Projections of emissions and removals from the LULUCF sector to 2050

Amanda Thomson & Steve Hallsworth,

Centre for Ecology and Hydrology, Bush Estate, Penicuik, Midlothian, EH26 0QB. lulucf@ceh.ac.uk

Centre for Ecology & Hydrology

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Introduction

The UK is required to report projections of greenhouse gas emissions and removals from Land Use, Land Use Change and Forestry (LULUCF) activities for carbon budgets under the UK Climate Change Act, for the European Union Monitoring Mechanism and the UK Framework Convention on Climate Change. Previously, the Centre for Ecology & Hydrology (CEH) projected emissions/removals to 2020 based on the continuation of current trends in forest planting, land use change and other land use activities (the 'Business as Usual' or Mid scenario). Scenarios of high and low emissions above and below the Mid scenario were based on reduced or increased rates of forest planting or the upper or lower limits of the 95% confidence interval of current activity rates.

The UK now requires projections of emissions/removals to 2050 (the target date for 80% emissions reductions below the 1990 baseline in the UK Climate Change Act). Such an undertaking is more complex and cannot use the simple trend extrapolation of the 2020 projection methodology. Land use policies and aspirations (e.g. achieving a certain percentage of forest cover by 2050) need to be taken into consideration. Projected land use change also needs to be internally consistent, i.e. the increased area of one land use type will be matched by the reduced area of another.

Projections to 2050 have been made for carbon stock changes (resulting in net CO_2 emissions) and CO_2, CH_4 and N_2O emissions arising from LULUCF activities reported in the latest (1990-2010) greenhouse gas inventory. Three scenarios (High emissions, Mid emissions and Low emissions) have been constructed. Following a request by the Scottish Government, the scenarios were modified to include continuing cropland-grassland turnover (churn). Separate projections have been developed for each country (England, Scotland, Wales and Northern Ireland) and combined into a total for the UK. The assumptions underlying the projections were developed by a group of representatives from DECC, Defra, CEH and the Devolved Administration governments (see Annex 1).

Basis for projections

The LULUCF sector (sector 5 in the national greenhouse gas inventory) is divided into six land use types for reporting of emissions/removals: 5A Forest Land, 5B Cropland, 5C Grassland, 5D Wetlands, 5E Settlements, 5F Other Land. Net carbon stock changes from Harvested Wood Products are reported in 5G Other. Emissions of greenhouse gases to the atmosphere are expressed as positive quantities, and removals of carbon dioxide as negative quantities. The net LULUCF emission is the balance of emissions and removals across the seven categories (5A-5G): the net total is smaller than most of the category totals.

Calculations in the LULUCF inventory are done on the basis of activities, which can fall across several land use types (Table 1). The current inventory methodology was used to make the projections to 2050. There are detailed descriptions of the datasets and methodology in Chapter 7 and Annex 3.7 of the National Inventory Report (Brown *et al.*2012). The *Afforestation* and *Land Use Change (soils)* activities contribute the majority of the emissions/removals in the LULUCF sector. Accordingly, most

consideration was given to these activities and to *Deforestation* when developing the assumptions for the different scenarios. Emissions/removals from minor activities were held constant, except where noted otherwise.

Table 1: Activities producing emissions/removals of greenhouse gases in the LULUCF sector.

Activity	Description	Inventory category
Afforestation	The CEH carbon flow model, CFlow, models carbon stock changes in forest biomass, litter, soil and timber products, driven by forest planting rates since 1921. Estimates are adjusted to take account of losses due to deforestation. Nitrogen fertilization of 'poor' forest soils (a subset of total forest planting) produces N_2O emissions.	5A Forest Land (carbon stock changes, N_2O emissions) 5G Harvested Wood Products (carbon stock changes)
Wildfires	Biomass burning emissions from wildfires on forest land.	5A Forest Land (CO_2, CH_4 and N_2O emissions)
Land Use Change (soils)	Soil carbon stock changes due to land use change since 1950 are modelled using a combined land use change matrix/soil carbon model.	5B Cropland (carbon stock changes) 5C Grassland (carbon stock changes) 5E Settlements (carbon stock changes)
Land Use Change (non-forest biomass)	Biomass carbon stock changes are modelled using the same land use change matrix approach as for soils. Biomass carbon stock changes due to changes to and from Forest Land are estimated under the *Afforestation* and *Deforestation* activities.	5B Cropland (carbon stock changes) 5C Grassland (carbon stock changes) 5E Settlements (carbon stock changes)
N_2O emissions from LUC to Cropland	N_2O emissions due to disturbance associated with land use conversion to cropland .	5B Cropland (N_2O emissions)
Deforestation	Carbon stock changes in forest biomass and soils due to permanent conversion of forest land. A proportion of the felled trees are burnt, and the remainder are converted to timber products.	5A Forest Land (biomass carbon stock changes) 5B Cropland (soil carbon stock changes; CO_2, CH_4 and N_2O emissions) 5C Grassland (soil carbon stock changes; CO_2, CH_4 and N_2O emissions) 5E Settlements (soil carbon stock changes; CO_2, CH_4 and N_2O emissions) 5G Harvested Wood Products (carbon stock changes)
Liming	Emissions of CO_2 from the application of lime (dolomite and limestone) to agricultural land.	5B Cropland (CO_2 emissions) 5C Grassland (CO_2 emissions)
Lowland drainage	Carbon stock losses from historic drainage of lowland wetlands (in England only)	5B Cropland (soil carbon stock changes)
Yield improvements	Annual increase in cropland biomass due to yield improvements (improved species strains	5B Cropland (biomass carbon stock changes)

	or management).	
Peat extraction	On-site emissions of CO_2 and N_2O from peat extraction and off-site emissions of CO_2 from the decomposition of horticultural peat.	5D Wetlands (soil carbon stock changes; CO_2 and N_2O emissions)

Scenarios were developed from trajectories in the 2050 calculator report (Section E: Agriculture and Land Use) (DECC 2010) in discussion with the projections group (Annex 1). The Low emission scenario was based on trajectory C, which emphasizes bioenergy crop production and woodland creation. The High emission scenario was based on trajectory B, where the policy priority is to increase food production, and there is less focus on bioenergy crops and forestry (exploring the highest level of emissions that the sector might produce). The Mid emission scenario used land use change, afforestation and deforestation rates midway between the High and Low scenario rates.

Assumptions that remained constant across all scenarios:

- Land areas for each country of the UK are assumed to remain constant. They are taken from the Standard Area Measurement (national baseline). (Land loss due to sea level rise is assumed not to have an impact before 2050).
- LULUCF input data for the different countries 1990-2010 in the published inventories (Brown et al 2012) have not been changed and will feed through to the projected emissions.
- Afforestation: The split in planting between conifers and broadleaves is assumed to stay the same as in 2010 in each country (conifer: broadleaf ratios are 1:99 (England), 19:81 (Scotland), 7:93 (Wales), 1:99 (Northern Ireland)).
- Afforestation on settlement land (e.g. remediation of mineral workings) continues at same rate as currently. Otherwise, all conversion to forest land was from grassland.
- Land Use Change: the Settlement area increases at 17 kha p.a. across the UK (based on assumption in the 2050 calculator report).
- N_2O emissions resulting from land use conversion to Cropland: emissions are calculated using the same input data as for soil carbon stock changes from land use change.

