National Atmospheric Emissions Inventory

Projections of Emissions and Removals from the LULUCF Sector to 2050/2100

Prepared by the UK Centre for Ecology & Hydrology (UKCEH) and Forest Research for DESNZ as part of the UK National Atmospheric Emissions Inventory

UK Centre for Ecology & Hydrology

Department for Energy Security & Net Zero

Forest Research

Reference: ERG 1103 | Issue Number 1 | Date October 2024

Customer:

Department for Energy Security and Net Zero (DESNZ)

Customer reference:

ERG1103

Contact:

Sam Bradley

e:

sam.bradley@energysecurity.gov.uk

Author:

Amanda Thomson (UKCEH)

Gwen Buys (UKCEH)

Hannah Clilverd (UKCEH)

Rachel Nickerson (UKCEH)

Hannah Young (UKCEH)

Paul Henshall (Forest Research)

Robert Matthews (Forest Research)

Approved By: Amanda Thomson

Date: 15/10/2024

Signed: 

Summary for Policy Makers

The Climate Change Act, passed in 2008, committed the UK to reducing greenhouse gas emissions by at least 80% by 2050 when compared with 1990 levels. In 2019, the UK passed a law which further tightened the target by requiring the UK to bring all greenhouse gas emissions to net zero by 2050. It also established a system of legally-binding carbon budgets which limit the net amount of greenhouse gases that can be emitted in successive five-year periods. Emissions and removals from Land Use, Land-Use Change and Forestry (LULUCF) are an integral component of those legislated targets. Projections of those emissions based on a range of policy assumptions are one component to monitor progress towards the UK's legislated targets through the Energy and Emissions Projections (EEP)[1] which extend to 2040 this year. Considering the inertia and long-term impact in the land-use sector, this report covers changes in land use as a result of different policy assumptions until 2050 and covers their longer-term impact until 2100. The full projections data are available on the NAEI website.

LULUCF activities can result in net annual emissions or removals of greenhouse gases, and changes in carbon stocks in the pools associated with LULUCF. The results presented here are based on the reporting conventions of the UNFCCC and additionally by Territorial Emissions Sectors for policy relevance.

This report provides projections at the UK and Devolved Administration (DA) level, with separate estimates for Scotland, England, Wales and Northern Ireland, which are summed to give the UK totals.

LULUCF is divided into six land use types: Forest Land (4A), Cropland (4B), Grassland (4C), Wetlands (4D), Settlements (4E), and Other Land (4F). Carbon stock changes of Harvested Wood Products are reported in an additional category, Harvested Wood Products (4G). The code refers to the IPCC (2006 Guidelines) inventory category of LULUCF. There is a separate inventory sector for Agriculture covering most emissions of methane and nitrous oxide from agricultural activities, which are not covered in this report.

The emissions resulting from three future scenarios (*Baseline, Central & Stretch*) have been described. The *Baseline* scenario is based on climate change-related and forestry policies extant in July 2009. The *Central* scenario takes account of current land use policies for which funding was secured by March 2024. The *Stretch* scenario is an estimate of the maximum technically feasible mitigation resulting from ambitious implementation of GHG mitigation policies exceeding current policy aspirations or funding.

The main results are:

- At the UK level, the net CO_2 equivalent emissions / removals from all components of the LULUCF sector are combined to produce a net source across the time series from 1990 onwards for the *Baseline* and *Central* scenarios. The *Stretch* scenario becomes a net sink in the 2020s. The 2050 value is 10.4 Mt CO_2e in the *Baseline* scenario, 4.7 Mt CO_2e in the *Central* scenario and -5.5 Mt CO_2e in the *Stretch* scenario.
- At a DA level, Wales is an increasing net sink under all scenarios (in the range -0.8 Mt CO_2e to -1.3 Mt CO_2e over the period 2023-2050 under all scenarios).
- England is a net source under the Baseline and Central scenarios in all but the earliest projected years. Under the Stretch scenario it is a net sink, due to the emissions reduction from peatland rewetting in the Cropland and Grassland sectors and increased forestry sink compared to the other scenarios. By 2050 the emissions in the LULUCF sector are estimated to be 3.5 Mt CO_{2e} in *Baseline,* 0.8 Mt CO_2e in the *Central* scenario and -2.3 Mt CO_2e in the *Stretch* scenario.
- Scotland is a net source of increasing magnitude over the 2020s and 2030s under all scenarios. All scenarios then decrease emissions through the 2040's with the Stretch scenario becoming a

[1] https://www.gov.uk/government/collections/energy-and-emissions-projections

net sink. By 2050 the emissions in the LULUCF sector are estimated to be 5.4 Mt CO_{2e} in *Baseline,* 2.8 Mt CO_2e in the *Central* scenario and -2.3 Mt CO_2e in the *Stretch* scenario.

- Northern Ireland is a small net source which remains fairly stable in the Baseline scenario and decreases across the projection period for the other scenarios. In 2050 the magnitude of the source is 2.2 Mt CO_{2e} in *Baseline,* 2.0 Mt CO_2e in the *Central* scenario 0.4 Mt CO_2e in the *Stretch* scenario.
- The LULUCF sector in the UK and in each of the Devolved Administrations (DAs) is dominated by CO_2 and CH_4 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 DAs, with Wetland also being significant in the *Stretch* scenario.
- When considering the Territorial Emissions Sectors, the Peatland and Forestry sectors are most significant in determining the difference between the scenarios.
- The main changes in the projections since those based upon the 1990-2021 inventory are revision to the data used for Northern Ireland peat extraction and updated projection assumptions for Northern Ireland forestry and for application of rewetting to grassland types in all DAs.

Contents

1 Introduction

Projections of UK greenhouse gas emissions and removals from Land Use, Land Use Change and Forestry (LULUCF) activities in the period to 2100 are described in this report. 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 Greenhouse Gas Inventory, for the period 1990-2022 (Brown *et al*., 2024).

The LULUCF projections address a number of policy needs including:

- Alignment with EU/international commitments 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 Energy Security and Net Zero (DESNZ) which help to track progress towards Government climate targets;
- The exploration of potential low carbon development strategies; and
- The requirement to monitor progress towards targets under the Climate Change (Scotland) Act, the Environment (Wales) Act. It is also used for the annual projection of greenhouse gases in Northern Ireland[2].

There have been updates to the scenario number and definitions compared to the previous set of projections (based on the 1990-2021 inventory). There are now three projection scenarios in this set as opposed to four in the previous.

- *Central* scenario: Based on current policies and the duration of agreed funding (as extant in March 2021 where the policy design is sufficiently advanced to quantify impacts) continuing at the same rate into the future. Categories for which there is no direct policy we can project, an average (2010-2022) is used. For afforestation, planting rates are maintained for the remainder of the current planned funding in each Devolved Administration (DA)[3], after which planting rates decline to those in *Baseline*. This is the EEP "reference" scenario.
- *Baseline* scenario: As Central, except excluding the impact of climate-change policies brought in since the 2009 Low Carbon Transition Plan published in July 2009. Climate-change policies are assumed to continue only for the duration of the policy lifetime. The first projected year is 2010.
- *Stretch* scenario: An estimate of the maximum technically feasible mitigation resulting from ambitious implementation of GHG mitigation policies exceeding current policy aspirations or funding.

The assumptions underlying the scenarios were developed by the DESNZ with input from the Forestry Commission (FC), The Department for Environment, Food and Rural Affairs (Defra), the Devolved Administrations (DAs) and LULUCF experts. The scenarios are designed to explore the magnitude of the changes in net emissions or removals 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). Separate projections have been developed for each administration (England, Scotland, Wales and Northern Ireland) and combined into a total for the UK.

2 Basis for projections

The LULUCF sector (sector 4 in the UNFCCC Common Reporting Format for national greenhouse gas inventory) 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)[4]. Net carbon stock changes from Harvested Wood Products (HWP) are reported under an additional category (4G). Finally, indirect emissions of N_2O from managed soils are reported without being allocated to a specific land use.

[2] https://www.daera-ni.gov.uk/news/northern-ireland-greenhouse-gas-projection-statistics-released
[3] In this report the term "Devolved Administration" includes the administrations within the UK which have devolved governments (Scotland, Wales and Northern Ireland) and England which does not.
[4] There are currently no emissions or removals of greenhouse gases from the Other Land category in the UK.

Emissions of greenhouse gases to the atmosphere (carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (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 the AR5 Global Warming Potential factors of 1 for CO_2, 28 for CH_4 and 265 for N_2O. 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 seem small in comparison with other individual sector totals. However, the LULUCF sector remains significant as it represents the net balance of much larger emissions and removals that if altered through changes in land-use practice can shift LULUCF between a net sink and source. Furthermore, LULUCF is currently the only sector which has the possibility of removing greenhouse gases from the atmosphere, offsetting emissions from other sectors.

Calculations in the LULUCF inventory are on the basis of activities, which can fall across several land use types (Table 1[5]). Consistency with the inventory (1990-2022) methodology is ensured throughout the projections (with the exception of some additional activities included for projected years only). There are detailed descriptions of the datasets and methodology in Chapter 6 and Annex 3.4 of the National Inventory Report (Brown *et al*. 2024). The *Afforestation, forest management*, *Land Use Change (mineral soils)* and *Organic soil drainage and rewetting* 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. The modelling of ongoing emissions and removals arising from land use changes up to 2050 has been extended to 2100 (although post-2050 changes in land use are assumed to be zero). This is predominantly relevant for forest carbon stock change and soil carbon stock change from other land use transitions. The corresponding mineralisation and fertilisation N_2O emissions have been estimated. For the other minor emissions either the 2050 value has been continued out to 2100, or a value of zero has been assigned (for emissions that occur within the year of land use change).

[5] 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 Intergovernmental Panel on Climate Change (IPCC); Tier 2 uses the same equations with country-specific emission factors and higher resolution activity data; Tier 3 uses country-specific models and/or 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; biomass and litter densities for forest land are taken from the CARBINE model output; biomass densities for Cropland and Grassland use UK-specific values.	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 mineral 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 a data assimilation approach (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 the transition sub-category e.g. Land converted to Cropland. Changes in biomass stocks are assumed to 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 are assumed to be burnt on site (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 except for reduced tillage or the absence of tillage.	4B Cropland (biomass and soil carbon stock changes)
Grassland	Changes in biomass carbon stocks due to changes between grassland types are calculated using the IPCC Tier 1	4C Grassland (biomass

Activity	Description	Inventory category
management	methodology.	carbon stock changes)
Organic soil drainage and rewetting	Emissions and removals from drainage and rewetting of organic (peatland) soils are estimated using a combination of Tier 1, 2 & 3 (forest CO_2 only) methodology as described in Evans *et al* 2017 and Brown *et al* 2024.	4A Forest Land (CO_2, CH_4 and N_2O emissions) 4B Cropland (CO_2 and CH_4 emissions) 4C Grassland (CO_2, CH_4 and N_2O emissions) 4D Wetlands (CO_2, CH_4 and N_2O emissions) 4E Settlements (CO_2, CH_4 and N_2O emissions)
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 Devolved Administration (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[6] publication (national baseline). Land loss due to sea level rise is neglected in these scenarios, as are changes in the UK land area due to coastal re-alignment.
- LULUCF input data (for 1990-2022 in the *Central* and *Stretch* scenarios and 1990-2009 in the *Baseline* scenario) in the published GHG inventories[7] have not been changed and feed through as the initial condition for the projected emissions.

Graphs of UK-level activity data are shown in this section; a break-down by DA is given in Annex 2. Table 2 shows which activities correspond to each UNFCCC land use category and Territorial Emissions Sector (used for the first time in the 1990-2021 projections).

Table 2: UNFCCC land use categories, contributing activities and National Communication policy sectors. Activities marked with * are present in the projected period only. Rewetting, Peat extraction & Near-natural are all activities on organic soil only.

UNFCCC LULUCF land use category	Carbon stock change or gas	Activity producing emissions/removals	Territorial Emissions Sector
Forest Land (4A)	Carbon stock change	Afforestation and forest management – conventional forest	Forestry
		Afforestation and forest management – short rotation forest*	Bioenergy crops
	CO_2 emissions from burning	Wildfires	Other LULUCF
	CH_4 emissions	Wildfires	Other LULUCF
		Organic Soil Drainage	Peatland
	N_2O emissions	Afforestation and forest management	Forestry
		Wildfires	Other LULUCF
		Mineral Soil Drainage	Forestry
		Organic Soil Drainage	Peatland
Cropland (4B)	Carbon stock change	Land Use Change Mineral Soil	Cropland mineral soils under LUC
		Land Use Change Biomass	Other LULUCF

[6] https://www.ons.gov.uk/methodology/geography/geographicalproducts/otherproducts/ukstandardareameasurementssam
[7] https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2022

UNFCCC LULUCF land use category	**Carbon stock change or gas**	**Activity producing emissions/removals**	**Territorial Emissions Sector**
		Deforestation	Forestry
		Cropland management	Bioenergy crops & Other LULUCF
		Organic Soil Drainage	Peatland
		Agroforestry*	Other LULUCF
	CO_2 emissions from burning	Deforestation	Forestry
	CH_4 emissions	Wildfires	Other LULUCF
		Deforestation	Forestry
		Organic Soil Drainage	Peatland
	N_2O emissions	Wildfires	Other LULUCF
		Land Use Change	Cropland mineral soils under LUC
		Deforestation	Forestry
		Organic Soil Drainage	Peatland
Grassland (4C)	Carbon stock change	Land Use Change Mineral Soil	Grassland mineral soils under LUC
		Land Use Change Biomass	Other LULUCF
		Deforestation	Forestry
		Grassland management	Other LULUCF
		Organic Soil Drainage	Peatland
		Rewetting	Peatland
		Agroforestry*	Other LULUCF
	CO_2 emissions from burning	Deforestation	Forestry
	CH_4 emissions	Wildfires	Other LULUCF
		Deforestation	Forestry
		Organic Soil Drainage	Peatland
		Rewetting	Peatland
	N_2O emissions	Wildfires	Other LULUCF
		Land Use Change	Grassland mineral soils under LUC
		Deforestation	Forestry
		Organic Soil Drainage	Peatland
		Rewetting	Peatland

UNFCCC LULUCF land use category	Carbon stock change or gas	Activity producing emissions/removals	Territorial Emissions Sector
Wetlands (4D)	Carbon stock change	Peat extraction Near-natural Rewetting	Peatland
		Deforestation	Forestry
		Reservoir Creation	Other LULUCF
	CO_2 emissions from burning	Deforestation	Forestry
	CH_4 emissions	Peat extraction Near-natural Rewetting	Peatland
	N_2O emissions	Peat extraction Near-natural Rewetting	Peatland
Settlements (4E)	Carbon stock change	Land Use Change	Settlement
		Deforestation	Forestry
		Organic Soil Drainage	Peatland
	CO_2 emissions from burning	Deforestation	Forestry
	CH_4 emissions	Deforestation	Forestry
		Organic Soil Drainage	Peatland
	N_2O emissions	Land Use Change	Settlement
		Deforestation	Forestry
		Organic Soil Drainage	Peatland
Harvested Wood Products (4G)	Carbon stock change	Afforestation and forest management Deforestation	Forestry

3.1 Afforestation and forest management

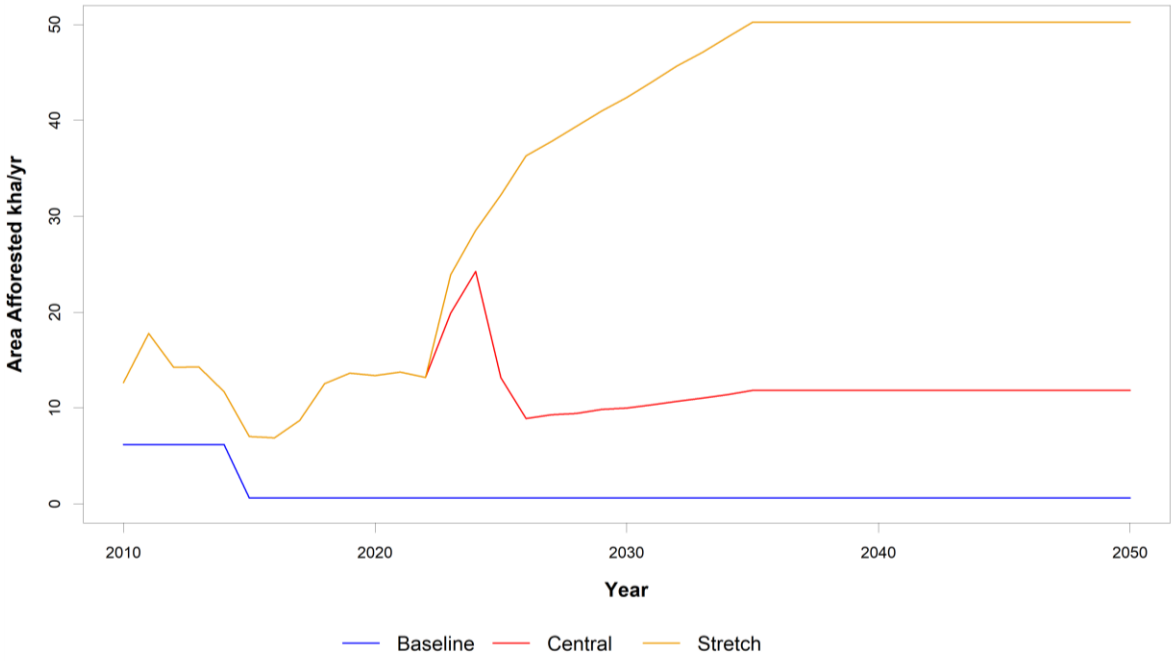
This activity is driven by the amount of new forest planting in each DA and affects forest carbon stock changes, changes in the Harvested Wood Products pool, nitrogen fertilisation of forests and forest drainage (CO_2 and N_2O). The following is a description for conventional forest planting.

