Technical Annex: How land can be used to achieve greenhouse gas reduction goals

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Introduction

This annex presents the results of the analysis of mitigation undertaken for the Committee's land use report published in October 2018[1] by each country of the United Kingdom and to assess the main similarities and differences.

Five mitigation scenarios were developed for the Land use report. These scenarios reflect different possible future land use pathways, developed to explore a range of 'what if' land use change and land management options that are technically feasible between now and 2050. The scenarios assume that land for settlements is met before options to use land for emission reduction are considered; that the current level of UK food production per capita is maintained; and that land designated as national parks and protected areas continues to be so in the future. The scenarios are described in Table A1.

Table A1. Key elements of the CCC land use scenarios

Scenario	Description
1. Business as usual (BAU)	Existing trends in land use and management continue to 2050. Levels of agricultural productivity and innovation reflect past trends and little change in behaviour on diets and food waste.
2. High biomass/natural peatland (HBP)	Agricultural land is released through higher agricultural productivity and some changes in behaviour on diets and food waste. Focus on high tree and bioenergy crops planting rates and peatland restoration on land freed up from other uses.
3. Innovation and behaviour focus (IBF)	Maximum ambition for agriculture innovation and technology and high levels of change in behaviour towards healthy eating guidelines, and willingness to try novel food sources that could release more land. High tree planting and productivity rates helped by innovative techniques.
4. Multi-functional land use (MFLU)	Medium levels of ambition on innovation and behaviour to release agricultural land for other uses. High levels of hedgerows and trees on farms and areas of afforestation leading to a more diverse agricultural landscape.
5. Off-track	Land spared through higher agricultural productivity and technology used mainly for growing more food in the context of increasing global food demand. Focus on maximising agriculture output and exports, with low levels of ambition for afforestation and bioenergy.

Source: CCC analysis.
Notes: See the consultant's report for a full explanation of the assumptions underpinning these scenarios https://www.theccc.org.uk/publication/land-use-reducing-emissions-and-preparing-for-climate-change/

[1] CCC (2018) *Land use: Reducing emissions and preparing for climate change*.

Results by England and the Devolved Administrations

This section presents key modelling results across the different scenarios by each country of the United Kingdom. This covers:

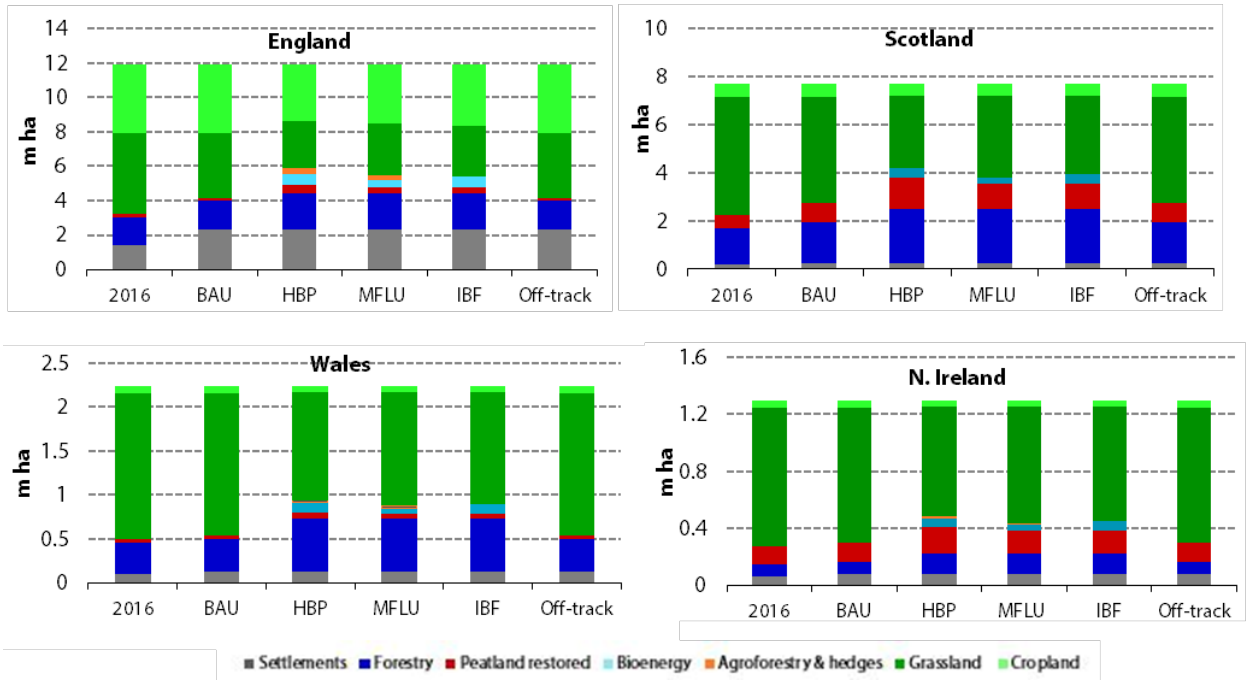
1. Land use in 2016 and under alternative scenarios in 2050.
2. GHG emissions to 2050.
3. GHG emissions by land use sector, 2050
4. Peatland emissions in 2016 and 2050.
5. Impact on agricultural output.
6. England NUTS 1 level results.