The assumptions for each activity, by country and projection scenario, are shown in Table 2.

Table 2: Assumptions for the LULUCF projections

Activity	Low emission scenario	Mid emission scenario	High emission scenario	Reasons for assumptions
Afforestation	Increased afforestation rates from 2011 onwards (see Annex 2) England: increasing from 2.5 to 10 kha p.a. by 2020, 10 kha p.a. 2021-2040, reducing to 6.0 kha p.a. by 2050 Scotland: increasing from 7.5 to 10 kha p.a. by 2020, at 10 kha p.a. 2021-2050 Wales: increasing from 1 to 5 kha p.a. by 2015, at 6 kha p.a. 2021-2030, at 5 kha p.a. to 2050 N. Ireland: 0.2 kha p.a. 2011-2014, increasing to 1.7 kha p.a. by 2029, at 1.7 kha p.a. 2030- 2050	Afforestation rates are assumed to be midway between the Low and the High emission scenarios. England: 3.6 kha p.a. 2011-2019, 6.0 kha p.a. 2020-2039, 4.9 kha 2040-2050 Scotland: 5.99 kha p.a. 2011-2019, 6.36 kha p.a. 2020-2050 Wales: 2.11 kha p.a. 2011-2019, 3.11 kha p.a. 2020-2030, 2.6 kha 2031-2050 N.Ireland: 0.28 kha p.a. 2011-2019, 0.725 kha p.a. 2020-2039, 0.95 kha 2040-2050	Afforestation rates remain at same level as in 2010 England: 1.99 kha p.a. Scotland: 2.72 kha p.a. Wales: 0.22 kha p.a. N. Ireland: 0.2 kha p.a.	The Low scenario afforestation rates for individual countries were supplied by the Forestry Commission (based on policy aspirations). The High scenario continues 2010 planting rates (low level compared to historical rates). The Mid scenario assumed afforestation rates midway between those in the Low and High scenarios.
Wildfires	See Mid scenario. Trend plus pdf sampled at 5th percentile	Trend extrapolation. Trend and associated probability distribution function (pdf) are derived by autoregression with 10 lagged terms, fitted to data from 1990 (as reported by the Forestry Commission to FAO-GFRA). Incidence of wildfire in future given by the trend plus sampling from the pdf.	See Mid scenario. Trend plus pdf sampled at 95th percentile	Current practice for projections to 2020 extended to 2050.

Land Use Change (soils)	Based on trajectory C (2050 calculator). England: Cropland area is stable, Settlement area increases 13.5 kha p.a., Grassland area decreases 18.7-23.2 kha p.a. Scotland: Cropland area is stable, Settlement area increases 1.9 kha p.a., Grassland area decreases 10.7-11.7 kha p.a. Wales: 2.5 kha p.a. converted to cropland from grassland, Settlement area increases 1.4 kha p.a., Grassland area decreases 7.7-9.5 kha p.a. N.Ireland: Cropland area is stable, Settlement area increases 0.7 kha p.a., Grassland area decreases 1.0-2.4 kha p.a. Grassland-Cropland "churn" each way England: 56.60 kha p.a. Scotland: 16.65 kha p.a. Wales: 5.24 kha p.a. N. Ireland: 4.19 kha p.a.	Land use change rates mid-way between the Low and High scenario rates. England: Cropland area is stable, Settlement area increases 13.5 kha p.a., Grassland area decreases 16.1-19.1 kha p.a. Scotland: Cropland area is stable, Settlement area increases 1.9 kha p.a., Grassland area decreases 7.0-8.0 kha p.a. Wales: 5.5 kha p.a. converted to cropland from grassland, Settlement area increases 1.4 kha p.a., Grassland area decreases 8.9-9.6 kha p.a. N.Ireland: Cropland area is stable, Settlement area increases 0.7 kha p.a., Grassland area decreases 0.9-1.6 kha p.a. Grassland-Cropland "churn" each way England: 56.60 kha p.a. Scotland: 16.65 kha p.a. Wales: 5.24 kha p.a. N. Ireland: 4.19 kha p.a.	Based on trajectory B (2050 calculator). England: Cropland area is stable, Settlement area increases 13.5 kha p.a., Grassland area decreases 15.2 kha p.a. Scotland: Cropland area is stable, Settlement area increases 1.9 kha p.a., Grassland area decreases 5.0 kha p.a. Wales: 10.0 kha p.a. converted to cropland from grassland, Settlement area increases 1.4 kha p.a., Grassland area decreases 11.6 kha p.a. N.Ireland: Cropland area is stable, Settlement area increases 0.7 kha p.a., Grassland area decreases 0.9 kha p.a. Grassland-Cropland "churn" each way England: 56.60 kha p.a. Scotland: 16.65 kha p.a. Wales: 5.24 kha p.a. N. Ireland: 4.19 kha p.a.	The High and Low scenarios were based on trajectories from the 2050 calculator report, with the Mid scenario using rates mid-way between these. Separate cropland conversion rates were requested for Wales. Grassland-cropland "churn" rates were based on the average annual conversion of cropland to grassland and vice versa between 1990 and 2010 for each country.
Land Use Change (non-forest biomass)	Based on same conversion areas as Land Use Change (soils) above	Based on same conversion areas as Land Use Change (soils) above	Based on same conversion areas as Land Use Change (soils) above	Same assumptions as for Land Use Change (soils)
N$_2$O *emissions from LUC to Cropland*	Zero post-2010 LUC to cropland for England, Scotland and N. Ireland Wales: 2.5 kha p.a. converted to cropland from grassland Grassland-Cropland "churn" as assumed for Land Use Change (soils) England: 56.60 kha p.a. Scotland: 16.65 kha p.a. Wales: 5.24 kha p.a. N. Ireland: 4.19 kha p.a	Zero post-2010 LUC to cropland for England, Scotland and N. Ireland Wales: 5.5 kha p.a. converted to cropland from grassland Grassland-Cropland "churn" as assumed for Land Use Change (soils) England: 56.60 kha p.a. Scotland: 16.65 kha p.a. Wales: 5.24 kha p.a. N. Ireland: 4.19 kha p.a	Zero post-2010 LUC to cropland for England, Scotland and N. Ireland Wales: 10.0 kha p.a. converted to cropland from grassland Grassland-Cropland "churn" as assumed for Land Use Change (soils) England: 56.60 kha p.a. Scotland: 16.65 kha p.a. Wales: 5.24 kha p.a. N. Ireland: 4.19 kha p.a	Cropland areas assumed stable post-2010 for England, Scotland and N. Ireland. Separate cropland conversion rates were requested for Wales. Grassland-cropland "churn" rates were based on the average annual conversion of grassland to cropland between 1990 and 2010 for each country.

