National Atmospheric Emissions Inventory

Projections of Emissions and Removals from the LULUCF Sector to 2050

(based on the 1990-2015 inventory)

Prepared by the UK Centre for Ecology & Hydrology (UKCEH) and Forest Research for the Department for Business, Energy and Industrial Strategy (BEIS) as part of the UK National Atmospheric Emissions Inventory

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Summary for Policy Makers

- The United Kingdom of Great Britain and Northern Ireland (UK) reports greenhouse gas (GHG) emission projections to 2050 for the Land Use, Land-Use Change and Forestry (LULUCF) sector to inform policy concerning domestic and international climate change commitments. The full projections data are available on the national atmospheric emissions inventory (NAEI) website[1].
- LULUCF activities can result in net annual emissions or removals of GHG, and changes in carbon stocks in the pools associated with LULUCF. The results presented here are based on the reporting conventions of the United Nations Framework Convention on Climate Change (UNFCCC). They do not represent potential future reported or accounted emissions and removals under the Kyoto Protocol.
- This report provides projections at the UK and country level, with separate estimates for Scotland, England, Wales and Northern Ireland, which are summed to give the UK totals. Estimates for the projected emissions from the UK's Overseas Territories and Crown Dependencies are included for the first time.
- LULUCF is divided into six land use types: Forest Land, Cropland, Grassland, Wetlands, Settlements, and Other Land. Carbon stock changes of Harvested Wood Products are reported in an additional category, Harvested Wood Products. There is a separate inventory sector for Agriculture dedicated to emissions, of mainly methane (CH_4) and nitrous oxide (N_2O), from other agricultural activities, which are not covered in this report.
- The emissions resulting from five future scenarios (*Baseline 1, Baseline 2, Central, Low* and *Stretch*) have been described. The scenarios take account of current land use policies or aspirations. The *Baseline* scenarios are based on climate change-related and forestry policies extant in July 2009. The *Central* scenario policy as of 2016, the *Low* scenario policy aspirations and the *Stretch* scenario an estimate of an upper bound of policy ambition.
- The main results are:
    - At a UK level, the LULUCF sector has been a net sink since 1992 and is predicted to remain so under all scenarios although declining from 2015 to 2050. The maximum sink size is in the historic inventory for 2015 of 12.8Mt carbon dioxide equivalent (CO_2e). By 2050 the UK sink in the central scenario is predicted as being 3.9Mt CO_2e
    - At a country level Wales, with removals between 0.2 and 1.0 Mt CO_2e, and Scotland, with removals between 3.7 and 8.6 Mt CO_2e, remain net sinks under all scenarios
    - England is a net sink under the *Low* and *Stretch* scenarios reflecting policy ambition beyond those in place in May 2015, but will later become a net source under *Baseline 1* (2046), *Baseline 2* (2047) and *Central* scenarios (2039). By 2050 the emissions in the LULUCF sector are estimated to be 0.7 Mt CO_2e in *Baseline 1*, 0.4 CO_2e in *Baseline 2* and 1.7 CO_2e in the *Central* scenario.
    - Northern Ireland is a small net source of between 0.0 and 0.5 MtCO_2e under the *Baseline 2* Scenario and between 0.0 and 0.3 MtCO_2e in the *Central* scenario during the period, but will become a small net sink of between 0.0 and 0.3 MtCO_2e during the 2040s under the *Baseline1, Stretch* and *Low* scenarios.
    - The LULUCF sector in the UK and in each of the countries is dominated by CO_2 emissions and removals, although N_2O emissions also make a significant contribution.
    - The changes in the Forest Land, Cropland, Grassland and Settlement categories determine the trend in the UK and countries.
    - The UK's Overseas Territories and Crown Dependencies are included in the projections for the first time. They contribute a small net source of upto 0.06 Mt CO_2e until 2050.
    - The main changes in the projections since the 1990-2014 projections are:
        - Forestry: the modelling of litter and soil carbon has been revised in the forest carbon accounting model CARBINE. This differs from the submitted 1990-2015 inventory.

[1] 1https://naei.beis.gov.uk/reports/reports?report_id=1011

- The UK definition of forest for the UNFCCC includes an area threshold of 0.1 ha, whereas the National Forest Inventory has an area threshold of 0.5 ha. Evidence of the carbon stock of woodland between 0.1 and 0.5 hectares was published after the finalisation of the 1990-2015 inventory but has been included in these projections.
- Settlements: new data from MHCLG on projected settlement expansion have been used to revise the scenarios.

Contents

1 Introduction

This report estimates projections of UK GHG emissions and removals from Land Use, Land Use Change and Forestry (LULUCF) activities in the period to 2050. Projections are made for carbon stock changes and carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions arising from LULUCF activities reported in the latest UK GHG Inventory, for the period 1990-2015 (Brown *et al*., 2016). The report provides the first projections of LULUCF emissions and removals for the UK's Overseas Territories and Crown Dependencies.

The LULUCF projections address a number of policy needs including:

- The projections must be aligned with international commitments including the EU requirement for biennial reporting of projections with and without policy measures, and with additional measures.
- The projections feed into the annually updated Energy and Emissions Projections (EEP) published by the Department for Business, Energy and Industrial Strategy (BEIS) which help to track progress towards Government climate targets.
- The projections support the exploration of potential low carbon development strategies.
- Projections are also required to monitor progress towards targets under the Climate Change (Scotland) Act, the Environment (Wales) Act and for the UNFCCC Framework Convention on Climate Change (UNFCCC).

There have been some changes to the forestry elements of the projection scenarios this year, but except for land use change to forest or settlement, land management elements are largely unchanged from the previous projections (based on the 1990-2014 inventory). Three policy scenarios (*Central*, *Low* and *Stretch*) have been constructed along with two *Baseline* scenarios which continue trends or policies from 2009. These policy scenarios reflect conditions before the July 2016 referendum on the UK's membership of the European Union.

- *Baseline 1* scenario: Underpins the option to submit a technical correction to the Forest Management Reference Level for the Second Commitment Period of the Kyoto Protocol. It is based on climate change-related and forestry policies extant in July 2009. The projections continue 2000-2009 average activity rates out to 2050.
- *Baseline 2* scenario: This is the EEP "baseline" scenario. It is based on climate change-related and forestry policies extant in July 2009 as in *Baseline 1* for the duration of the original policy. Forest planting rates drop to a low level after 2015 to project the impact of no further grant-aided planting beyond that which was contained in existing policy in 2009 under the then programme of the Common Agricultural Policy. Other activities not driven by policies with a specific time limit are projected to continue at 2000-2009 average rates until 2050.
- *Central* scenario: Based on current policies and the duration of agreed funding (as extant in 2016) continuing at the same rate into the future. Continues 2015 rates to 2050 for non-forest activities. For afforestation, 2015 planting rates are maintained for the remainder of the current Rural Development Programme (RDP) to 2021, after which planting rates decline to those in *Baseline 2*. This is the EEP "reference" scenario.
- *Low* scenario: Climate change mitigation policy aspirations for the UK and each of the Devolved Administrations (DAs) are projected forward beyond 2021.
- *Stretch* scenario: This assumes an ambitious climate change mitigation programme exceeding current policy aspirations or funding.

The assumptions underlying the scenarios were developed by the Department for Business, Energy and Industrial Strategy (BEIS) with input from the Forestry Commission, the Department for Environment, Food and Rural Affairs (Defra), the DAs and LULUCF experts. The scenarios are designed to capture the range of net emissions that could potentially be produced by LULUCF activities in the future, taking into account current land use policies and/or aspirations (e.g. achieving a certain

percentage of forest cover by 2050). Domestic agriculture- and forestry-specific policies and funding are not in place to meet some of the aspirations, particularly for the *Low* and *Stretch* scenarios, and they must therefore be treated as exploratory. Separate projections have been developed for each administration (England, Scotland, Wales and Northern Ireland) and combined into a total for the UK. The Crown Dependencies and Overseas Territories are reported separately in Annex 4.

2 Basis for projections

The LULUCF sector (sector 4 in the common reporting format for national GHG inventories submitted to the UNFCCC) is divided into six land use types for reporting of emissions/removals: Forest Land (4A), Cropland (4B), Grassland (4C), Wetlands (4D), Settlements (4E) and Other Land (4F)[2]. Net carbon stock changes of Harvested Wood Products (HWP) are reported under an additional category (4G). Emissions of greenhouse gases to the atmosphere (CO_2, CH_4 and N_2O) are expressed as positive quantities, and removals of CO_2 as negative quantities. Emissions of all three greenhouse gases are combined into total CO_2 equivalents, using Global Warming Potential (GWP) factors from the fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), published in 2007[3]: 1 for CO_2, 25 for CH_4 and 298 for N_2O. LULUCF is the only sector which currently removes greenhouse gases from the atmosphere. The net LULUCF emission is the total of emissions and removals across the seven categories (4A-4G). The balance between emissions and removals within the sector means that the net total LULUCF emission or removal may currently be small in comparison with other individual sector totals but the LULUCF sector remains significant as the relative small net LULUCF emission is the net balance of much larger emissions. Also removals and emissions from other sectors are projected to decrease.

Calculations in the LULUCF inventory are on the basis of activities, which can fall across several land use types (Table 1[4]). The current inventory (1990-2015) methodology for non-forest activities is used to make the projections to 2050. There are detailed descriptions of the datasets and methodology in Chapter 6 and Annex 3.4 of the National Inventory Report (Brown *et al*. 2017). The modelling of forestry activities has been improved since the 1990-2015 inventory submission and these changes have been incorporated into the full time series from 1990. 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 the corresponding activities and to *Deforestation* when developing the assumptions for the different scenarios.

[2] There are no emissions or removals of greenhouse gases from the Other Land category.
[3] The GWPs for CH_4 and N_2O were updated in the GHG inventory guidelines adopted in 2013; previously a GWP of 21 was used for CH_4 and 310 for N_2O.
[4] The reference to Tiers 1-3 in Table 1 refers to the sophistication of the methodological approach: Tier 1 uses simple equations and default GHG emission factors provided by the IPCC; Tier 2 uses the same equations with country-specific emission factors and higher resolution activity data; Tier 3 uses complex country-specific models and inventory measurement systems with high resolution activity data).

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

Activity	Description	Inventory category
Afforestation and forest management	Carbon stock gains and losses in trees, litter, soils and harvested wood products are calculated by the forest carbon accounting model CARBINE (Tier 3). The model uses administration-specific data on forest planting, productivity, and forest management/ harvesting patterns. N_2O emissions from fertilization and drainage of forest soils are calculated from the same planting data (Tier 1). Estimates are adjusted to take account of forest area losses due to deforestation. The changes in the Harvested Wood Products (HWP) pool reflect changes in the forest harvesting rate and the use of forest products.	4A Forest Land (carbon stock changes, N_2O emissions) 4G Harvested Wood Products (carbon stock changes)
Wildfires	Emissions of greenhouse gases due to wildfires on forest land, cropland and grassland are modelled with a Tier 1 approach, with biomass and litter densities for forest land are taken from the CARBINE model output.	4A Forest Land (CO_2, CH_4 and N_2O emissions), 4B Cropland (CH_4 and N_2O emissions), 4C Grassland (CH_4 and N_2O emissions)
Land Use Change	Changes in biomass and soil carbon stocks due to non-forest land use change are modelled by a dynamic model of carbon stock change driven by land use change matrices calculated from land surveys (1950-2007) (Tier 3). Continuing changes in soil carbon stocks due to historical LUC (>20 years before current year) are reported under the relevant IPCC category, e.g. Cropland remaining Cropland, and changes due to more recent LUC (<20 years) are reported under e.g. Land converted to Cropland. Changes in biomass stocks occur in the year of the land use change. N_2O emissions associated with land use change are calculated from the same activity data using the IPCC Tier 1 methodology.	4B Cropland (carbon stock changes, N_2O emissions) 4C Grassland (carbon stock changes, N_2O emissions) 4E Settlements (carbon stock changes, N_2O emissions)
Deforestation	Carbon stock changes in the soil due to deforestation to another land use are calculated using the dynamic model of carbon stock change, while changes in biomass and HWP are calculated using the CARBINE forest carbon accounting model (both Tier 3). A proportion of the felled trees extracted from the forest is assumed to be burnt (releasing CO_2, CH_4 and N_2O), and the remainder are converted to timber products.	4A Forest Land (biomass carbon stock changes) 4B Cropland (soil carbon stock changes; CO_2, CH_4 and N_2O emissions) 4C Grassland (soil carbon stock changes; CO_2, CH_4 and N_2O emissions) 4E Settlements (soil carbon stock changes; CO_2, CH_4 and N_2O emissions) 4G Harvested Wood Products (carbon stock changes)
Cropland management	Changes in soil carbon stocks due to inputs of fertilizer, manure and crop residues and changes in biomass stock due to changes in crop type are calculated using the IPCC Tier 1 methodology.	4B Cropland (biomass and soil carbon stock changes)
Grassland management	Changes in biomass carbon stocks due to changes between grassland types are calculated using the IPCC Tier 1 methodology.	4C Grassland (biomass carbon stock changes)

Activity	Description	Inventory category
Agricultural drainage	Emissions from drainage on lowland agricultural organic soils are estimated using the IPCC Tier 1 methodology.	4B Cropland (soil carbon stock changes) 4C Grassland (soil carbon stock changes)
Peat extraction	The IPCC Tier 1 methodology is used to calculate on-site emissions from peat extraction and off-site emissions from the decomposition of domestically produced horticultural peat. Emissions from the extraction of horticultural peat imported to the UK is not included in the UK inventory.	4D Wetlands (soil carbon stock changes; CO_2 and N_2O emissions)

3 Assumptions underlying the scenarios

The scenario assumptions for each activity and country (summed to give the UK total) are described in this section. The following assumptions remain 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[5] publication (national baseline). Land loss due to sea level rise is assumed not to have an impact before 2050. Changes in the UK land area due to coastal re-alignment are not considered.
- Non-forest LULUCF input data for 1990-2015 in the published GHG inventories[6] have not been changed and feed through as the initial condition for the projected emissions.
- Forest input data are based on the latest National Forest Inventory (NFI). The UK definition of forest for the UNFCCC includes an area threshold of 0.1 ha, whereas the NFI has an area threshold of 0.5 ha. Evidence of the carbon stock of woodland between 0.1 and 0.5 hectares was published after the finalisation of the 1990-2015 inventory but has been included here (Forest Inventory 2017). Consequently, this differs from the input data used in the 1990-2015 GHG Inventory.

Graphs of UK-level activity data are shown in this section; a break-down by country is given in Annex 2. Table 2 shows which activities correspond to each UNFCCC land use category.

Table 2: UNFCCC land use categories and contributing activities

UNFCCC LULUCF land use category	Carbon stock change or gas	Activity producing emissions/removals
Forest Land (4A)	Carbon stock change	Afforestation and forest management Deforestation
	CO_2 emissions	Wildfires
	CH_4 emissions	Wildfires
	N_2O emissions	Afforestation and forest management Wildfires
Cropland (4B)	Carbon stock change	Land Use Change

[5] https://www.ons.gov.uk/methodology/geography/geographicalproducts/otherproducts/ukstandardareameasurementssam
[6] https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2015

UNFCCC LULUCF land use category	Carbon stock change or gas	Activity producing emissions/removals
		Deforestation
		Cropland management
		Agricultural drainage
	CO_2 emissions	Deforestation
	CH_4 emissions	Wildfires
		Deforestation
	N_2O emissions	Wildfires
		Land Use Change
		Deforestation
Grassland (4C)	Carbon stock change	Land Use Change
		Deforestation
		Grassland management
		Agricultural drainage
	CO_2 emissions	Deforestation
	CH_4 emissions	Wildfires
		Deforestation
	N_2O emissions	Wildfires
		Land Use Change
		Deforestation
Wetlands (4D)	Carbon stock change	Peat extraction
	CO_2 emissions	Peat extraction
	N_2O emissions	Peat extraction
Settlements (4E)	Carbon stock change	Land Use Change
		Deforestation
	CO_2 emissions	Deforestation
	CH_4 emissions	Deforestation
	N_2O emissions	Land Use Change
		Deforestation
Harvested Wood Products (4G)	Carbon stock change	Afforestation and forest management
		Deforestation

3.1 Afforestation

This activity is driven by the amount of new forest planting in each country and affects forest carbon stock changes, changes in the Harvested Wood Products pool, nitrogen fertilisation of forests and forest drainage (CO_2 and N_2O).

- The *Baseline 1* scenario uses the 2009 planting rates for all projection years (2016 onwards), as in the Forest Management Reference Level (FMRL) used in the Kyoto Protocol reporting.
- The *Baseline 2* scenario assumes that grant-aided planting ceases after 2016, when the Rural Development programme current in 2009 finished, and reverts to an estimate of the level of afforestation that would occur without grants of 10% of the average forest planting rate from 2008 to 2014 out to 2050.
- The *Central* scenario uses forest planting rates to 2020 determined by the available grants for woodland creation within each DA. After 2021, planting rates drop to 10% of the *Baseline 1* rates, reflecting the lack of funding beyond the current Rural Development Plan.
- The *Low* (emissions) scenario uses forest planting rates to 2020 determined by the available grants for woodland creation within each DA, supplemented by additional planting activity in line with meeting policy aspirations after 2020. From 2021, planting rates are projected based on policy aspirations in each DA.
- The *Stretch* scenario assumes an ambitious planting programme exceeding current policy aspirations or funding (differentiated by DA). This is consistent with the stretch scenario adopted as Maximum Technical Potential used in the Marginal Abatement Cost Curve for the development of the Impact Assessment for the 5th Carbon Budget regulations.
- Planting rates for 2016 have been published and are used in the projections (see Annex 3).
- Proportion of conifer/broadleaf planting: for the *Baseline(1)* scenario the conifer/broadleaf split reported for 2009 is projected forward; and for all other scenarios each country has proposed a conifer/broadleaf split consistent with current policy aspirations and grant availability/targeting (Scotland: 60% conifer; England: 30% conifer; Wales: 16% conifer (current 2014 value); Northern Ireland: 2% conifer (current default)).

The UK afforestation rates are presented in Figure 1, with a breakdown by country provided in Annex 3.