- The *Baseline* scenario assumes average planting over the years 2008-2009 will continue throughout the Rural Development Programme (until 2014), and then reducing to 10% of this rate for 2015-50.
- The *Central* scenario uses forest planting rates according to funding secured for grants within each DA.

  - For England, the estimate for 2023 assumes that the new planting rate for 22/23 (April-March) continues for the rest of 2023 (giving an afforestation rate of 3.128kha for 2023, which somewhat underestimates the afforestation for 2023 estimated from the latest new planting statistics of 4.2kha). The afforestation rates from 2024 are based on an assumed level of afforestation on a trajectory to plant 9kha/year by 2035 and the scenario maintains this level of planting until 2050 (this is the assumption for the required afforestation to meet the land cover target).
  - For Scotland, the afforestation rates for 2023 and 2024 are based on an assumed trajectory to reach an afforestation rate of 18kha/year in 2024/25 and then no further funding leading to baseline afforestation after April 2025.
  - For Wales, the afforestation rates assume no funding for afforestation and are therefore the same as the baseline.
  - For NI, the afforestation rates are based on an assumed trajectory to reach 2.5kha/year of afforestation in 2035 and to then maintain that afforestation rate until 2050.
  -
- The *Stretch* scenario follows the level assumed by the Committee on Climate Change in the CB6 "Net Zero Balanced Pathway".
  - For England, afforestation is as per the central scenario 2023-2025 and then 10kha/year from 2026-2050.
  - For Scotland, afforestation is as per the central scenario 2023-2024, then an assumed trajectory to reach an afforestation rate of 28.75kha/year in 2035, then maintaining this level until 2050.
  - For Wales, the afforestation rates are based on an assumed trajectory to reach 8.625 kha/year by 2035 and then maintain that level to 2050.
  - For NI, the afforestation rate is assumed to be 0.9kha/year for 2023 and 2024, then for the afforestation rate to follow an assumed trajectory to 2.875.
  -
- Proportion of conifer/broadleaf planting: for the *Baseline* scenario the conifer/broadleaf split reported for 2009 is projected forward; and for all other scenarios each DA has proposed a conifer/broadleaf split consistent with current policy aspirations and grant availability/targeting (Scotland: 60% conifer; England: 20% conifer; Wales: 16% conifer; Northern Ireland: 20% conifer).
- Harvested wood products: for the *Baseline* and *Central* scenarios the allocation of products to paper, wood panels and sawn wood is based on the average allocations for the period 2010-2022. In the *Stretch* scenario there is an increase of up to 10 percentage points of the share of wood harvested used in wood panels and as sawn wood (with a split between the two based on their relative share of use over 2010-2022), compensated by an equivalent reduction in pulp and bioenergy (again based on the pro rata of their relative share over 2010-2022).

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

Figure 1: UK afforestation rates for all emissions scenarios expressed in kha/y. Note that a disaggregation of these data by Devolved Administration is provided in Annex 3.



Forest management is projected based on percentages of conifers and broadleaves that are used as productive forests and rotation lengths estimated using the Reconcile process. These rotations and level of harvesting are applied into the future, assuming no changes in the management of forests occur in the projection period.

In the *Stretch* scenario in England there is also short rotation forest planting for biomass production for the energy sector. Rates are detailed in Annex 3.

3.2 Wildfires

Burnt area arising 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 by wildfires, affecting GHG emissions from biomass burning (CO_2, CH_4 and N_2O)[8]. Carbon dioxide emissions from wildfires on cropland and grassland are assumed to be replaced within the year by vegetation regrowth, so only emissions of methane and nitrous oxide 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 (not presented here) shows high inter-annual variability (dependent upon the weather conditions at certain times of year).

- In the *Baseline, Central* and *Stretch* scenarios the annual burnt area from 2023 onwards equals the average annual burnt area for the 13 years up to the latest inventory year, *i.e.* 2010-22.

[8] 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 GB burnt area.

Figure 2: UK forest wildfire activity data for all emissions scenarios expressed as area burnt in kha/y

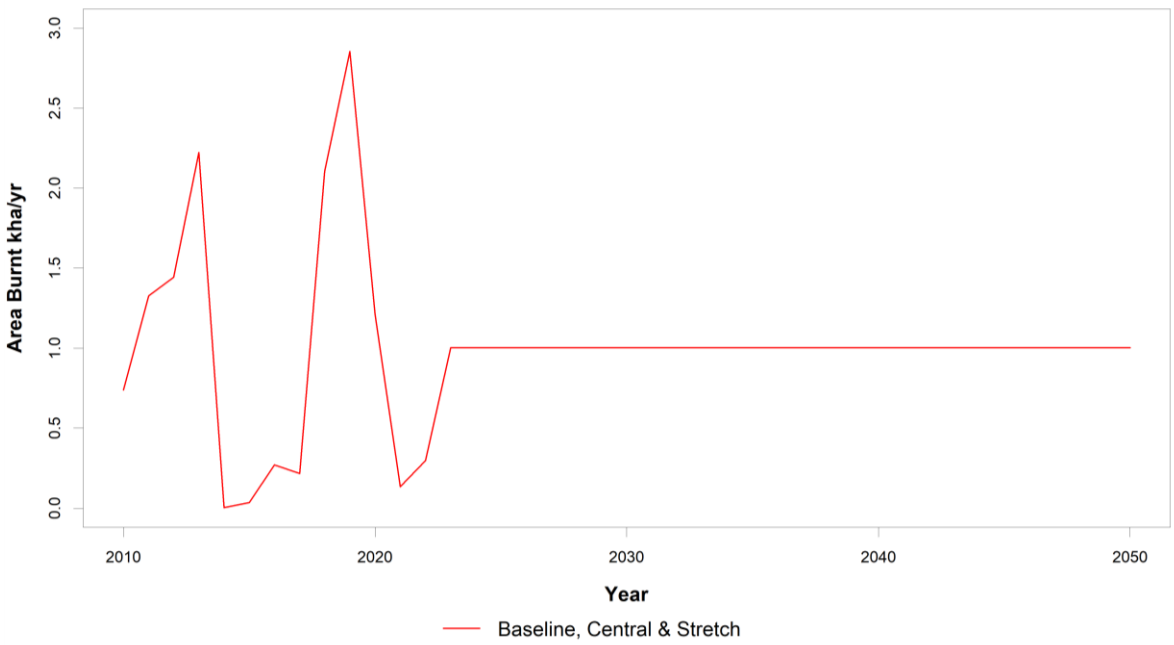


Figure 3: UK Cropland wildfire activity data for all emissions scenarios expressed as area burnt in kha/yr

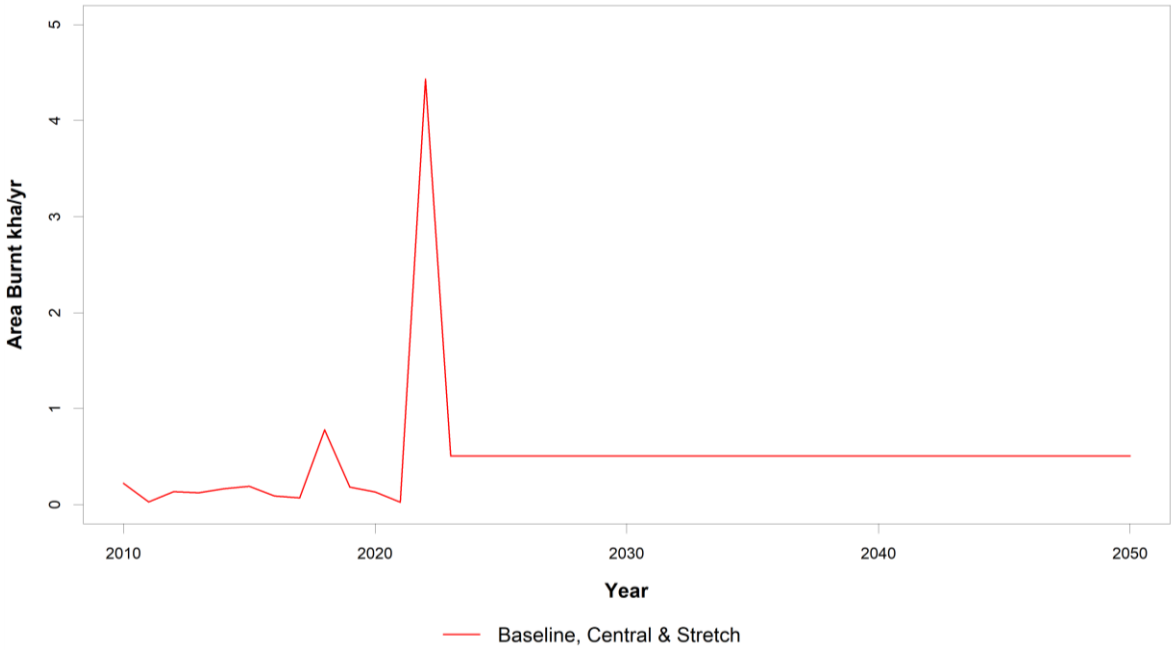
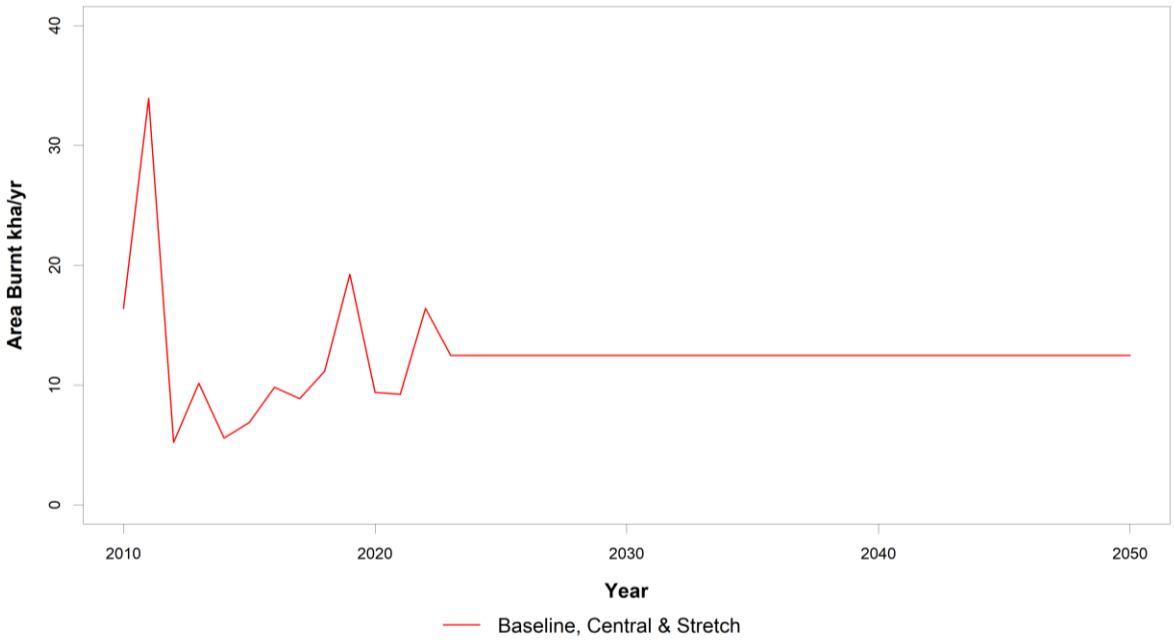


Figure 4: UK Grassland wildfire activity data for all emissions scenarios. Expressed as area burnt in kha/yr



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 in biomass and soils, and N mineralisation to N_2O as a result of carbon stock changes from land use change. Conversion to and from Forest Land are taken into account within the Afforestation and Deforestation activities.

In all DAs, it is assumed that there is a constant level of cropland-grassland conversion and vice-versa (with no net change in areas) to reflect agricultural land rotation. This is based on the average annual conversion each way 2010-2022 for each country (36.6 kha in England, 9.5 kha in Scotland, 3.4 kha in Wales and 3.3 kha in Northern Ireland each way). In addition, an additional conversion of grassland to cropland is assumed in Wales (based on advice from Welsh Government).

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

- In all scenarios the 2010-2022 averages 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 for the *Baseline* and *Central* scenarios, and is 50% of this rate for the *Stretch* scenario;
    - a Grassland to Cropland conversion rate of 1 kha/y for Wales is assumed in addition to the rotation rate in all scenarios.
    - In England in the *Stretch* scenario there is additional conversion from Grassland to Cropland as a result of bioenergy crop and agroforestry creation.

Figure 5: UK activity data for Cropland to Grassland land use change for all emissions scenarios, expressed as area converted in kha/yr.

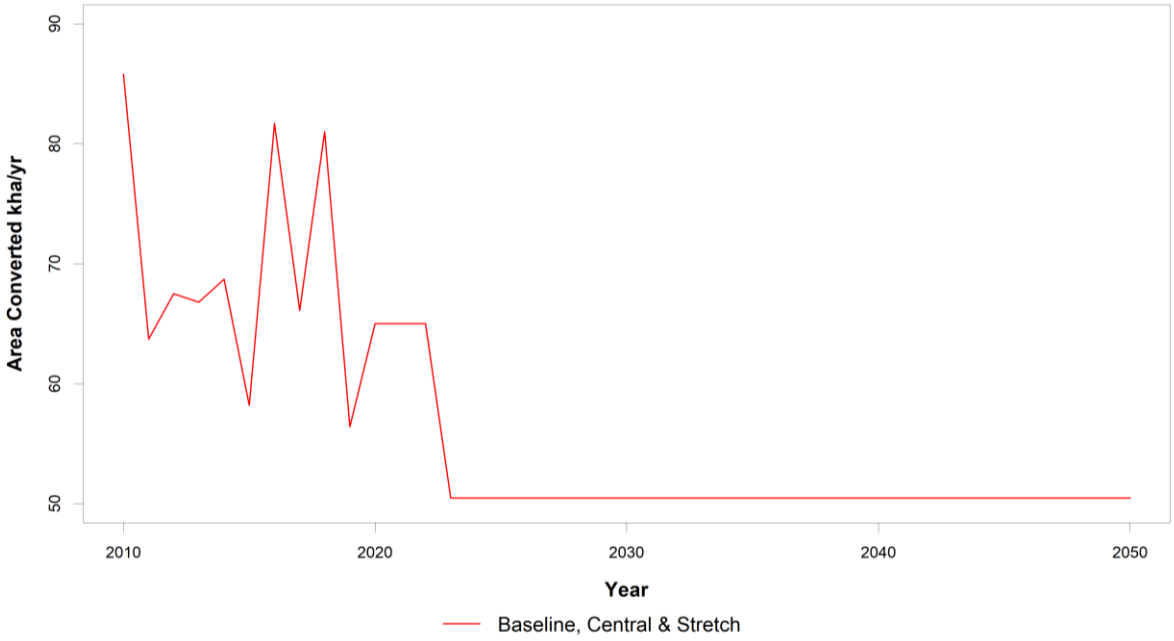


Figure 6: UK Activity data for Grassland to Cropland land use change for all emissions scenarios, expressed as area converted in kha/yr.