Deforestation	Deforestation rate assumed to be the same as the average rate 2001-2010, declining to zero 2020-2030 for forest-grassland and forest-cropland (England only) conversion. 2011-2020 England: 0.87 kha p.a Scotland: 0.52 kha p.a. Wales: 0.18 kha p.a. N.Ireland: 0.09 kha p.a. 2030-2050 England: 0.29 kha p.a Scotland: 0.22kha p.a. Wales: 0.13 kha p.a. N.Ireland: 0.05 kha p.a.	Deforestation rates are assumed to fall midway between the Low and High scenario rates.	High rates of deforestation (see Annex 2). England: 1.65 kha p.a. 2011-2015, falling to 0.3 kha p.a. by 2040. Scotland: 1.5 kha pa. 2010-2015, falling to 0.5 kha p.a. in 2020 and 0.3 kha p.a. by 2040 Wales: 0.05-0.35 kha p.a. 2010-2020, then 0.036 kha p.a. until 2050 N. Ireland: 0.17 kha p.a. in 2011 falling to 0.048 kha p.a. in 2040	Deforestation is considered to be probably under-reported in the current LULUCF inventory, due to a lack of information. Therefore, the Low scenario uses the current inventory rates. The High scenario deforestation rates for individual countries were supplied by the Forestry Commission, based on expert knowledge and unpublished data from the latest National Forest Inventory.
Liming	Amount of lime applied is assumed to be 25% below the average for 2001-2010.	Amount of lime applied is assumed to be the same as the average for 2001-2010.	Amount of lime applied is assumed to be 25% above the average for 2001-2010.	No clear trend in this activity.
Lowland drainage	Flux remains at 2010 value	Flux remains at 2010 value	Flux remains at 2010 value	No clear trend in this activity. Only reported for England.
Yield improvements	Flux remains at 2010 value	Flux remains at 2010 value	Flux remains at 2010 value	No clear trend in this activity.
Peat extraction	Current levels of extraction assumed to remain at same level as mean 2001-2010 level.	Current levels of extraction assumed to remain at same level as mean 2001-2010 level.	Current levels of extraction assumed to remain at same level as mean 2001-2010 level.	No clear trend in this activity.

Projections 2011-2050

A summary of the results is given here. Detailed emission estimates by activity, country and scenario area also available for download from the NAEI website.

The distribution of land use areas in each country between 2010 and 2050 is shown in Tables 3-5. The modified scenarios with increased cropland-grassland turnover will have the same overall land use areas as cropland-grassland and grassland-cropland conversion are equal. There is greatest land use change in the Low emissions scenario at the UK level (due to increases in forest area), but for Wales the greatest land use change is under the High emission scenario, due to the assumption of grassland-cropland conversion. Grassland is lost at the expense of other land use types under all scenarios.

Table 3: Land use areas 2010-2050 in the Low emission scenario

Country	Land use category	2010 area, kha	2020 area, kha	2030 area, kha	2040 area, kha	2050 area, kha	% of land area in 2010	% of land area in 2050
England	Forest land	1,128.0	1,179.6	1,273.5	1,370.6	1,445.8	9%	11%
13,044 kha	Grass- natural	966.1	933.0	871.7	807.2	756.8	7%	6%
	Grass- pasture	3,769.8	3,616.4	3,448.6	3,281.0	3,121.2	29%	24%
	Cropland	4,067.0	4,067.3	4,067.4	4,067.4	4,067.4	31%	31%
	Settlement	1,475.7	1,610.7	1,745.7	1,880.7	2,015.7	11%	15%
	Other	1,636.9	1,636.6	1,636.6	1,636.6	1,636.6	13%	13%
Scotland	Forest land	1,385	1,473	1,569	1,666	1,764	18%	22%
7,881 kha	Grass- natural	3,925	3,865	3,798	3,730	3,662	50%	46%
	Grass- pasture	1,233	1,187	1,138	1,090	1,041	16%	13%
	Cropland	572	572	572	572	572	7%	7%
	Settlement	191	210	229	248	267	2%	3%
	Other	575	575	575	575	575	7%	7%
Wales	Forest land	304	342	401	449	498	15%	24%
2,078 kha	Grass- natural	478	442	390	344	298	23%	14%
	Grass- pasture	1,055	1,014	971	929	888	51%	43%
	Cropland	87	112	137	162	187	4%	9%
	Settlement	152	166	180	194	208	7%	10%
	Other	2	2	0	0	0	0%	0%
Northern Ireland	Forest land	88	91	104	120	137	6%	10%
1,413 kha	Grass- natural	219	218	212	204	196	16%	14%
	Grass- pasture	733	725	711	695	680	52%	48%
	Cropland	56	56	56	56	56	4%	4%
	Settlement	80	87	94	101	108	6%	8%
	Other	237	237	237	237	237	17%	17%
UK	Forest land	2,905	3,086	3,347	3,607	3,845	12%	16%
24,415 kha	Grass- natural	5,589	5,457	5,272	5,085	4,913	23%	20%
	Grass- pasture	6,791	6,542	6,269	5,995	5,730	28%	23%
	Cropland	4,781	4,806	4,832	4,857	4,882	20%	20%
	Settlement	1,899	2,074	2,249	2,424	2,599	8%	11%
	Other	2,450	2,450	2,448	2,448	2,448	10%	10%

Table 4: Land use areas 2010-2050 in the Mid emission scenario

Country	Land use category	2010 area, kha	2020 area, kha	2030 area, kha	2040 area, kha	2050 area, kha	% of land area in 2010	% of land area in 2050
England	Forest land	1,128	1,154	1,207	1,263	1,309	9%	10%
13,044 kha	Grass- natural	966	948	912	874	843	7%	6%
	Grass- pasture	3,770	3,622	3,467	3,314	3,164	29%	24%
	Cropland	4,067	4,067	4,068	4,068	4,068	31%	31%
	Settlement	1,476	1,611	1,746	1,881	2,016	11%	15%
	Other	1,637	1,642	1,644	1,644	1,644	13%	13%
Scotland	Forest land	1,385	1,437	1,496	1,556	1,617	18%	21%
7,881 kha	Grass- natural	3,925	3,886	3,843	3,798	3,754	50%	48%
	Grass- pasture	1,233	1,193	1,154	1,115	1,076	16%	14%
	Cropland	572	572	572	572	572	7%	7%
	Settlement	191	210	229	248	267	2%	3%
	Other	575	583	587	591	594	7%	8%
Wales	Forest land	304	324	353	379	404	15%	19%
2,078 kha	Grass- natural	478	455	425	397	370	23%	18%
	Grass- pasture	1,055	980	905	830	755	51%	36%
	Cropland	87	149	211	274	336	4%	16%
	Settlement	152	167	181	196	210	7%	10%
	Other	2	3	2	2	2	0%	0%
Northern Ireland	Forest land	88	90	97	106	115	6%	8%
1,413 kha	Grass- natural	219	218	215	210	206	16%	15%
	Grass- pasture	733	725	714	702	691	52%	49%
	Cropland	56	56	56	56	56	4%	4%
	Settlement	80	87	94	101	108	6%	8%
	Other	237	238	238	238	239	17%	17%
UK	Forest land	2,905	3,005	3,153	3,304	3,445	12%	14%
24,415 kha	Grass- natural	5,589	5,507	5,395	5,281	5,173	23%	21%
	Grass- pasture	6,791	6,520	6,240	5,961	5,687	28%	23%
	Cropland	4,781	4,844	4,907	4,969	5,032	20%	21%
	Settlement	1,899	2,074	2,249	2,425	2,600	8%	11%
	Other	2,450	2,465	2,471	2,475	2,479	10%	10%

