Department for Energy Security & Net Zero

# Mapping greenhouse gas emissions & removals for the land use, land-use change & forestry sector

## A report of the National Atmospheric Emissions Inventory 1990-2021

Prepared by the UK Centre for Ecology & Hydrology for the Department for Energy Security and Net Zero.

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# Contents

# Land Use, Land-Use Change and Forestry in the National Inventory

The Department for Energy Security and Net Zero (DESNZ) takes the lead in the UK in preparing the annual Inventory of Greenhouse Gas Emissions for the United Nations Framework Convention on Climate Change (UNFCCC). DESNZ contract Ricardo Energy & Environment (REE) to compile the overall greenhouse gas emissions inventory and they in turn subcontract the UK Centre for Ecology and Hydrology (UKCEH) and Forest Research (FR) to prepare the data relating to Land Use, Land-Use Change and Forestry (LULUCF) in the UK.

This report is prepared in order to describe the method used to spatially disaggregate the emissions and removals in the LULUCF sector to enable the compilation of LULUCF estimates for Local Authorities (LAs) as part of DESNZ's assistance to LAs in tracking progress on decarbonisation.

The LULUCF data reported to the annual inventory is prepared in accordance with the reporting requirements of the UNFCCC. These estimates are made using dynamic models of changes in stored carbon, driven by land use change data. For forestry, the CARBINE model (developed and run by FR) deals with plant carbon, dead organic matter, soil carbon and harvested wood products and is driven by the area of land newly afforested each year, management practices and harvesting. Changes in soil carbon are driven by estimated time series of land use transitions between grassland, cropland, forest land and settlement land uses. These models, and those for other LULUCF activities (e.g. nitrogen fertilisation of forest soils, drainage and rewetting of organic soils), are run for each of the four countries of the UK to report emissions and removals of greenhouse gases ($CO_2$, $CH_4$ and $N_2O$). Until the 1990-2004 inventory (submitted in 2006) no data were reported in map format at a scale below the Devolved Administrations (DAs) (England, Scotland, Wales and Northern Ireland); here we report results from methods to provide estimates of LULUCF emissions and removals at the scale of LA within the UK for the 2021 inventory year (published in 2023).

The LULUCF Sector differs from other sectors in the Greenhouse Gas Inventory in that it contains both sources and sinks of greenhouse gases. The sources, or emissions *to the atmosphere*, are given as positive values; the sinks, or removals *from the atmosphere*, are given as negative values. The values reported here are given as net emissions/removals, i.e. the sum of emissions and removals for each category.

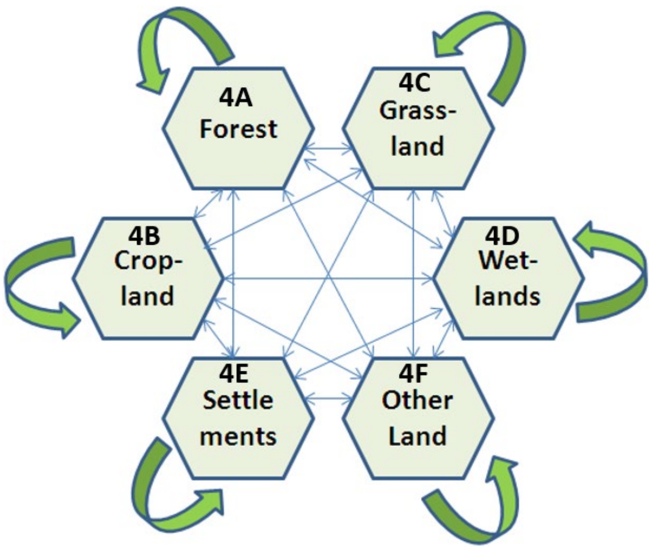
## Categories

The IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006, IPCC 2014) describes a uniform structure for reporting emissions and removals of greenhouse gases. This format for reporting can be seen as "land based"; all land in the country must be identified as having remained in one of six classes since a previous survey, or as having changed to a different (identified) class in that period. The six land classes are A: Forest Land, B: Cropland, C: Grassland, D: Wetlands, E: Settlements and F: Other land. There is a seventh category for the pool of harvested wood products, category G.