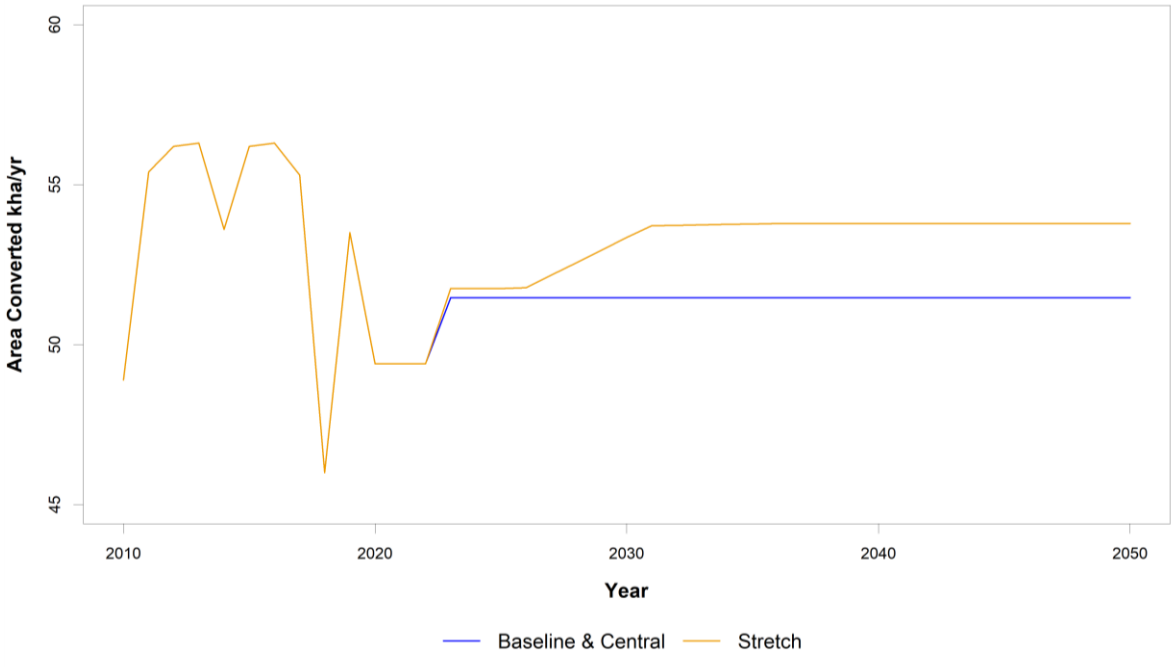
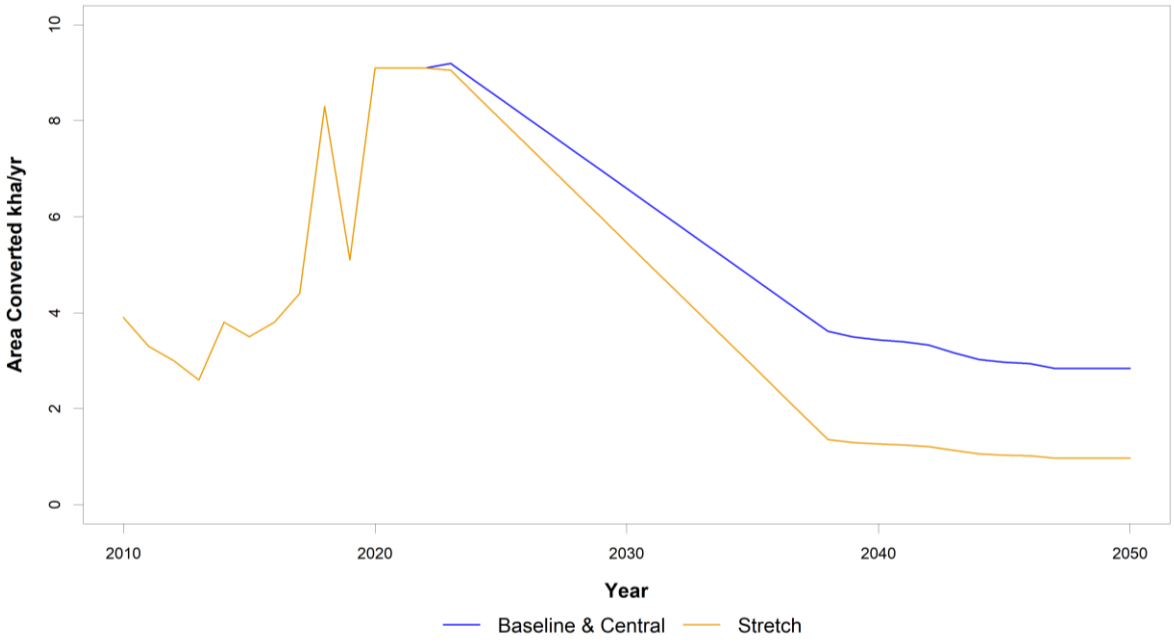


Figure 7: UK activity data for Grassland and Cropland to Settlement land use change for all emissions scenarios expressed as area converted in kha/yr.



3.4 Deforestation

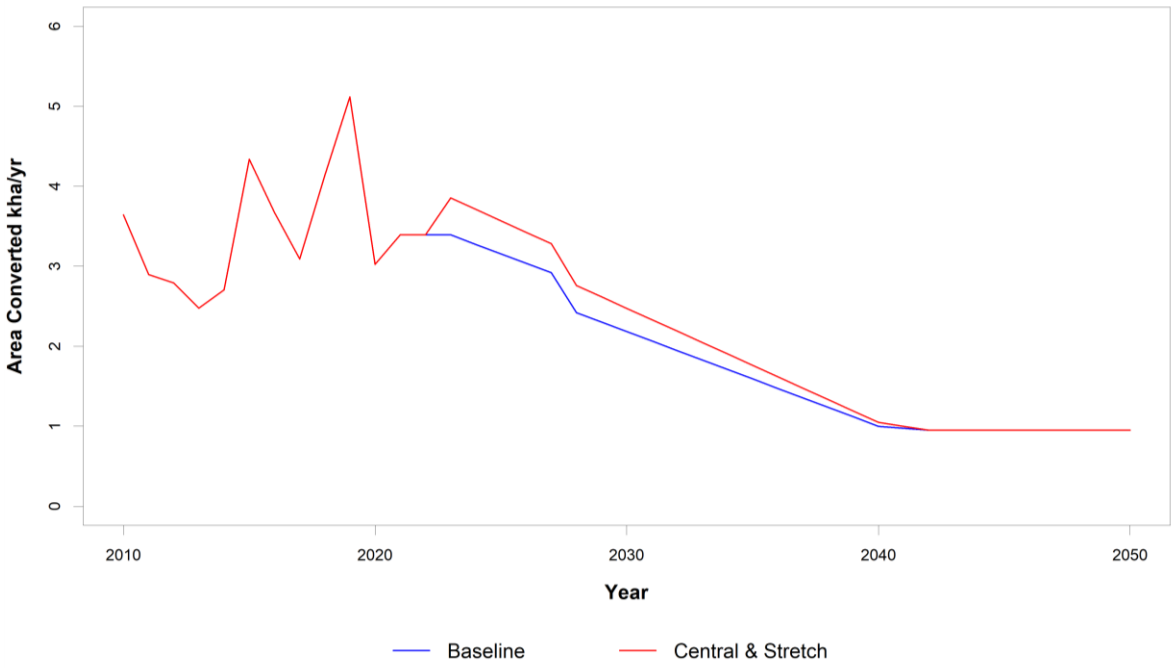
This activity is driven by the area of forest annually converted to other land uses (Figure 8). It affects forest carbon stocks, the Harvested Wood Products pool and GHG emissions from biomass burning (CO_2, N_2O, and CH_4).

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.

The *Baseline* scenario uses a linear transition from the 2012/13-2016/17 average in 2021-22 to a level corresponding to the contribution from settlements expansion only from 2040 onward. In England, Scotland, and Wales the rate of conversion of forest to settlement remains constant at its 2012/13-2016/17 average (throughout the projection) and the rest correspond to conversion of forest to grassland and wetlands (in proportion of their relative share in deforestation over 2010-2022). In Northern Ireland forest to settlement conversion is zero for the projected time period and forest to wetland conversion is 380 ha per year until 2027.

The *Central* and *Stretch* scenarios have the same deforestation rates as *Baseline* for Scotland, Wales, and Northern Ireland. In England there is a higher rate of assumed deforestation resulting from the higher assumed afforestation rates, following the setting of the legally binding long term woodland cover target for England in January 2023, allowing a higher level of open-ground habitat restoration to help achieve legally binding biodiversity objectives.

Figure 8 : UK Deforestation rate for all emissions scenarios (UK)[9] expressed as area converted in kha/yr.



[9] Disaggregation of these data by Devolved Administration is provided in Annex 3.

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, crop residue inputs and tillage. Grassland management activity is driven by within-grassland changes, e.g. from non-shrubby to shrubby grassland.

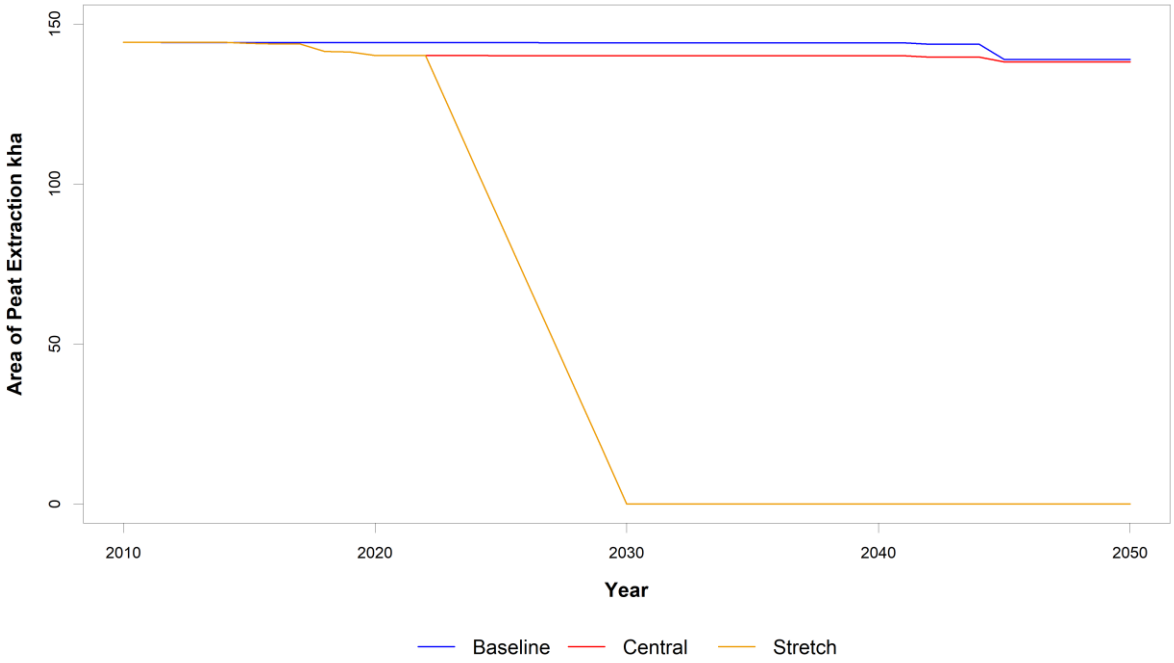
- For the *Baseline* scenario, levels of management activity remain at 2022 levels until 2050.
- For the *Central* scenario the manure and crop residue inputs and the tillage percentages are as 2022. Changes in biomass from 2022 levels are as follows:
    - In England, silvopastoral (grassland) agroforestry is included from 2026 increasing by 0.13 kha per year per year to 2035, then constant at 1.3kha per year.
- For the Stretch scenario the manure and crop residue inputs and the tillage percentages are as 2022. Changes in biomass from 2022 levels are as follows:
    - Hedges extended by 40% with a linear rate until 2050
    - In England, 10% of grassland converted to silvopastoral agroforestry
    - In England silvoarable agroforestry is included from 2024 with rate increasing to a maximum of 2.7kha/yr in 2036 & 2037 and then decreasing again towards 2050.
    - In England, increase in Short Rotation Coppice (SRC) and Miscanthus with SRC assumed to develop half on cropland and half on grassland and Miscanthus on cropland.

3.6 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* scenario the area drained for horticultural and domestic peat extraction remains at 2009 levels for Scotland and Northern Ireland. In England, horticultural peat extraction sites are either restored at their planned expiry dates or by 2045 if they have no expiry date. Restoration to target habitats is assumed to have a 100% success rate. The volume of horticultural peat extracted (and decomposing) each year is projected to be fixed at the 2009 level. There is no peat extraction in Wales.
- For the *Central* scenario the area drained for peat extraction remains at 2022 levels for Scotland and Northern Ireland. In England, horticultural peat extraction sites are either restored at their planned expiry dates or by 2045 if they have no expiry date. Restoration to target habitats is assumed to have a 100% success rate. The volume of horticultural peat extracted each year is projected to be fixed at the 2022 level for Scotland and Northern Ireland, but in England the volume of extraction is calculated on an area basis (average 2012-2022) which falls over time as the extraction sites are restored. There is no peat extraction in Wales.
- For the *Stretch* scenario across all DAs the area drained for peat extraction is reduced to zero with 100% restoration by 2030. In England and Northern Ireland horticultural peat volumes reduce to zero by 2030. In Scotland horticultural peat volumes fall by 66% in 2025 and then decline to zero by 2045. There is no peat extraction in Wales.

Figure 9: UK Peat extraction areas over time for all scenarios expressed in kha/yr.



3.7 Rewetted Peat

Lowland peat restoration

The restoration of areas subject to agricultural restoration includes cropland and pastoral (intensive and extensive) grassland. In the *Baseline* scenario, the 2009 value is used across the time series, i.e. no restoration post 2009.

In the *Central* scenario, the 2022 values for Scotland, Northern Ireland and Wales are used across the time series. For England, 25% of cropland is restored and 50% of the lowland grassland area (applied to intensive grassland) is restored by 2050.

In the *Stretch* scenario in all Devolved Administrations 25% of lowland peat on cropland is restored and 50% of lowland peat on grassland (equal split between intensive and extensive grassland where possible) is restored by 2050.

Upland peat restoration

In the *Baseline* scenario, it is assumed that there has been no additional restoration of upland peatland post 2009.

In the *Central* scenario, some restoration of upland peat is assumed for all Devolved Administrations:

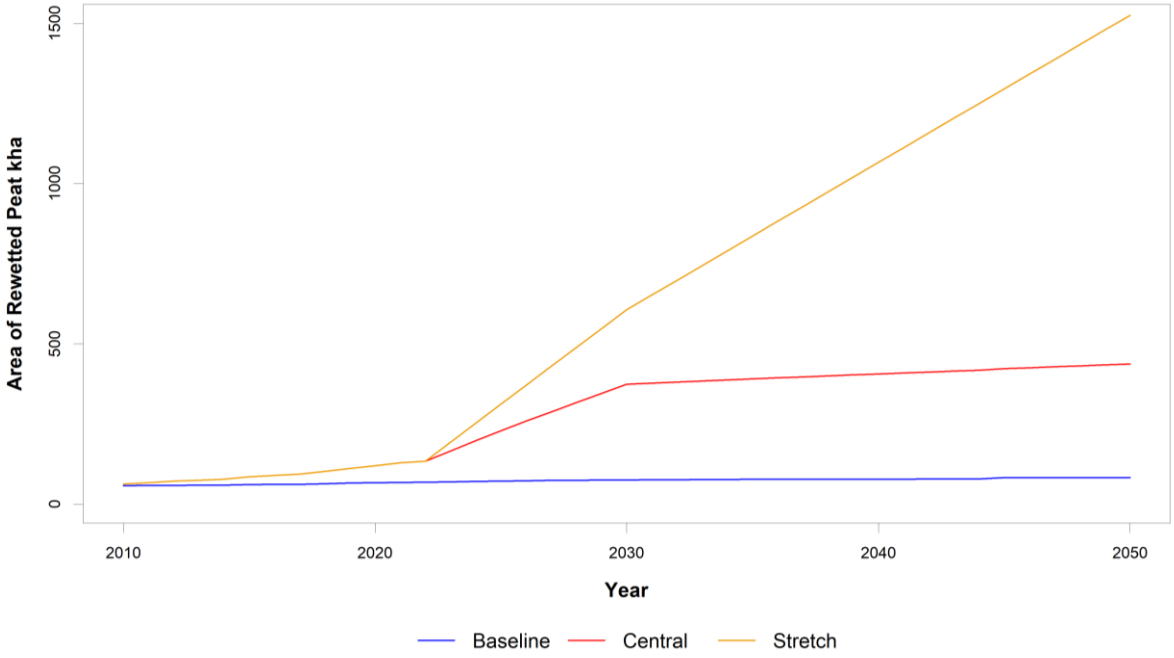
- In Scotland, restoration of 250,000 ha of degraded peat by 2030 is modelled. This is assumed to occur on eroding modified bog and modified bog in proportion of their relative area, after deduction of the rewetted areas of afforested peat.
- In England the scenario definition states restoration of 30,000 ha by 2025. This target is reached by 2022 so no further restoration on eroding modified bog and modified bog is modelled.
- For Northern Ireland there were no quantitative restoration targets, instead the relative areas of upland peat in England and Northern Ireland were used to scale the England targets, resulting in a target rewetted area in Northern Ireland of 6,418 ha by 2025.

- In Wales 700 ha of restoration per year over the period 2021-2025 is modelled. This is assumed to occur on eroding modified bog, and modified bog in proportion of their relative area, after deduction of the rewetted areas of afforested peat.

In the *Stretch* scenario the highest levels of restoration of upland peat are assumed:

- In England, Wales and Northern Ireland 100% of upland peat is restored by 2050. In England, this covers the 197,000 ha target for modified or lowland bog restored by 2050 through additional spend on Nature for Climate.
- In Scotland, restoration of 250,000 ha of degraded peat by 2030 is modelled. Additional restoration is then applied between 2031 and 2050 to reach a total of 860,000 ha restored by 2050, after deduction of the rewetted areas of afforested peat.

Figure 10: UK Rewetted Peat areas over time for all scenarios expressed in kha



4 Projections 2023-2100

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

4.1 Land Use Areas

Table 4 shows the projected distributions of land use areas in the UK between 2022 and 2050 - the areas for each Devolved Administration 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*., 2024). These land use change matrices are derived from a data assimilation process combining information from multiple spatial and non-spatial datasets and may therefore differ from other national datasets. From 2051 to 2100 no further land use change is included in the scenarios, but emissions and removals occurring from previous land use change are modelled.

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.

Table 4: Land use areas[10] 2022-2050 for the United Kingdom (24,438 kha).