Table 5: Land use areas 2010-2050 in the High emission scenario

Country	Land use category	2010 area, kha	2020 area, kha	2030 area, kha	2040 area, kha	2050 area, kha	% of land area in 2010	% of land area in 2050
England	Forest land	1,128	1,133	1,144	1,159	1,176	9%	9%
13,044 kha	Grass- natural	966	960	951	940	927	7%	7%
	Grass- pasture	3,770	3,626	3,485	3,346	3,206	29%	25%
	Cropland	4,067	4,068	4,068	4,068	4,068	31%	31%
	Settlement	1,476	1,611	1,746	1,881	2,016	11%	15%
	Other	1,637	1,646	1,650	1,650	1,650	13%	13%
Scotland	Forest land	1,385	1,400	1,422	1,446	1,470	18%	19%
7,881 kha	Grass- natural	3,925	3,909	3,888	3,868	3,846	50%	49%
	Grass- pasture	1,233	1,199	1,170	1,140	1,112	16%	14%
	Cropland	572	572	572	572	572	7%	7%
	Settlement	191	210	229	248	267	2%	3%
	Other	575	591	599	607	614	7%	8%
Wales	Forest land	304	303	305	307	309	15%	15%
2,078 kha	Grass- natural	478	470	462	453	444	23%	21%
	Grass- pasture	1,055	947	840	732	625	51%	30%
	Cropland	87	186	286	386	486	4%	23%
	Settlement	152	166	180	194	208	7%	10%
	Other	2	4	5	5	5	0%	0%
Northern Ireland	Forest land	88	89	90	91	93	6%	7%
1,413 kha	Grass- natural	219	219	218	217	216	16%	15%
	Grass- pasture	733	725	717	709	701	52%	50%
	Cropland	56	56	56	56	56	4%	4%
	Settlement	80	87	94	101	108	6%	8%
	Other	237	238	239	240	240	17%	17%
UK	Forest land	2,905	2,925	2,961	3,003	3,048	12%	12%
24,415 kha	Grass- natural	5,589	5,557	5,519	5,477	5,434	23%	22%
	Grass- pasture	6,791	6,497	6,211	5,927	5,644	28%	23%
	Cropland	4,781	4,882	4,982	5,082	5,182	20%	21%
	Settlement	1,899	2,074	2,249	2,423	2,598	8%	11%
	Other	2,450	2,480	2,493	2,502	2,509	10%	10%

Projected emissions of CO_2, CH_4, N_2O and CO_2equivalents are shown in Tables 6-9. Graphs of the CO_2equivalents projections, for the UK and each Devolved Administration, are shown in Figures 1-5.

The LULUCF sector, at the UK level, is predicted to become a net source of GHG emissions at some point between 2011 and 2050 under all scenarios. This occurs at different times under different scenarios: as early as 2013 under the High-churn scenario, but not until 2030 under the Low scenario (where the UK LULUCF sector becomes a net sink again by 2036). The Forest Land, Cropland and Grassland categories dominate the trend: Forest Land is a shrinking net sink (due to a combination of forest management and historical planting distribution – discussed in more detail in the National Inventory report), Cropland is a shrinking net source under the non-churn scenarios (as Cropland conversion is assumed to be minimal after 2011) and Grassland is a shrinking net sink, as its area decreases at the expense of other land use types.

The LULUCF sector in England is a net source of GHG emissions under all scenarios, apart from the Low and Low-churn scenarios, where it becomes a small net sink after 2042 and 2046 respectively. All scenarios show a tendency for the net source to increase between 2011 and 2030 before decreasing to a relatively stable level between 2045 and 2050. Patterns in Cropland, Grassland and Forest Land are similar to the UK trends, except that Forest Land shows a tendency to become an increasing net sink after the mid-2020s under all scenarios.

The LULUCF sector in Scotland shows a shrinking of the net sink between 2011 and 2034 under all scenarios, becoming a net source under the High and the "churn" scenarios. This trend is dominated by the Forestland sector, where the net sink shrinks and oscillates around zero from 2030 onwards (due to a combination of forest management and historical planting distribution, as mentioned above). The Cropland and Grassland patterns are similar to the UK trends.

The LULUCF sector in Wales increases from a small net sink in 2010 to a net source under all scenarios. In the Low and Mid scenarios, the net emissions/removals decrease again from the mid-2020s (becoming a net sink in 2032 in the case of the Low scenario). In the High scenarios the net emissions/removals stabilise around 1800 Gg CO_2e from 2030 onwards. The spread of the scenarios is dominated by the Cropland (a range of Cropland conversion rates were assumed for Wales) and Forestland categories.

The LULUCF sector in Northern Ireland is a net source under all scenarios until post-2040 when the sector becomes a net sink again under the Low and Mid scenarios. Maximum net emissions occur between 2023 and 2032, with all scenarios showing a trend towards reduced net emissions after that point. This pattern is driven by the Forest Land sector, which is projected to become a small net source in 2020 for all scenarios, before becoming an increasing net sink again from 2030 onwards.

The "churn" scenarios demonstrate the impact that cropland-grassland turnover can have upon overall GHG emissions (through carbon stock changes and N_2O emissions arising from conversion to Cropland). They increase overall net emissions for all scenarios, as net emissions from Cropland are maintained, rather than declining over time, as in the original scenarios. Their impact in the Grassland category is to increase or maintain the size of the net sink, which is otherwise projected to shrink under the original scenarios. The assumption about the rate of cropland-grassland turnover merits more discussion, given the significant impact that it has on the net emissions of the LULUCF sector. The issue of cropland-grassland rotation, and its impact on soil carbon stock changes, is currently under investigation in DECC and Defra funded development programmes for the LULUCF inventory.

Table 6: LULUCF emissions and removals of CO_2 2010-2050

Scenario	Country	2010 emissions/removals, Gg CO_2	2020 emissions/removals, Gg CO_2	2030 emissions/removals, Gg CO_2	2040 emissions/removals, Gg CO_2	2050 emissions/removals, Gg CO_2
Low	England	1380.40	2218.81	1781.35	230.79	-583.06
Mid	England	1380.40	2467.94	2517.78	1320.26	947.71
High	England	1380.40	2909.39	3380.41	2634.26	2653.39
Low_churn	England	1380.40	3134.95	2914.08	735.41	-567.62
Mid_churn	England	1380.40	3384.08	3650.51	1824.87	963.15
High_churn	England	1380.40	3825.52	4513.14	3138.88	2668.84
Low	Scotland	-5765.11	-4468.49	-2257.77	-1322.38	-2164.23
Mid	Scotland	-5765.11	-4351.76	-1831.90	-578.31	-1070.64
High	Scotland	-5765.11	-4007.82	-1162.73	461.76	356.05
Low_churn	Scotland	-5765.11	-2633.27	307.21	839.01	-369.78
Mid_churn	Scotland	-5765.11	-2516.53	733.09	1583.07	723.81
High_churn	Scotland	-5765.11	-2172.60	1402.26	2623.15	2150.51
Low	Wales	-100.23	308.54	77.73	-617.05	-1419.29
Mid	Wales	-100.23	654.68	812.82	466.36	-9.96
High	Wales	-100.23	1130.57	1753.82	1794.91	1671.47
Low_churn	Wales	-100.23	451.28	256.28	-530.87	-1405.04
Mid_churn	Wales	-100.23	846.81	1072.22	635.35	83.27
High_churn	Wales	-100.23	1273.31	1932.36	1881.09	1685.73
Low	Northern Ireland	75.72	172.41	226.51	-56.27	-214.97
Mid	Northern Ireland	75.72	182.90	256.73	44.15	-36.82
High	Northern Ireland	75.72	220.82	324.92	173.91	174.13
Low_churn	Northern Ireland	75.72	388.77	493.15	59.70	-216.33
Mid_churn	Northern Ireland	75.72	399.26	523.36	160.12	-38.18
High_churn	Northern Ireland	75.72	437.18	591.56	289.89	172.77
Low	UK	-4409.22	-1768.73	-172.18	-1764.91	-4381.55
Mid	UK	-4409.22	-1046.24	1755.43	1252.45	-169.71
High	UK	-4409.22	252.96	4296.42	5064.84	4855.05
Low_churn	UK	-4409.22	1341.72	3970.72	1103.26	-2558.76
Mid_churn	UK	-4409.22	2113.62	5979.18	4200.42	1732.06
High_churn	UK	-4409.22	3363.41	8439.32	7933.01	6677.84

