation for the conventional cage ban in 2012 and the Integrated Pollution Prevention Control rules) also increased input cost over the period. Outbreaks of Avian Influenza between 2006 and 2008 may have been an influencing factor too. However, more recently there have been increases in numbers.

Crops and grasses

Rationale

Trends in crop and grass areas are shown to illustrate other key drivers of emissions. Levels of emissions are dependent on a range of factors primarily the nitrogen quantity applied but also including: timing and application method used. Nitrogen requirements differ between the types of "crop" grown (including grass).

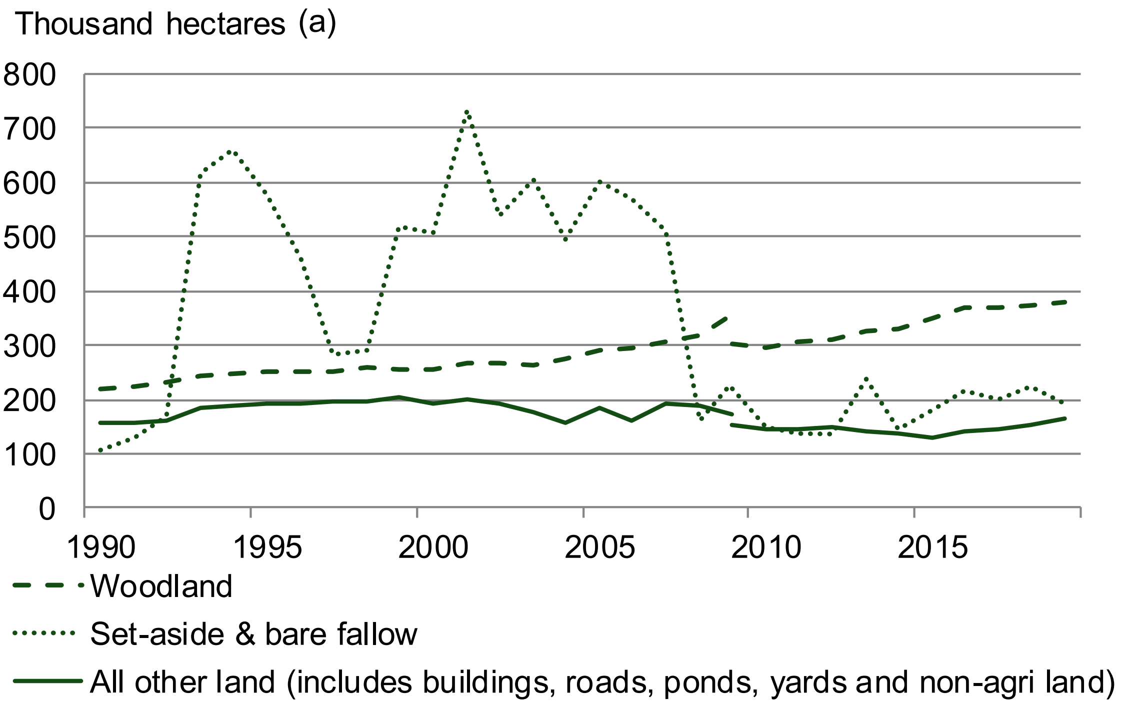
Figure 2.3 Arable land and grassland, England



Source: Defra. June Agricultural Survey

(a) Excludes fallow and set-aside land. Includes grasses less than 5 years old.
(b) Grasses less than 5 years old are shown separately but are also included within “Arable land”.
(c) Break in time series in 2009

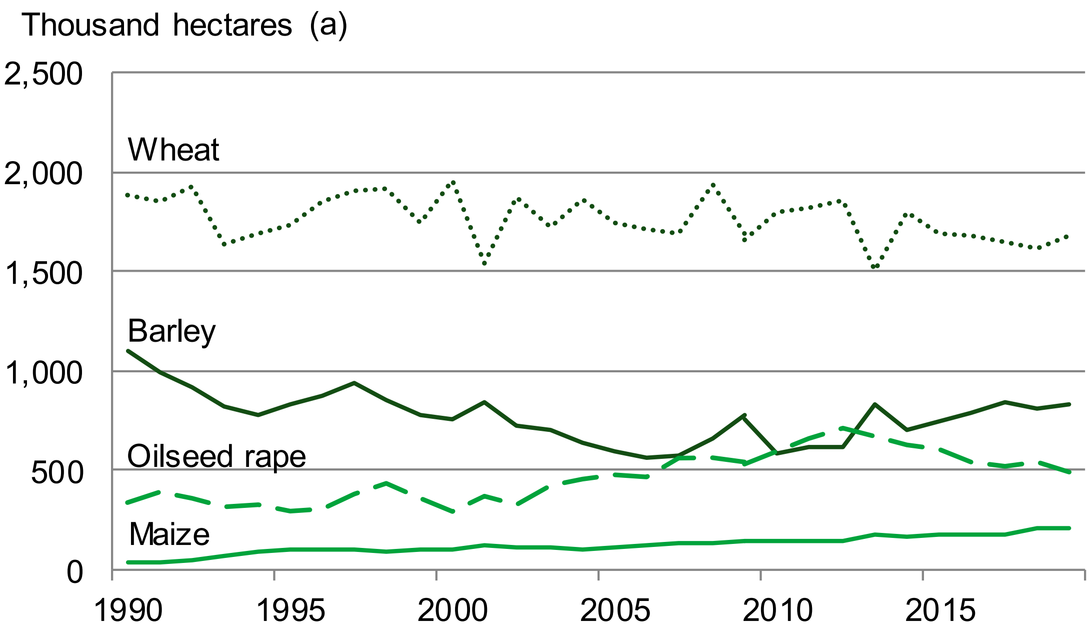
Figure 2.4 Woodland, bare fallow, set-aside* and other land, England



*Set-aside removed in 2008
(a) Break in time series in 2009

Source: Defra, June Agricultural Survey

Figure 2.5 Wheat, barley, maize and oilseed rape areas*, England



*Excludes areas grown on set-aside land
(a) Break in time series in 2009

Source: Defra, June Agricultural Survey

Note: estimates for 2009 onwards are not directly comparable with earlier years due to a large number of inactive holdings being removed from the survey register following the 2010 census and the introduction of a survey threshold. Further details can be found in the June Survey methodology report

Trends

The main crops grown in England are wheat, barley and oilseed rape; together these accounted for 33% of utilised agricultural land in 2019.

The total area of cropped land increased (by 14%) in 2008 following the removal of set-aside requirements as farmers responded to high global cereal prices by planting more wheat.

There was a gradual increase in the area of permanent grassland (grass at least 5 years old) from 2000 which peaked in 2008. The reasons for this are unclear but it could be due, in part, to increased survey coverage of agricultural holdings rather than actual increases in grassland areas. Following the Foot and Mouth Disease (FMD) outbreak in 2001 an increased number of farms were registered with holding numbers for animal health and disease control purposes. The introduction of the Single Payment Scheme (SPS) in 2005 may also have resulted in an increase in registered holdings and may have led some farmers to reclassify grassland on their June Survey returns to reflect SPS requirements for recording grass.

The area of (primarily forage) maize increased from 116 thousand hectares in 2000 to 211 thousand hectares in 2019. Whilst there have been some fluctuations across this period, the overall trend is upwards. Although largely grown on holdings with dairy cows, in recent years there have also been increases on other types of farms[26] and from 2014 data have been collected on the area of maize grown as a feedstock for anaerobic digestion. In 2014 this amounted to 29 thousand hectares, increasing to 67 thousand hectares in 2019 which is an increase of 10 thousand hectares compared to 2018.

Within this section we have shown that there have been changes in the number of livestock and in agricultural land use in England. This has had an impact on the total level of emissions. Additionally, any changes in productivity may have had an impact on the intensity of emissions - that is, the emissions of GHGs per tonne of crop or litre of milk or kilogramme of meat produced. Because it is not currently possible to calculate emissions on farms directly, proxy measures are required to help understand intensity; these include for example, ratio of feed production to milk produced. Sections 2.4 to 2.10 consider proxies for intensity and some other key measures.

2.4 Dairy

Since the introduction of milk quotas in 1984 there has been a significant reduction in the number of dairy cows in England overall, an important driver in the reduction in greenhouse gas (GHG) emissions. It is not possible to calculate emissions or emissions intensity on farms directly. For this reason proxy measures have been developed which are associated with emissions; these include output per unit of feed, longevity, fertility and mortality. In this section we explore productivity in the dairy sector and how this relates to GHG emissions intensity.

2.4.1 Dairy: efficiency of output

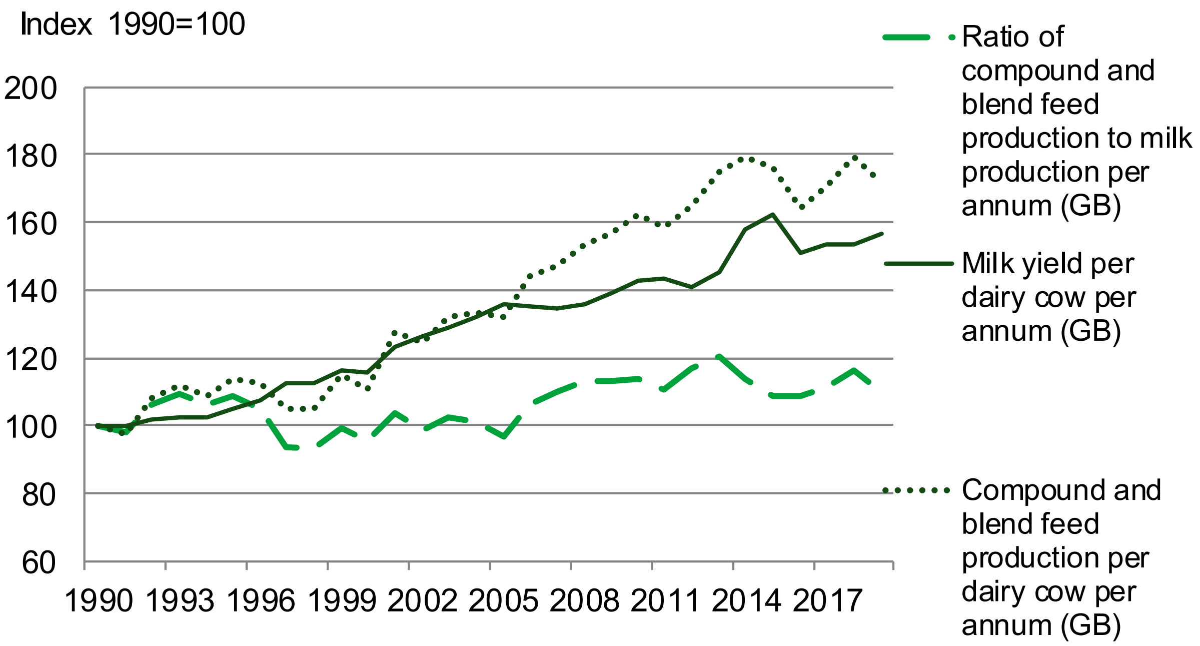
Ratio of dairy cow feed production to milk production

Rationale

Considering milk yields in conjunction with trends in inputs (such as dry matter feed) provides an indication of GHG intensity in the dairy sector. The ratio of dairy cow feed production to milk production is used here as a proxy measure for on-farm GHG emission intensity.

The ratio of dairy cow feed production to milk production is the GHG indicator[27] for the dairy sector. More details of this can be found in the [Summary](#) earlier in the publication and in the [full indicator text](#).

Figure 2.6 Ratio of dairy cow compound and blend feed production to milk production per annum, GB



Source: Defra statistics

Trends

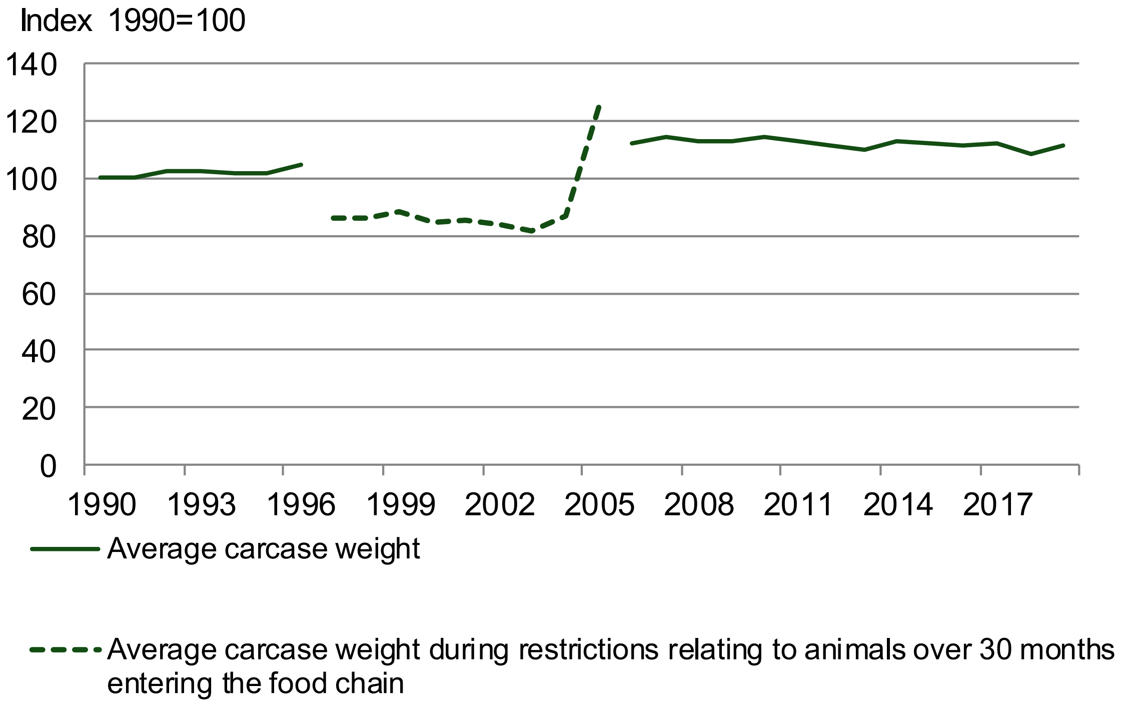
In terms of moving towards the desired outcome, milk yields per dairy cow have increased since 1990. However, for much of the last decade the rate of increase of compound and blended feed production has been greater than the rate of increase in average milk yields. This might suggest that overall there has been a reduction in feed efficiency and an increase in GHG intensity. In the shorter term, the ratio of compound and blend feed production to milk production has fallen, driven by a decrease in feed production. This indicates improving emission intensity for milk production. The picture is complex however because the quantity of compound and blend feed produced (shown in the chart) will be influenced by changes in the availability of on-farm feeds, forages and grazed grass but for which data are not currently available.

Weight of cull cows

Rationale

Live weight can also be used as a proxy for milk yield; all other things being equal, a heavier cow will produce more milk than a lighter one. As limited information is currently available on live weight, the carcase weight of cull cows (cows culled at the end of their productive life) is considered here as a proxy for live weight. The chart below provides an index of cull cow carcase weights. This includes cull cows from both the dairy and suckler (beef) herds.

Figure 2.7 Average cull cow carcase weights, UK



The lower carcase weight between 1997 and 2005 (shown by the dashed line) is due to restrictions prohibiting beef from animals aged over thirty months from entering the food chain.

Source; Slaughterhouse surveys, Defra, The Scottish Government, DARD (NI)

Note: it is not possible to distinguish between dairy and beef cows from the slaughter statistics.

Trends

On average, cull cows are now heavier than in the 1990s. Genetic selection for milk yield has increased the mature weight in dairy cattle leading to the overall increase, despite there being relatively fewer dairy cows now than 20 years ago.

Figures since 2006 (by which time the restrictions prohibiting beef from animals aged over thirty months from entering the food chain had been lifted) do not show any clear upward (or downward) trend. Milk yields have increased more than the carcase weight of cull cows.

2.4.2 Dairy: longevity and fertility

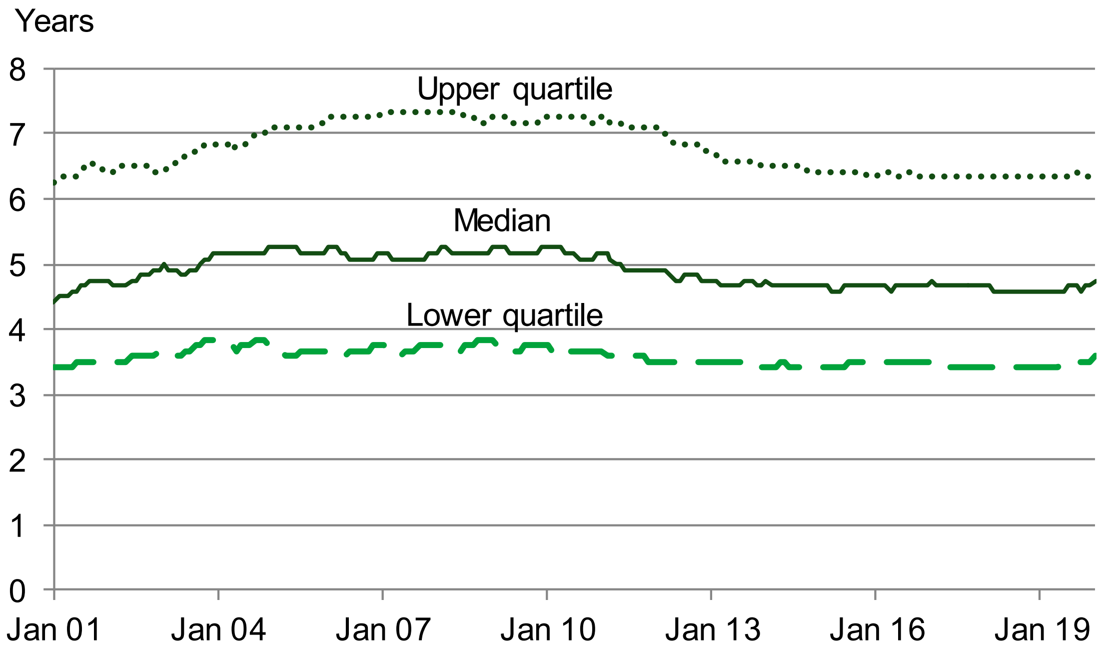
Age of cattle and fertility

Rationale

Increased fertility rates and longevity of breeding animals will help secure reductions in greenhouse gas emissions as fewer replacement females will be required to deliver the same level of production. This would also reduce an 'overhead' cost of milk production. Age of dairy herd (breeding animals)

The chart below shows the median age and inter quartile range of female dairy cattle aged 30 months and over.

Figure 2.8 Age of female dairy cattle over 30 months, monthly data, GB



Source: Defra, RADAR Cattle Tracing System

Trends

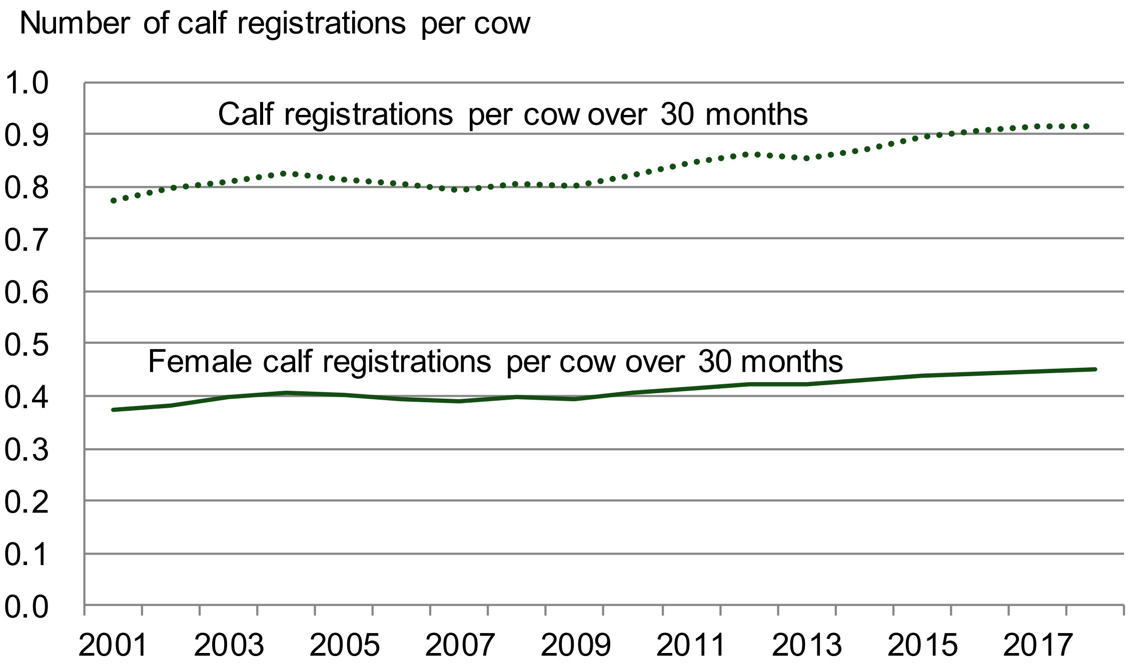
The median age of the dairy breeding herd (cows aged over 30 months) is slightly higher than in 2001, but has declined a little over the last five years. The increase between 2001 and 2004 is thought to be due to a recovery following the 2001 outbreak of Foot and Mouth Disease (FMD) and changes to restrictions associated with Bovine Spongifom Encephalopathy (BSE) where Over Thirty Month scheme and Older Cattle Disposal scheme impact on the trends. The current situation does not suggest any significant increase in the age of breeding herds above levels prior to FMD and BSE restrictions.

The inter quartile range (IQR) is given to assess the spread of the age of cattle. An increase in longevity will be demonstrated by an increase in the median or an increase in the IQR, such that the upper quartile increases by more than the lower quartile. The IQR for dairy cattle ages has been relatively stable since 2007 although recent decreases in the upper quartile suggest a slight reduction in longevity.

Further information on the distribution of dairy cows by age in months can be found at (ii) in the Appendix.

Figure 2.9 Calf registrations per cow GB

Note: at present, data are not separately available for dairy and beef cattle[28]

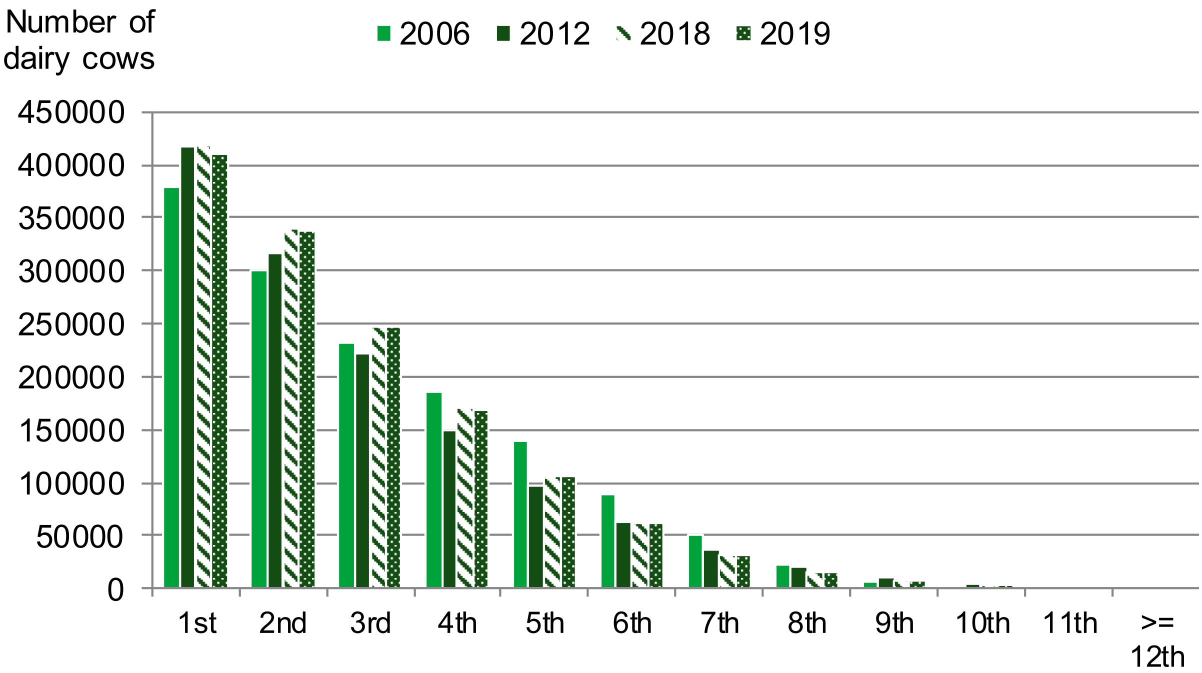


Source: Defra, RADAR Cattle Tracing System

Trends

Overall, the numbers of calf registrations per cow have remained relatively stable over the 16 year period for which data are available, although recent indications suggest an increasing number of registrations per cow.

Figure 2.10 Number of calvings by dairy cow in GB – 2006, 2012, 2018 and 2019



Source: Defra, RADAR Cattle Tracing

Trends

In 2019, 1.39 million dairy cows had calves compared to 1.41 million in 2006. Of these, the proportion of dairy cows that calved for the first time (the effective replacement rate) was 29% in 2019 compared to 27% in 2006, while the proportion calving for a second time increased from 21% in 2006 to 24% in 2019.

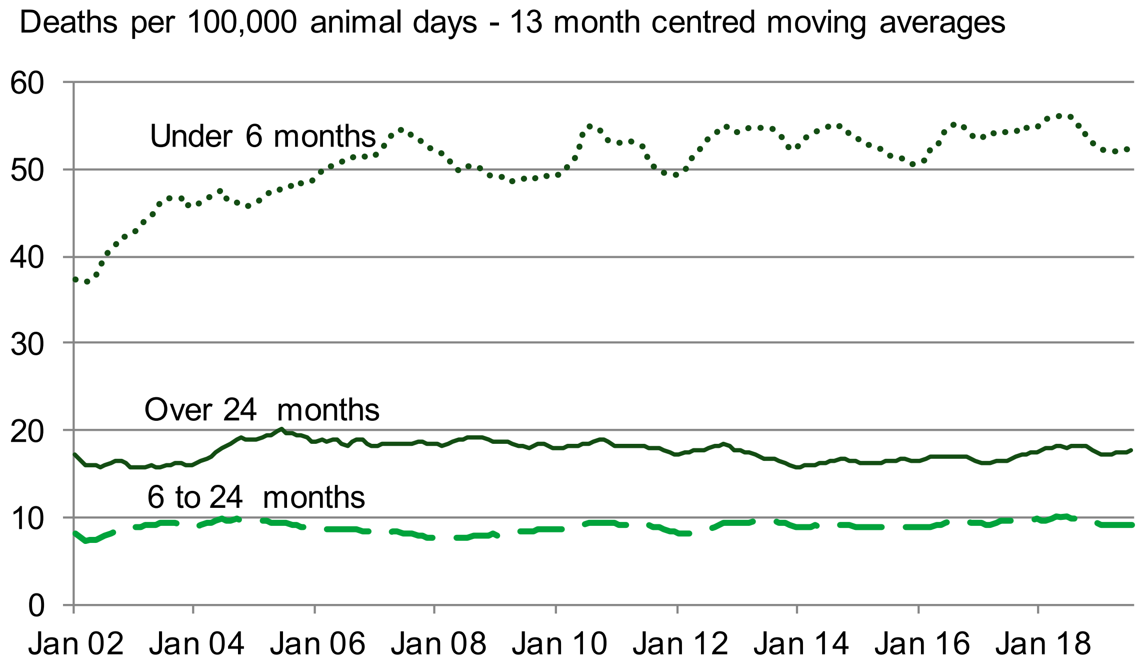
2.4.3 Dairy: animal health

On-farm mortality

Rationale

Reductions in on-farm mortality[29] will lead to less wastage. Reduced disease will lead to greater productivity. For cattle, overall mortality may be a better indicator than the incidence of specific diseases for which we do not have full data.

Figure 2.11 On-farm mortality for dairy cattle, GB



Source: Defra, RADAR Cattle Tracing System

Trends

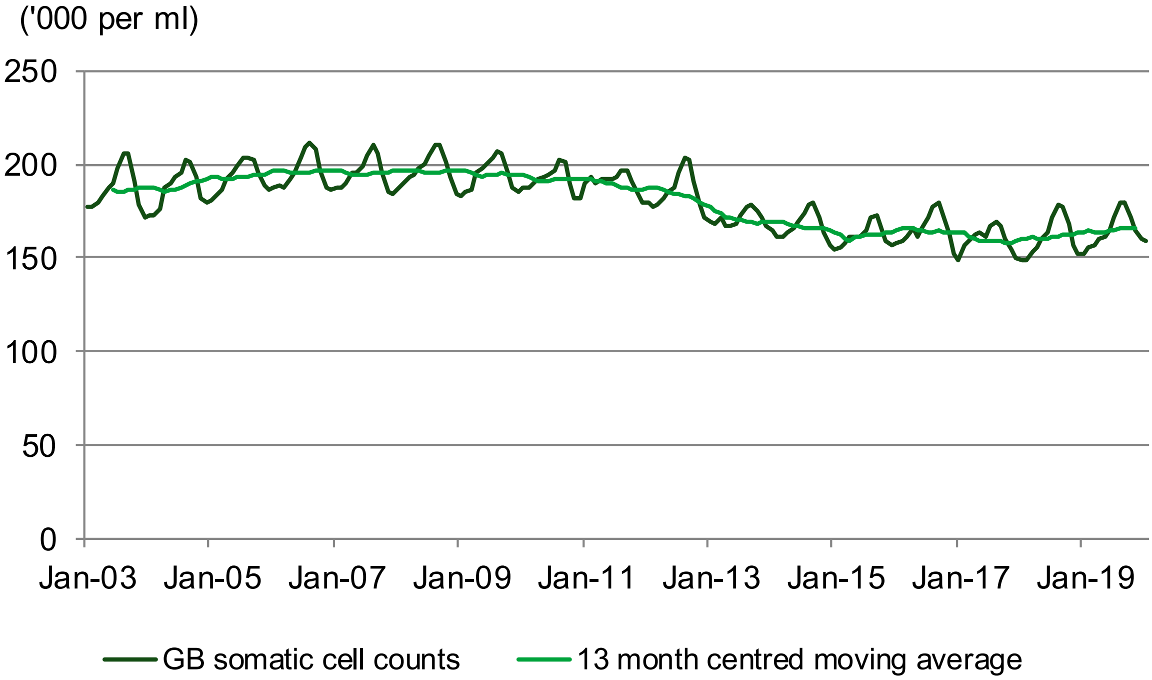
There was an overall reduction in on-farm mortality for registered dairy calves (under 6 months) between 2007 and early 2010. This was followed by an increase during 2010. It is not clear why this increase occurred as there were no obvious causes, such as a disease outbreak or adverse weather conditions. There has been some fluctuation since then; levels are now similar to those seen at the start of 2010. For dairy cattle age 6 to 24 months there has been little variation in on-farm mortality since 2009 but for those in the over 24 month category there has been a slight downward trend.

Somatic cell counts in the dairy herd

Rationale

High counts of somatic cells normally indicate a mastitis infection or udder damage often caused by faulty milking machines or improper use of milking equipment. A high cell count can mean reduced productivity whilst low counts of somatic cells in milk indicate a healthy, well managed dairy herd.

Figure 2.12 Somatic cell counts, GB



Source: AHDB Dairy, GB Dairies

Trends

The somatic cell count increased from 2003 to 2006 but has decreased significantly since 2009. A “healthy” somatic cell count range is generally accepted to be between 50,000 and 250,000 cells per ml.

2.4.4 Dairy: manure management

Good manure management practices, in terms of both storage and application, can help reduce the environmental risks to both air and water, including emissions of ammonia.

In terms of solid manure systems, the 2020 Farm Practices Survey (FPS)[30] reported that:

- 67% (+/-5%) of dairy farms had facilities to store solid manure in heaps on a solid base, a decrease from 71% in 2019. Overall 9% (+/-4%) of such stores were covered.
- 64% (+/-5%) of dairy farms could store solid manure in temporary heaps in fields.

In terms of slurry based systems, the 2020 FPS reported that:

- 63% (+/- 8%) of dairy farms had facilities to store slurry in a tank, of these around 22% (+/- 7%) were covered.
- 50% (+/- 7%) could store slurry in lagoons (without strainers) and 15% (+/- 5%) in a strainer facility.

Note: some farms have more than one type of storage system. For details on manure application see Section 2.9.2

2.4.5 Dairy: economic position

Table 5: Gross margins from dairy herds grouped by economic performance band, England

(£/head unless otherwise stated)	2017/18 Low performers (bottom 25%)	2017/18 High performers (top 25%)	2017/18 All	2018/19 Low Performers (bottom 25%)	2018/19 High performers (top 25%)	2018/19 All
Average herd size (head)	73	328	178	75	324	182
Forage area (ha per head)	0.7	0.5	0.5	0.7	0.5	0.5
Yield (litre per cow)	5,858	8,195	7,794	6,115	8,735	8.088
Price (pence per litre)	28	30	30	29	31	30
Milk sales	1,626	2,481	2,305	1,786	2,719	2,445
Calf sales & transfers out	122	117	122	117	120	119
Miscellaneous output	39	2	9	3	0	1
Less herd depreciation	-215	-192	-202	-212	-181	-204
Enterprise output/cow	1,573	2,408	2,234	1,693	2.658	2,361
Variable costs						
Concentrates	459	633	612	557	767	703
Conc/litre (pence)	7.8	7.7	7.9	9.1	8.8	8.7
Coarse fodder	39	49	41	79	91	76
Vet and medicine costs	58	79	73	58	91	79
Other livestock costs	170	172	174	181	201	193
Forage variable costs	62	75	76	64	80	81
Fert/litre (pence)	0.7	0.5	0.6	0.7	0.5	0.6
Total variable costs/cow	788	1008	976	929	1230	1132
Gross margin/cow	**785**	**1401**	**1258**	**754**	**1428**	**1229**
Variable costs pence/litre	13	12	13	15	14	14

Source: Farm Business Survey

Table 5 provides a comparison of gross margins for dairy herds between low and high economic performance groups. Data from the Farm Business Survey indicates that the average milk yield for high performing farms was around 40% higher than low performing farms in 2018/19, the same difference found in 2017/18. High performing farms tend to spend more per cow than low performing farms, the percentage difference increased from 28% more in 2017/18 to 31% more in 2018/19. The cost per litre of milk was 7% greater for high performers in 2018/19, the same as in 2017/18. Fertiliser costs per litre of milk were lower for high performing groups across both years. Concentrated feed is the greatest input cost for both groups with high performers spending 38% more than lower performing enterprises in 2018/19.