Emission scenario	*Land use category*	*2022 area, kha*	*2025 area, kha*	*2030 area, kha*	*2040 area, kha*	*2050 area, kha*	*% of land area in 2022*	*% of land area in 2050*
Baseline	Forest land	3509	3501	3491	3482	3479	14%	14%
	Cropland	4751	4743	4733	4724	4721	19%	19%
	Grassland	12983	12967	12942	12903	12875	53%	53%
	Wetland	969	973	977	979	974	4%	4%
	Settlement	1805	1834	1875	1930	1969	7%	8%
	Other	421	421	421	421	421	2%	2%
Central	Forest land	3633	3679	3712	3810	3918	15%	16%
	Cropland	4751	4737	4719	4692	4671	19%	19%
	Grassland	12855	12787	12720	12579	12441	53%	51%
	Wetland	974	983	995	1014	1028	4%	4%
	Settlement	1805	1831	1871	1923	1958	7%	8%
	Other	421	421	421	421	421	2%	2%
Stretch	Forest land	3633	3706	3903	4445	5011	15%	21%
	Cropland	4751	4734	4710	4692	4682	19%	19%
	Grassland	12855	12818	12693	12135	11569	53%	47%
	Wetland	974	931	856	875	892	4%	4%
	Settlement	1805	1829	1857	1869	1864	7%	8%
	Other	421	421	421	421	421	2%	2%

[10] 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, and the full dataset is available for download with this report from the NAEI website. Graphs of greenhouse gas emissions at the UK and DA level for the whole LULUCF sector and for the individual land use categories are shown in Figure 11, Figure 12, Figure 13, Figure 14 and Figure 15. These graphs show the projected data to 2100 together with the reported inventory data for 1990-2022 for the *Central & Stretch,* and 1990-2009 for the *Baseline* scenario.

At the UK level, (Figure 11) the net CO_2 equivalent emissions / removals from all parts of the LULUCF sector are combined to produce a net source across the time series from 1990 onwards for the Baseline and Central scenarios. The Stretch scenario becomes a net sink in the 2020s. The net trend in the 2020s & 2030s is largely influenced by decreasing net removals in the forestry category as mature forests planted when afforestation rates were at a maximum from the 1950s to 1980s are harvested. In the Stretch scenario this begins to reverse in the 2040s as significant new planting in the projected years increases the forest sink. Additionally, this scenario sees decreasing emissions / increasing sinks in the Grassland and Wetland categories. From 2051-2100 only ongoing emissions / removals from previous land use change are modelled, so the time series are indicative only.

Forest Land is projected to be a net sink under all scenarios. It is an increasing sink between 1990 and 2009, 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 2040s, when the *Central* and *Baseline* scenarios stabilise, and the Stretch scenario sink continues to increase. The scenarios are driven by the projected planting rates and management. The decrease in the sink between 2020 and 2040 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 decreasing source, mostly driven by land use change to Cropland in Wales and a lower level of crop-grass rotations than in 2000-2022. Grassland is projected to be a slowly decreasing source / increasing sink which ultimately becomes a small source post 2050 onwards. The difference between the *Baseline* and *Central* scenarios for these land use categories predominantly arises from the different scenario assumptions for peatland rewetting. The decreasing source / increasing sink in the *Stretch* scenario is predominantly due to rewetting of peatland. Post 2050 with no further land use change the trends for Cropland and Grassland decrease / increase as soil carbon losses / gains tail off.

The scale of changes in the Wetlands net source is small compared to the other land use categories. Figure 16 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, the restoration of former extraction sites and rewetting of forestry.

Emissions from land use change to Settlements are projected to decrease over the time period in all scenarios. Although Settlement areas are predicted to increase, the rate of change of land to Settlement (and hence emissions from land use change) varies only slightly between the scenarios. The activity data for the projections are discussed further in Annex 1. As in the case of Cropland, the Settlement emissions reduce post 2050 with no further transitions to the category.

Harvested Wood Products (HWPs) are projected to be a small sink over the whole timeseries. 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.

Carbon dioxide, arising from soil and biomass carbon stock changes, is the main greenhouse gas associated with LULUCF (Figure 17). Methane (CH_4) emissions (Global Warming Potential of 28) are of increasing dominance across the projections, arising predominantly from drainage and re-wetting of organic soils with a small contribution from biomass burning. N_2O emissions also make a significant contribution when the Global Warming Potential of N_2O of 265 is taken into account. These N_2O emissions arise from forest fertilisation, drainage and rewetting, soil nitrogen mineralisation following land use change and from biomass burning.

England shows an increase in emissions in the 2020s (Figure 12) under the *Baseline* and *Central* scenarios, and a slight increase in net removals under the *Stretch* scenario. The differences between the scenarios in the 2020-2050 time period come predominantly from differences in the Forest Land, Cropland and Grassland categories.

The projection trends for Scotland (Figure 13) are dominated by Forest Land and Grassland, with the main

differences between the scenarios being the forest planting rates and the peatland restoration.

Wales (Figure 14) is a small net LULUCF GHG sink for all scenarios throughout the projected time series. Up to 2050 the differences in scenarios are predominated by Grassland with some contribution from Forest Land. However, after 2050 the Forest Land differences drive the trend.

Northern Ireland (Figure 15) is projected to be a net LULUCF GHG source for the projected time series. The main differentiation between the scenarios arises from the Wetland and Grassland categories, where differences in projected peat extraction and peatland restoration dominate the trend.

The relative contributions of the LULUCF sector from the Devolved Administrations to the UK total are shown in Figure 18 (Central scenario).

The projections are presented in the policy relevant Territorial Emissions Sectors in Figure 20, Figure 21, Figure 22, Figure 23 & Figure 24. This breakdown shows that for all Devolved Administrations a large majority of the projected changes occur in the Forestry and Peatland sectors. The projections for increased planting of miscanthus and short-rotation coppice and introduction of short-rotation forestry and agroforestry planting (England only) can be seen in the Bioenergy Crops and Other policy sections in Figure 21.

4.3 Changes from the 1990-2021 projections

There have been minor changes to activity data and methodology used for estimating the LULUCF emissions and removals since the previous projections report. These differences are shown at the UK level in Figure 19 by comparing the *Central* projections based on the 2022 and 2021 inventories.

The main changes in the 1990-2022 inventory were: updates to the soil component of the CARBINE forest accounting model, inclusion of urban trees within forest modelling, minor updates to forest planting and harvesting data, changes to the baseline organic soil areas for Northern Ireland and England and inclusion of new peat extraction volume data for Northern Ireland. In the inventory part of the time series these changes mostly impact the Forest and Wetland categories.

The main changes in the scenario modelling were updates to the forest planting assumptions for Northern Ireland and updated assumptions for peatland rewetting. In the projection years this impacts Forest, HWP, Cropland, Grassland and Wetland.

Table 5: LULUCF emissions and removals of carbon and CO_2 as CO_2e 1990-2100.

Scenario	Country	1990 Gg CO_2e	2022 Gg CO_2e	2025 Gg CO_2e	2030 Gg CO_2e	2040 Gg CO_2e	2050 Gg CO_2e	2075 Gg CO_2e	2100 Gg CO_2e
Baseline	**UK**	3252	-5633	-4703	-2669	1795	3614	-245	1424
Central	**UK**	3252	-6254	-5746	-4932	-2290	-2584	-7654	-4662
Stretch	**UK**	3252	-6254	-8017	-8614	-8839	-14351	-26682	-15985

Table 6: LULUCF emissions and removals of CH_4 1990-2100.

Scenario	Country	1990 Gg CH_4	2022 Gg CH_4	2025 Gg CH_4	2030 Gg CH_4	2040 Gg CH_4	2050 Gg CH_4	2075 Gg CH_4	2100 Gg CH_4
Baseline	**UK**	198.95	201.26	201.78	201.84	201.67	201.93	200.75	200.75
Central	**UK**	198.95	204.29	209.35	216.06	217.00	218.26	217.08	217.08
Stretch	**UK**	198.95	204.29	213.06	226.57	249.15	272.13	270.95	270.95

Table 7: LULUCF emissions and removals of N_2O 1990-2100.

Scenario	Country	1990 Gg N_2O	2022 Gg N_2O	2025 Gg N_2O	2030 Gg N_2O	2040 Gg N_2O	2050 Gg N_2O	2075 Gg N_2O	2100 Gg N_2O
Baseline	**UK**	7.19	4.82	4.77	4.66	4.41	4.25	1.90	1.70
Central	**UK**	7.19	4.87	4.88	4.78	4.56	4.39	1.82	1.63
Stretch	**UK**	7.19	4.87	4.88	4.87	4.86	4.79	1.48	1.32

Table 8: LULUCF emissions and removals of CO_2 equivalents 1990-2100 (1 Mt CO_2eq = 1000 Gg CO_2eq).

Scenario	Country	1990 Gg CO_2 eq	2022 Gg CO_2 eq	2025 Gg CO_2 eq	2030 Gg CO_2 eq	2040 Gg CO_2 eq	2050 Gg CO_2 eq	2075 Gg CO_2 eq	2100 Gg CO_2 eq
Baseline	**UK**	10728	1279	2213	4218	8610	10395	5881	7495
Central	**UK**	10728	758	1410	2385	4995	4690	-1094	1847
Stretch	**UK**	10728	758	-758	-980	-575	-5461	-18704	-8048

Figure 11: UK LULUCF CO_2 equivalent emissions scenarios 1990-2100. The individual graphs refer to LULUCF reporting categories; see Section 3 text for description of what is reported in these categories (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is shaded in grey, a grey line indicates zero emissions, and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

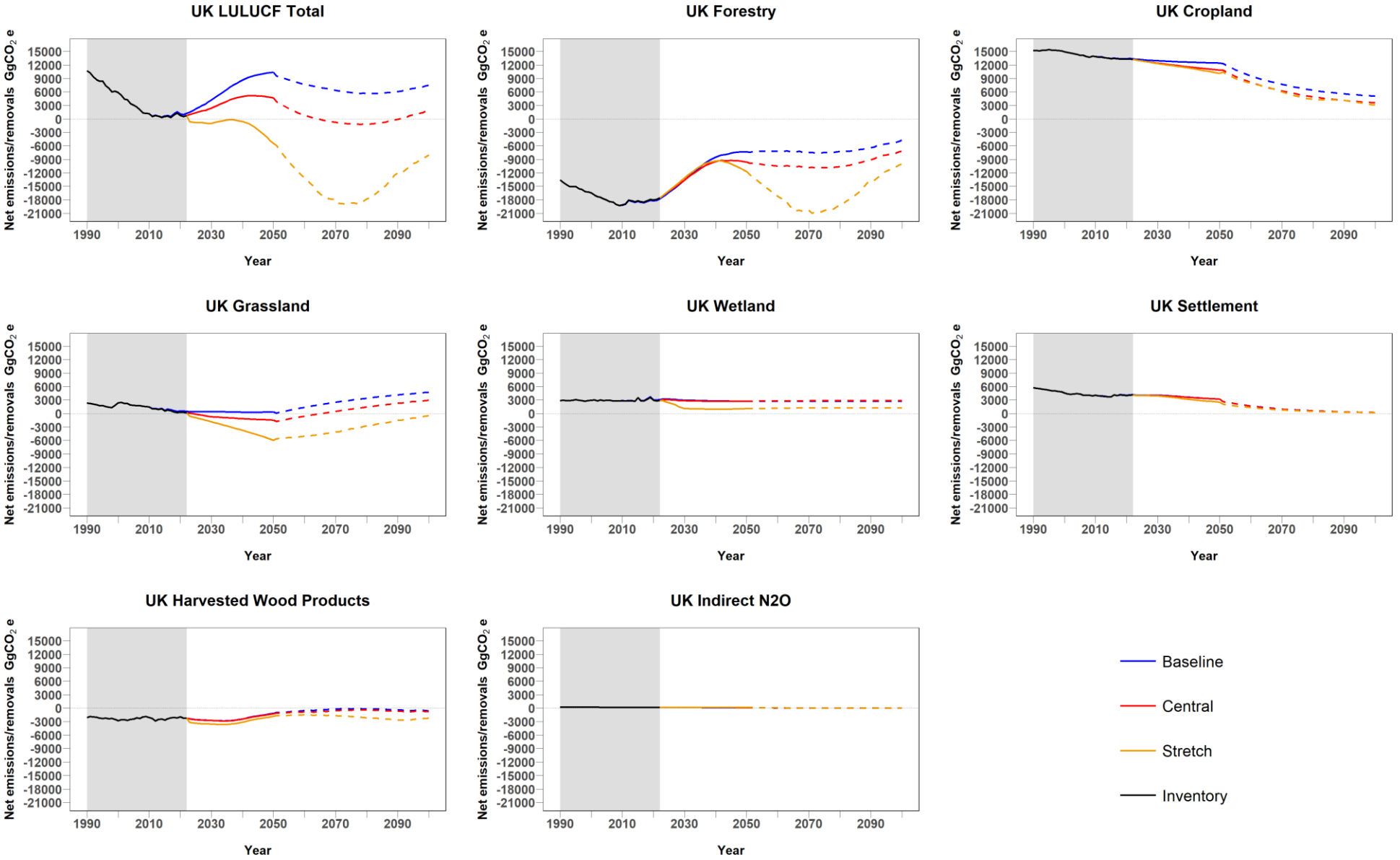


Figure 12: England LULUCF CO_2 equivalent emissions scenarios 1990-2100. The individual graphs refer to LULUCF reporting categories; see Section 3 text for description of what is reported in these categories (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is shaded in grey, a grey line indicates zero emissions, and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

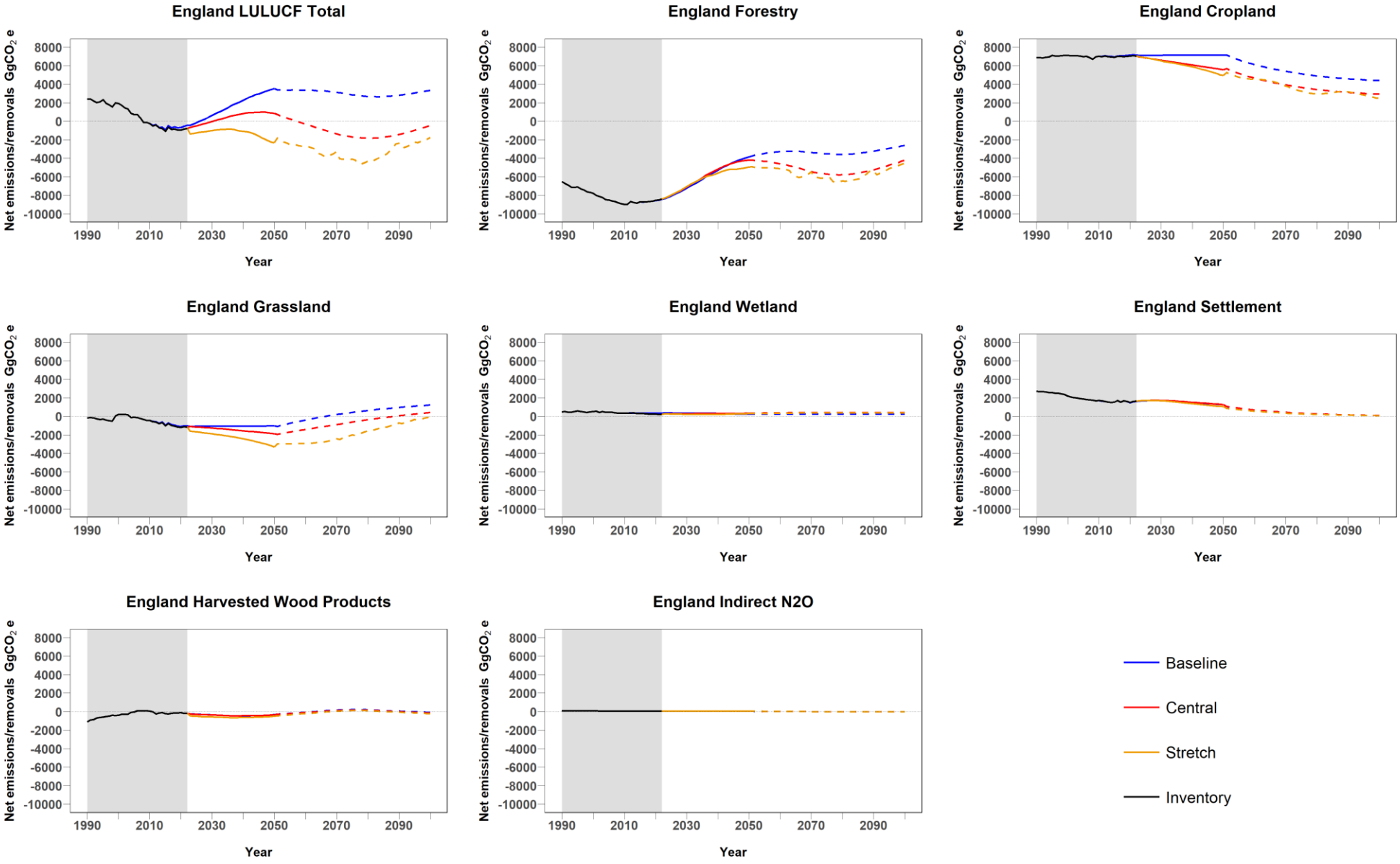


Figure 13: Scotland LULUCF CO_2 equivalent emissions scenarios 1990-2100. The individual graphs refer to LULUCF reporting categories; see Section 3 text for description of what is reported in these categories (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is shaded in grey, a grey line indicates zero emissions, and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