Table 7: LULUCF emissions and removals of CH_4 2010-2050

Scenario	Country	2010 emissions/removals, Gg CH_4	2020 emissions/removals, Gg CH_4	2030 emissions/removals, Gg CH_4	2040 emissions/removals, Gg CH_4	2050 emissions/removals, Gg CH_4
Low	England	0.70	0.71	0.20	0.20	0.20
Mid	England	0.70	0.87	0.49	0.29	0.27
High	England	0.70	1.38	1.08	0.90	1.01
Low_churn	England	0.70	0.71	0.20	0.20	0.20
Mid_churn	England	0.70	0.87	0.49	0.29	0.27
High_churn	England	0.70	1.38	1.08	0.90	1.01
Low	Scotland	0.42	0.46	0.16	0.16	0.16
Mid	Scotland	0.42	0.55	0.44	0.27	0.24
High	Scotland	0.42	1.08	1.18	0.95	0.93
Low_churn	Scotland	0.42	0.46	0.16	0.16	0.16
Mid_churn	Scotland	0.42	0.55	0.44	0.27	0.24
High_churn	Scotland	0.42	1.08	1.18	0.95	0.93
Low	Wales	0.18	0.15	0.09	0.09	0.09
Mid	Wales	0.18	0.21	0.09	0.08	0.07
High	Wales	0.18	0.36	0.17	0.16	0.19
Low_churn	Wales	0.18	0.15	0.09	0.09	0.09
Mid_churn	Wales	0.18	0.21	0.09	0.08	0.07
High_churn	Wales	0.18	0.36	0.17	0.16	0.19
Low	Northern Ireland	0.06	0.06	0.03	0.03	0.03
Mid	Northern Ireland	0.06	0.09	0.07	0.06	0.06
High	Northern Ireland	0.06	0.17	0.16	0.16	0.19
Low_churn	Northern Ireland	0.06	0.06	0.03	0.03	0.03
Mid_churn	Northern Ireland	0.06	0.09	0.07	0.06	0.06
High_churn	Northern Ireland	0.06	0.17	0.16	0.16	0.19
Low	UK	1.36	1.38	0.48	0.48	0.48
Mid	UK	1.36	1.72	1.08	0.69	0.64
High	UK	1.36	3.00	2.59	2.17	2.33
Low_churn	UK	1.36	1.38	0.48	0.48	0.48
Mid_churn	UK	1.36	1.72	1.08	0.69	0.64
High_churn	UK	1.36	3.00	2.59	2.17	2.33

Table 8: LULUCF emissions and removals of N_2O 2010-2050

Scenario	Country	2010 emissions/removals, Gg N_2O	2020 emissions/removals, Gg N_2O	2030 emissions/removals, Gg N_2O	2040 emissions/removals, Gg N_2O	2050 emissions/removals, Gg N_2O
Low	England	0.80	0.47	0.29	0.18	0.11
Mid	England	0.80	0.47	0.29	0.17	0.11
High	England	0.80	0.47	0.29	0.18	0.11
Low_churn	England	0.80	0.85	0.86	0.88	0.88
Mid_churn	England	0.80	0.85	0.86	0.87	0.88
High_churn	England	0.80	0.85	0.87	0.88	0.89
Low	Scotland	0.96	0.57	0.35	0.21	0.13
Mid	Scotland	0.96	0.57	0.35	0.21	0.13
High	Scotland	0.96	0.57	0.35	0.21	0.13
Low_churn	Scotland	0.96	1.00	1.01	1.02	1.02
Mid_churn	Scotland	0.96	1.00	1.01	1.02	1.02
High_churn	Scotland	0.96	1.00	1.01	1.02	1.02
Low	Wales	0.18	0.13	0.11	0.09	0.08
Mid	Wales	0.18	0.16	0.16	0.15	0.15
High	Wales	0.18	0.21	0.23	0.24	0.25
Low_churn	Wales	0.18	0.19	0.19	0.20	0.20
Mid_churn	Wales	0.18	0.20	0.20	0.20	0.20
High_churn	Wales	0.18	0.27	0.32	0.35	0.36
Low	Northern Ireland	0.09	0.11	0.07	0.04	0.03
Mid	Northern Ireland	0.09	0.11	0.07	0.04	0.03
High	Northern Ireland	0.09	0.11	0.07	0.04	0.03
Low_churn	Northern Ireland	0.09	0.20	0.21	0.21	0.21
Mid_churn	Northern Ireland	0.09	0.20	0.21	0.21	0.21
High_churn	Northern Ireland	0.09	0.20	0.21	0.21	0.21
Low	UK	2.02	1.28	0.81	0.52	0.35
Mid	UK	2.02	1.31	0.86	0.58	0.41
High	UK	2.02	1.37	0.94	0.68	0.52
Low_churn	UK	2.02	2.24	2.28	2.30	2.31
Mid_churn	UK	2.02	2.24	2.28	2.30	2.31
High_churn	UK	2.02	2.32	2.40	2.45	2.49

Table 9: LULUCF emissions and removals of CO2 equivalents2010-2050

Scenario	Country	2010 emissions/removals, Gg CO_2e	2020 emissions/removals, Gg CO_2e	2030 emissions/removals, Gg CO_2e	2040 emissions/removals, Gg CO_2e	2050 emissions/removals, Gg CO_2e
Low	England	1641.70	2379.43	1874.11	289.38	-545.66
Mid	England	1641.70	2631.69	2616.58	1380.28	986.53
High	England	1641.70	3084.79	3492.68	2708.11	2709.13
Low_churn	England	1641.70	3412.26	3186.14	1011.28	-289.90
Mid_churn	England	1641.70	3664.52	3928.62	2102.18	1242.29
High_churn	England	1641.70	4117.62	4804.71	3430.01	2964.88
Low	Scotland	-5459.23	-4282.12	-2146.81	-1252.80	-2119.76
Mid	Scotland	-5459.23	-4164.39	-1715.34	-507.11	-1025.20
High	Scotland	-5459.23	-3808.66	-1029.60	548.14	417.00
Low_churn	Scotland	-5459.23	-2313.04	623.87	1157.84	-49.63
Mid_churn	Scotland	-5459.23	-2195.30	1055.34	1903.53	1044.94
High_churn	Scotland	-5459.23	-1839.58	1741.08	2958.78	2487.13
Low	Wales	-41.54	352.74	112.72	-587.04	-1392.22
Mid	Wales	-41.54	709.99	862.90	514.46	37.11
High	Wales	-41.54	1204.33	1828.69	1873.05	1752.27
Low_churn	Wales	-41.54	513.08	318.32	-468.06	-1341.70
Mid_churn	Wales	-41.54	912.48	1135.24	694.97	145.82
High_churn	Wales	-41.54	1364.67	2034.30	1992.02	1802.80
Low	Northern Ireland	105.39	208.91	248.48	-42.51	-206.18
Mid	Northern Ireland	105.39	219.67	279.44	58.43	-27.47
High	Northern Ireland	105.39	259.56	349.81	190.61	186.54
Low_churn	Northern Ireland	105.39	452.77	557.83	125.23	-150.29
Mid_churn	Northern Ireland	105.39	463.83	588.79	226.17	28.42
High_churn	Northern Ireland	105.39	503.71	659.16	358.35	242.43
Low	UK	-3753.69	-1341.34	88.50	-1592.97	-4263.83
Mid	UK	-3753.69	-603.03	2043.58	1446.06	-29.02
High	UK	-3753.69	640.02	4641.58	5319.91	5064.93
Low_churn	UK	-3753.69	2065.07	4686.17	1826.29	-1831.52
Mid_churn	UK	-3753.69	2845.52	6707.99	4926.84	2461.47
High_churn	UK	-3753.69	4146.43	9239.25	8739.17	7497.24