The top 25% of performers achieved higher gross margins overall, influenced by the more favourable price per litre of milk they achieved in both years. In terms of gross margin per cow, the overall gap between the high and low performers increased between 2017/18 and 2018/19, the longer term trends also show the gap growing[31].

2.4.6 Dairy: summary

In the longer term, compound and blended feed production increased at a greater rate than the average milk yield, suggesting an overall reduction in feed efficiency and an increase in greenhouse gas (GHG) intensity. In the shorter term, the ratio of compound and blend feed production to milk production has decreased, driven by a decrease in feed production. This indicates improving emission intensity for milk production. With respect to milk production, increased milk yields have partially offset reduced cow numbers (Section 2.3).

Information from the Farm Business Survey indicates that the difference between high and low economic performance groups is largely driven by yield and average milk price achieved (Section 2.11 for average milk prices). In terms of gross margin per cow, the overall gap between the high and low performers decreased between 2016/17 and 2017/18. Further details of economic and GHG performance in the dairy sector can be found in Section 4 of the 2nd Edition of Agricultural Statistics and Climate Change.

Over the last 7 years, the average age of breeding animals has decreased slightly which may suggest a slight decline in longevity. Overall, calf registrations have increased marginally in the last 7 years to around 0.96 per breeding cow (note due to data availability this is for both dairy and beef cattle). There have been fluctuations in on-farm mortality for registered dairy calves (under 6 months old) and levels are currently similar to those seen in 2010, prior to a period of increased mortality. For dairy cattle aged 6 to 24 months there has been little change since 2009 while for those over 24 months levels of on-farm mortality have seen a slight downward trend. Somatic cell counts have reduced significantly since 2009. Taking all these factors into consideration suggests that there may have been a reduction in the intensity of GHG emissions from the dairy sector.

2.4.7 Dairy: further developments

Current statistics provide a partial picture of the relevant drivers of GHG emissions as, for example, it is not possible to calculate milk production per kilogramme live weight. The following measures would provide a more complete picture but not all can feasibly be populated with robust data in the short term; although some of the data are collected through the Cattle Tracing System there are significant complexities in extracting it from its current format.

- Calving interval (reasons why intervals are longer than expected)
- Age at first calving
- Number of lactations
- Live weight split by beef and dairy
- Herd replacement rate (via lactation number)
- Number of calves available for finishing as beef
- Calving season
- Grazing days
- Percentage of milk from grass based systems
- Reasons for culling

2.4.8 Dairy: notes on data collection methodology and uncertainty

Milk production and feed production

The data on compound and blended feed production shown here are from the survey returns of all of the major GB animal feed companies. Data on raw material use, stocks and production of the various categories of compound animal feed are recorded. The major producers typically cover 90% of total animal feed production surveyed each month. The remaining smaller companies are sampled annually in December for their figures in the preceding 12 months. Sampling errors of the production estimates are small. Links to the survey methodology are given in the Appendix.

On-farm production of animal feed is not covered here, nor are transfers between farms or exports of compound feed. However, trade in compound feeds in the UK is not significant (unlike trade in raw ingredients used to produce compound feeds).

Annual milk production based on data supplied by the Scottish Government and information collected through a producer survey.

Information from the Cattle Tracing System

The CTS is an administrative dataset and all cattle in GB are included in the dataset. Thus estimates shown here are based on the full cattle population. Links to the methodology are given in the Appendix.

Farm Business Survey

Where the sample size is relatively small, confidence intervals can be quite large, and care needs to be taken with interpretation of the significance of the differences. A link to information on the Farm Business Survey methodology is given in the Appendix.

2.5 Beef

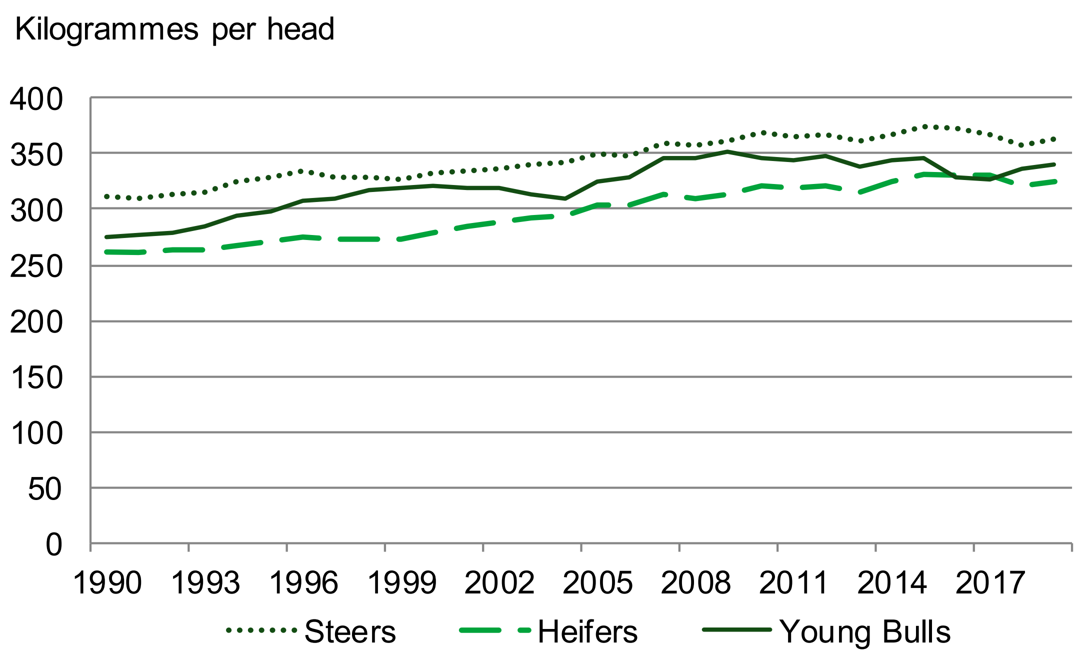
2.5.1 Beef: efficiency of output

Weight at slaughter

Rationale

More efficient finishing[32] has the potential to reduce emissions and increase productivity. It is desirable for average carcase weights to increase, though not at the expense of increased intensity of emissions, i.e. greenhouse gas (GHG) emissions per kilogramme of meat produced.

Figure 2.13 Cattle: average home killed dressed carcase weights from prime cattle, UK



Source: Slaughterhouse surveys, Defra, The Scottish Government, DARD (NI)

Trends

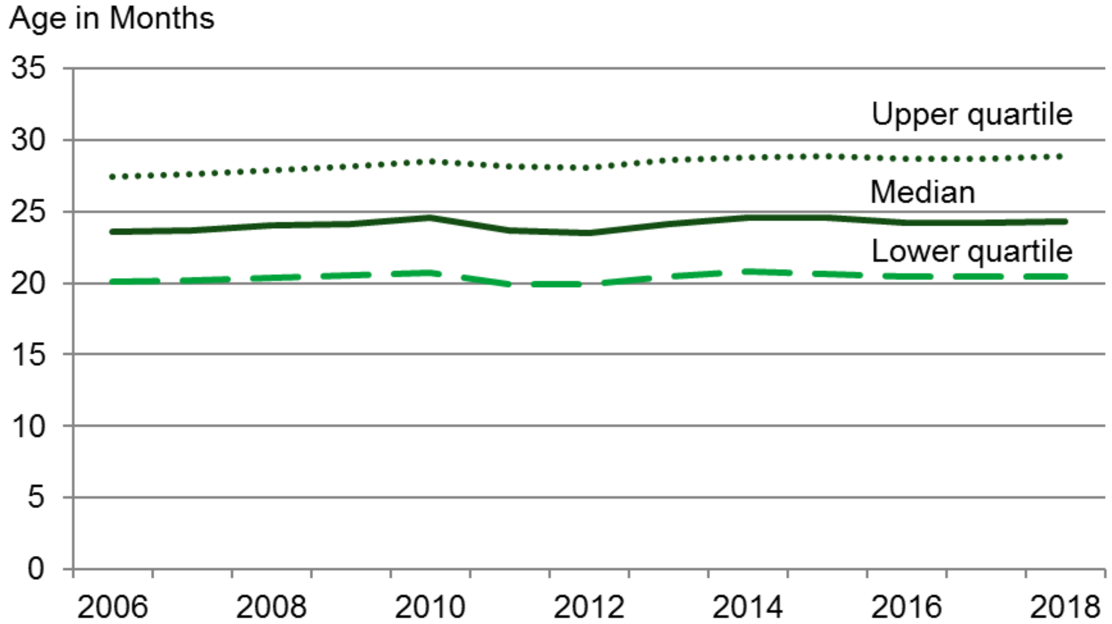
Since 1990 there has been an overall increase in the average carcase weight of prime beef cattle, although the rate of increase has slowed in more recent years. For young bulls and steers there has been a slight decrease over the last 3 years.

Age at which cattle under 4 years are slaughtered

Rationale

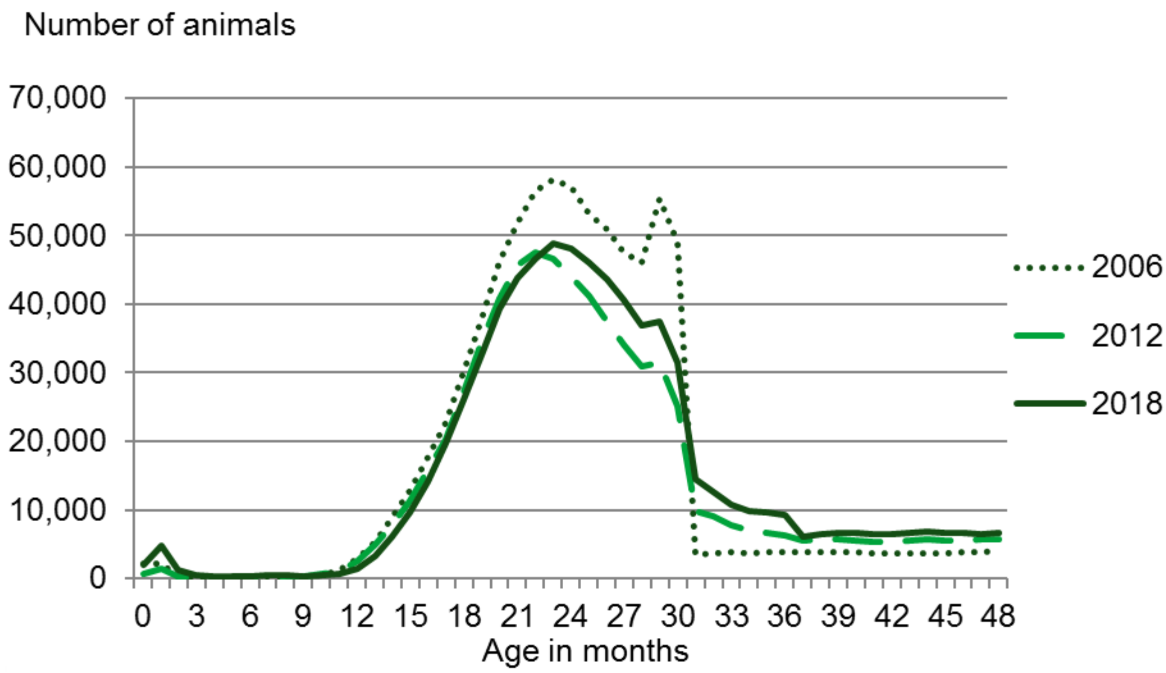
Both the average meat produced per animal (see previous page), and the age of cattle at slaughter are factors in determining emissions. Considering these jointly helps to inform understanding of the emissions intensity. Here we use the median as a measure of age at slaughter. It is also relevant to understand the age distribution; the lower and upper quartiles provide a measure of this. The second chart provides more details of the age at which animals have been slaughtered since 2006. Cattle over 4 years have been excluded as these will primarily be breeding animals. Please note 2019 data was unavailable at time of publication.

Figure 2.14 Age at slaughter for female cattle under 4 years, GB



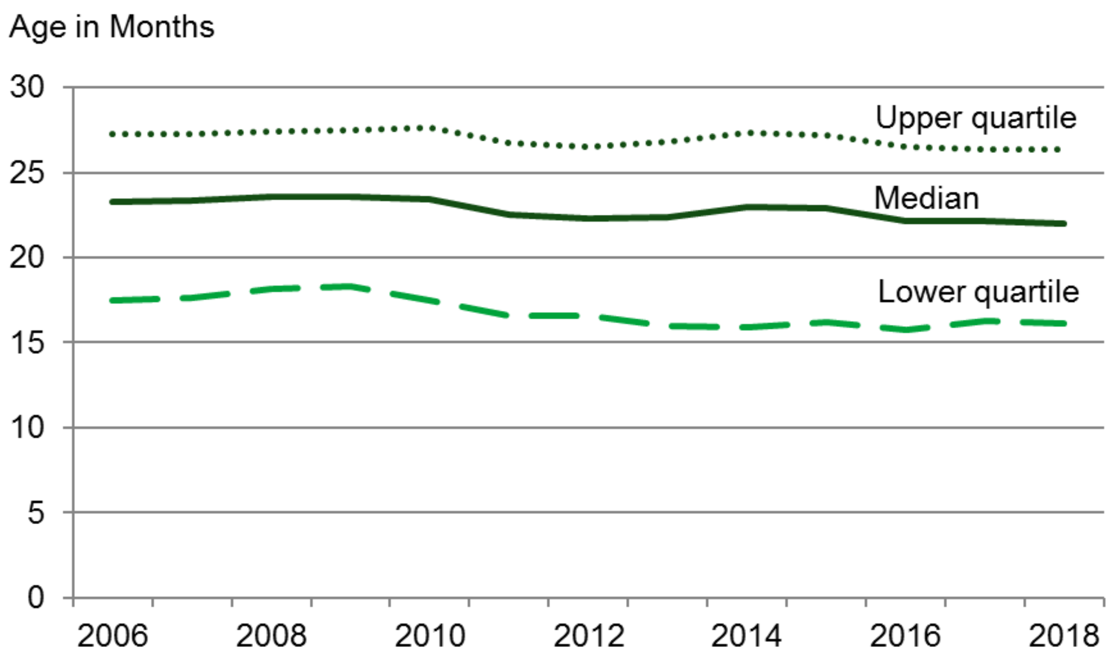
Source: Defra, RADAR Cattle Tracing System

Figure 2.15 Age at slaughter for female cattle under 4 years in 2006, 2012 & 2018, GB



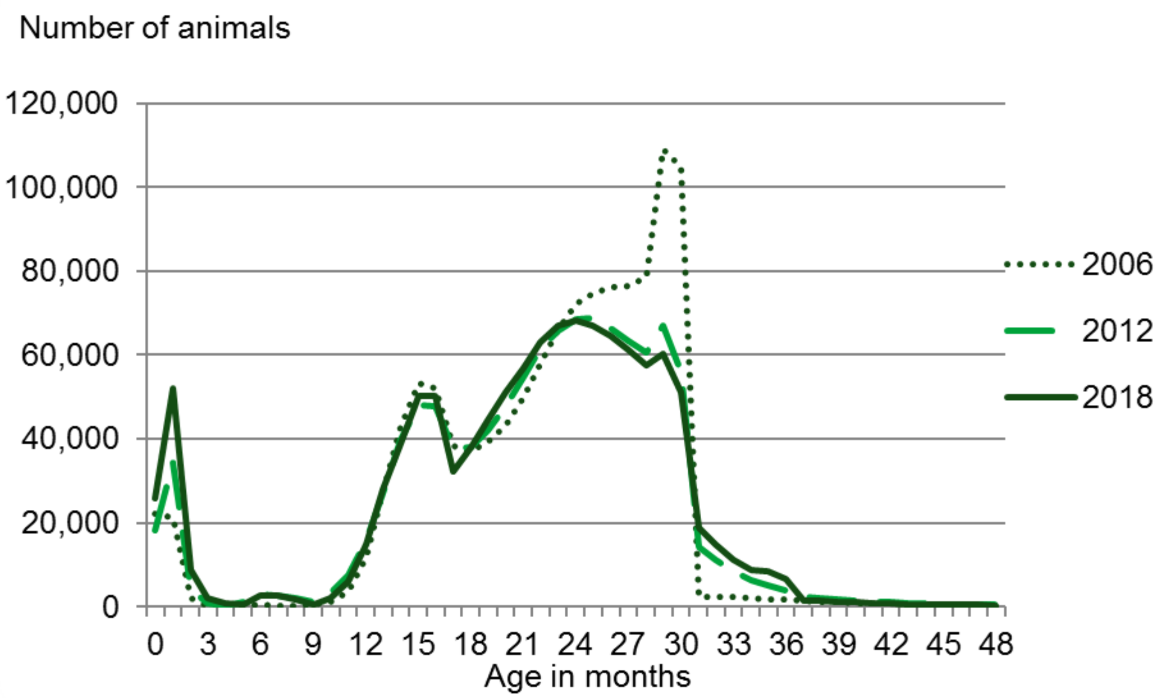
Source: Defra, RADAR Cattle Tracing System

Figure 2.16 Age at slaughter for male cattle under 4 years, GB



Source: Defra, RADAR Cattle Tracing System

Figure 2.17 Age at slaughter for male cattle under 4 years in 2006, 2012 & 2018, GB



Source: Defra, RADAR Cattle Tracing System

Trends

The average age at slaughter of both male and female cattle (under 4 years old) has remained at a similar level since 2006 although slight declines were seen in 2011 and 2012, particularly in male cattle. There has been some increase in the number of animals slaughtered beyond 30 months as meat from older animals is now allowed to enter the food chain, but there is still a significant dip around 30 months. The overall increase in average carcase weights, with little change in the age at slaughter suggests the intensity of greenhouse gas emissions may have improved slightly since 2006.

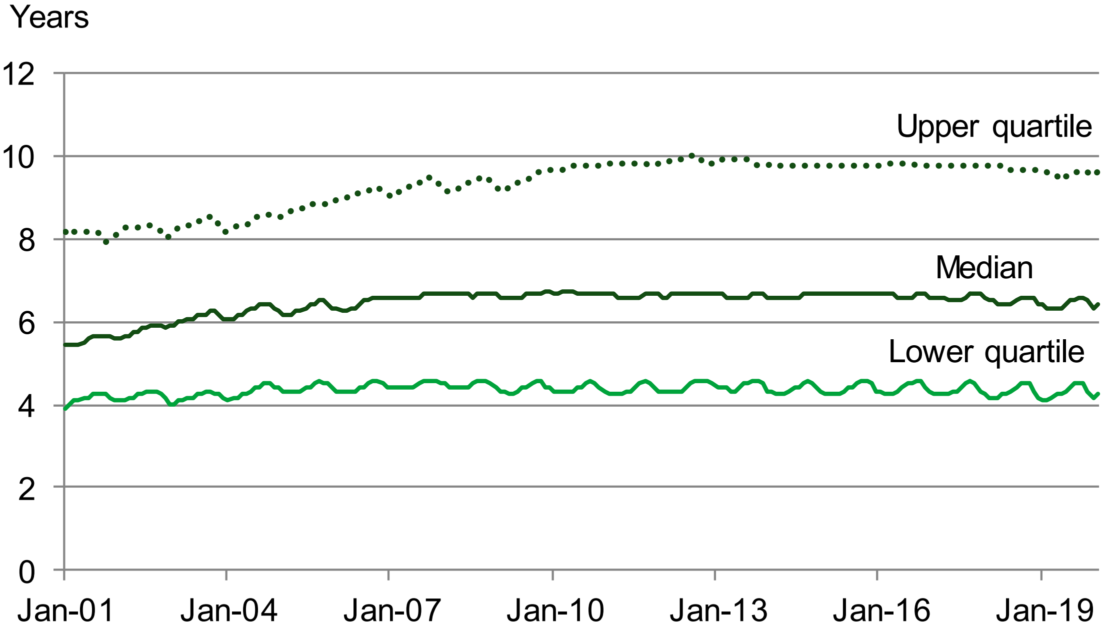
2.5.2 Beef: longevity and fertility

Age of cattle and fertility

Rationale

Increased fertility rates and longevity of breeding animals will help secure reductions in greenhouse gas emissions given that, all things being equal, fewer breeding females would be required.

Figure 2.18 Age of female beef cattle over 30 months old, monthly data, GB



Source; Defra, RADAR Cattle Tracing System

Trends

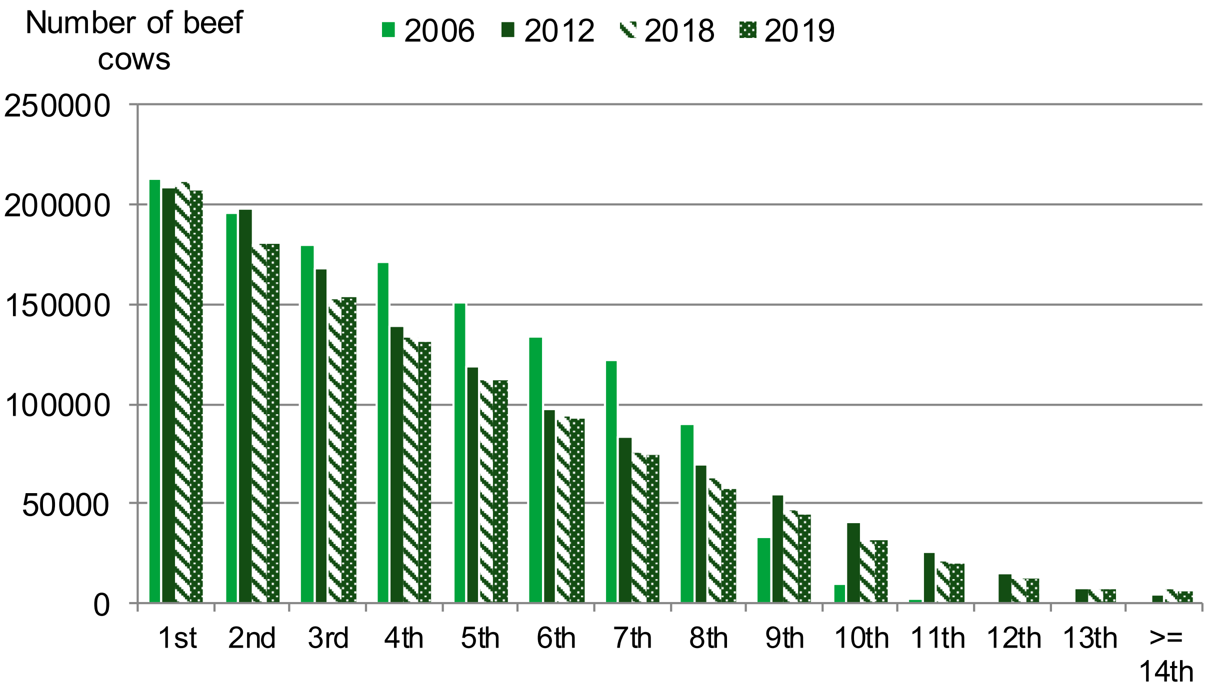
The median age of the beef breeding herd (cows aged over 30 months) has increased since 2001 but has remained relatively stable since 2007. This rise is thought to be due to a recovery following Foot and Mouth (FMD) and changes to restrictions associated with Bovine Spongiform Encephalopathy (BSE) (where Over Thirty Month scheme and Older Cattle Disposal scheme impact on the trends). The data do not suggest any significant increase in age of breeding cattle above levels prior to FMD and BSE restrictions.

The inter quartile range (IQR) is given to assess the spread of the age of cattle. Increased longevity in the beef breeding herd will be demonstrated by an increase in the median or an increase in the IQR, such that the upper quartile increases by more than the lower quartile. The IQR for beef cattle ages has increased since 2007 and the upper quartile has changed more than the lower quartile implying some increase in the overall longevity. For distribution of beef cows by age in months please see (iii) in the Appendix.

Calf registrations per cow (at present data is only available for all dairy and beef animals)

See Section 2.4 Dairy. The overall levels have remained relatively stable with no major upward or downward trend.

Figure 2.19 Number of calvings by beef cows in GB – 2006, 2012, 2018 and 2019



Source: Defra, Cattle Tracing System

Trends

In 2019, 1.13 million beef cows had calves compared to 1.30 million in 2006. Of these, 18% calved for the first time (the effective replacement rate) in 2019, a slight increase on 2006 when the level was 16%. The proportion calving for a second time has remained virtually unchanged over the period standing at 15% and 16% in 2006 and 2019 respectively.

In recent years there has been an increase in the number and proportion of beef cows calving over 8 times; from around 46 thousand in 2006 to 122 thousand in 2019 with a peak of 149 thousand in 2012. This trend suggests that overall longevity within the breeding herd has increased across this period.

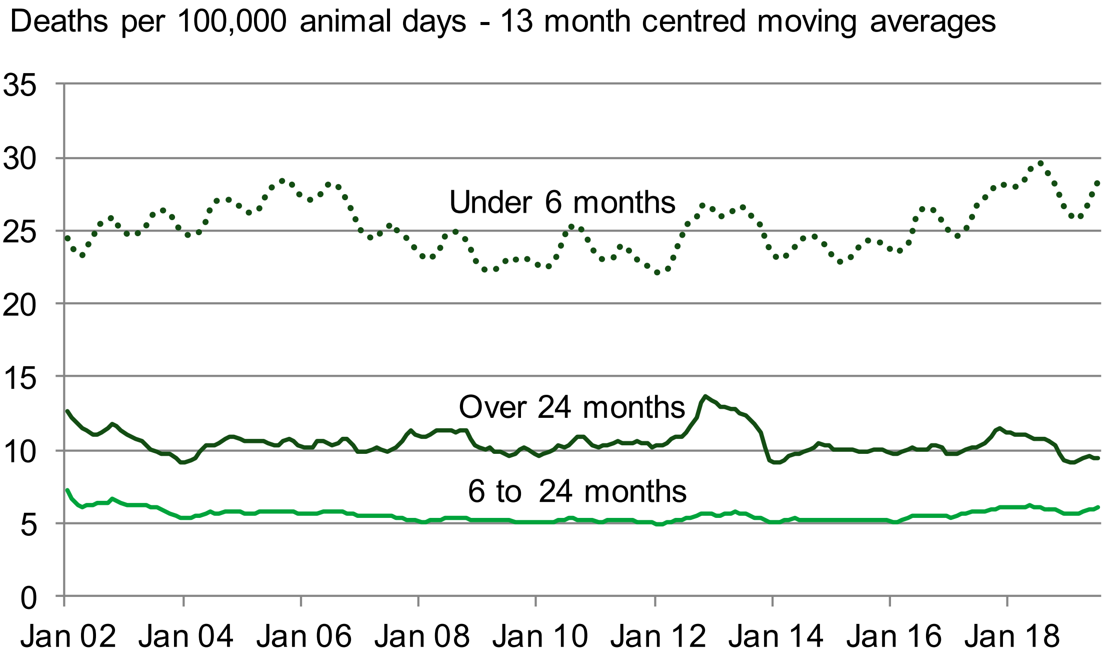
2.5.3 Beef: animal health

On-farm mortality

Rationale

All other things being equal, reductions in on-farm mortality[33] will lead to fewer animals being required for a given level of food production. Reduced disease should also lead to greater productivity. For cattle, overall mortality may be a better indicator than specific disease levels (for which we do not have full data in many cases).

Figure 2.20 Mortality for beef cattle, GB



Source: Defra, RADAR Cattle Tracing System

Trends

Although there have been fluctuations across the period, there has been an overall reduction in the on-farm mortality of beef calves (under 6 months) between 2006 and 2012. It is not clear why the increases towards the end of 2012 occurred as there are no obvious causes, such as a disease outbreak. Current levels have seen a rise, peaking in January 2018. For beef cattle aged 6 months and above there have also been fluctuations but overall there has been a slight downward trend in on-farm mortality since 2002.

2.5.4 Beef: manure management

Good manure management practices, in terms of both storage and application, can help reduce the environmental risks to both air and water, including emissions of ammonia.

For grazing livestock farms the 2020 Farm Practices Survey (FPS)[34] reported that:

- 56% (+/-6%) of lowland farms had facilities to store solid manure in heaps on a solid base which is the same figure as in 2019. For those in less favoured areas (LFA) the proportion was 75% (+/- 7%) in 2020, an increase from 72% in 2019. These stores were covered on 20% (+/- 6%) of lowland farms and 14% (+/- 5%) of LFA.
- In 2020, 66% (+/-5%) of lowland farms had facilities to store solid manure in temporary heaps in fields. For LFA farms the proportion was 43% (+/- 7%).
- 14% (+/- 5%) of lowland grazing livestock farms were able to store slurry in a tank, of these 20% (+/-14%) were covered. 36% (+/- 9%) of LFA farms had facilities to store slurry in tanks, of these 23% (+/-11%) were covered.

For details of manure application see Section 2.9.2

2.5.5 Beef: economic position

Table 6a: Gross margins for finished cattle from calves and stores from dairy herd (£ per head), 2015/16 – 2018/19 England

	2015/2016	2016/2017	2017/2018	2018/2019
Average herd size (head)	141	125	123	122
Finished livestock sales	555	602	618	654
Other cattle/ throughput	96	98	104	64
Less herd depreciation /calf & store cattle purchases	-241	-214	-228	-229
Enterprise output	411	486	494	489
Variable costs				
Concentrates	136	181	175	221
Coarse fodder	5	6	5	6
Vet and medicine costs	11	13	12	13
Other livestock costs	52	60	60	70
Forage variable costs	40	36	35	35
Total variable costs	244	295	287	345
Gross margin per cow	**167**	**191**	**207**	**145**

Source: Farm Business Survey

Table 6b: Gross margins for finished cattle from calves and stores from suckler herd (£ per head), 2015/16 – 2018/19 England

	2015/2016	2016/2017	2017/2018	2018/2019
Average herd size (head)	73	77	75	77
Finished livestock sales	888	947	1002	1041
Other cattle/ throughput	91	137	144	60
Less herd depreciation /calf & store cattle purchases	-562	-599	-605	-592
Enterprise output	418	485	543	512
Variable costs				
Concentrates	121	140	160	203
Coarse fodder	10	8	10	15
Vet and medicine costs	13	15	16	15
Other livestock costs	62	68	78	79
Forage variable costs	35	35	31	33
Total variable costs	242	266	295	345
Gross margin per cow	**176**	**219**	**248**	**167**

Source: Farm Business Survey

Tables 6a and 6b provide a comparison of beef cattle gross margins from the Farm Business Survey based on standard output typology[35]. Figures are in £ per head and have not been adjusted to reflect price changes due to inflation.

For dairy herds from 2015/16 the biggest contribution to total variable costs are concentrates. Over the time period in table 6 the largest decrease in total variable cost was in 2015/16 largely driven by a 25% decrease in concentrate costs from the previous year. In 2018/19 the total variable costs for dairy herds increased compared to the previous year, this was mainly due to an increase in concentrate costs. Outputs on dairy herds have seen a 13% decrease in herd size and sales increased by 18% from 2015/16 to 2018/19. After gross margins for dairy cattle being at their highest level in 2017/18, they have decrease to their lowest in 2018/19 data.

Suckler herd total variable costs are also largely influenced by concentrate costs. Total variable costs increased by 17% between 2017/18 and 2018/19 due to an increase in concentrate costs. Average herd size has remained similar throughout the time period in table 6. Finished livestock sales increased by 17% whilst other cattle sales decreased by 35%. As with the dairy herds the suckler herd gross margin is highest in 2017/18, decreasing by 33% when compared to 2018/19.

2.5.6 Beef: summary

Since 1990, average carcase weights have increased. At the same time the age at which animals are being slaughtered has remained at a broadly similar level, although there was a slight reduction in the median age at slaughter between 2010 and 2012, particularly in male cattle.

The median age of the beef herd has changed little since pre Bovine Spongiform Encephalopathy (BSE) and Foot and Mouth Disease (FMD) restrictions, though overall longevity has increased. There has been an overall reduction in the on-farm mortality of registered beef calves (under 6 months) between 2006 and 2012. Following increases towards the end of 2012 current levels are similar to those seen before that peak. For beef cattle aged 6 months and above there has been a slight decrease in on-farm mortality since 2002. Calving numbers suggest that more beef cows are productive for longer. Considering all these factors together suggests that, all other things being equal, the intensity of greenhouse gas emissions may have reduced.

2.5.7 Beef: further developments

Current statistics provide a partial picture of the relevant drivers of greenhouse gas emissions. The following measures would help provide a more complete picture but not all can feasibly be populated with robust data in the short term; although some of the data are collected through the Cattle Tracing System (CTS) there are significant complexities in extracting it from the current format.

- System including winter forage from maize or grass silage or hay and concentrate level
- Housing period, which can vary considerably from year to year
- More information on combining age and weight at slaughter
- Fat score at slaughter
- Calving interval
- Grassland management including legume use

2.5.8 Beef: notes on data collection methodology and uncertainty

Meat production

Carcase weights given here are from the Defra Slaughter house surveys. These surveys cover all the major slaughter houses, and are subject to small sampling errors. Links to the survey methodology are given in the Appendix.