The IPCC (2006) guidelines for LULUCF accommodate differences in national land-use classification systems. Emissions from the drainage and rewetting of peatlands, are reported under all LULUCF land use categories. For the purposes of this report peatlands and organic soils may be considered synonymous. These are compiled following guidance for estimating emissions from inland organic soils set out in chapters 2 and 3 of the 2013 IPCC Wetlands Supplement, and employing the Tier 2 methodological approach for implementation described in the BEIS-funded wetlands report (Evans et al. 2017), with additional updates summarised in section A.3.4 of the National Inventory Report Annexes (Brown et al. 2023). Emissions from drained and rewetted organic soils have been allocated to their local authorities in the UK using the peat condition mapping outputs from Evans et al. (2017) alongside spatial location of rewetting and peat extraction activities. The majority of peatland area is reported in the Grassland category, which includes semi-natural bog categories, extensive and intensive grassland, and rewetted bog or fen from semi-natural bog and intensive and extensive grassland. Emissions from active peat extraction (onsite, and off-site for horticultural peat[1]), as well as organic soils affected by historical peat extraction are reported under Wetlands. Naturally occurring emissions and removals from pristine areas of bog and fen, and rewetted bog or fen from Forest Land, Cropland, peat extraction, and pre-1990 rewetted fen are included in LULUCF reporting under Wetlands. Emissions of $CO_2$, $CH_4$, and $N_2O$ from drained organic soils under Forest, Cropland and Settlement are reported in those respective categories.

The Other land category is predominantly made up of bare rock and scree and no emissions or removals are reported. In addition, it is assumed that there are very few, if any, transitions of land to a type that is classified as 'Other'.

**Figure 1: UK Sector 4 land-use transitions showing categories for carbon stock change. See text for details.**




The UK land-use change matrix can be simplified to that shown in **Error! Reference source not found.**, including Forest Land (A), Cropland (B), Grassland (C), Wetlands (D), and Settlements (E). For each land use and land-use transition, the change in stocks of carbon in living biomass (above and below ground), dead biomass and soil organic matter should be reported. In **Error! Reference source not found.**, each arrow represents the possible change for an area of land between two time points.

Different activities are associated with each land use or land-use change. For example, 'afforestation' refers to all land-use change *to* Forest Land, 'drainage' activity can relate to

[1] While emissions from the combustion of peat used as fuel are reported in the energy sector of the country of consumption.

Forest Land, Cropland, Grassland, Wetlands, and Settlement. 'Peat extraction' affects Wetlands. The change in carbon stocks of living biomass, dead biomass and soil organic matter must be reported for each activity together along with other relevant non-$CO_2$ gases (i.e. $CH_4$ and $N_2O$).

Further subdivision of the classes by ecosystem, administrative region or time of occurrence of change is also encouraged in the IPCC Good Practice Guidance. For the UK, the data are currently subdivided into England, Scotland, Wales and Northern Ireland where possible. Subdivision into smaller units is appropriate for modelling purposes and the development of estimates at local authority scale as described in this report.

# Activities

The activities reported within LULUCF are listed in **Error! Reference source not found.**. The main category designations are listed with the activity description and the UK total emissions/removals (Gg $CO_2$e) for 2021 as reported in the 1990-2021 Inventory (excluding emissions from the UK's Overseas Territories and Crown Dependencies). This year additional gages, $CH_4$ and $N_2O$, have been added to the $CO_2$ emissions and removals reported in the LA report, given in units of Gg of carbon dioxide equivalent ($CO_2$e). The activities are sorted in order of magnitude and divided into four groups; afforestation, emissions from soils due to land-use change, emissions from organic soils due to drainage and rewetting and minor emissions. Full details are given in the National Inventory Report (Brown et al. 2023).

