Farming and Food Analysis
RESAS
March 2021

Evidence for the Hill, Upland & Crofting Farmer-Led Climate Change Group

Briefing

This report highlights evidence on Scotland’s upland sheep, upland cattle, and crofting sectors for the Hill, Upland and Crofting farmer-led group, covering the context and structure of the industry, greenhouse gas emissions, biodiversity, performance and productivity. Some figures have also been included on lowland sheep.

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Executive Summary

This report highlights evidence on hill, upland and crofting in Scotland and its contribution to Green House Gas (GHG) emissions.

Data on the hill and upland cattle and sheep sectors are not readily available. However, the elevated areas of the hills and uplands in Scotland will typically be on land designated as Less Favoured Area (LFA). For the purposes of this report, farms (also referred to as holdings) categorised as specialist LFA are used as the best proxy for hill and upland livestock farming.

The main findings from this report are:

Context and structure:

- In 2019, the standard output from LFA cattle and sheep farm types in Scotland (5.6 million sheep and 0.9 million beef cattle) accounted for a quarter of agricultural output with a value of £718 million.
- These farms accounted for 3.2 million hectares, over half of all of Scottish agricultural land and roughly 30% of all Scottish holdings. An additional 0.6 million hectares of land associated with crofting is classified as common grazing.
- In 2018-19, the average LFA farm[1] had a farm business income between around £11,800 to £24,800, depending on the main enterprise. This includes income from support payments and diversification. This is substantially below the average Scottish farm business income of £38,700.
- When including support payments, over 60% of LFA farms are profitable. However, when excluding support, this falls to less than 10% – the lowest of all sectors.
- In 2016, 7% of all LFA cattle and sheep farm types made more than half of their turnover from diversified activities, lower than the 9% average across all farm types. A further 7% made 10-50% of their turnover from diversified activities. For the remaining 86% of LFA farms, diversification activities account for less than 10% of turnover.
- Since 2001, the volume of beef and veal purchased by Scottish consumers has decreased by 10%, while the volume of lamb and mutton purchased has halved. In 2019 around two-thirds of beef outputs and just over half of sheepmeat outputs from Scottish abattoirs were exported to the rest of the UK.
- Crofts account for approximately 1% of Scotland’s cropland, 11% of its sheep and 4% of its cattle.

Greenhouse gas emissions and biodiversity:

- Large reductions in emissions are required from all sectors of the Scottish economy to meet Scotland’s legally binding 2045 Net Zero target, and the target of a 75% reduction from 1990 levels by 2030.

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[1] This covers three farm types where two thirds or more of output are (i) specialist sheep, (ii) specialist cattle, or (iii) cattle & sheep.

- Agriculture represented 18% of Scotland’s emissions, or 7.5 MtCO2e[2], in 2018. The Scottish Government’s Climate Change Plan update requires the equivalent of a 31% reduction in agricultural emissions by 2032 from 2018 levels, a pace nearly four times faster than historic declines.
- Emissions from less favoured area farms account for around 3.4 MtCO2e, or 45% of total agricultural emissions, nearly all of which are from cattle and sheep. This highlights the imperative for the group to consider practical measures for reducing emissions.
- Evidence on technically feasible mitigation specific to cattle and sheep covers feed additives, selective breeding, improved health and slurry storage, of which feed additives provide significant potential.
- Evidence suggests these measures could deliver reductions around 0.38 MtCO2e, if applied to their maximum technical capacity based on current levels of livestock in LFA areas. This scale of reduction would not be sufficient to meet agriculture’s envelopes by 2032, even if matched with equivalent reductions across all sectors. In fact it would fall short of targets by around two-thirds.
- The Climate Change Committee states changes in farming practices, woodland planting and reductions in livestock numbers are all required to achieve net zero. Their advice also highlights three key changes required to reduce agricultural emissions:

    1 - diet change with their main pathway to net-zero assuming a 20% reduction in UK consumption of red meat by 2030, rising to 35% by 2050
    2 – low-carbon farming practices, similar to those outlined above
    3 – productivity measures to improve crop yields and reduce stocking rates

- The Climate Change Committee have also stressed that not only are the changes outlined critical for agriculture to reduce its emissions but also critical to free up the land required for other sectors to achieve the emissions reductions needed.
- Overall biodiversity benefits from a mix of habitats and land use intensities. Where livestock numbers have fallen in upland areas reduced grazing pressure can be positive for biodiversity due to recovery of habitats such as heath, blanket bog and native woodland. Other herbivores will generally increase however under grazing can become a problem leading to loss of biodiversity. Some farming systems in hill, upland and crofting areas are considered of High Nature Value.

Performance and productivity:

- Evidence suggests that Scotland is mid-table in international comparisons when it comes to agricultural productivity growth. This report sets out some potential options for increasing agricultural productivity in Scotland.
- LFA farms typically have lower profitability and efficiency than other farm types in Scotland, and many rely on support payments to turn a profit.

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[2] Million tonnes of carbon dioxide equivalent

Contents

1 Context and Structure

1.1 Composition of the LFA Cattle and Sheep Sector

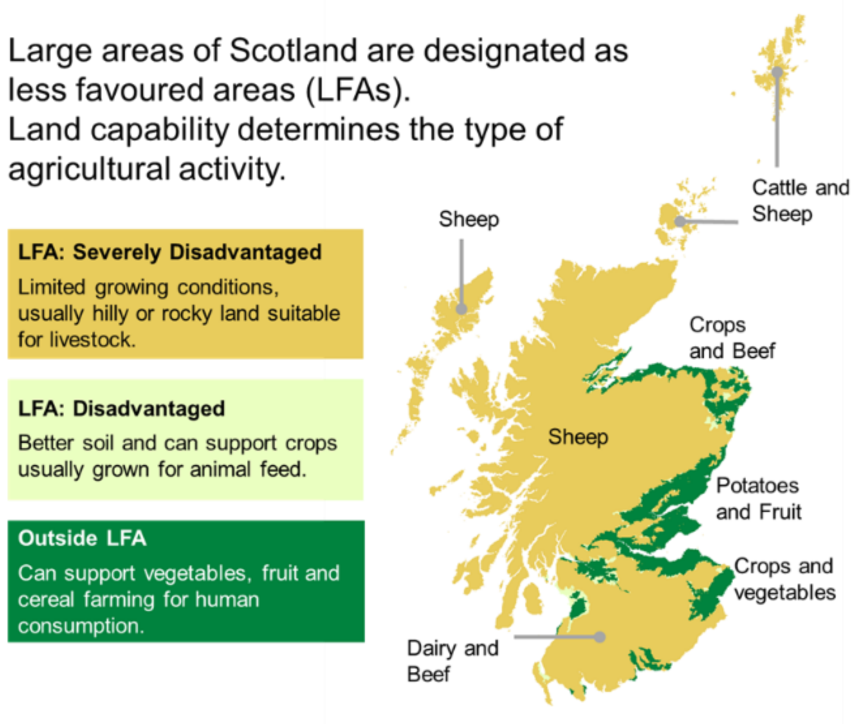
1.1.1 Definition

Data on the hill and upland cattle and sheep sectors are not readily available. However, the elevated areas of the hills and uplands in Scotland will typically be on land designated as Less Favoured Area (LFA). For the purposes of this report, farms categorised as specialist LFA are used as the best proxy for hill and upland livestock farming. Specialist dairy farms have not been included. A glossary and definitions of these categories and other terms can be found in Annex A.

Unless otherwise stated, data in this chapter are drawn from the June Agricultural Census, Total Income from Farming (TIFF), and the Farm Business Survey (FBS), with further detail available in Annex B.

A farm is considered to be a specialist LFA farm where two-thirds or more of output from farming comes from LFA land, typically in the form of cattle, sheep or (more likely) a combination of the two. Limitations of this approach include that: livestock may not be held on a farm's LFA land; not all LFA land will be hills and uplands; and, not all hills and uplands will exclusively be LFA land. However, we consider this to be the best proxy available within the timelines available for preparing this report.

Figure 1: Land use for agriculture in Scotland



1.1.2 Outputs and Value

Standard Outputs provide an estimated farm-gate value of crop and animals. This provides an estimate of the value of a farm's total output that can be used to compare farms. Costs incurred in production are not taken in to consideration.

In 2019, the standard output produced by all LFA cattle and sheep farms in Scotland was around £718 million. This was around £10 million less than in the previous year. LFA cattle and sheep farms accounted for around 27% of total standard output in Scotland.

LFA cattle and sheep farms accounted for over half of all of Scotland 5.7 million hectares of agricultural land and roughly 30% of all Scottish holdings. The average standard output per holding was around £48,000, less than the average of £52,000 across all farm types.

Non-LFA cattle and sheep farms had an estimated £140 million standard output in 2019, a decrease of around £4 million from the previous year. This is around 5% of total output. Non-LFA cattle and sheep farms accounted for just 2% of agricultural land and 6% of all Scottish holdings. Average standard output per holding was £49,000.

1.1.3 Scottish Cattle and Sheep Farms

5,901,000	1,007,000	86%
Number of sheep on farms with LFA land	Number of cattle on farms with LFA land	Percentage of land which is LFA[3]

Around 86% of Scotland's agricultural land is classified as Less Favoured Area (or LFA). Of Scotland's 51,000 holdings, 29% were classified as specialist LFA cattle and sheep farms – these farms accounted for the majority of the cattle herd and sheep flock (77%).

In 2019, specialist LFA farms, on which output figures above are based, held around 5.6 million sheep (84%) and around 873,000 beef cattle (62%). This rises to 88% of all sheep and 72% of all beef cattle for all holdings with LFA land (figures above). The majority was located in Southern Scotland and the Highlands and Islands, as shown in Table 1.

Table 1. Cattle and sheep numbers and holdings by region, 2019

	Specialist LFA holdings			All holdings with LFA Land		
NUTS2 Region	Animals (000's)		Holdings	Animals (000's)		Holdings
	Cattle	Sheep		Cattle	Sheep	
North East Scotland	89	227	800	116	259	1,200
Eastern Scotland	88	879	1,000	107	946	1,300
Southern Scotland	404	2,494	3,200	470	2,643	4,100
Highlands & Islands	260	1,841	8,500	278	1,894	9,300
West Central Scotland	33	157	400	36	159	400
Total	**873**	**5,598**	**13,900**	**1,007**	**5,901**	**16,400**

Source: June Agricultural Census 2019, via RESAS Agricultural Analysis Unit

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[3] LFA as a percentage of Utilised Agricultural Area (UAA). Excludes woodland and other land such as yards and derelict land.

Additionally, nearly 580,000 sheep are held on non-LFA holdings, with less than half of these on specialist sheep holdings.

Table 2. Sheep holdings and numbers on non-LFA land, 2019

Non-LFA	Specialist Sheep Holdings	Holdings with sheep
Average Flock Size	160	150
Total Sheep	151,000	427,000
Number of Farms	934	2,855

Specialist lowland farms held around 430,000 sheep (6% of all sheep) and around 180,000 cattle (13% of all cattle). The majority of this livestock was located in the North East, Southern and Eastern regions of Scotland (as shown in Table B1 in the annex).

1.1.4 Farm Size

While small herd sizes (1-149) in both cattle and sheep were most common amongst specialist LFA farms (7,900 holdings or 57%), larger herd sizes were common as well: 14% of specialist LFA farms had 1,000 animals or more, accounting for 46% and 71% of all cattle and sheep on specialist LFA farms, respectively. Specialist lowland farms follow a similar pattern. Smaller herd sizes (1-149) make up 68% of farms, having 12% of the cattle and 6% of the sheep. 8% if specialist lowland farms had more than 1000 animals. Full details are shown in Table B2 in the annex).

Table 3. Cattle and sheep numbers and holdings by herd size, 2019

	Specialist LFA holdings			All holdings with LFA Land		
Herd Size	**Animals (000's)**		**Holdings**	**Animals (000's)**		**Holdings**
	Cattle	Sheep		Cattle	Sheep	
1-149	95	276	7,900	132	298	9,800
150-299	107	256	1,700	140	265	1,900
300-499	105	304	1,000	125	324	1,200
500-999	164	763	1,300	184	814	1,400
1000 & over	402	3,998	2,000	426	4,200	2,100
Total	**873**	**5,598**	**13,900**	**1,007**	**5,901**	**16,400**

Source: June Agricultural Census 2019, via RESAS Agricultural Analysis Unit

1.1.5 Workforce

Specialist LFA farms commonly do not have any employees, and more often rely on occupiers and spouses only – occupiers and spouses working either full-time or part-time accounted for 65% of the total workforce (including part-time and seasonal workers). Less than a fifth of specialist LFA farms had full-time employees. The picture was similar for specialist lowland sheep farms (as shown in Table B3 in the annex).

Table 4. Agricultural workforce in the LFA sector(s), 2019

Category	Specialist LFA holdings		All Holdings with LFA Land	
	Holdings	*Workforce*	*Holdings*	*Workforce*
Occupiers and spouses working more than half time	7,200	8,900	8,100	10,100
Occupiers and spouses working less than half time	6,800	8,800	7,300	9,400
Full-time employees	2,400	4,100	3,000	5,500
Part-time employees	2,200	3,300	2,600	3,900
Casual and seasonal workers	1,200	2,000	1,400	2,200
Total workforce	**12,300**	**27,100**	**13,500**	**31,000**

Source: June Agricultural Census 2019, via RESAS Agricultural Analysis Unit

1.1.6 Red Meat Processing

Quality Meat Scotland's 2020 edition of the Scottish Red Meat Industry Profile shows that twenty-one red meat abattoirs operated in Scotland in 2019 – two fewer than 2018. Slaughter output of cattle decreased in quantity, volume, and value on 2018, while sheep slaughter numbers and value increased.