1. Land use in 2016 and under alternative scenarios in 2050

Figure A1 below shows how land is currently used across England and the Devolved Administrations (DAs) and how this could change under the alternative scenarios shown in Table A1. The main points from this analysis are:

- **England:** England has a larger proportion of land used for crops than in the DAs, making up around one-third of land area in 2016, compared with one-fifth for the UK as a whole. In the scenarios that offer significant emissions reduction (scenarios 2-4), the area used to grow crops reduces by 10-18% by 2050, but cropland continues to be the dominant land use. The area used for grassland declines by 37-42% across scenarios 2-4, with increases in forestry, biomass, restored peatlands and agro-forestry.
- **Northern Ireland:** The livestock sector dominates agriculture with over 90% of agriculture Gross Value Added (GVA) in 2016, with beef and dairy accounting for two-thirds. This reflects the high proportion of grassland, which comprise 75% of land area in 2016. Crops are only 4% of land, with forest land making up 6%. Given their dominance, grasslands offer the biggest opportunity to move to lower carbon land uses such as forestry, agro-forestry and biomass, which could increase by up to 11% of land by 2050.
- **Scotland:** Grassland was the main land use in Scotland in 2016, making up two-thirds of land, with croplands comprising 7%. One-fifth of land is currently forested, the highest proportion among all the countries, which could rise to almost approximately 30% under the deep emissions reduction scenarios. There is also the potential to double the area of restored peatland, from 0.6m hectares to over 1.4m hectares by 2050.
- **Wales:** Livestock is an important activity in Wales, with grassland being the dominant land use (74% in 2016). This could reduce by around 22-26% in scenarios 2-4, with land for forestry increasing by around 70%.