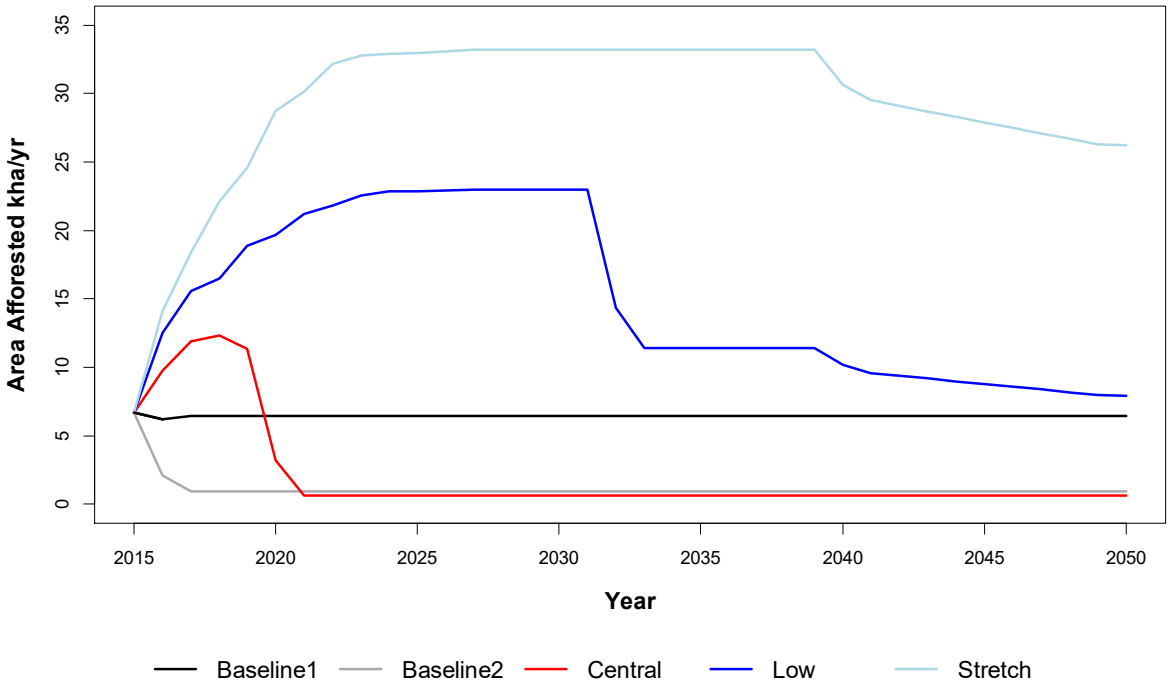

Figure 1: Afforestation rates for the emissions scenarios (UK). Note that a disaggregation of these data by country is provided in Annex 3.

3.2 Wildfires

Emissions from wildfires on Forest, Cropland and Grassland are presented in Figure 2, Figure 3 and Figure 4, respectively. This activity is driven by the area of forest, cropland and grassland burnt annually in wildfires, affecting GHG emissions from burning (CO_2, CH_4 and N_2O)[7]. CO_2 emissions from wildfires on cropland and grassland are assumed to be replaced within the year by vegetation regrowth, so only emissions of CH_4 and N_2O are reported in 4B and 4C. The amount of fuel available to forest wildfires varies for each scenario as afforestation rates are different.

The wildfire historical time series shows high inter-annual variability (dependent upon the weather conditions at certain times of year). Activity data are adjusted to ensure a smooth transition from the latest inventory year to the different scenarios (2015-2020) using a sigmoid curve.

- In the *Baseline 1* and *Baseline 2* scenarios the annual burnt area from 2016 onwards equals the average burnt area during the historical baseline period (2000-2009 for forest wildfires and 2001-2009 for cropland and grassland wildfires where the available time series was shorter).
- In the *Central* scenario the annual burnt area from 2016 onwards equals the average annual burnt area for the decade up to the latest inventory year (2015).
- In the *Low* and *Stretch* scenario the annual burnt area from 2016 onwards is the value of the 5th percentile of the wildfire area time series for the decade up to the latest inventory year (2015).

[7] There are no non-forest wildfire data for Northern Ireland, so the area burnt was estimated using the NI Countryside Survey areas for cropland and grassland scaled by the % burnt of cropland and grassland in Scotland 2010-2014. The time series was extended using the ratio of the estimated NI burnt area to the Great Britain (GB) burnt area.

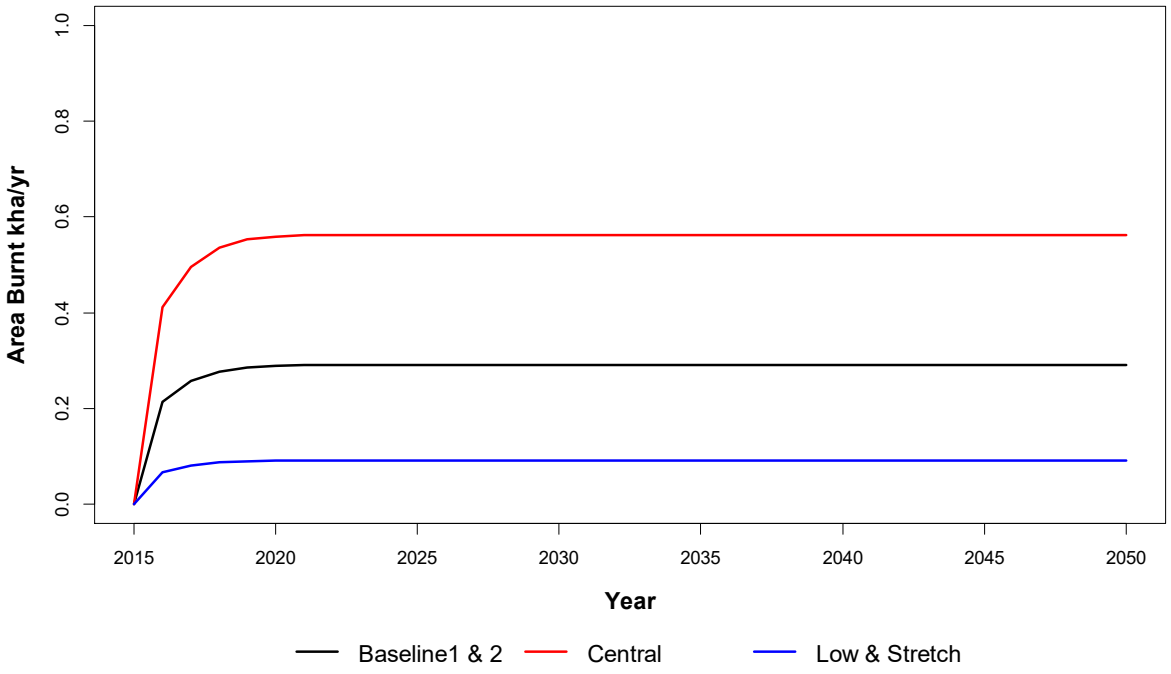

Figure 2: Forest wildfire activity data for the emissions scenarios (UK)

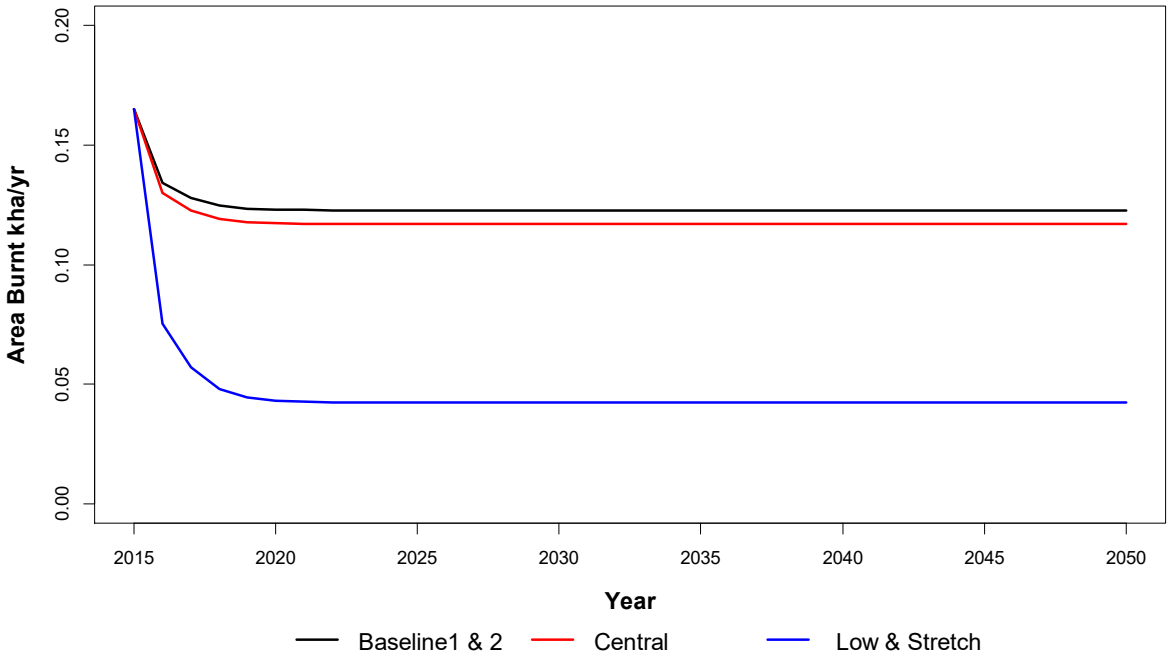

Figure 3: Cropland wildfire activity data for the emissions scenarios (UK)

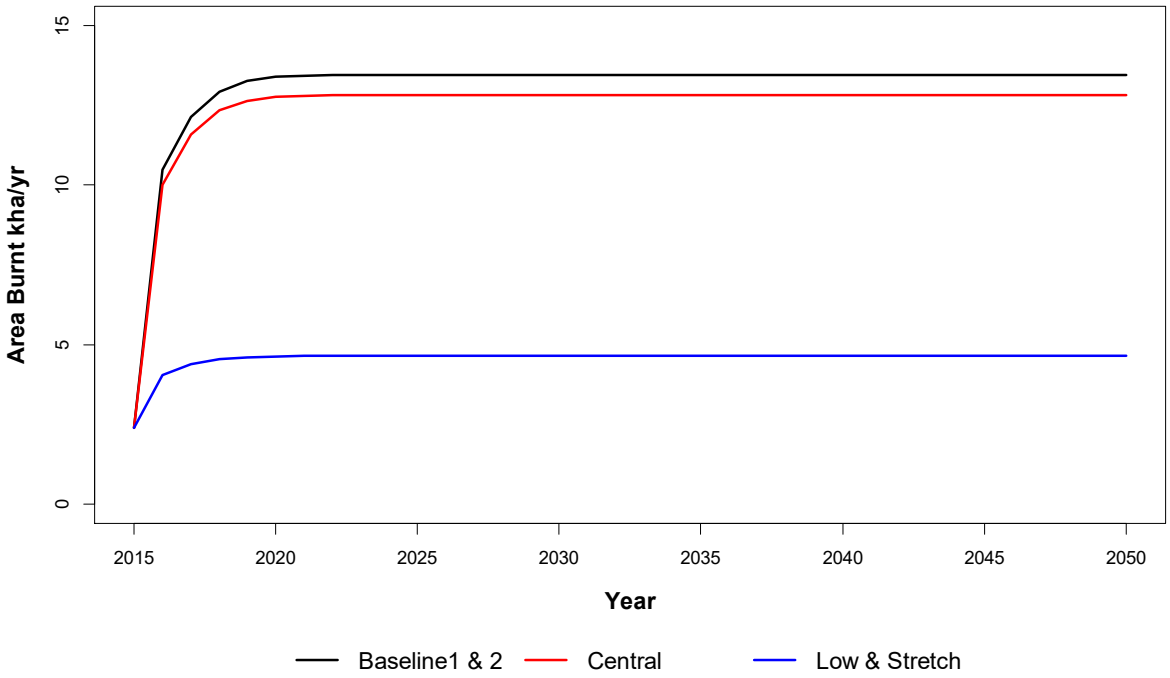

Figure 4: Grassland wildfire activity data for the emissions scenarios (UK)

3.3 Land Use Change (LUC)

This activity is driven by the areas of annual land use change between Cropland, Grassland and Settlement (Figure 5, Figure 6 and Figure 7), affecting carbon stocks of biomass and soils, and N mineralisation to N_2O as a result of carbon stock losses from land use change. Conversion to and from Forest Land are taken into account within the Afforestation and Deforestation activities.

The net Cropland area is assumed to remain stable for all countries except Wales (where continuing permanent conversion of grassland to cropland is assumed, based on advice from Welsh Government experts). However, it is assumed that there is a constant level of cropland-grassland conversion and vice-versa across all projection scenarios (with no net change in areas). This reflects agricultural land rotation and is based on the average annual conversion each way 1990-2009 for each country (47.70 kha in England, 14.61 kha in Scotland, 4.75 kha in Wales and 3.66 kha in Northern Ireland each way).

Conversion to Settlement is based on different house-building scenarios (see Annex 1) and is assumed to be from Grassland (after taking Deforestation areas into account).

- In the *Baseline 1* and *Baseline 2* scenarios decadal averages (2000-2009) are used for each land use transition except in the following cases: in Scotland, Wales and Northern Ireland the annual area converted to Settlement is 70% of the *Central* scenario annual area; and a Grassland to Cropland conversion rate of 5.5 kha/y for Wales is assumed in addition to the rotation rate.
- In the *Central* scenario decadal averages (2000-2009) are used for each land use transition except in the following cases: conversion to Settlement assumes that house building is sufficient to meet the projected housing demand in each DA; and a Grassland to Cropland conversion rate of 10 kha/y for Wales is assumed in addition to the rotation rate.
- The *Low* and *Stretch* scenarios are the same as in the *Baseline 1* scenario except that the annual area converted to Settlement is 50% of the *Central* scenario annual conversion area for all countries.

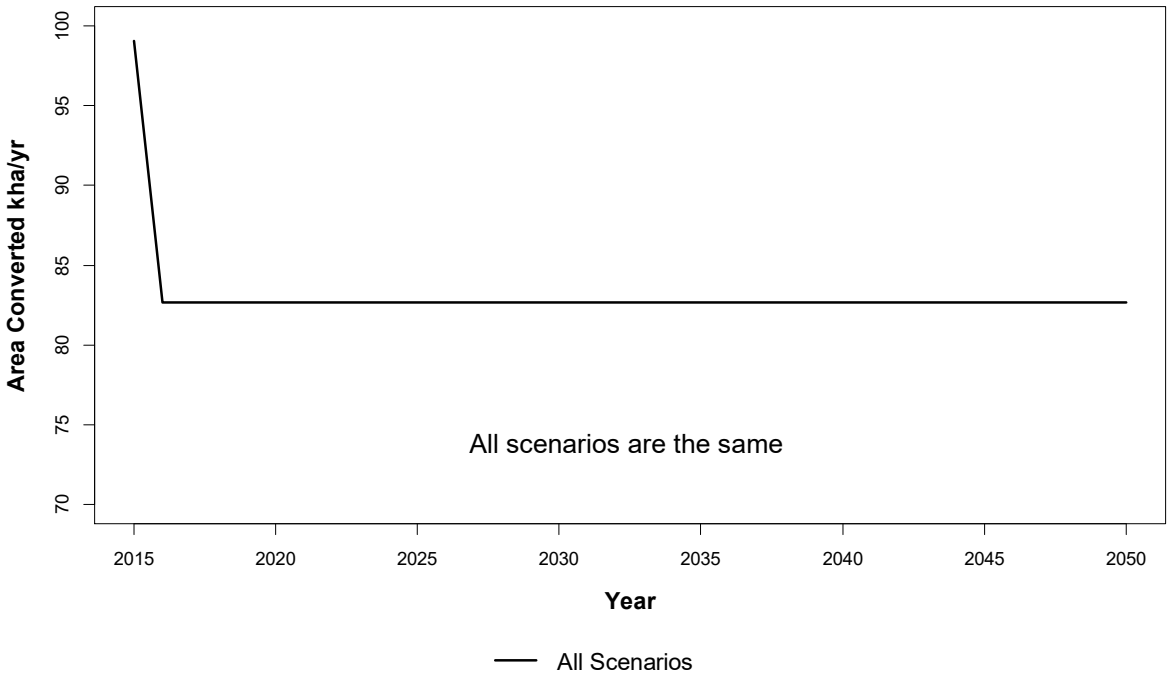

Figure 5: Activity data for Cropland to Grassland land use change for the emissions scenarios (UK)

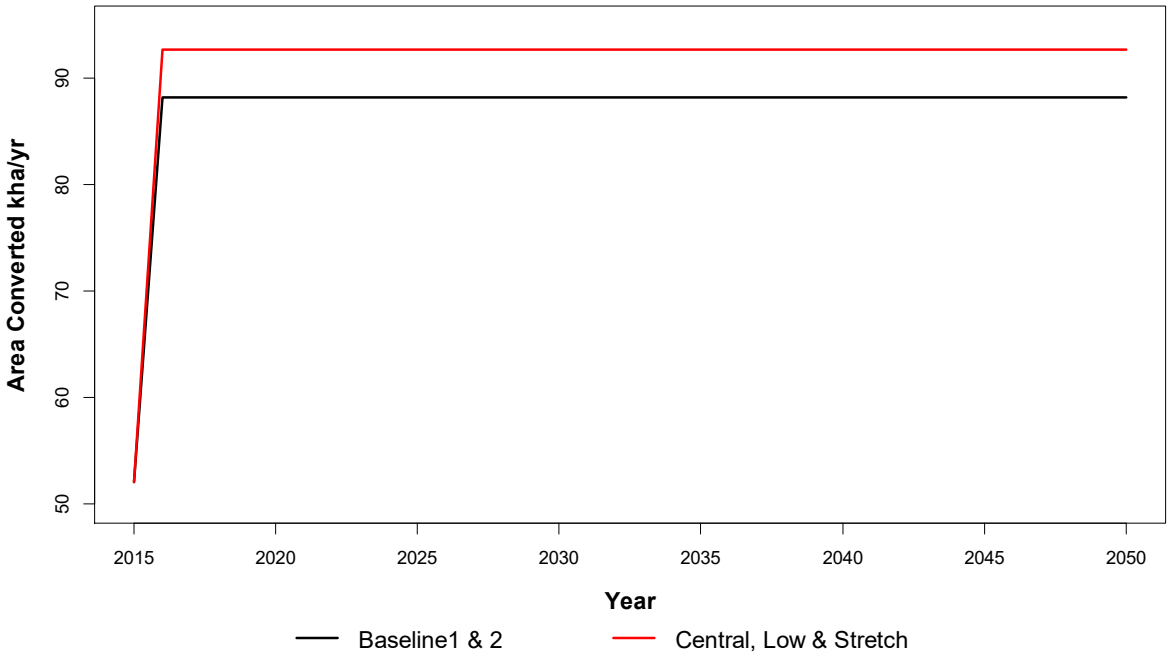

Figure 6: Activity data for Grassland to Cropland land use change for the emissions scenarios (UK)

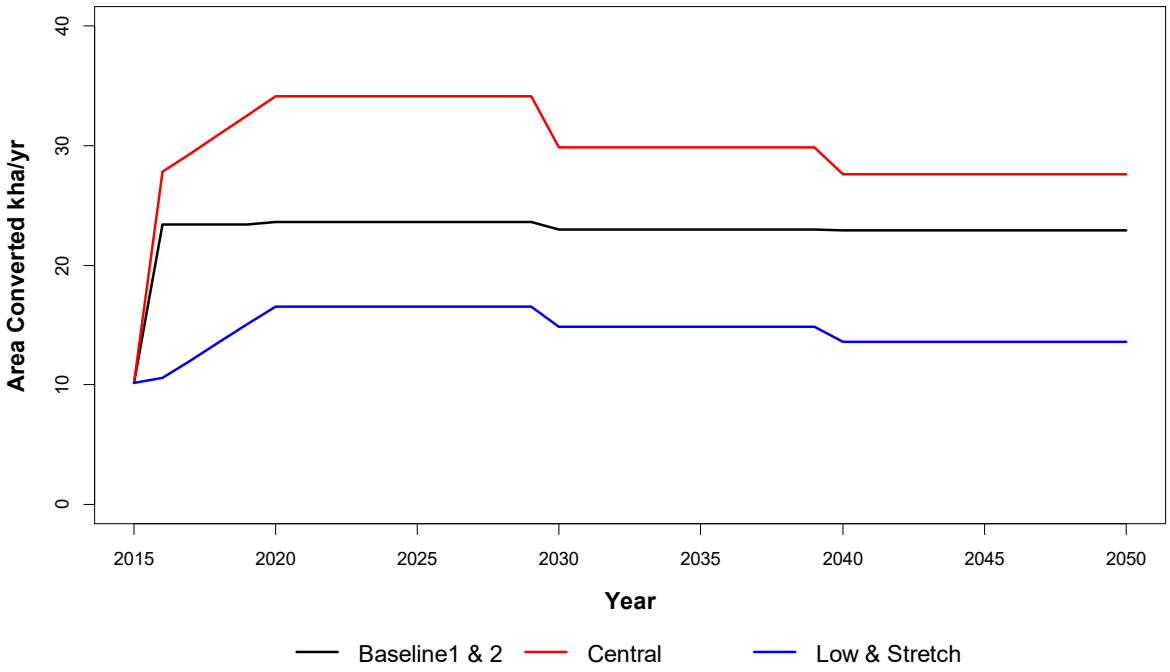

Figure 7: Activity data for Grassland to Settlement land use change for the emissions scenarios (UK)

3.4 Deforestation

This activity is driven by the area of forest annually converted to other land uses (Figure 8). It affects forest carbon stocks, the Harvested Wood Products pool and GHG emissions from biomass burning (CO_2, N_2O, and CH_4).