Table 5. Scottish abattoir output, 2019

Category	**Number of animals** (thousands)		**Volume** (thousand tonnes)		**Estimated Value** (£m)	
	2018	*2019*	*2018*	*2019*	*2018*	*2019*
Cattle	459	449	167	165	643	599
Sheep	1,119	1,265	23	26	102	111
Total cattle and sheep	**1,579**	**1,715**	**190**	**192**	**745**	**710**

Source: QMS 2020 edition of the Scottish Red Meat Industry Profile, p. 27., RESAS calculations.

The same report estimates that Scottish abattoirs sold 27% of their beef and 17.5% of their sheepmeat to Scottish businesses or consumers in 2019. The majority was sold to the rest of the UK (65% of beef and 53% of sheepmeat), while overseas exports accounted for 8% of beef sales and 29.5% of sheepmeat sales.

1.1.6.1 Overseas Exports and Imports

Trade data from HMRC[4] suggests that the UK as a whole imported more beef (fresh and frozen carcass meat) than it exported: in 2020, the UK exported 117 million kg and imported 241 million kg (or by value, £384m and £953m, respectively). Between 2010-2017, beef imports also increased in value and volume, although recent years have seen a reversal in trend. Lamb and mutton are exported from and imported to the UK at roughly the same volume and value.

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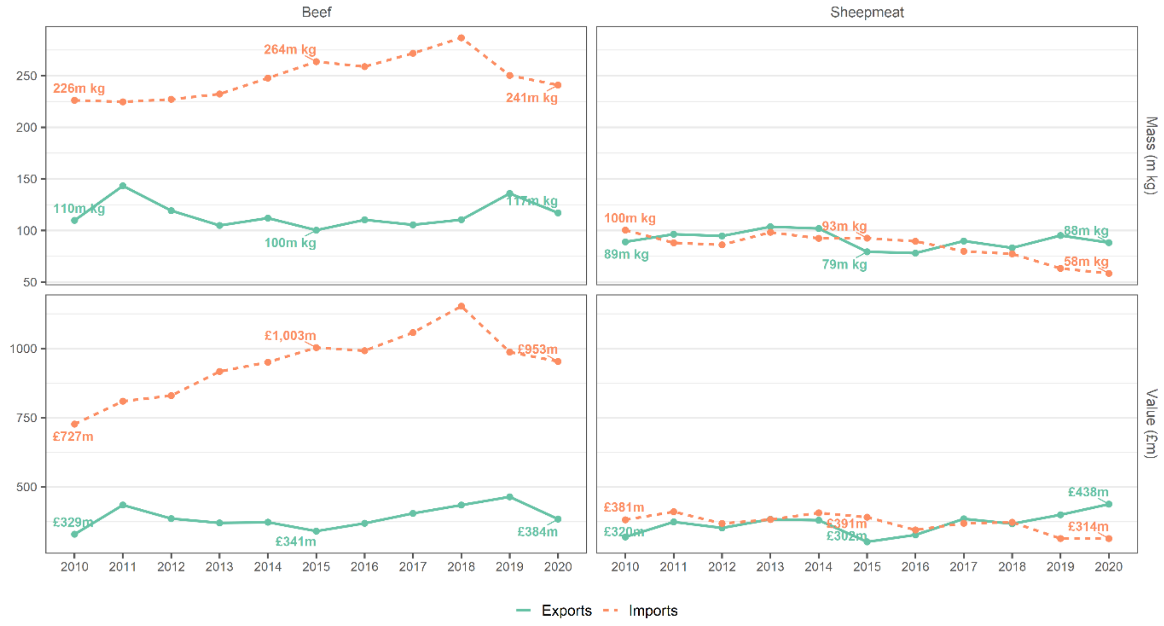
[4] UK Overseas Trade Statistics, February 2021. Available at: https://www.uktradeinfo.com/trade-data/.

Beef and sheepmeat trade, 2010-2020

UK exports and imports of beef and sheepmeat, fresh and frozen



Includes BTTA estimates and unscheduled revisions. 'Beef' consists of HS4 codes 0201 and 0202; 'sheepmeat' consists of HS4 code 0204 excl. 020450. Source: HMRC OTS, February 2021.

1.2 Profitability and Turnover

1.2.1 Estimated Farm Business Incomes and Profit

Farm Business Income statistics are estimated from a sample of nearly 500 farms with a standard output (the average monetary value of the agricultural output at farm-gate price) over €25,000. The FBS does not collect information on non-supported sectors, which include farms predominantly engaged in horticulture, pigs, poultry and some fruit production. A large number of part-time and small Scottish farms with low output are also not included[5]. As such, these figures exclude the vast majority of crofts.

Specialist LFA farms are broadly categorised in statistical reports as Specialist Sheep LFA, Specialist Cattle LFA, and Specialist Cattle & Sheep LFA. The remaining category including sheep, Lowland Cattle & Sheep, is also included in Table 6 below. A glossary and definitions of these categories and other terms can be found in Annex A.

Table 6 shows the estimated Farm Business Income (FBI) by upper and lower performance band, based on income with and without support payments. FBI is used here as an indication of how much profit a farm makes, and includes income from diversification. FBI figures are therefore not just measuring profitability from agricultural activity, but include income from non-agricultural activities that use farm resources. These non-agricultural activities can include, for example, tourism, renewables or processing and sale of farm products. There are wide variations in performance across farm types.

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[5] Farms with a Standard Labour Requirement (SLR) of more than 0.5. Standard Labour Requirements represent the approximate average labour requirement for a livestock or crop enterprise. The annual hours of a full-time worker is 1,900 hours. The FBS also does not collect information on non-supported sectors, which include farms predominantly engaged in pigs, poultry, some fruit production and horticulture.

In 2018-19, the average FBI in Scotland was around £38,700. Excluding support payments, this falls to around -£4,700, suggesting that for many Scottish farms CAP support plays an important role.

On average, Lowland Cattle and Sheep farms and Specialist Sheep (LFA) farms had the lowest FBI (both around £12,000). Excluding support payments all farm types saw a reduction in FBI, with Specialist Sheep (LFA) farms seeing the greatest fall, at around -£34,900, compared to -£21,800 for the average Lowland Cattle and Sheep farm.

Table 6. Cattle and sheep farm business income, 2018-19

Farm Type	**Performance Band by Income**					
	Lower 25%		**Average**		**Upper 25%**	
	Including Support	Excluding Support	Including Support	Excluding Support	Including Support	Excluding Support
Specialist Sheep (LFA)	-£17,500	-£68,700	£11,800	-£34,900	£62,000	-£22,100
Specialist Cattle (LFA)	-£16,400	-£52,600	£12,700	-£29,300	£52,800	-£7,000
Specialist Cattle & Sheep (LFA)	-£7,700	-£46,400	£24,800	-£44,900	£66,600	-£50,000
Lowland Cattle & Sheep	-£46,000	-£98,900	£11,500	-£21,800	£72,100	£21,600
All Farms	**-£15,500**	**-£53,800**	**£38,700**	**-£4,700**	**£159,800**	**£100,800**

Source: Farm Business Survey 2018/2019

The figure below shows profitability by farm type, represented by the proportion of farms with income from farming greater than zero (i.e. agricultural output is greater than input). Around 60% or more of LFA farms are profitable with support payments. In comparison to other farming sectors, this drops by a large proportion when support payments are removed. Without support payments less than 10% of LFA farms were profitable. Fewer Lowland Cattle & Sheep farms were profitable with support payments, but the proportion of farms making a profit when these are excluded was larger, at over 20%.

Proportion of farms with agricultural output greater than input, 2018-19

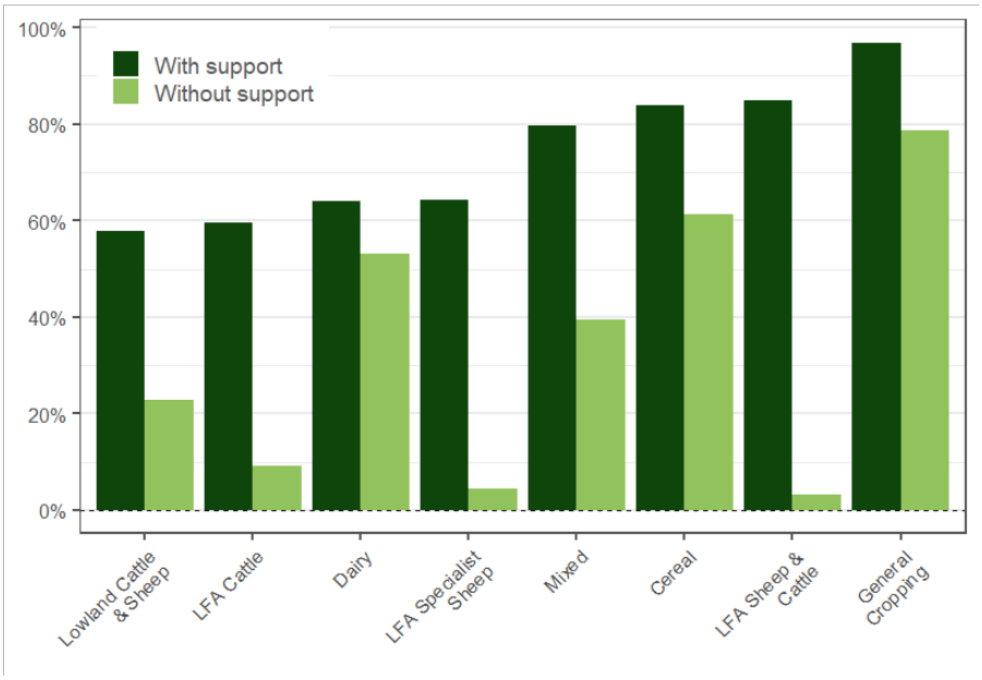


Table 7 shows the average total input, amount received from support payments and grants, and output for LFA farm types. On average, specialist LFA farms have an output of around £91,600, make £2,800 from diversified activities and receive around £48,400 from subsidies and payments. Inputs are around £128,000 a year, with the largest part associated with livestock expenses.

Economic efficiency is calculated as a ratio of outputs to inputs. Therefore, the average specialist LFA farm has an economic efficiency of around 122%.

Table 7. Cattle and sheep farm output and input, 2018-19

Farm Type	Average per farm				
	Output	**Input**	**Support payments and grants**	**Diversification Margin**	**Economic efficiency***
Specialist Sheep (LFA)	£39,600	£76,200	£46,700	£1,600	150%
Specialist Cattle (LFA)	£108,700	£140,900	£41,900	£2,900	110%
Specialist Cattle & Sheep (LFA)	£114,600	£163,500	£69,700	£4,000	115%
All Specialist LFA farms	£91,600	£128,000	£48,400	£2,800	122%
Lowland Cattle & Sheep	£128,900	£153,200	£33,300	£2,500	110%
All Farms	**£190,000**	**£199,300**	**£43,400**	**£4,600**	**124%**

** Includes support payments and diversification. Source: Farm Business Survey 2018/2019*

As shown in Table 7, many LFA and sheep farms receive a significant proportion of their output from support payments and grants. For many LFA farms, the Less Favoured Area

Support Scheme (LFASS) is an important part of this. Table 8 shows the number of farm businesses receiving LFASS in the bracketed amounts (figures are rounded).

Table 8. Farm businesses receiving LFASS by payment bracket, 2018

LFASS	Number of farm businesses
£0 to £385	1,790
£385 to £1,000	1,880
£1,000 to £2,500	2,170
£2,500 to £5,000	1,820
£5,000 to £10,000	1,600
£10,000 to £25,000	1,390
£25,000 to £50,000	390
£50,000 to £75,000	50
Over £75,000	30
Total	**11,100**

Source: RPID Administrative Data, 2018/2019

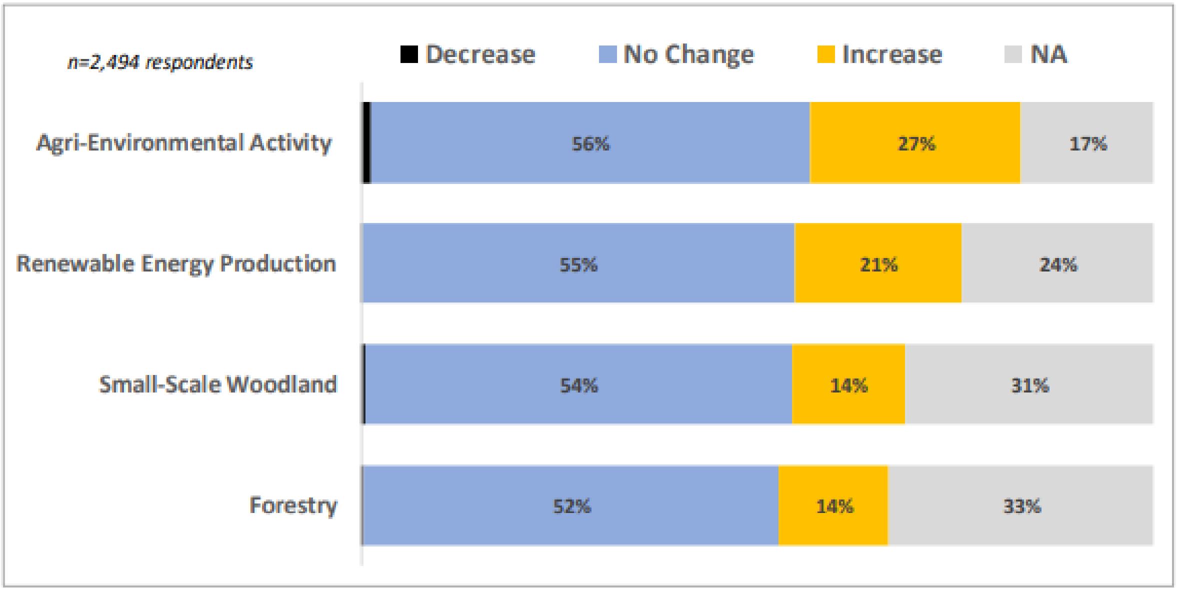
1.2.2 Diversification

Data on diversification and investment in renewable energies on hill and upland farms in Scotland is scarce. The Farm Structure Survey 2016 found that across all farming around 9% of farms made more than 50% of their turnover from diversified activities and 16% made more than 10%. 7% of all LFA cattle and sheep farm types and 8% of all non-LFA cattle and sheep farm types made more than 50% of their turnover from diversified activities. This was slightly lower than the 9% average across all farm types. A further 7% of LFA and 8% of non-LFA cattle and sheep farms made 10-50% of their turnover from diversified activities. The majority of LFA (86%) and non-LFA (84%) cattle and sheep farms made less than 10% of their turnover from diversified activities.