Note that the IPCC 5$^{th}$ Assessment Report (AR5) Global Warming Potentials (GWPs) are used to convert $N_2O$ and $CH_4$ to carbon dioxide equivalents ($CO_2$e) in this report and dataset. This is in line with the wider UK GHG Inventory whereby AR5 GWPs were introduced in 2023 for the 1990-2021 inventory. Where data for the 1990-2020 inventory is presented this has also been converted using AR5 GWPs to allow direct comparison.

**Table 1: The UK $CO_2$e emissions and removals in Sector 4 (Land Use, Land-Use change and Forestry) for 2021 sorted in order of magnitude.**

| LULUCF Category | Parameter | Gases | Gg $CO_2$e | Group |
|---|---|---|---|---|
| 4A | Forest (mineral soil and all biomass) | Carbon | -18,127.84 | Forest Land |
| 4B | Cropland (mineral soil) | Carbon | 8,970.95 | Emissions from soils due to land-use change on mineral soils |
| 4C | Grassland (mineral soil) | Carbon | -8,701.45 | Emissions from soils due to land-use change on mineral soils |
| 4C | Grassland (drainage of organic soil) | Carbon, $CH_4$, $N_2O$ | 5,050.73 | Emissions from soils due to drainage, rewetting, and management of organic soils |

| | | | | |
|---|---|---|---|---|
| 4B | Cropland (drainage of organic soil) | Carbon, $CH_4$ | 4,276.03 | Emissions from soils due to drainage, rewetting, and management of organic soils |
| 4E | Settlement (mineral soil) | Carbon | 3,266.89 | Emissions from soils due to land-use change on mineral soils |
| 4C | Grassland (undrained organic soil) | Carbon, $CH_4$, $N_2O$ | 2,810.51 | Emissions from soils due to drainage, rewetting, and management of organic soils |
| 4D | Wetlands (peat extraction) | Carbon, $CH_4$, $N_2O$ | 2,418.08 | Emissions from soils due to drainage, rewetting, and management of organic soils |
| 4G | Harvested Wood Products | Carbon | -2,037.46 | NA |
| 4C | Land converted to Grassland (deforestation to Grassland) | Carbon, $CH_4$, $N_2O$ | 519.85 | Minor emissions |
| 4A | Forest (drainage of organic soil) | Carbon, $CH_4$, $N_2O$ | 453.80 | Emissions from soils due to drainage, rewetting, and management of organic soils |
| 4E | Land converted to Settlement (deforestation to Settlement) | Carbon, $CH_4$, $N_2O$ | 388.99 | Minor emissions |
| 4C | Land converted to Grassland (non-forest biomass) | Carbon | 381.45 | Minor emissions |
| 4B | Land converted to Cropland (soil mineralisation) | $N_2O$ | 353.12 | Emissions from soils due to land-use change on mineral soils |
| 4B | Land converted to Cropland (non-forest biomass) | Carbon | -283.10 | Minor emissions |
| 4E | Land converted to Settlements (soil mineralisation) | $N_2O$ | 247.24 | Emissions from soils due to land-use change on mineral soils |
| 4D | Land converted to Wetland (deforestation to Wetland) | Carbon, $CH_4$, $N_2O$ | 239.56 | Minor emissions |
| 4D | Wetlands (near-natural organic soil) | Carbon, $CH_4$ | 202.77 | Emissions from soils due to drainage, rewetting, and management of organic soils |
| 4 | Indirect N2O Emissions from Managed Soils | $N_2O$ | 152.29 | Minor emissions |