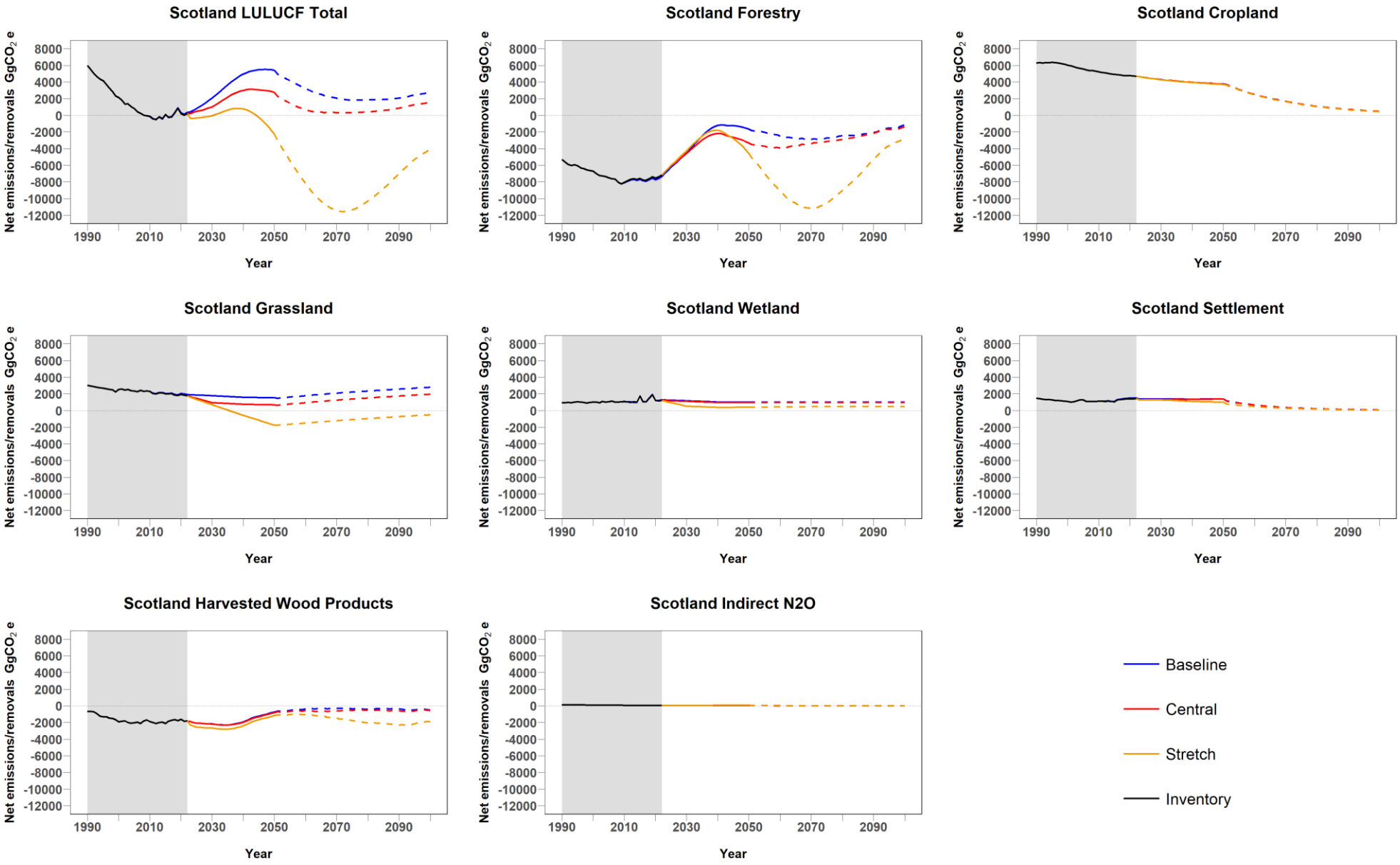


Figure 14: Wales LULUCF CO_2 equivalent emissions scenarios 1990-2100. The individual graphs refer to LULUCF reporting categories, which for cropland and grassland are mainly driven by land use change (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is shaded in grey, a grey line indicates zero emissions, and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

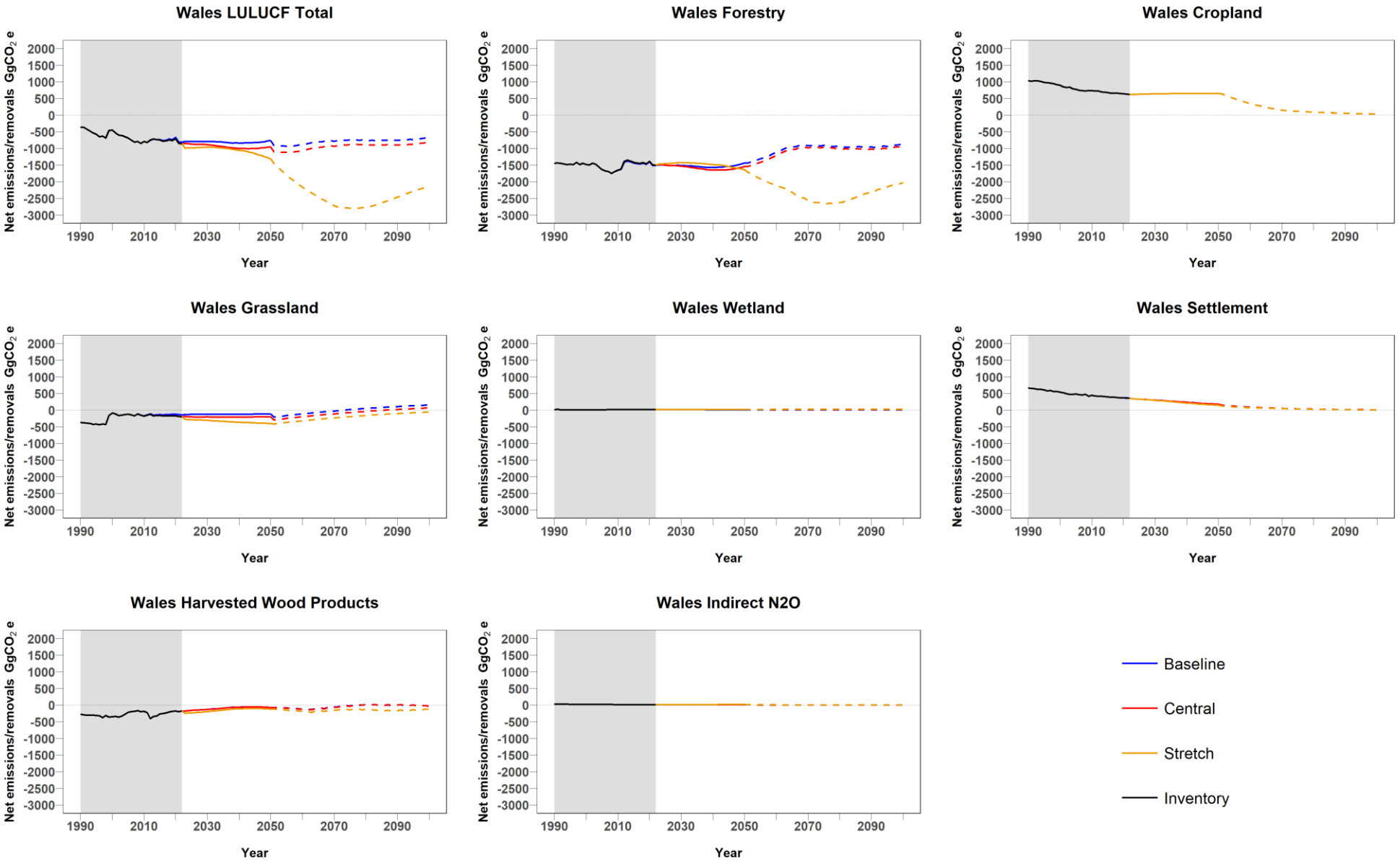


Figure 15: Northern Ireland LULUCF CO_2 equivalent emissions scenarios 1990-2100. The individual graphs refer to LULUCF reporting categories; see Section 3 text for description of what is reported in these categories (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is shaded in grey, a grey line indicates zero emissions, and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

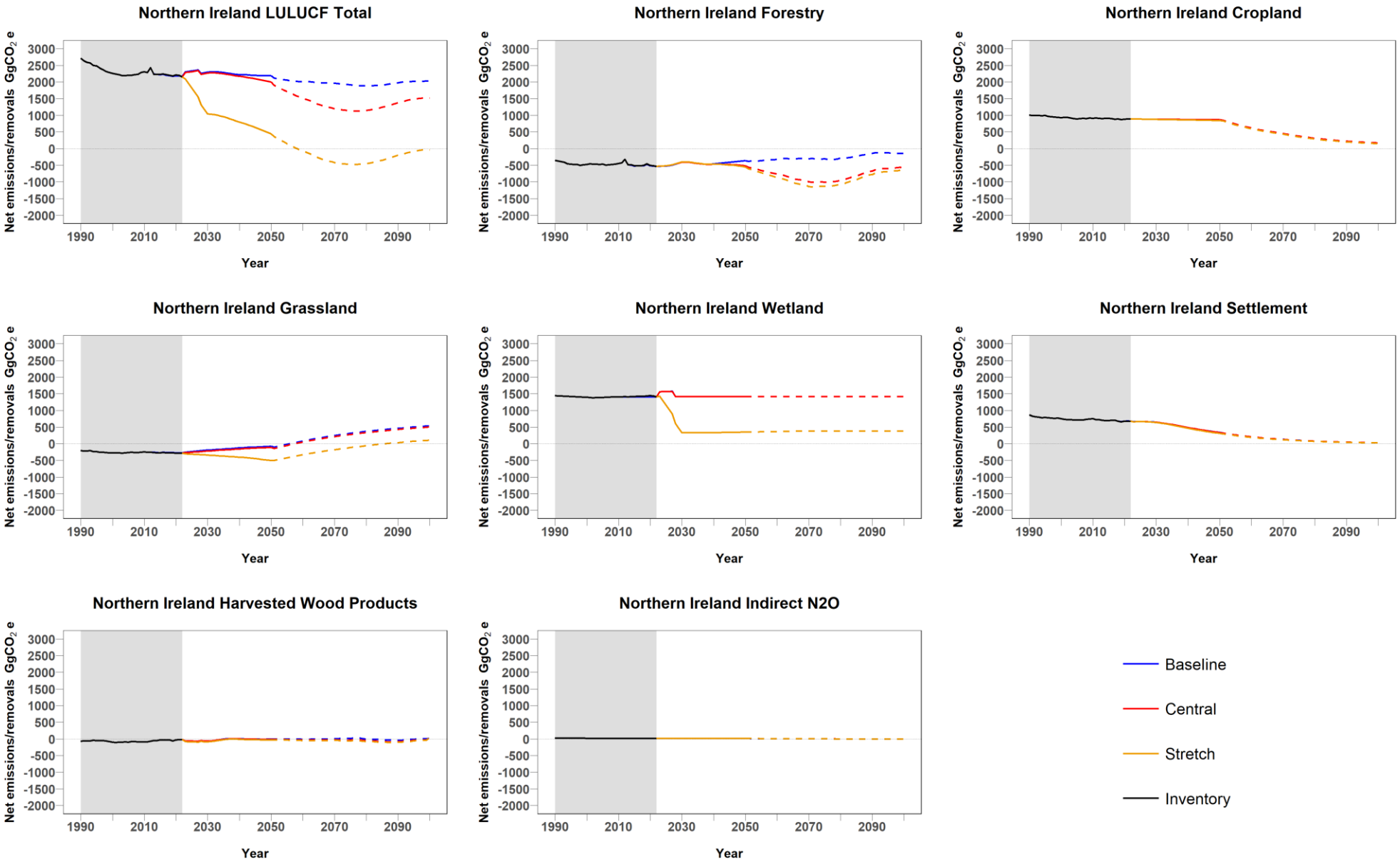


Figure 16: Net emissions from Wetlands under all scenarios (shown on larger scale for clarity) (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is shaded in grey and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

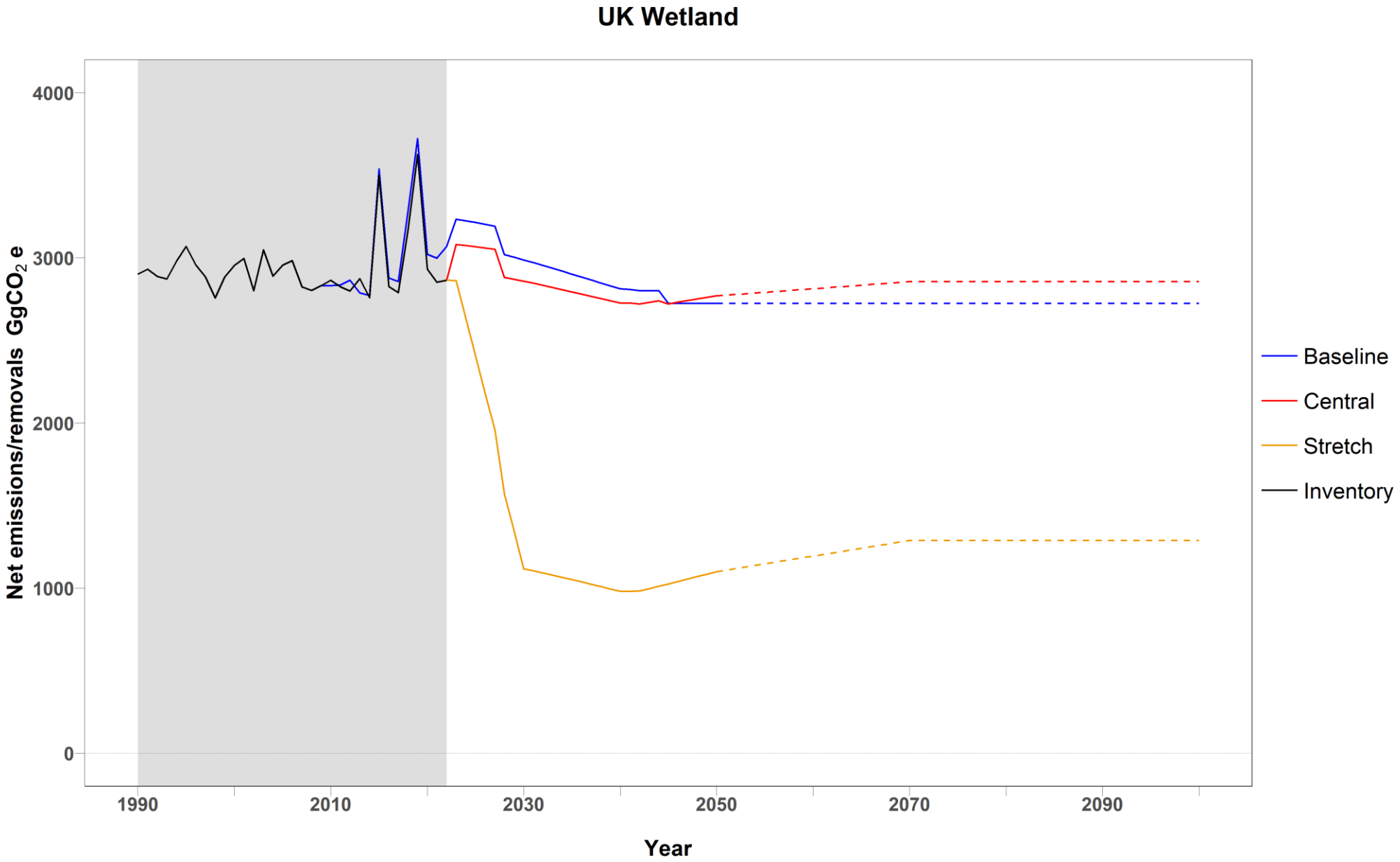


Figure 17: UK LULUCF Sector emissions of individual gases 1990-2100 (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is shaded in grey and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