It is difficult to assign deforestation levels to specific afforestation/emissions scenarios, as in some cases a low deforestation rate might arise when planting rates are low, with policy responding to avoid net deforestation. Alternatively, deforestation might be independent of afforestation, responding to economic and housing development, for example. Although the Scottish Government's policy on 'the Control of Woodland Removal' and FCE's Open Habitats policy (When to convert woods and forests to open habitats in England) are mentioned in the UK's LULUCF Action Plan and the 2011 Carbon Plan, they are not associated with explicit estimates of potential abatement and the impact of their implementation cannot be quantified.

Two deforestation levels have been used: Baseline 1 projects the 2009 levels of deforestation forward at a constant level to 2050; reflecting the lack of explicit policies (see above) to reduce deforestation prior to this date. However, as there is a limit to the potential area available for restoration from forest to open habitat (currently the main driver of deforestation) this assumption represents a high emission assumption.

The other scenarios use a single deforestation level based on the average deforestation levels between 2010 and 2014[8], projected forward and declining to a low, constant, rate from 2040 onwards. The post-2040 deforestation rate assumes that: open habitat restoration programmes have been completed for all countries; wind-farm development has no further impact on forested areas after this date; the UK Forestry Act and EIA (forestry) regulations continue to provide protection from conversion to cropland or grassland; and that deforestation reflects historical rates of conversion to settlement only.

[8] These deforestation levels were compiled by forestry .experts using reported definite land cover change and administrative data on habitat restoration and deforestation for wind farm development.

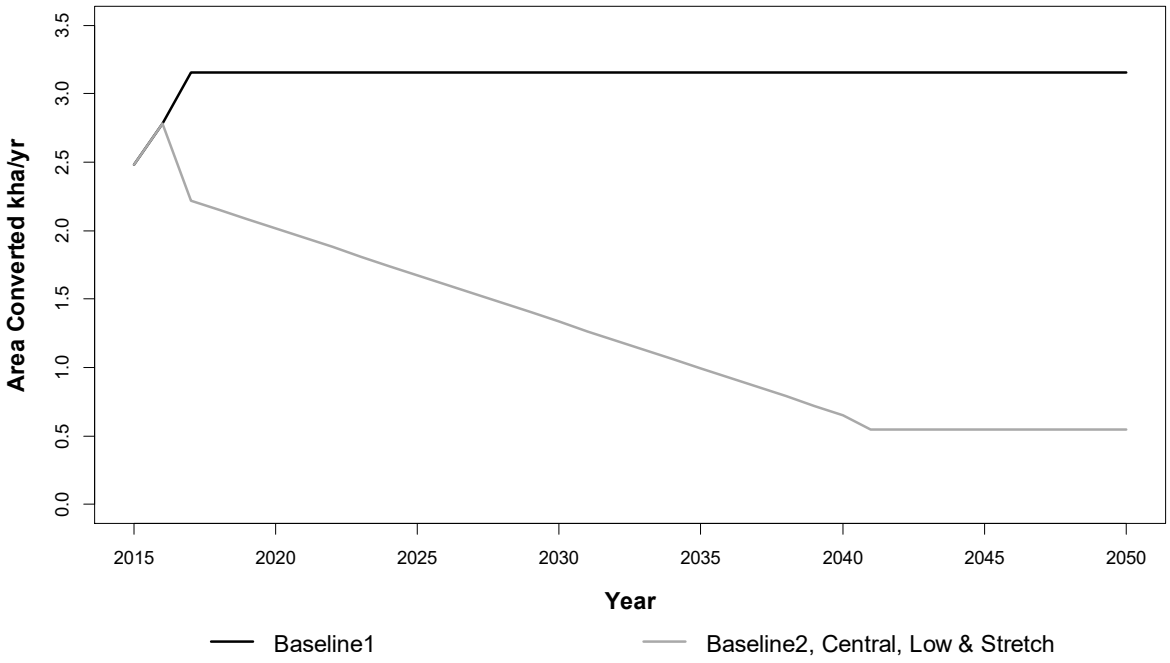

Figure 8 : Deforestation rate for all emissions scenarios (UK)[9].

3.5 Cropland and Grassland management

Cropland Management activity is driven by differences between land management on cropland, mainly the balance between perennial and annual crops, manure inputs and crop residue inputs. Grassland management activity is driven by within grassland changes, e.g. from non-shrubby to shrubby grassland.

- For the *Baseline 1* and *Baseline 2* scenarios pre-2009 decadal average rates of management inputs are used (Table 3).
- For the *Central*, *Low* and *Stretch* scenarios, levels of management activity remain at 2015 levels until 2050.
- For Grassland Management the time series has been stable since 1999 so there is no difference between the scenarios.
- Cropland and grassland areas are adjusted over time to account for land use change, so the numbers shown in Table 3 are for the initial projected values.

[9] a disaggregation of these data by country is provided in Annex 3.

Table 3: Activity data for Cropland Management scenarios

		England (E)/ Wales (W)/ Northern Ireland (NI)		Scotland	
		Baseline 1* and *2	***Central/ Low/ Stretch***	***Baseline 1* and *2***	***Central/ Low/ Stretch***
Soil carbon stocks	% crop area receiving mineral N fertiliser	90	90	96	96
	% crop area receiving Farmyard Manure	18	23	29	23
	Tillage: full inversion % area	56 (E, W) 94 (NI)	56(E, W) 91 (NI)	89	81
	Tillage: minimum tillage % area	40 (E, W) 2 (NI)	40 (E, W) 5 (NI)	11	11
	Tillage: None or direct seeding % area	4 (E, W) 5 (NI)	4 (E, W) 4 (NI)	0	8
	% crop residue removed	68 (E) 81 (W, NI)	76 (E) 81 (W) 79 (NI)	76	74
	% land manured	8.8	9.4	8.8	9.4
	% crop area with residue/stubble	-	-	39	41
	% crop area with bare fallow	-	-	15	19
	% crop area with cover crop	-	-	2	3
	% crop area with autumn/winter crop	-	-	44	37
Biomass carbon stocks	Annual change in biomass carbon, tC	-1805 (E) -79 (W) -111 (NI)	9036 (E) 30 (W) 270 (NI)	2	15023

3.6 Agricultural drainage

It is assumed that no new areas of agricultural organic soils have been drained since 1990 so the area drained remains steady throughout the projected time series.

3.7 Peat extraction

The area covered by peat extraction and extraction site restoration is small compared with other land use activities (Figure 9). Even after extraction ceases, this area may not always be converted to another land use and so remains in the Wetland category.

- For the *Baseline 1* and *Baseline 2* scenarios the area drained for peat extraction remains at 2009 levels for all countries, except those in England with planned expiry dates, where restoration to target habitats is assumed to have a 50% success rate. The volume of horticultural peat extracted (and decomposing) each year is projected to be fixed at the decadal average for 2000-2009.

- For the *Central* scenario the area drained for peat extraction remains at 2015 levels for all countries, except those in England with planned expiry dates, where restoration to target habitats is assumed to have a 50% success rate. The volume of horticultural peat extracted each year is projected to be fixed at the decadal average 2006-2015 for Scotland and Northern Ireland, but in England there is a projected 50% drop in volume production by 2030 on sites still in operation.
- For the *Low* scenario it is assumed that there is a cessation of all peat extraction with 50% successful site restoration by 2050 for sites in Scotland, Wales and Northern Ireland. In England, extraction is the same as in the Central scenario, with 100% restoration success to target habitats. The volume of horticultural peat extracted each year is projected to be fixed at the decadal average 2006-2015 for Northern Ireland, to decline to zero by 2050 for Scotland and drop to zero by 2030 for England.
- For the *Stretch* scenario, it is assumed that there is cessation of all peat extraction with 100% successful restoration in all countries by 2030, with a concomitant reduction in horticultural peat volume.

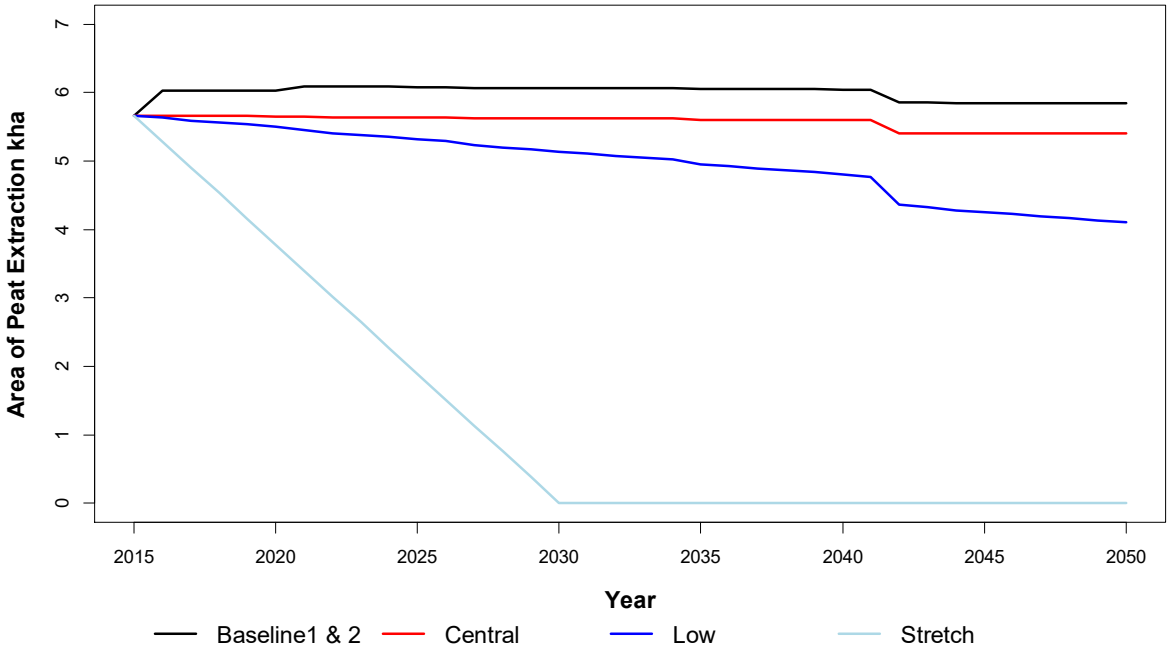

Figure 9: Peat extraction areas over time for all scenarios.

4 Projections 2016-2050

A summary of the results is given here. Detailed emission estimates by activity, country and scenario are available for download from the NAEI website[10].

4.1 Land Use Areas

Table 4 shows the projected distributions of land use areas in the UK between 2016 and 2050 - the areas for each country are reported in Annex 2. The areas of land in each category were produced via extrapolation of the land use change matrices listed in the National Inventory Report (Brown *et al*., 2017). These land use change matrices rely largely on Countryside Survey datasets and may therefore differ from other national datasets.

There is greatest land use change in the *Stretch* emissions scenario at the UK and country level (due to increases in forest area and accompanying losses in grassland area). Wales shows the greatest land use changes under all scenarios, due to the assumption of additional grassland-cropland conversion in Wales. Grassland is lost at the expense of other land use types under all scenarios.

[10] https://naei.beis.gov.uk/reports/reports?report_id=1011

Table 4: Land use areas[11] 2015-2050 for the United Kingdom (24,418 kha)

Emission scenario	Land use category	2015 area, kha	2020 area, kha	2030 area, kha	2040 area, kha	2050 area, kha	% of land area in 2015	% of land area in 2050
Central	Forest land	3449	3486	3475	3472	3472	14%	14%
	Cropland	5055	5105	5205	5305	5405	21%	22%
	Grassland	13461	13231	12787	12382	11995	55%	49%
	Wetland	171	171	171	171	170	1%	1%
	Settlement	1971	2110	2452	2751	3030	8%	12%
	Other	311	316	329	339	346	1%	1%
Baseline 1	Forest land	3449	3466	3499	3532	3565	14%	15%
	Cropland	5055	5082	5137	5192	5247	21%	21%
	Grassland	13461	13294	12964	12642	12322	55%	50%
	Wetland	171	171	171	171	170	1%	1%
	Settlement	1971	2089	2325	2555	2784	8%	11%
	Other	311	317	322	326	330	1%	1%
Baseline 2	Forest land	3449	3443	3435	3434	3438	14%	14%
	Cropland	5055	5082	5137	5192	5247	21%	21%
	Grassland	13461	13313	13019	12726	12432	55%	51%
	Wetland	171	171	171	171	170	1%	1%
	Settlement	1971	2091	2331	2565	2797	8%	11%
	Other	311	318	325	330	334	1%	1%
Low	Forest land	3449	3521	3730	3847	3928	14%	16%
	Cropland	5055	5105	5205	5305	5405	21%	22%
	Grassland	13461	13270	12801	12436	12115	55%	50%
	Wetland	171	171	170	170	170	1%	1%
	Settlement	1971	2021	2178	2320	2454	8%	10%
	Other	311	331	334	340	347	1%	1%
Stretch	Forest land	3449	3545	3855	4174	4446	14%	18%
	Cropland	5055	5105	5205	5305	5405	21%	22%
	Grassland	13461	13244	12676	12122	11619	55%	48%
	Wetland	171	169	166	166	166	1%	1%
	Settlement	1971	2019	2167	2298	2422	8%	10%
	Other	311	336	350	354	361	1%	1%

[11] The percentages reflect the UK area including water bodies.

4.2 UK projected emissions and removals

Table 5, Table 6, Table 7 and Table 8 show projected emissions of CO_2, CH_4, N_2O and total CO_2 equivalents for the LULUCF sector for the UK; similar summary numbers for each country are included in Annex 2, and the full dataset is available for download with this report from the NAEI website. Graphs of greenhouse gas emissions at the UK and country level for the whole LULUCF sector and for the individual land use categories are shown in Figure 10, Figure 13, Figure 14, Figure 15 and Figure 16. These graphs show the projected data to 2050 together with a consistent data set for 1990 to 2015, together with the reported inventory data for 1990-2015 as there are differences due to updates in the forest modelling and input data.

At the UK level, (Figure 10) the net CO_2 equivalent emissions / removals from all parts of the LULUCF sector are combined to produce an increasing net carbon sink (increasing net removals) between 1992 and 2015. This trend reverses around 2015, driven by the decreasing net removals in the Forest Land category as now mature forests planted when afforestation rates were at a maximum from the 1950s to 1980s are harvested, and an increasing trend in net Cropland and Settlement emissions. The difference between scenarios widens in the 2030s, with the *Central* and *Baseline* scenarios continuing towards zero (stabilising between -6.0 and -4.0 Mt CO_2e in the 2040s) and the *Low* and *Stretch* scenarios becoming increasing sinks again. The main driver of the trend in net total LULUCF emissions / removals over the projected time series is the reduction in the forestry net removals (this varies between scenarios), although the increase in settlement emissions and the reversal in the declining trend in cropland emissions also contribute.

Forestry is projected to be a net sink under all scenarios. It is an increasing sink between 1990 and 2012, and then shows some variation between then and 2020, before showing a net decrease in sink strength under all scenarios. This decrease continues until the mid-2030s when the *Central* and *Baseline* scenarios stabilise, while the net sink strength starts to increase again under the Low and Stretch scenarios. The scenarios are driven by the projected planting rates and management, with the biggest projected sink coming from the *Stretch* scenario with high planting rates, and the smallest sink coming from the *Baseline* and *Central* scenarios with the most conservative planting rates. The decrease in the sink between 2020 and 2035 is due to large numbers of trees being thinned or reaching maturity (some 35-50 years since planting) and hence being harvested, and a low planting rate from the 1990s.

Cropland is projected to be a slowly increasing source post-2015, mostly driven by land use change to Cropland and crop to grass rotations. Grassland is projected to be a slowly increasing sink. There is little difference between the scenarios for either of these land use categories as the differences in the scenario land use change assumptions are small.

The scale of changes in the Wetlands net source is small compared to the other land use categories. Figure 11 shows the changes in net emissions on a larger scale graph. The differences between scenarios are driven by assumptions about the reduction in peat extraction and the restoration of former extraction sites.

Emissions from land use change to Settlements are projected to decrease over the time period under the *Low* and *Stretch* scenarios, but to increase under the *Central* and *Baseline* scenarios (driven predominantly by the net emissions from England). Although Settlement areas are predicted to increase under all scenarios, the rate of change of land to Settlement (and hence emissions from land use change) varies between the different scenarios. The activity data for the projections have been revised this year and are discussed further in Annex 1.