The Farmers' Intention Survey 2018, summarised by SRUC in their October 2019 briefing, revealed that over 50% of (Scottish) farmers (from all sectors) plan no changes to the levels of agri-environmental provision on their holding in the succeeding five years. Between approximately 14% and 27% of farmers plan to increase provision of "public goods" through increased agri-environmental, forestry, small-scale woodland and renewable energy production.

Of those who did signal intentions to increase these activities, identification of a successor, status as a new entrant, tenure, gender and land type were the most significant characteristics of those intending to increase public good activities. Lower productivity of land appears to be a factor which positively influences the decision of farmers to increase the level of forestry and small-scale woodland on their farm or holding.

The figure below shows the overall intentions of the farmers, crofters and smallholders surveyed to change the level of activities on their farm or holding that may enhance 'public good' provision in the next five years (2018-2023). Over 50% of respondents planned no changes to the level of each of the activities and for many the question was not applicable as they currently don’t engage in that activity. The type of public good provision that most respondents planned to increase is agri-environmental activity, at 27%.



1.2.3 Crofting

Within Scotland, crofting continues to form an integral part of its rural area. Numbering over 20,000 crofts and the home of over 33,000 people traditionally situated in the former crofting counties in the Highland and Islands of Scotland. Crofts are around five hectares on average. The agricultural census also reports around 0.6m ha of land classified as common grazing. Common grazings are not exclusively used by crofts but crofts use them.

The economic position for crofting remains mixed. As reported in the Economic condition of crofting 2015 to 2018, the median revenue reported was £2,000, although there was significant variation across the group, with a quarter reporting to have received no revenue from crofting. At the same time, reported average running costs were £2,000.

The rearing of livestock and growing of crops remain the main crofting activities (undertaken by 80% and 42% of crofters respectively). Census data shows that crofts account for approximately 1% of Scotland’s cropland, 11% of its sheep and 4% of its cattle. However, like other parts of Scottish agriculture, crofters have been diversifying their activities over recent years with growth in leisure activities and holiday accommodation.

As a result, income from non-crofting activities has increased over recent years, as has the median level of investment, although the proportion of crofters who state an intention to invest in coming years has fallen.

The report found that among crofters, there is ongoing uncertainty about the future of crofting, with the majority of crofters stating that they do not have a succession plan in place, and widespread agreement that crofting is not viable without income from non-crofting activities.

1.3 Future Trends

1.3.1 Impacts of Brexit

The Anderson Centre produced a report for Scottish Government in late 2020, assessing the impacts on Scottish agriculture of a UK-EU Free-Trade Agreement (FTA), and a No-Deal Brexit.

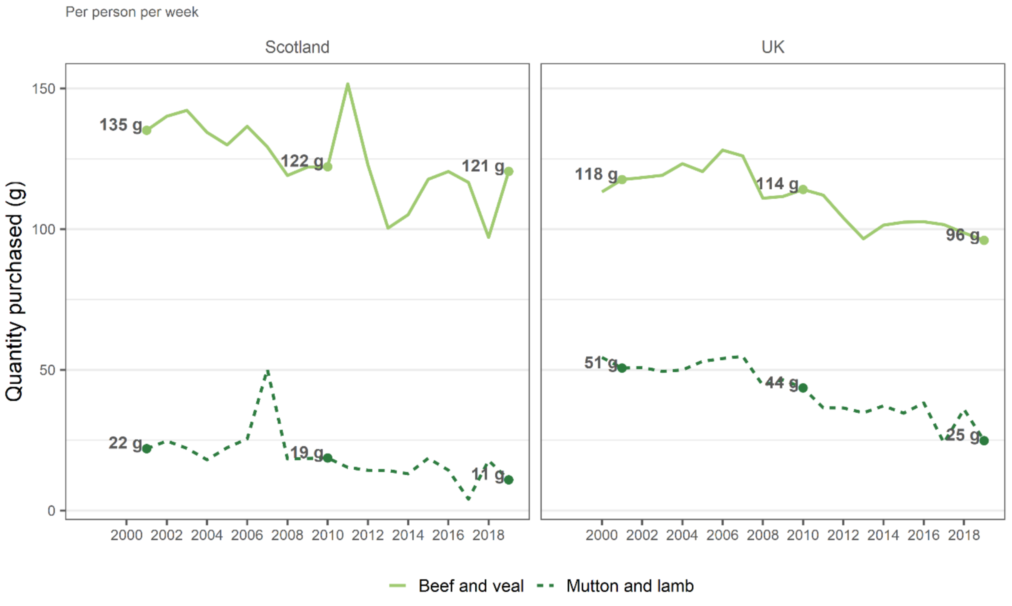
Overall, the modelled impacts of an FTA were projected to result in relatively small changes in Scottish agricultural output over the longer term. This is because agricultural trade, with the exception of seed potatoes, can continue effectively tariff-free and quota-free. Indeed, the modelling suggests that increased demand from the rest of the UK could actually increase Scottish agricultural output in some cases.

Specifically for sheepmeat and beef, output by value was projected to increase by around 1.0% and 1.1% respectively, by 2021. It should be noted that this modelling is not suitable for capturing the initial disruption being experienced by individual businesses in the early stages of the deal.

Trade between the UK and EU, however, is no longer frictionless with new non-tariff measures (NTM) – additional certifications, enhanced border checks, etc. – now in place. As a result, the costs of such trade are set to increase. For sheepmeat carcass products, the NTM costs are estimated between 0.9% and 2.0% of their price (also referred to as ad-valorem equivalent (AVE)). For beef, these costs are estimated to be larger, averaging between 1.2% and 2.9%.

1.3.2 Changing Dietary Demands

DEFRA's Family Food datasets, based partly on ONS' Living Costs and Food Survey, provide an overview of UK and Scottish household purchases and expenditure of food and drink. The latest release, with data up to 2018/2019, shows that the volume of beef and sheepmeat purchased by both UK and Scottish consumers for at-home consumption has declined. Since 2001, the volume of beef and veal purchased by Scottish consumers has decreased by 10%, while the volume of lamb and mutton purchased has halved.



Quantity of beef and sheep meat purchased, 2000-2019

Per person per week

Source: Family Food Datasets, DEFRA, October 2020

In addition, the latest data suggests Scottish consumers purchase less than half the quantity of lamb and mutton per week on average (11g) than UK households (25g). Beef is consumed in greater quantities in Scotland, however: 121g vs. 96g per person per week.

Table 9. Average expenditure on beef and sheep meat per person per week, 2018/2019

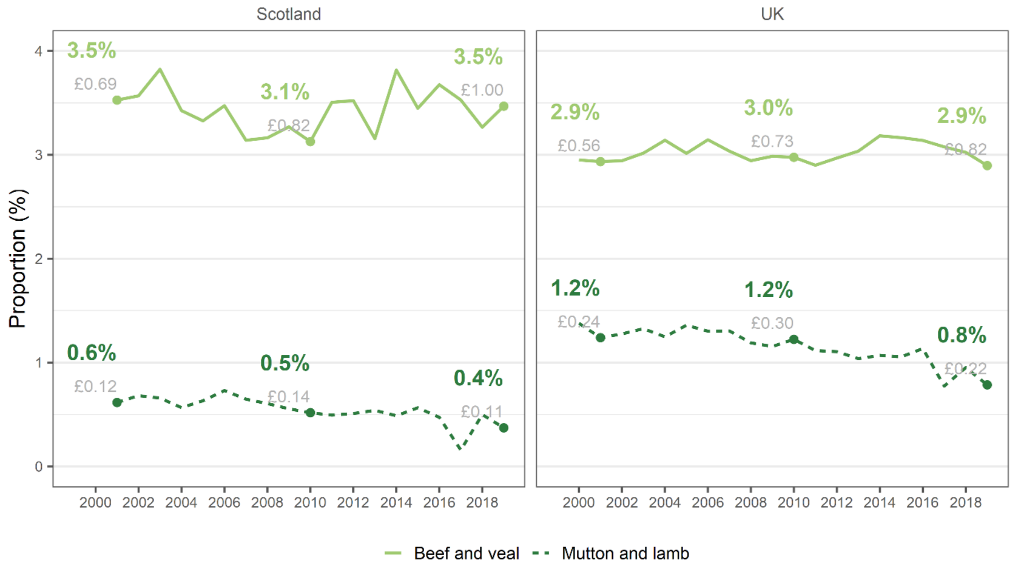
Region	Category	Purchase	Expenditure
UK	Beef and veal	96g	£0.82
	Mutton and lamb	25g	£0.22
	Food and Non-Alcoholic Drinks	..	£28.32
Scotland	Beef and veal	121g	£1.00
	Mutton and lamb	11g	£0.11
	Food and Non-Alcoholic Drinks	..	£28.85

Source: Family Food, DEFRA, October 2020

The proportion of total food and drink expenditure spent on beef and veal has remained largely stable. In 2018/2019, 2.9% of total UK food and drink expenditure was spent on beef and veal, a similar level to that seen in since 2001 (3.5% for Scottish households). Mutton and lamb expenditure as a proportion of total food and drink expenditure, however, decreased for both UK and Scottish households.

Expenditure on beef and sheep meat, 2000-2019

Proportion of total spending on food and non-alcoholic drinks, per person per week



Source: Family Food Datasets, DEFRA, October 2020

A number of key reports have discussed changes to red meat consumption. The UK Climate Assembly[6] – a citizens' assembly on climate change – discussed their preferred future for food, farming and land use on the path to net zero in the UK. This included 20-40% voluntary and education driven reductions in red meat and dairy consumption.

The Climate Change Committee[7] have also formally modelled these reductions in their 6th Carbon Budget report in order to determine their pathways for the UK, including Scotland, to reach net-zero by 2050.

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[6] https://www.climateassembly.uk/report/read/final-report-exec-summary.pdf

[7] Sixth Carbon Budget - Climate Change Committee (theccc.org.uk)

Their advice also highlights three key changes required to reduce agricultural emissions:

i. diet change with their main pathway to net-zero assuming a 20% reduction in UK consumption of red meat by 2030, rising to 35% by 2050;
ii. low-carbon farming practices;
iii. productivity measures to improve crop yields and reduce stocking rates.

The sectoral pathway for Scottish agriculture in the CCC report requires an emissions reduction of 23% by 2030 and the CCC state changes in farming practices, woodland planting and reductions in livestock numbers are all required to achieve net zero.

2 Greenhouse Gas Emissions and Biodiversity

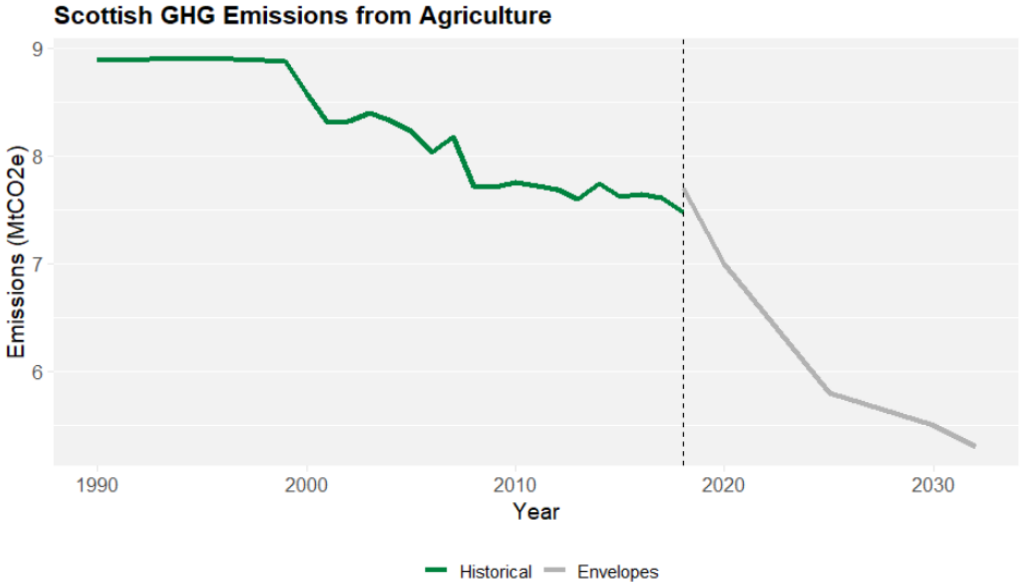
2.1 Sector Emissions

The Scottish Government has committed to reaching net zero emissions by 2045, including a reduction of 75% from 1990 levels by 2030. While a number of countries have adopted net zero targets by on or around 2045, Scotland's 2030 target is particularly ambitious and requires quick action.

Scotland has a legal requirement to meet these goals, and every industry must adjust to contribute to reducing emissions. The Greenhouse Gas (GHG) inventory measures the domestic emissions, i.e. those produced in Scotland. It is the key data source against which Scottish Government measures its progress against its net zero targets. Emissions arising from goods produced in Scotland and exported overseas for consumption are counted in the Scottish GHG inventory. Emissions arising from goods produced overseas and imported into Scotland for consumption are not counted in the Scottish GHG inventory.

In 2018 total Scottish emissions were 41.6 million tonnes of carbon dioxide equivalent (MtCO2e). The 2019 figures are scheduled to be published in summer 2021.

In 2018 emissions from agriculture were 7.5 MtCO2e, or 18% of Scottish emissions. The sectoral envelope as set out in the Climate Change Plan update requires agricultural emissions to reduce from current levels by 2.4 MtCO2e to 5.3 MtCO2e[8] by 2032, the equivalent of a 31% reduction from 2018 levels. As shown below this requires agriculture to reduce emissions at a pace nearly four times faster than historic reductions. Progress towards delivering the plan will be part of statutory annual reporting at a sector-by-sector level to the Scottish Parliament from May 2021 onwards.