Figure A1: Land use in 2016 and under alternative scenarios, 2050



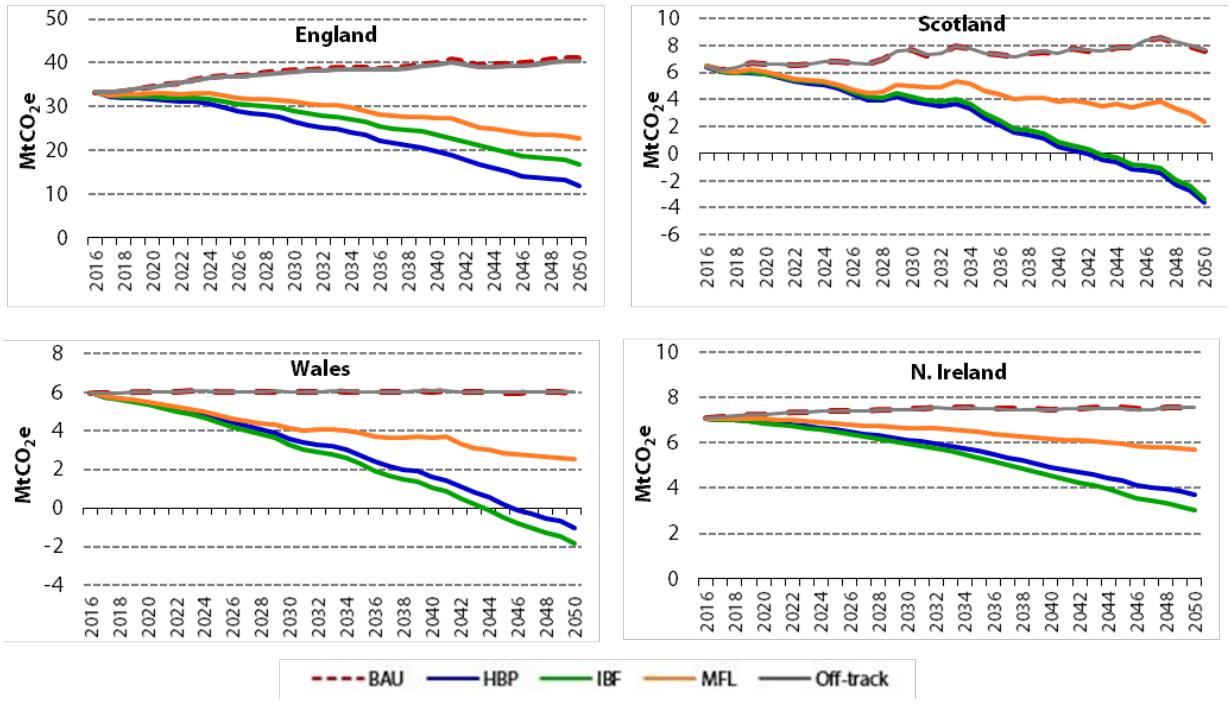
Source: CEH and Rothamsted Research (2018) and CCC analysis.

2. GHG emissions to 2050

The modelling results suggest that, for the UK as a whole, significant changes in land use patterns could deliver emissions reductions of between 35-80% (20-40 $MtCO_2e$) by 2050. The results disaggregated by each country of the UK show (Figure A2):

- England has a lower level of emissions reduction than the UK as a whole, of between 31-64% by 2050 (10-21 $MtCO_2e$), under scenarios 2-4. This reflects the high share of cropland in England, which has lower potential to switch to forestry than grassland under the land release measures and assumptions considered.
- Northern Ireland has the lowest level of emissions reduction among all the nations, 20-58% (1-4 $MtCO_2e$) by 2050 in scenarios 2-4. The share of non-urban land is 6% in Northern Ireland, but is responsible for 13% of GHG emissions, largely reflecting its large livestock sector and low forestry share.
- In Scotland emissions could reduce by 63-157% (4-10 $MtCO_2e$) by 2050 in scenarios 2-4, with negative net emissions from land sectors in scenarios with high afforestation rates.
- Wales has the potential for significant emissions reduction of 58-130% (3-8 $MtCO_2e$) by 2050 under scenarios 2-4. As in Scotland emissions are negative under the high biomass and innovation focus scenarios, reflecting high levels of woodland and biomass planting and peatland restoration.

Figure A2: GHG Emissions for different land use scenarios, 2016-2050



Source: CEH and Rothamsted Research (2018) and CCC analysis.
Notes: Includes emissions from land use change for settlement and urban expansion. A 2016 start date is illustrative only. In practice, pathways would start to diverge from BAU from the point at which land use drivers change.