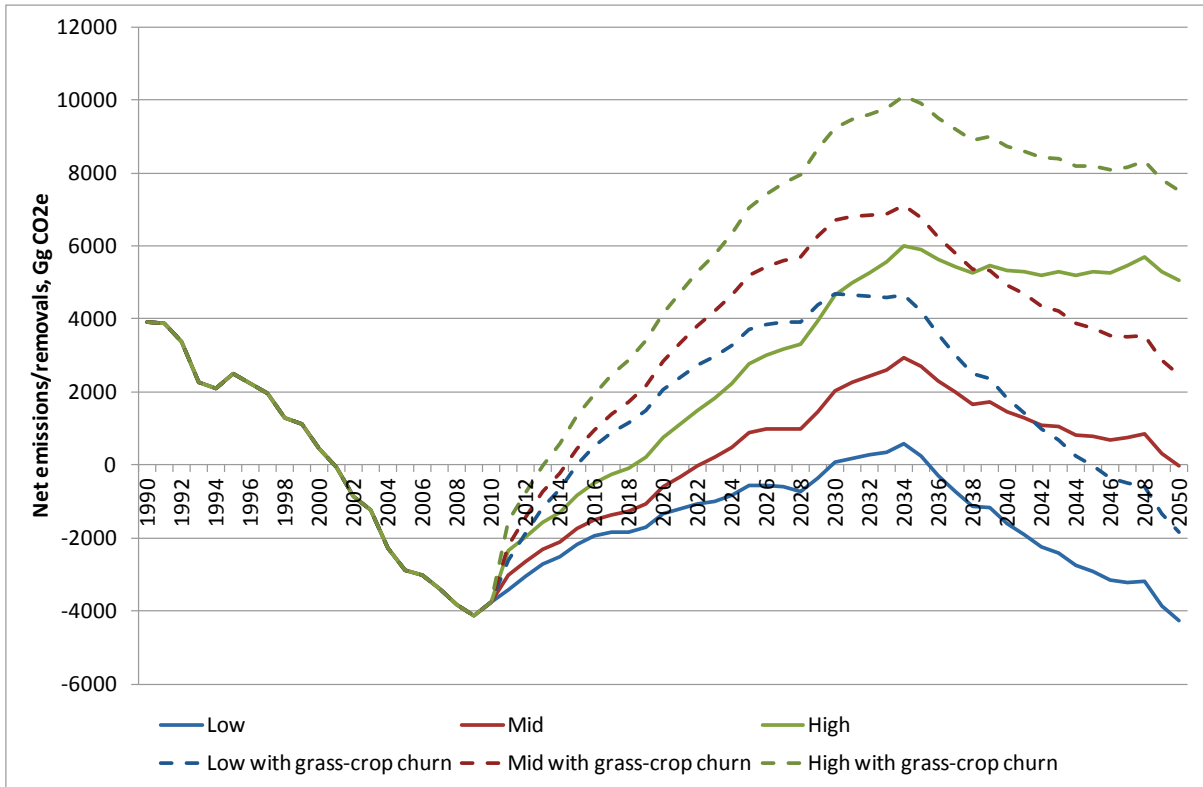Figure 1: UK LULUCF sector emissions scenarios 1990-2050

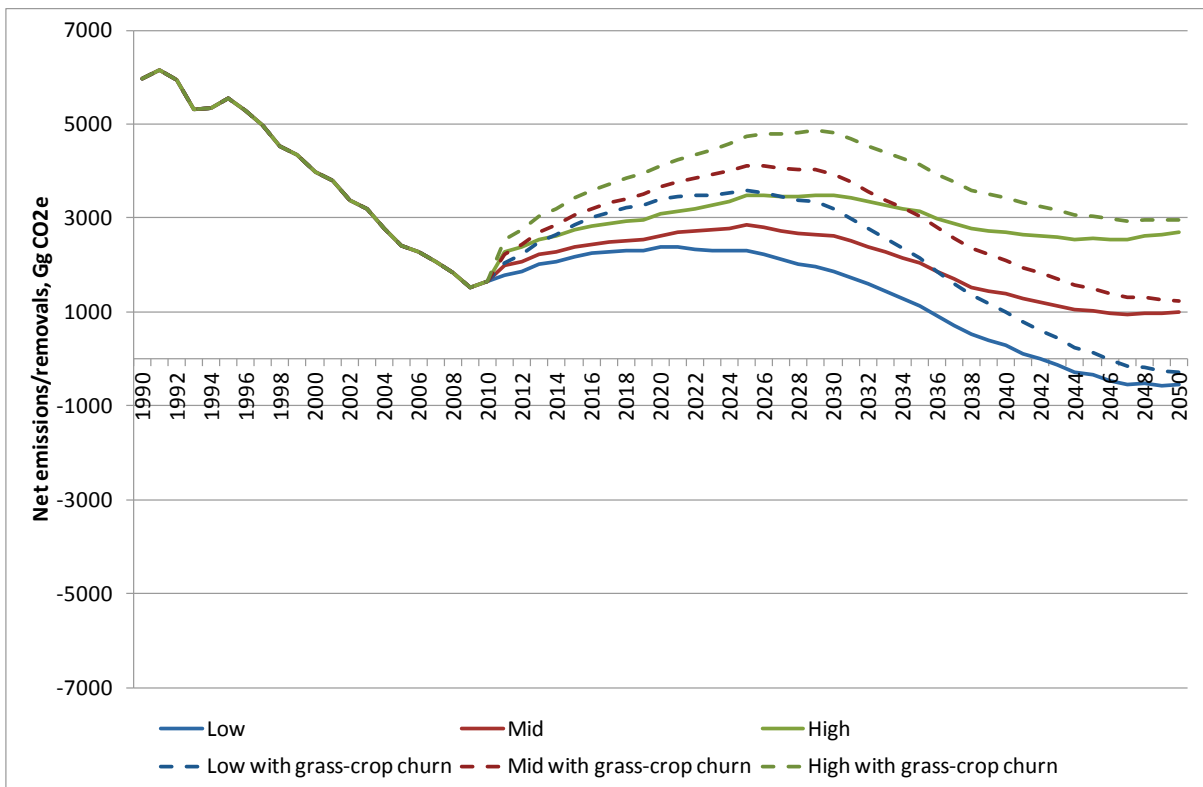Figure 2: England LULUCF sector emissions scenarios 1990-2050