Harvested Wood Products (HWPs) are projected to be a small sink over the period 2016 to 2050. The trend is driven by the balance between deforestation rates, thinning and felling regimes and the expected lifetime of the HWPs. There is little difference between the scenarios as the majority of harvest originates from trees planted before the projection time period.

CO_2, arising from soil carbon stock changes, is the main GHG associated with LULUCF (Figure 12), although N_2O emissions also make a significant contribution when the GWP of N_2O of 298 is taken into account. These N_2O emissions arise from forest fertilisation, forest drainage, soil nitrogen mineralisation following land use change and from biomass burning. The *Stretch* scenario does not result in the lowest emissions of N_2O because the increased afforestation (with increased CO_2 removals) in this scenario also produces increased N_2O emissions from forest fertilisation and drainage. CH_4 emissions (GWP of 25) arising from biomass burning are included in the projections but they do not make a significant contribution to the overall totals.

4.3 Country-level projected emissions and removals

England shows a sharp reduction in the net sink strength after 2020 (Figure 13), becoming a net source of LULUCF emissions by 2046-47 under the *Baseline* scenarios and 2039 under the *Central* scenario. The differences between the scenarios come mostly from differences in the Settlement category emissions, as there is little difference between the scenarios for the Forest Land category.

The overall pattern of projected emissions and removals for Scotland (Figure 14) is similar to the UK, being driven primarily by the Forest Land sink.

Wales (Figure 15) is a net LULUCF GHG sink for all scenarios throughout the time series. The *Baseline 1* and *2* scenarios are a larger sink than the *Central*, *Low* and *Stretch* scenarios due to differences in projected land use change to Cropland (a lower additional rate of Grassland to Cropland conversion is assumed in the Baseline scenarios). Some differentiation between scenarios due to net removals from the Forest Land category also become apparent in the 2040s.

Northern Ireland (Figure 16) is projected to be a net LULUCF GHG source for much of the time period, although under the *Stretch* and *Low* scenarios it is projected to become a small net sink during the 2040s. This is mainly driven by the trend in emissions from Settlements, which peak in 2015 and then decrease to 2050.

The relative contributions of the LULUCF sector from the countries to the UK total are shown in Figure 17 (Central scenario).

4.4 Changes from the 1990-2014 projections

There have been some changes to activity data and methods used for estimating the LULUCF emissions and removals projections since the previous projections report. These differences are shown at the UK level in Figure 18 by comparing the *Central* projections based on the 2015 and 2014 inventories. As can be seen in previous graphs the 2015 projections differ from the 1990-2015 inventory due to improvements in the forestry data, but are actually comparatively similar to the 2014 projections, as the increased sink in the Forest Land category is offset by an increased source in the Settlement category. The forestry projections differ from the forestry numbers published in the 1990-2015 inventory because the following improvements were included to better represent the effects of afforestation:

- Include a simple representation of non-tree litter, as there would otherwise be too much loss of soil carbon on conversion to forest, as there would be no carbon inputs to the soil until canopy closure several decades after planting.
- Reduce the implied level of recent afforestation by changing the assumptions used in including the area of small woods (woodlands between 0.1 and 0.5ha).

This had the effect of reducing CO_2 emissions from the soil on afforestation and after harvesting, thereby increasing the Forest Land carbon sink, especially for recently forested land. These improvements will be refined and included in the 1990-2016 inventory.

Projections from the Settlement category have changed because the methodology of the activity data source has been revised (and improved), leading to larger estimates of conversion to Settlement in England in particular. Further details are given in Annex 1.

Table 5: LULUCF emissions and removals of CO_2 1990-2050

Scenario	Country	1990 Gg CO_2	2015 Gg CO_2	2020 Gg CO_2	2030 Gg CO_2	2040 Gg CO_2	2050 Gg CO_2
Central	**UK**	-1186	-14448	-12739	-8727	-6461	-5923
Baseline 1	**UK**	-1186	-14448	-13080	-9870	-7378	-6724
Baseline 2	**UK**	-1186	-14448	-13544	-10633	-8343	-7645
Low	**UK**	-1186	-14448	-13594	-11139	-10689	-12703
Stretch	**UK**	-1186	-14448	-13570	-11060	-10645	-13930

Table 6: LULUCF emissions and removals of CH_4 1990-2050

Scenario	Country	1990 Gg CH_4	2015 Gg CH_4	2020 Gg CH_4	2030 Gg CH_4	2040 Gg CH_4	2050 Gg CH_4
Central	**UK**	0.67	1.01	1.27	1.07	0.83	0.83
Baseline 1	**UK**	0.67	1.01	1.58	1.63	1.66	1.77
Baseline 2	**UK**	0.67	1.01	1.18	0.97	0.73	0.71
Low	**UK**	0.67	1.01	0.87	0.65	0.41	0.39
Stretch	**UK**	0.67	1.01	0.87	0.65	0.41	0.39

Table 7: LULUCF emissions and removals of N_2O 1990-2050

Scenario	Country	1990 Gg N_2O	2015 Gg N_2O	2020 Gg N_2O	2030 Gg N_2O	2040 Gg N_2O	2050 Gg N_2O
Central	**UK**	7.50	4.83	5.17	6.30	6.58	6.56
Baseline 1	**UK**	7.50	4.83	4.97	5.69	6.02	6.10
Baseline 2	**UK**	7.50	4.83	4.93	5.60	5.82	5.83
Low	**UK**	7.50	4.83	4.90	5.56	5.69	5.42
Stretch	**UK**	7.50	4.83	4.93	5.68	6.02	5.86

Table 8: LULUCF emissions and removals of CO_2 equivalents 1990-2050 (1 Mt CO_2e = 1000 Gg CO_2e)

Scenario	Country	1990 Gg CO_2 eq	2015 Gg CO_2 eq	2020 Gg CO_2 eq	2030 Gg CO_2 eq	2040 Gg CO_2 eq	2050 Gg CO_2 eq
Central	**UK**	1065	-12982	-11166	-6824	-4480	-3948
Baseline 1	**UK**	1065	-12982	-11560	-8133	-5543	-4863
Baseline 2	**UK**	1065	-12982	-12045	-8941	-6589	-5889
Low	**UK**	1065	-12982	-12113	-9466	-8982	-11077
Stretch	**UK**	1065	-12982	-12079	-9350	-8843	-12175

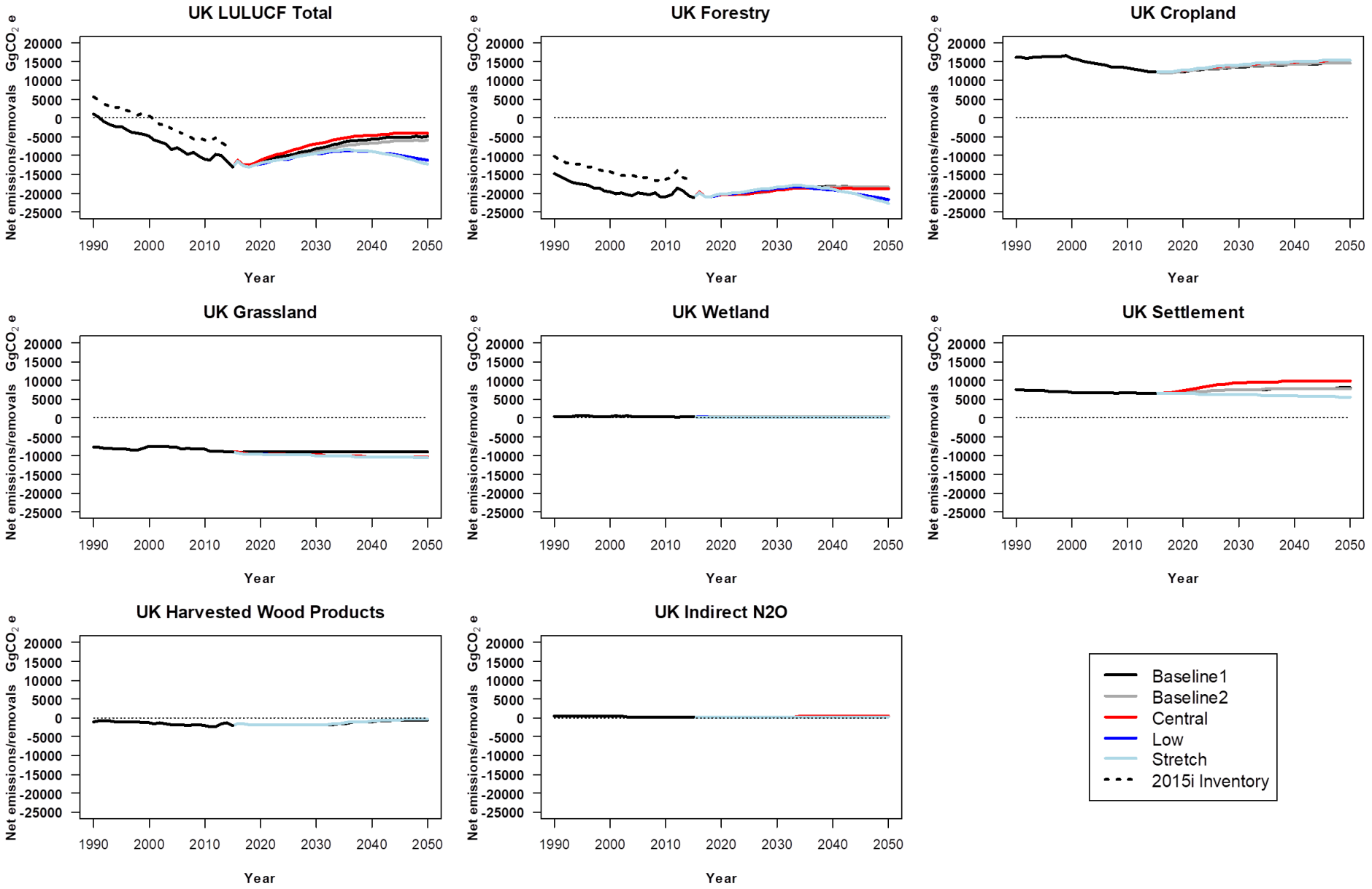

Figure 10: UK LULUCF CO_2 equivalent emissions scenarios 1990-2050. The individual graphs refer to LULUCF reporting categories; see Section 3 text for description of what is reported in these categories. (1 Mt CO_2e = 1000 Gg CO_2e)

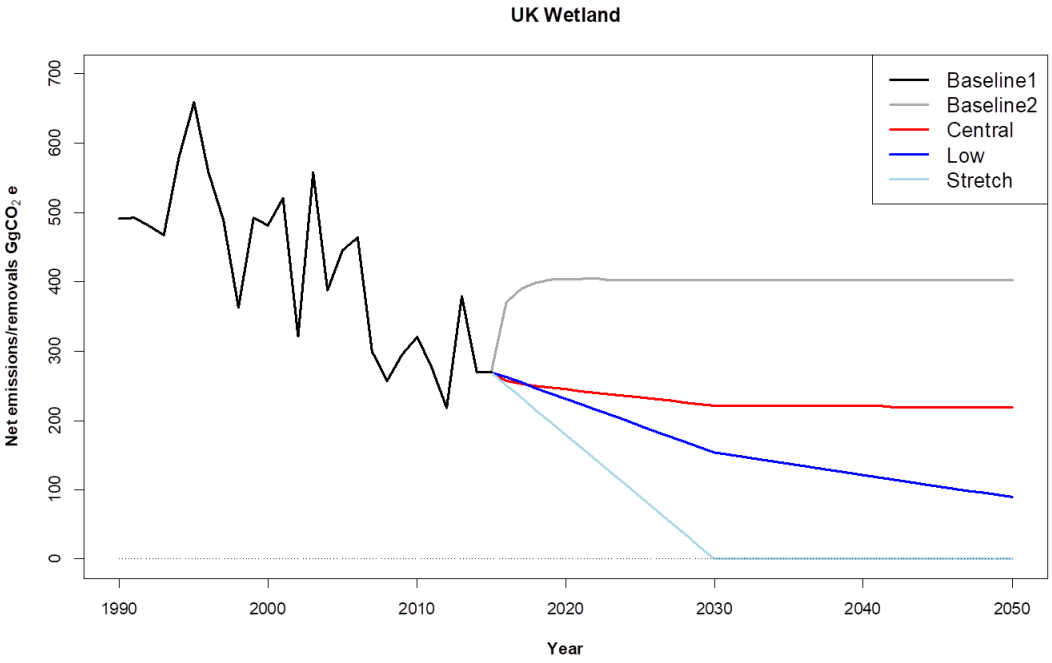

Figure 11: Net emissions from Wetlands under all scenarios (shown on larger scale for clarity) (1 Mt CO_2e = 1000 Gg CO_2e).

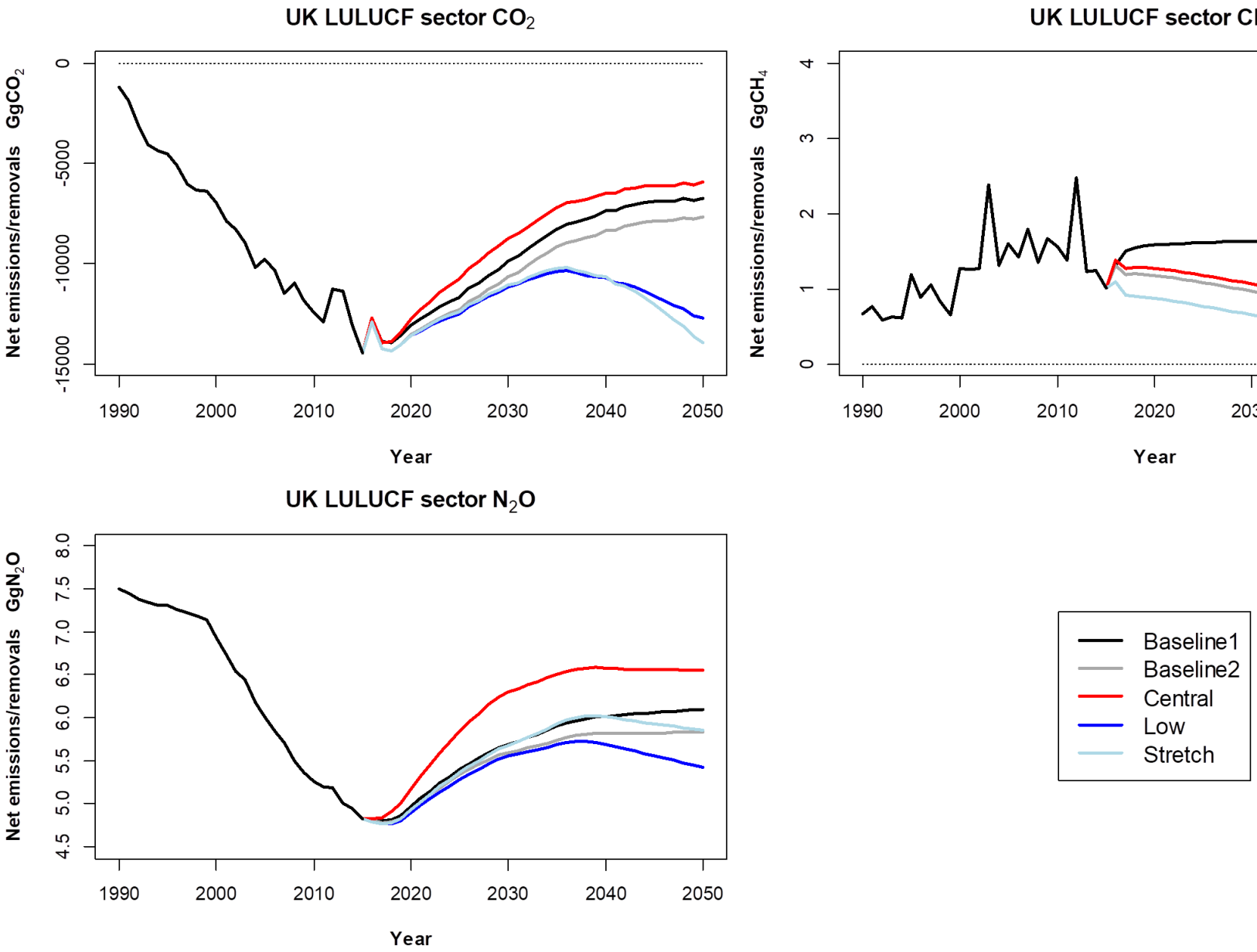

Figure 12: UK LULUCF Sector emissions of individual gases 1990-2050 (1 Mt CO_2e = 1000 Gg CO_2e)

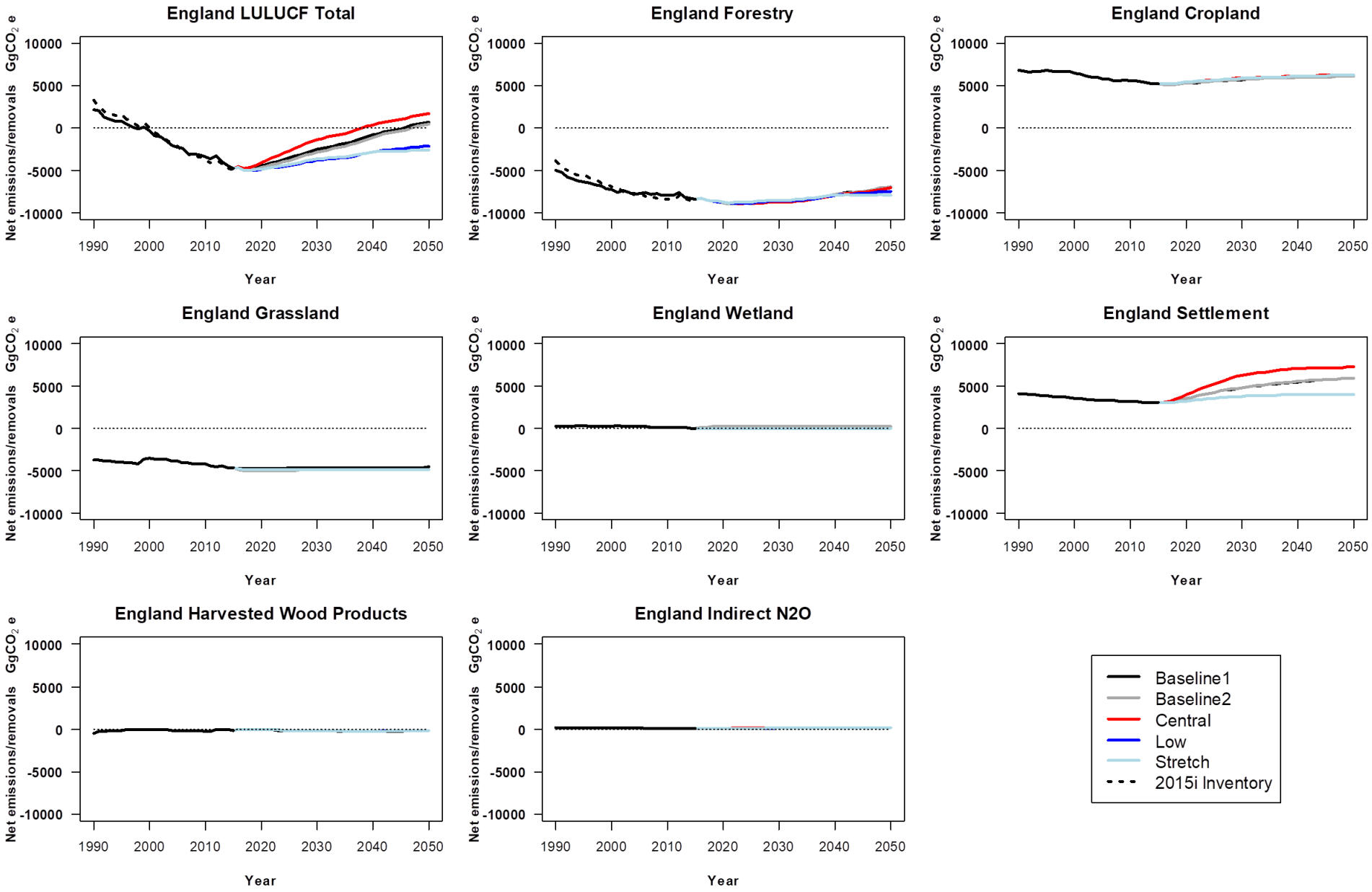

Figure 13: England LULUCF CO_2 equivalent emissions scenarios 1990-2050. The individual graphs refer to LULUCF reporting categories; see Section 3 text for description of what is reported in these categories. (1 Mt CO_2e = 1000 Gg CO_2e)