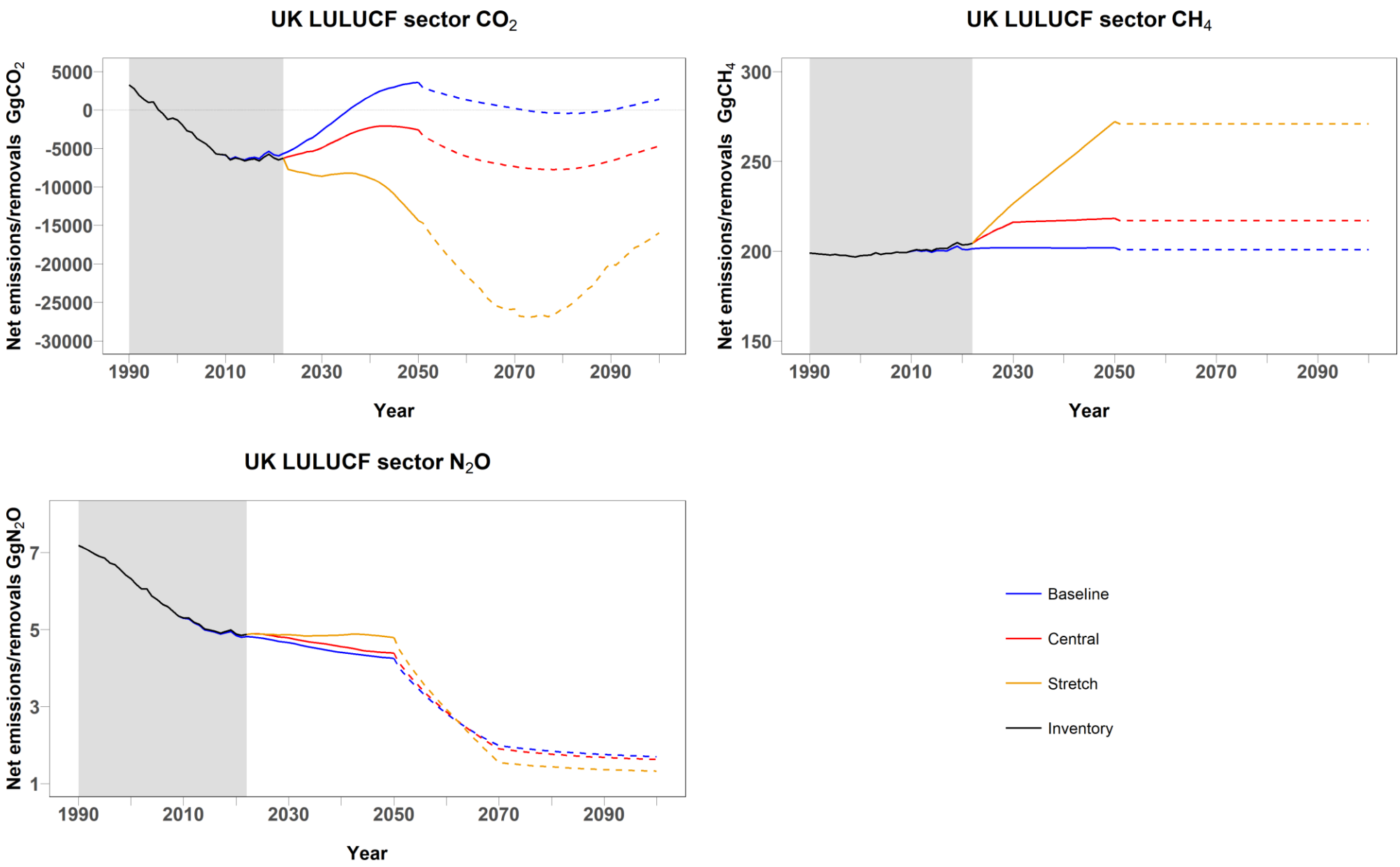


Figure 18: The combined total of the LULUCF emissions from each Devolved Administration for the *Central* emissions scenario. The projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

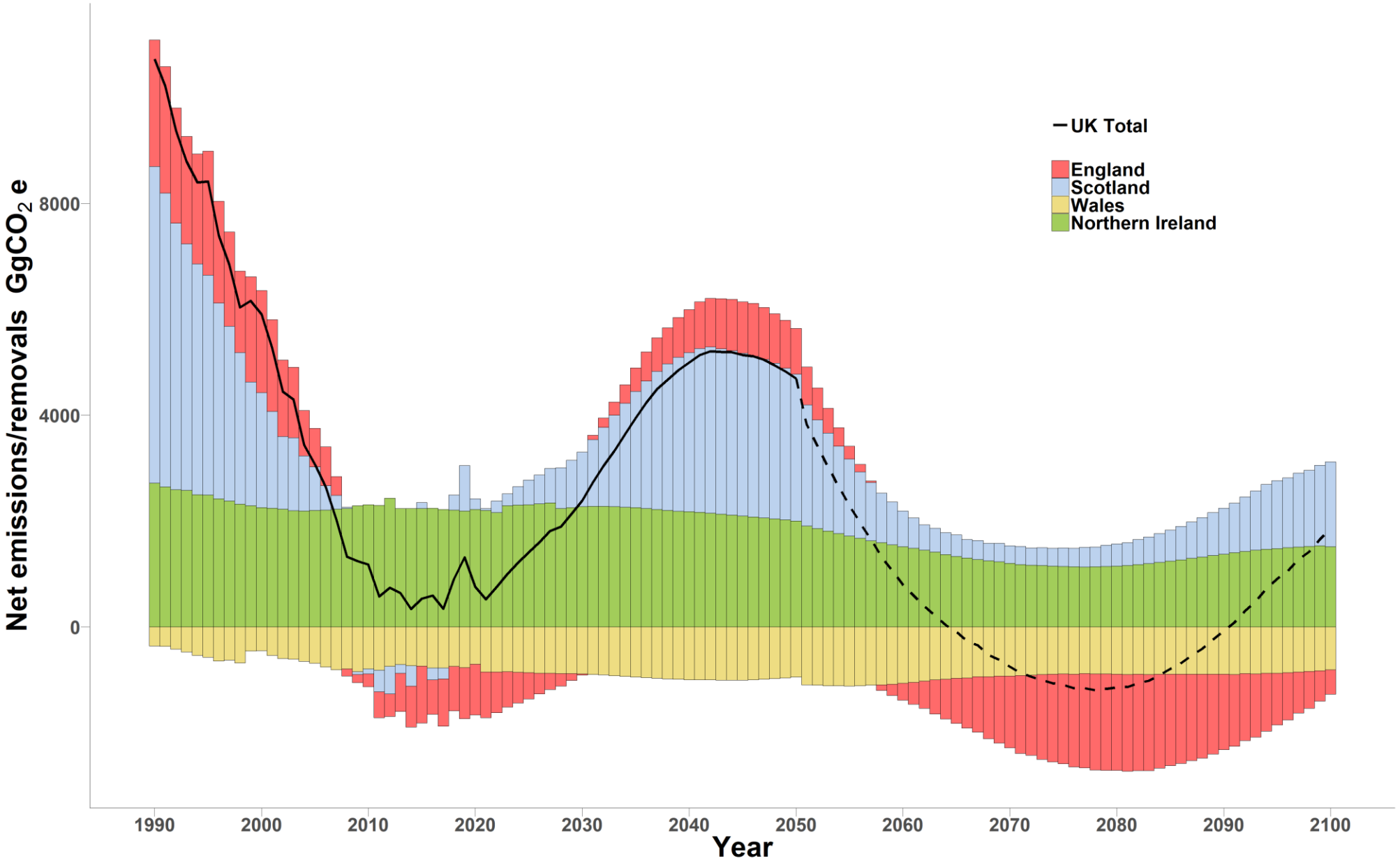


Figure 19: UK LULUCF CO_2 equivalent comparison of the Central emissions scenario for the 2022 and 2021 inventories respectively 1990-2100 (1 Mt CO_2eq = 1000 Gg CO_2eq). The projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

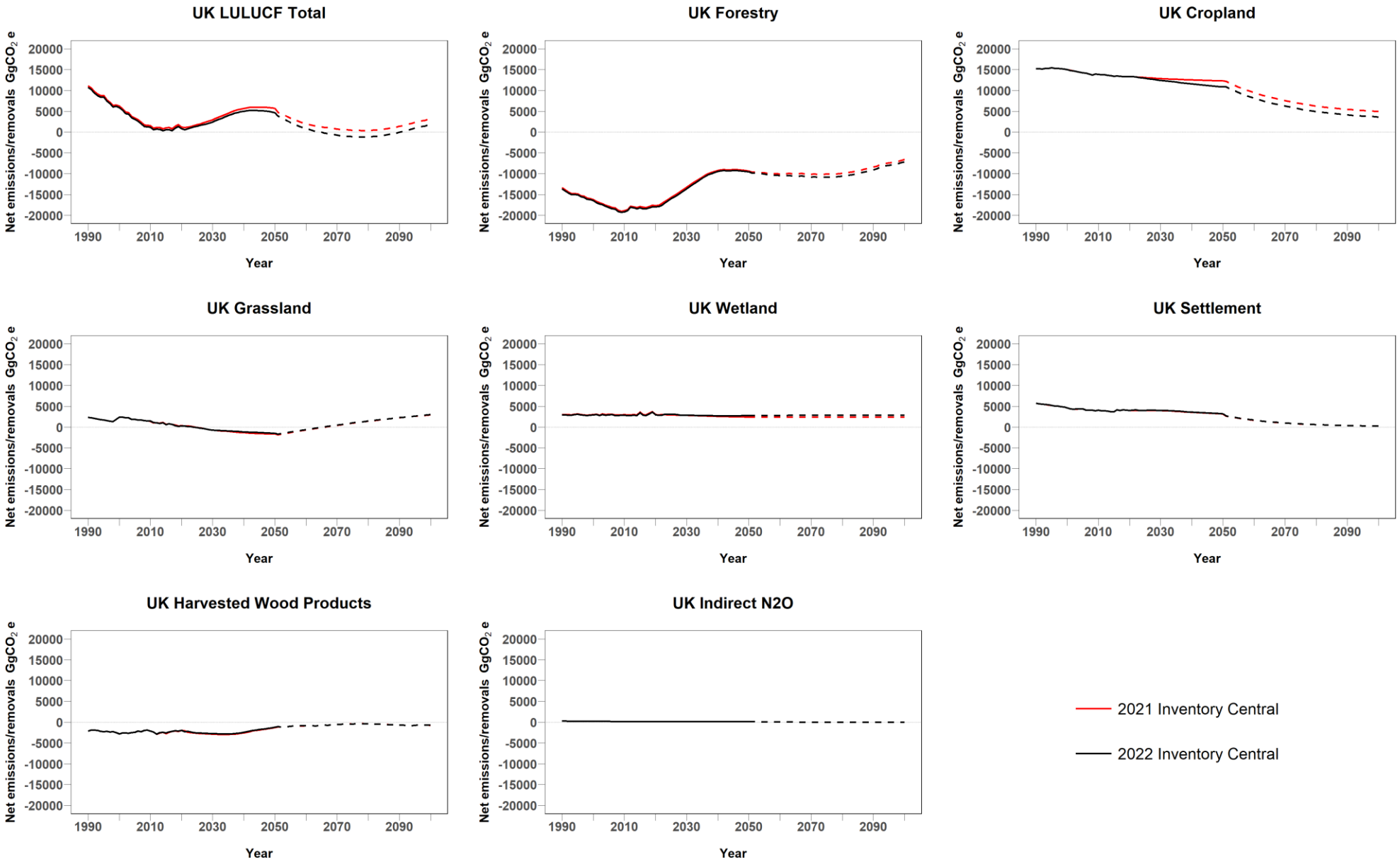


Figure 20: UK LULUCF CO_2 equivalent emissions scenarios 1990-2100. The individual graphs refer to the National Communication policy categories; see Section 3 text for description of what is reported in these categories (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is marked in grey and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

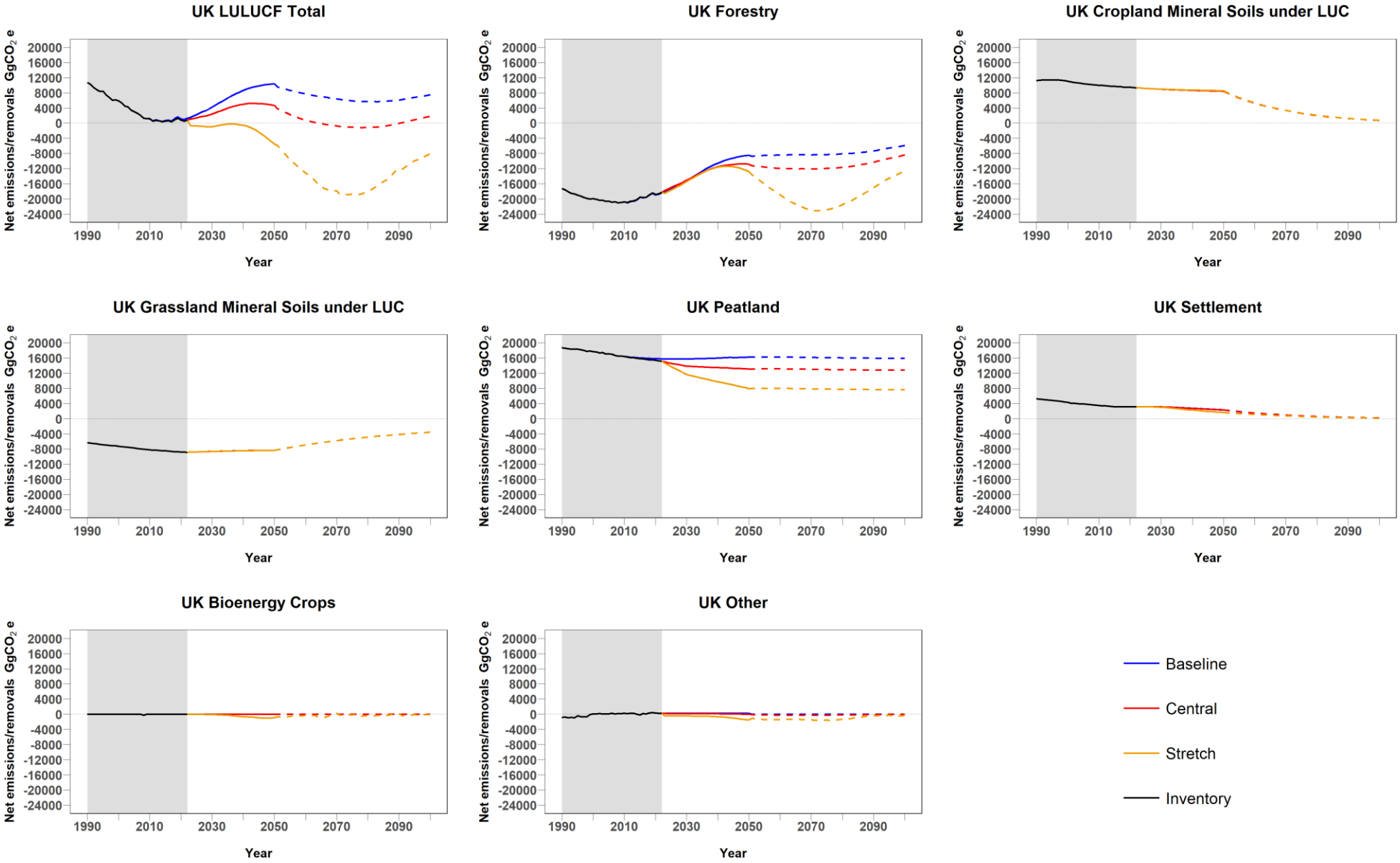


Figure 21: England LULUCF CO_2 equivalent emissions scenarios 1990-2100. The individual graphs refer to the Territorial Emissions Sector categories; see Section 3 text for description of what is reported in these categories (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is marked in grey and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

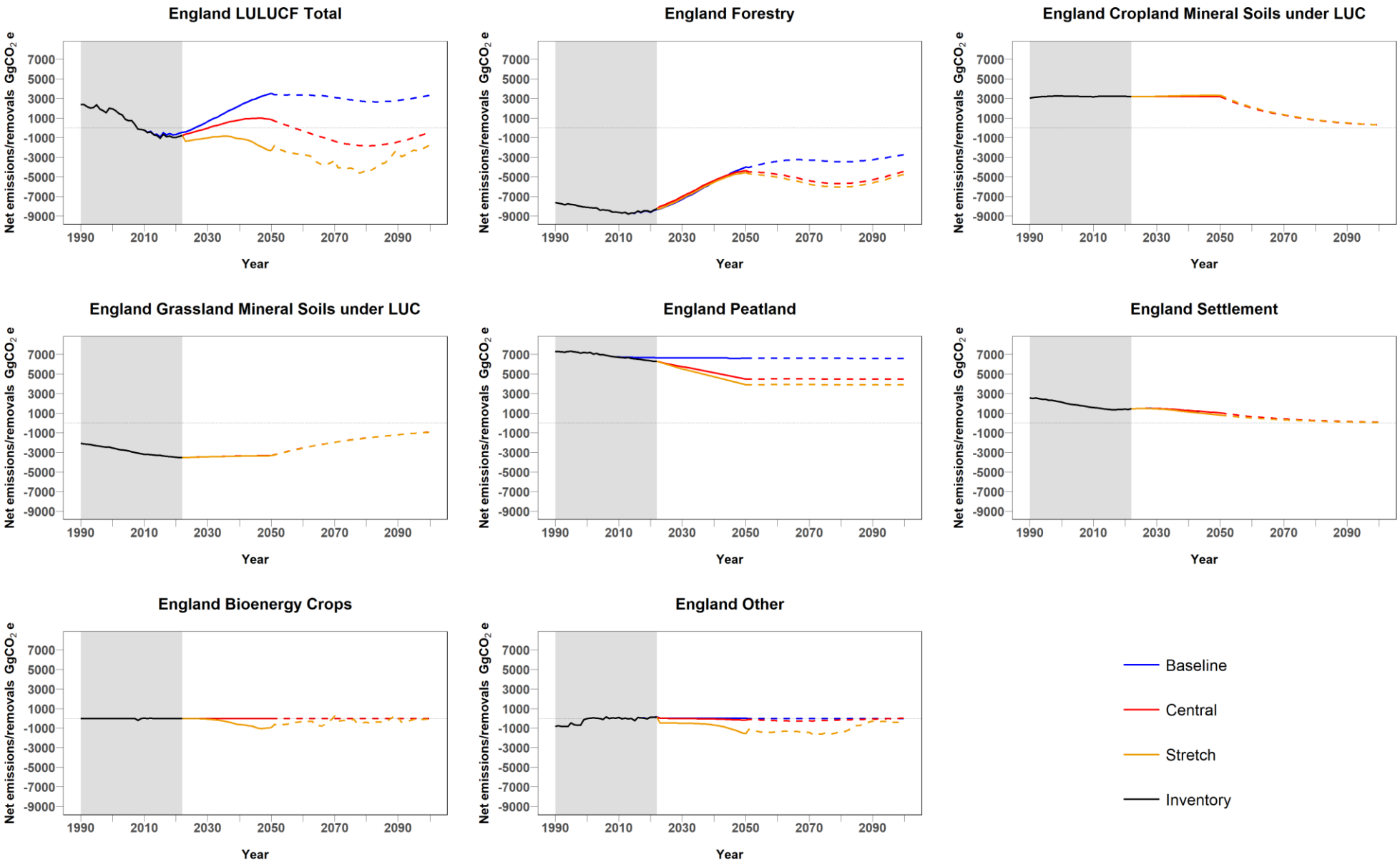


Figure 22: Scotland LULUCF CO_2 equivalent emissions scenarios 1990-2100. The individual graphs refer to the Territorial Emissions Sector categories; see Section 3 text for description of what is reported in these categories (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is marked in grey and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