Source: Scottish Greenhouse Gas Emissions 2018 - gov.scot (www.gov.scot), Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update - gov.scot (www.gov.scot)
Note: there is a small break in the series due to a slight mismatch in the historic data and the forecast envelopes

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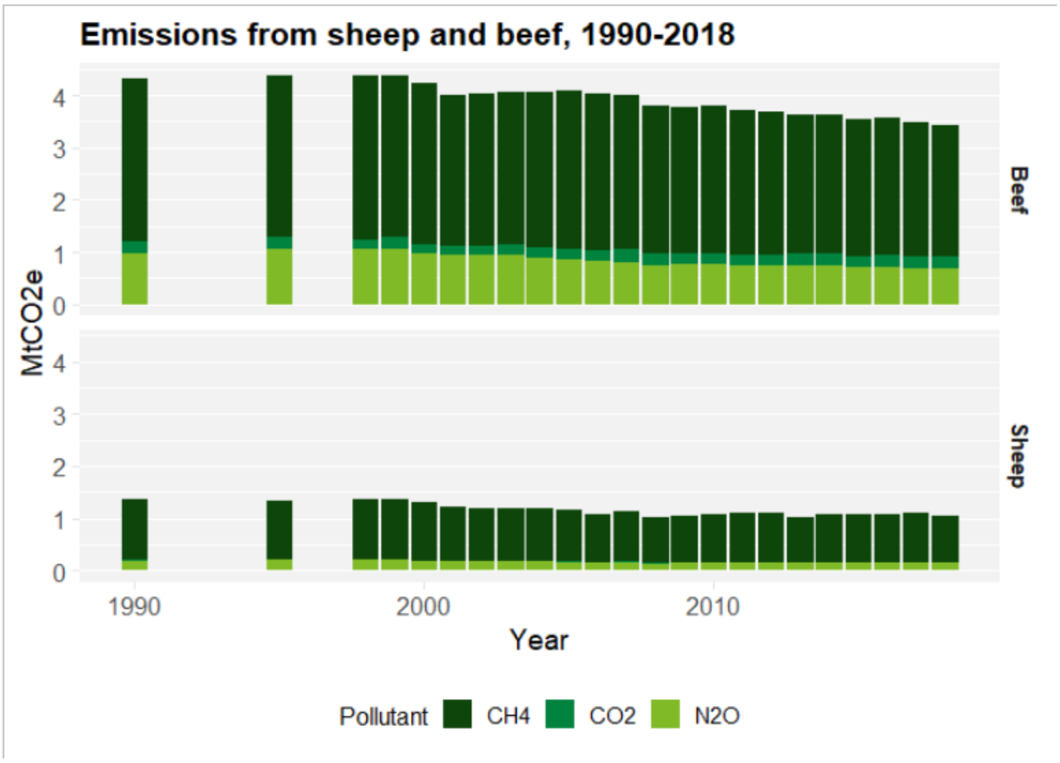
[8] The Climate Change Plan update incorporates some likely methodological changes not yet included in GHG inventory figures, resulting in 7.7 MtCO2e in 2018 rather than 7.5.

2.1.1 Emissions from Hill and Upland Farms

The Greenhouse Gas Inventory does not publish break downs of emissions specific to hill and upland farming. We have therefore estimated emissions based on the percentage of sheep (88%) and cattle (72%) on all farms with LFA land.[9]

This method implies that the 6 million sheep in LFA areas contribute around 0.92 MtCO2e and 1 million beef cattle around 2.47 MtCO2e, suggesting around 3.38 MtCO2e in total from livestock on LFA land, or 45% of all agricultural emissions. Further detail on the breakdown of agricultural emissions is in Annex C. Some farms with LFA land may have emissions arising from other agricultural activities but relatively these are likely to be quite small. This estimate includes a small amount of emissions from cattle described as 'other dairy' in census data and so slightly overstates the emissions. Emissions reductions, shown below for all sheep and beef cattle, since 1990 are driven by falling sheep and cattle numbers.



Source: Scottish Greenhouse Gas Emissions 2018 - gov.scot (www.gov.scot)

2.1.2 Sources

The chart below shows how the 2018 emissions from LFA farms break down by source and pollutant. Enteric fermentation is the largest source contributing 68% of emissions from LFA farms. The next largest source contributing a further 15% is manure management.

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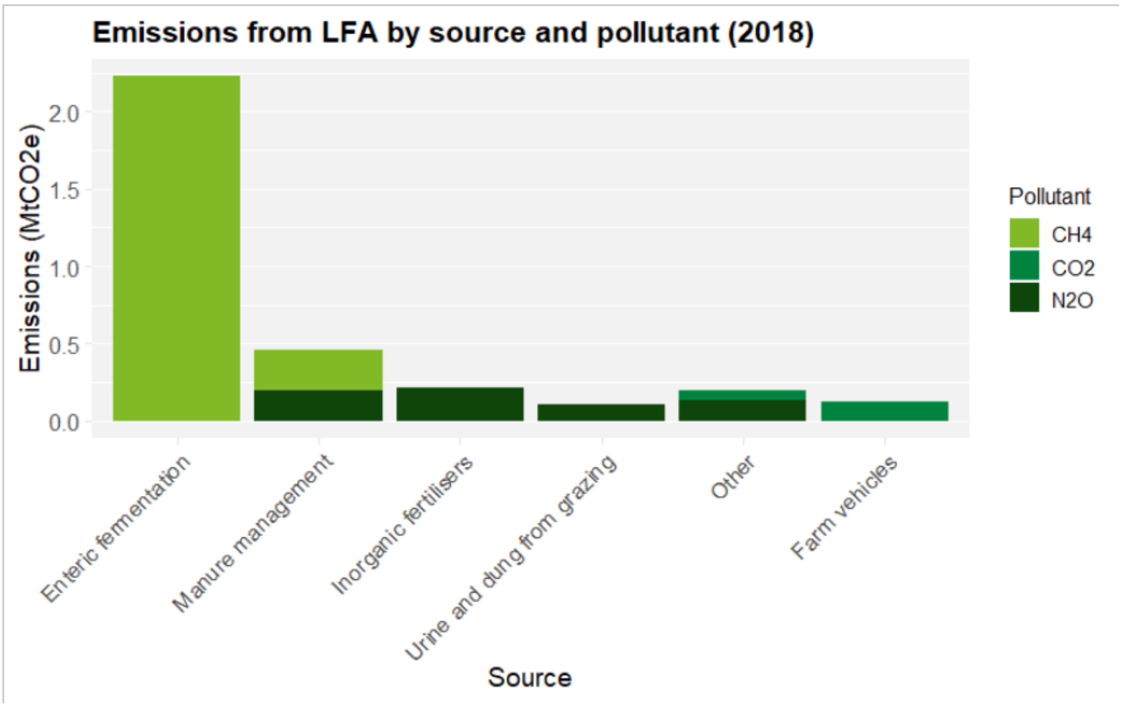
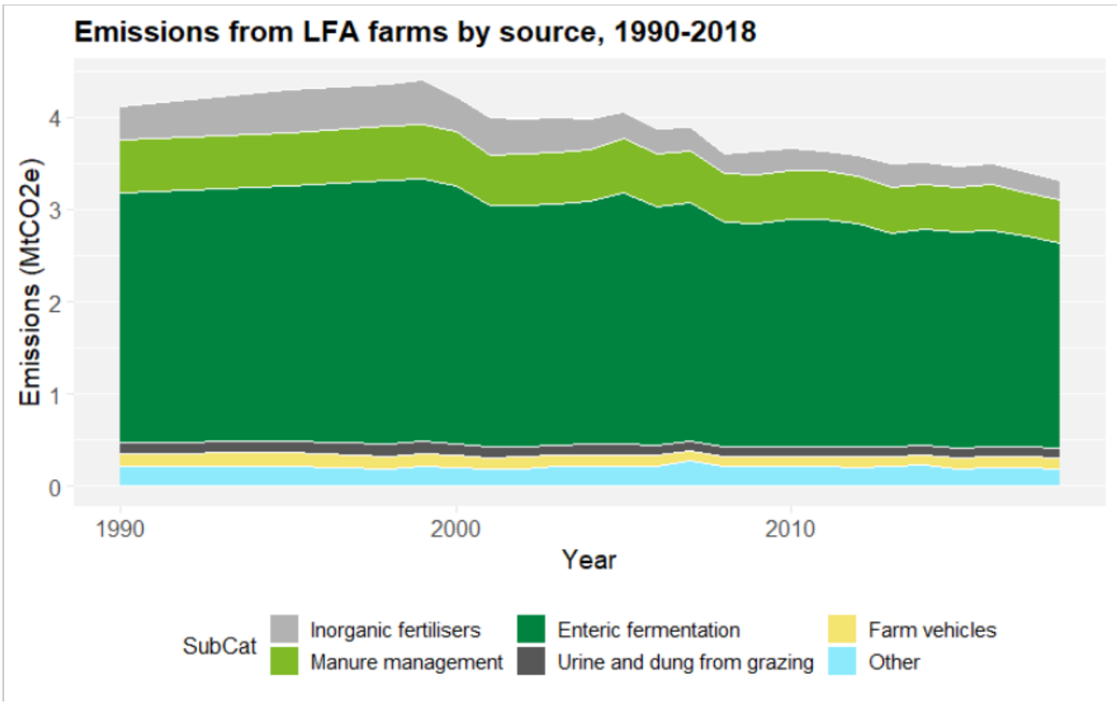
[9] To check the estimates from this approach we also calculate the emissions using the detailed underlying breakdowns from another dataset (ADAS). This leads to very similar estimates.



Source: [Scottish Greenhouse Gas Emissions 2018 - gov.scot (www.gov.scot), RESAS classification based on ADAS data]

Over time, the largest reductions by source have come from reductions in emissions from enteric fermentation, related to reductions in livestock numbers.



Source: [Scottish Greenhouse Gas Emissions 2018 - gov.scot (www.gov.scot), RESAS classification based on ADAS data]

2.2 Options for Reducing Emissions

2.2.1 Potential Savings

Research undertaken by CXC and SRUC on behalf of Scottish Government assessed the potential savings from a range of mitigation measures that could be applied in Scotland and the likely maximum uptake that could be achieved. The report did not assess timescales for uptake of these measures, which will be influenced heavily by factors such as behaviour change and policies. Table 10 summarises the measures that could be applied to sheep and beef cattle. Estimates of the aggregate emissions savings have been added based on most recent data on levels of livestock in LFA areas. There may be some overlap with potential reductions in beef emissions with the SBCS.

Table 10. Sources of climate change mitigation in the HUC sector by 2050

LFA Livestock 2020	Mitigation measure	Maximum Uptake 2050	Per unit mitigation (kg CO2e)	Aggregate Mitigation (MtCO2e)
1,007,000 Cattle **5,901,000 Sheep**	3NOP feed additive	52%	420	0.22
	Breeding low methane cattle	19%	120	0.02
	Slurry cover - impermanent	25%	230	0.06
	Improved health	78%	30	0.02
	Improved health (Sheep)	72%	10	0.06
	Additive Total	**..**	**810**	**0.38**

Source: Marginal abatement cost curve for Scottish agriculture (climatexchange.org.uk)

Strictly speaking the ‘additive totals’ overstate the savings as some measures may interact and reduce the impact of other measures. However these interactions were assessed to be relatively low and these interactions could mainly happen between 3NOP feed additive and breeding for low methane emissions.

If each of these measures were applied to their maximum potential as identified in the report, estimated reductions from emissions based on current levels of all livestock on LFA land would be in the region of 0.38 MtCO2e.

This would be a 11% reduction in terms of 2018 emissions from the LFA sector or 16% of the 2.4 MtCO2e reductions required by agriculture by 2032 with the remaining 84% needed to come from elsewhere in the sector. A reduction of 2.4 MtCO2e is equivalent to a 31% reduction from 2018 levels. Therefore, even if all agricultural sectors were to achieve an equivalent 11% reduction in their emissions this would not be sufficient, by over two-thirds, for the agriculture sector to meet its envelope by 2032.

The Climate Change Committee states changes in farming practices, woodland planting and reductions in livestock numbers are all required to achieve net zero. Their advice also highlights three key changes required to reduce agricultural emissions:

1 - Diet change with their main pathway to net-zero assuming a 20% reduction in UK consumption of red meat by 2030, rising to 35% by 2050
2 – Low-carbon farming practices, similar to those outlined above
3 – Productivity measures to improve crop yields and reduce stocking rates

It is important to note that the figures above are average estimates that were provided for Scotland as a whole and may not reflect issues specific to LFA livestock. Further, on an individual farm basis, both the mitigation and the net costs (below) can be very different and some measures above cover a wide range of possible actions which would be demanding to assess individually. Therefore the GHG benefits achieved and costs could vary widely.

Further details on each of these measures, such as costs, underpinning assumptions, constraints and potential uptake can be found on pages 12-13 of the CXC report and in the Annexes on pages 43-53. They have also been collated into Annex D for ease.

As set out within the CXC report, there is scope for all sectors in agriculture to mitigate their operational GHG emissions through other practises and alternative land use such as those to encourage carbon sequestration.

2.2.2 Costs

Some of these measures would involve the purchase of capital equipment with upfront costs. The table below shows the net costs to farmers including capital costs on an average annual basis. These do not include any wider costs such as those to Government or Research and Development from developing measures. Negative figures below show a net saving to the farmer, i.e. if implemented they would provide a financial saving to the farmer as well as a reduction in emissions. Based on current livestock levels the average potential cost to the sector is around £27.6m which – to put this in context - is just under 4% of the value of standard output from LFA farms.