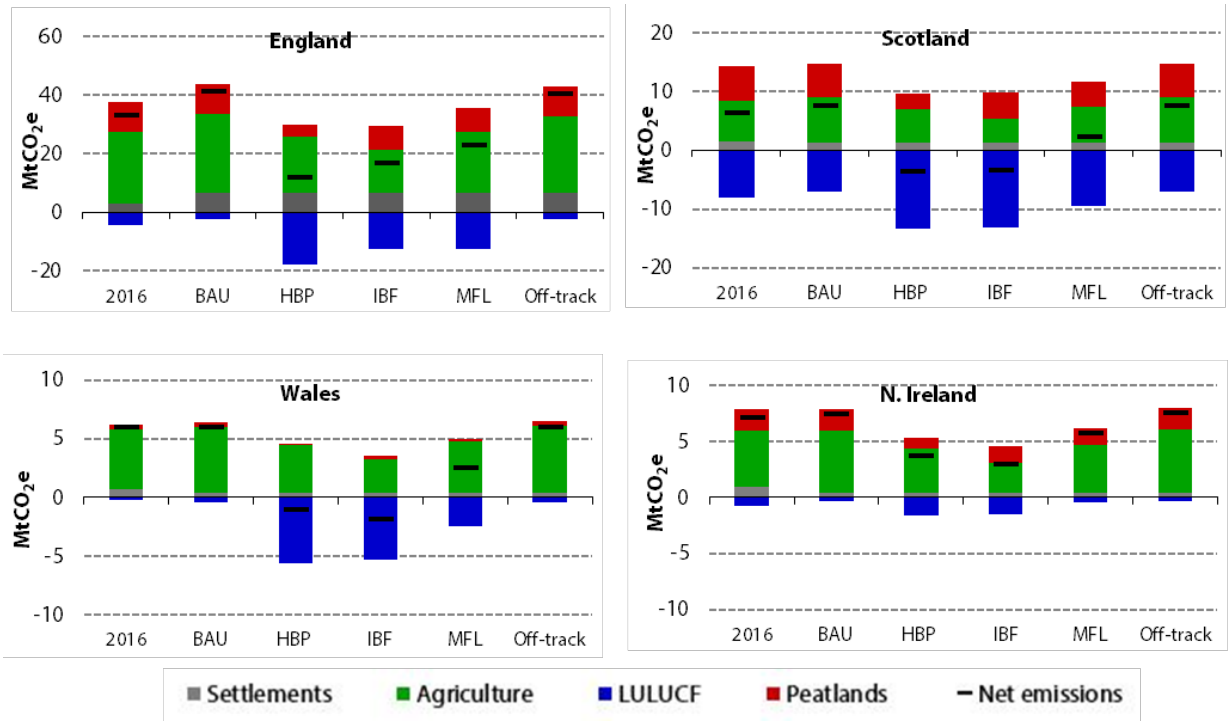
3. GHG emissions by land use sector, 2050

A key finding from Chapter 2 of the Committee's Land use report was that in order to deliver deep emissions reduction, integrated mitigation actions were needed in agriculture, forestry and peatlands, as these land uses are closely linked. This also applies to the individual nations of the UK, although there are differences in the relative importance of different sectors (Figure A3):

- Of the 10-20 $MtCO_2e$ reduction in emissions in England by 2050, the LULUCF sector contributes the most, 8-14 $MtCO_2e$, largely through afforestation and bioenergy followed by agriculture with 4-10 $MtCO_2e$.
- In Northern Ireland the absolute level of emissions reduction is much lower (1-4 $MtCO_2e$ by 2050) with up to 60% of this coming from reducing emissions from agriculture, with a lower proportion from afforestation and biomass.
- In Scotland emissions could reduce by 4-10 $MtCO_2e$ by 2050, with one-third to a just over one-half of the reduction in emissions from the LULUCF sector, reflecting the high woodland planting rates assumed in scenarios HBP and IBF. Restoring peatlands could also reduce peat emissions by 2-3 $MtCO_2e$ by 2050.

- In Wales, agriculture emissions dominate overall land emissions and continue to do so by 2050. The LULUCF sector could contribute up to around three-quarters of the reduction in emissions if high forestry and bioenergy planting rates are achieved.