Information from the Cattle Tracing System (CTS)

The CTS is an administrative dataset and all cattle in Great Britain are included in the dataset. Thus estimates shown here are based on the full cattle population. Links to the methodology are given in the Appendix.

Farm Business Survey

Where the sample size is relatively small, confidence intervals can be quite large, and care needs to be taken with interpretation of the significance of the differences. A link to information on the Farm Business Survey methodology is given in the Appendix.

2.6 Sheep

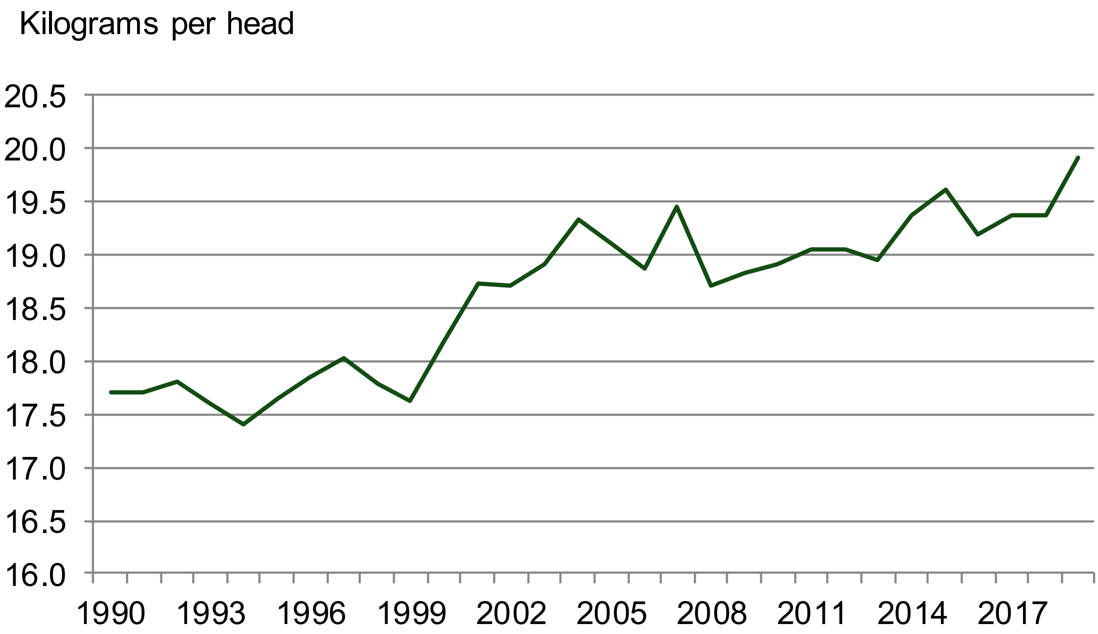
2.6.1 Sheep: efficiency of output

Weight at slaughter

Rationale

Reducing age at slaughter has the potential to reduce intensity of greenhouse gas (GHG) emissions (defined as GHG emitted per kilogramme of meat produced) by increasing growth rate through breed improvement, feeding and health management. However, an increase in the annual average carcase weights as a consequence of lambs being slaughtered later will not improve the intensity of emissions. A move to later slaughtering would be evident from a change in the monthly slaughtering pattern.

Figure 2.21 Average dressed carcase weight for sheep and lambs, UK

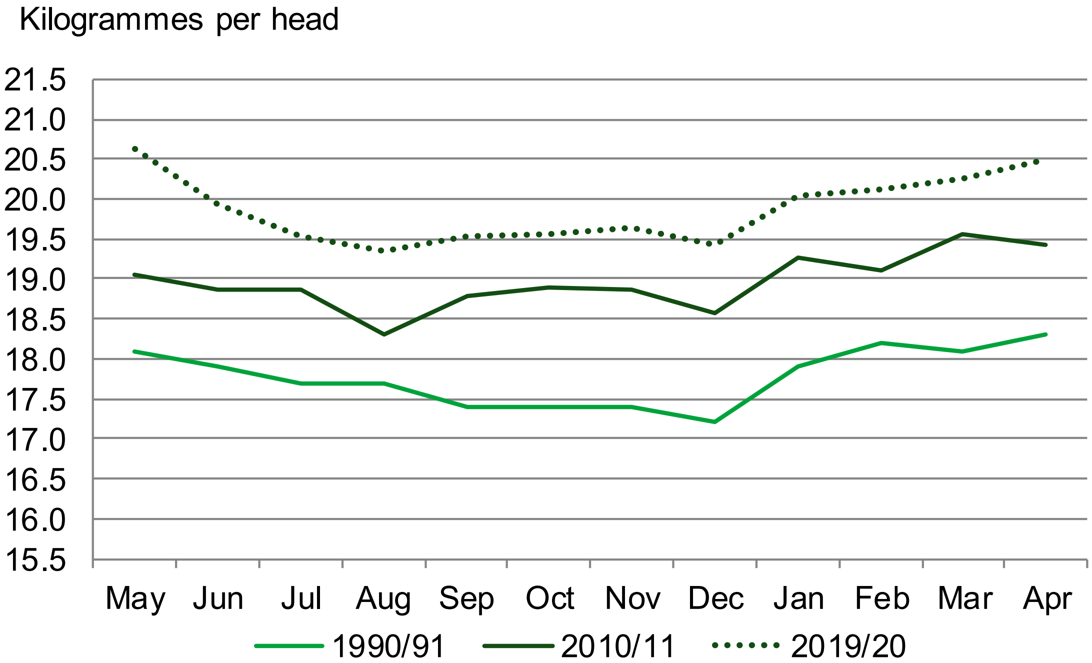


Source: Slaughterhouse surveys, Defra, The Scottish Government, DARD (NI)

Note: Excludes ewes and rams

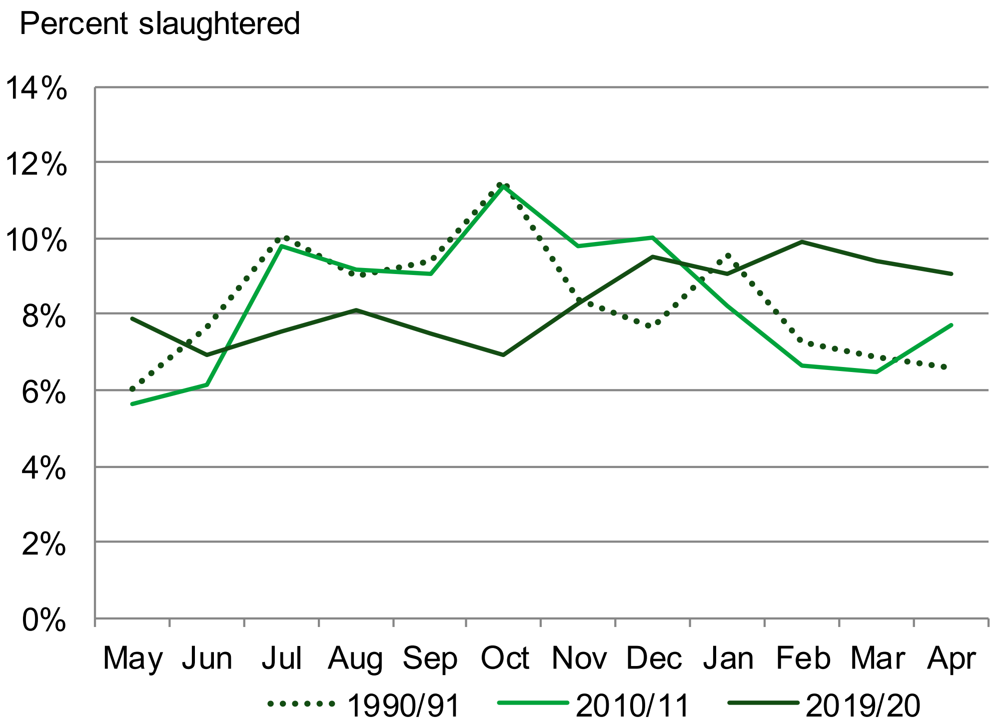
Monthly distribution of slaughter weights and marketing pattern

Figure 2.22 Average dressed carcase weights for clean sheep and lambs, UK



Source: Slaughterhouse surveys, Defra, The Scottish Government, DARD (NI)

Figure 2.23 Monthly marketing pattern for clean sheep and lambs, UK



Source: Slaughterhouse surveys, Defra, The Scottish Government, DARD (NI)

Trends

Average carcase weights for sheep and lambs have increased overall since 1990; after remaining relatively stable during the 1990s carcase weights increased steadily between 2000 and 2004/05. This will, in part, have been driven by farmers finishing to greater weights to achieve better prices. The peak in 2007 is probably due to the effects of the Foot and Mouth Disease (FMD) outbreak in that year which resulted in some producers retaining lambs on farm for longer. The increase in carcase weights has taken place across the year with no sustained changes to the monthly marketing pattern over time to suggest a move to later finishing. Changes within years tend to be shorter term reactions to weather and prices. For instance, the wet summer of 2012 led to problems finishing lambs and resulted in delayed marketings and lower carcase weights than in 2011.

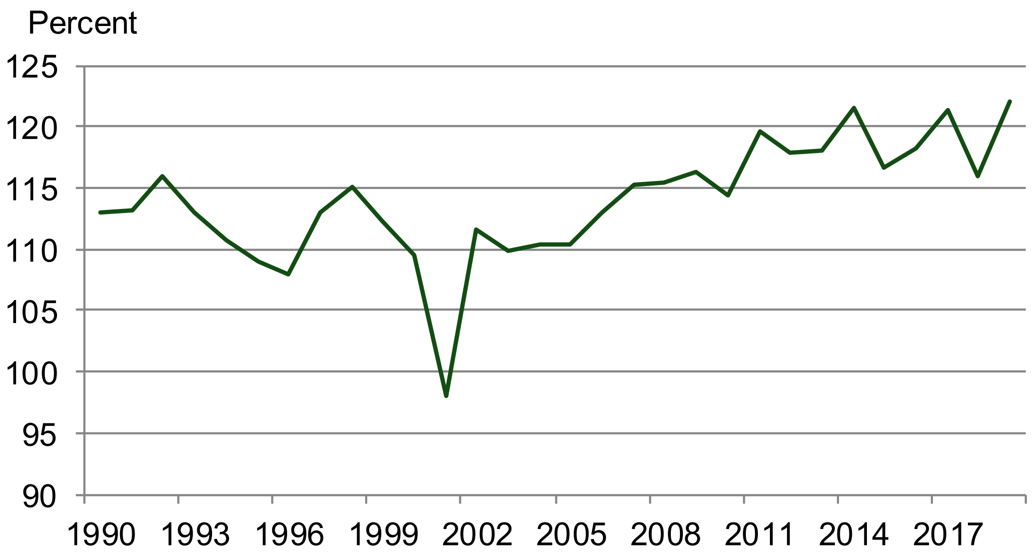
2.6.2 Sheep: longevity and fertility

Surviving lamb percentage

Rationale

Increased fertility rates and longevity of breeding animals could help reduce greenhouse gas (GHG) emissions intensity because fewer breeding females would be required for the same level of output. By assessing the "surviving lamb percentage" (based on populations and slaughter statistics - see below for definition) it is possible to gain an overall indication of both the productivity of the ewe flock and lamb survival; all other things being equal an increase will represent an improvement in emissions intensity.

Figure 2.24 Surviving lamb percentage, GB



Source: Defra statistics, AHDB survey of auction markets

Trends

There has been an overall upward trend in the surviving lamb percentage over the last 10 years. In the shorter term, following the high survival rate in 2011 (helped by favourable weather conditions) the surviving lamb percentage fell slightly in 2012 before reaching the highest level since 1990 in 2014. Lamb survival rates increase again in 2019 after a decline in 2018 which was due to cold snap during that lambing season which increased both lamb and ewe mortality.

Definition of the surviving lamb percentage

The lambing percentage is calculated as (A + B)/(C + D)*100, where:

A: Number of lambs at June (source June Survey)
B: Number of lambs born after December, but slaughtered before June (i.e. new season lamb slaughter), source: AHDB and Defra slaughter stats
C: Number of breeding ewes at December (source December Survey)
D: Number of ewe lambs put to the ram at December (source December Survey)

Note: the survival of lambs is dependent on weather conditions, and this needs to be considered when interpreting year on year changes.

2.6.3 Sheep: economic context

Table 7a: Gross margins for lowland breeding ewes (£/head), England 2015/16 - 2018/19

	2015/2016	2016/2017	2017/2018	2018/2019
Average flock size (head)	273	287	279	285
Forage area (hectares/head)	0.2	0.2	0.2	0.2
Finished livestock sales	81	88	92	94
Store sales	8	11	11	12
Other lamb throughput	17	18	19	15
Miscellaneous revenue	3	3	2	2
Less flock depreciation	-12	-15	-14	-14
Enterprise output	96	104	111	109
Variable costs				
Concentrates	18	20	20	25
Coarse fodder	2	2	2	2
Vet and medicine costs	8	8	8	8
Other livestock costs	14	13	15	14
Other crop costs	8	9	8	9
Total variable costs	50	53	53	59
Gross margin per ewe	**46**	**52**	**58**	**50**

Source: Farm Business Survey

Table 7a: Gross margins for LFA breeding ewes (£/head), England 2015/16 - 2018/19

	2015/2016	2016/2017	2017/2018	2018/2019
Average flock size (head)	445	469	532	530
Forage area (hectares/head)	0.2	0.3	0.3	0.3
Finished livestock sales	44	44	42	41
Store sales	9	13	13	12
Other lamb throughput	24	28	29	23
Miscellaneous revenue	2	2	1	1
Less flock depreciation	-11	-15	-20	-15
Enterprise output	69	71	64	62
Variable costs				
Concentrates	14	14	16	19

	2015/2016	2016/2017	2017/2018	2018/2019
Coarse fodder	6	4	6	7
Vet and medicine costs	7	7	7	7
Other livestock costs	9	10	9	9
Other crop costs	5	4	3	3
Total variable costs	41	40	42	46
Gross margin per ewe	**28**	**32**	**21**	**16**

Source: Farm Business Survey

Tables 7a and 7b provide a comparison of gross margins for breeding ewes on lowland and Less Favoured Area (LFA) farms from the Farm Business Survey. Figures are in £ per head and have not been adjusted to reflect price changes due to inflation.

Gross margins per ewe have fluctuated across the period for both lowland and LFA ewes. When compared to 2017/18, the gross margin in 2018/19 decreased by 14% per lowland ewe whilst for LFA ewes the figure decreased by 24%.

2.6.4 Sheep: summary

Carcase weights for lambs have increased since 1990 and this has occurred across the year, suggesting that there has not been a sustained move to later slaughtering but that more are being finished[36] at greater weights. This change can be explained as a result of a combination of productivity gains, restrictions on the movement of the animals during the FMD outbreak and the reduction in the uplands which are generally of lower weight. Overall trends in the last 5 years suggest that ewe flock fertility and lamb survival have improved with 2017 and 2019 seeing the highest surviving lamb percentage of the period since 1990.

2.6.5 Sheep: further developments

Current statistics provide a partial picture of the relevant drivers of greenhouse gas emissions. The following are the most relevant pieces of information which are currently not included. Not all of the following can feasibly be populated with robust data in the short term.

- More information on the age at which lambs are slaughtered. This would be about providing more detail than is currently available.
- Measures of the longevity of breeding flock. This information represents an important gap. It is not clear if this could be populated with data in the short term.

2.6.6 Sheep: notes on data collection methodology and uncertainty

Meat production

Carcase weights given here are from the Defra slaughter house surveys. These surveys cover all the major slaughter houses and are subject to small sampling errors. Links to the survey methodology are given in the Appendix.

Where the sample size is relatively small, confidence intervals can be quite large, and care needs to be taken with interpretation of the significance of the differences. A link to information on the Farm Business Survey methodology is given in the Appendix.

2.7 Pigs

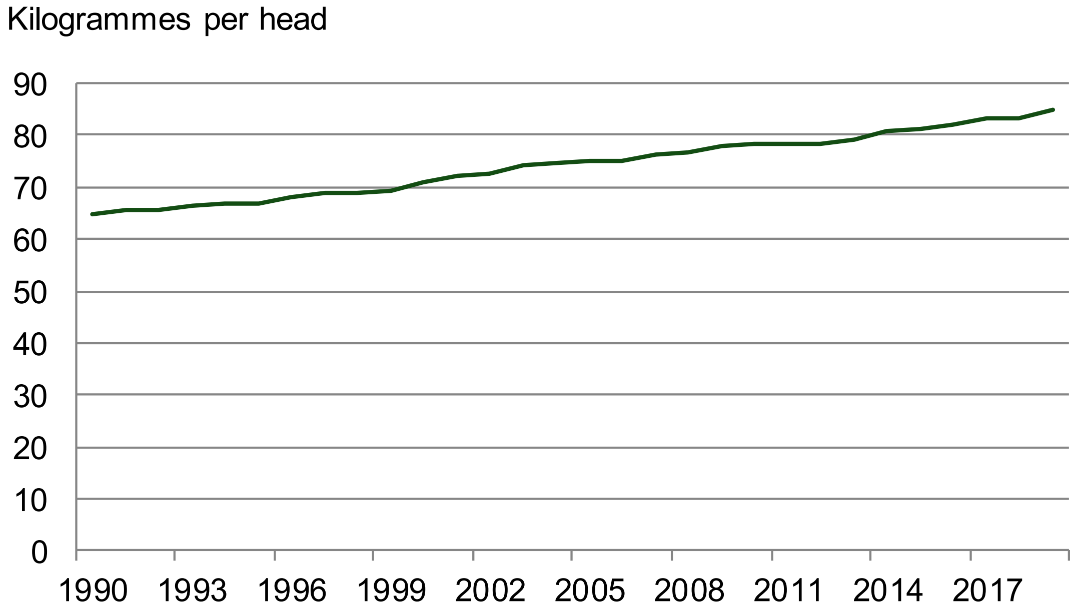
2.7.1 Pigs: efficiency of output (finishing pigs feed conversion and daily gain)

Weight at slaughter and daily live weight gain

Rationale

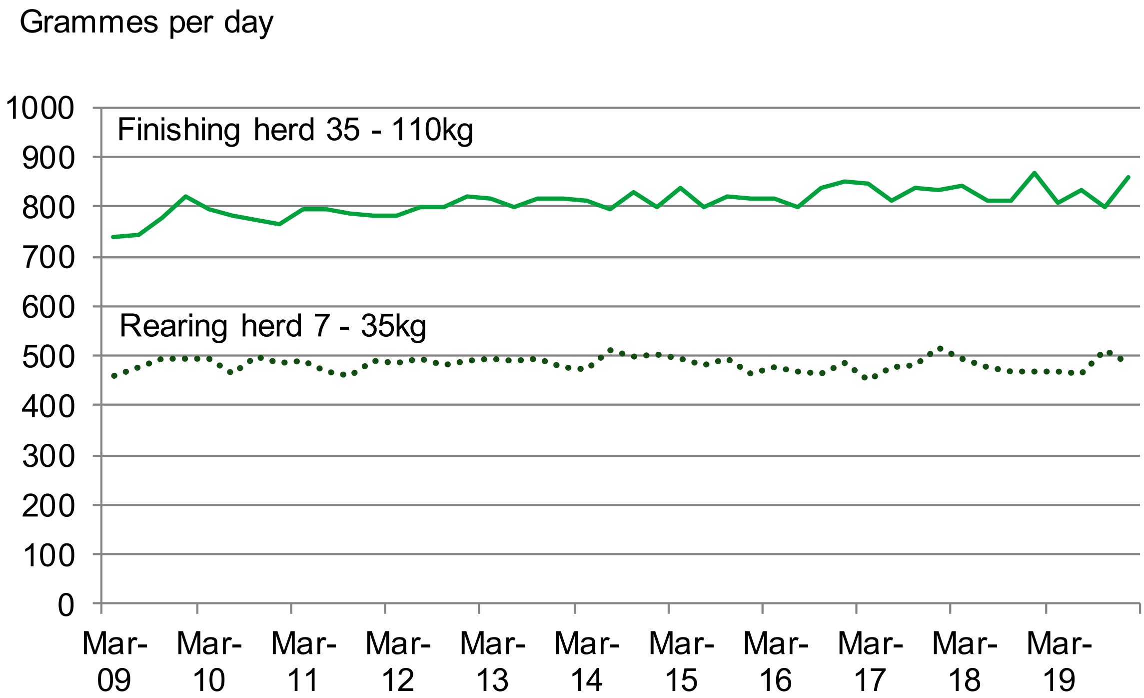
Increasing slaughter weight spreads the costs of production per kilogramme of pig meat but may increase absolute emissions per finished pig. Improving daily live weight gain reduces the time to finish at a fixed slaughter weight, resulting in improved productivity and reduced greenhouse gas (GHG) emissions.

Figure 2.25 Average dressed carcase weights for clean pigs, UK



Source: Slaughterhouse Surveys, Defra, The Scottish Government, DARD (NI)

Figure 2.26 Daily live weight gain rearing and finishing herds, GB



Source: AHDB Pork

Trends

Average carcase weights have increased steadily by around 0.7kg per year since 1990. Overall there have been improvements in daily live weight gain in both the rearing and finishing herd since 2009, although there have been fluctuations over the period.

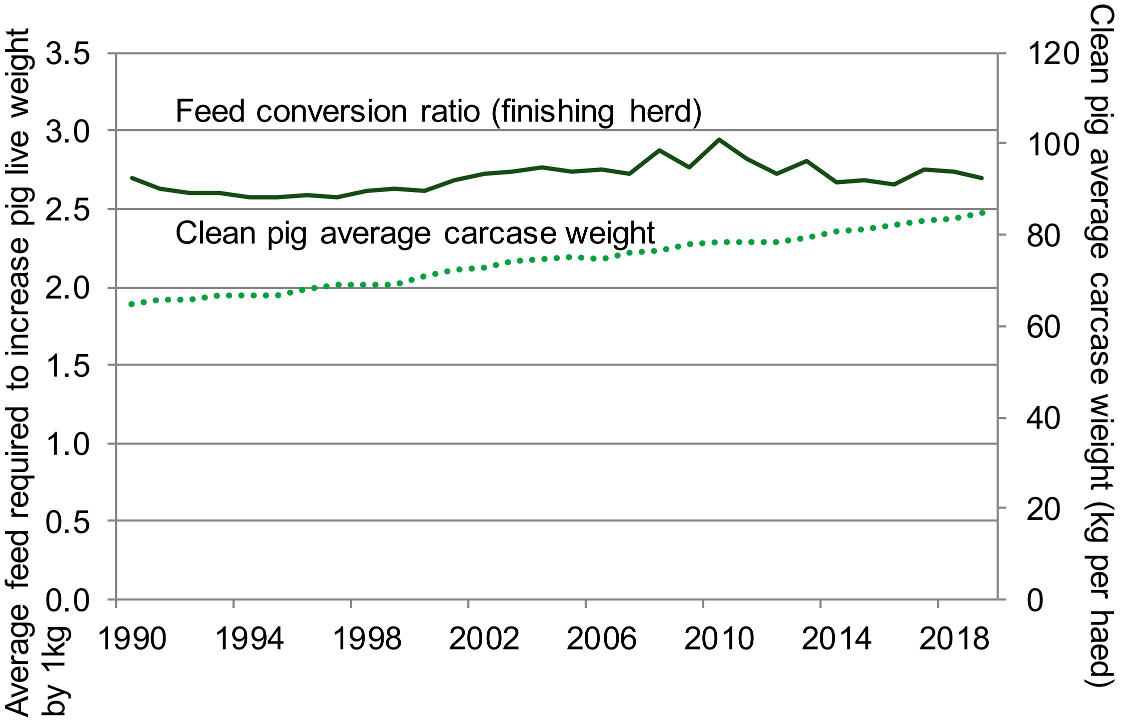
Finishing herd feed conversion

Rationale

The feed conversion ratio (FCR) is a measure of the amount of feed required to produce 1 kilogramme of pig live weight i.e. a lower FCR indicates improved feed use efficiency. More efficient use of feed reduces greenhouse gas (GHG) intensity and improves productivity.

The feed conversion ratio of the fattening herd is the GHG indicator[37] for the pig sector. More details of this can be found in the Summary earlier in the publication and in the full indicator text.

Figure 2.27 Feed conversion ratios: GB finishing herd



Sources: Feed conversion AHDB Pork, carcase weight Slaughterhouse surveys, Defra, The Scottish Government, DARD (NI)

Trends

The FCR for the pig finishing herd deteriorated from around 2005 to 2009, an indication that more feed has been required to produce 1 kilogramme of pig live weight, albeit with some fluctuations. This suggests higher levels of GHG emissions from the GB finishing herd over this period.

Several factors could explain this including the trend towards heavier finishing weights, changes in production systems and disease. As the FCR is a broad indicator of feed efficiency and GHG emissions, it is not possible to separate the effects of different factors (such as type of feed) on GHG emissions from the finishing herd.
Since 2010 there has been an improvement in the FCR although again with some fluctuations. At the same time average clean pig carcase weight has steadily increased. This suggests improvements in feed use efficiency and a reduction in GHG emissions.

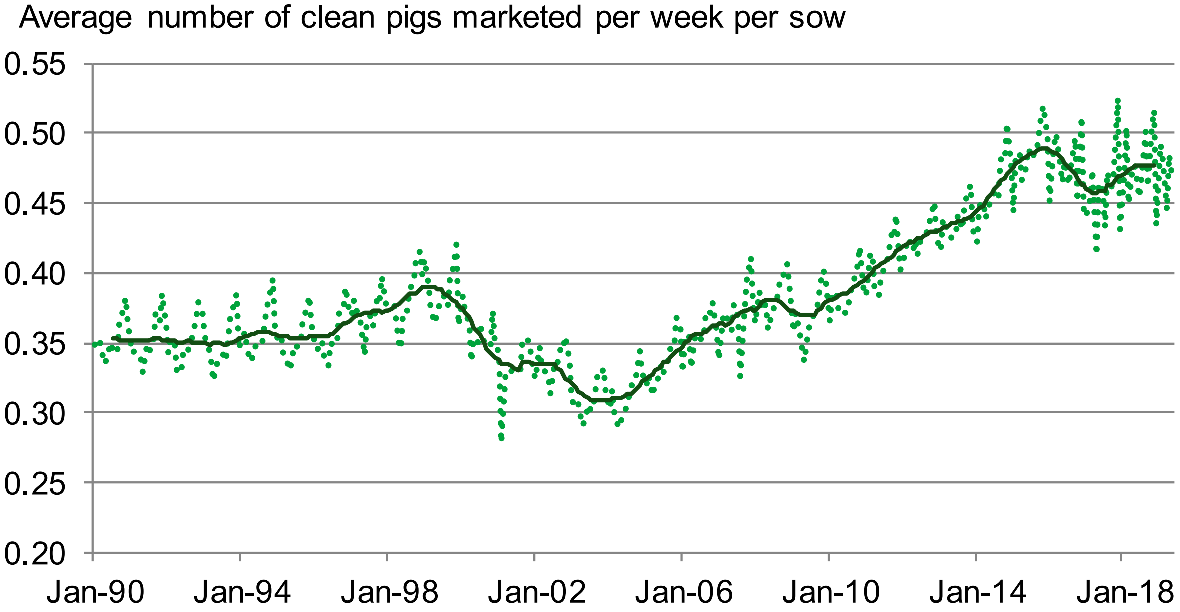
2.7.2 Pigs: animal health and fertility (sow productivity and piglet mortality)

Sow productivity

Rationale

A trend in the average number of clean pigs marketed per week per sow and kilogramme weaned per sow per year provide a measure of sow productivity and in turn an indicator of GHG emissions from the breeding herd.

Figure 2.28 Sow productivity, GB



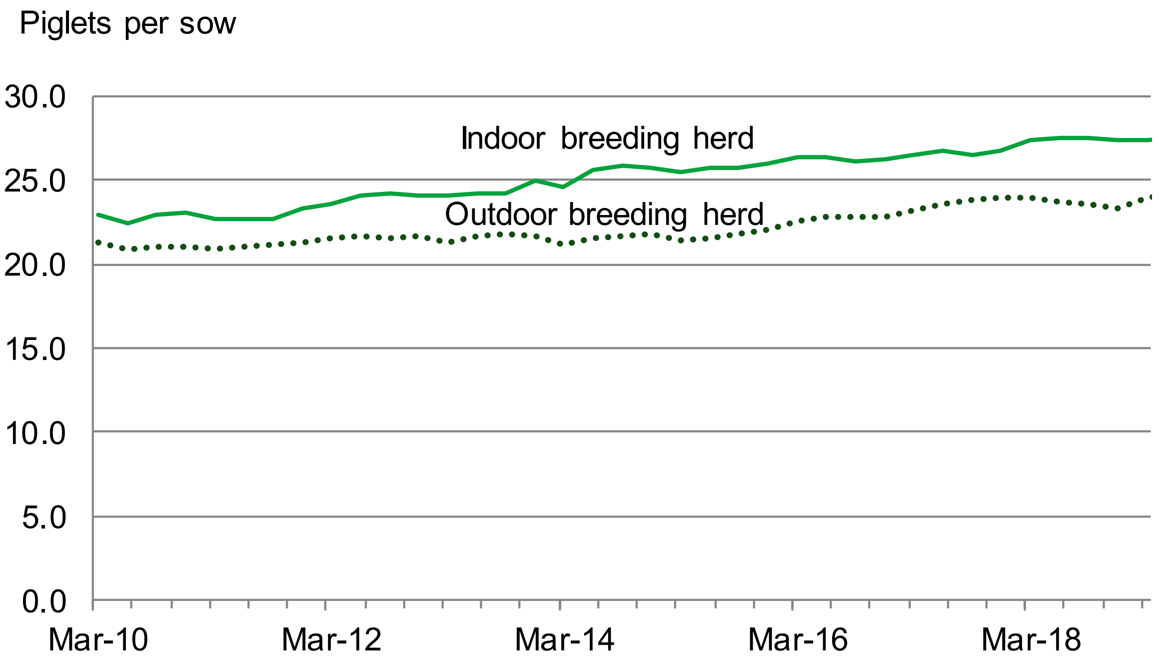
Source: Agricultural surveys Defra, Slaughterhouse surveys Defra, The Scottish Government, DARD (NI)

Trends

Clean pigs marketed per sow per week dip around 2003/04 but there has been a steady upward trend since then and current levels exceed the previous high points of the late 1990s. Disease is likely to have influenced this trend, for example swine flu in 2000 and Foot and Mouth Disease (FMD) in 2001 - both of which contributed to a loss of productivity. Additionally, non-notifiable pig wasting diseases were prevalent from the late 1990s, though these are considered to have been brought under better control since 2004.

The trend towards outdoor production may have offset some of the productivity gains seen in recent years. The following chart compares trends in sow productivity through piglets weaned in indoor and outdoor systems. There are numerous reasons for this difference between the 2 systems: the impact of adverse weather conditions on piglet survival, seasonal infertility, lighter piglet weaning weights due to differences in nutrient intake and energy balance and differing selection objectives (with indoor genotypes selected for prolificacy and outdoor for robustness).

Figure 2.29 Piglets weaned per sow per year, GB



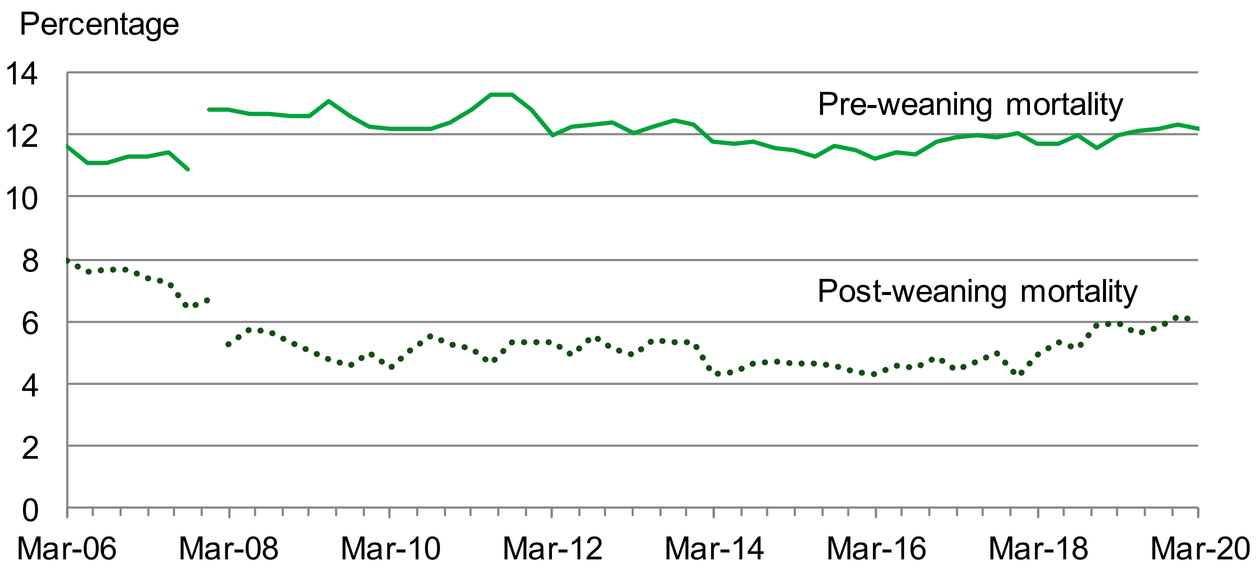
Source: AHDB Pork

Mortality

Rationale

All other things being equal, reductions in pre-weaning piglet mortality require fewer breeding animals to produce an equivalent number of weaned pigs.