Table 11. Sources of climate change mitigation in the HUC sector by 2050

Dairy Cattle 2020	Mitigation measure	Maximum Uptake 2050	Per Unit Annualised Cost (£)	Aggregate Cost (£m)
1,007,000 Cattle	3NOP feed additive	52%	31.38	16.4
	Breeding low methane cattle	19%	-15.96	-3.1
	Slurry cover - impermanent	25%	-0.25	-0.1
5,901,000 Sheep	Improved health	78%	20.26	15.9
	Improved health (Sheep)	72%	-0.36	-1.5
	Additive Total	..		**27.6**

Source: Marginal abatement cost curve for Scottish agriculture (climatexchange.org.uk)

2.2.3 Current Uptake & Implementation Constraints

This section contains a brief summary of some of the key issues relating to each of the measures outlined in Tables 10 and 11 above, drawing heavily on the CXC report.

2.2.3.1 3NOP feed additive for cattle

Feed additives are not yet available on the market for the purposes of reducing methane. However some products have already sought regulatory approval and are expected to be approved this year for dairy, with other sectors likely to follow.

Current uptake is effectively zero. Practically feed additives will be easier to provide to housed cattle where potential uptake at least is 100%. National inventories and monitoring programs will need to be adjusted to track, record and measure the reductions from such additives.

2.2.3.2 Cattle breeding for low-methane emissions

The measure requires enteric methane emissions to be included in breeding goals with low emission animals selected for breeding. It requires farmers buying (semen from) breeding animals, which have a high score of this breeding index (i.e. lower methane emissions). If genomic tools are used in the selection then the genetic improvement can be sped up, meaning that the methane emissions reduce at a faster rate.

The CXC study estimated improvements could be applied to around 45% of the dairy herd. There would be upfront research costs estimated in the region of £2.5m across the UK and ongoing research costs as well. The farmers are not likely to experience costs beyond the costs of their current breeding practices (like artificial insemination). Moreover, they can expect improvements in productivity and therefore achieving a better gross margin.

In terms of current uptake the option of low-methane breeding does not exist in Scotland or the UK, as a low emission breeding index is not in use yet.

2.2.3.3 Covering slurry stores with impermeable cover

A review of experimental results showed that impermeable plastic covers have the potential to reduce ammonia and GHG emissions in parallel. However, there can be feasibility problems with floating covers if applied on slurry tanks or larger lagoons and their durability is not yet well tested. Furthermore, the presence of a slurry cover increases the ammonia concentration of the slurry and hence its nitrogen content and fertiliser value, but also the potential subsequent ammonia and nitrous oxide losses when the slurry is applied to the soil, unless low ammonia emission spreading techniques are implemented.

Impermeable covers do not inhibit methane formation, so the gas built up under the cover needs to be managed to avoid an explosion risk. The report states that all slurry tanks could be covered. The Survey of Agricultural Production Methods[10] (2016) shows that nine per cent of all holdings had storage facilities for slurry, with 62 per cent of these having covered storage.

2.2.3.4 Improved health of cattle & sheep

Animal health is a complex topic, influenced by numerous diseases. The emissions intensity of ruminant meat and milk production is sensitive to changes in key production aspects, such as maternal fertility rates, mortality rates, milk yield, growth rates and feed conversion ratios - all of which are influenced by the health status of the animal. In particular the report discusses worms in sheep and cattle and liver fluke in cattle. The CXC study estimated 80% of the herd could have improved health and estimated the cost-effectiveness to the farmer from productive gains.

A simplistic approach was taken; rather than estimating the GHG effects of the prevention and control of individual diseases, a general improvement in the health status was assumed, without reference to specific management options.

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[10] Survey of Agricultural Production Methods, 2016

2.2.4 Evidence from the Climate Change Committee

Agriculture, and land-use, feature prominently in the Climate Change Committee's sixth Carbon Report, which expresses the need to reduce red meat and dairy intake, via behavioural change, and transform farmland.

The sectoral pathway for Scottish agriculture in the CCC report requires an emissions reduction of 23% by 2030. The CCC state changes in farming practices, woodland planting and reductions in livestock numbers are all required to achieve net zero. Their advice also highlights three key changes required to reduce agricultural emissions: 1 - diet change with their main pathway to net-zero assuming a 20% reduction in UK consumption of red meat by 2030, rising to 35% by 2050. 2 – low-carbon farming practices, similar to those outlined above. 3 – productivity measures to improve crop yields and reduce stocking rates.

The CCC and its key speakers have stressed that not only are the changes outlined critical for agriculture to reduce its emissions but also critical to free up the land required for other sectors to achieve what they need.

The CCC recommend the following policies are implemented in fair way to farmers; a strengthened regulatory baseline, incentive schemes such as auctioned contracts and measures to address skills issues, supply chains and barriers for tenant farmers. The CCC state that policies are also needed to cut food waste and encourage a reduction in consumption of meat and dairy.

A number of farm-level challenges were highlighted including uptake of measures, particularly cost-incurring measures, lack of knowledge, skills and experience to transition to low carbon farming, contractual issues and incentives around tenancies and common-land. Wider barriers on dietary change were around lack of awareness, metrics, labelling issues and lack of public sector leadership.

2.3 Biodiversity

2.3.1.1 What do we know about biodiversity?

The Convention on Biological Diversity defines biodiversity as the variability among living organisms from all sources including within and between species and of ecosystems. It is vital to supporting humans by contributing to food production, manufacturing supplies, recreation, soil quality, and climate stabilisation. In December 2020 the Scottish Government published a Biodiversity Statement of Intent which includes proposals in relation to land use.

The Dasgupta Review of the Economics of Biodiversity commissioned by HM Treasury highlights that we are demanding more goods and services than nature can sustainably supply. This means global stocks of natural assets have been depleted. The review makes clear that increased biodiversity helps mitigate risks to economic prosperity and climate change. Acting immediately on biodiversity loss is significantly more cost effective than delaying action. We can respond by reducing our use of natural resources, increasing the efficiency with which we use them or increasing them through conservation and rebuilding.

2.3.1.2 What is the relationship between farming and biodiversity?

The UKG review states the relationship between farming and biodiversity is complex. Agriculture is the dominant land use in Scotland and includes some of the country's most important wildlife habitats. Farmland management is recognised as one of the most significant pressures on biodiversity[11]. Some of the habitats and species associated with Scottish upland areas are important at European level (for example the level of peatland and heath area) and fragile. The Scottish uplands contain a large proportion of Europe’s heathland. Caithness and Sutherland host the largest and most intact area of blanket bog in Europe, around 4% of the world’s blanket bogs. Agriculture has a significant influence through grazing, drainage and application of nutrients.

Species-rich grasslands, habitat mosaics (including grassland/heath and wetlands), coastal heaths and machair habitats are particularly relevant in crofting areas. A significant number of priority species, which are rare, or in decline, are found here. The great yellow bumblebee is restricted to machair areas and other flower-rich areas in Orkney, Scottish islands, and Caithness and Sutherland. Marsh fritillary is restricted to the west coast in Scotland. The Corncrake, now restricted to the Western Isles and Orkney is one vulnerable species that has made a recovery with the support of Agri-Environment schemes[12]

Biodiversity can benefit farmers by improving productivity including soil health, and farming approaches can be tailored to benefit wildlife and biodiversity[13]. However, this is not always true: for example, an area of farmland may have high biomass, but low biodiversity.

A change of land use can result in various impacts on biodiversity: for example, conversion from semi-natural grazing to forestry may be detrimental, as the diversity and richness of wildlife associated with the former can be considerable, whereas conversion from improved grassland (which can be poor for wildlife) to forestry is likely to make little difference[14].

Farmland is particularly able to deliver services such as energy sources, food production and recreation. The Natural Capital Asset Index shows that the natural capital[15] asset value of agricultural and cultivated land has been reducing over recent years, while the value of heathland has been improving. The Index is made up of quality (38) x quantity indicators (i.e. area)[16].

Biodiversity varies across regions, land uses and species. A commonly used indicator for biodiversity is bird populations. Research by Nature.Scot shows that most wader species have seen significant declines while seed-eaters show stable or increasing long-term trends. Seventeen species contribute to the upland bird indicator, and of these, nine are in significant long-term decline. Five species (dotterel, curlew, black grouse, hooded crow and dipper) have declined by more than 45%. One of the biggest stories is the disappearance of many wader species from much of their former breeding ranges in Scotland and across the UK[17]. Concern about both upland and lowland breeding wader declines has resulted in a wide range of research and conservation initiatives (through AECS and Working for Waders[18]). Long-term changes have been driven by a number of factors including climate change, forest expansion, and changes in site based management practices such as grazing and predator control.

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[11] State of Nature Report 2019, NatureScot

[12] https://www.researchgate.net/publication/307548407_The_Corncrake_Crex_crex_population_in_Scotland_from_1993_to_2015_with_an_overview_of_conservation_measures_taken_during_this_period

[13] The importance of biodiversity and wildlife on farmland | Business Wales (gov.wales)

[14] Does plantation forestry restore biodiversity or create green deserts? - Bremer, L., Farley, K.

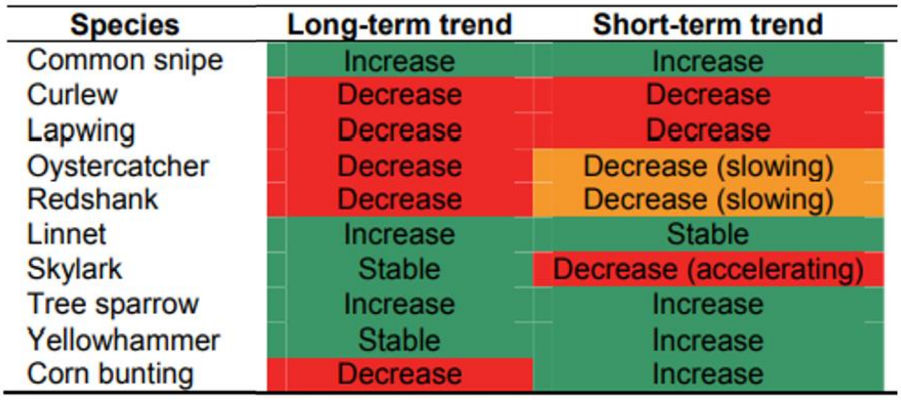
[15] “Natural capital is part of nature which directly or indirectly underpins value to people including ecosystems, species, freshwater, soils, minerals, the air and oceans, and natural processes and functions. In combination with other types of capital it forms part of our wealth; our ability to produce actual or potential goods and services into the future to support our wellbeing.”

[16] Scotland's Natural Capital Asset Index - 2019 Update summary.pdf (nature.scot)

[17] https://www.nature.scot/official-statistics-terrestrial-breeding-birds-1994-2019

[18] Action — Working for Waders

Summary of long and short term trends for bird species on farmland in Scotland



Species	Long-term trend	Short-term trend
Common snipe	Increase	Increase
Curlew	Decrease	Decrease
Lapwing	Decrease	Decrease
Oystercatcher	Decrease	Decrease (slowing)
Redshank	Decrease	Decrease (slowing)
Linnet	Increase	Stable
Skylark	Stable	Decrease (accelerating)
Tree sparrow	Increase	Increase
Yellowhammer	Stable	Increase
Corn bunting	Decrease	Increase

There is evidence on the impact of Scottish agri-environment schemes on biodiversity. An evaluation of the 2007-2013 SRDP, using limited data, found some agri-environmental measures appeared to have a positive impact on biodiversity, particularly grass margins and beetlebanks, cropped machair, hedgerow management, and management of semi-natural habitats. An evaluation of the current AECS scheme is underway but is not yet published.

Pollinators play an essential role in plant reproduction and ecosystem functions, and there are currently large worrying declines in their populations. The European Court of Auditors on Pollinators have found that EU measures did not ensure the protection of wild pollinators, and that key EU policies, including the Common Agricultural Policy, do not include specific requirements for the protection of wild pollinators.

2.3.1.3 What is the relationship between hill and upland farming and crofting and biodiversity?

It is difficult to ascribe biodiversity impacts to particular farming sectors, as biodiversity data are collected on the basis of habitat rather than sector. Some land types, particularly machair, rely on grazing to maintain species richness and hold very high populations of breeding waders. Equally, a substantial proportion of the High Nature Value farming in Scotland is associated with extensive grazing[19]. Options available to support management practices that are important for biodiversity in upland and crofting areas include moorland management, summer hill grazing of cattle and support for native cattle on small units[20].

NatureScot highlights that moderate grazing by both sheep and cattle supports areas of short grass which benefit many kinds of insects, plants and ground nesting birds. In addition patches of short vegetation form good breeding sites for waders like lapwing, redshank and golden plover while areas of tall grasses are favoured by species like curlew. Dung is useful for insect populations and scavenging birds feed on carion. Management through stocking rates and shepherding is important to avoid problems of overgrazing such as soil erosion, or undergrazing – which can reduce diversity as the most competitive plants take over. Areas

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[19] (PDF) The effects of cattle on the natural heritage of Scotland : Scottish Natural Heritage Commissioned Report No. 203 (ROAME No. F04AA103) (researchgate.net)

[20] More info on biodiversity value and managing moorland habitats is compiled in i. Backshall, J, Manley, V.J., Rebane, M. (2001) *The upland management handbook* Peterborough: English Nature; and Brooks, S. and ii. Stoneman, R. (1997) *Conserving bogs: the management handbook.* Edinburgh: Stationery Office

cultivated for hay or silage that aren't mown or grazed during the breeding season can provide cover for nesting birds. Species such as skylark, partridge and corncrake nest on the ground and favour tall vegetation. On farms with no crop cultivation, reintroducing small arable areas – e.g. for whole crop silage – may increase availability of food and habitats for wildlife.

Research commissioned by RSPB to look at the impact of reductions that have been seen in livestock numbers[21], suggests reduced grazing pressure on semi-natural areas has led to a recovery of habitats and has been broadly positive for biodiversity. "Upland habitats such as dry heath, wet heath and blanket bog have recovered (and continue to recover) as a result of reduced grazing by sheep in particular, contributing to the improving condition of many sites. However undergrazing and loss of vegetation structure is now occurring in some areas, with adverse impacts for some species such as golden plover and other waders." "Less grazing is contributing to both native woodland regeneration but also conifer regeneration. On the other hand, less livestock has allowed an increase in grazing by deer and other herbivores."[22].