Figure A3: Net GHG Emissions under different land use scenarios, 2050



Source: CEH and Rothamsted Research (2018) and CCC analysis.
Note: The HBP scenario includes partial rewetting (i.e. seasonal raising of the water table) on the area of lowland agricultural land that remains in agricultural production. LULUCF includes forestry, bioenergy, agro-forestry, hedges, and agriculture land use change.

4. Peatland emissions in 2016 and 2050

Two sub-scenarios for assessing peatland emissions were considered:

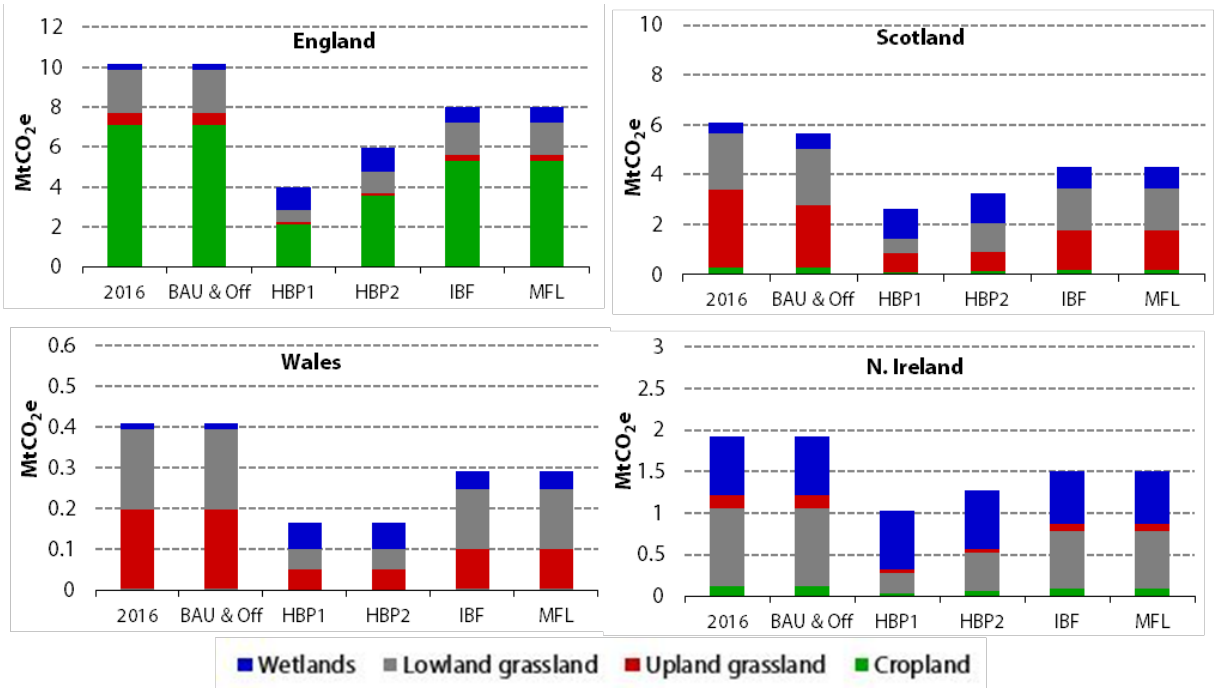
- HBP1 includes partial rewetting (i.e. seasonal raising of the water table) for the area of lowland agricultural peatland that is not restored.
- HBP2 excludes partial rewetting of unrestored lowland agricultural land.

Wetlands include extraction sites, rewetted peat and near-natural sites. The disaggregation by nation shows (Figure A4):

- In England, current peatland emissions are mainly from area used for crops, and offers the highest technical abatement potential in the future. Whilst there is a reduction in overall emissions from peatland restoration by 2050, there is an increase in emissions from wetlands in scenarios HBP1 and 2, IBF and MFL. This reflects an increase in area that is now restored wetlands, and the associated increase in methane (CH_4) emissions.