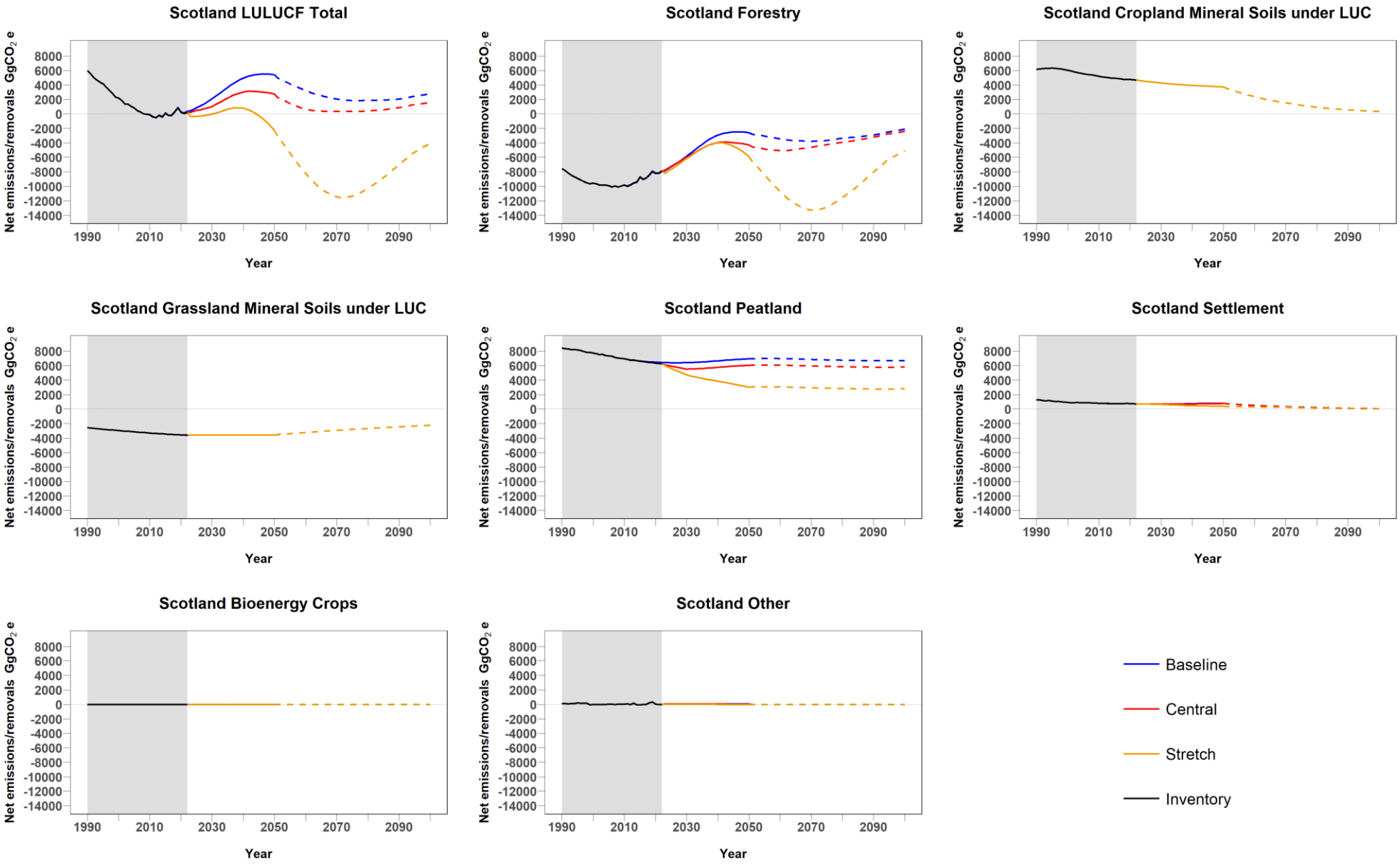


Figure 23: Wales LULUCF CO_2 equivalent emissions scenarios 1990-2100. The individual graphs refer to the Territorial Emissions Sector categories; see Section 3 text for description of what is reported in these categories (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is marked in grey and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.

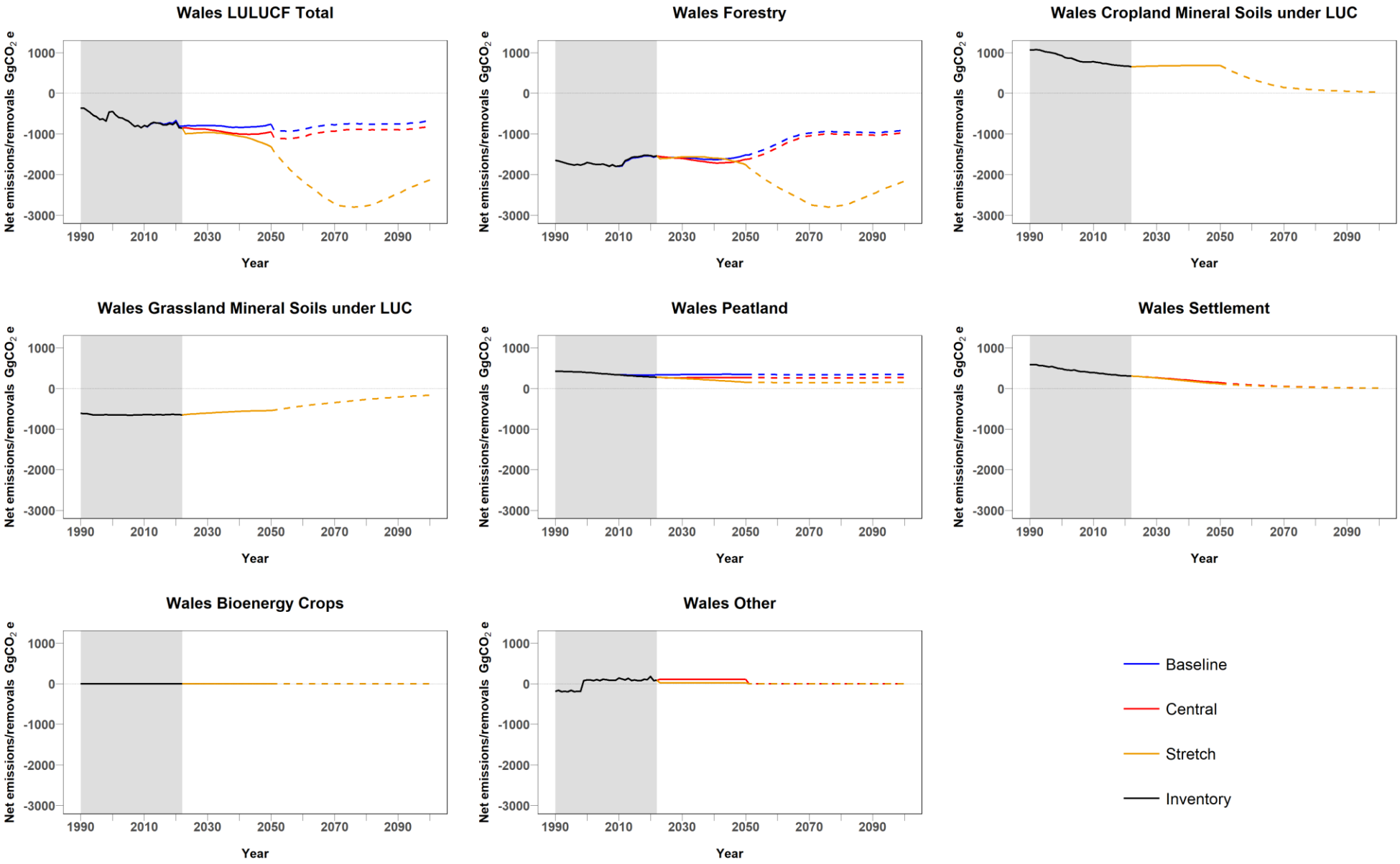
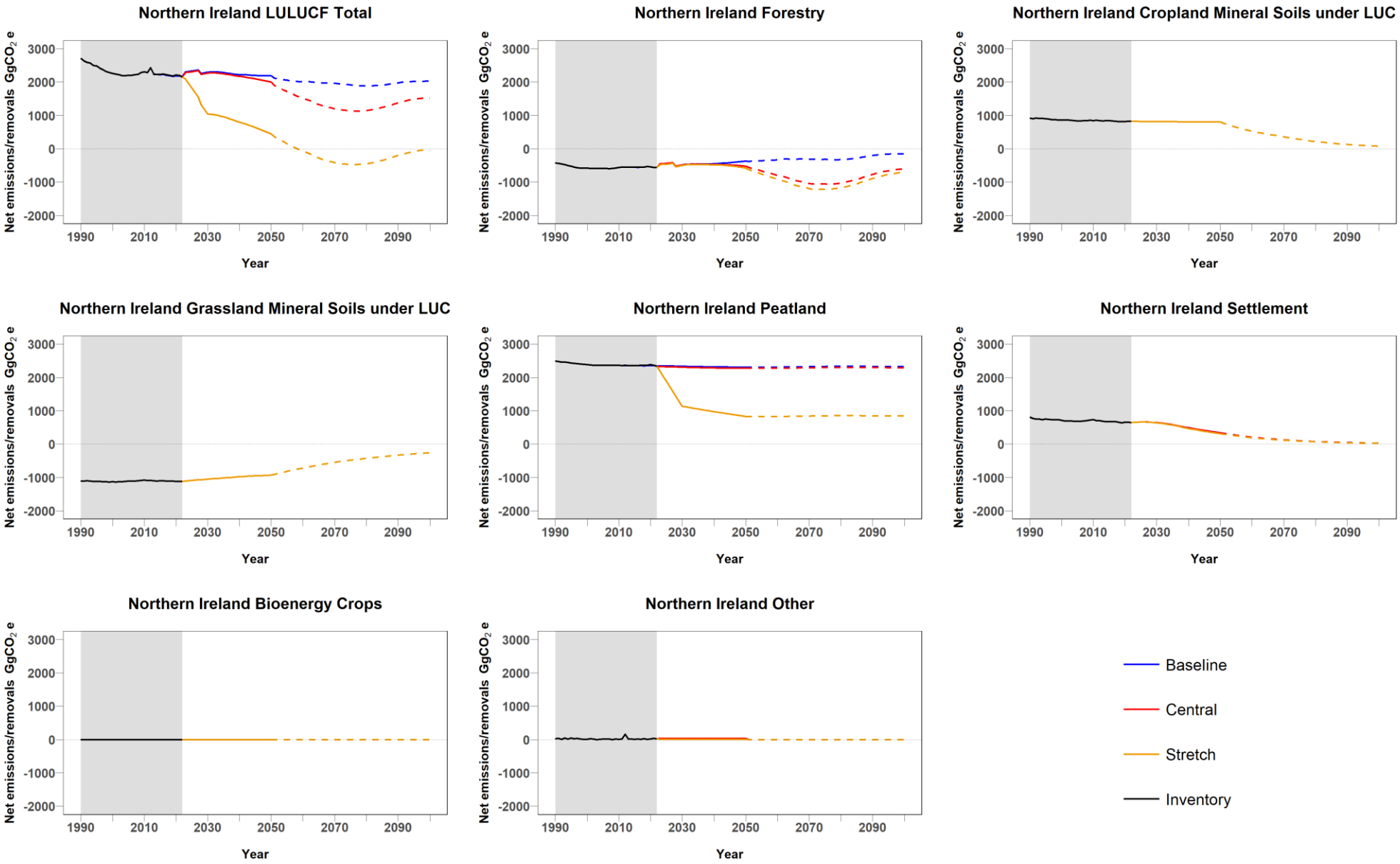


Figure 24: Northern Ireland LULUCF CO_2 equivalent emissions scenarios 1990-2100. The individual graphs refer to the Territorial Emissions Sector categories; see Section 3 text for description of what is reported in these categories (1 Mt CO_2eq = 1000 Gg CO_2eq). The inventory period (1990-2022) is marked in grey and the projections from 2051-2100 are dashed to indicate ongoing emissions/ removals with no further land use change.



5 References

Brown *et al*. (2024) UK Greenhouse Gas Inventory, 1990 to 2019. UK Greenhouse Gas Inventory, 1990 to 2022: Annual Report for submission under the Framework Convention on Climate Change. Ricardo. https://naei.energysecurity.gov.uk/reports/uk-greenhouse-gas-inventory-1990-2022-annual-report-submission-under-framework-convention

DCLG, 2015. Land use change statistics 2013/14. Methodology changes guidance. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/432348/DCLG_LUCS_New_Methodology_Guidance.pdf

DCLG, 2016. Household projections for England and local authority districts. https://www.gov.uk/government/statistical-data-sets/live-tables-on-household-projections

Evans, C., Artz, R., Moxley, J., Smyth, M-A., Taylor, E., Archer, N., Burden, A., Williamson, J., Donnelly, D., Thomson, A., Buys, G., Malcolm, H., Wilson, D., Renou-Wilson, F., Potts J. (2017). Implementation of an emission inventory for UK peatlands. Report to the Department for Business, Energy and Industrial Strategy, Centre for Ecology and Hydrology, Bangor. Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1904111135_UK_peatland_GHG_emissions.pdf

MHCLG, 2018a. Land use change statistics 2016-17: land use based change tables. https://www.gov.uk/government/statistics/land-use-change-statistics-2016-to-2017 (Tables 350, 360, 361, 370).

MHCLG, 2018b. Land use change statistics 2016-17: residential address based change tables. (Tables 300 and 330). https://www.gov.uk/government/statistics/land-use-change-statistics-2016-to-2017

MHCLG, 2018c. Live tables on house building: new build dwellings. https://www.gov.uk/government/statistical-data-sets/live-tables-on-house-building (Table 209)

National Forest Inventory (2017). Tree cover outside woodland in Great Britain. Forestry Commission Statistical Report.

https://www.forestry.gov.uk/pdf/FR_Tree_cover_outside_woodland_in_GB_statistical_report_2017.pdf/$FILE/FR_Tree_cover_outside_woodland_in_GB_statistical_report_2017.pdf

Office for National Statistics (2018) 2016-based household projections for local authorities and higher administrative areas in England.

https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/2016basedhouseholdprojectionsinengland/2016basedhouseholdprojectionsinengland

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

Conversion of “rural” land to Settlement can vary considerably over time, driven by national and global factors affecting, for example, housing demand, construction material availability/cost and political priorities. Settlement land includes both housing and other infrastructure and ‘developed’ land.

We assume that projected increase in numbers of households in the future can be used as a simple proxy for future demand for land conversion to Settlement. The projections of household numbers (ONS 2020) use the latest national population census and trends in population demography and household formation to project household numbers for England and the devolved administrations[11]. The England data are 2018-based household projections, Wales are 2014-based, and Scotland and Northern Ireland are 2016-based. The projections extend to 2043 (England), to 2039 (Wales) and to 2041 (Scotland, Northern Ireland). A three-year rolling average was used to smooth the projected increase in number of households and the final values in the time series were held constant to 2050.