NatureScot has a project testing an outcome based approach to supporting biodiversity on farms and crofts in Scotland.   Three of the pilots are in crofting areas (Skye, Argyll, and Strathspey)[23]. The project is also working closely with two partner projects in Shetland (with the RSPB) and in the Outer Hebrides (with the European Forum for Nature Conservation and Pastoralism).

Other good examples can be seen at:

- Tomintoul: Farming and Nature case study
- Balnakeil farm: http://www.highnaturevaluefarming.org.uk/hnv-in-scotland/
- Pontbren Project in Wales - a farmer-led approach to sustainable Land management in the uplands – the project was led by local farmers who identified the need to move to a more sustainable system from higher production-cost systems to using hardier native stock with less costs by planting strategic areas of trees that have also helped with runoff and benefitted wildlife.
- The Burren (Ireland) was the first to test payments by results. Described as a pioneering agri-environmental programme which aims to conserve and support the heritage, environment and communities of the Burren. The Burren has focussed round the management of species rich grassland and key indicator species/habitats.
- The Yorkshire Dales National Park has also used a results-based payments approach for the management of hay meadows.

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[21] the decline in livestock numbers experienced over the last decades and the changes in managements can be seen in an SNH report on trends in hill farming shows. This report points to the decline in active hill management and land abandonment affecting some areas, An Analysis of the Impact on the Natural Heritage of the Decline in Hill Farming in Scotland,

[22] Microsoft Word - RSPB - Changing livestock numbers in the UK LFA - FINAL Report

[23] For more information see https://www.nature.scot/piloting-outcomes-based-approach-scotland-pobas-project

3 Performance and Productivity

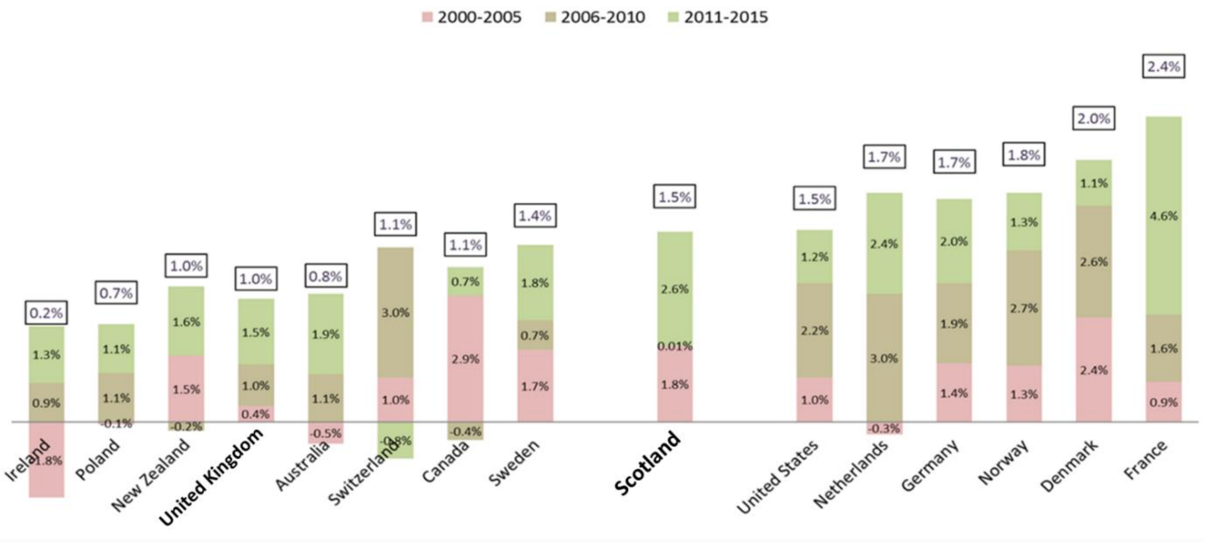
3.1 Key Metrics for Performance and Productivity

Productivity refers to the efficiency of production. One method of quantifying productivity commonly used is Total Factor Productivity (TFP). This looks at an industry's overall efficiency in converting all of its inputs into all of its outputs, and is usually presented in terms of TFP growth over time.

Productivity is a key measure of sustainable growth, and growth in productivity is usually assumed to be related to the increase and adoption of new technology. In the case of agriculture, low productivity means more inputs per unit of output, which may lead to higher pollution, lower wages and lower farm incomes.

SRUC's Boosting Productivity Growth in Scottish Agriculture report assesses the productivity of agriculture in Scotland and elsewhere. Since 2000, agricultural productivity has been growing, with average annual growth of 1.5%. Scottish agricultural productivity appears to have had stronger growth than UK agricultural productivity overall. However, it is important to note that this is from a fairly low base.

Average annual growth in agricultural productivity by selected countries, 2000 to 2015



Source: Boosting Productivity Growth in Scottish Agriculture

The chart above shows international estimates of agricultural productivity growth, with variation over time. Scotland appears to sit around the middle of international rankings of agricultural productivity growth. It is important to note that the Scottish Government uses data from the agricultural census to calculate agricultural TFP internally, whereas TFP growth for the other countries is based on data published by the United States Department of Agriculture (USDA). Therefore, this comparison should be viewed with some caution.

In the case of agriculture, productivity can be heavily impacted by factors such as land quality, weather conditions and outbreaks of crop and livestock diseases. There are challenges to supporting agricultural productivity in Scotland, particularly around land and weather disadvantages, and lack of adoption of new and existing technologies.

Analysis shows a diversity of performance across these farm types and time periods with low or negative annual rates of change identified in most sectors in Scotland. Within recent years, cereals have shown the strongest growth, while LFA farm type have experienced a contraction.

Table 12. Total Factor Productivity Growth by Sector

	Cereals	LFA Cattle & Sheep	General Cropping	LFA Sheep	LFA Cattle	Dairy
2000-05	-0.2%	-0.2%	-0.7%	+0.4%	+0.1%	-0.1%
2006-10	-1.4%	+0.9%	+1.0%	+0.6%	+0.1%	+1.3%
2011-17	+1.2%	-0.3%	+0.7%	-0.1%	-0.8%	-2.1%

Source: SRUC, Boosting Productivity Growth in Scottish Agriculture, April 2020

Additionally, there is considerable variance in performance seen within farm types. This is particularly true for the LFA Sheep farming systems, which again show disturbances from weather but also policy reform, as these sectors are heavily reliant on subsidy systems.

3.2 Options for Improving Performance

3.2.1 Measures

3.2.1.1 Implementing Established Technologies

SRUC's Boosting Productivity Growth in Scottish Agriculture report provides a high level summary of a long list of measures which would potentially increase productivity in Scottish farming; broadly covering approaches to information sharing, financial schemes and management changes. Information sharing covers, for example, knowledge exchange, education and implementation. Financial schemes covers positive and negative effects of support and grant schemes. Further details on these can be found in Annex E. It should be noted that there are limits and caveats to both uptake and effectiveness of these measures and the report was not specifically targeted at the sector covered in this report.

The SRUC report highlights that in Scotland there is generally a low uptake of current, mainstream technologies and techniques. For Scottish livestock farms, better use of well-established feeding, breeding, health, marketing and budgeting practices should lift productivity and profitability on most farms, e.g. low uptake of sexed semen in dairy, sheep and beef sectors, limited rotational grazing practices, progeny tested sires and benchmarking and budgeting skills.

In Scotland, some farm businesses have not adopted basic practices which are already existing and available. For example, practices such as variable liming, consistent weighing of livestock, and business planning are all likely to improve business productivity at low cost to the farmer; however, they have not been widely adopted. Increased adoption of existing, low cost and practical approaches such as these is likely to increase Scottish agricultural productivity.

Previous efforts to increase agricultural productivity through policy have sometimes been “over-successful”, leading to negative impacts from intensification such as biodiversity loss and the “lock-in” of farmers on a productivity-debt cycle.

3.2.2 Current Uptake

The Survey of Agricultural Production Methods (2016) collected information on the usage of genetic information on holdings reporting the breeding of cattle and sheep. Holdings reporting the breeding of sheep had the lowest usage of genetic information: 77% of holdings reported not using information on genetics, 24% reported using specific breeds or traits, and 8% reported using genetic information such as EBVs.

Holdings reporting the breeding of beef cattle had a higher uptake – 23% of these holdings reported using genetic information, and 33% reported used specific breeds or traits. The highest usage of genetic information was found on holdings reporting the breeding of dairy cattle.

Discussions with researchers at SRUC also highlighted that at a UK level genomic testing in cows generally is around 1-2%. However, in the past 5 to 7 years the proportion of young genomically improved bulls (where scope for the greatest gains lies) being used has risen from around 25% to around 70% of inseminations and the benefits of that are starting to flow through to milk production.

Initiatives like the Farm Advisory Service (FAS) can provide a link between national policy and individual farmers, which can then translate the goals of policy into concrete actions.

The FAS One to Many service was procured by Scottish Government as part of the broader Scottish Rural Development Programme (SRDP) 2014-2020, and sought to improve the business and environmental performance of Scottish Agriculture through the provision of advice. There is clear evidence that the FAS One to Many delivered a wide-ranging programme, which appears to be well regarded by those who use it, as outlined in the recent Farm Advisory Service - One to Many: evaluation. However, this evaluation also demonstrated that FAS impacts are hard to measure. At present there is limited data about the extent of engagement with the programme, and limited monitoring of on-farm improvements resulting from that engagement. To ensure that the FAS can support policy delivery in the ways envisaged in this report, this gap will need to be addressed.

Annex A – Definitions and Classifications of Farms

Definitions

Farm Business Income (FBI)	The total income available to all unpaid labour (farmers and spouses, non-principal partners and directors and their spouses and family workers) and on their capital invested in the farm business, including land and buildings. Income from diversified activities are included in overall FBI.
Farm types	Farms are classified based on the how much of their standard output is from the crop and livestock enterprises on each farm.
Less Favoured Area (LFA)	Land where farming is more difficult due to natural constraints, such as hills and soil quality.
Standard Output	The standard output of an enterprise is an estimate of the average output value for every unit of production. It is defined as the estimated worth of crops and livestock without taking into account the costs incurred in the process.

Classification of Farms

The classification is based on detailed sub-types as defined in the European Commission (EC) farm typology 2, which have been grouped together where required to give the types shown below. The classification is based on the relative importance of the various crop and livestock enterprises on each farm assessed in terms of standard output. The method of classifying each farm is to multiply the area of each crop (other than forage) and the average number of each category of livestock by the appropriate standard output, with the largest source of output determining the type of farm. The list below defines the main types that are reported in the Farm Business Survey.

- ***Specialist Sheep (LFA)*** - Farms in the less-favoured areas with more than two thirds of the total standard output coming from sheep.
- ***Specialist Beef (LFA)*** - Farms in the less-favoured areas with more than two thirds of the total standard output coming from cattle.
- ***Cattle and Sheep (LFA)*** - Farms in the less-favoured areas with more than two thirds of the total standard output coming from sheep and beef cattle together.
- ***Cereals*** - Farms where more than two-thirds of the total standard output comes from cereals and oilseeds.
- ***General Cropping*** - Other farms where more than two-thirds of the total standard output comes from all crops.
- ***Dairy*** - Farms where more than two-thirds of the total standard output comes from dairy cows.
- ***Lowground Cattle and Sheep*** - Farms NOT in the less-favoured areas with more than two-thirds of the total standard output coming from sheep and beef cattle.
- ***Mixed*** - Farms where no enterprise contributes more than two-thirds of the total standard output.

Annex B – Tables

Table B1. Cattle and sheep numbers and holdings by region, 2019

	Specialist Lowland holdings			Holdings with no LFA land		
NUTS2 Region	**Animals (000’s)**		**Holdings**	**Animals (000’s)**		**Holdings**
	Cattle	Sheep		Cattle	Sheep	
North East Scotland	76	149	700	145	242	1,300
Eastern Scotland	39	138	600	122	260	1,400
Southern Scotland	54	109	600	99	198	1,000
Highlands & Islands	9	29	200	28	65	300
West Central Scotland	4	2	100	5	3	100
Total	**182**	**427**	**2,100**	**400**	**768**	**4,100**

Source: June Agricultural Census 2019, via RESAS Agricultural Analysis Unit

Table B2. Cattle and sheep numbers and holdings by herd size, 2019

	Specialist Lowland holdings			Holdings with no LFA land		
NUTS2 Region	**Animals (000’s)**		**Holdings**	**Animals (000’s)**		**Holdings**
	Cattle	Sheep		Cattle	Sheep	
1-149	22	27.0	1,400	60	40	2,500
150-299	28	19.4	200	78	43	600
300-499	30	29.6	200	74	60	300
500-999	38	83.0	200	83	161	300
1000 & over	64	267.9	200	104	465	300
Total	**182**	**426.8**	**2,100**	**400**	**768**	**4,100**

Source: June Agricultural Census 2019, via RESAS Agricultural Analysis

Table B3. Agricultural workforce in the LFA sector(s), 2019

	Specialist Lowland Holdings		Holdings with No LFA Land	
Category	*Holdings*	*Workforce*	*Holdings*	*Workforce*
Occupiers and spouses working more than half time	1,100	1,300	2,400	3,000
Occupiers and spouses working less than half time	1,200	1,600	1,700	2,100
Full-time employees	400	700	1,300	3,000
Part-time employees	300	400	800	1,200
Casual and seasonal workers	200	200	400	2,000
Total workforce	**2,000**	**4,300**	**3,500**	**11,400**

Source: June Agricultural Census 2019, via RESAS Agricultural Analysis Unit

Annex C – GHG Inventory Assumptions

Estimates of emissions by broad sector have been derived in line with descriptions in the inventory. Not all sources are disaggregated into specific sectors therefore the following sources in the inventory have been attributed based on the following percentages.