Figure 2.30 Average pig mortality, GB



Source: AHDB Pork

Note, the break in the series indicates a change in methodology, including a change in the sample size which increased from the breeding herd in Q4 (December) of 2007 to the rearing and feeding herd in Q1 (March) of 2008.

Trends

The data suggests that there appears to have been little change in pre weaning mortality over much of the period. The step change in the chart is associated with a change in the sample size which increased from the fourth quarter of 2007 (December) for breeding herd and from the first quarter (March) of 2008 for the rearing and feeding herd. Post-weaning mortality has shown a slight increase above levels seen in recent years but it is too early to know whether this is a systematic trend or annual variation.

2.7.3 Pigs: housing and manure/slurry management

Housing system and type of manure application

The type of manure application method, the housing system used (e.g. the type of manure/slurry management), whether pigs are kept outdoors and systems which relate to length of time to finish can all have an effect on the levels of greenhouse gas emissions.

Trends

The results of the Farm Practices Survey 2009 give some details on pig housing and can be found in Section 2.7 of the third edition of Agriculture and Climate Change.

The 2020 Farm Practices Survey (FPS) surveyed 124 holdings with pigs. From this relatively small sample it is difficult to draw a precise conclusion; however, they do provide an approximate indication that:

- 56% (+/- 11%) of holdings with pigs had storage facilities for solid manure on a solid base.
- 23% (+/- 11%) of holdings with pigs could store in a tank; of these 35% (+/- 26%) were covered.
- 12% (+/- 8%) could store slurry in a lagoon without a strainer. There is insufficient evidence to draw conclusion on the proportions with covers.

For details on manure/slurry application see Section 2.9.2

2.7.4 Pigs: economic position

Table 8: Gross margins for breeding sows (£/head), England 2015/16 to 2018/19

	2015/16	2016/17	2017/18	2018/19
Average herd size	204	203	102	187
Finished livestock sales	2,003	1,973	2,410	1,616
Store sales	179	292	180	69
Miscellaneous revenue	1	2	4	2
Less herd depreciation	-44	-29	-20	-25
Enterprise output	2,139	2,244	2,580	1,663
Variable costs				
Concentrates	1,318	1,124	1,399	1,038
Vet and medicine costs	78	60	69	44
Other livestock costs	179	157	188	127
Heating	0	2	0	0
Total variable costs	1,567	1,343	1,658	1,209
Gross margin/sow	**563**	**901**	**922**	**454**

Source: Farm Business Survey

Table 8 provides a comparison of gross margins for breeding sows from the Farm Business Survey. Figures are in £ per head and have not been adjusted to reflect price changes due to inflation. Gross margins per sow fluctuated across throughout the time period. In 2018/19 gross margins decreased to £454 per sow, this was mainly driven by a decrease in finished stock sales.

2.7.5 Pigs: summary

Carcase weights have increased steadily since 1990, however there was a gradual but continuous loss in feed conversion in the GB finishing herd from around 1995 to 2009 suggesting a loss of feed use efficiency and in turn higher greenhouse gas (GHG) emissions from finishing pigs. This trend has been largely reversed since 2010, the improved efficiency suggesting a reduction in GHG emissions.

From 2014 to 2016 pre-weaning mortality decreased to less than 12%, however more recently this has increased to above 12%. Post-weaning mortality had been falling gradually over time from around 6% to nearer 4%, over the last couple of years it has increased again to around 6%. From 2004 and onwards, sow productivity (clean pigs marketed per week per sow) has steadily improved, which suggests a reduction in GHG emissions from the GB breeding herd.

2.7.6 Pigs: further developments

Current statistics provide only a partial picture of the relevant drivers of GHG emissions. The following are the most relevant pieces of information which are currently not included. Not all of them can feasibly be populated with robust data in the short term.

- More productivity measures such as: rearing feed conversion ratio; average live weight; feed consumed per sow. This would be about providing more detailed information than is currently provided in this section. Some data are available although currently for relatively short timescales.

2.7.7 Pigs: notes on data collection methodology and uncertainty

Meat production

Carcase weights given here are from the Defra Slaughter house surveys. These surveys cover all the major slaughter houses, and are subject to small sampling errors. Links to the survey methodology are given in the Appendix.

Farm Business Survey

Where the sample size is relatively small, confidence intervals can be quite large, and care needs to be taken with interpretation of the significance of the differences. A link to information on the Farm Business Survey methodology is given in the Appendix.

AHDB Pork data[38]

Data are taken from publicly available datasets published on the AHDB Pork website. These are not official government statistics. The data are collected by Agrosoft Ltd from customers submitting regular data. Agrosoft Ltd verifies all data before delivery / publication.

2.8 Poultry

2.8.1 Poultry: efficiency of output

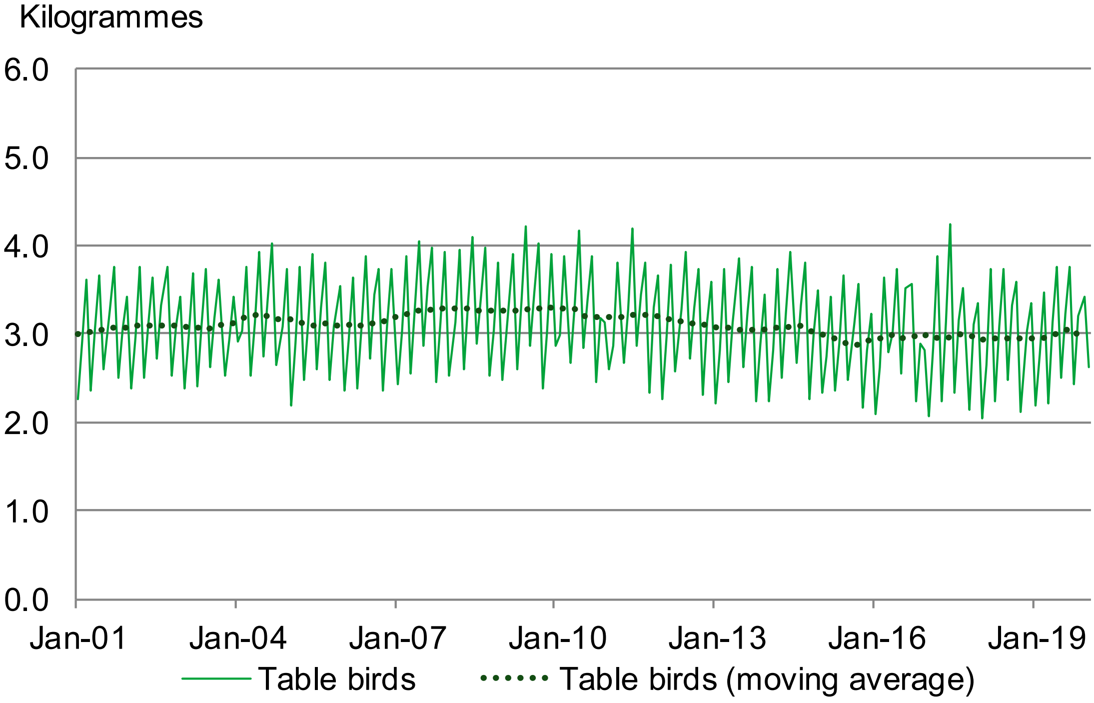
Feed conversion ratio[39]

Rationale

More efficient use of feed has the potential to increase productivity and reduce greenhouse gas (GHG) emissions intensity. The feed conversion ratio (FCR) is a measure of the amount of feed required (in kilogrammes) to produce 1 kilogramme of poultrymeat (dressed carcase weight). The quantity of poultry feed produced per kilogramme of poultrymeat produced is used here as a proxy measure for the intensity of on-farm GHG emissions.

The feed conversion ratio for table birds is the GHG indicator[40] used for the poultry sector. More details of this can be found in the Summary earlier in the publication and in the full indicator text.

Figure 2.31 Kilogrammes of feed per kilogramme of poultry meat, GB



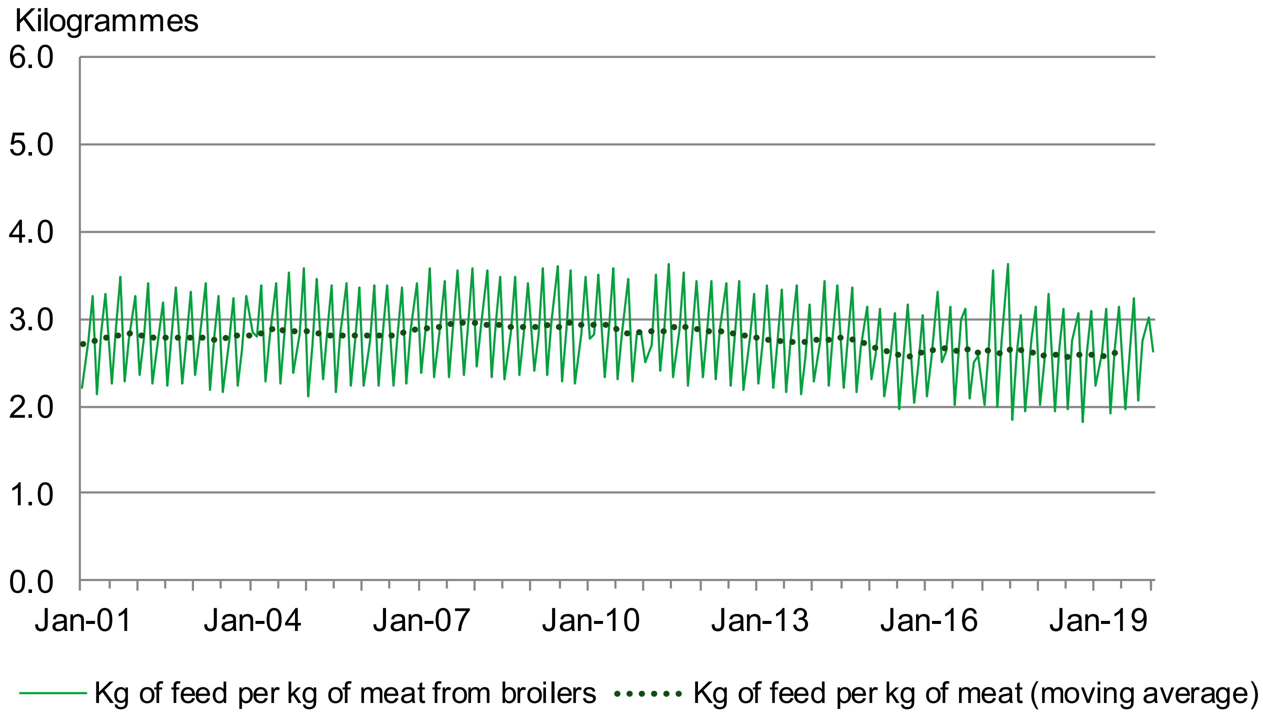
Source: Defra, Hatcheries and Poultry Slaughterhouse Surveys, Integrated Poultry Unit Survey

Trends

The chart above shows that the overall moving average trend is relatively stable; a slight upward trend since 2007 has been largely reversed between 2010 and 2013 while recent years have seen the moving average level out.

Aggregated data for all table birds provides an overall measure of feed efficiency. However, within this there are differences between species. The following charts are presented to illustrate this and show FCRs for broilers (chickens bred and raised specifically for meat production) and turkeys. Whilst there will also be differences between production systems, data are not readily available to allow such a breakdown to be made.

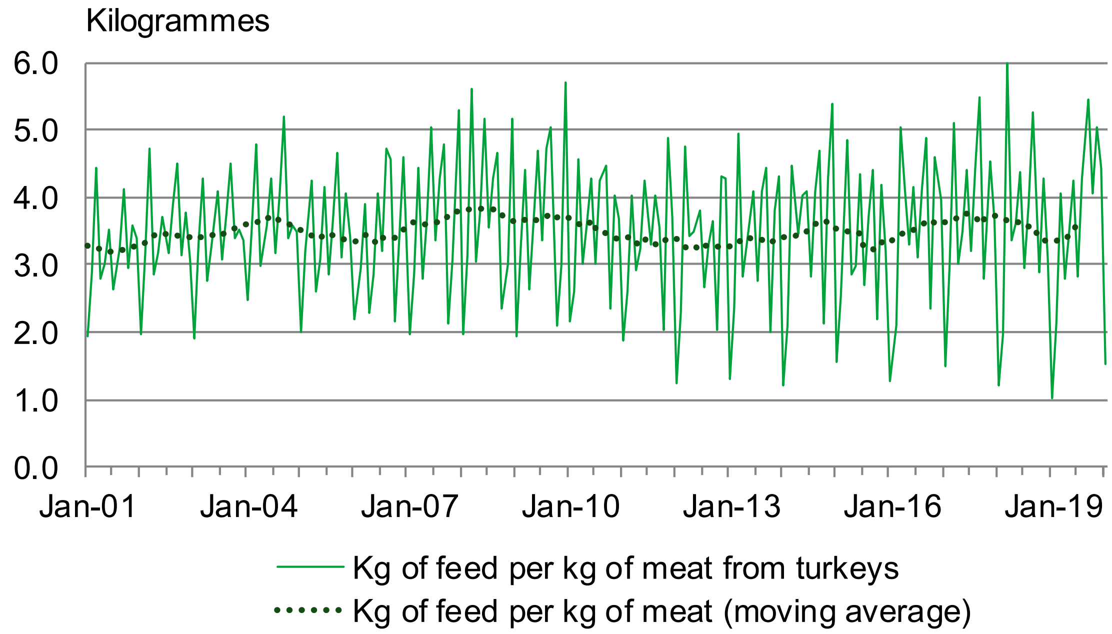
Figure 2.32 Broilers: kilogrammes of feed per kilogramme of meat, GB



Source: Defra, Hatcheries and Poultry Slaughterhouse Surveys, Integrated Poultry Unit Survey

The average FCR for broilers is consistently lower than for all table birds, but follows a similar trend. Within this, there will be variations between different rearing systems, such as indoor rearing and organic production. In addition, a significant proportion of birds are reared to an older age (and have a higher resulting FCR) as a deliberate marketing choice. The average liveweight of broilers at slaughter has remain at a similar weight since the year 2000.

Figure 2.33 Turkeys: kilogrammes of feed per kilogramme of meat, GB



Source: Defra, Hatcheries and Poultry Slaughterhouse Surveys, Integrated Poultry Unit Survey

The average turkey FCR is higher than that for chickens but follows a broadly similar trend albeit more exaggerated. The trend has fluctuated over the period but has not changed significantly.

2.8.2 Poultry: housing and manure management

Housing systems and type of manure management, for example use of in-house litter drying and incorporation time of manure, can have an effect on the levels of emissions. Whilst some data were collected as part of the 2009 Farm Practices Survey the implementation of the EU-wide ban on the keeping of hens in conventional cages at the beginning of 2012 means that this may no longer be reflective of the current situation.

2.8.3 Poultry: summary

Defra has limited information from national level datasets for the poultry sector. From information which is available the underlying trend in feed conversion for ‘table birds’ increased marginally from 2001 followed by a decrease between 2010 and 2013. Since 2013 there has been an overall downward trend with the moving average levelling off over the last 2 years and currently standing at some of the lowest level seen since 2001. Similar trends can be seen in the FCR of broilers and turkeys.

2.8.4 Poultry: further developments

Limited information is currently provided on the poultry sector. The main factors proposed for the inventory development relate to information on housing type and system. The feasibility of providing robust data in the short term is not clear at present.

2.8.5 Poultry: notes on data collection methodology and uncertainty

Meat production and feed production

i) Meat production is derived from Defra's survey of poultry slaughterhouses and registered hatcheries in England and Wales and similar surveys run by The Rural & Environment Research and Analysis Directorate for Scotland. Links to the survey methodologies are given in the Appendix.

ii) Data on feed production are from the survey returns of all of the major GB animal feed companies. The survey records data on raw material use, stocks and production of the various categories of compound animal feed. The major producers typically cover 90% of total animal feed production surveyed each month. The remaining smaller companies are sampled annually in December for their figures in the preceding 12 months. Sampling errors of the production estimates are small. Links to the survey methodology are given in the Appendix.

iii) Feed data are sourced from Defra's Integrated Poultry Units Survey. This survey covers all of the major GB poultry feed manufacturers of integrated poultry units. The accuracy of the results is very high as they are based on a census carried out across all companies. Links to the survey methodology are given in the Appendix.

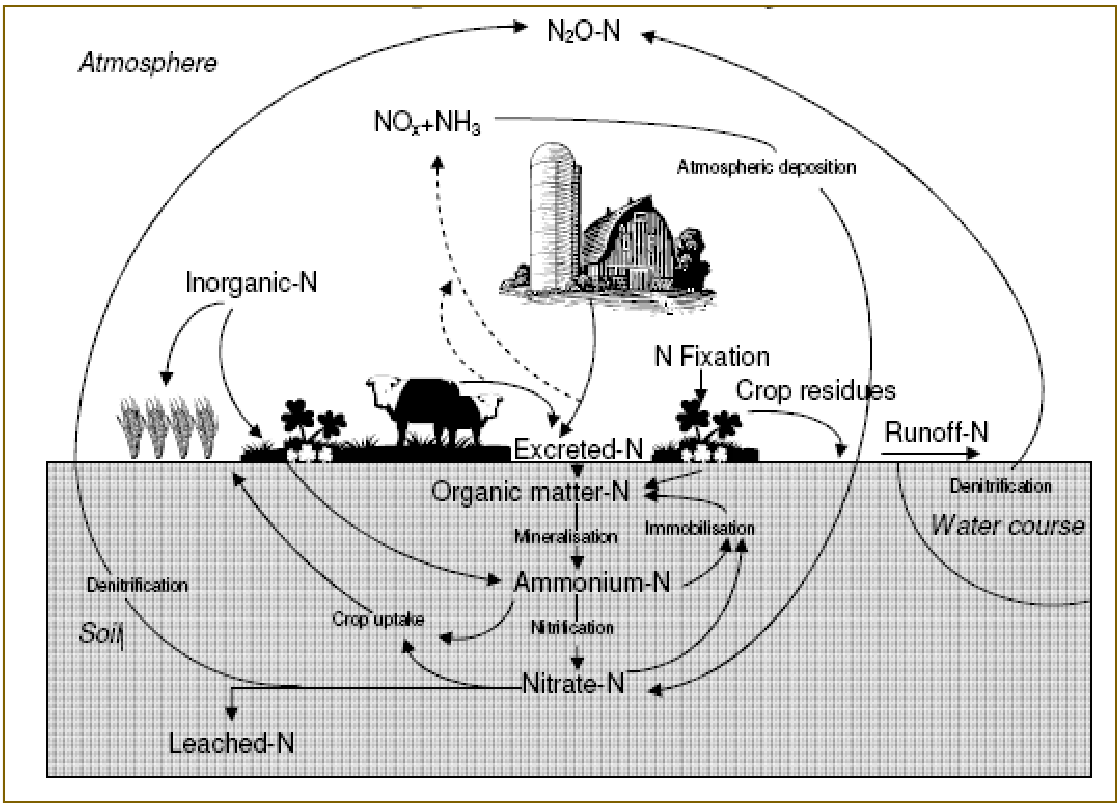
2.9 Land and Nutrient Use

Background information

Inputs of manufactured or livestock derived nitrogen fertilisers are critical to maintain yields of food and fodder crops[41], but the yield benefits of nitrogen application come at the expense of polluting losses to air and water and emissions of greenhouse gasses (GHG). Losses can be minimised by reducing the surplus in soils or reducing the risk of this surplus being lost to the environment by implementing on-farm efficiency measures and best practice management techniques. This section covers the outcomes associated with the uptake of these practices by considering GHG intensity measures, while Section 3 presents information on attitudes towards, and uptake of, specific on-farm practices.

GHG emissions from nitrogen fertilisers principally arise directly from the soil as microbes transform fertilisers in the nitrification and denitrification processes (see Figure 2.34). Some losses can occur within the first few days of application. However, significant losses also occur indirectly after nitrogen has leached from soils into water courses, or after gaseous loss as ammonia followed by deposition to soils. In both cases, there are potentially detrimental impacts on biodiversity and human health.

Figure 2.34 Soil, Nitrogen and Emissions



A number of factors influence the level of GHG emissions resulting from a given level of nitrogen applications. These include land use, the soil nitrogen content before application, the organic carbon content of the soil, the soil moisture content and compaction of the soil (the latter two are associated with reduced soil aeration).

Within this publication we focus on GHG emissions intensity, a reduction in absolute levels of nitrogen would however provide a number of environmental benefits.

2.9.1 Land and nutrient use: efficiency of output

Long term measure of change: Crop production per unit of manufactured N applied[42]

Rationale

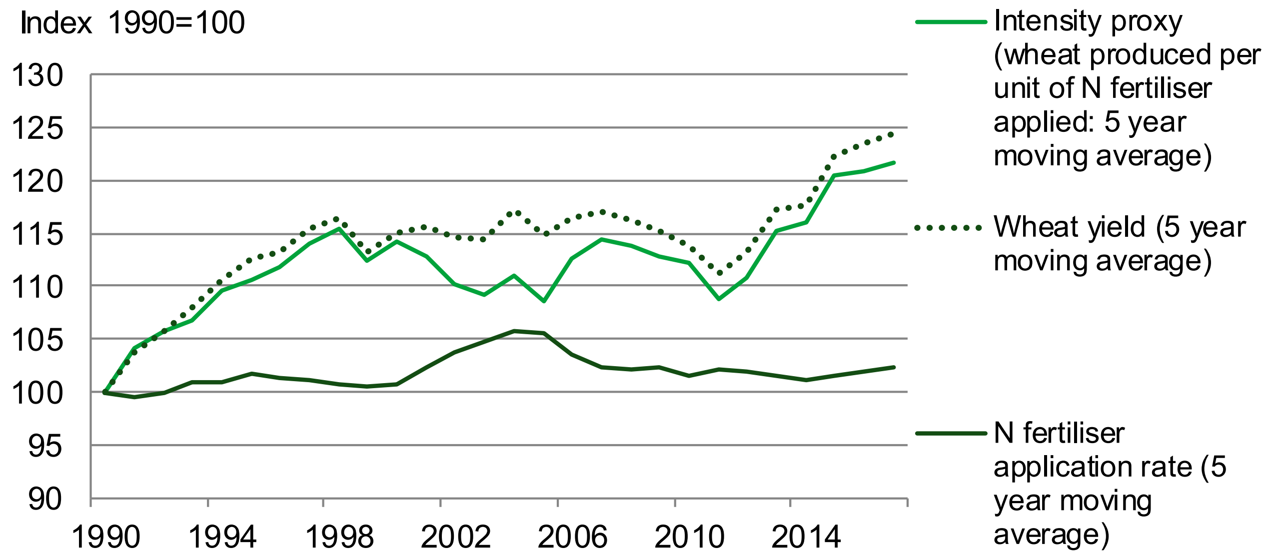
Trends in crop yields provide a headline measure of productivity; more efficient use of nitrogen fertiliser has the potential to increase productivity and reduce the environmental risk. The ratio of the weight of crops produced to the weight of manufactured nitrogen fertiliser applied provides a proxy measure for the intensity of greenhouse gas (GHG) emissions. This section does not cover slurries and manures which are considered in 2.9.2 Land and nutrient use: application of organic nitrogen.

Manufactured fertiliser application is the GHG indicator[43] for the cereal and other cropping sector. More details of this can be found in the Summary earlier in the publication and in the full indicator text.

Random factors in crop production (such as the weather) also impact on yields. This measure is, therefore, more suitable for monitoring change over the longer term (5 to 10 years). The measures referred to here are 5 year centred moving average trends which smooth the random year on year variation present in the time series. The latest year for which figures are available using this method is 2017. Any later estimates of the trend are less certain as these cannot use a 5 year trend so are annual point estimates only and as such are relatively volatile and influenced by external factors.

Application rates of nitrogen based fertiliser per hectare provide an indication of short term changes (year on year) and are explored later in this section.

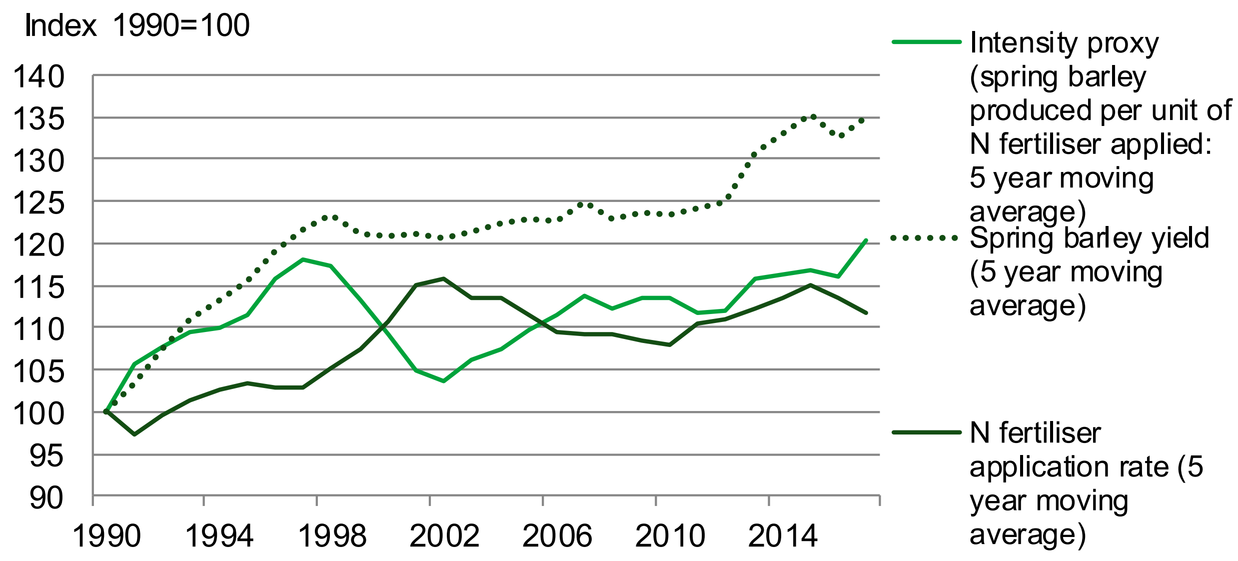
Figure 2.35 Wheat produced per unit of manufactured N fertiliser applied, England



Source: British Survey of Fertiliser Practice, Defra Cereal and Oilseed Rape Production Survey

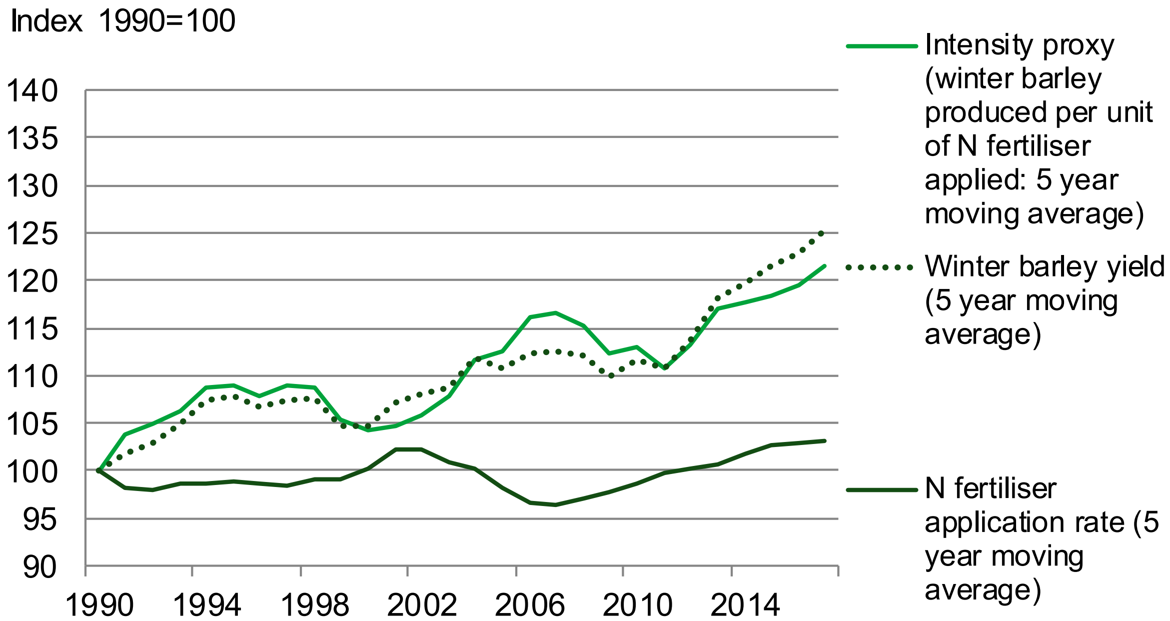
For an illustration of the magnitude of the trend and irregular components of the time series for wheat please see (iv) in the [Appendix.]

Figure 2.36 Spring barley produced per unit of manufactured N fertiliser applied, England



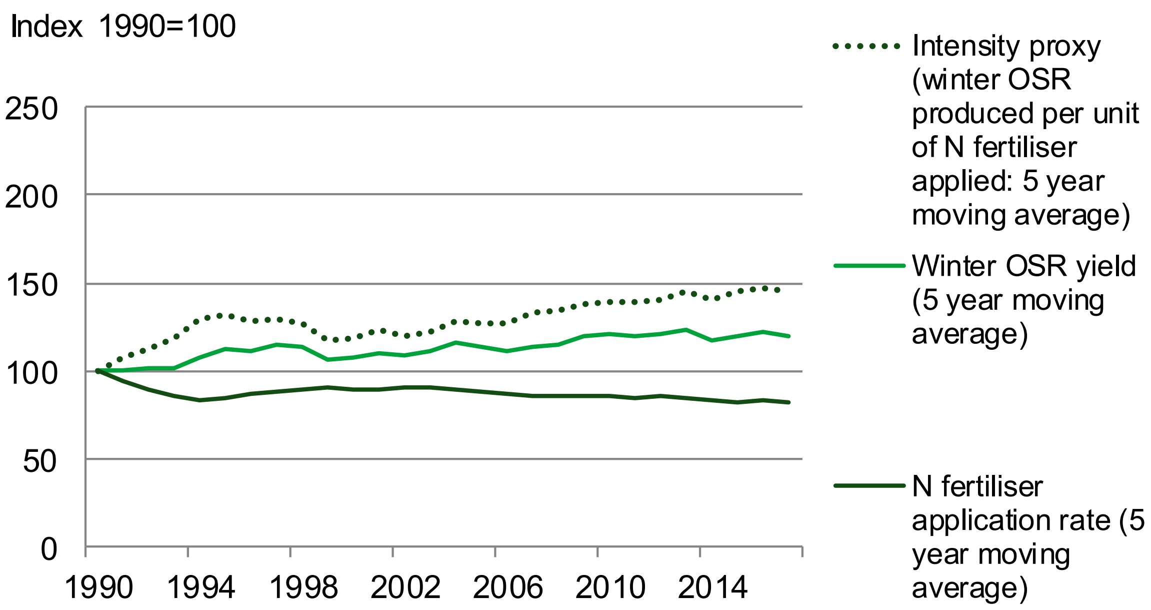
Source: British Survey of Fertiliser Practice, Defra Cereal and Oilseed Rape Production Survey

Figure 2.37 Winter barley produced per unit of manufactured N fertiliser applied, England



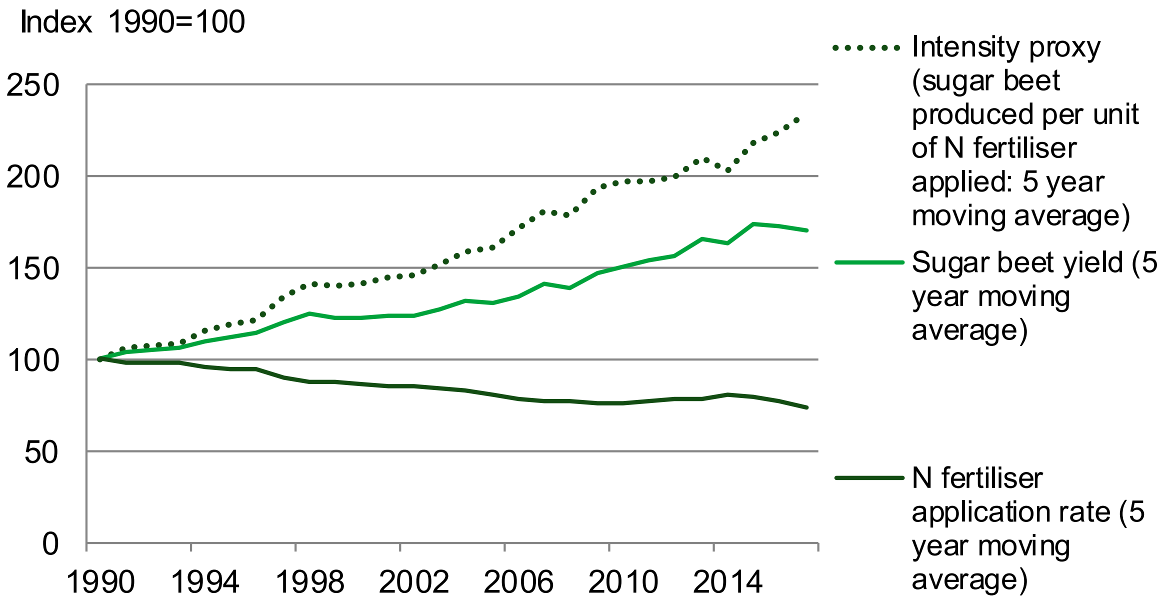
Source: British Survey of Fertiliser Practice, Defra Cereal and Oilseed Rape Production Survey

Figure 2.38 Winter oilseed rape produced per unit of manufactured N fertiliser applied, England



Source: British Survey of Fertiliser Practice, Defra Cereal and Oilseed Rape Production Survey

Figure 2.39 Sugar beet produced per unit of manufactured N fertiliser applied, England



Source: British Survey of Fertiliser Practice,
Defra Cereal and Oilseed Rape Production Survey

Trends

Long term measure of change: since 1990 there has been an increase in the quantity of wheat produced per unit of manufactured nitrogen applied. Much of the increase took place during the 1990s as wheat yields increased whilst application rates remained relatively constant.