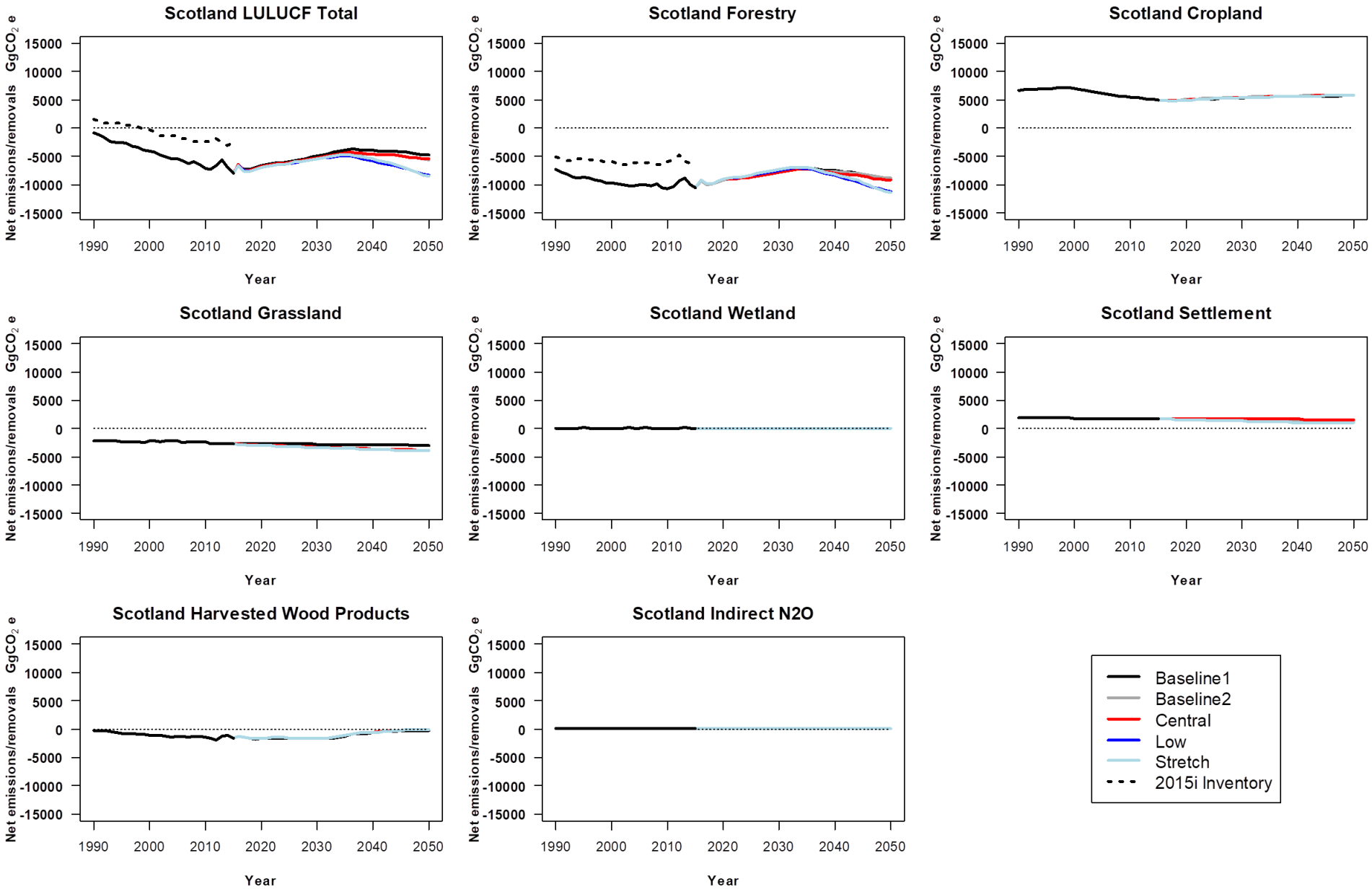

Figure 14: Scotland LULUCF CO_2 equivalent emissions scenarios 1990-2050. The individual graphs refer to LULUCF reporting categories; see Section 3 text for description of what is reported in these categories. (1 Mt CO_2e = 1000 Gg CO_2e)

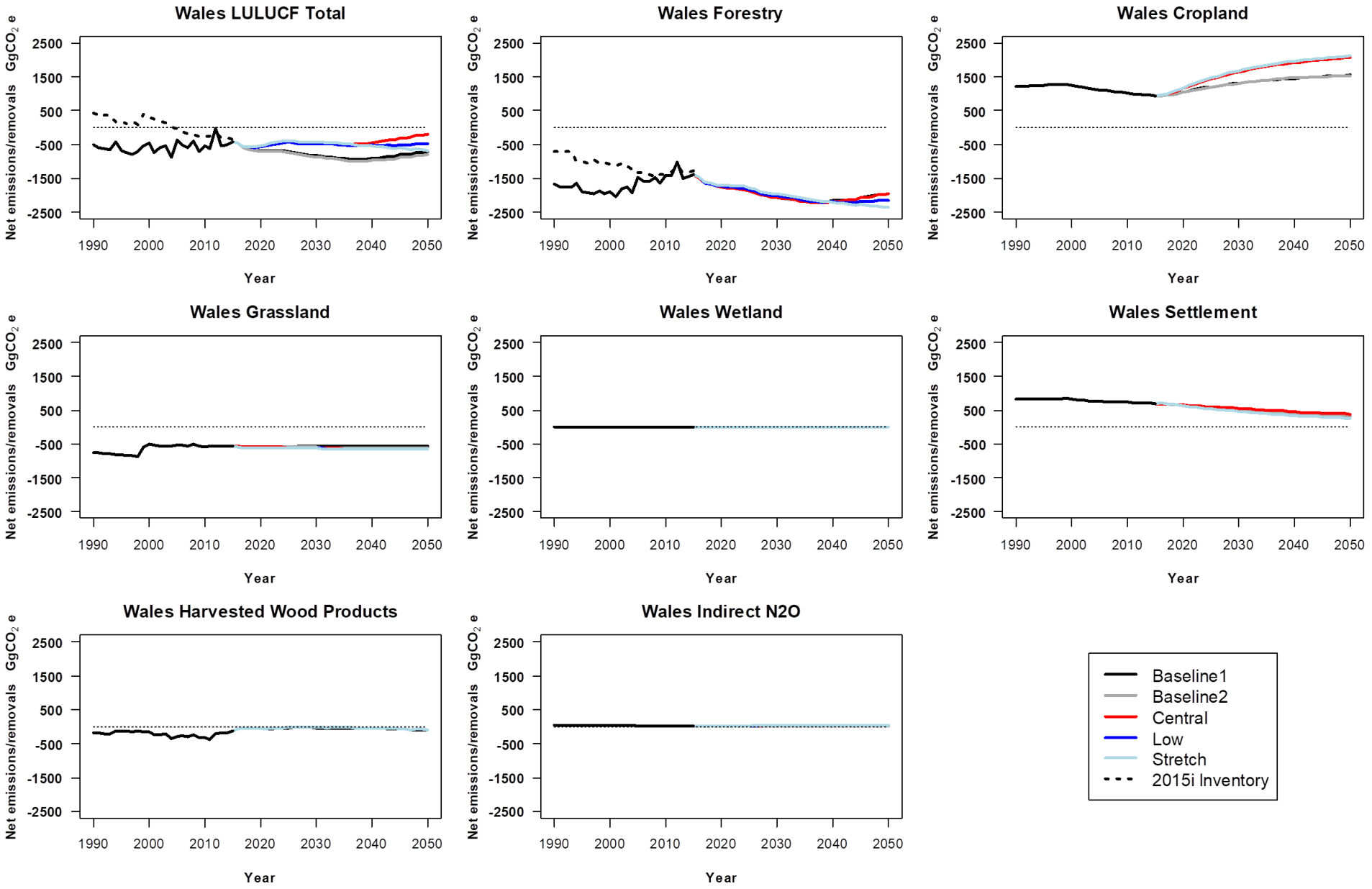

Figure 15: Wales LULUCF CO_2 equivalent emissions scenarios 1990-2050. The individual graphs refer to LULUCF reporting categories, which for cropland and grassland are mainly driven by land use change. (1 Mt CO_2e = 1000 Gg CO_2e)

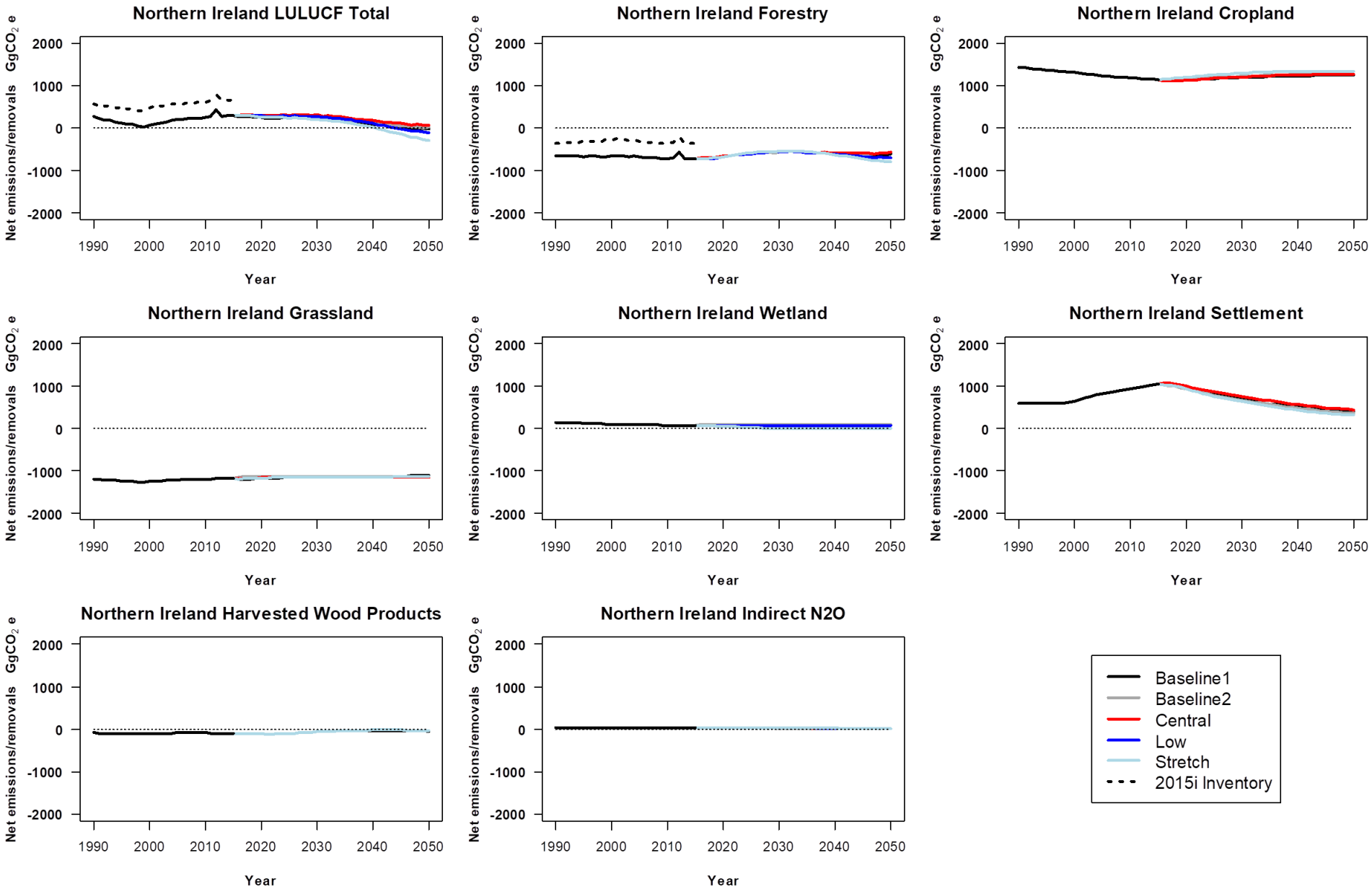

Figure 16: Northern Ireland LULUCF CO_2 equivalent emissions scenarios 1990-2050. The individual graphs refer to LULUCF reporting categories; see Section 3 text for description of what is reported in these categories. (1 Mt CO_2e = 1000 Gg CO_2e)

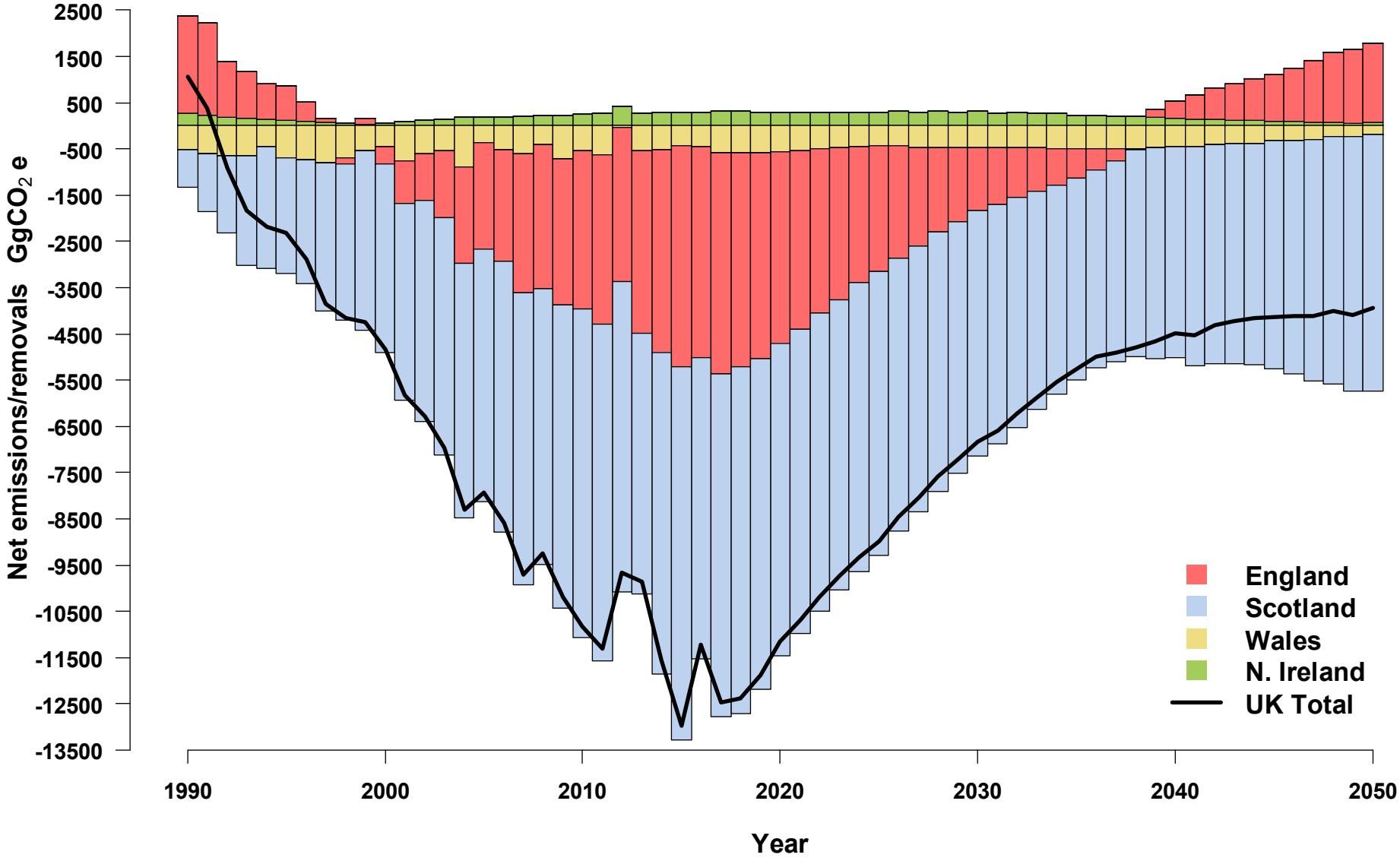

Figure 17: The combined total of the LULUCF emissions from each country for the *Central* emissions scenario