Table C1. Emission source attribution

IPCC	SourceName	Crops	Dairy	Deer	Goats	Horses	Beef	Pigs	Sheep
3H_Urea_application	Fertiliser Application	80%	10%				10%		
1A4cii_Agriculture/ Forestry/Fishing:Off-road	Agriculture - mobile machinery	60%	20%				20%		
3A4_Enteric_Fermentation _other_livestock	Enteric			7%	1%	67%		25%	
3D11_Inorganic_nitrogen _fertilizers	Grass - Direct		30%				60%		10%
3D14_Crop_residues	Grass - Direct		30%				60%		10%
3G1_Liming - limestone	Liming	50%	15%				30%		5%
3G2_Liming - dolomite	Liming	50%	15%				30%		5%

Michael MacLeod, Ilkka Leinonen and Vera Eory (2018) Biotic material flows in Scottish cattle supply chains SRUC 10/4/18

This results in the following estimates of GHG emissions for agriculture in 2018:

Table C2. Estimates of GHG emissions for agriculture, 2018

Agricultural Sector	Emissions in Inventory	Attributed based on expert input	Proportion attributed
	$MtCO_2e$	$MtCO_2e$	%
Beef	2.97	0.47	16
Crops	1.02	0.59	58
Dairy	0.86	0.31	36
Sheep	0.99	0.05	5
Other livestock	0.20	..	..
Uncategorised	0.02	..	..

Annex D – CXC Measures for LFA Cattle & Sheep

This annex contains an extract of mitigation measures from the CXC (2020) report that are specific to the dairy sector.

3NOP feed additive for cattle

3-Nitrooxypropanol (3NOP) is a chemical substance that reduces the emission of enteric methane by ruminants when added to their rations. It does so by reducing the rates at which rumen microbes convert the hydrogen in ingested feed into methane. Specifically, 3NOP inhibits the final step of methane synthesis by microbes. For housed animals, the 3NOP could be mixed in with the ration, while in grazing situations it may be possible to deliver the 3NOP via a bolus.

Overview

3NOP is a chemical that reduces the excretion of enteric methane by ruminants when added to their rations (or introduced via a bolus). It does so by reducing the rates at which rumen archaea convert the hydrogen in ingested feed into methane. Specifically, 3NOP inhibits methyl-coenzyme M reductase, the final step of methane synthesis by archaea (Duin *et al.* 2016).

The ingestion of a small amount of 3NOP each day is required, typically in the range of.0.05 to 0.2g NOP per kg of DMI (Javanegara *et al.* (2017), i.e. for cattle the effective dose is likely to be in the order of 2-3g of 3NOP/animal/day (Haisan *et al.* 2014, Martinez-Fernandez *et al.* 2018). For housed animals. the 3NOP could be mixed in with the ration. For grazing animals, it may be possible to deliver the 3NOP via a bolus (Rooke *et al.* 2016, p13).

Greenhouse gas mitigation summary

While 3NOP is a new mitigation measure (it was patented in 2012, Duval and Kindermann 2012) a range of experimental studies and meta-analyses have been undertaken. Most of the studies with 3NOP have focused on high quality concentrate-based diets. However Martinez-Fernandez et al (2018) found a reduction in enteric methane from beef cattle fed a roughage diet.

Table D1: Summary of studies of the mitigation effect of 3NOP

Livestock type	Parameter	Effect	Country	Year	Reference
Dairy cattle	Enteric methane yield Milk yield and fat Milk protein	-4 to -7% No effect Increase	UK	2014	Reynolds *et al.* (2014)
Beef cattle	Enteric methane yield Daily weight gain DMI	-33% No effect Small decrease	Canada	2014	Romero-Perez *et al.*, (2014)
Dairy cattle	Enteric methane yield DMI, milk yield Daily weight gain	-60% No effect Increased	Canada	2014	Haisan *et al.*, (2014)
Dairy cattle	Enteric methane yield DMI, milk yield	-30% No effect	USA	2015	Hristov *et al.*, (2015)

Livestock type	Parameter	Effect	Country	Year	Reference
	Daily weight gain	Increased			
Beef cattle	Enteric methane yield Daily weight gain DMI	-7 to- 81% (varies with diet and dose) No effect High dose: reduced	Canada	2016	Vyas *et al.*, (2016)
Beef and dairy cattle	Enteric methane yield	-30%	Canada	2016	Duin *et al.* (2016)
Ruminants	Enteric methane yield	-19 to -33%	Various	Various	Jayanegara *et al.*, (2017)
Beef cattle	Enteric methane yield Daily weight gain	-38% Increase	Australia	2018	Martinez-Fernandez et al (2018)
Beef cattle	Enteric methane yield FCR	-37 to -42% -5%	Canada	2018	Vyas *et al.* (2018)
Beef cattle **Dairy cattle**	Enteric methane yield Enteric methane yield	-17.1% ±4.2% -38.8% ±5.5%	Various	Various	Dijkstra *et al.* (2018)

*methane yield: the kg of methane per kg of dry matter intake (DMI)

Jayanegara *et al.* (2017) undertook a meta-analysis of 3NOP based on 12 *in vivo* studies from 10 articles. Their results showed that increasing level of 3NOP addition in diets of ruminants decreased enteric methane emissions per unit of DMI, while having no effect on DMI and limited effects on the production performance of both dairy cows and beef cattle. They concluded that “3NOP is an effective feed additive to mitigate enteric methane emissions without compromising productive performance of ruminants”. Papers published since 2017 reinforce this conclusion. Based on the above-mentioned results, we assumed that 3NOP reduces the enteric methane yield by 30% and 20%, respectively, in dairy and beef.

In theory, the feed energy otherwise lost as methane will be transferred for animal functions; this will improve the animal performance. Assuming that 10% of the feed energy is consumed in generating methane, and that the methane reduction as a result of the use of 3NOP ranges from 20% (beef) to 30% (dairy), then the reduction of feed consumption when 3NOP is used would range from 2% (beef) to 3% (dairy). As a conservative estimate, we applied a 2% yield increase for both dairy and beef.
It should be noted that changes in enteric methane conversion factor as a result of 3NOP are likely not to be additive with other methane mitigation methods, e.g. breeding and high-starch diet.

Costs

No one-off costs arising from the measure are predicted. The main recurring costs are likely to arise from the purchase and administering of 3NOP. It has been estimated that the cost of Mootral (an alternative to 3NOP) would be $50 per cow per year (Zwick 2017). i.e. £38.

Current uptake and maximum additional future uptake

In theory, 3NOP could be used with beef cattle, dairy cattle, and sheep. The current uptake of the measure is zero. The industry is seeking approval for commercial application of 3NOP by early 2021. If it is successful, the potential uptake rate from that date is 100% in Scotland - we assumed maximum uptake on all housed animals.

Assumptions used in the MACC

Table D2: Assumptions used in the modelling

Parameter	Change in value
Dairy	
Y_M	-30%
Milk yield	+2%
Cost	£38 animal^{-1}
Beef	
Y_M	-20%
Live weight	+2%
Cost	£38 animal^{-1}

Cattle breeding for low methane emissions

The composition of the micro-organisms present in the gut of mammals is influenced by the genetics of the host animal. Studies indicate that it is possible to select dairy cattle for low methane emission, as methane production is heritable to some extent. Inclusion of low enteric methane emission in the breeding goal could reduce methane emissions from cattle, though might limit the productivity and fitness improvements, as selection for low emission causes changes in the animal’s nutritional physiology.

The measure assumes that enteric methane emission is introduced in the breeding goal and therefore animals are started to be selected considering their enteric methane emissions. The measure requires farmers buying (semen from) breeding animals with lower methane emissions. The improvements in emissions are cumulative over the years as the emissions from the individual animals get reduced by breeding. Genetic improvement in the national herd can be enhanced by using genomic tools, while farmers collect performance information on the individual animals and genetic testing, and feed this information back for breeding goal development. As well as the methane emission reductions, using genomics also means production traits can be improved.

Overview

The composition of the micro-organisms present in the gut of mammals is influenced by the genetics of the host animal (Hegarty and McEwan, 2010). It has been shown possible to select sheep for high or low methane emissions, as methane production is heritable to some extent (Pinares-Patiño *et al.* 2013). Studies indicate that dairy cattle have the potential for genetic selection for low methane emission too (de de Haas *et al.* 2011, Roehe *et al.* 2016). Inclusion of low enteric-methane emission in the breeding goal could reduce methane emissions from cattle, but might limit the productivity and fitness improvements to some extent, because selection for low emission causes changes in the animal's nutritional physiology.

The measure entails starting breeding for low enteric-methane emission in the national herd (via including the methane emissions in the breeding indices) and farmers buying the animals with lower methane emissions. The improvements in emissions are cumulative over the years as the emissions from the individual animals get reduced by breeding.

Genetic improvement in the national herd can be enhanced by using genomic tools. This entails farmers collecting performance information on the individual animals and genetic testing and feeding back this information to breeding goal development. By using these tools not only can the gains in methane emission reduction be achieved more quickly but production traits can also be improved.

Greenhouse gas mitigation summary

Dairy and beef production would increase (annual gain of 0.75% in milk yield, milk protein and fertility for dairy, and annual gain of 0.25% in live-weight, growth rate and fertility for beef cattle), reducing the emission intensity of products, and the enteric methane conversion factor would decrease by 0.15% of its value every year.

Costs

To realise the measure £2.5m in research investment would be needed in the UK for the dairy herd, of which 9% would be attributed to Scotland (based on dairy cow proportions between the four nations). The beef research would need another £2.5m in the UK, 21% of it falling to Scotland. Furthermore, in every five years £0.5m would be needed to fund both the dairy and the beef genomic tools in the UK. The genomic testing required on farms costs £20 for each bull (either dairy or beef). It is assumed a dairy bull would serve 500 cows while a beef bull would serve 100 cows. The productivity gains would translate into increased income from sales at the farm level.

Current uptake and maximum additional future uptake

The measure is assumed to be applicable to 45% of the dairy and 20% of the beef herd.

Assumptions used in the MACC

Table D3: Assumptions used in the modelling

Parameter	Change in value
Dairy	
Milk yield	0.75% year^{-1}
Milk protein content	0.75% year^{-1}
Cow fertility	0.75% year^{-1}
Methane conversion factor	-0.15% year^{-1}
R&D cost	£2.5M in every 5 years in the UK (9% of it in Scotland)
Genomic tool cost	£0.5M in every 5 years (9% of it in Scotland)
Genomic testing	£20 bull^{-1} (serving 500 cows)
Beef	
Live-weight	0.25% year^{-1}

Parameter	Change in value
Growth rate	0.25% year^{-1}
Cow fertility	0.25% year^{-1}
Methane conversion factor	-0.15% year^{-1}
R&D cost	£2.5M in every 5 years in the UK (21% of it in Scotland)
Genomic tool cost	£0.5M in every 5 years (21% of it in Scotland)
Genomic testing	£20 bull^{-1} (serving 100 cows)

Covering slurry stores with impermeable cover

Animal excreta stored in liquid systems is a source of substantial ammonia and methane emissions, as during the storage N and the volatile solids excreted turn into these gaseous compounds. Though nitrous oxide is not generated in large quantities in slurry stores, a small portion of the ammonia turns into nitrous oxide subsequently in the environment (the process is called indirect nitrous oxide emission). Several factors affect the rate of ammonia, methane and nitrous oxide emissions, including the airflow over the manure; by covering the stores these emissions can be reduced. The presence of a slurry cover increases the ammonia concentration of the slurry and hence its nitrogen content and fertiliser value, but also the potential subsequent ammonia and nitrous oxide losses when the slurry is applied to the soil, unless low ammonia emission spreading techniques are implemented. Cover technologies include floating covers, rigid covers, natural crust and suspended, tent-like structures, and their effects on the pollutant gases are very different.

A review of experimental results showed that impermeable plastic covers have the potential to reduce ammonia and GHG emissions in parallel. However, there can be feasibility problems with floating covers if applied on slurry tanks or larger lagoons and their durability is not yet well tested. Impermeable covers do not inhibit methane formation, so the gas built up under the cover needs to be managed to avoid an explosion risk (in this measure the flaring or purification of the methane is not assumed). Furthermore, depending on the structure, rainwater can accumulate on impermeable floating covers and needs to be removed via e.g. pumping.

Overview

Animal excreta stored in liquid systems is an important source of ammonia and methane emissions because, during the storage, N and the volatile solids excreted turn into these gaseous compounds. In these systems (unless the slurry is aerated), direct nitrous oxide formation is less important as the anaerobic environment blocks denitrification (Sommer et al. 2000). However, a small portion of ammonia emissions turns into nitrous oxide (indirect nitrous oxide emissions). Several factors affect the rate of ammonia, methane and nitrous oxide emissions, including the airflow over the manure. Thus, by covering the store, these emissions can be reduced (Hou et al. 2014; VanderZaag et al. 2015).

Cover technologies include floating covers, rigid covers, natural crust and suspended, tent-like structures (VanderZaag et al. 2015). Ammonia loss is a physiochemical process controlled by the ability of ammonia in the slurry to diffuse to the atmosphere; covers restrict diffusion by creating a physical barrier. With reduced ammonia emissions, indirect nitrous oxide emissions also reduce. The presence of a slurry cover increases the ammonia concentration of the slurry and hence its N content and fertiliser value, but also potential subsequent ammonia and nitrous oxide losses when the slurry is applied to the soil, unless low ammonia-emission spreading techniques are implemented.

The effects of cover solutions on direct GHG emissions are less explored however, with variable and inconclusive results (Hou et al. 2014; Montes et al. 2013; Sajeev et al. 2018; VanderZaag et al. 2008; VanderZaag et al. 2015). Crust formation, straw addition and the use of granules, in particular, tend to increase nitrous oxide emissions substantially, often overriding the emission savings in methane and indirect nitrous oxide emission reductions (Hou et al. 2014; Sajeev et al. 2018). The effects of these covers on methane emissions are variable, with high probability of increased emissions. A review of Hout et al. (2014) showed that impermeable plastic covers have the potential to reduce ammonia and GHG emissions in parallel.