The trend in wheat yields has remained relatively stable since 2000 with changes in the intensity measure driven by overall application rates (increasing application rates between 2000 and 2005; reducing thereafter). The last 3 harvests have seen some improvement in yields after reductions in recent years (particularly 2012 due to weather conditions) which led to more wheat being produced per unit of nitrogen applied.

The trends for the intensity measures for winter and spring barley are similar to those for wheat although the weather in 2012 affected barley yields to a much lesser extent. Over the last 10 years the intensity measure for winter oilseed rape has seen a slight upward trend.

All cereals have increased yields in 2017 data, this was mainly driven by 2019 yield data which saw significant increases in the harvest that year.

For sugar beet, until 2015, the trend had been consistently upward since 1990. Historically bonuses were offered by British Sugar for low amino-nitrogen levels, which may have influenced this trend. However the sugar industry in England has undergone considerable restructuring following reform of the EU sugar regime in 2006. Most recently higher sugar beet yields in 2017 have contributed to an increase in the moving average for 2015 and 2016.

2020 harvest summary

There is variability in production from year to year due to weather, disease, and pest pressure affecting yields. Early indications for 2020 show that arable crops have suffered from two main contrasting periods of weather – heavy rainfall during the winter planting season caused waterlogging and compaction, followed by a spring drought which affected the establishment of spring sown crops. Due to the difficulties faced in the winter planting season growers looked to spring sowing to replace failed winter crops – spring barley, oats and pulses were planted to compensate for winter wheat and oilseed rape especially.

For **wheat** the planted area is expected to be around 17% less than last year and could be much lower with provisional Defra June Survey results for England showing a 24% decrease in area, the lowest since the 1970's. Poor drilling conditions into wet cloddy soil led to poor crop establishment. Pest and disease pressure has been low. As of the 18th of August 2020 the GB harvest was 59% complete with the biggest contribution coming from the East, South East, South West and North West of England, however a start has been made in most regions. Yields so far are below the 5 year average of 8.4 tonnes/ha at 7.3 – 7.7 tonnes/ha. The best yields so far have come from heavy yet free draining soils such as the Yorkshire Wolds.

The area of **winter barley** is expected to show a decrease of around 23% whereas the area of **spring barley** is expected to show an increase of this year (in contrast to last year when there was a return to winter barley from spring barley). Provisional June Survey areas for England shows an even bigger switch with winter barley area down 35% with an increase of 79% in spring barley. Winter barley establishment was generally good for the September sown crop and declined as the autumn progressed and the weather turned progressively wetter. Spring barley planting was complete by May, sometimes into dry seedbeds which affected establishment. By the 18th August 2020 the GB **winter barley** harvest was effectively complete with only a few fields left to harvest with the GB yield estimate at 6.3-6.6 tonnes/ha against a 5 year average of 7.1 tonnes/ha.19% of **spring barley** had been harvested by this time, mostly in the South West and South East and the harvest has been hampered by rain resulting in little progress in other regions. Yields so far are close to the 5 year average at between 5.7-6.2 tonnes/ha. Barley quality has been good with exception of some malting barley with high nitrogen content which means it will be reassigned as animal feed.

The **oat** area is forecast to be around 26% higher than last year, oats are a cheap crop to grow, and usually profitable for most growers (demand from the oat milling sector remains strong). The UK oats area has increased year on year since 2015. By the 18th August 2020 24% of the oat harvest was complete, mostly in the South East and South West with a start made in Wales and the Midlands. Little progress has been made further north due to wet weather. Yields so far are below the 5 year average at 4.5-5.5 tonnes/ha.

Winter oilseed rape area is forecast to decline further; provisional Defra June Survey results show that the England area has fallen by 32%, OSR suffered from poor establishment in the wet autumn and has been affected by cabbage stem flea beetle with both the adults and then larvae feeding on crops. Pigeon and slug damage has also affected some areas. The **winter oilseed rape** harvest is 96% complete in small areas of northern England, Yorkshire and Scotland with uncertainty over the final area harvested due to crop loses. Yields are reported to be below the 5 year average (3.6 tonnes/ha) at between 2.6-3.0 tonnes/ha. The best yields were from areas that were well established, not waterlogged and avoided the ravages of cabbage stem flea beetle.

The area of **field beans and peas** *was* expected to increase by around 27% but this is unlikely to be realised given that estimates suggest around 50% of the **winter bean** crop was not planted (although some of this area will be made up for by increased spring bean planting). The pea harvest has got off to an interrupted start due to the weather. Yields so far have been just below average although the pea size is small due to dry conditions in the growing season. There have been problems with Pea moth damage.
The **winter bean crop** has not been of good quality and a good proportion will end up as animal feed. The **spring bean crop** looks to be in much better condition especially in the Midlands and North. Although the southern crop is better than the winter sown crop it has suffered bruchid beetle damage.

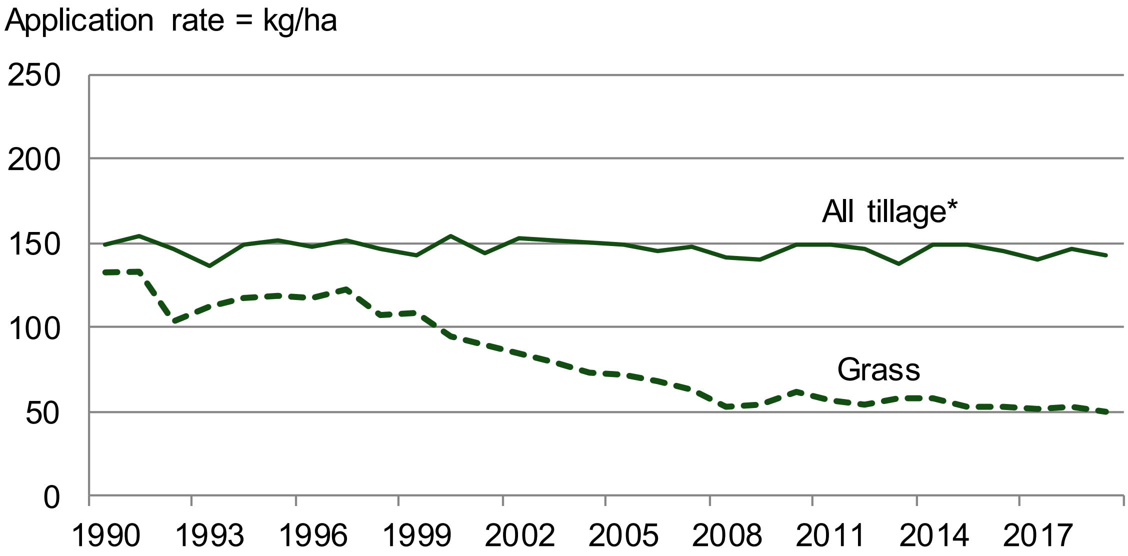
The area for other crops on arable land includes potatoes, sugar beet, vegetables and forage crops and is expected to increase by around 5%. **Sugar beet** area is likely to increase by 4% for the 2020-21 sugar beet campaign but with lower yields sugar production is likely to be similar to last season at just under 1.2million tonnes. The 2020 area of harvested potatoes is estimated to be around 117-120 thousand hectares.

Short term measure of change: manufactured nitrogen application per hectare

Rationale

Trends in average application rates provide a short term indication of greenhouse gas (GHG) emissions intensity (since they are less affected by random factors which impact on yields).

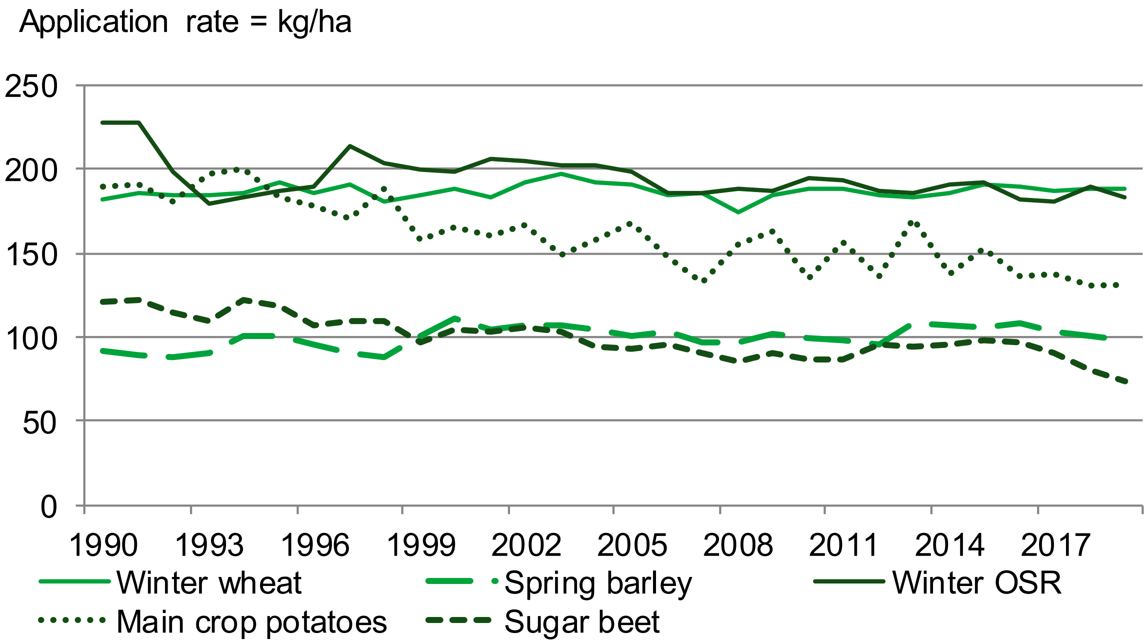
Figure 2.40 Average nitrogen fertiliser application rates, England



*All tillage includes crops but not bare fallow, set-aside or grassland

Source: British Survey of Fertiliser Practice

Figure 2.41 Average nitrogen fertiliser application rates, England



Source: British Survey of Fertiliser Practice

Trends

Short term measure of change: the overall application rate for manufactured nitrogen fertilisers has fallen substantially over the last 20 years. Whilst arable application rates have remained relatively stable, grassland application rates have reduced; accounting for the majority of the fall in recorded nitrous oxide emissions. As shown in the previous section, cereal yields have increased over this period, leading to more cereals being produced for roughly the same amount of manufactured nitrogen applied.

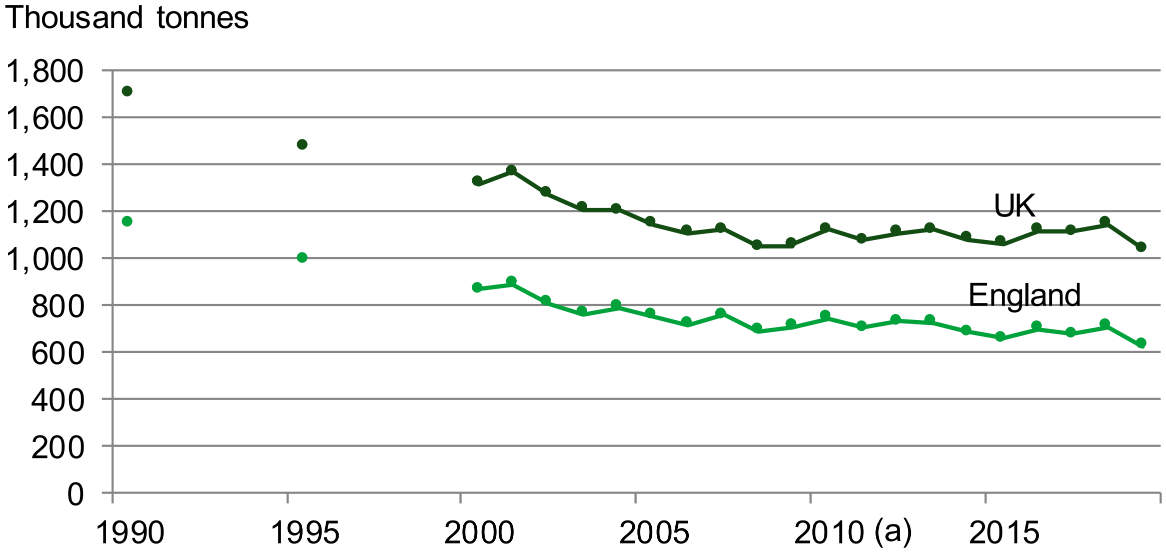
Soil nitrogen balance

The soil nitrogen balance provides a measure of the total loading of nitrogen on agricultural soils each year.

Rationale

The overall balance of nitrogen provides a high level indicator of potential environmental pressure allowing comparisons over time and between countries. All other things being equal, more efficient use of manufactured and organic nitrogen fertilisers will result in a declining nitrogen balance which will in turn lead to a reduced risk of nitrous oxide emissions and other environmental pressures.

Figure 2.42 Nitrogen balance from agriculture, UK and England



(a) From 2010 in England, June survey data for land and animals are collected only for commercial farms resulting in a break in the series

Source: Defra statistics

Trends

The estimates of nitrogen balances show an overall decline over the last 20 years. This will be associated with a lower risk of all forms of nitrogen loss to the environment.

Provisional estimates for 2019[44] indicate that the nitrogen balance for England was a surplus of 624 thousand tonnes. This is a decrease of 84 thousand tonnes (12%) compared to 2018 and a reduction of 240 thousand tonnes (28%) compared to 2000. The increase between 2018 and 2019 has been driven by an increase in overall offtake (mainly via harvested crops) which more than offset a small decrease in inputs (mainly from inorganic fertilisers and livestock manures.) The increase in uptake by harvested crops was driven by significantly higher yields and production for cereals in 2019 with the largest cereal harvest for decades.

2.9.2 Land and nutrient use: application of organic nitrogen

This section has largely focused on the application of manufactured nitrogen. Organic manures are also an important source of nitrogen but data on the volume of manures applied are sparse. Historically, the British Survey of Fertiliser Practice (BSFP) has focussed on the application of manufactured fertilisers although in more recent years it has also collected information on the use and movement of organic manures. However, it should be remembered that the underlying sample design is constructed to measure manufactured fertiliser usage and may not represent the population of farmers using organic manures as robustly.

Organic manures applied to agricultural land may be produced on farm by livestock as slurries, farmyard manure (FYM) and poultry manures or imported from other sources such as treated sewage sludges (also called bio-solids) and some industrial ‘wastes’ such as paper waste or brewery effluent. Of the 1,327 farms in the 2019 BSFP around 67% (951) used organic manures on at least one field on the farm. Table 9 shows the percentage of farms using each type of manure in Great Britain between 2006 and 2019.

Table 9: Percentage (%) of farms using each type of manure, GB 2006 to 2019

	None	Cattle FYM	Cattle slurry	Pig FYM	Pig slurry	Layer manure	Broiler/ turkey litter	Other FYM	Other
2006	30	59	19	2	1	2	2	3	3
2007	33	56	20	1	1	2	2	2	3
2008	31	55	18	3	1	2	3	5	4
2009	32	53	17	2	1	2	2	3	4
2010	33	53	17	2	1	2	2	4	4
2011	32	53	17	2	1	2	2	5	5
2012	36	48	19	2	1	2	2	4	5
2013	35	51	17	2	1	3	2	5	4
2014	34	52	16	2	1	2	1	4	4
2015	35	50	16	1	1	2	2	6	4
2016	35	51	16	2	1	2	2	6	4
2017	37	47	16	2	1	1	1	5	4
2018	32	51	17	2	0	1	2	7	4
2019	33	50	17	2	0	1	2	6	4

Source: British Survey of Fertiliser Practice

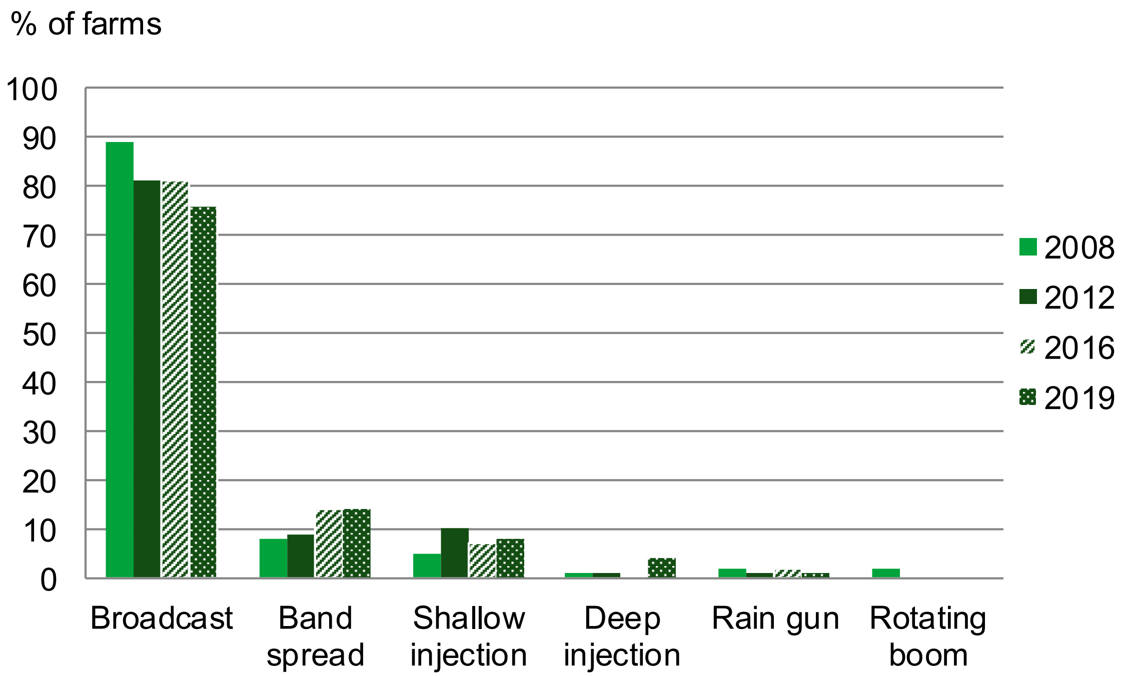
Manure from beef and dairy farms is by far the largest volume of manure type generated in Great Britain. The percentage of farms using cattle FYM has declined by 15% since 2006, whereas the use of cattle slurry is more consistent over the period and was used on 17% of farms in 2019. Not all of the manure generated by a farm is necessarily retained for use by that farm and excess manure/slurry can be exported for use elsewhere.

Application methods for slurry

Methods of slurry application can have a bearing on greenhouse gas (GHG) emissions; slurries can have high GHG emissions since the majority of the nitrogen content is in available forms. This high available nitrogen content can also make them prone to indirect emissions from ammonia losses. Certain methods of application, such as injection or use of a trailing shoe can help mitigate these losses. Both slurry injection and band spreading application techniques are also good mitigation methods for ammonia (which is associated with secondary GHG emissions).

The following chart compares the percentage of farms using each type of slurry application method in Great Britain in 2008, 2012, 2016 and 2019. The data serve only as a guide. They do not account for the area of each farm receiving slurry (or any variation in the rate at which slurry may have been applied using different application methods). Notwithstanding these considerations, it is clear that broadcast application is by far the most widespread method adopted. In 2019 there was a decrease in the use of broadcast, whilst shallow injection and deep injection application methods saw an increase.

Figure 2.43 Application methods for slurry, GB 2008, 2012, 2016 and 2019



Source: British Survey of Fertiliser Practice

Application of slurries to land in the autumn and winter months can be less effective (as there is little or no crop uptake) and may be associated with environmental losses. These indirect emissions from slurry can potentially be high unless careful storage and application management is in place. Table 10 shows the timing of applications of different organic manure types for 2019 (as a proportion of fields receiving applications of each manure type). The crops have been classified as either “winter sown”, “spring sown” or “grass”. This segmentation highlights the prevalence of applications in August and

September for winter sown crops (prior to drilling), whereas spring sown and grass fields are predominantly treated between November and April.

Table 10: Percentage (%) of fields receiving each organic manure type by sowing season and timing, GB 2019

	Cattle FYM	Cattle slurry	Pig FYM	Pig slurry	Layer manure	Broiler/ turkey litter	Other FYM	Other farm manure	Bio-solids	Other non-farm
Winter sown										
August	3	0	17	57	12	16	6	0	22	12
September	12	2	30	2	20	28	6	0	42	5
October	2	0	5	0	0	7	1	0	0	1
Winter (Nov-Jan)	0	0	2	0	0	0	1	0	0	0
Spring (Feb-Apr)	1	1	0	24	0	2	0	0	8	18
Summer (May - Jul)	0	0	0	0	0	8	0	0	1	5
Spring sown										
August	1	1	0	1	4	0	0	0	2	2
September	1	0	1	0	15	0	1	0	6	1
October	1	0	0	0	0	0	0	0	3	0
Winter (Nov-Jan)	2	0	12	0	0	0	0	0	2	4
Spring (Feb-Apr)	11	5	23	7	17	15	6	0	9	16
Summer (May - Jul)	1	2	1	0	0	2	0	0	3	1
Grass										
August	5	6	0	0	0	1	8	0	0	0
September	7	1	0	3	10	10	9	0	0	2
October	6	4	0	0	0	4	10	0	1	0
Winter (Nov-Jan)	8	8	0	0	9	6	9	0	0	4
Spring (Feb-Apr)	28	45	9	6	6	3	34	51	2	20
Summer (May - Jul)	12	26	0	1	5	1	10	49	0	10

Source: British Survey of Fertiliser Practice

Organic manures are valuable sources of the major plant nutrients, including nitrogen, and their use can lead to a reduction in applications of manufactured fertiliser. The BSFP does not ask farmers directly whether they make adjustments to fertiliser inputs as a result of using manure. However, an indication of possible adjustments has been derived by comparing fields that received manure with those that did not (Table 11). Organic fields, which use no mineral fertilisers, have been excluded from these comparisons since they would distort the influence of manures on mineral application rates. The trend for reduced manufactured nitrogen rates on fields also receiving manure is evident across all major tillage crops throughout the period, with the exception of potatoes in 2010 and 2013.

Table 11: Overall application rates (kg/ha) of manufactured nitrogen fertiliser to tillage crops with and without applications of organic manure, GB 2010 – 2018

	2012	2013	2014	2015	2016	2017	2018	2019
Winter wheat with manure	170	175	167	179	177	175	170	170
Winter wheat without manure	190	187	192	196	193	191	193	191
Spring barley with manure	95	96	100	95	93	92	94	83
Spring barley without manure	105	113	113	111	112	106	106	102
Winter barley with manure	140	141	137	147	135	128	125	124
Winter barley without manure	145	145	147	148	150	155	149	150
Potatoes with manure	133	183	137	126	124	137	141	159
Potatoes without manure	136	167	149	178	140	136	145	146
Sugar beet with manure	89	87	89	92	93	80	83	76
Sugar beet without manure	99	103	101	105	100	103	80	74
Oilseed with manure	166	161	175	174	153	164	174	162
Oilseed without manure	191	187	195	197	197	184	193	186

Source: British Survey of Fertiliser Practice

2.9.3 Land and nutrient use: impact of farm performance

Table 12 below provides a comparison of winter wheat gross margins per hectare for 2017/18 and 2018/19 for economically low and high performing farms.

Table 12: Gross margins per hectare of winter wheat, England

£ per ha unless Otherwise stated	2017/18 Low (bottom 25%)	2017/18 High (top 25%)	2017/18 All	2018/19 Low (bottom 25%)	2018/19 High (top 25%)	2018/19 All
Average crop area (ha)	15	143	59	14	153	60
Average yield (tonnes/ha)	7	9	9	7	9	8
Average price/tonne(£)	139	143	141	162	165	165
Crops sales	964	1,294	1,230	1,145	1,440	1,383
Straw	86	63	74	101	76	87
Total crops output	1,049	1,358	1,304	1,247	1,516	1,470
Variable costs						
Seed	75	69	72	86	78	78
Fertiliser	163	169	169	179	176	178
Crop protection	210	221	216	226	223	223
Other crop costs	44	27	30	26	29	29
Total variable costs	492	494	493	518	509	510
Gross margin	**557**	**863**	**810**	**728**	**1,007**	**960**

Source: Farm Business Survey

Economically high performing farms have, on average, about ten times the area of wheat than lower performing farms and achieve greater yields driving the better levels of achieved output. In 2018/19 the total variable costs for high performing farms was slightly lower than low performing farms. In terms of overall gross margins, the gap between low and high performing farming was marginally lower in 2018/19 when compared to 2017/18.

2.9.4 Land and nutrient use: soil carbon

Soil carbon

The extent to which soil carbon sequestration can offset agricultural emissions in the UK is uncertain at present but the best available science indicates that potential in the UK is limited. There is, however, significant potential to reduce carbon emissions from the UK's peat soils, particularly where they are highly degraded or modified.

Over three quarters of UK peatlands are in a modified state, ranging from relatively minor changes to vegetation cover and hydrology, through to the complete replacement of wetland vegetation by arable and horticultural crops, agricultural grasses and non-native conifers, with accompanying deep drainage. Recently published research for BEIS[45] estimates that the UK's peatlands are emitting approximately 23 million tonnes of carbon dioxide equivalents per year.

Arable cropland occupies just 7% of the UK's peat area, but has the highest greenhouse gas emissions from peat degradation per unit area of any peat land-use. As a result, degraded peat soils under cropland are estimated to emit approximately 32% of total UK peat greenhouse gas emissions.

Peatlands converted to grassland occupy a further 8% of the UK's peat area, and emit around 27% of total UK peat emissions. Drained intensive grasslands in lowland areas are the primary source of these emissions.

There are large variations in the main sources of peatland greenhouse gas emissions throughout the countries of the UK. In Scotland, with the largest total peat area, the largest sources are blanket bogs modified by human activities (including drainage, burn-management, and livestock grazing) and forests. In England, the smaller peat area (including areas of shallow residual peat) makes a larger overall contribution to total UK emissions, as a result of intensive arable and grassland cultivation, predominantly in lowland areas. In Northern Ireland, intensive grassland in the lowlands and domestic peat extraction in the uplands are major sources, and in Wales sources include intensive and extensive grasslands and modified bogs.

Defra funded research is currently examining mitigation options for peat management in lowland peat cropland. This will feed into the work of a taskforce being established to deliver recommendations for a new more sustainable future for agriculture on lowland peatlands in England, with a particular focus on greenhouse gas emission reductions.

Wet agriculture, or paludiculture, also offers a potential way forward for these sites. The opportunity for these systems to deliver both economic and environmental objectives is being explored at a range of experimental sites across England. A recent Defra funded review of the practical, social, economic and environmental constraints on the large-scale adoption of paludiculture in England and Wales[46] found it has considerable potential to make a valuable contribution to climate change mitigation and adaptation in England, whilst also maintaining the economic output and extending the lifetime of agriculturally productive lowland peat regions. To realise this potential, further research and development into the potential of high-water table crops is necessary, as well as the expansion and scale-up of paludiculture trials where successful.

2.9.5 Land and nutrient use: summary

The greenhouse gas emissions intensity of cereal production has reduced significantly over the last 20 years through improved yields from constant amounts of nitrogen based fertiliser. Cattle manure is the predominant source of organic nitrogen across farms in Great Britain although the percentage of farms using cattle FYM has declined by 8% since 2006. The proportion of farms using cattle slurry has remained little changed over the same period although is currently 2% lower than 2006. The 2019 BSFP again indicated that broadcast application remained the most common method adopted for both pig and cattle slurries. This suggests that there could be scope to reduce emission intensity and indirect emissions if other methods of application were adopted.

2.9.6 Land and nutrient use: further developments

Considerable work has been carried out in recent years to improve our understanding emissions related to land and nutrients. Much of this has taken place under the greenhouse gas inventory improvement programme. More details of this can be found in Section 4 . Information on individual projects relating to this area can also be found in Section 2.9 of the 7th edition of Agriculture and Climate Change.

2.9.7 Land and nutrient use: notes on data collection methodology and uncertainty

British Survey of Fertiliser Practice (BSFP)

The reliability of estimates of manufactured nitrogen from the BSFP are quantified in the annual report. This states that in 2019: for winter wheat the GB overall application rate was 185 kg/ha and standard error was 2.3 kg/ha; for sugar beet the GB overall application rate was 74 kg/ha and standard error 5.0 kg/ha; for main crop potatoes the overall application rate was 150 kg/ha and the standard error was 9.4 kg/ha. A link to the report including more on the methodology and sampling errors is given in the Appendix.

Cereal Production

The reliability of the estimates of cereal yields are quantified in the Cereal and Oilseed Rape Production annual time series dataset. For wheat in 2019, the yield estimate for England was 9.0 tonnes per ha, and the 95% confidence interval was +/- 0.1. Information on other crops is given in the time series dataset, a link to this can be found in the Appendix.

Soil Nitrogen Balance

The soil nitrogen balances are compiled using a system which draws on many data sources combined with a set of coefficients. The level of uncertainty around the components of soil surface balances has been explored, although an overall level of uncertainty for the overall balances has not been derived. Much of the activity data has quantified low levels of uncertainty, though some of the factors are expected to have a large degree of uncertainty. Links to the methodology reports are given in the Appendix.

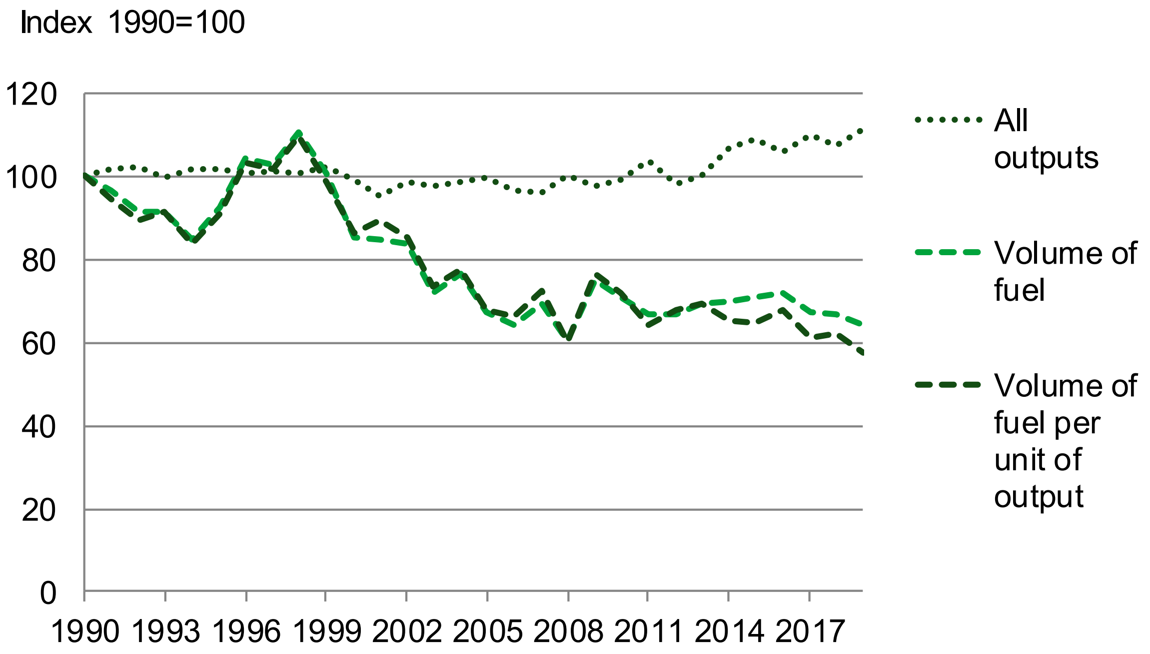
Farm Business Survey

Where the sample size is relatively small, confidence intervals can be quite large, and care needs to be taken with interpretation of the significance of the differences. A link to information on the Farm Business Survey methodology is given in the Appendix.

2.10 Fuel use

2.10.1 Fuel use in agriculture

Figure 2.44 Volume of fuels used in agriculture, UK



Source: Defra, Farm Business Survey

Rationale

Modern agriculture is reliant on mechanisation. Although the fuel needed to power this is the main source of carbon dioxide from agriculture, it only accounts for 11% of all agricultural GHG emissions.

Trends

Since 1990 there has been an overall decrease in the volume of motor and machinery fuel[47] used, with some year on year variation. Additionally, total agricultural output has been largely similar to 1990 levels across the period, although with some fluctuation, thus the volume of fuel per unit of output has fallen since 1990.

2.10.2 Fuel use: further developments

The information presented here is used within the agricultural accounts, and is derived from fuel values, and price information. This means that the headline measures over the long term are reliable. However it would be of value to have more detailed information on the actual volume of fuel, as well as information on the type of fuel (red diesel, LPG, natural gas, fuel oil, petrol, (and possibly coal on old horticultural units). It is not clear at present whether this information is available.

2.10.3 Fuel use: notes on data collection methodology and uncertainty

Farm Business Survey

Where the sample size is relatively small, confidence intervals can be quite large, and care needs to be taken with interpretation of the significance of the differences. A link to information on the Farm Business Survey methodology is given in the Appendix.