- In Northern Ireland most peatland emissions are currently in lowland grasslands followed by wetlands. Overall peatland emissions could reduce by 0.64 -0.89 $MtCO_2e$ (34-47%) under scenarios HBP1 and HBP2.
- Scottish peatland emissions are mainly from grasslands, both upland and lowland. The high peatland restoration scenarios (HBP1 and HBP2) could reduce peat emissions by 2.8-3.4 $MtCO_2e$ by 2050 (-47-56%).
- Wales has the lowest area of peatland and therefore the lowest peatland emissions of all the nations, mainly on grassland. Emissions from peatland can be reduced by up to 60% in the most ambitious restoration scenario (HBP1).

Figure A4: 2016 net peatland emissions and by scenario, 2050



Source: CEH and Rothamsted Research (2018) and CCC analysis.
Note: The HBP1 scenario includes partial rewetting (i.e. seasonal raising of the water table) on the area of lowland agricultural land that remains in agricultural production. LULUCF includes forestry, bioenergy, agro-forestry, hedges, and agriculture land use change

5. Impact on agriculture output

In constructing the alternative land use pathways, we took account of the different demands on land, including food demand. We assume that the level of food production per capita is at least maintained at current levels by 2050 and that the proportion of meat in imported food does not exceed current levels to avoid exporting emissions. Future exports are assumed to remain the same as in 2016 in absolute terms.

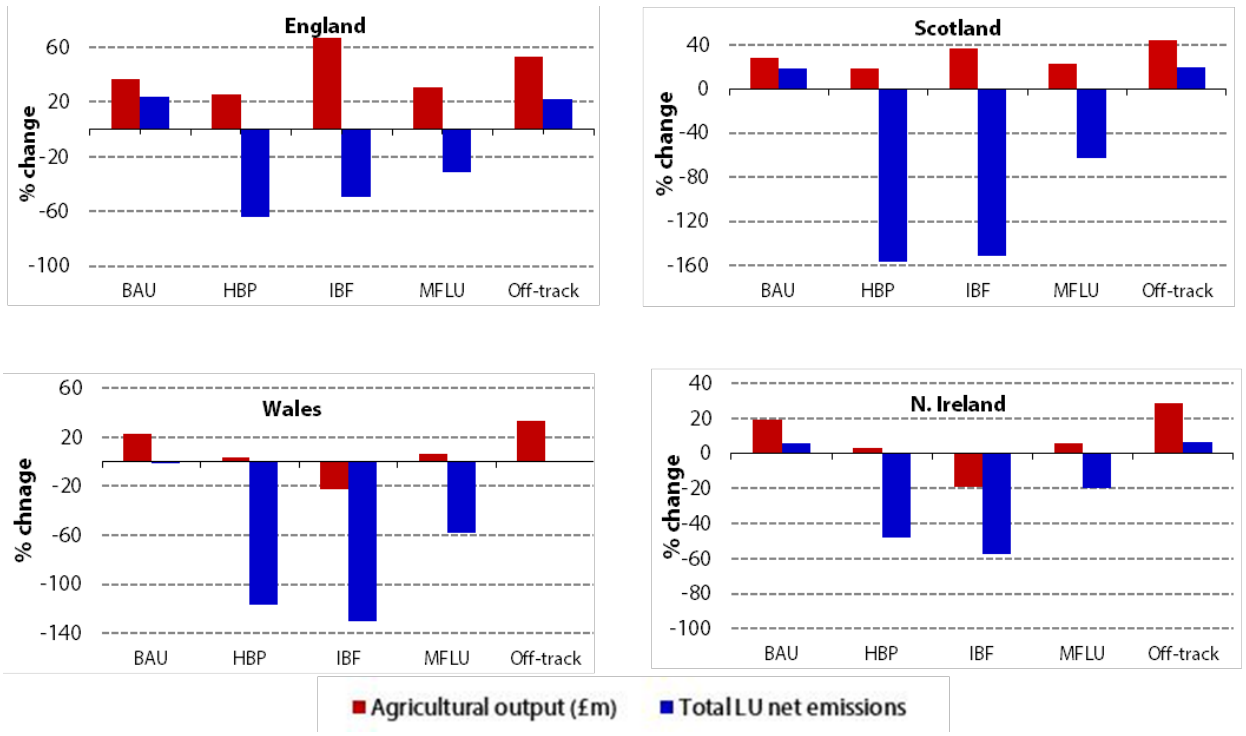
The modelling for the UK found that deep cuts in emissions can be achieved while increasing food output (in £m terms), and this was the case across all scenarios. The picture by each country is slightly different, particularly for Wales and Northern Ireland (Figure A5):