However, there are feasibility problems with floating covers, in general, if applied on slurry tanks or larger lagoons (not on small earth-banked lagoons), and their durability is not yet well tested (Amon et al. 2014). When the slurry is covered by impermeable films, the formation of methane is not eliminated, and the gas builds up under the cover and in the liquid, creating an explosion risk and escaping when the cover is opened (Montes et al. 2013). With additional devices (gas pipes and pumping system) most of the methane can be captured and converted to CO2 either by direct flaring, reducing the GWP substantially, or by purification and use in electricity or heat generation. Furthermore, depending on the structure, rainwater can accumulate on impermeable floating covers and needs to be removed via e.g. pumping.

Greenhouse gas mitigation summary

Table D4: Data from literature on abatement

Abatement	Value	Country	Reference
Methane emissions	-47% (g methane–C (kg VS)$^{-1}$)	Sweden	(Rodhe *et al.* 2012)
Direct nitrous oxide emissions	-100% (g nitrous oxide–N m^{-2})	Sweden	(Rodhe *et al.* 2012)
Ammonia emissions	-80% (range: -59% - -95%)	Various	Review of four papers in (VanderZaag *et al.* 2015)

Costs

Cost information on slurry covers has been collated by VanderZaag et al. (2015) from North American and UK sources. They estimated the capital costs of floating impermeable covers to be in the range of €1.70 m-2 to €63 m-2 with a lifespan of 8-10 years and 2% annual maintenance costs for rainwater collection. The high cost solutions included negative pressure covers to keep the film tight on the slurry surface.

Current uptake and maximum additional future uptake

The slurry covers can be installed on all slurry tanks and lagoons.

Assumptions used in the MACC

Table D5: Assumptions used in the modelling

Parameter	Change in value
Methane conversion factor	-47%
Direct nitrous oxide emissions from storage	-100%
Ammonia emissions from storage	-80%

Improved health of ruminants

Endemic, production-limiting diseases are a major constraint on efficient livestock production, both nationally and internationally, and have an impact on the carbon footprint of livestock farming. UK systems are particularly vulnerable to endemic disease impacts because they are largely pasture-based. The emissions intensity of ruminant meat and milk production is sensitive to changes in key production aspects, such as maternal fertility rates, mortality rates, milk yield, growth rates and feed conversion ratios - all of which are influenced by the health status of the animal. Therefore, improving health status is expected to lead to reductions in emission intensity. Animal health is a complex topic, influenced by a plethora of diseases. It can be improved through preventative controls (such as changing housing and management to reduce stress and exposure to pathogens; vaccination; improved screening and biosecurity; disease vector control) and curative treatments such as antiparasitics and antibiotics. In this work a simplistic approach was chosen; rather than estimating the GHG effects of the prevention and control of individual diseases, a general improvement in the health status was assumed, without reference to specific management options.

Overview

Endemic, production-limiting diseases are a major constraint on efficient livestock production, both nationally and internationally, and have an impact on the carbon footprint of livestock farming (Elliott et al. 2014). UK systems are particularly vulnerable to endemic disease impacts because they are largely pasture based. The emissions intensity of ruminant meat and milk production is sensitive to changes in key production aspects, such as maternal fertility rates, mortality rates, milk yield, growth rates and feed conversion ratios. All of these parameters are influenced by health status, so improving health status is expected to lead to reductions in emission intensity (Skuce et al. 2014). However, there have been few empirical studies investigating the impact of any of the production diseases on GHG emissions intensity.

Health can be improved through preventative controls (such as changing housing and management to reduce stress and exposure to pathogens, vaccination, improved screening and biosecurity, disease vector control) and curative treatments such as antiparasitics and antibiotics.

Greenhouse gas mitigation summary

The impact of endemic disease is difficult to quantify, often relying on old data from experimental challenge studies, which do not reflect the natural presentation of many of these diseases. ADAS (2014) attempted to quantify the impact of the top cattle health ‘conditions’ on the carbon footprint of a litre of milk, and the reductions that could be made via veterinary and/or farm management interventions. The study concluded that a 50% movement from current health status to a healthy cattle population (assumed to be the maximum improvement achievable) would reduce the UK emissions by 1436 kt CO2e year-1, or 6%. Eory et al. (2015) used a similar approach to quantify the effect of improving sheep health, and estimated that a 50% movement from current health status to a healthy sheep population would reduce the UK emissions by 484 kt CO2e year-1 by 2035.

Several studies have been undertaken since the 2015 MACC (Eory et al. 2015), which are briefly summarised below.

UK cattle and sheep health

Skuce et al. (2016) reviewed the evidence on prevalence and impact for 12 key ruminant diseases. They identified potential GHG emissions savings for all twelve diseases evaluated, while noting that some diseases are more tractable than others. They concluded that emissions intensity could be reduced through control measures relating to:

- milk yield and cow fertility rates (dairy systems)
- cow/ewe fertility and abortion rates
- calf/lamb mortality and growth rates (beef and sheep systems), and
- feed conversion ratios (all systems).

Three diseases, one from each of the major livestock sectors, were considered more cost-effective and feasible to control: neosporosis (beef cattle), infectious bovine rhinotracheitis, IBR (dairy cattle) and parasitic gastroenteritis (sheep).

Worms in sheep

Houdijk et al. (2017) undertook experiments to determine the effect of parasitism on the emissions intensity (EI) of sheep and found that infection with Teladorsagia increased calculated global warming potential per kg of lamb weight gain by 16%. Fox et al. (2018) also undertook experiments infecting sheep with Teladorsagia and found that infection led to a 33% increase in methane yield and a significant decrease in lamb growth rates, which led the authors to conclude that “there is potential for parasitism to have an extensive impact on greenhouse gas emissions”.

Worms in beef cattle

Gut worms are the most important gastrointestinal nematode parasites of grazing cattle, responsible for considerable sub-clinical disease and production loss. Bellet et al. (2016) undertook an abattoir study of prevalence and production impacts in England and Wales of Ostertagia spp. (the study also recorded the effects of rumen fluke and liver fluke). Based on this data set, MacLeod and Skuce (2019) estimated that the growth rates of cattle with a high Ostertagia burden were about 10% lower than those with a low burden. This translates into a difference in EI of 3.9%, i.e. the high-burden herd produced 3.9% more GHG for every kg of liveweight output. Assuming the overall burden could be halved with appropriate treatment implies that the EI could be reduced by 2%.

Liver fluke in beef cattle

Skuce et al. (2018) investigated the impact of liver fluke infection on cattle productivity and associated GHG emissions intensity (EI) using abattoir data from NE Scotland from 2014-2016. The study focused on a cohort of 22,349 Charolais males from a total dataset of ~250,000 cattle. Liver fluke infection resulted in a statistically significant reduction in liveweight gain of 0.023kg/day and an extra 21 days to slaughter. As a result, the EI of meat from a herd with no fluke is approximately 1% lower than the same herd with fluke. The study only focused on one impact of fasciolosis (reduced growth rates) - other effects include changes in feed conversion ratio, mortality and fertility, milk yields and quality of output (e.g. carcass conformation and rates of liver condemnation). These will have an additive effect on greenhouse gas EI, so removing fluke may have a much greater impact on EI in practice.

Lameness in dairy cattle

Lameness can reduce dairy cow milk yield, thereby increasing the EI of the milk produced. Chen et al. (2016) calculated the effect of lameness on EI, using the impacts of lameness reported in a series of studies undertaken in Europe and North America. They estimated that lameness can lead to an increase in emissions intensity of 1-8% compared to a baseline scenario, depending on the prevalence of the disease. Mostert et al. (2018) investigated the effects of three types of foot lesions in Dutch dairy cattle: digital dermatitis (DD), white line disease (WLD), and sole ulcer (SU). They found that the impacts of these lesions on milk yield and calving interval led to an average increase in milk emissions intensity of 1.5%.

Conclusion

The studies undertaken since 2015 indicate that the abatement potentials given for improved cattle and sheep health in Eory et al. (2015) are achievable (while bearing in mind that studies with negative findings are less likely to be submitted for publication). Furthermore, they provide specific examples of how the abatement potential might be achieved, i.e. by reducing the incidence of gastrointestinal parasites, liver fluke and lameness.

Costs

As improving livestock health is a very broad measure, encompassing a variety of livestock management, disease prevention and treatment options, this study, following previous studies, estimated the cost-effectiveness of the measures (based on earlier publications) and derived the costs from the cost-effectiveness.

Eory et al. (2015) estimated that improving cattle health could be achieved at an average of £-42 t CO2e-1, while the cost-effectiveness of improving sheep health would be £30 t CO2e-1. As there are many possible combinations of health challenges and treatments, the cost-effectiveness of achieving mitigation via improved health is likely to vary considerably; flocks and herds with below average health status are likely to provide scope for larger and more cost-effective reductions in greenhouse gas.

Current uptake and maximum additional future uptake

We assume that 80% of the herd could have improved animal health.

Assumptions used in the MACC

Table D6. Assumptions used in modelling

Parameter	Change in value
Milk yield	+6.38%
Cost	£28 animal^{-1}

Annex E - Productivity Measures – long list

Measures for Improving Performance – Information Sharing

Measure	Logic behind intervention	Potential barriers	Feasibility in Scotland
Farm advisory service	Studies have found high rates of return on public investment in applied advice.		Existing in the SRDP - could be extended
Farmer discussion groups	Studies have found high rates of return on public investment in applied advice.	Lack of strong evidence; depends on method and context.	Can be encouraged
Support for farmer learning	Support for new entrants and for continued professional development likely to increase adoption of new technologies and management practices.	Low turnover in farming.	Can be implemented
Agriculture education	Apprenticeships, college and university courses have improved the level of specialist knowledge among farmers in other countries.	Low turnover in farming.	Can be implemented
Required qualifications	Some countries have created "license to farm" to ensure continuous improvement of current farming systems, including environmental goals.	May be politically unpopular.	Can be implemented
Support for Research and Development	Research suggests that reduction of government support for R&D in the 1980s had a negative impact on productivity.	Must be strategic, targeted, and adopted by farmers.	Can be implemented
Demonstration farms	Some evidence to support that farmers who attend improve practice on their own farms.	Unclear how it would impact farmers at scale.	Relatively untested
Smart farms	Have been used in Australia to implement cutting edge technologies.	Potential high costs.	None existing in Scotland
Monitor farms	Evaluation suggests the model has been effective in improving farming performance and enterprise among active participants.	Potential high costs.	Existing - could be extended

Measures for Improving Performance – Financial Schemes

Measure	Logic behind intervention	Potential barriers	Feasibility in Scotland
Reduction in direct support	Most studies find a negative relationship between subsidies and productivity. May lead to significant restructuring in agriculture, particularly for smaller/more vulnerable farms.	Likely to have negative political impacts; may lead to further "middling out".	Can be implemented; may not be feasible due to Scottish agricultural context

Capital grants or loans	Studies find both positive and negative impacts on productivity: increased ability to innovate/develop business; low risk and potential crowding out. Loans may be more effective due to requirement to pay back.	May not be WTO eligible; may lead to overcapitalisation.	Can be implemented; limited by WTO rules
Support for new entrants	Younger entrants may have more innovative approaches to business, and may have stronger ICT and business planning skills.	Lack of retirement housing; lack of long leases for farmland.	Existing in the SRDP - could be extended
Support for exit	There are barriers to succession, meaning less productive management can continue longer than in other industries.	Lack of retirement housing; lack of business planning and succession.	Can be implemented
Changing tax incentives	Evidence from Ireland suggests that tax incentives for longer tenancies on agricultural land may increase productivity.	Potential high costs, both financial and administrative.	Can be implemented

Measures for Improving Performance – Established Technologies

Measure	**Logic behind intervention**	**Potential barriers**	**Feasibility in Scotland**
Precision Agricultural Techniques	Evidence suggests some PATs can reduce fuel use and management time; there is a training requirement for farmers.	High initial costs; high training requirement; lack of take-up by farmers.	Needs wider adoption
Nutrient management and soil nutrient mapping	Promising in increasing yield and additional benefits in managing GHG emissions	Lack of take-up by farmers.	Needs wider adoption
Improved soil management	For example, nutrient management and mapping; reduced cultivations to increase soil quality.	Lack of take-up by farmers.	Needs wider adoption
Robotic Milkers	More effective for larger herds and potential for growth; there is a training requirement.	Lack of take-up by farmers.	Can be encouraged
EID	Appears to give significant savings in labour use.	High initial costs; lack of take-up by farmers.	Needs wider adoption
EBVs; pedigree recording	Studies suggest EBVs can increase profitability of livestock farms.	High initial costs; lack of take-up by farmers.	Needs wider adoption
Changing cereal yields and varietal uptake	Improved crop yields have not been consistent across Scottish farms; it is not clear why this is so.	Lack of take-up by farmers.	Further research required

Measures for Improving Performance – Management Changes

Measure	Logic behind intervention	Potential barriers	Feasibility in Scotland
Precision livestock farming	Targeted precision livestock farming has potential to increase net margins per animal.	High initial costs; lack of take-up by farmers.	Needs wider adoption
Changing business size	Large farms tend to be more efficient and better adopters of new technology.	Politically unpopular "middling out"	Can be encouraged
Collaborative farming agreements	May be of particular benefit to new entrants, through increased availability of land.		Existing - could be extended
Disease control and eradication	Reduces loss and improves productivity.		Existing - could be extended
Risk management	Investment in productivity should be accompanied by steps to manage and reduce risk.	Could reduce incentive to innovate.	Can be implemented
Changing the input-output mix	Switching from specialised farms to more mixed operations may offer opportunities for recycling of inputs, and best use of land.	High training requirement for farmers.	Can be encouraged
Widen the range of planted crops	A wider range of crops could diffuse the intensity of work and machinery requirements over the course of the year.	High training requirement for farmers.	Further research required