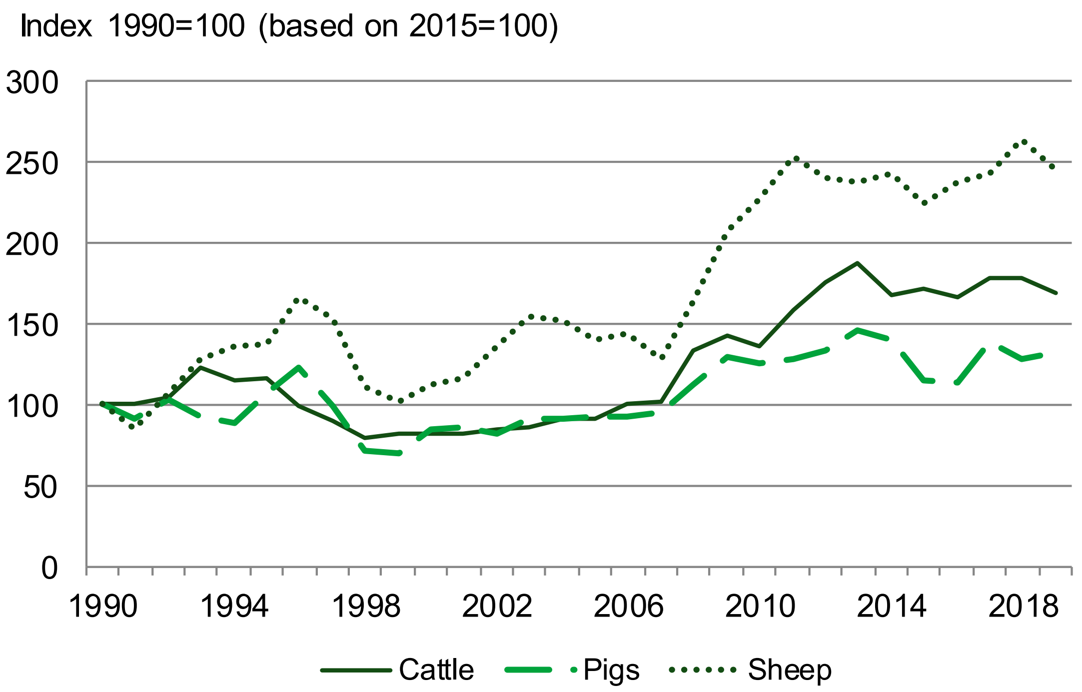
2.11 Contextual factors: prices of inputs and outputs

Output prices

Rationale

Prices of both inputs and outputs can influence management and business decisions taken by farmers which can in turn have an impact on greenhouse gas (GHG) emissions from the agricultural sector. For example, market prices may influence the use of mineral fertilisers and the age at which livestock are slaughtered.

Figure 2.45 Livestock Prices, UK



Source: Defra, Agricultural Price Index

Trends

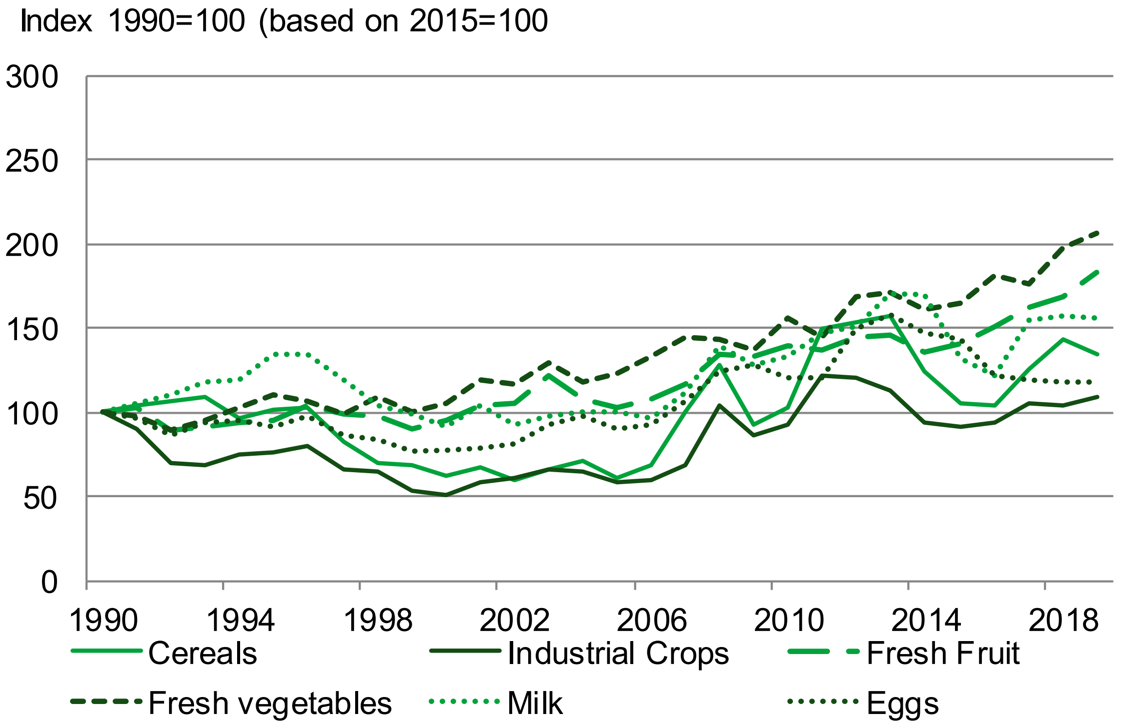
Livestock prices are influenced by exchange rates, the UK (and global) supply and demand situation and other factors such as disease outbreaks. After remaining relatively stable between 2003 and 2007 cattle, sheep and pig prices all rose sharply in 2008 and 2009.

Cattle price increases in 2008 and 2009 were driven by lower supplies of prime cattle and strong domestic demand combined with increased export demand (due to the exchange rate). The subsequent reduction in prices in 2010 was the result of increased supplies. More recently, an increase in demand and lack of supply led to increased prices, which continued through to 2013. The horsemeat revelations also added significant upwards pressure to beef prices during the spring and summer of 2013 as demand for British beef intensified. Following the record high in 2013 cattle and calf prices fell in 2014.

Sheep prices increased in 2008, supported by tight domestic supplies and a strong export market. In 2011, strong competition for British lamb (driven by reduced global supplies stemming from a shortage of New Zealand lamb) continued to result in considerably higher prices which reached record levels. During 2012 there was a drop in lamb prices influenced by the bad weather, limiting finishing and tightening supplies. Lamb prices in 2018 were high as a result of the cold snap during the lambing season that year. Due to the wintery weather lamb mortality rates were higher than normal meaning the remaining lambs commanded a premium.

Pig prices have improved in recent years, largely in response to higher production costs but also as a result of increased demand both at home and on the continent.

Figure 2.46 Crop, milk and egg prices, UK



Source: Defra, Agricultural Price Index

Trends

Fluctuations in cereal prices have generally been a result of the global supply and demand situation and currency movements. From 2006, cereal prices rose steeply peaking in 2008, this year also saw a peak in prices of industrial crops, fresh fruit, milk and eggs; only fresh vegetables were unaffected. 2009 brought a reduction in prices across all categories except eggs although 2010 and 2011 saw increases in cereal and industrial crop prices. Average cereal prices rose in 2011 due to tight global stocks and strong demand. They remained high as a result of weather conditions in 2012 and a tight world market. More recently, 2014 and 2015 cereal prices were below those seen in

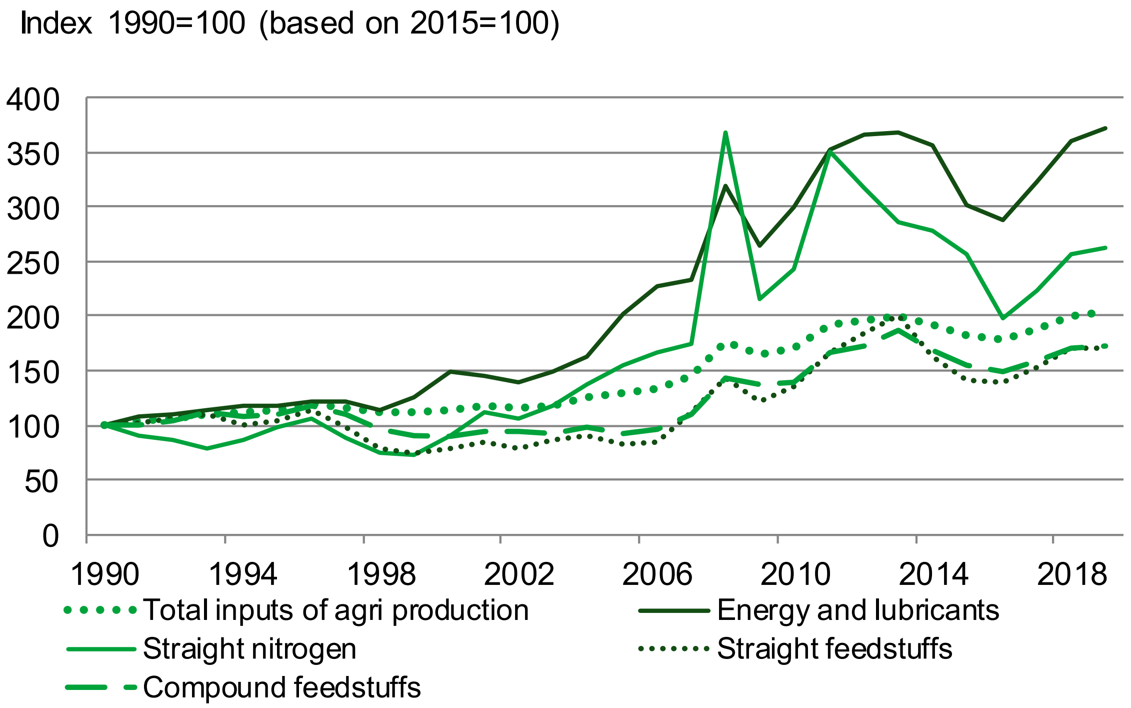
2013, influenced by increased global production and stocks. In 2017 and 2018 cereal prices increased due to the pound being weak against the dollar and euro and the demand was up, particularly in the biofuels sector. Egg prices have been dropping since 2016 due to oversupply in the free-range sector as more farmers are making the switch from more intensive systems, causing the market to struggle.

Increased prices for fresh vegetables in 2010 were the result of a number of factors: wet weather reduced imports from Spain while UK weather conditions affected domestic supplies. More recently the poor weather conditions in 2012 reduced fresh vegetable production resulting in large price increases. Price increases continued during 2013 before falling in 2014. Since then prices have increased with rises for most types of vegetables.

In the long term milk prices have fluctuated but show an overall increase since 2000. In the shorter term prices fell significantly during the second half of 2014; high domestic production combined with falling returns from global commodity markets having a large impact. In 2015, milk volume rose with monthly domestic production consistently higher than 2014. Good grazing due to favourable weather conditions led to high milk yields. This contributed to an abundance of supply and subsequent fall in milk price; a trend which continued across 2015 and 2016. From 2016 to 2019 prices have begun to increase again.

Input prices

Figure 2.47 Purchase prices of agricultural production, UK



Source: Defra, Agricultural Price Index

Trends

The cattle, pigs, poultry and sheep sectors all purchase compound feed. Purchaser prices (the price paid by producers for agricultural inputs) for compound (and straight) feedingstuffs are influenced by changes in cereal and oilseed prices, although farmers can mitigate some of the price increase seen here by substituting for different forms of animal feed. More recent increases in animal feed price, for example in 2012, are linked to poor harvests, particularly in Australia and the USA, and the increasing interest in biofuels, primarily abroad and to a more limited extent in the UK, has added some pressure to the demand side of the market. By contrast in 2014 and 2015 average prices for animal feedingstuffs decreased reflecting the lower price of cereals in those years. This was largely due to abundant global supplies. Since 2016 all purchase prices have increased due to the weakened pound, and the heavy influence of rising global energy prices on industrial inputs, such as fertiliser and fuels.

Prices of straight nitrogen peaked sharply in 2008 resulting in slightly lower levels of usage of nitrogen fertilisers, as illustrated in Section 2.9.

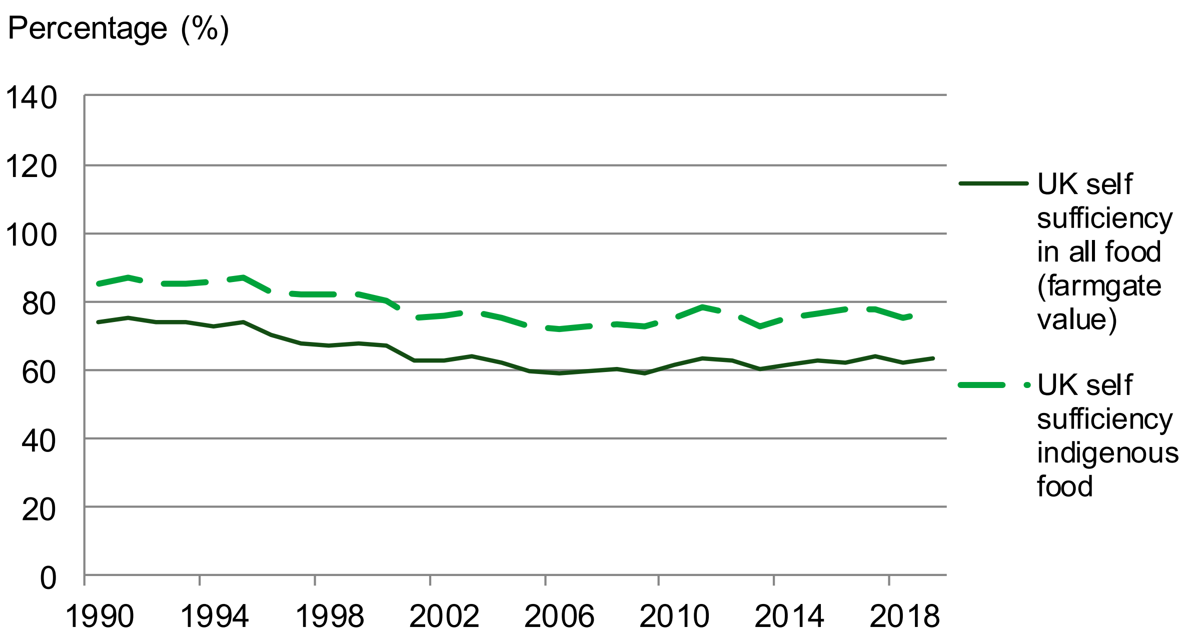
2.12 Contextual factors: trends in UKs ability to meet domestic demand and contribute to the international market

2.12.1 Contextual factors

Rationale

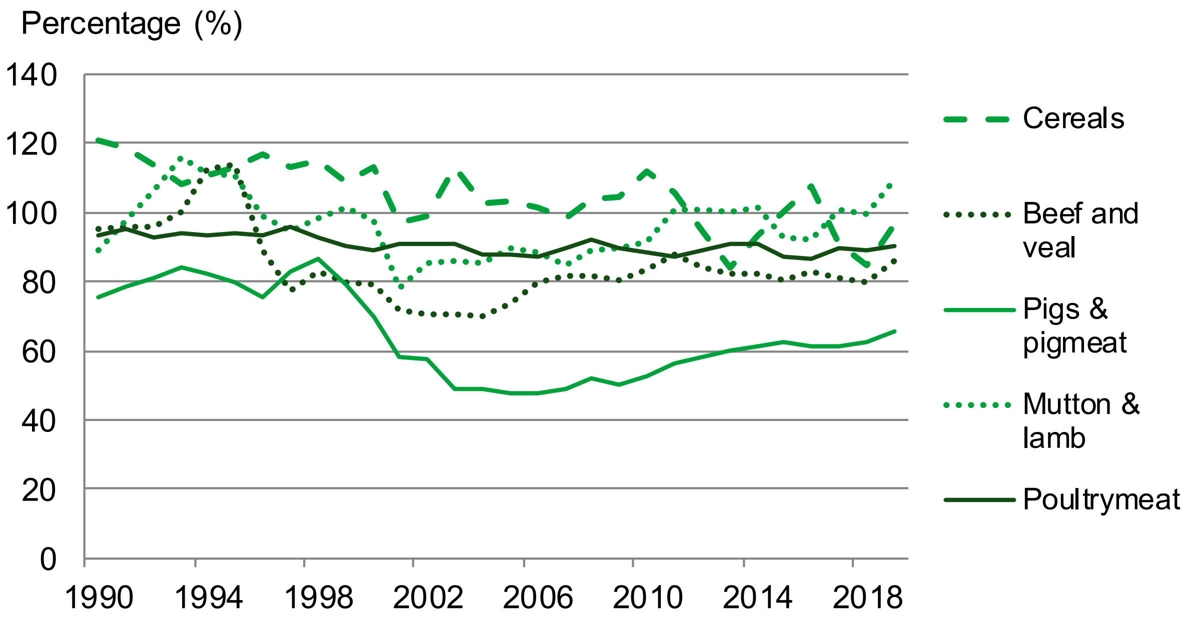
All other things being equal, greenhouse gas (GHG) emissions associated with UK production would fall if UK production was displaced by produce from international competitors. However this would not result in a reduction in emissions intensity. Measures of UK production as a percentage of UK consumption are shown here to provide an indication of displacement and hence any 'carbon leakage'. These measures only provide an overview and do not capture the GHG emissions associated with food production. However, they do provide a useful high level summary.

Figure 2.48 UK production to supply ratio ("self-sufficiency") in food



Source: Defra, Agriculture in the U

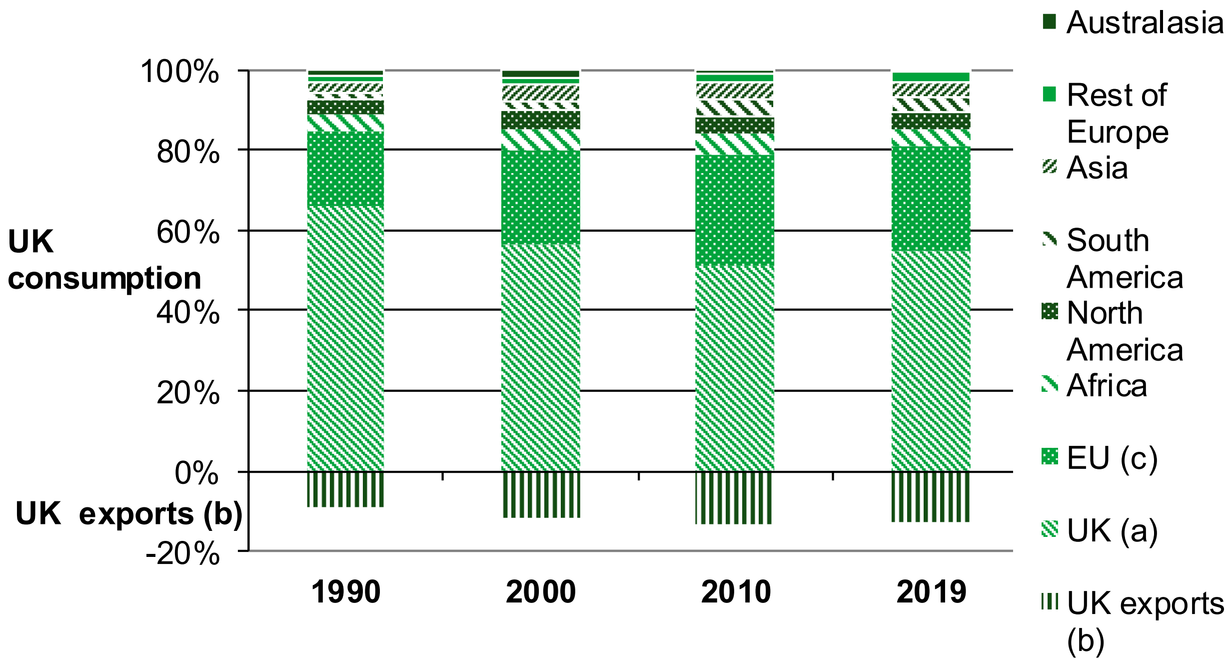
Figure 2.49 UK production to supply ratio (“self-sufficiency”) in key commodities



Note, measures of production to new supply ratio for commodities shown are volume based, whilst headline measure of production to supply ratio in all food is a value at the farm-gate measure.

Source: Defra, Agriculture in the UK

Figure 2.50 Origin of food consumed in the UK: 1990, 2000, 2010 and 2019



Based on the farm-gate value of raw food

(a) Consumption of UK origin consists of UK domestic production minus UK exports

(b) UK exports are given as a percentage of total UK consumption

Source: Defra, Agriculture in the UK

Trends

UK consumption of agricultural products and carbon leakage: whilst production in the UK has fallen overall for some commodities since 1990, which may result in lower total emissions, in the main, domestic production (in particular meat) has been replaced with imports. Therefore, any reduction of emissions in the UK will have been at the expense of increases overseas. There is insufficient evidence to say with any certainty that this displacement will have been of a significantly different level of GHG intensity (that is, GHGs produced per tonne of grain, litre of milk or kilogramme of meat produced).

UK domestic demand and production of agricultural products

The impact of changes in domestic demand for agricultural products on price is limited as UK farmers are price takers within the wider international market

The theory of supply and demand would suggest that a fall in domestic demand might be expected to translate into a fall in price for agricultural products in the UK. However, the influences on food prices are subject to international factors (e.g. UK pig prices follow wider EU prices over time), and coupled with the fact that domestic demand is small relative to global demand, changes in UK demand would not be expected to have a significant impact on prices in an international market.

With any reduced demand domestically, exports of agricultural products should rise

We would therefore expect change in domestic demand to impact on trade flows, rather than on prices. For example, given a rising global demand, but a falling domestic demand, UK producers would find international markets more attractive relative to domestic markets, even with the additional costs of exporting. Hence, exports should rise. Similarly, those countries currently exporting to the UK would, if prices started to fall as a consequence of falling demand, assess whether to continue exporting the same quantities to the UK or perhaps instead redirect exports to markets with a better price. This change in trade flows would 're-balance' supply and demand until the UK price was equal to international prices; UK imports would fall while exports would rise.

We can expect greater volatility for individual items than is seen at the all outputs level, and there will be some parts of the market where local supply/demand will have more of a bearing, but overall overseas trade flows will soon adjust to dampen down the impact of any price differential that emerges between the UK and the wider EU and international market as a consequence of changes to UK demand. This adjustment through trade flows can be illustrated by looking at trends in UK production and consumption of pigmeat since the late 1990s. UK pigmeat production reduced by 37% between 1998 and 2010 while at the same time UK consumption rose by 5%. This imbalance between rising UK demand, and falling domestic production was not reflected in higher prices, rather UK prices over the period continued to follow the trends seen across the EU. But, UK imports rose by 64% and exports fell by 58% thus demonstrating how trade flows adjust to dampen down any differences in price that emerge.

Section 3: Farmer attitudes and uptake of on-farm mitigation measures

Background information

The following section provides key summary statistics on farmer attitudes and views - what farmers think about greenhouse gases (GHGs) and their uptake of a range of mitigation measures.

The farming industry, in England and the UK is comprised of a large number of relatively small businesses. The characteristics of the many businesses and individual farmers are critical to the uptake of climate change mitigation measures where there is a need for farmers to understand the issues and be willing and able to implement measures. Understanding what practices are adopted, and why, can help highlight the barriers and motivations to action on GHGs.

Many farmers recognise the significance of GHG emissions but some remain unconvinced about the business benefits of reducing emissions. Greater understanding of GHG emissions is likely to encourage adoption of practices to reduce emissions, although this is not guaranteed. A greater understanding may also lead to the adoption of more measures and cost-effective-solutions for reducing agricultural GHGs that fit with the farm business.

While research suggests that most practices to reduce GHG emissions could save farmers money (and many farmers are likely to be influenced to change their practices because it makes good business sense) there are several key barriers to uptake which are non-financial, or not directly financial. These include a lack of willingness to undertake (e.g. limited trust in what is being asked and the outcomes that will result) and a lack of ability to undertake (e.g. a lack of understanding, skills, time or capital). Whilst most farm businesses should be able to implement key actions, not all measures are suitable for all farm businesses.

The industry-led Greenhouse Gas Action Plan (now linked with Tried & Tested within the Campaign for the Farmed Environment) is intended to convey coherent messages covering good farming practices which include resource use efficiency and nutrient management as well as farmland biodiversity and resource protection.

This Chapter links to data on farmer understanding and awareness of actions towards reducing GHG emissions. This includes actions undertaken to reduce emissions and motivations and barriers to action.

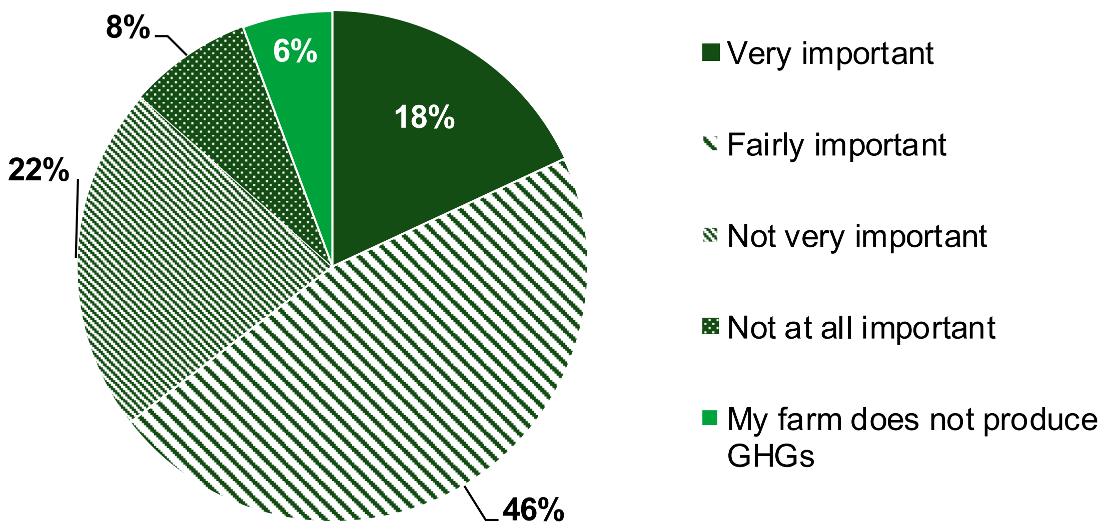
3.1 Farmer understanding, awareness and uptake of actions towards reducing GHGs

Awareness of greenhouse gas emissions

Measuring awareness of the importance of GHGs for the farm business and sources of emissions can provide an indication of the ease with which mitigation measures will be adopted and help to highlight motivations and barriers. However, whilst important, improving understanding and attitudes towards GHGs are not a guarantee of the adoption of mitigation practices; business sustainability and financial implications are important drivers for change.

Attitudes to, and knowledge of GHGs is one of the GHG indicators and covers all farming sectors. More details of the indicator can be found in the Summary earlier in the publication and in the full indicator text.

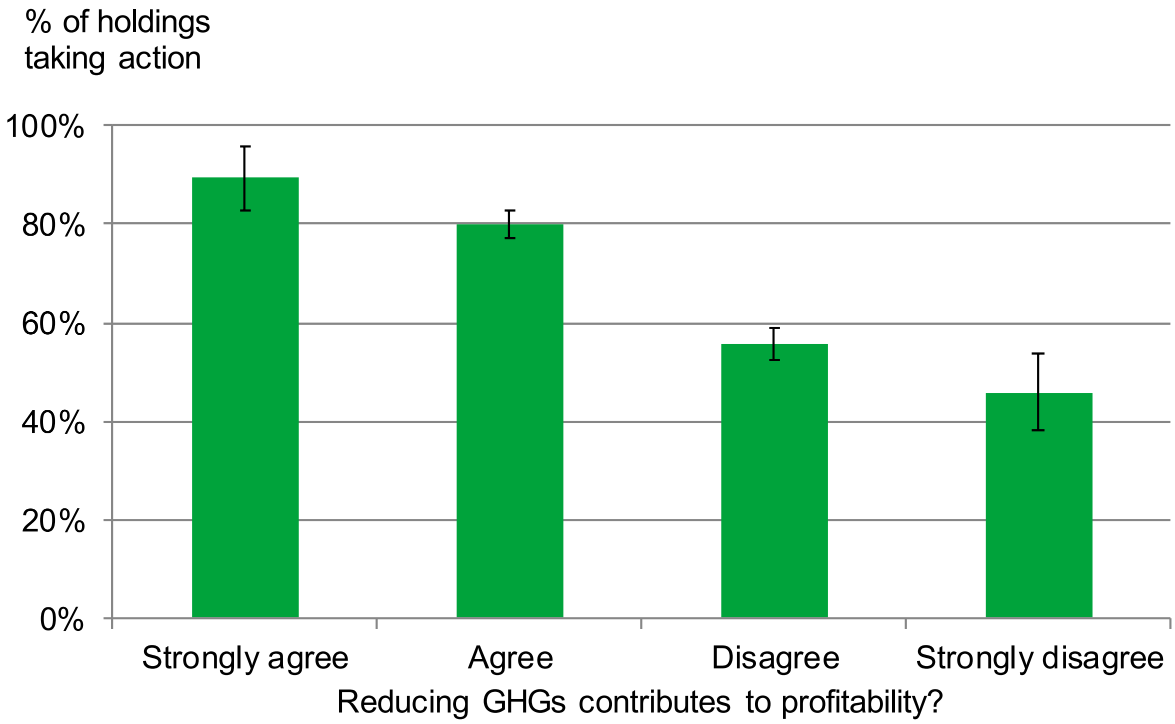
Figure 3.1 How important is it to consider GHGs when taking decisions about crops, land and livestock?



Source: Farm Practices Survey 2020

The 2020 Farm Practices Survey (FPS) indicated that 65% of farmers thought it important to consider GHGs when making farm business decisions, whilst 30% considered it not important. There were a relatively small number that still consider that their farm did not produce GHGs (6%). Dairy farms placed the greatest importance on GHGs followed by pigs and poultry and cereal farms.

Figure 3.2 Proportion of farmers taking action to greenhouse gas emissions by views on link to profitability



Source: Farm Practices Survey 2020

55% of farmers thought that reducing emissions would improve farm profitability, an increase from 41% in 2019. Dairy and cereal were the most likely to recognise the link to profitability while grazing livestock farmers were least convinced.

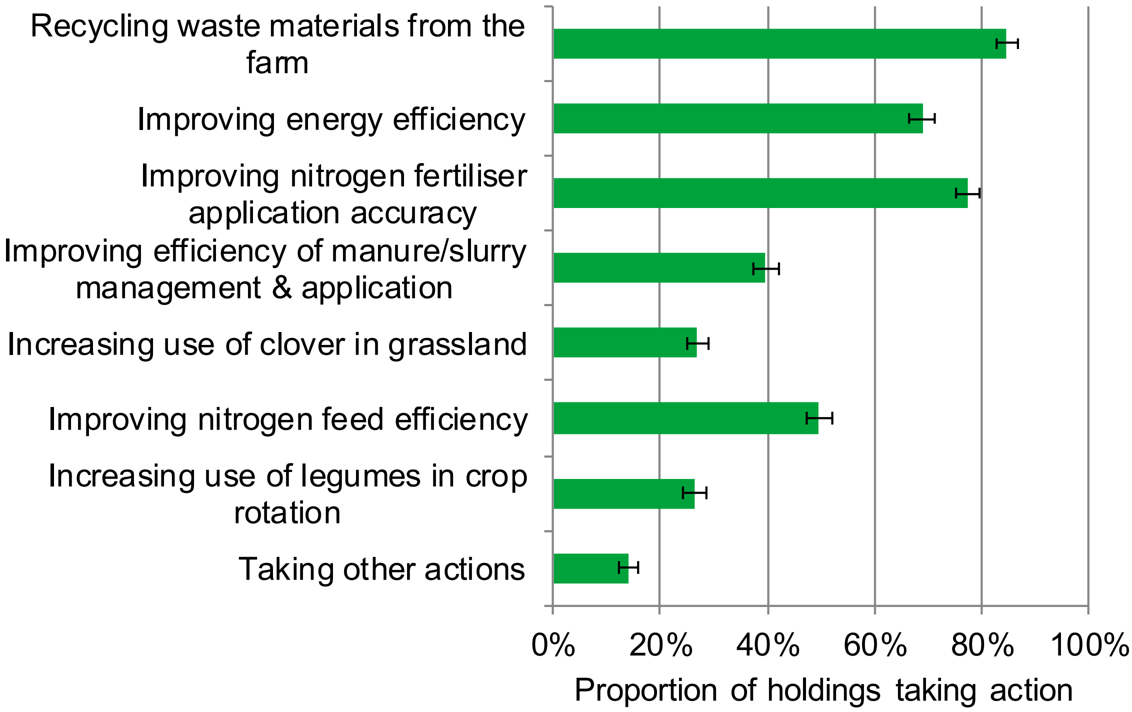
Of those strongly agreeing that reducing GHGs increases profitability 11% were still not taking any actions (compared to 17% in 2019) while 46% of those strongly disagreeing that reducing GHGs would increase profitability nevertheless took action (compared to 34% in 2019).

What farmers say they do to reduce greenhouse gas emissions

The 2020 FPS results indicated that 66% of farmers were taking actions to reduce emissions. Larger farms were more likely to be taking action than smaller farms. LFA and lowland grazing livestock were less likely to be taking action (51% and 57% respectively) than other farm types. The results are a change from 2019 where pigs and poultry and dairy farms were least likely to take up action. Unsurprisingly, those who think that reducing emissions is important are more likely to undertake an action to reduce, for example 88% of those who thought it was very important, took action.

The most common actions to reduce GHG emissions (cited by more than half of those undertaking actions in 2020) were recycling waste materials, improving nitrogen fertiliser application and improving energy efficiency. These are actions that are relevant to most farm enterprises. Those actions-more suited to livestock enterprises had a lower level of uptake.