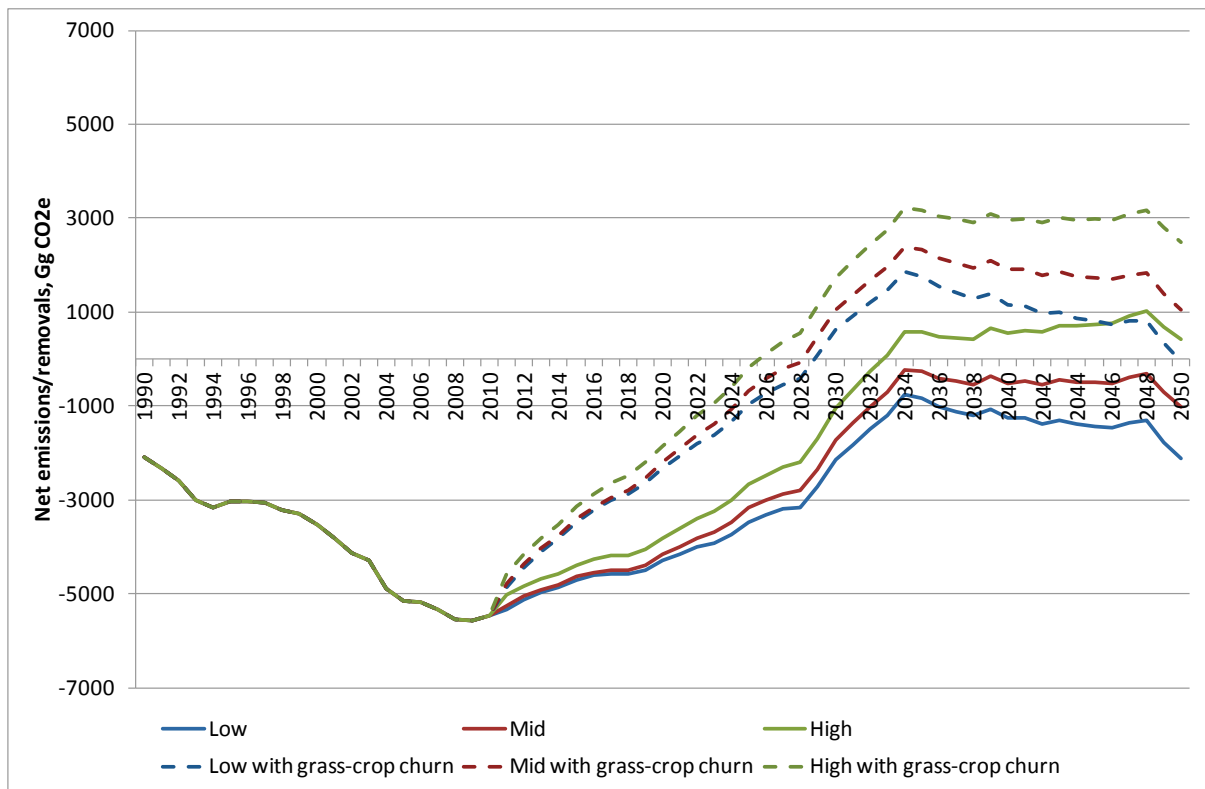Figure 3: Scotland LULUCF sector emissions scenarios 1990-2050

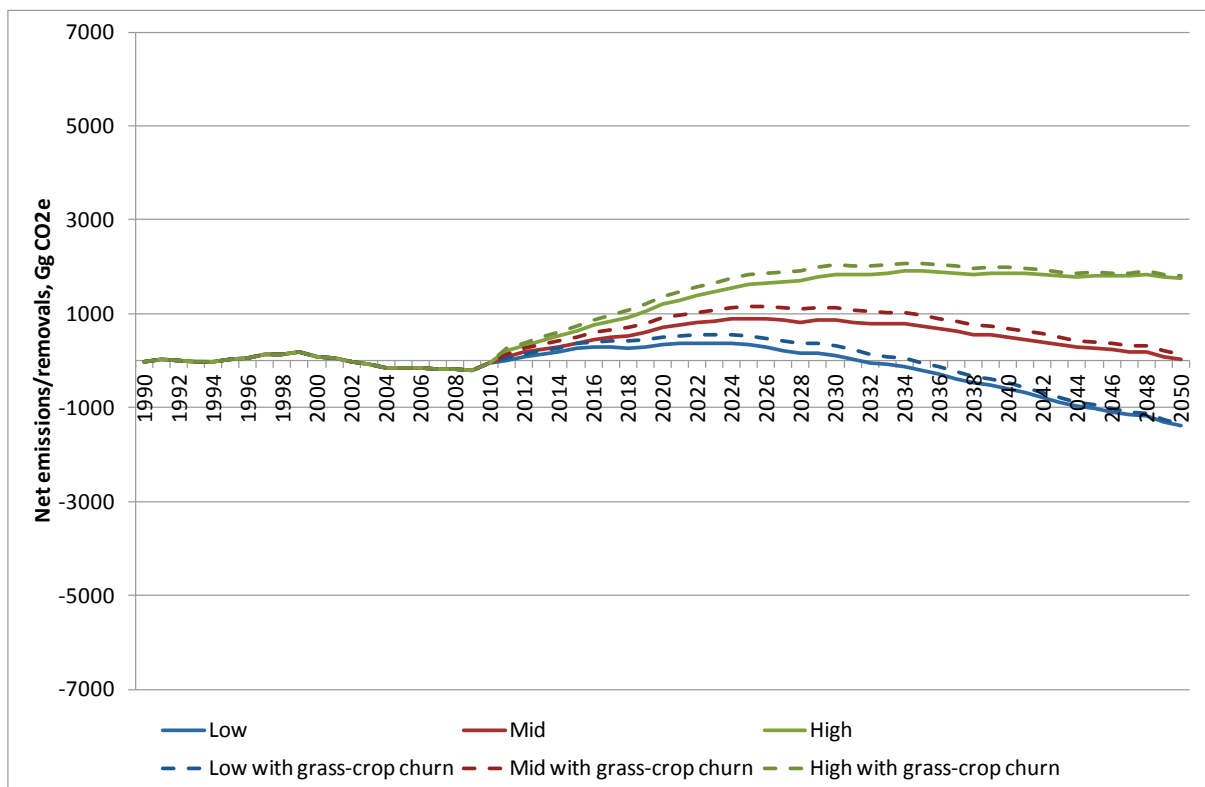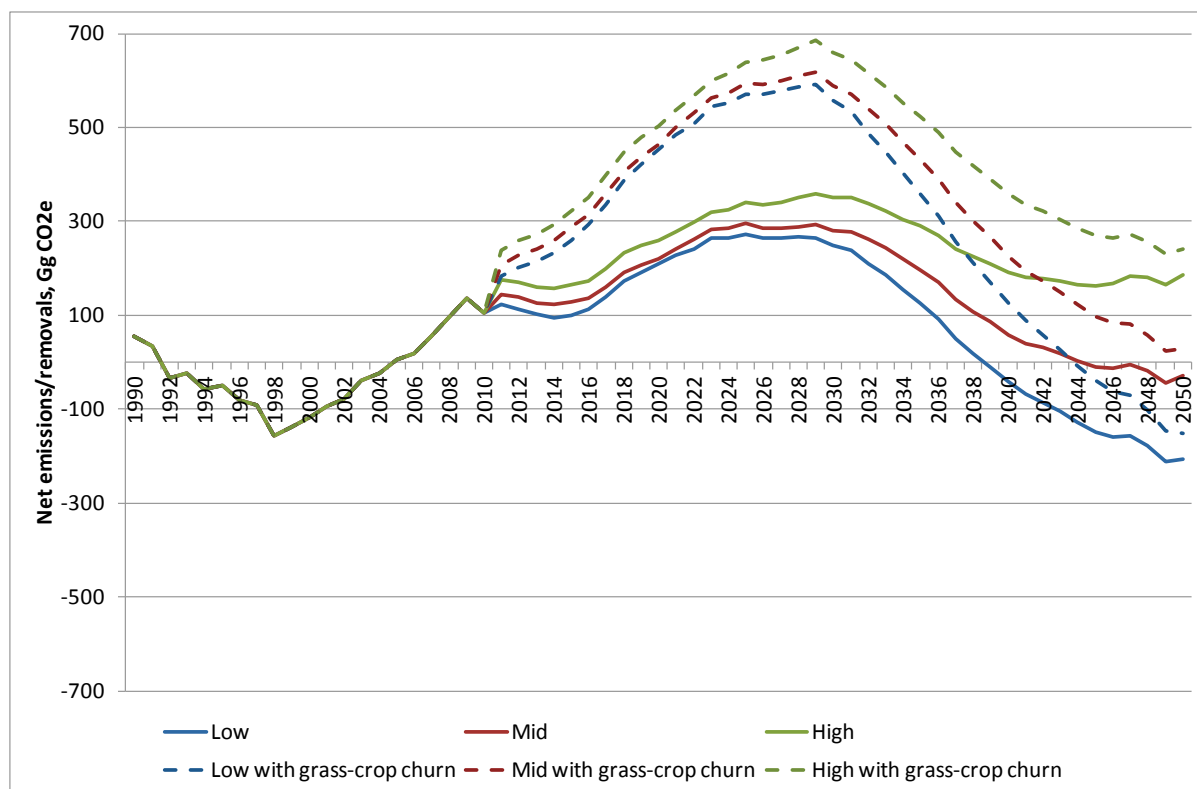Figure 4: Wales LULUCF sector emissions scenarios 1990-2050