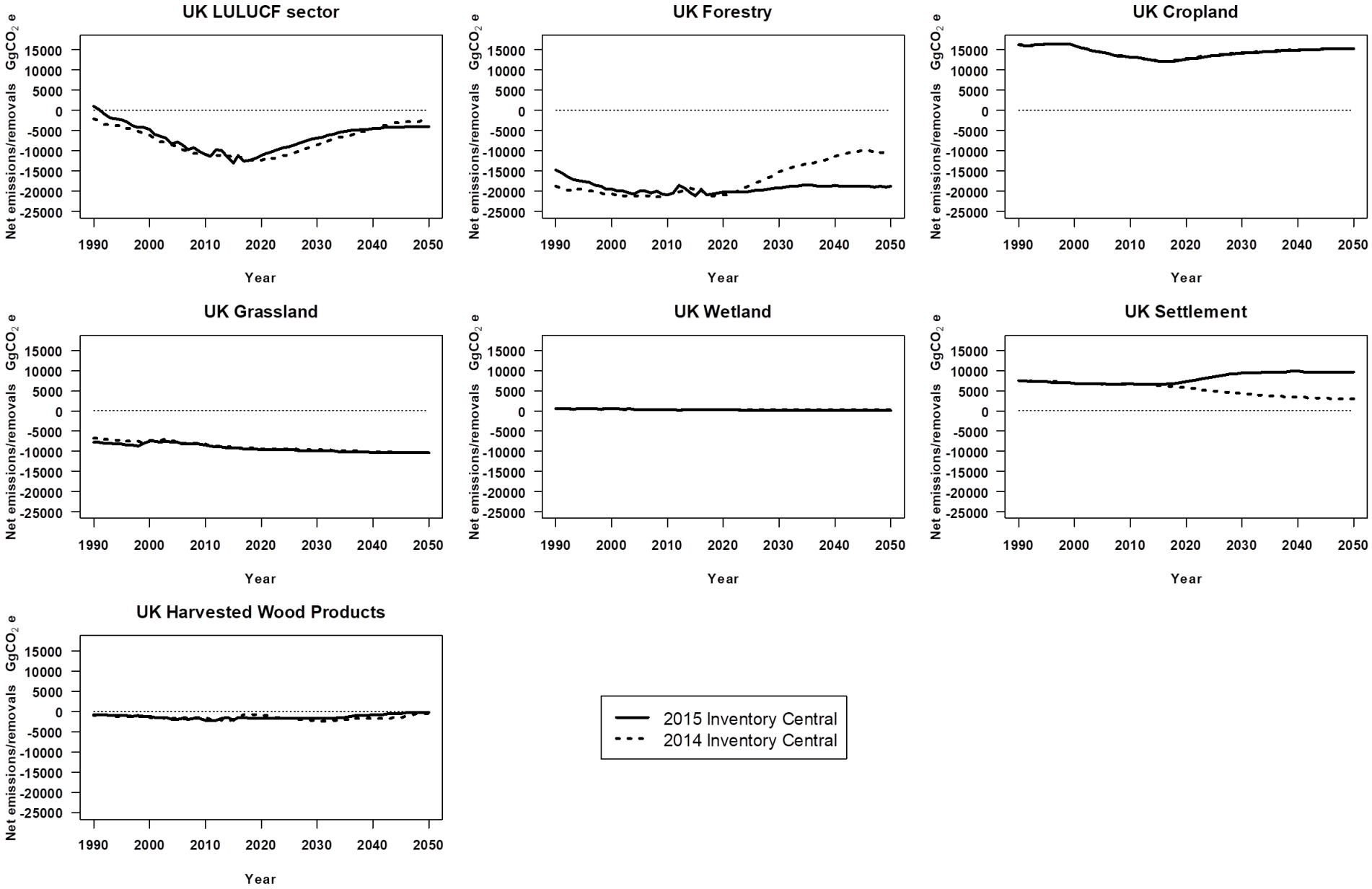

Figure 18 UK LULUCF CO_2 equivalent comparison of the Central and Mid emissions scenario for the 2015 and 2014 inventories respectively 1990-2050 (1 Mt CO_2e = 1000 Gg CO_2e)

5 References

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DCLG, 2015. Land use change statistics 2-13/14. Methodology changes guidance. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/432348/DCLG_LUCS_New_Methodology_Guidance.pdf

DCLG, 2017a. Land use change statistics in England: 2015-16. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/595749/Land_use_change_statistics_England_2015-16_-_2_March_2017_version.pdf (Tables 300, 330, 350, 360, 361, 370).

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Annex 1: Methodology for projection of land use change to Settlement

Statistics on recent conversion of undeveloped land to developed land (i.e. land conversion to Settlement) suggest that the rate of land conversion has changed significantly in recent years (DCLG, 2017a), compared with the rates of conversion between 1998 and 2007 (as calculated from the Countryside Survey data). There has also been much media coverage of the need for increased construction to meet housing demand in the future. A new methodology for projecting land use change to Settlement was implemented in the projections report for 1990-2013 and is updated here. This methodology is based on the Land Use Change Statistics (LUCS) released by the Department of Communities and Local Government (DCLG) and projections of the number of households in the UK and its constituent countries (DCLG 2016).

The LUCS data describe land area change to developed use in England, based on the change to and from 28 land use categories. The latest LUCS data (2013/14 to 2015/16) are derived by a methodology based on changes in Ordnance Survey products, rather than the physical observations of the previous methodology. The change in methodology was sought by Government to increase cost-effectiveness and to enable more detailed statistical and spatial analysis of the LUCS dataset (DCLG 2015). There are important differences between the two methodologies and "due to the changes in methodology and land use classification, comparison and interpretation between the two series is not recommended" (p.6, DCLG 2015).

The LUCS dataset reports the annual areas changing from previously non-developed to developed use, the area converted to residential use, the proportion of residential development compared to all development and the average density of new residential dwellings (England only).

In the previous LUCS methodology the total area of change from a previously non-developed use to a developed use in 2011 was 2180 ha, of which 1130 ha changed to residential use. The historic time series was used to derive an assumption that 50% of all conversion from previously non-developed use was to residential use and 50% to non-residential use.

In the new LUCS methodology, the total area of change from a previously non-developed use to a developed use in 2013/14 is 13,531 ha, of which 2,105 ha is to residential use. The proportion (16%) is also explicitly given in the LUCS. Using this ratio in the LULUCF projections to extrapolate total area converted to developed land (Settlement) from the estimated area converted to residential land (from household projections and average housing density) has caused a large difference to the projected Settlement areas. The projected areas of residential use conversion in England are the same order of magnitude as the 1990-2014 inventory projections (2016-50 average of 2639 ha/yr for the 2014 inventory and 4619 ha/yr for the 2015 inventory). However, the projected areas of all developed land conversion are 5,278 ha/yr in 2014i and 26,792 ha/yr for the 2015i.

The projections of household numbers (DCLG 2016) use the 2011 national population census updated to 2014 and trends in population demography and household formation to project household numbers to 2037-2039. In the LULUCF projections, the area of land converted to developed use is projected using the method described below and three key assumptions:

- The detailed LUCS data for England 2013/14 to 2015/16 are representative of the time series for projections to 2050 (this assumption can be refined as more annual data are published using the new LUCS methodology).
- The density of residential dwellings and the proportions of development on non-previously developed land in England are also representative of Scotland, Wales and Northern Ireland, in the absence of similar data.
- The projected number of households in the future can act as a proxy for the area of urban development (a constant rate of additional households per year is assumed after 2037/39 as household numbers are only projected by DCLG to this year.

The *Central* scenario assumes that residential development on previously non-developed (PND) land, and proportionally all development, is sufficient to meet the demand for housing predicted by the household projections dataset, where:

$$aALL_i = ((\Delta Household_i * pcRes)/densRes)/pcALL$$

$aALL_i$ = Area of ALL conversion to developed land in year I (hectares)

pcRes = fraction of change to residential use on land that was previously non-developed land that was developed in year i (%)

densRes = average density of residential addresses created on previously non-developed land, (dwellings per hectare)

pcALL = fraction of residential development of all development on previously non-developed land (%)

$\Delta Household_i$ = change in number of households (by country) for year i compared to year i-1

The other scenarios reflect what would happen if there was insufficient construction to meet demand, if there was an alteration in household demand, or if dwellings were constructed at a greater density or with a greater preference for previously developed sites, therefore reducing the amount of land use change. The *Baseline* scenarios use the 2000-2009 average rate for conversion of PND land to developed land for England out to 2050. There are no equivalent rates for the other countries of the UK, so 70% of the decadal averages of the *Central* scenario are used. The *Low* and *Stretch* scenarios use 50% of the decadal average of the *Central* scenario for all countries.

The area of developed land, i.e. land converted to Settlement, is divided between conversion categories, using the projected areas of deforestation to Settlement, with the remaining area assigned to Grassland converted to Settlement.

Annex 2: Land use areas by Country

Table A2.1: Land use areas 2015-2050 for England (13,046 kha)

Emission scenario	*Land use category*	*2015 area, kha*	*2020 area, kha*	*2030 area, kha*	*2040 area, kha*	*2050 area, kha*
Central	Forest land	1575	1587	1584	1583	1583
	Cropland	4163	4163	4163	4163	4163
	Grassland	5642	5510	5208	4940	4691
	Wetland	19	19	19	19	19
	Settlement	1525	1644	1945	2213	2463
	Other	121	123	127	127	127
Baseline 1	Forest land	1575	1583	1599	1615	1631
	Cropland	4163	4163	4163	4163	4163
	Grassland	5642	5528	5301	5076	4851
	Wetland	19	19	19	19	19
	Settlement	1525	1630	1839	2048	2257
	Other	121	124	125	125	125
Baseline 2	Forest land	1575	1573	1570	1569	1569
	Cropland	4163	4163	4163	4163	4163
	Grassland	5642	5536	5325	5114	4902
	Wetland	19	19	19	19	19
	Settlement	1525	1631	1843	2055	2267
	Other	121	124	126	126	126
Low	Forest land	1575	1591	1637	1685	1720
	Cropland	4163	4163	4163	4163	4163
	Grassland	5642	5577	5386	5210	5054
	Wetland	19	19	19	19	19
	Settlement	1525	1568	1710	1840	1960
	Other	121	127	131	130	130
Stretch	Forest land	1575	1600	1695	1791	1864
	Cropland	4163	4163	4163	4163	4163
	Grassland	5642	5567	5335	5118	4929
	Wetland	19	18	16	16	16
	Settlement	1525	1567	1703	1827	1943
	Other	121	130	134	131	132

Table A2.2: Land use areas 2015-2050 for Scotland (7,881 kha)

Emission scenario	*Land use category*	*2015 area, kha*	*2020 area, kha*	*2030 area, kha*	*2040 area, kha*	*2050 area, kha*
Central	Forest land	1450	1475	1469	1467	1468
	Cropland	589	589	589	589	589
	Grassland	5406	5368	5342	5317	5290
	Wetland	92	92	92	92	92
	Settlement	199	210	232	251	269
	Other	146	148	157	165	172
Baseline 1	Forest land	1450	1458	1474	1489	1504
	Cropland	589	589	589	589	589
	Grassland	5406	5389	5355	5323	5293
	Wetland	92	92	92	92	92
	Settlement	199	205	219	232	243
	Other	146	149	153	157	160
Baseline 2	Forest land	1450	1447	1443	1444	1447
	Cropland	589	589	589	589	589
	Grassland	5406	5399	5382	5363	5344
	Wetland	92	92	92	92	92
	Settlement	199	205	221	234	246
	Other	146	150	155	159	163
Low	Forest land	1450	1495	1633	1677	1709
	Cropland	589	589	589	589	589
	Grassland	5406	5346	5201	5143	5096
	Wetland	92	92	91	91	91
	Settlement	199	202	209	217	225
	Other	146	158	158	164	171
Stretch	Forest land	1450	1500	1663	1833	2005
	Cropland	589	589	589	589	589
	Grassland	5406	5339	5162	4980	4796
	Wetland	92	91	91	91	91
	Settlement	199	202	208	212	216
	Other	146	159	169	177	184

Table A2.3: Land use areas 2015-2050 for Wales (2,078 kha)

Emission scenario	*Land use category*	*2015 area, kha*	*2020 area, kha*	*2030 area, kha*	*2040 area, kha*	*2050 area, kha*
Central	Forest land	343	342	341	340	340
	Cropland	187	237	337	437	537
	Grassland	1362	1307	1197	1090	982
	Wetland	5	5	5	5	5
	Settlement	156	162	174	181	188
	Other	25	26	25	25	26
Baseline 1	Forest land	343	343	342	342	341
	Cropland	187	214	269	325	380
	Grassland	1362	1332	1270	1210	1150
	Wetland	5	5	5	5	5
	Settlement	156	160	168	173	178
	Other	25	25	24	24	24
Baseline 2	Forest land	343	342	341	340	341
	Cropland	187	214	269	325	380
	Grassland	1362	1332	1270	1210	1150
	Wetland	5	5	5	5	5
	Settlement	156	160	168	173	178
	Other	25	25	25	25	25
Low	Forest land	343	351	370	388	393
	Cropland	187	237	337	437	537
	Grassland	1362	1301	1179	1060	951
	Wetland	5	5	5	5	5
	Settlement	156	158	162	165	168
	Other	25	26	25	24	24
Stretch	Forest land	343	361	399	436	446
	Cropland	187	237	337	437	537
	Grassland	1362	1293	1152	1017	905
	Wetland	5	5	5	5	5
	Settlement	156	157	160	161	163
	Other	25	26	25	23	23

Table A2.4: Land use areas 2015-2050 for Northern Ireland (1,413 kha)

Emission scenario	*Land use category*	*2015 area, kha*	*2020 area, kha*	*2030 area, kha*	*2040 area, kha*	*2050 area, kha*
Central	Forest land	82	82	82	81	82
	Cropland	116	116	116	116	116
	Grassland	1051	1046	1040	1035	1030
	Wetland	55	55	55	55	55
	Settlement	91	94	101	105	109
	Other	19	19	20	21	21
Baseline 1	Forest land	82	83	85	87	89
	Cropland	116	116	116	116	116
	Grassland	1051	1045	1039	1033	1028
	Wetland	55	55	55	55	55
	Settlement	91	95	99	102	105
	Other	19	19	20	20	20
Baseline 2	Forest land	82	82	81	81	81
	Cropland	116	116	116	116	116
	Grassland	1051	1047	1042	1039	1036
	Wetland	55	55	55	55	55
	Settlement	91	95	99	102	105
	Other	19	19	20	20	20
Low	Forest land	82	83	90	98	106
	Cropland	116	116	116	116	116
	Grassland	1051	1046	1035	1024	1014
	Wetland	55	55	55	55	55
	Settlement	91	93	97	99	100
	Other	19	20	21	22	22
Stretch	Forest land	82	84	98	114	131
	Cropland	116	116	116	116	116
	Grassland	1051	1045	1027	1008	989
	Wetland	55	55	55	55	55
	Settlement	91	93	96	98	100
	Other	19	20	22	22	23

Annex 3: Afforestation and Deforestation data

Table A3.1 *Baseline 1* Scenario Afforestation Rates (kha)

	Annual Forest Planting Rate				
Year	England	Scotland	Wales	N. Ireland	UK Total
2016	2.064	3.738	0.177	0.230	6.209
2017-2050	2.515	3.440	0.189	0.289	6.433

Table A3.2 *Baseline 1* Scenario Deforestation Rates (kha)

	Annual Deforestation Rate				
Year	England	Scotland	Wales	N. Ireland	UK Total
2016	0.930	1.474	0.282	0.093	2.779
2017-2050	0.904	1.930	0.225	0.093	3.152

Table A3.3 *Baseline 2* Scenario Afforestation Rates (kha)

	Annual Forest Planting Rate				
Year	England	Scotland	Wales	N. Ireland	UK Total
2016	0.376	1.593	0.073	0.038	2.080
2017-2050	0.264	0.580	0.050	0.033	0.927

Table A3.4 *Central* Scenario Afforestation Rates (kha)

	Annual Forest Planting Rate				
Year	England	Scotland	Wales	N. Ireland	UK Total
2016	2.642	6.827	0.113	0.170	9.751
2017	4.013	7.559	0.103	0.208	11.883
2018	4.473	7.559	0.103	0.208	12.343
2019	3.476	7.559	0.103	0.208	11.346
2020	0.969	2.148	0.040	0.074	3.230
2021-2050	0.252	0.344	0.019	0.029	0.643

Table A3.5 *Baseline 2/Central/Low/Stretch* Scenario Deforestation Rates (kha)

Year	Annual Deforestation Rate				
	England	Scotland	Wales	N. Ireland	UK Total
2016	0.930	1.474	0.282	0.093	2.779
2017	0.602	1.252	0.223	0.143	2.220
2018	0.589	1.211	0.215	0.138	2.152
2019	0.576	1.169	0.207	0.132	2.084
2020	0.562	1.128	0.198	0.127	2.015
2021	0.549	1.087	0.190	0.121	1.947
2022	0.536	1.045	0.182	0.116	1.879
2023	0.523	1.004	0.174	0.110	1.811
2024	0.510	0.962	0.166	0.105	1.743
2025	0.497	0.921	0.158	0.099	1.675
2026	0.484	0.880	0.150	0.094	1.607
2027	0.471	0.838	0.142	0.088	1.539
2028	0.457	0.797	0.133	0.083	1.470
2029	0.444	0.755	0.125	0.077	1.402
2030	0.431	0.714	0.117	0.072	1.334
2031	0.418	0.673	0.109	0.066	1.266
2032	0.405	0.631	0.101	0.061	1.198
2033	0.392	0.590	0.093	0.055	1.130
2034	0.379	0.548	0.085	0.050	1.062
2035	0.366	0.507	0.077	0.044	0.994
2036	0.352	0.466	0.068	0.039	0.925
2037	0.339	0.424	0.060	0.033	0.857
2038	0.326	0.383	0.052	0.028	0.789
2039	0.313	0.341	0.044	0.022	0.721
2040	0.300	0.300	0.036	0.017	0.653
2041	0.300	0.210	0.025	0.012	0.547
2042	0.300	0.210	0.025	0.012	0.547
2043	0.300	0.210	0.025	0.012	0.547
2044	0.300	0.210	0.025	0.012	0.547
2045	0.300	0.210	0.025	0.012	0.547
2046	0.300	0.210	0.025	0.012	0.547
2047	0.300	0.210	0.025	0.012	0.547
2048	0.300	0.210	0.025	0.012	0.547
2049	0.300	0.210	0.025	0.012	0.547
2050	0.300	0.210	0.025	0.012	0.547

Table A3.6 *Low* Scenario Afforestation Rates (kha)