Figure 3.3 Actions being taken by farmers to reduce greenhouse gas emissions



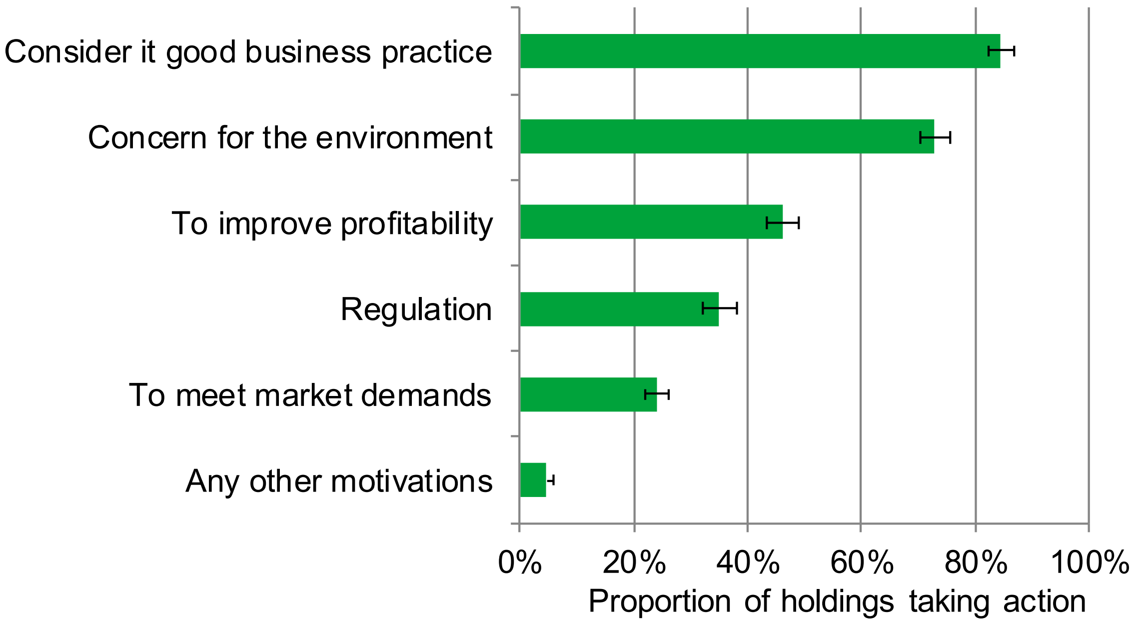
Source: Farm Practices Survey 2020

In general, larger farms were more likely to take action, but there were some key differences between enterprises which reflected the nature of the business. Grazing livestock, dairy and mixed farm types had the highest uptake of clover in grassland (as fits the nature of management). However, grazing livestock and mixed enterprises were less likely to take action when compared to dairy farms in relation to manure / slurry management and feed efficiency. This suggests that there are still opportunities for improved practice. In another example, 92% of cereals and 84% of other cropping farm types are taking actions to improve nitrogen fertiliser application compared to 78% of dairy farms. Figures for grazing livestock farms are lower at 42% of lowland farms and 44% of Less Favoured Area (LFA) farms taking action. It is also recognised that not all enterprises apply nitrogen fertiliser e.g. organic farms and some grazing livestock farms. In 2020, 53% of LFA and 51% of lowland grazing livestock farms were improving slurry / manure management compared to 83% of dairy enterprises. Less than a third of grazing livestock farms were improving nitrogen feed efficiency compared to 64% for dairy enterprises, similar levels to those seen over the last 3 years.

What are the main motivations for undertaking the actions to reduce greenhouse gas emissions?

In 2020 most farmers (85%) consider it to be good business practice to undertake action to reduce GHGs and concern for the environment is also a strong positive motivator (73%). Just under half undertake the actions to improve profitability and 24% to fit with market demands. Regulatory reasons for the actions e.g. around nutrient management, were a motivation for 35% of farmers.

Figure 3.4 Main motivations for taking action to reduce greenhouse gas emissions



Source: Farm Practice Survey 2020

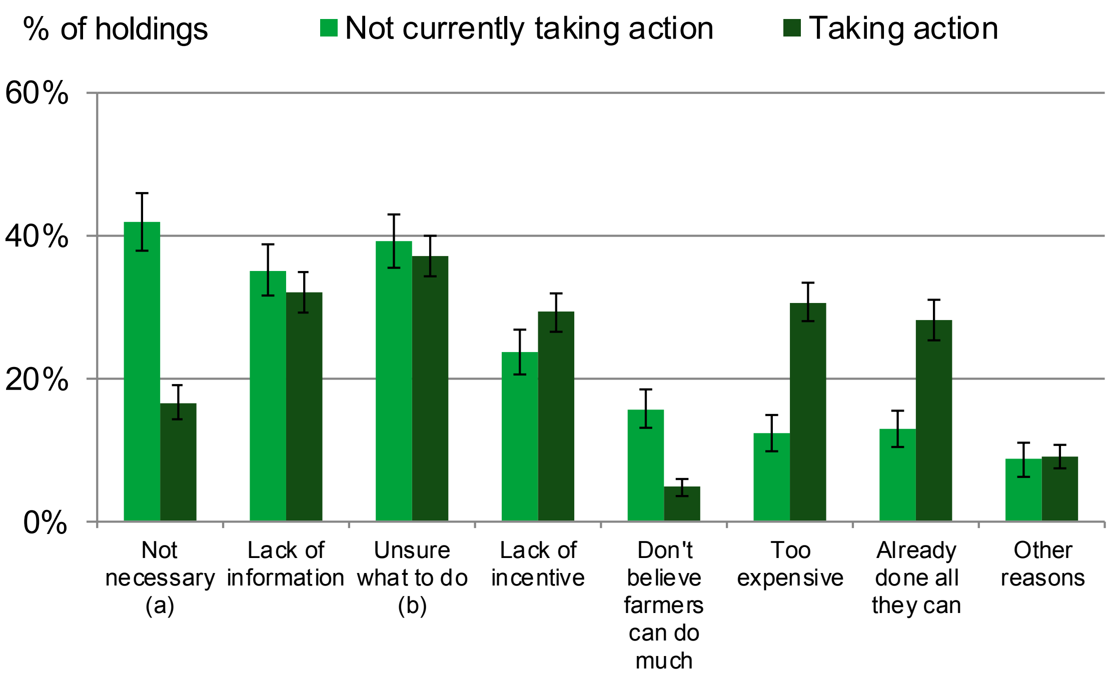
What farmers say are the barriers to reducing emissions

For those farmers not undertaking any actions to reduce GHG emissions, informational barriers are important i.e. the lack of information (35%) and lack of clarity on what to do (39%) were key reasons for not taking action. This could be described as 'personal capacity for action'. However, there is also a wider issue around understanding or willingness to take action with 42% not believing any action is necessary,16% believing there is not much they can do and 13% believing they have done enough. These findings show little variation from those in the FPS surveys of 2013 to 2019.

Actual financial barriers are smaller in comparison, with 24% saying not enough incentive and 12% too expensive. Some smaller farms considered that they did not produce enough emissions (48% thought action was not necessary for this reason compared to 25% of larger farms). The recognition that action was necessary also varied by farm type with only 15% of dairy farms thinking they did not need to take action compared to a higher percentage of grazing livestock farms (57% Less Favoured Area (LFA) farms and 48% lowland) and 41% of Pigs and poultry farms.

For those already taking actions, financial barriers are stronger (31% saying too expensive). Information barriers are still important i.e. the lack of information (32%) and lack of clarity on what to do (37%). However, the need to take action was reflected in only 17% believing that action is not necessary and just 5% believing that there is not much they can do. Nearly a third (28%) of those taking action believe that they have already done enough. The recognition of the need for action again varied by farm type with only 8% of dairy farms thinking they did not need to take action compared to 38% of LFA grazing farms.

Figure 3.5 Factors preventing action to reduce greenhouse gas emissions



(a) Not necessary as don't think my farm produces many emissions.
(b) Unsure what to do due to too many conflicting views.

Source: Farm Practice Survey 2020

3.2 Uptake of on-farm mitigation measures

Details of uptake rates for a wide range of on-farm mitigation measures can be found in the results of the February 2020 Farm Practices Survey.

The survey focused on practices relating to greenhouse gas mitigation with topics including nutrient and manure management, manure and slurry storage, farm health plans, cattle and sheep breeding and feeding regimes and anaerobic digestion.

Uptake of on-farm mitigation measures is one of the GHG indicators, it covers all farming sectors. More details of the indicator can be found in the Summary earlier in the publication and in the full indicator text.

Section 4: Emerging evidence

This section highlights research and development around greenhouse gas (GHG) emissions and mitigation in the agricultural sector

4.1 Ongoing Research Projects

Defra has recently commissioned a project entitled "Delivering Clean Growth Through Sustainable Intensification" to better understand the key measures and technologies that can be implemented to reduce emissions from the sector and contribute to achieving net zero emissions in the UK by 2050. The work will review the evidence base to develop a revised and updated cost curve for agricultural mitigation, and work with stakeholders to develop realistic trajectories of change that could be implemented by policy. Interested stakeholders should contact farmingscience@defra.gov.uk for more information on how to engage with the project.

Defra continues to engage with international partners to better understand opportunities for the sector to improve productivity whilst reducing its environmental impacts. This includes engagement with the Global Research Alliance on Agricultural Greenhouse Gas Emissions[48] and ongoing research partnerships under the European Horizon 2020 European Research Area Networks (ERAnets) including:

- Greenhouse Gasses in Agriculture and Silviculture (ERAgas)[49]
- Sustainable Animal Production (SUSAN)[50]

A range of ongoing research projects are underway to support the R&D platform and efforts by the agricultural sector to reduce emissions. These cover livestock and forage improvement, crop improvement, more efficient use of fertilisers on crops and protein in animal diets and collation of evidence to encourage implementation of the industry's GHG Action Plan. Evidence generated by these projects have been fed into the inventory improvement programme. Details of these and other projects can be found on the internet at: http://randd.defra.gov.uk/

4.2 The Greenhouse Gas Platform

Defra and the Devolved Administration Governments supported the development of an improved Greenhouse Gas Inventory for direct methane (CH_4) and nitrous oxide (N_2O) emissions from agriculture through a five-year research programme: the Greenhouse Gas Platform. The Platform comprised three, closely-linked projects, designed to improve the accuracy and resolution of the United Kingdom's national reporting system including the development of regionally-specific emission factors to reflect current and changing specific practices and production systems within agriculture. Since 2017 we have implemented an improved inventory model based on the outcomes of the platform. This has enabled better forecasting and monitoring of performance against the wider UK target emission reductions set by the UK Climate Change Act (2008) as well as targets set in the legislation and policies of Devolved Administrations. The improved inventory

will also help the agricultural industry track uptake of mitigation measures included within the greenhouse gas reduction plans and sector-specific roadmaps.
The Greenhouse Gas Platform consisted of the following three projects:

- Data Management and Modelling: project AC0114 - brought together existing and newly-researched activity and emissions data to create a new, more-disaggregated inventory model and a set of revised emission factors with an assessment of uncertainty. Improved calculations methodologies for agricultural emissions accounting were developed in AC0114 and have been implemented in the current inventory submission.

- Methane (ResearCH4) project: AC0115 - developed new enteric CH_4 emission factors from different ruminant species, breeds and genotypes (and their manures) under a range of typical farming systems. The final report can be found online[51].

- Nitrous Oxide (InveN2Ory) project: AC0116 - improved quantification of soil nitrous oxide emissions through measuring and modelling N_2O emissions from different nitrogen inputs as influenced by season, climate, crop, soil types and conditions, and land management representative of UK farming systems. The final report can be found online[52]. In January 2015, Defra also launched a parallel 'Representative Feeds and Diets' project (SCF0203) to assist with the collation of necessary information on the quality and composition of ruminant livestock diets, to support the operational inventory. Reporting of this project has been delayed due to staffing changes at the institute compiling the data; we anticipate publication in 2020.

Outputs from all the projects are closely coordinated with Defra project SCF0107, which calculates and delivers the annual UK agricultural greenhouse gas and ammonia inventories (and projections) for submission to the United Nations Framework Convention on Climate Change (UNFCC), the UK's component administrations, and the United Nations Convention on Long-range Transboundary Air Pollution, respectively.

A legacy has also been left by the GHG Platform projects created through interactions between policy makers, industry and the research community. The significant data resources developed under the GHG platform have been made publicly available on the Agri-Environment Data Archive: http://www.environmentdata.org

In addition the data have been submitted for inclusion in the UNFCCC emissions factor database (https://www.ipcc-nggip.iges.or.jp/EFDB/main.php) to allow researchers, businesses and other countries to benefit from the insights developed in the platform. Data from the platform has also underpinned revised IPCC good practice guidance for the compilation of agricultural GHG inventories.

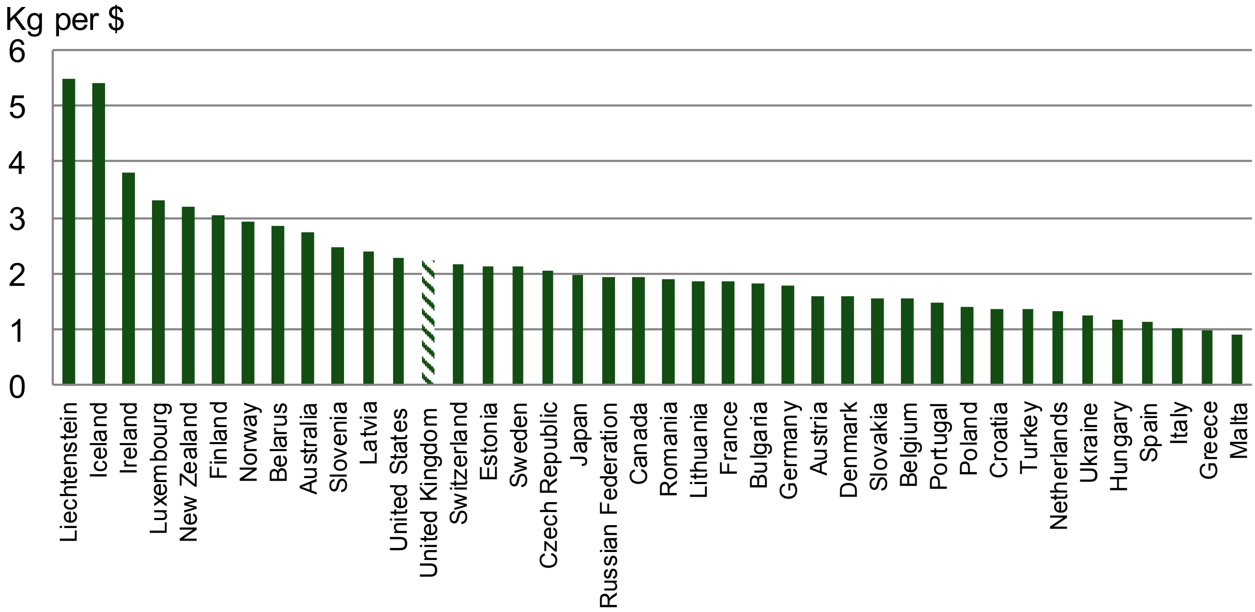
Section 5 International comparisons

This section provides international comparisons of both the productivity and greenhouse gas (GHG) intensity of agriculture. There are many challenges with making international comparisons due to differing farming systems, lack of comparable data and, in some instances, a lack of data. In exploring international comparisons for GHGs, two illustrative examples are given for cereals and milk. Here, where available, yields are considered alongside factors associated with risk of high GHG intensity.

5.1 Comparisons of GHG emissions per unit of production

Comparisons of agricultural GHG emissions across countries are difficult, not only because of data availability but also due to the differing types of agriculture undertaken in each country. It is possible to gain some indication of carbon intensity across countries by assessing agricultural emissions on the basis of emissions per unit of output (expressed in financial rather than biological or physical terms) although this is still largely driven by the mix of farming undertaken within different countries. The chart below considers the UNFCCC (Annex1)[53] countries in this way for 2016 (latest published data).

Figure 5.1 Agricultural emissions in CO2 equivalent per unit of gross agricultural production, 2016



Note: Gross agricultural production expressed in constant 2004-2006 prices
Sources: FAO, UNFCCC

Malta, Italy and Greece have some of the lowest levels of emissions per unit of gross agricultural production. This reflects the production of high value crops with low emissions (for example, olives and grapes) in these countries. Countries such as New Zealand and Ireland have some of the highest levels of emissions per unit of gross agricultural production reflecting the dominance of livestock farming in those countries. The diverse farming systems found in the UK leads to a lower level of emissions per unit of gross agricultural production. However, the preponderance of grassland, the largest population of sheep in Europe and a large population of suckler cows (which produce methane and are produced largely at very low or negative profit margins even though they may be comparatively efficient in production terms) place the UK amongst the upper half of UNFCCC countries when considering emissions in this way.

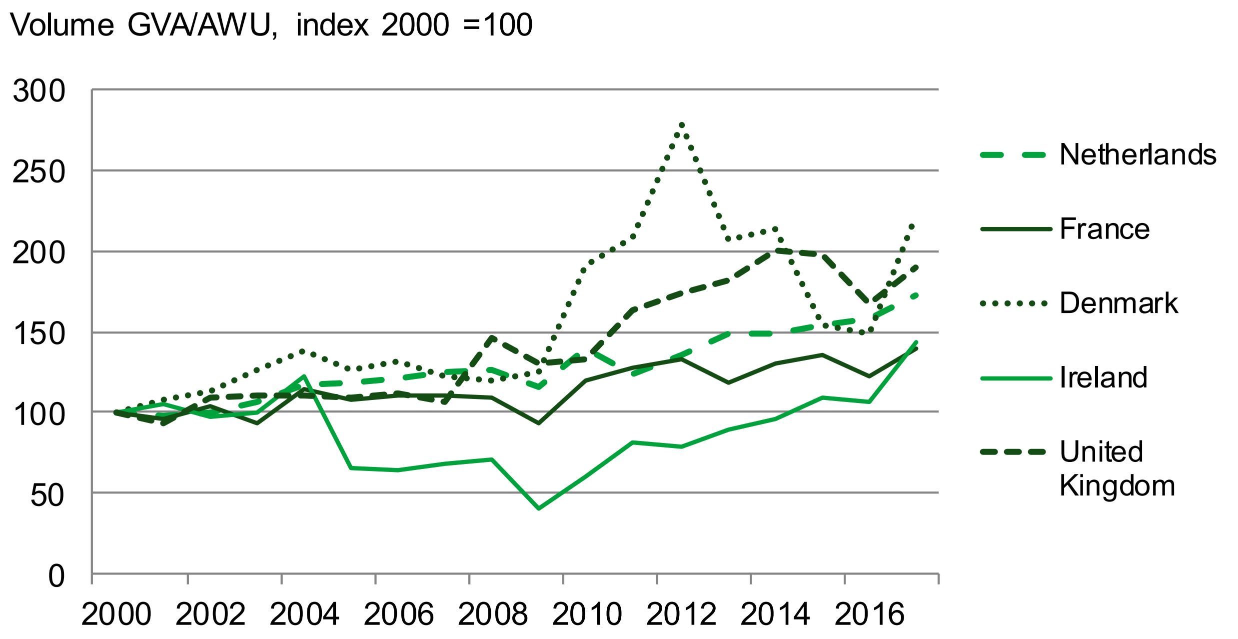
5.2 International comparisons of productivity

Productivity can be defined as the efficiency with which inputs are turned into outputs. Considering labour productivity in agriculture is a way of assessing this.

The following chart shows trends in agricultural labour productivity for a selection of countries based on gross value added (GVA) and annual work unit (AWU). GVA is gross output less intermediate consumption (consumption of goods and services, e.g. feed, seeds, fertiliser, pesticides) while AWUs represent the equivalent of an average full time person engaged in agriculture.

The UK's rate of labour productivity growth has lagged relative to some of our European competitors over recent years although equally has not seen the volatility of others. We also know that some sectors perform well on international comparisons of costs of production (dairy and cereals) while others perform more poorly (sheep, beef).

Figure 5.2 Labour productivity in agriculture



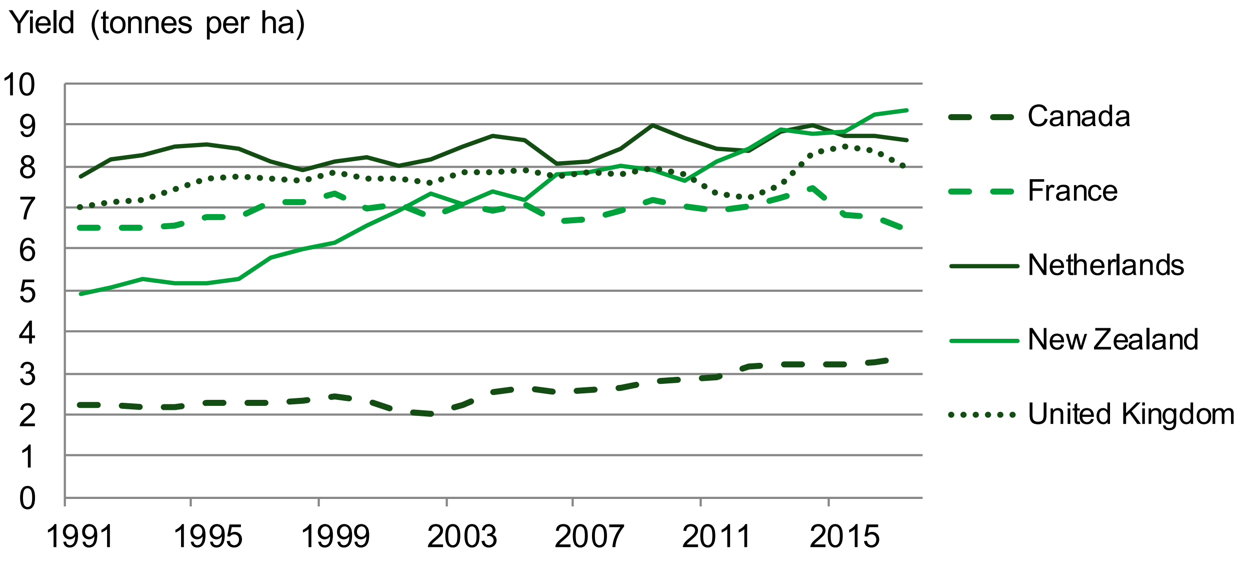
Source: Eurostat

5.3 Yields and GHG risk factors: cereals

Wheat and barley are the main cereal crops produced in the UK. Other cereals of global importance such as maize, sorghum and rice are not included here.

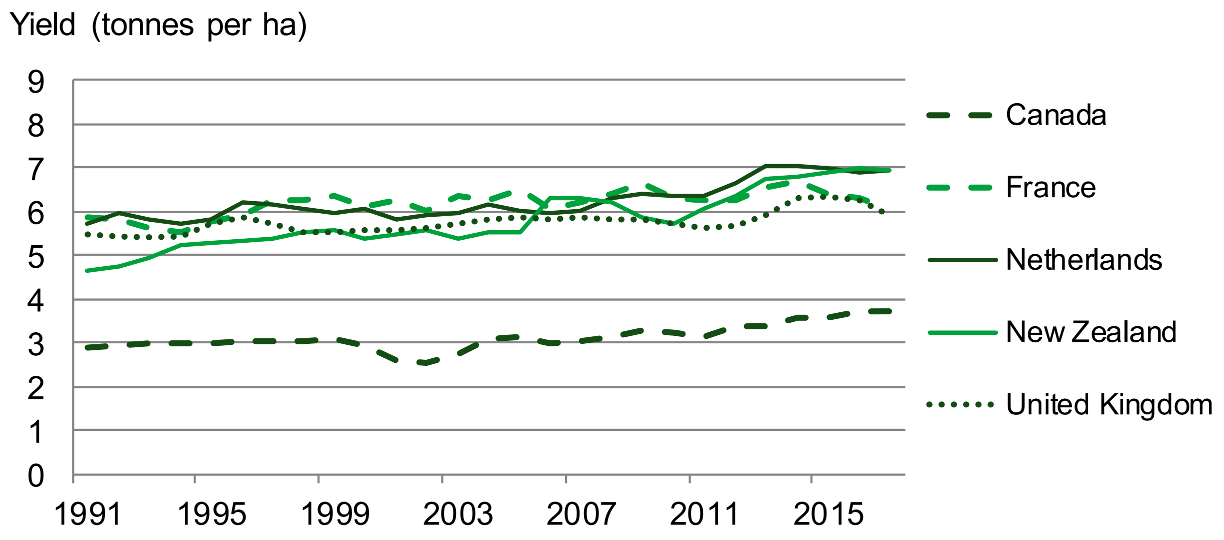
In 2017, the UK accounted for 2% of the world's production of wheat and 5% of barley (source: FAO). The following charts show trends in wheat and barley yields for a selection of countries with broadly similar characteristics (such as climate and type of crops grown) over the last twenty five years. UK wheat yields have risen by over 14% during this period whilst barley yields increased by 9%.

Figure 5.3 Wheat yields (3 year moving average) 1991 to 2017



Source: FAO

Figure 5.4 Barley yields (3 year moving average) 1991 to 2017



Source: FAO

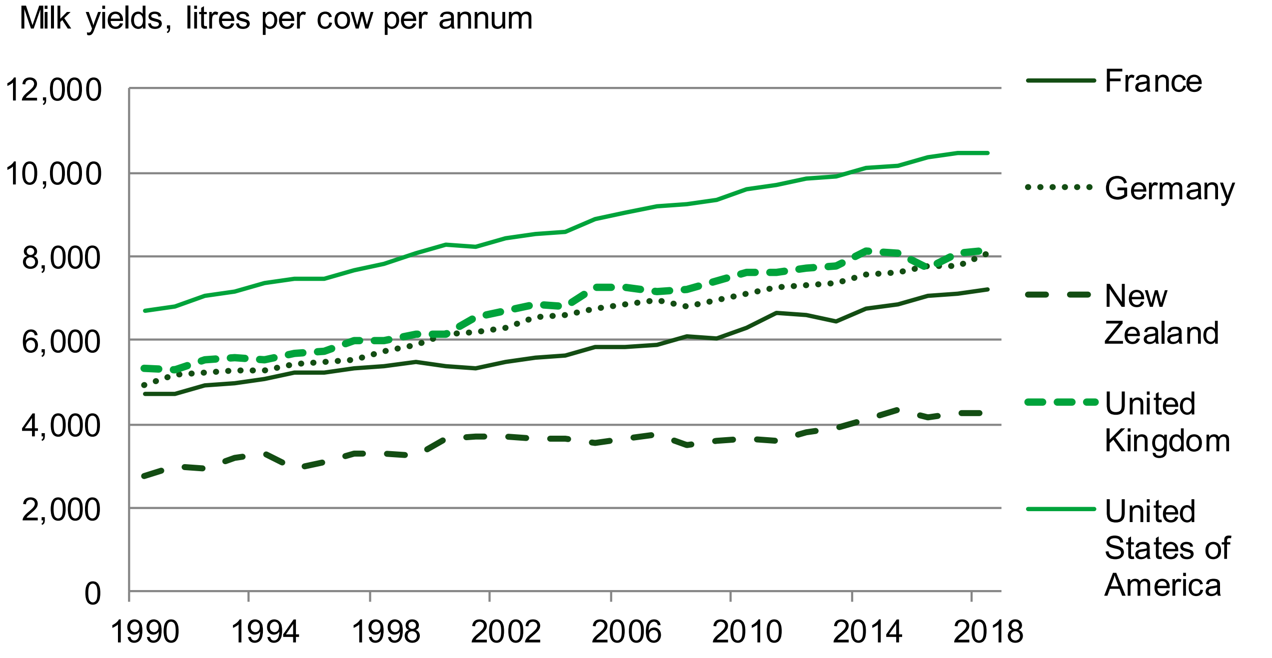
Focussing on cereal yields has its limitations since nitrous oxide emissions are produced from sources other than cereals such as pastures and fodder crops etc. An approach which considers the efficiency of all nitrogen use (the percentage ratio of total nitrogen uptake by crops and forage to the total nitrogen available from fertiliser, livestock manure and other nitrogen inputs) and the balance is potentially enlightening in understanding risks of high GHG intensity. A comparison illustrating this can be found in Section 5.3 of the 3rd edition of Agricultural Statistics and Climate Change.

5.4 Yields and GHG risk factors: milk

The chart below provides some international comparison of milk yields. Whilst yields do not provide a measure of the intensity of GHG emissions, for the countries shown, yields will be positively correlated with the levels of input (there is limited information available to quantify this). For example:

- New Zealand and Ireland's dairy production systems may be defined as low-input/low-output (around 4,000 litres per cow / year). Feeding is based mainly on grazing.
- The USA's dairy production systems may be classified as high-input/high-output (around 10,000 litres per cow/year). Feeding is based mainly on grass/maize silage and compound feed.
- Germany's dairy production systems may be classified as high-input/high-output (around 7,500 litres per cow/year). Feeding is based mainly on grass/maize silage and compound feed.

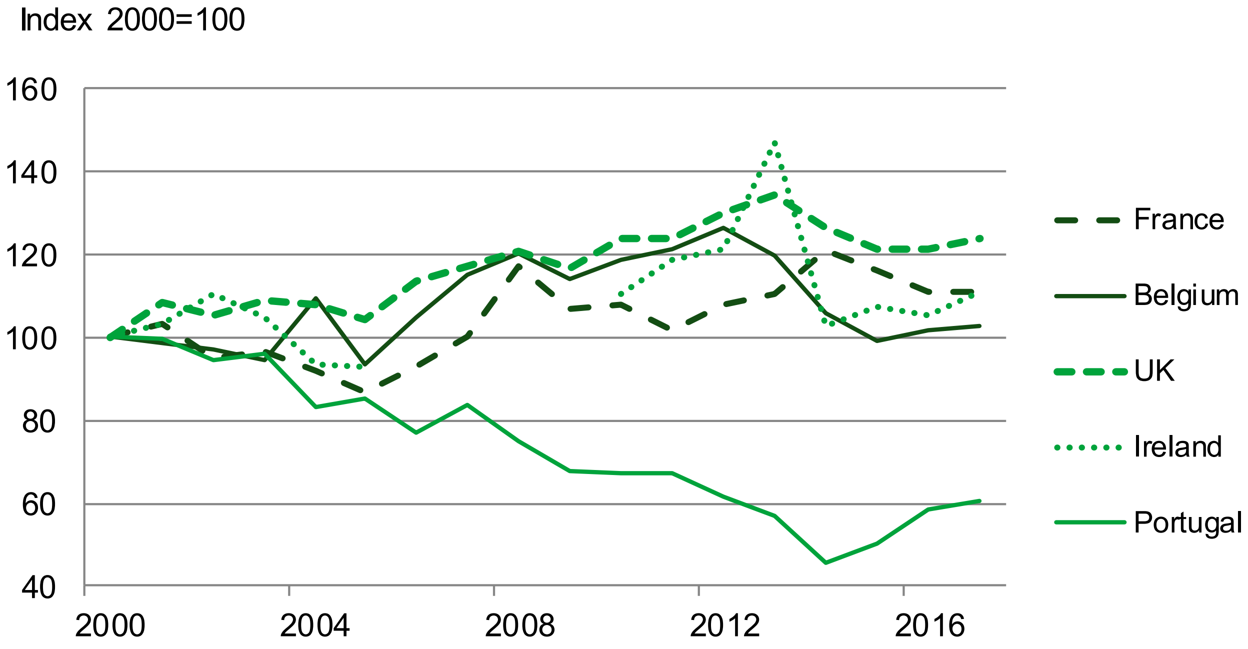
Figure 5.5 Milk yields, 1990 to 2018



Source: FAO

The following chart shows a country level comparison of milk production to dairy cow compound feed production. As explained in Section 2.4, the ratio of milk produced to compound feed production can be used as a proxy measure for the emissions intensity of the dairy sector.