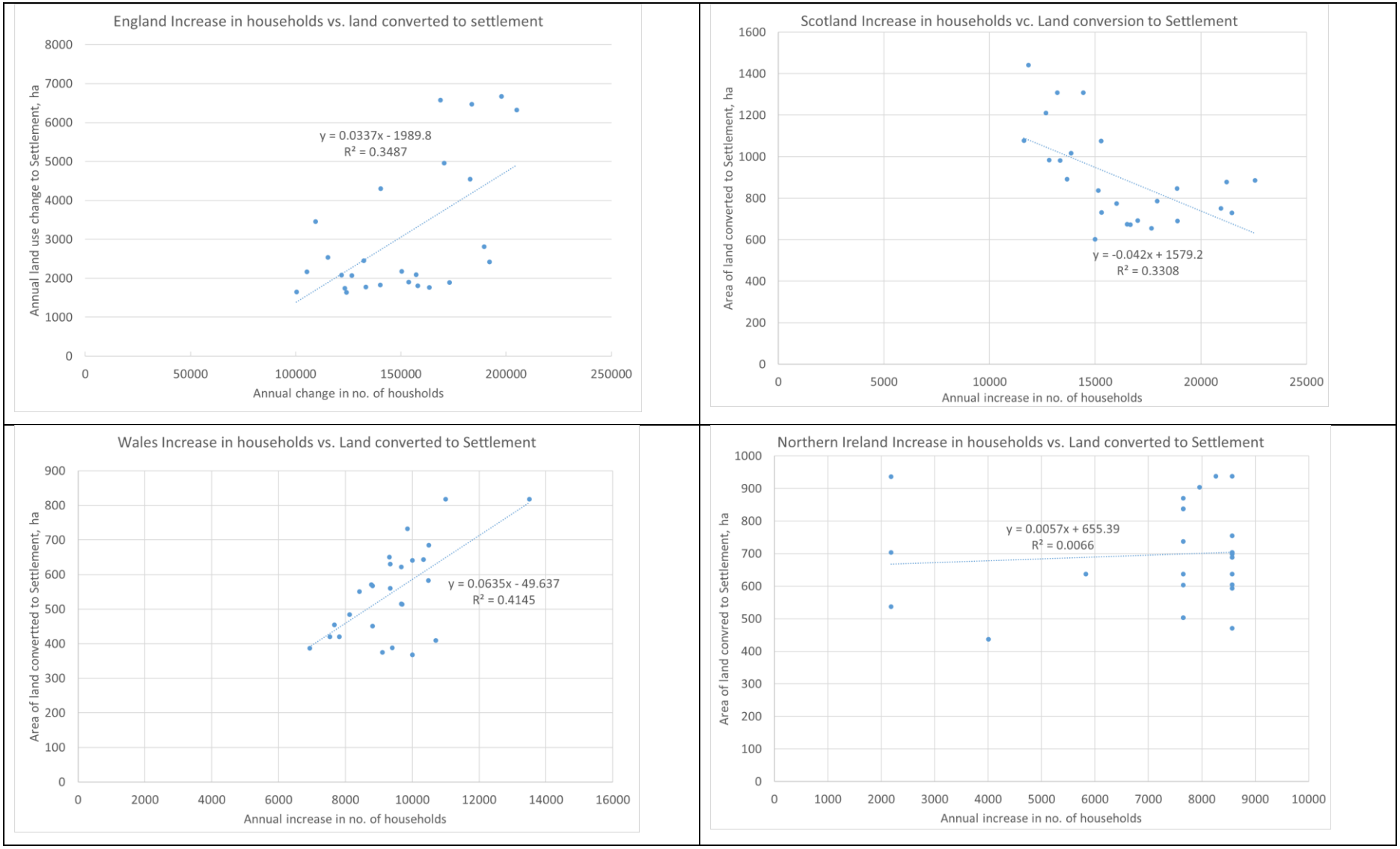
We explored the relationship between the change in the number of households per year and the area of land converted to Settlement on mineral soils reported in the national GHG inventory 1990-2018 for each country of the UK. There is no land conversion to Settlement on organic soils in the inventory time series from 1990. This analysis indicated that the best fit for England, Scotland and Wales, using linear regression, used a five-year offset between household increase and land conversion to Settlement for the period 1995-2020 (Figure A1.1). The scatter plots showed a wide spread of values, so the best fit relationships had R^2 values of between 0.33 and 0.41. No best fit relationship was found for Northern Ireland, presumably because the household number dataset was intermittent and only had values for 1991, 2001, 2011 and 2016 onwards. The best fit relationship for Wales was used for Northern Ireland to estimate projections.

The best fit relationships were used to project the total area of land conversion to Settlement from the smoothed projected increase in the number of households for each country in the UK. A 15-year ramp was used between the latest reported inventory year (2022) and 2037 in order to avoid a sudden step change in the time series. The total area of land converted to Settlement is divided between land conversion categories for each country. The projected areas of deforestation to Settlement[12] are subtracted from the country total. The remaining area is assigned to Grassland converted to Settlement and Cropland converted to Settlement, weighted by the proportions converted in each country in 2010-2022.

[11] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/householdprojectionsforengland

[12] Forest conversion to Settlement is projected as part of the deforestation projections

Figure A1.1 Linear regression of annual increase in household numbers (5-year offset) vs. annual area of land converted to Settlement 1995-2020



Annex 2: Land use areas by Devolved Administration

Table A2.1: Land use areas 2022-2050 for England (13,046 kha).

Emission scenario	*Land use category*	*2022 area, kha*	*2025 area, kha*	*2030 area, kha*	*2040 area, kha*	*2050 area, kha*
Baseline	Forest land	1625	1623	1621	1618	1617
	Cropland	4050	4041	4028	4012	4002
	Grassland	5673	5662	5646	5626	5618
	Wetland	116	117	117	118	112
	Settlement	1455	1477	1507	1545	1570
	Other	127	127	127	127	127
Central	Forest land	1639	1653	1687	1769	1855
	Cropland	4050	4038	4018	3986	3961
	Grassland	5653	5626	5573	5471	5374
	Wetland	121	126	135	152	166
	Settlement	1455	1477	1506	1542	1564
	Other	127	127	127	127	127
Stretch	Forest land	1639	1652	1712	1877	2046
	Cropland	4050	4037	4021	4025	4036
	Grassland	5653	5630	5555	5344	5138
	Wetland	121	124	130	147	163
	Settlement	1455	1476	1503	1527	1537
	Other	127	127	127	127	127

Table A2.2: Land use areas 2022-2050 for Scotland (7,881 kha).

Emission scenario	*Land use category*	*2022 area, kha*	*2025 area, kha*	*2030 area, kha*	*2040 area, kha*	*2050 area, kha*
Baseline	Forest land	1422	1418	1412	1407	1406
	Cropland	565	564	564	562	560
	Grassland	4815	4815	4814	4808	4800
	Wetland	639	641	644	645	645
	Settlement	184	187	192	203	215
	Other	255	255	255	255	255
Central	Forest land	1517	1551	1545	1540	1538
	Cropland	565	562	561	559	557
	Grassland	4720	4687	4686	4680	4672
	Wetland	639	641	644	645	645
	Settlement	184	185	190	201	213
	Other	255	255	255	255	255
Stretch	Forest land	1517	1565	1668	1937	2220
	Cropland	565	561	552	531	509
	Grassland	4720	4692	4626	4384	4131
	Wetland	639	624	597	599	600
	Settlement	184	184	183	175	166
	Other	255	255	255	255	255

Table A2.3: Land use areas 2022-2050 for Wales (2,078 kha).

Emission scenario	*Land use category*	*2022 area, kha*	*2025 area, kha*	*2030 area, kha*	*2040 area, kha*	*2050 area, kha*
Baseline	Forest land	347	347	346	345	345
	Cropland	93	95	100	109	119
	Grassland	1474	1471	1465	1454	1443
	Wetland	31	31	32	32	32
	Settlement	106	107	109	112	113
	Other	27	27	27	27	27
Central	Forest land	358	358	357	356	356
	Cropland	93	95	100	109	119
	Grassland	1463	1460	1454	1443	1432
	Wetland	31	31	32	32	32
	Settlement	106	107	109	112	113
	Other	27	27	27	27	27
Stretch	Forest land	358	370	397	478	564
	Cropland	93	94	97	100	103
	Grassland	1463	1450	1421	1341	1259
	Wetland	31	31	32	32	32
	Settlement	106	106	105	101	94
	Other	27	27	27	27	27

Table A2.4: Land use areas 2022-2050 for Northern Ireland (1,433 kha).

Emission scenario	*Land use category*	*2022 area, kha*	*2025 area, kha*	*2030 area, kha*	*2040 area, kha*	*2050 area, kha*
Baseline	Forest land	114	113	112	112	112
	Cropland	43	42	41	40	40
	Grassland	1021	1019	1017	1015	1015
	Wetland	182	184	184	184	184
	Settlement	60	63	67	70	70
	Other	12	12	12	12	12
Central	Forest land	118	118	123	145	170
	Cropland	43	42	40	37	35
	Grassland	1017	1014	1007	986	964
	Wetland	183	184	185	185	185
	Settlement	60	63	66	68	68
	Other	12	12	12	12	12
Stretch	Forest land	118	119	127	153	181
	Cropland	43	42	40	37	34
	Grassland	1017	1046	1091	1067	1042
	Wetland	183	151	97	97	98
	Settlement	60	63	66	67	66
	Other	12	12	12	12	12

Annex 3: Afforestation and Deforestation data

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

	Annual Forest Planting Rate				
Year	England	Scotland	Wales	N. Ireland	UK Total
2010	2.44	3.26	0.20	0.29	6.19
2011	2.44	3.26	0.20	0.29	6.19
2012	2.44	3.26	0.20	0.29	6.19
2013	2.44	3.26	0.20	0.29	6.19
2014	2.44	3.26	0.20	0.29	6.19
2015-2050	0.24	0.33	0.02	0.03	0.62

Table A3.2 *Central* Scenario Afforestation Rates (kha).

	Annual Forest Planting Rate				
Year	England	Scotland	Wales	N. Ireland	UK Total
2020	2.1241	10.7542	0.2380	0.2635	13.3798
2021	2.2047	10.5217	0.5396	0.4758	13.7419
2022	2.9099	8.7609	1.0472	0.4739	13.1919
2023	3.3000	16.1250	0.0200	0.4500	19.8950
2024	6.0000	17.6250	0.0200	0.6000	24.2450
2025	7.5000	4.7450	0.0200	0.9000	13.1650
2026	7.6500	0.3260	0.0200	0.9000	8.8960
2027	7.8000	0.3260	0.0200	1.1500	9.2960
2028	7.9500	0.3260	0.0200	1.1500	9.4460
2029	8.1000	0.3260	0.0200	1.4000	9.8460
2030	8.2500	0.3260	0.0200	1.4000	9.9960
2031	8.4000	0.3260	0.0200	1.6000	10.3460
2032	8.5500	0.3260	0.0200	1.8000	10.6960
2033	8.7000	0.3260	0.0200	2.0000	11.0460
2034	8.8500	0.3260	0.0200	2.2000	11.3960
2035-2050	9.0000	0.3260	0.0200	2.5000	11.8460

Table A3.4 *Stretch* Scenario Afforestation Rates for conventional planting (kha).

Year	Annual Forest Planting Rate				
	England	Scotland	Wales	N. Ireland	UK Total
2020	2.1241	10.7542	0.2380	0.2635	13.3798
2021	2.2047	10.5217	0.5396	0.4758	13.7419
2022	2.9099	8.7609	1.0472	0.4739	13.1919
2023	3.1280	16.1250	3.7500	0.9000	23.9030
2024	6.0000	17.6250	4.0000	0.9000	28.5250
2025	7.5000	19.1000	4.4200	1.2000	32.2200
2026	10.0000	20.1000	4.8000	1.4000	36.3000
2027	10.0000	21.0000	5.3000	1.5000	37.8000
2028	10.0000	22.0000	5.7000	1.7000	39.4000
2029	10.0000	23.0000	6.1000	1.9000	41.0000
2030	10.0000	23.9000	6.5000	2.0000	42.4000
2031	10.0000	24.9000	6.9000	2.2000	44.0000
2032	10.0000	25.9000	7.4000	2.4000	45.7000
2033	10.0000	26.8000	7.8000	2.5000	47.1000
2034	10.0000	27.8000	8.2000	2.7000	48.7000
2035-2050	10.0000	28.7500	8.6250	2.8750	50.2500

Table A3.5 Alternative tree/crop planting rates (kha). Note that this planting is for England only and there is no planting under the Baseline scenario. SP Agroforestry = silvopastural, i.e. agroforestry within grassland. SA Agroforestry = silvoarable, i.e. agroforestry within cropland. Biomass crops split as follows: Short Rotation Forest Exotic (eucalyptus and paulownia): 13.66%; Short Rotation Forest Native (Sitka and native): 34.54%; Short Rotation Coppice willow: 26.94%; Miscanthus: 24.86%.

Year	Central Scenario				Stretch Scenario			
	SP Agroforestry	SA Agroforestry	Biomass	Total	SP Agroforestry	SA Agroforestry	Biomass	Total
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2023	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2024	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.25
2025	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.33
2026	0.13	0.00	0.00	0.13	0.67	0.43	0.20	1.30
2027	0.26	0.00	0.00	0.26	1.34	0.56	3.12	5.02
2028	0.39	0.00	0.00	0.39	2.01	0.73	6.04	8.78
2029	0.52	0.00	0.00	0.52	2.68	0.94	8.96	12.58
2030	0.65	0.00	0.00	0.65	3.35	1.19	11.88	16.42
2031	0.78	0.00	0.00	0.78	4.02	1.47	14.60	20.09

2032	0.91	0.00	0.00	0.91	4.69	1.78	14.70	21.17
2033	1.04	0.00	0.00	1.04	5.36	2.09	14.80	22.25
2034	1.17	0.00	0.00	1.17	6.03	2.37	14.90	23.30
2035	1.30	0.00	0.00	1.30	6.70	2.58	15.00	24.28
2036	1.30	0.00	0.00	1.30	6.70	2.70	15.10	24.50
2037	1.30	0.00	0.00	1.30	6.70	2.70	15.10	24.50
2038	1.30	0.00	0.00	1.30	6.70	2.58	15.10	24.38
2039	1.30	0.00	0.00	1.30	6.70	2.37	15.10	24.17
2040	1.30	0.00	0.00	1.30	6.70	2.09	15.10	23.89
2041	1.30	0.00	0.00	1.30	6.70	1.78	15.10	23.58
2042	1.30	0.00	0.00	1.30	6.70	1.47	15.10	23.27
2043	1.30	0.00	0.00	1.30	6.70	1.19	15.10	22.99
2044	1.30	0.00	0.00	1.30	6.70	0.94	15.10	22.74
2045	1.30	0.00	0.00	1.30	6.70	0.73	15.10	22.53
2046	1.30	0.00	0.00	1.30	6.70	0.56	15.10	22.36
2047	1.30	0.00	0.00	1.30	6.70	0.43	15.10	22.23
2048	1.30	0.00	0.00	1.30	6.70	0.33	15.10	22.13
2049	1.30	0.00	0.00	1.30	6.70	0.25	15.10	22.05
2050	1.30	0.00	0.00	1.30	6.70	0.18	15.10	21.98

Table A3.6 *Baseline* Scenario Deforestation Rates (kha).

	Annual Deforestation Rate				
Year	**England**	**Scotland**	**Wales**	**N. Ireland**	**UK Total**
2020	0.22238	2.4099	0.299	0.09262	3.02389
2021	0.732	2.27024	0.299	0.09262	3.39386
2022	0.732	2.27024	0.299	0.09262	3.39386
2023	0.829	1.845	0.253	0.466	3.393
2024	0.804	1.765	0.241	0.464	3.274
2025	0.78	1.685	0.229	0.461	3.155
2026	0.756	1.605	0.217	0.459	3.037
2027	0.732	1.526	0.205	0.457	2.92
2028	0.707	1.446	0.193	0.074	2.42
2029	0.683	1.366	0.18	0.072	2.301
2030	0.659	1.286	0.168	0.07	2.183
2031	0.635	1.207	0.156	0.068	2.066
2032	0.61	1.127	0.144	0.065	1.946
2033	0.586	1.047	0.132	0.063	1.828
2034	0.562	0.967	0.12	0.061	1.71
2035	0.538	0.887	0.108	0.059	1.592
2036	0.513	0.808	0.095	0.056	1.472
2037	0.489	0.728	0.083	0.054	1.354
2038	0.465	0.648	0.071	0.052	1.236
2039	0.441	0.568	0.059	0.05	1.118
2040	0.416	0.489	0.047	0.047	0.999

2041	0.392	0.489	0.047	0.047	0.975
2042-2050	0.368	0.489	0.047	0.047	0.951

Table A3.7 *Central & Stretch* Scenario Deforestation Rates (kha).

	Annual Deforestation Rate				
Year	**England**	**Scotland**	**Wales**	**N. Ireland**	**UK Total**
2020	0.22238	2.4099	0.299	0.09262	3.02389
2021	0.732	2.27024	0.299	0.09262	3.39386
2022	0.732	2.27024	0.299	0.09262	3.39386
2023	1.289	1.845	0.253	0.466	3.853
2024	1.241	1.765	0.241	0.464	3.711
2025	1.192	1.685	0.229	0.461	3.567
2026	1.144	1.605	0.217	0.459	3.425
2027	1.095	1.526	0.205	0.457	3.283
2028	1.047	1.446	0.193	0.074	2.76
2029	0.998	1.366	0.18	0.072	2.616
2030	0.95	1.286	0.168	0.07	2.474
2031	0.901	1.207	0.156	0.068	2.332
2032	0.853	1.127	0.144	0.065	2.189
2033	0.804	1.047	0.132	0.063	2.046
2034	0.756	0.967	0.12	0.061	1.904
2035	0.707	0.887	0.108	0.059	1.761
2036	0.659	0.808	0.095	0.056	1.618
2037	0.61	0.728	0.083	0.054	1.475
2038	0.562	0.648	0.071	0.052	1.333
2039	0.513	0.568	0.059	0.05	1.19
2040	0.465	0.489	0.047	0.047	1.048
2041	0.416	0.489	0.047	0.047	0.999
2042-2050	0.368	0.489	0.047	0.047	0.951