Figure 5: Northern Ireland LULUCF sector emissions scenarios 1990-2050 (scale is different from other graphs)

Further work

This work was envisaged as a first iteration of the projections, aiming to feed into the Fourth Carbon Budget analysis and encourage discussion of the assumptions. Forest Research is undertaking further work looking at the impact of woodland management on net emissions in the Forest Land category. This will be incorporated into the projections once it becomes available. Further work to update these projections is planned for 2013, with further development of assumptions and scenarios.

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Annex 1: Members of the projection assumption development group

- Matthew Brown, Defra
- Judith Stuart, Defra
- Marjorie Roome. DECC
- Philip Earl, Defra
- Bill Parish, Defra
- Marion Rawlins, Defra
- Daniele Viappiani, Defra
- Jim Penman, DECC
- Sekai Ngarize, DECC
- Aimee Griffiths, DECC
- Amanda Thomson, CEH
- Heath Malcolm, CEH
- Mark Broadmeadow, Forestry Commission
- Robert Matthews, Forest Research
- Liam Kelly, Scottish Govt
- Sinclair Mayne, NI Govt
- Peter Scott, NI Govt
- James Skates, Welsh Assembly Govt

Annex 2: Forestry Commission estimates of afforestation and deforestation

Afforestation rates for the low emission scenario (gross area planted each year, kha)

Year	England	Wales	Scotland	NI
2010	2.3	0.1	2.7	0.2
2011	2.5	1.0	7.5	0.2
2012	3.0	2.0	8.0	0.2
2013	3.7	3.0	8.5	0.2
2014	4.6	4.0	9.0	0.2
2015	5.5	5.0	9.5	0.3
2016	6.4	5.0	10.0	0.4
2017	7.3	5.0	10.0	0.5
2018	8.2	5.0	10.0	0.6
2019	9.1	5.0	10.0	0.7
2020	10.0	5.0	10.0	0.8
2021	10.0	6.0	10.0	0.9
2022	10.0	6.0	10.0	1.0
2023	10.0	6.0	10.0	1.1
2024	10.0	6.0	10.0	1.2
2025	10.0	6.0	10.0	1.3
2026	10.0	6.0	10.0	1.4
2027	10.0	6.0	10.0	1.5
2028	10.0	6.0	10.0	1.6

Year				
2029	10.0	6.0	10.0	1.7
2030	10.0	6.0	10.0	1.7
2031	10.0	5.0	10.0	1.7
2032	10.0	5.0	10.0	1.7
2033	10.0	5.0	10.0	1.7
2034	10.0	5.0	10.0	1.7
2035	10.0	5.0	10.0	1.7
2036	10.0	5.0	10.0	1.7
2037	10.0	5.0	10.0	1.7
2038	10.0	5.0	10.0	1.7
2039	10.0	5.0	10.0	1.7
2040	10.0	5.0	10.0	1.7
2041	9.6	5.0	10.0	1.7
2042	9.2	5.0	10.0	1.7
2043	8.8	5.0	10.0	1.7
2044	8.4	5.0	10.0	1.7
2045	8.0	5.0	10.0	1.7
2046	7.6	5.0	10.0	1.7
2047	7.2	5.0	10.0	1.7
2048	6.8	5.0	10.0	1.7
2049	6.4	5.0	10.0	1.7
2050	6.0	5.0	10.0	1.7

Deforestation rates for the high emissions scenario (ha per year)

Year	England	Scotland	Wales	N Ireland
2010	1475	1500	318	0
2011	1650	1500	308	0
2012	1650	1500	298	0
2013	1650	1500	202.7	0
2014	1650	1500	218.5	0
2015	1650	1500	50	0
2016	1550	1300	342.4	0
2017	1450	1100	280.6	0
2018	1350	900	340	0
2019	1250	700	351.3	0
2020	1150	500	295.4	0
2021	1100	500	36.36	0
2022	1050	500	36.4	0
2023	1000	500	36.4	0
2024	950	500	36.4	0
2025	900	500	36.4	0
2026	850	500	36.4	0
2027	800	500	36.4	0
2028	750	500	36.4	0
2029	700	500	36.4	0
2030	700	500	36.4	0
2031	660	480	36.4	0
2032	620	460	36.4	0
2033	580	440	36.4	0
2034	540	420	36.4	0
2035	500	400	36.4	0

2036	460	380	36.4	0
2037	420	360	36.4	0
2038	380	340	36.4	0
2039	340	320	36.4	0
2040	300	300	36.4	0
2041	300	300	36.4	0
2042	300	300	36.4	0
2043	300	300	36.4	0
2044	300	300	36.4	0
2045	300	300	36.4	0
2046	300	300	36.4	0
2047	300	300	36.4	0
2048	300	300	36.4	0
2049	300	300	36.4	0
2050	300	300	36.4	0