Figure 5.6 Ratio of dairy cow compound feed production to milk production per annum



Gaps in the time series are due to unavailable data

Source: FAO, European Feed Manufacturers Federation

Appendix

(i) Methodology details for source data

Agricultural Price Index
https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs/series/agricultural-price-indices

AHDB auction market reports
http://www.eblex.org.uk/markets/

British Survey of Fertiliser Practice – section A2
https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs/series/fertiliser-usage

Cattle Tracing System - see under "cattle populations" heading:
https://www.gov.uk/structure-of-the-agricultural-industry-survey-notes-and-guidance

Cereal and Oilseed Rape Production Survey - methodology notes see page 22
https://www.gov.uk/government/statistics/farming-statistics-final-crop-areas-yields-livestock-populations-and-agricultural-workforce-at-1-june-2016-uk

Cereal and Oilseed Rape Production Survey - annual time series dataset
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/579404/structure-june-ukcerealoilseed-20Dec2016.xls

Emissions data methodology - compilation and methodology at:
https://www.gov.uk/government/publications/uk-greenhouse-gas-emissions-explanatory-notes

Farm Business Survey - data collection and methodology:
https://www.gov.uk/farm-business-survey-technical-notes-and-guidance

Farm Practices Surveys 2008 - 2011 see under "National Archive",
Farm Practices Survey 2012 (Greenhouse gas mitigation measures) - pages 3-4,
Farm Practices Survey 2013 (Greenhouse gas mitigation practices) - pages 37-39,
Farm Practices Survey 2014 (Greenhouse gas mitigation practices) - pages 34-35
Farm Practices Survey 2015 (Greenhouse gas mitigation practices) - pages 33-34
Farm Practices Survey 2016 (Greenhouse gas mitigation practices) - pages 36-37
Farm Practices Survey 2017 (Greenhouse gas mitigation practices) - pages 34-35
Farm Practices Survey 2018 (Greenhouse gas mitigation practices) - pages 32-33
Farm Practices Survey 2019 (Greenhouse gas mitigation practices) - pages 32-33
Farm Practices Survey 2020 (Greenhouse gas mitigation practices) - pages 43-45
https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs/series/farm-practices-survey

GB Animal feed statistics – Animal feed methodology paper https://www.gov.uk/government/collections/animal-feed-production

Poultry Slaughterhouse and Hatcheries Surveys - “information” tab in the UK Poultry meat production monthly dataset:
https://www.gov.uk/government/collections/poultry-and-poultry-meat-statistics

Integrated Poultry Unit Survey - Animal feed methodology paper
https://www.gov.uk/government/collections/animal-feed-production

June Agricultural Survey:
https://www.gov.uk/structure-of-the-agricultural-industry-survey-notes-and-guidance

Milk production data are from surveys run by Defra, RERAD, DARDNI on the utilisation of milk by dairies. Information on the survey methodology are given at:
http://www.defra.gov.uk/statistics/foodfarm/food/milk/milk-utilisation/

National Soils Inventory:
http://www.landis.org.uk/data/nsi.cfm

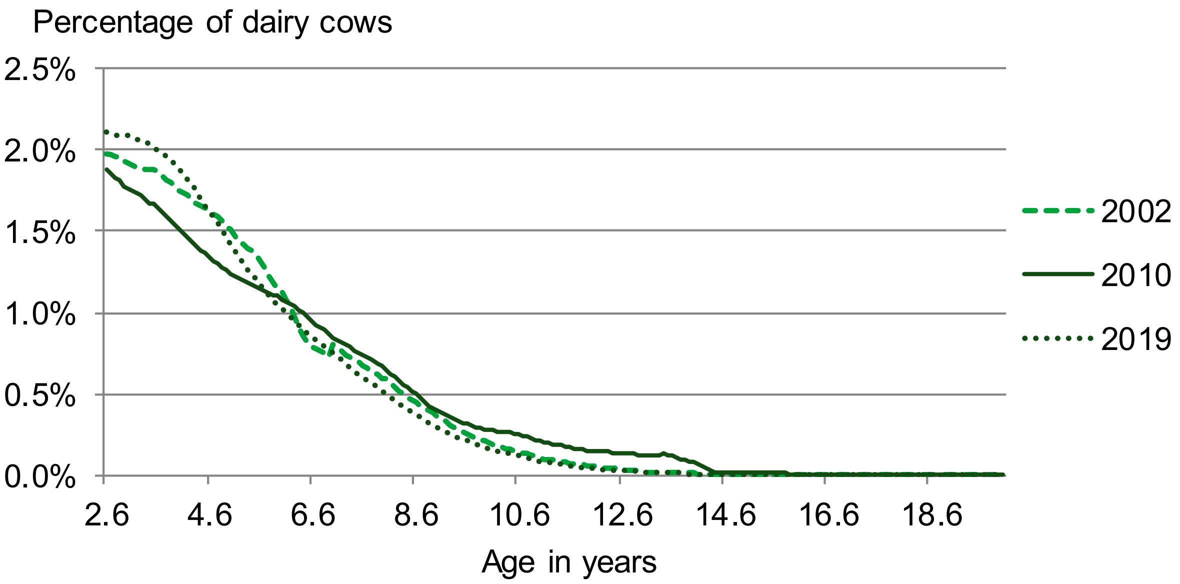
Slaughterhouse Survey - see monthly dataset “information” tab:
https://www.gov.uk/government/statistics/cattle-sheep-and-pig-slaughter

Soil Nutrient Balances
Information on the methodology for deriving Soil Nutrient Balances can be found under “Soils” at:
https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs/series/agri-environment-analysis See link “strategic evidence funded project: UK agriculture nutrient balances methodology review” for the ADAS report ‘Soil Nutrient Balances Draft Report June 2010’ which explores uncertainty.

The Countryside Survey:
http://www.countrysidesurvey.org.uk/

(ii) Distribution of dairy cows by age in years

Figure 6.1 Distribution of dairy cattle by age in years, GB

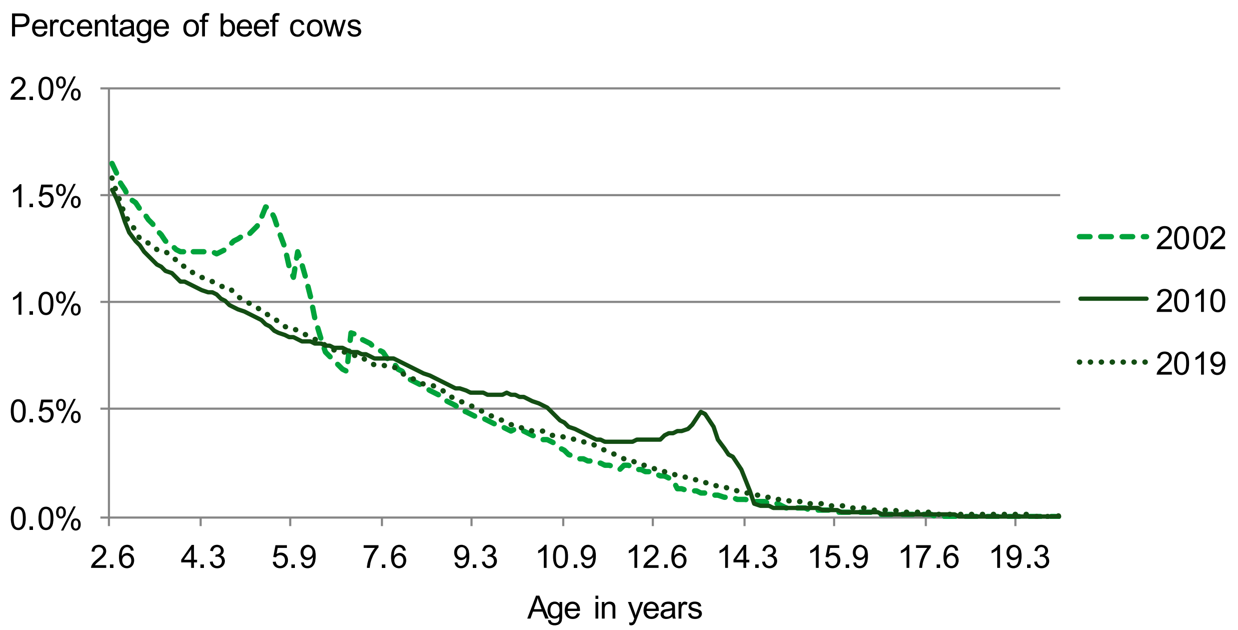


The number of animals on which the percentage shown is based is an average of the number of animals in each month of the year.

Source: Defra RADAR, Cattle Tracing System

(iii) Distribution of beef cows by age in years

Figure 6.2 Distribution of beef cattle by age in years, GB



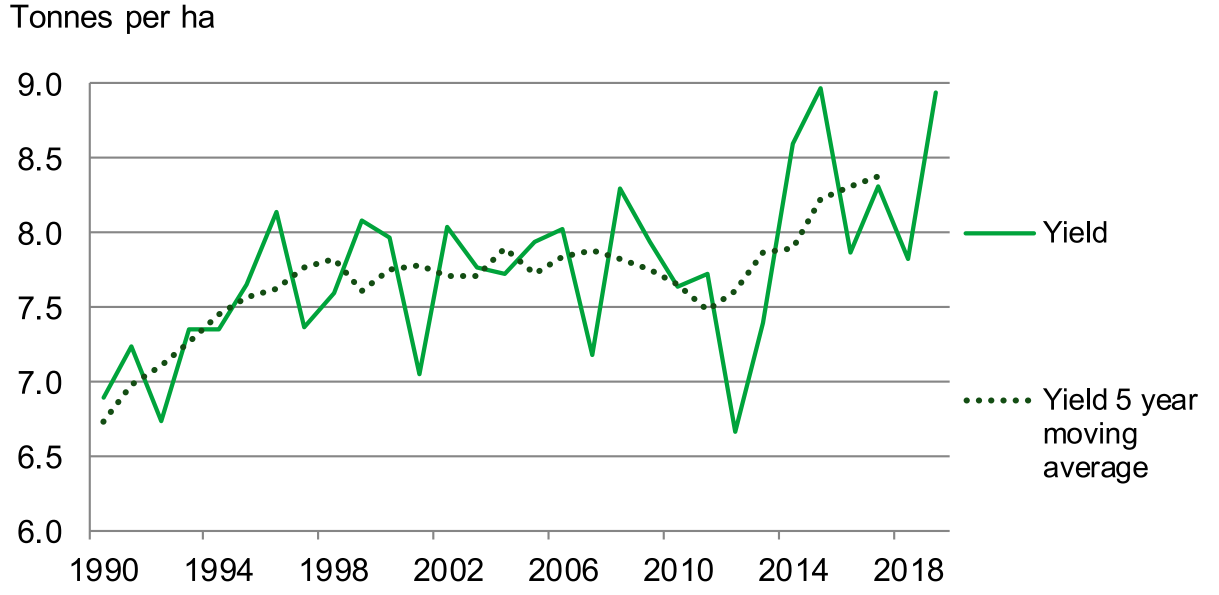
The number of animals on which the percentage shown is based is an average of the number of animals in each month of the year.

Source: Defra RADAR, Cattle Tracing System

(iv) Wheat production per unit of manufactured N applied

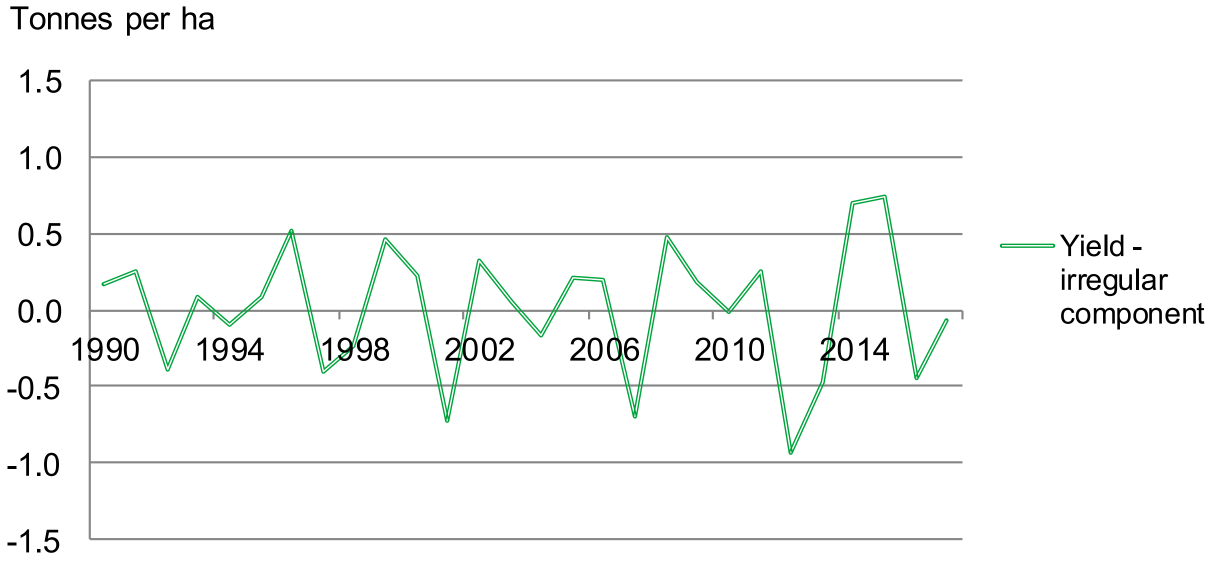
The following charts illustrate the magnitude of the trend and irregular components of the time series given in Section 2.9. The charts show wheat only, similar charts for the other crops shown in Section 2.9 can be obtained by contacting Agri.EnvironmentStatistics@defra.gov.uk

Figure 6.3 Wheat yield, England



Source: Defra Cereal Production Survey

Figure 6.4 Wheat yield irregular component*, England

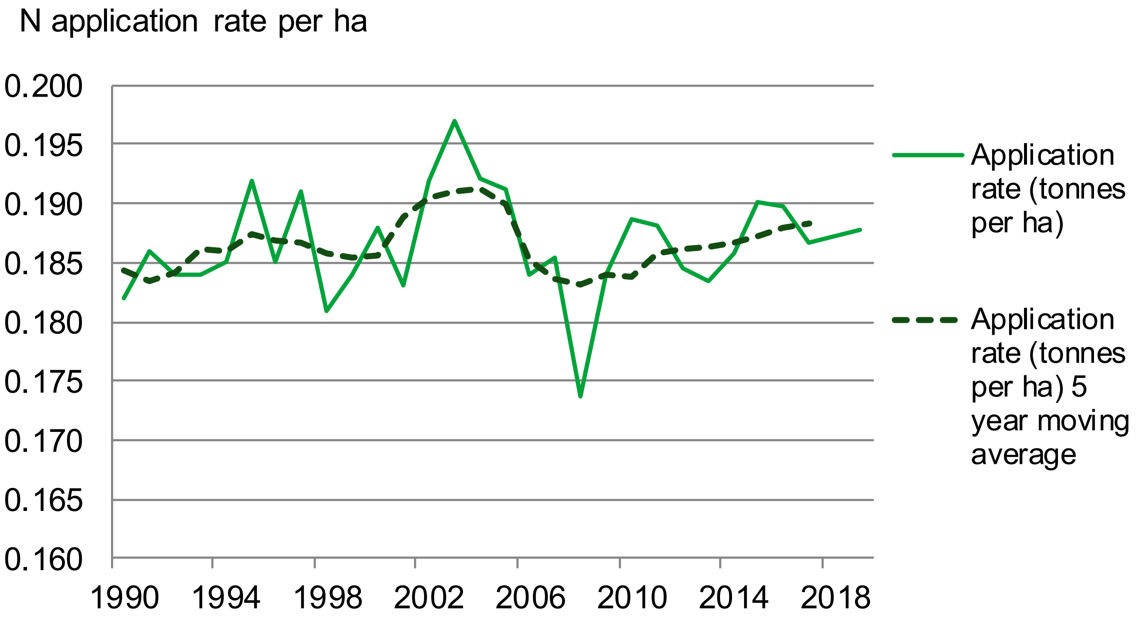


*Yield minus 5 year moving average of yield

Source: Defra Cereal Production Survey

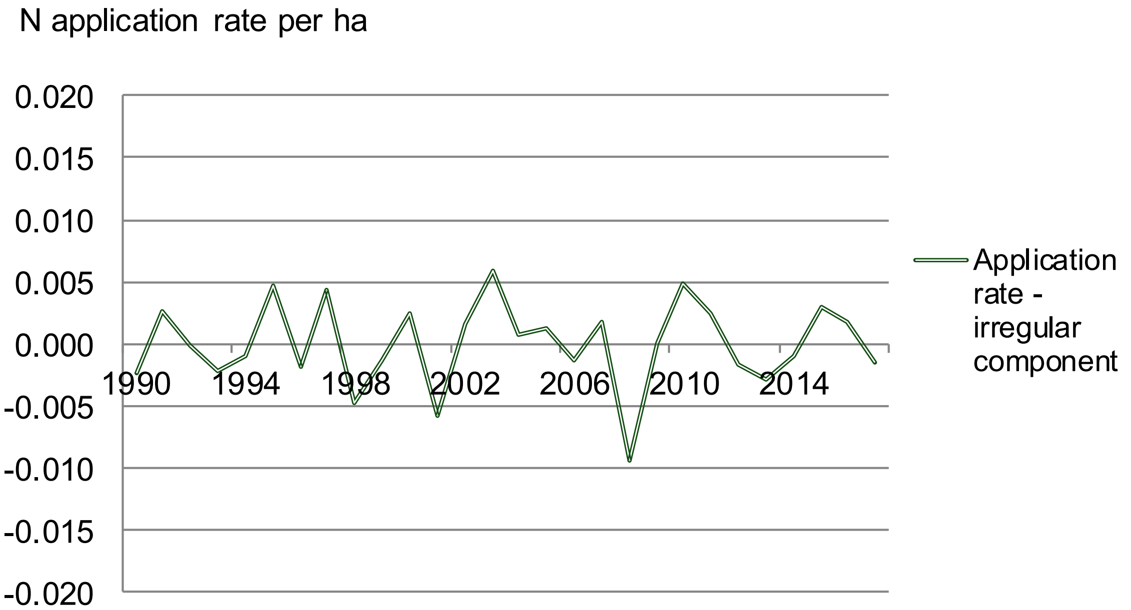
(iv) Wheat production per unit of manufactured N applied (continued)

Figure 6.5 Wheat N application rate, England



Source: British Survey of Fertiliser Practice

Figure 6.6 Wheat N application rate irregular component*, England

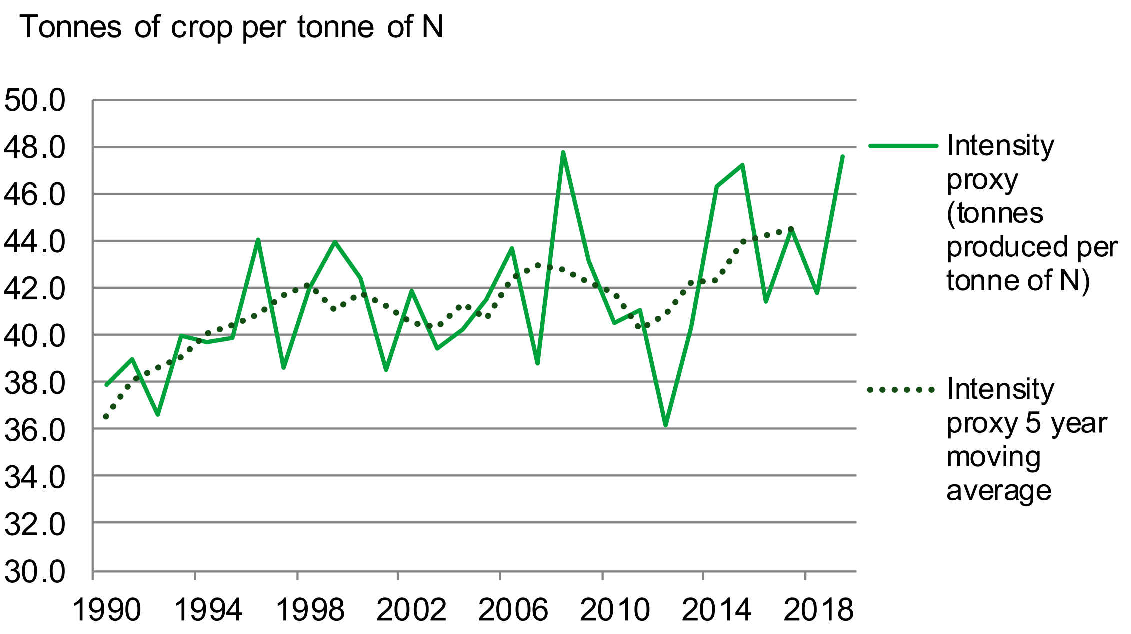


*N application rate minus 5 year moving average of N application rate

Source: British Survey of Fertiliser Practice

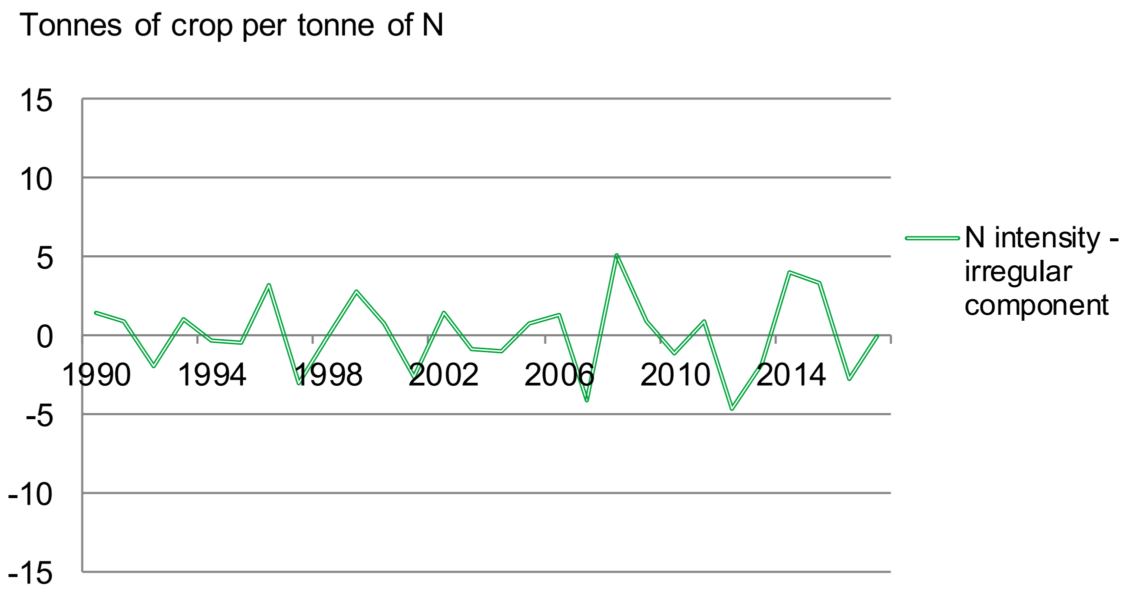
(iv) Wheat production per unit of manufactured N applied (continued)

Figure 6.7 Wheat N intensity, England



Source: British Survey of Fertiliser Practice, Defra Cereal Production Survey

Figure 6.8 Wheat N intensity irregular component*, England



*N intensity minus 5 year moving average of N intensity

Source: British Survey of Fertiliser Practice, Defra Cereal Production Survey

Glossary

Annual work unit (AWU)
An annual work unit represents the equivalent of an average full time person engaged in agriculture.

BSE
Bovine spongiform encephalopathy is a fatal disease in cattle that causes degeneration in the brain and spinal cord. BSE is commonly known as 'mad cow disease'.

Carcase weights
The weight of the meat produced from an animal. Cold dressed carcase weights are recorded.

Cattle Tracing System (CTS)
The CTS records births, deaths and all movements of cattle as well as breed types and gender. It is mandatory for every bovine animal to have a passport and ear tag and for owners to report every movement via the CTS.

Clean pigs
Pigs bred purely for meat production.

Dairy herd and beef herd
Unless otherwise stated, the dairy herd refers to those breeding animals which produce milk, and the beef herd refers to those breeding animals which produce offspring for slaughter. The beef herd is also commonly referred to as the suckler herd.

Estimated Breeding Values (EBV)
Estimated Breeding Values estimate the genetic worth of animals using desirable traits such as meat production.

Feed conversion ratio (FCR)
A measure of an animal's efficiency in converting feed mass into increased body mass expressed as feed per kg of liveweight; a low FCR is more efficient than a high FCR.

Finishing
Finishing is the feeding process used prior to slaughter for cattle or sheep intended for meat production.

Greenhouse gas intensity
Greenhouse gases produced per tonne of grain or litre of milk or kilogramme of beef. This may also be referred to as GHG efficiency.

Gross valued added (GVA)
Gross valued added is the gross output less intermediate consumption (consumption of goods and services, e.g. feed, seeds, fertiliser, pesticides).

Less favoured areas (LFA)
Less favoured areas are land that is classified as difficult to farm due to limitations such as climate, location or features of the landscape (e.g. mountainous or hilly areas).

Marketing pattern
The pattern of animals slaughtered per month over the course of a year.

Over thirty month scheme (OTMS)
In March 1996 the EU imposed a worldwide ban on the export of bovine and bovine products from the UK due to BSE in UK cattle. The Over Thirty Month (OTM) Rule prohibited beef from animals aged over thirty months from entering the food chain. The Over Thirty Month Slaughter Scheme (OTMS) provided a disposal outlet for OTM cattle which could not be sold for the food chain. Cattle entering the scheme were slaughtered and destroyed with compensation paid to the farmer.

Pig fattening herd
Pigs intended for meat production.

Profitable Lifetime Index (PLI)
PLI is a scoring system to identify cattle with the best ‘genetic merit’. It is used when choosing bulls to breed with dairy cattle. The PLI uses a combination of attributes including life expectancy, health, fertility and milk production.

Soil nitrogen balance
The soil nitrogen balance is a measure of the total loading of nitrogen on agricultural soils over the crop year.

Total Factor Productivity (TFP)
Total factor productivity shows the volume of output leaving the industry per unit of all inputs including fixed capital and labour. It includes all businesses engaged in farming activities including specialist contractors.

UNFCC countries
Parties to the United Nations Framework Convention on Climate Change (UNFCCC) include the industrialized countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States.

References

[1] Down to Earth - The Beef and Sheep Roadmap Phase 3: https://www.google.com/url?q=http://www.eblex.org.uk/wp/wp-content/uploads/2013/04/roadmap_3_-_down_to_earth_180112-final-report.pdf&sa=U&ei=uJdwU46WMoPIsASxhoKABA&ved=0CAYQFjAB&client=internal-uds-cse&usg=AFQjCNHZZx62oOPqefUngdNcSJorf9ptUQ
Dairy Roadmap - our route towards environmental success, DairyCo. 9 May 2011 https://dairy.ahdb.org.uk/resources-library/research-development/environment/dairy-roadmap/#.XMHUU5UUmUk
Dairy Roadmap – Environmental Sustainability Report 2013 https://dairy.ahdb.org.uk/resources-library/research-development/environment/dairy-roadmap-2013/#.XMHWVZUUnoo
Advancing together - a roadmap for the English Pig industry - The British Pig Executive (BPEX). 27 April 2011
Positive Progress - an update on the roadmap for the environmental sustainability of the English Pig industry - The British Pig Executive (BPEX) 21 January 2014 https://pork.ahdb.org.uk/media/2677/an_update_on_the_roadmap_for_the_environmental_sustainability_of_the_english_pig_industry.pdf

[2] https://horticulture.ahdb.org.uk/project/ahdb-farm-scale-resource-use-efficiency-calculator

[3] The 2012 review report and supporting papers are available on the internet at: https://www.gov.uk/government/publications/2012-review-of-progress-in-reducing-greenhouse-gas-emissions-from-english-agriculture

[4] The 2016 review is available on the internet at: https://www.gov.uk/government/publications/greenhouse-gas-action-plan-ghgap-2016-review

[5] Here, long term refers to comparisons back to 1990 or the closest year, and short term refers to changes within the last 5 years

[6] https://www.gov.uk/government/publications/2012-review-of-progress-in-reducing-greenhouse-gas-emissions-from-english-agriculture

[7] GHG produced per tonne of crop or litre of milk or kilogramme of meat produced.

[8] https://www.nfuonline.com/assets/2889

[9] https://www.theccc.org.uk/publication/meeting-carbon-budgets-3rd-progress-report-to-parliament http://www.theccc.org.uk/reports/2012-progress-report

[10] Calculated as the quantity of crop produced per unit of applied manufactured nitrogen fertiliser.

[11] Maximum technical potential is the amount that could be saved if all mitigation potential was enacted regardless of cost assuming no prior implementation of measures.
[12] The 2016 assessment includes potential GHG reductions associated to the processing of livestock manures by anaerobic digestion which were not included in earlier years.

[13] C The initial version of Farmscoper was developed by ADAS under Defra projects WQ0106 http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=14421 and FF0204 http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=17635&FromSearch=Y&Publisher=1&SearchText=FF0204&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description . The current version (version 3) used in the analysis here has been further developed and expanded under Defra project SCF0104.: http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=18702

[14]http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=17780&FromSearch=Y&Publisher=1&SearchText=AC0226&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

[15] Maximum technical potential is the amount that could be saved if all mitigation potential was enacted regardless of cost assuming no prior implementation of measures

[16] GHG emitted per tonne of crop, litre of milk or kilogramme of meat produced.

[17] The assessment of the practices “Do not spread FYM to fields at high risk times” and “Do not spread slurry or poultry manure at high risk times” have been revised in 2017. Data for 2015 and 2016 have also been updated to reflect the change and allow a comparison

[18] Maximum technical potential is the amount that could be saved if all mitigation potential was enacted regardless of cost assuming no prior implementation of measures.

[19] The entire time series is revised each year to take account of methodological improvements in the UK emissions inventory.

[20] www.ghgplatform.org.uk

[21]The 95% confidence interval given in the **“**Analysis of uncertainties in the estimates of nitrous oxide and methane emissions in the UK’s greenhouse gas inventory for agriculture**”** for the estimate of total N_2O emissions from soils in 2010 is (−56%, +143%). This reduced uncertainty reflects improved analysis and is substantially different to that given by Brown et al. (2012). Their confidence interval, based on expert opinion, was (−93%, +253%). However (−56%, +143%) is still much larger than that derived by Monni et al. (2007) who quote a 95% confidence interval of (−52%, +70%). Their analysis was based on more conservative estimates for the uncertainty in emissions factors (from IPCC 1997) whereas the 95% confidence interval of (−56%, +143%) was derived using more recent IPCC guidelines (Eggleston et al., 2006).

[22] http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/10116.php

[23] Both ruminant animals (e.g. cattle and sheep), and non-ruminant animals (e.g. pigs and horses) produce methane, although ruminants are the largest source per unit of feed intake.

[24] Enteric fermentation is a digestive process whereby carbohydrates are broken down by micro-organisms into simple molecules. Methane is produced as a by-product of enteric fermentation.

[25] GHG emitted per tonne of crop, litre of milk or kilogramme of meat produced.

[26] http://webarchive.nationalarchives.gov.uk/20130315143000/http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-environ-obs-research-cattle-dairy09-jun09.pdf

[27] The ten GHG indicators cover farmer attitudes and knowledge, uptake of mitigation methods and the GHG emission intensity of production across key agricultural sectors.

[28] No distinction is made between dairy and beef animals. Male dairy calves are under reported in CTS and in the 'Calf registrations per female cow over 30 months' measure the number is modelled on beef calf registrations. The approach taken is consistent with Agriculture and Horticulture Development Board **(**AHDB) methodology.

[29] On-farm mortality rate is defined as the number of deaths per 100,000 days at risk on agricultural premises. It is calculated using the number of cattle deaths divided by the number of cattle days in the period. The number of cattle days in the period represents 1 day for each animal each day. For example, if 5 animals were present on a location for 20 days the sum of the animal days would be 100. Conversely, if 20 animals were present on a location for 5 days the sum of the animal days would also be 100. This means, for any specified risk to the cattle in an area, that areas with a high density of cattle can be compared directly with areas with a low density of cattle.
On-farm mortality was calculated by analysing only those premises that were registered as being agricultural and therefore excludes deaths at slaughter houses.

[30] Slurry and manure storage questions were reworded on the 2015 FPS to include greater detail on types of storage and covers. As a result the data from 2015 onwards may not be fully comparable with previous years.

[31] For longer term trends see Section 2.4 of 2nd Edition of Agricultural Statistics and Climate Change at:
http://webarchive.nationalarchives.gov.uk/20130305023126/http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-enviro-climate-climatechange-120203.pdf

[32] Finishing is the feeding process used prior to slaughter for cattle or sheep intended for meat production.

[33] On-farm mortality rate is defined as the number of deaths per 100,000 days at risk on agricultural premises. It is calculated using the number of cattle deaths divided by the number of cattle days in the period. The number of cattle days in the period represents 1 day for each animal each day. For example, if 5 animals were present on a location for 20 days the sum of the animal days would be 100. Conversely, if 20 animals were present on a location for 5 days the sum of the animal days would also be 100. This means, for any specified risk to the cattle in an area, that areas with a high density of cattle can be compared directly with areas with a low density of cattle. On-farm mortality was calculated by analysing only premises that were registered as being an agricultural premise. Therefore, this data excludes deaths at slaughter houses.

[34] Slurry and manure storage questions were reworded on the 2015 Farm Practices Survey. As a result the data from 2015 onwards may not be fully comparable with previous years.

[35] Further details about farm typology can be found at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/182207/defra-stats-foodfarm-landuselivestock-june-results-typology.pdf

[36] Finishing is the feeding process prior to slaughter for cattle and sheep intended for meat production.

[37] The ten GHG indicators cover farmer attitudes and knowledge, uptake of mitigation methods and the GHG emission intensity of production across key agricultural sectors.

[38] AHDB Pork is a division of the Agriculture and Horticulture Development Board representing pig levy payers in England.

[39] For data availability reasons the feed conversion ratio (FCR) shown is kilogrammes of feed per kilogrammes of meat based on carcase weights. The FCR is more usually expressed in relation to live weight. Carcase weight is approximately 75% of the live weight which would give a lower ratio feed per kilogrammes of meat produced.

[40] The ten GHG indicators cover farmer attitudes and knowledge, uptake of mitigation methods and the GHG emission intensity of production across key agricultural sectors.

[41] http://www.bis.gov.uk/assets/foresight/docs/food-and-farming/science/11-573-sr31-fertiliser-availability-in-resource-limited-world.pdf

[42] This measure does not include organic nitrogen from manure or slurry.

[43] The ten GHG indicators cover farmer attitudes and knowledge, uptake of mitigation methods and the GHG emission intensity of production across key agricultural sectors.

[44] The latest estimates for UK soil nutrient balances can be found under “Soils” at: https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs/series/agri-environment-analysis

[45]Evans, C., Artz, R., Moxley, J., Smyth, M-A., Taylor, E., Archer, N., Burden, A., Williamson, J., Donnelly, D., Thomson, A., Buys, G., Malcolm, H., Wilson, D., Renou-Wilson, F. (2017). Implementation of an emission inventory for UK peatlands. Report to the Department for Business, Energy and Industrial Strategy, Centre for Ecology and Hydrology, Bangor.88pp.
http://naei.beis.gov.uk/reports/reports?report_id=980

[46] Mulholland, B., Abdel-Aziz, I., Lindsay, R., McNamara, N., Keith, A., Page, S., Clough, J., Freeman, B., and Evans, C. (to be published). An assessment of the potential for paludiculture in England and Wales. Report to Defra Project SP1218, pp. 97.

[47] Volume indices are calculated by taking a weighted average of volume relatives (volume relatives are the volume in year n / volume in year n-1) using the monetary values of components of the aggregated index as weights.

[48] https://globalresearchalliance.org/

[49] https://eragas.eu/

[50] https://era-susan.eu/

[51]http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17180

[52]http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17181

[53] **Annex I** Parties to the United Nations Framework Convention on Climate Change (UNFCCC) include the industrialized countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (the EIT Parties).