	Annual Forest Planting Rate				
Year	England	Scotland	Wales	N. Ireland	UK Total
2016	2.050	8.658	1.574	0.241	12.524
2017	3.194	10.000	2.051	0.304	15.549
2018	4.122	10.000	2.051	0.304	16.478
2019	5.051	11.500	2.051	0.304	18.907
2020	5.165	12.000	2.020	0.462	19.647
2021	5.126	13.500	2.009	0.589	21.225
2022	5.126	14.000	2.009	0.652	21.787
2023	5.126	14.750	2.009	0.664	22.550
2024	5.126	15.000	2.009	0.702	22.837
2025	5.126	15.000	2.009	0.752	22.887
2026	5.126	15.000	2.009	0.802	22.937
2027	5.126	15.000	2.009	0.852	22.987
2028	5.126	15.000	2.009	0.864	23.000
2029	5.126	15.000	2.009	0.864	23.000
2030	5.126	15.000	2.009	0.864	23.000
2031	5.126	15.000	2.009	0.864	23.000
2032	5.126	6.330	2.009	0.864	14.330
2033	5.126	3.440	2.009	0.864	11.440
2034	5.126	3.440	2.009	0.864	11.440
2035	5.126	3.440	2.009	0.864	11.440
2036	5.126	3.440	2.009	0.864	11.440
2037	5.126	3.440	2.009	0.864	11.440
2038	5.126	3.440	2.009	0.864	11.440
2039	5.126	3.440	2.009	0.864	11.440
2040	4.976	3.440	0.884	0.864	10.165
2041	4.776	3.440	0.509	0.864	9.590
2042	4.576	3.440	0.509	0.864	9.390
2043	4.376	3.440	0.509	0.864	9.190
2044	4.176	3.440	0.509	0.864	8.990
2045	3.976	3.440	0.509	0.864	8.790
2046	3.776	3.440	0.509	0.864	8.590
2047	3.576	3.440	0.509	0.864	8.390
2048	3.376	3.440	0.509	0.864	8.190
2049	3.176	3.440	0.509	0.864	7.990
2050	3.126	3.440	0.509	0.864	7.940

Table A3.7 *Stretch* Scenario Afforestation Rates (kha)

Year	Annual Forest Planting Rate				
	England	Scotland	Wales	N. Ireland	UK Total
2016	2.104	8.658	3.035	0.314	14.111
2017	3.962	10.000	4.000	0.400	18.362
2018	5.820	11.875	4.000	0.400	22.095
2019	7.678	12.500	4.000	0.400	24.578
2020	9.536	14.375	4.000	0.850	28.761
2021	10.000	15.000	4.000	1.150	30.150
2022	10.000	16.875	4.000	1.275	32.150
2023	10.000	17.500	4.000	1.300	32.800
2024	10.000	17.500	4.000	1.375	32.875
2025	10.000	17.500	4.000	1.475	32.975
2026	10.000	17.500	4.000	1.575	33.075
2027	10.000	17.500	4.000	1.675	33.175
2028	10.000	17.500	4.000	1.700	33.200
2029	10.000	17.500	4.000	1.700	33.200
2030	10.000	17.500	4.000	1.700	33.200
2031	10.000	17.500	4.000	1.700	33.200
2032	10.000	17.500	4.000	1.700	33.200
2033	10.000	17.500	4.000	1.700	33.200
2034	10.000	17.500	4.000	1.700	33.200
2035	10.000	17.500	4.000	1.700	33.200
2036	10.000	17.500	4.000	1.700	33.200
2037	10.000	17.500	4.000	1.700	33.200
2038	10.000	17.500	4.000	1.700	33.200
2039	10.000	17.500	4.000	1.700	33.200
2040	9.700	17.500	1.750	1.700	30.650
2041	9.300	17.500	1.000	1.700	29.500
2042	8.900	17.500	1.000	1.700	29.100
2043	8.500	17.500	1.000	1.700	28.700
2044	8.100	17.500	1.000	1.700	28.300
2045	7.700	17.500	1.000	1.700	27.900
2046	7.300	17.500	1.000	1.700	27.500
2047	6.900	17.500	1.000	1.700	27.100
2048	6.500	17.500	1.000	1.700	26.700
2049	6.100	17.500	1.000	1.700	26.300
2050	6.000	17.500	1.000	1.700	26.200

Annex 4: Overseas Territories and Crown Dependencies

Projections of net GHG emissions to 2050 from the UK's Overseas Territories and Crown Dependencies (OT/CDs) LULUCF sector are produced for the first time for the 1990-2015 inventory. The OT/CDs reported here are the Crown Dependencies of the Isle of Man, Guernsey and Jersey and the Overseas Territory of the Falkland Islands. There are insufficient data to estimate LULUCF sector emissions for Bermuda, the Cayman Islands and Montserrat. LULUCF net emissions from Gibraltar have been assessed as not occurring by the Government of Gibraltar and are not reported in the inventory or projections

Policy assumptions are made in line with those used for the UK's LULUCF projections where possible. In general, there are fewer and more limited activity datasets available for the OT/CDs and emissions and removals are calculated using simpler Tier 1 methodologies. As a consequence, policy assumptions have been simplified and it has not been possible to construct the full suite of projection scenarios. This area of inventory reporting will be kept under review with regard to potential improvement.

A single *Baseline* scenario was constructed for afforestation. Only the Isle of Man and Guernsey have any managed forest areas, with the Isle of Man known to have undergone conifer and broadleaved afforestation between 1961 and 1990, and Guernsey undergoing a steady rate of broadleaved afforestation from 2000 (assumed to continue to 2020). There is an intention to improve the representation of Forest Land for the OT/CDs by modelling forest carbon stock flows using the UK's CARBINE model. This has not been achieved in this projection cycle, as other CARBINE development for UK inventory reporting has been prioritised. At present, the OT/CD Forest Land and HWP emissions and removals are modelled by the C-Flow model (used for reporting in the UK inventory until 2012), and the model output has been adjusted to project biomass, litter, soil and harvested wood product carbon stock changes out to 2050.

The most recent available development plans and rural strategy policy documents for each OT/CD (Table 9) were examined to assist in scenario construction.

- *Baseline* emissions scenario: in this scenario the average activity rates for 2000-2009 are extended out to 2050.
    - Applies to all OT/CDs
- *Central* emissions scenario: the 2015 levels of activity or rates of change (including known policies) are extended to 2050.
    - Applies to all OT/CDs
    - In addition:
        - Isle of Man: strategic policy to construct 5,100 additional dwellings 2011-2026 (Grassland to Settlement conversion of 0.029 kha/yr)
        - Isle of Man: environmental policy on the avoidance of any permanent loss of high-grade agricultural land (cessation of any land use change between Cropland and Grassland, no new afforestation)
        - Falkland Islands: allow Settlement area to increase in line with need identified by the 2015 Development Plan (Grassland to Settlement conversion of 0.005 kha/yr)
- *High* emissions scenario: levels of activity are adjusted to take account of policy aspirations likely to increase LULUCF emissions.
    - Only applies to Falkland Islands, the Baseline scenario activity data are used for the other OT/CDs.
    - Falkland Islands: allow Settlement area to increase in line with the maximum area allocated for housing in the 2015 Development Plan. (Grassland to Settlement conversion of 0.010 kha/yr)

- *Low* emissions scenario: levels of activity are adjusted to take account of policy aspirations likely to reduce LULUCF emissions.
    - Applies to Jersey and Guernsey, the Central scenario activity data are used for the Isle of Man and Falkland Islands.
    - Jersey and Guernsey: general presumption against all forms of new development and any permanent loss of high-grade agricultural land (cessation of any land use change between Cropland and Grassland, or conversion to Settlement)
    - Guernsey: assume no further loss of forest area but continuing afforestation to 2020

Table 9 List of policy documents examined

Overseas Territory or Crown Dependency	Policy document
Isle of Man	A climate challenge mitigation strategy for the Isle of Man 2016 – 2020 A Strategy for the Landscape and Amenity of the IoM to 2050 Policy on Sustainable Development and Mitigating Climate Challenges The Isle of Man Strategic Plan 2016
Guernsey	Environmental Policy Plan Island Development Plan 2016
Jersey	States of Jersey Island Plan 2011: Natural Environment Rural Economic Strategy 2017-2021 Jersey Strategic Plan 2015-18 Future-proofing Jersey 2015 report
Falkland Islands	Stanley Town Plan Falkland Islands State of the Environment Report 2008 Falkland Islands Development Plan (2015) Falkland Islands Rural Development Strategy (RDS) 2012 – 17 RDS Action Plan and Budget 2012 – 2013

The change in land use areas within the total OT/CD area are shown in Table 10. The proportions of the land use categories do not change significantly over the 2015-2050 period, with grassland covering 98% of the area (due to the large expanse in the Falkland Islands).

Projections of GHG emissions and removals from the LULUCF sector in the UK's OT/CDs are shown in Table 11, Table 12 and Table 13. There are no estimated emissions of CH4 from the OT/CDs. Graphs of the projections for the total sector and for individual OT/CDs are shown Figure 19, Figure 20, Figure 21, Figure 22 and Figure 23.

The LULUCF sector in the OT/CDs remains a small net source post-2015, with an increasing trend in emissions to the 2030s in all scenarios. This trend is a result of the Forest Land category becoming a net source after 2024, combined with continuing net emissions from the Cropland and Settlement categories and a diminishing net Grassland sink. Emissions/removals of CO_2 dominate the net total, with N_2O making a small contribution.

The Forest Land category switches from being a net sink to a small net source in 2024: this is driven by the management of existing forestry in the Isle of Man, where forest planted in the 1960s is reaching maturity and felling age. The absence of afforestation since 1990, whose increasing removals would have counterbalanced the emissions from felling, makes the change in the trend particularly noticeable. The HWP category switches to be a net sink at the same time point, as felled timber enters the Harvested Wood Products pool.

The Cropland category remains a net source until 2050, but its size diminishes after 2023 for all scenarios as cropland conversion is projected to reduce.

Table 10: Land use areas 2015-2050 for the UK's Overseas Territories and Crown Dependencies (1,293 kha)

Emission scenario	*Land use category*	*2015 area, kha*	*2020 area, kha*	*2030 area, kha*	*2040 area, kha*	*2050 area, kha*
Baseline	Forest land	4.7	4.7	4.8	4.9	4.9
	Cropland	10.4	10.4	9.4	8.3	6.8
	Grassland	1264.4	1263.6	1262.9	1262.3	1262.2
	Wetland	0.1	0.1	0.2	0.2	0.2
	Settlement	13.1	13.8	15.4	17.0	18.5
	Other	0.1	0.1	0.1	0.1	0.1
Central	Forest land	4.7	4.7	4.8	4.9	4.9
	Cropland	10.4	10.9	10.7	10.5	10.0
	Grassland	1264.4	1263.7	1263.5	1263.5	1264.1
	Wetland	0.1	0.2	0.2	0.2	0.2
	Settlement	13.1	13.2	13.5	13.6	13.5
	Other	0.1	0.1	0.1	0.1	0.1
High	Forest land	4.7	4.7	4.9	5.0	5.1
	Cropland	10.4	10.9	10.9	10.9	10.9
	Grassland	1264.4	1263.7	1263.5	1263.4	1263.4
	Wetland	0.1	0.1	0.1	0.1	0.1
	Settlement	13.1	13.2	13.3	13.2	13.2
	Other	0.1	0.1	0.1	0.1	0.1
Low	Forest land	4.7	4.7	4.8	4.9	4.9
	Cropland	10.4	10.5	9.5	8.5	7.2
	Grassland	1264.4	1263.7	1263.2	1262.8	1263.0
	Wetland	0.1	0.1	0.2	0.2	0.2
	Settlement	13.1	13.7	15.0	16.3	17.4
	Other	0.1	0.1	0.1	0.1	0.1

The Grassland category is a net sink until 2050 but is projected to reduce in size in all scenarios. This is primarily driven by the trends in the Isle of Man and Jersey, as the Grassland category net emissions/removals are very small for the Falkland Islands and Guernsey.

There are currently no estimated emissions or removals from Wetlands in the OT/CDs.

The Settlement category is a net source until 2050 in all scenarios, with the Baseline scenario increasing slightly over time, the High scenario declining slightly and the Central and Low scenarios reducing to close to zero by 2050.

The proportional contribution of each OT and CD to the net LULUCF emission/removal is demonstrated in Figure 24. The OTs and CDs differ in their relative contribution to emissions and removals from each land category. The Isle of Man moves from being a net LULUCF sink to a net source (largely due to its Forest Land category). The Falkland Islands and Guernsey are net but diminishing sources, while Jersey is projected to be either a stable net source or sink by 2050, depending on the scenario.

The net LULUCF emissions/removals from the Overseas Territories and Crown Dependencies are calculated to be ≤1% of the UK LULUCF total; therefore they do not make a significant difference to the UK's net emissions for UNFCCC reporting.

Table 11 LULUCF emissions and removals of CO_2 1990-2050

Scenario	Country	1990 Gg CO_2	2015 Gg CO_2	2020 Gg CO_2	2030 Gg CO_2	2040 Gg CO_2	2050 Gg CO_2
Central	OTs and CDs	-17.98	0.47	7.13	15.97	21.20	11.71
Baseline 1	OTs and CDs	-17.98	0.47	13.64	37.15	52.85	45.16
Low	OTs and CDs	-17.98	0.47	5.60	13.51	19.45	12.93
High	OTs and CDs	-17.98	0.47	11.80	31.53	44.80	37.48

Table 12 LULUCF emissions and removals of N2O 1990-2050

Scenario	Country	1990 Gg N_2O	2015 Gg N_2O	2020 Gg N_2O	2030 Gg N_2O	2040 Gg N_2O	2050 Gg N_2O
Central	OTs and CDs	0.002	0.025	0.024	0.012	0.003	0.001
Baseline 1	OTs and CDs	0.002	0.025	0.028	0.026	0.022	0.022
Low	OTs and CDs	0.002	0.025	0.023	0.011	0.001	0.000
High	OTs and CDs	0.002	0.025	0.025	0.017	0.009	0.008

Table 13 LULUCF emissions and removals of CO_2 equivalents 1990-2050 (1 Mt CO_2e = 1000 Gg CO_2e)

Scenario	Country	1990 Gg CO_2 eq	2015 Gg CO_2 eq	2020 Gg CO_2 eq	2030 Gg CO_2 eq	2040 Gg CO_2 eq	2050 Gg CO_2 eq
Central	OTs and CDs	-17.40	7.88	14.16	19.48	21.95	12.03
Baseline 1	OTs and CDs	-17.40	7.88	22.04	44.85	59.52	51.66
Low	OTs and CDs	-17.40	7.88	12.52	16.71	19.79	13.00
High	OTs and CDs	-17.40	7.88	19.29	36.46	47.49	39.74

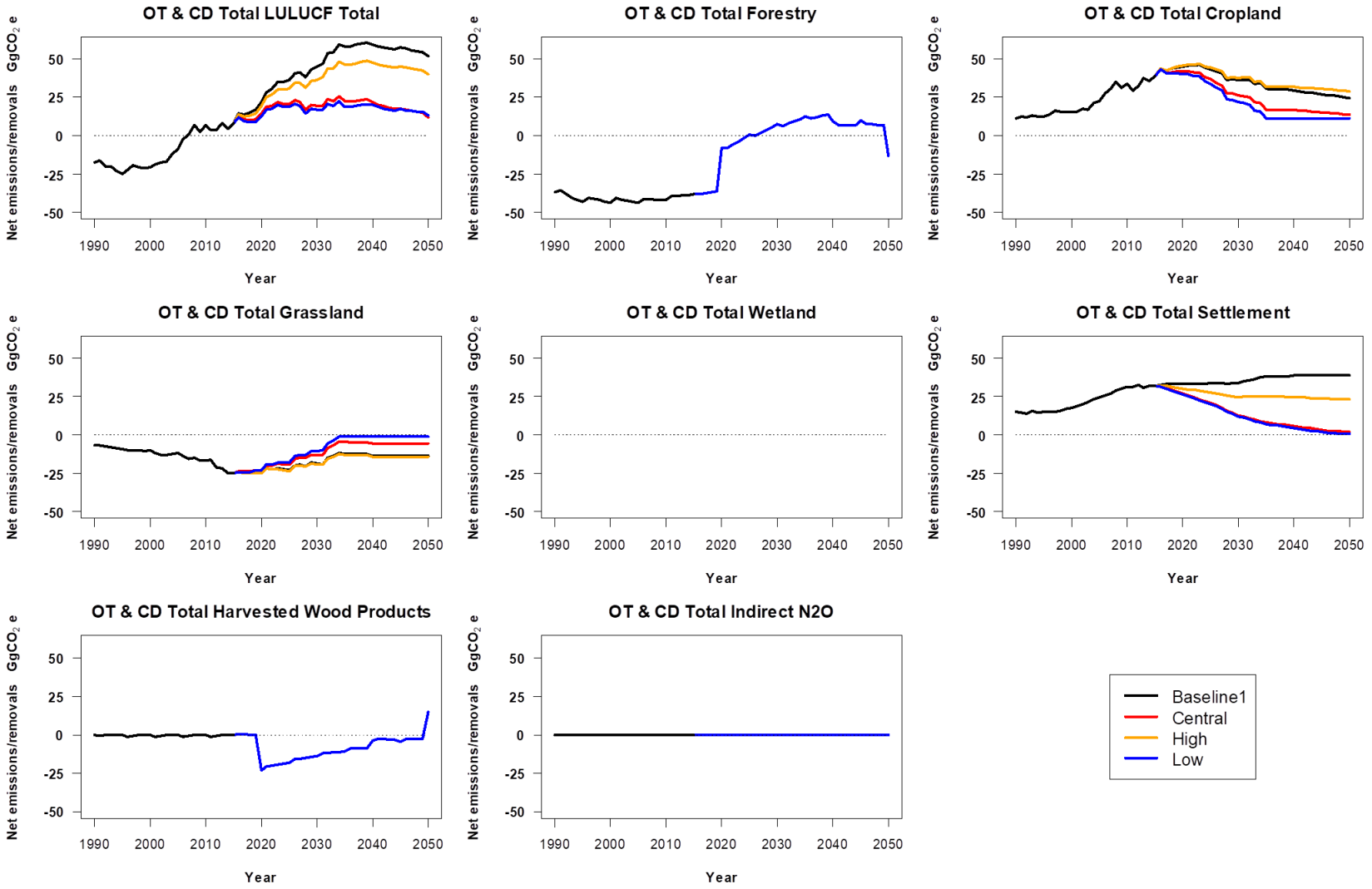

Figure 19 Overseas Territories and Crown Dependencies LULUCF CO_2 equivalent emissions scenarios 1990-2050. The individual graphs refer to LULUCF reporting categories.