- In England, the scenarios that deliver deep GHG emission reduction (2-4) are associated with a 26-67% increase in agricultural output. This is a similar picture to the UK.
- In Northern Ireland, while agriculture output increases by 3-6% under the HBP and MFLU scenarios, it decreases significantly under the IBF (high innovation/high behaviour change) scenario. This is because of the reduction in the beef and dairy cattle numbers and the relative importance of the livestock sector in the country.
- In Scotland, agriculture output increases in all the scenarios, in parallel with a reduction in net GHG emissions.
- Wales is similar to Northern Ireland in having a large livestock sector relative to the total agriculture sector. In the IBF scenario, which assumes a high level of diet change away from red meat and dairy, there is a decrease in agricultural output of about 23% alongside a decrease in net GHG emissions of about 130%. The HBP and MFLU scenarios have a reduction in GHG emissions from land (58-117%) whilst increasing agricultural output (3-6%).

It is important to note that this analysis does not take account of the impact of changes in the value of output from other land based sectors, mainly forestry and bioenergy, which provide wood for timber and biomass products for the energy sector. As all scenarios that deliver deep emissions reduction have a higher volume of timber output, the value of these products would also be expected to rise in 2050 compared with 2016 levels. This is an area for further exploration.

It was also not possible to assess the potential UK and individual nation impacts on other services that land provides. These include regulating services (e.g. water regulation and erosion control), cultural services such as tourism and recreation and supporting services such as nutrient recycling and provision of habitats. However, these were considered on a case-study basis in Chapter 3 of the main land use report which found that transforming land to deliver climate objectives can also deliver wider environmental benefits in many cases. In areas where there are potential trade-offs, these need to be managed.

Figure A5: Change in agriculture output (£m) and change in net emissions by scenario, 2016 & 2050



Source: CEH and Rothamsted Research (2018) and CCC analysis.
Note: The modelling assumes exports remain at 2016 absolute levels, and imports per capita remain as in 2016. The exception is the Off-track scenario where food output and exports are higher. The value of agricultural products (e.g. per hectare or per livestock) is assumed to be constant in real terms, though the level of agricultural production changes across scenarios. Emissions cover agriculture and land use.

6. England NUTS 1 level results.

Tables A2-5 below set out the key modelling results for NUTS 1 level in England[2]. Note that the totals at this level of disaggregation do not match exactly the modelling results at the country level. This is due to two factors: a difference in estimates of urban expansion between the two sets of results and a difference in estimating the area of different land uses in each local authority. More detail on these is given in Box A1.

The main purpose of the NUTS 1 disaggregation is to show the potential differences between different areas of England.

[2] NUTS 1 is a geographical classification that sub-divides England into eight regions.

Box A1: Differences in results by DA and NUTS 1 region

In order to estimate the key outputs at NUTS 1 level, it was necessary to use a slightly different methodology than used for the country level results. The two key differences in the methodology are:

- In estimating the area of urban expansion a bottom-up approach was used with Ministry of Housing, Communities and Local Government (MHCLG) household projections used to give the projected increase in households at the local authority level. These were combined to give the NUTS 1 projected increase in demand for settlements, and the split by NUTS 1 level has been used to assign the area of conversion needed for settlements and associated emissions. This bottom-up approach gives a slightly different result in the amount of permanent grassland, temporary grassland and rough grassland converted to urban areas than the top-down approach used for the DA level splits. This is because the regions with a lot of land available (particularly rough grassland) have a much lower projected increase in urban area than areas such as SE England.
- A difference in the data and methodology used in estimating land uses for each country of the UK and the NUTS 1 regions:
  - The 2016 agricultural census for land areas in each country was used (permanent grassland, temporary grassland, rough grazing and common land, cropland). The Forestry Commission provided data on forest planting areas (conifer and broadleaf forest) and the Wetland Supplement report for peat mapping (arable and intensive grassland, extensive grassland, semi-natural (near natural, rewetted and peat extraction sites).
  - For disaggregation to the NUTS 1 level, the areas of cropland and improved grassland on peat soils that are used in the GHG inventory were used in each local authority. This was used to calculate the fraction of the English total area of cropland and permanent/temporary grassland on peat soils that are available for restoration that occurred in each NUTS 1 area. The other land uses on peat soils were assumed to be distributed in proportion to the distribution of rough grassland in each NUTS 1 region. These fractions were used to split the peatland emissions between each NUTS 1 region. Although the Wetland Supplement peat areas are more up to date, it was not possible to access the underlying spatial data from this source.

Source: CEH and Rothamsted Research (2018) and CCC analysis.

Table A2. Arable, grassland and forest areas (000 ha) by NUTS 1 region, 2016

NUTS1 region	Arable crops	Temporary grass	Permanent grass	Rough grazing	Forest
NE England	163	32	258	121	334
NW England and Merseyside	121	75	586	113	815
Yorkshire and the Humber	537	52	368	100	827
East Midlands	760	54	279	26	682
West Midlands	389	87	377	13	813
Eastern England	1,055	37	167	14	1,063
SE England (incl. London)	544	74	371	21	2,614
SW England	504	217	876	71	1,920
England	**4,073**	**628**	**3,282**	**479**	**9,768**

Source: CEH and Rothamsted Research (2018) and CCC analysis.

Table A3. Total grassland area (000 ha) converted into forest by NUTS 1 region, 2050

NUTS1 region	BAU	HBP	IBF	MFL
NE England	5.9	55.1	55.1	34.4
NW England and Merseyside	9.9	92.7	92.7	57.9
Yorkshire and the Humber	6.8	64.0	64.0	40.0
East Midlands	4.1	38.6	38.6	24.1

Table A3. Total grassland area (000 ha) converted into forest by NUTS 1 region, 2050				
NUTS1 region	**BAU**	**HBP**	**IBF**	**MFL**
West Midlands	5.1	47.7	47.7	29.8
Eastern England	2.4	22.6	22.6	14.1
SE England (incl. London)	5.2	23.8	23.8	30.3
SW England	12.6	143.6	143.6	74.3
England	**51.6**	**488.1**	**488.1**	**305.0**

Source: CEH and Rothamsted Research (2018) and CCC analysis.

Table A4. Total grassland area (000 ha) converted to peatland mitigation by NUTS 1 region ,2050				
NUTS1 region	**BAU**	**HBP**	**IBF**	**MFL**
NE England	0	41.8	27.5	27.5
NW England and Merseyside	0	46.1	29.3	29.3
Yorkshire and the Humber	0	36.0	23.5	23.5
East Midlands	0	10.0	6.5	6.5
West Midlands	0	7.1	4.3	4.3
Eastern England	0	14.9	8.2	8.2
SE England (incl. London)	0	8.0	5.2	5.2
SW England	0	30.6	19.2	19.2

Table A4. Total grassland area (000 ha) converted to peatland mitigation by NUTS 1 region ,2050

NUTS1 region	BAU	HBP	IBF	MFL
England	**0**	**194.5**	**123.6**	**123.6**

Source: CEH and Rothamsted Research (2018) and CCC analysis.