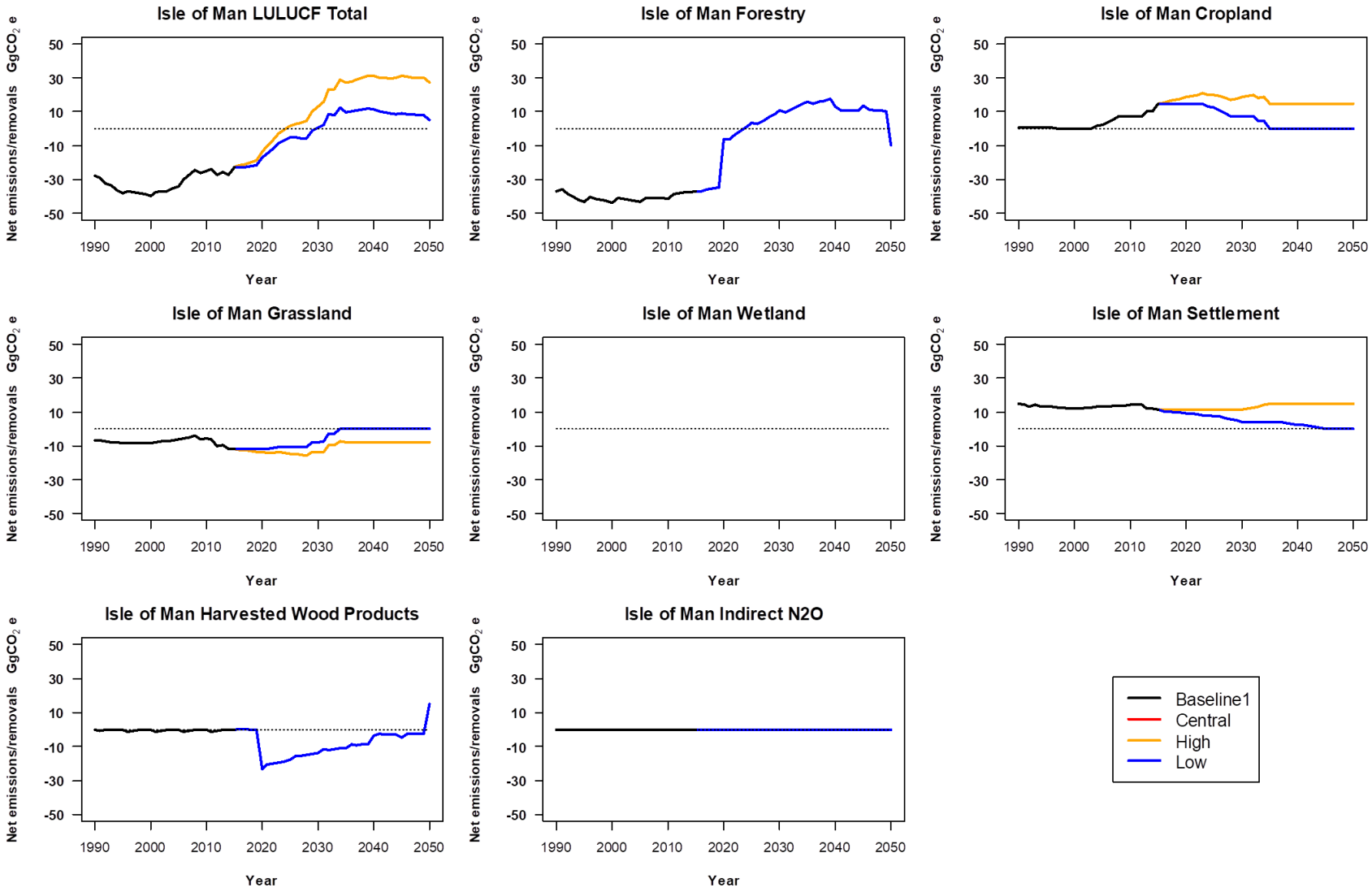

Figure 20 Isle of Man LULUCF CO_2 equivalent emissions scenarios 1990-2050. The individual graphs refer to LULUCF reporting categories.

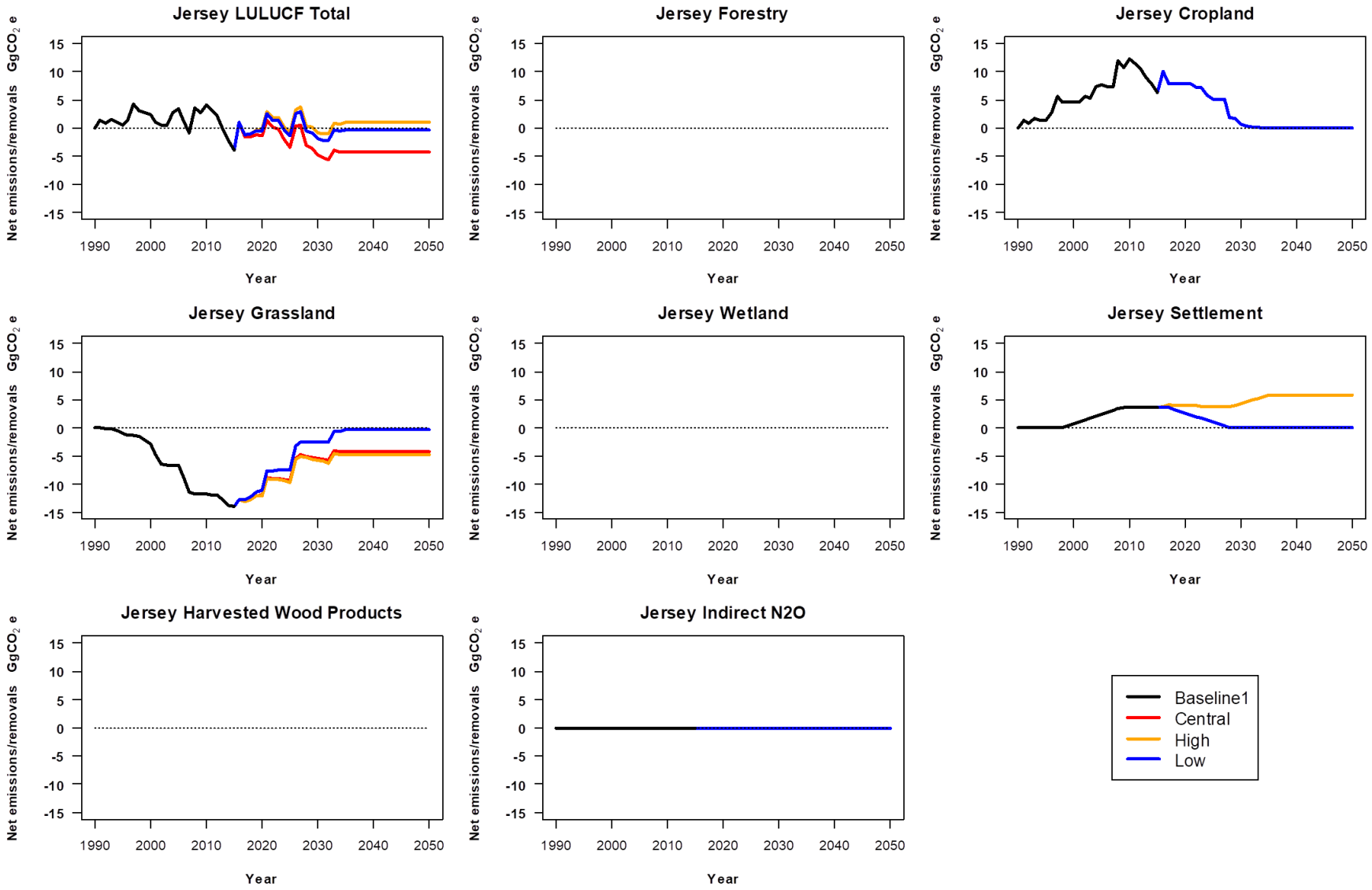

Figure 21 Jersey LULUCF CO_2 equivalent emissions scenarios 1990-2050. The individual graphs refer to LULUCF reporting categories.

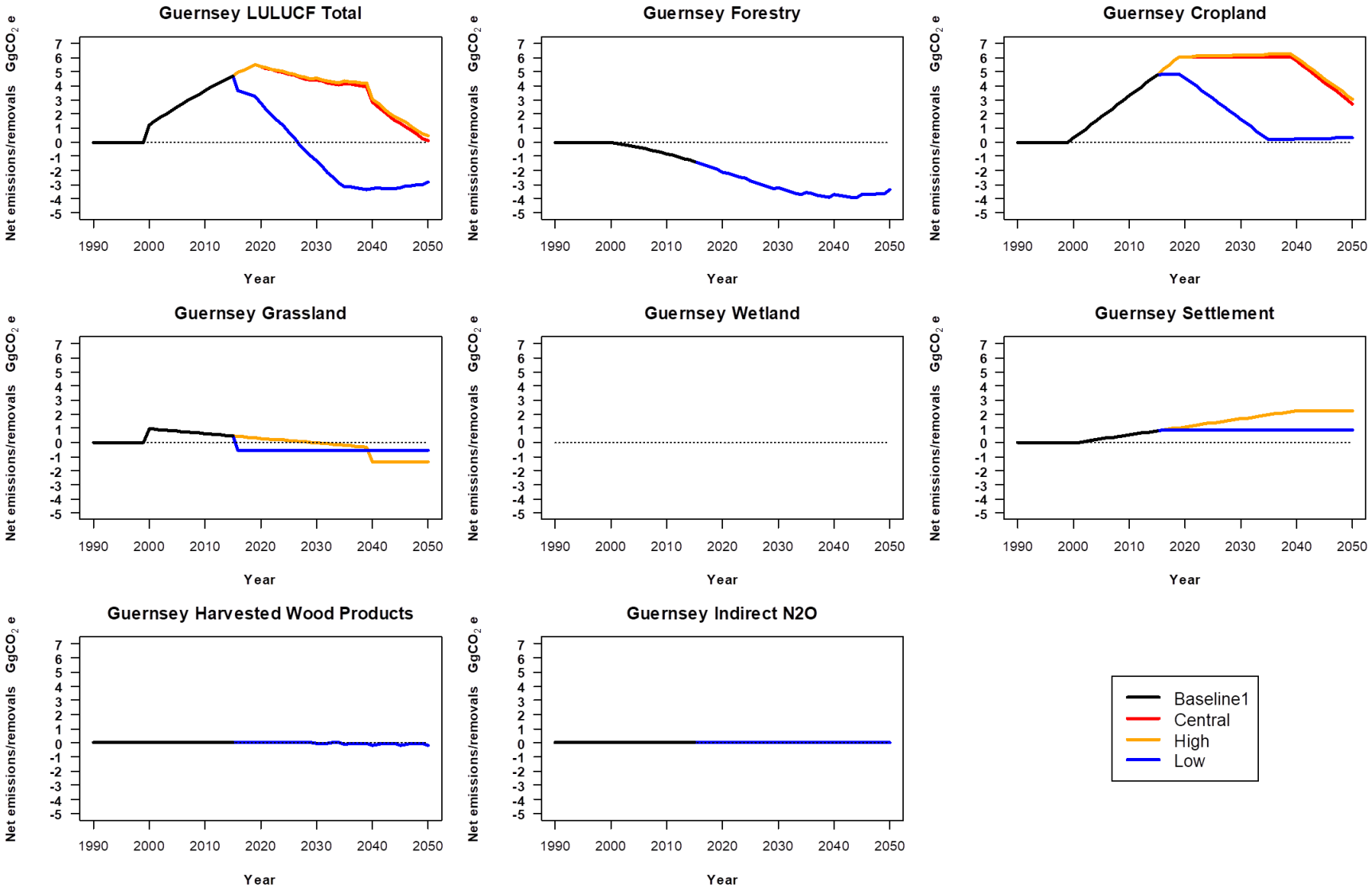

Figure 22 Guernsey LULUCF CO_2 equivalent emissions scenarios 1990-2050. The individual graphs refer to LULUCF reporting categories.

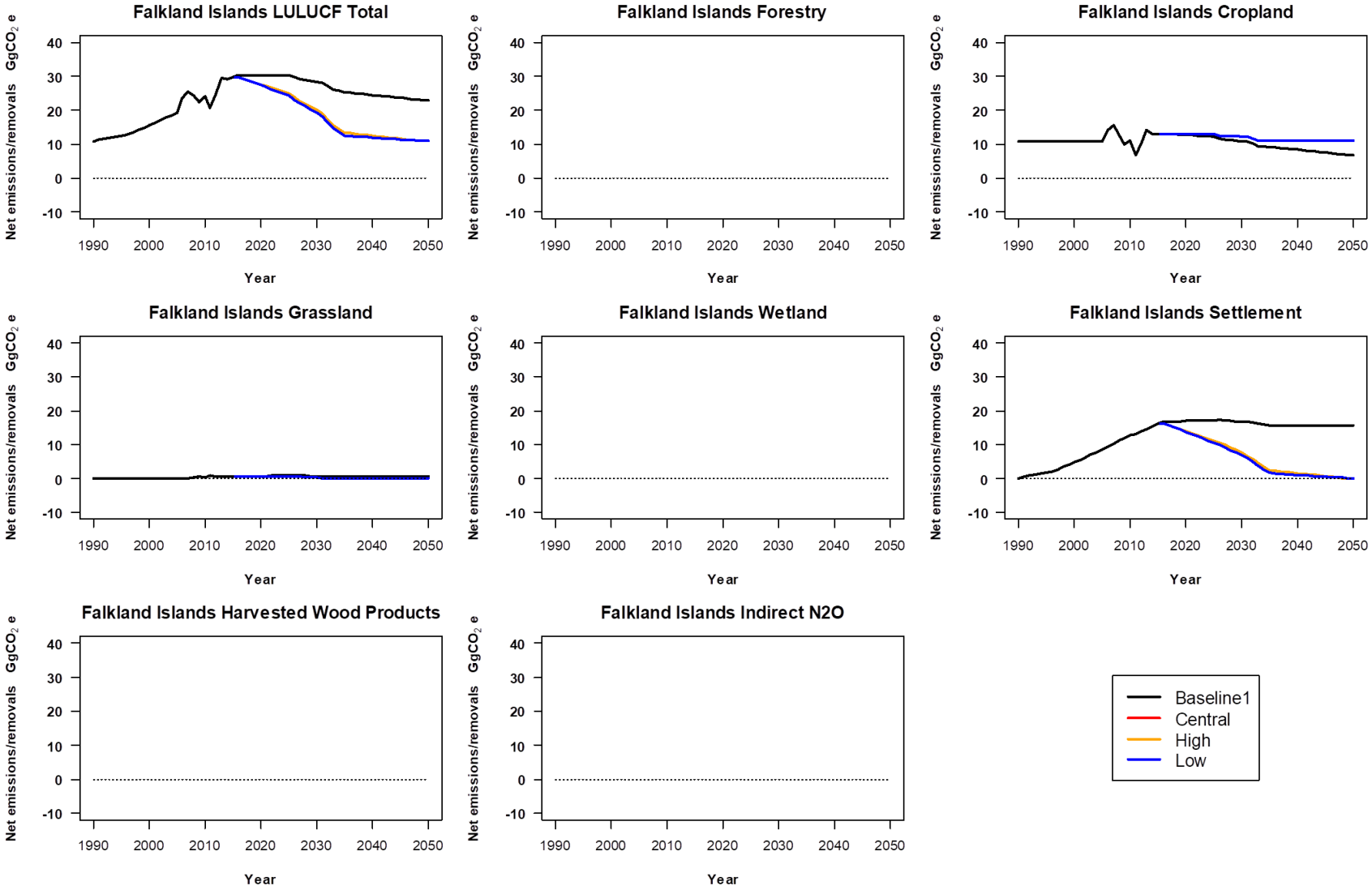

Figure 23 Falkland Islands LULUCF CO_2 equivalent emissions scenarios 1990-2050. The individual graphs refer to LULUCF reporting categories.

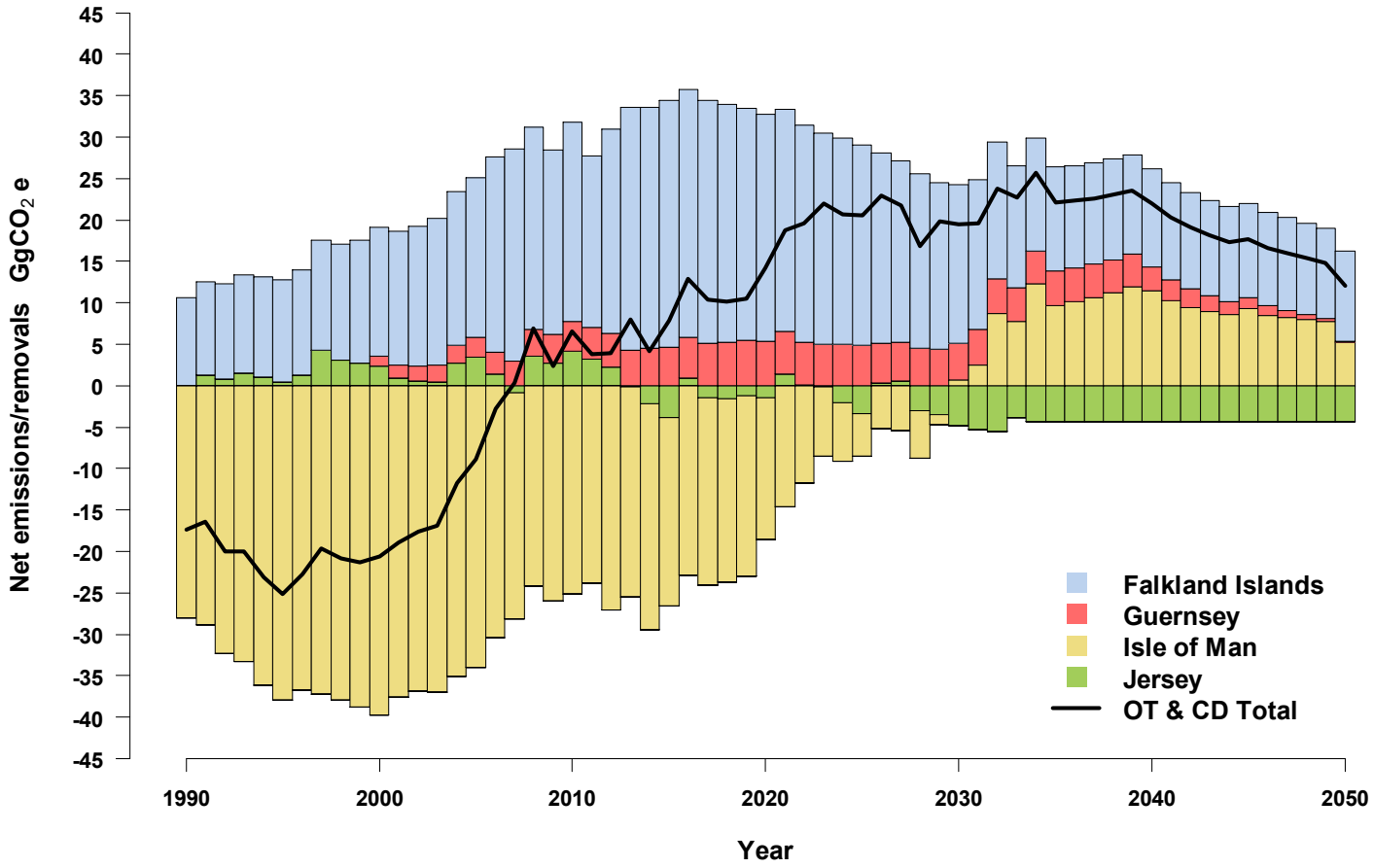

Figure 24 Combined contribution of the Overseas Territories and Crown Dependencies to the Central emission scenario.

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