| | | | | |
|---|---|---|---|---|
| 4C | Grassland (rewetted organic soil) | Carbon, $CH_4$, $N_2O$ | 117.39 | Emissions from soils due to drainage, rewetting, and management of organic soils |
| 4D | Wetlands (rewetted organic soil) | Carbon, $CH_4$, $N_2O$ | 92.29 | Emissions from soils due to drainage, rewetting, and management of organic soils |
| 4A | Land converted to Forest (soil mineralisation) | $N_2O$ | 59.31 | Forest Land |
| 4C | Grassland remaining Grassland (grassland management biomass) | Carbon | 54.88 | Minor emissions |
| 4E | Land converted to Settlements (non-forest biomass) | Carbon | 40.13 | Minor emissions |
| 4E | Settlement (drainage of organic soil) | Carbon, $CH_4$, $N_2O$ | 30.46 | Emissions from soils due to drainage, rewetting, and management of organic soils |
| 4A | Forest (drainage of mineral soil) | $N_2O$ | 30.29 | Forest Land |
| 4B | Cropland remaining Cropland (cropland management soils) | Carbon | 25.12 | Minor emissions |
| 4A | Forest (wildfires) | Carbon, $CH_4$, $N_2O$ | 18.67 | Forest Land |
| 4C | Land converted to Grassland (soil mineralisation) | $N_2O$ | 15.82 | Emissions from soils due to land-use change on mineral soils |
| 4C | Grassland (wildfires) | $CH_4$, $N_2O$ | 12.66 | Minor emissions |
| 4B | Cropland remaining Cropland (cropland management biomass) | Carbon | 2.87 | Minor emissions |
| 4A | Forest (fertilisation) | $N_2O$ | 0.83 | Forest Land |
| 4B | Cropland (wildfires) | $CH_4$, $N_2O$ | 0.01 | Minor emissions |
| 4B | Land converted to Cropland (deforestation to Cropland) | Carbon, $CH_4$, $N_2O$ | 0.00 | Minor emissions |
| 4D | Land converted to Wetlands (grassland to flooded land) | Carbon | 0.00 | Minor emissions |

* Sector 4G (Harvested Wood Products) is not included in the LA estimates because of insufficient data for distributing the emissions and removals.

Each of the activities are described below. Changes in net emissions from the LULUCF Sector over time are dominated by the decrease in $CO_2$ net emissions. While $CH_4$ emissions are fairly stable over time, they dominate LULUCF overall net emissions by gas in $CO_2$ equivalents over the timeseries (Brown et al. 2023). This is due to $CH_4$ emissions from drained and rewetted organic soils. Emissions of greenhouse gases are produced by undrained modified, rewetted and near natural peatlands (note that $CH_4$ emissions from near-natural bogs are cancelled out by $CO_2$ uptake in $CO_2$-equivalent terms), drainage ditches on peatlands, biomass burning during wildfires or the conversion of Forest Land to Cropland, Grassland or Settlements. Direct and indirect emissions of $N_2O$ are also produced from nitrogen fertilisation of new forests and soil mineralisation following land-use change. Emissions of non-$CO_2$ gases from agricultural land (e.g. due to fertilisation) are reported in the Agriculture sector of the Greenhouse Gas Inventory. Estimates in the 2021 inventory for the different GHGs are -5,893 Gg $CO_2$ for carbon dioxide, 5,692 Gg $CO_2$e for methane (or 203 Gg $CH_4$), and 1,284 Gg $CO_2$e for nitrous oxide (or 4.85 Gg $N_2O$) across the UK in 2021.

## Coverage

The methods used for disaggregating each activity from DA to LA scale are described below. The level of spatial detail available differs between activities. For all activities there is currently no spatial activity data available for the Isle of Scilly, hence all LULUCF emissions and removals are estimated as zero for this LA.

# Disaggregation Methodologies

The methodology for disaggregating the DA LULUCF data to LA scale has been updated for the 2021 inventory cycle to utilise detailed spatial activity data where possible. The updated methodology spans two main workflows which are described below.

## Land Use Change Tracking Maps

### Data Preparation

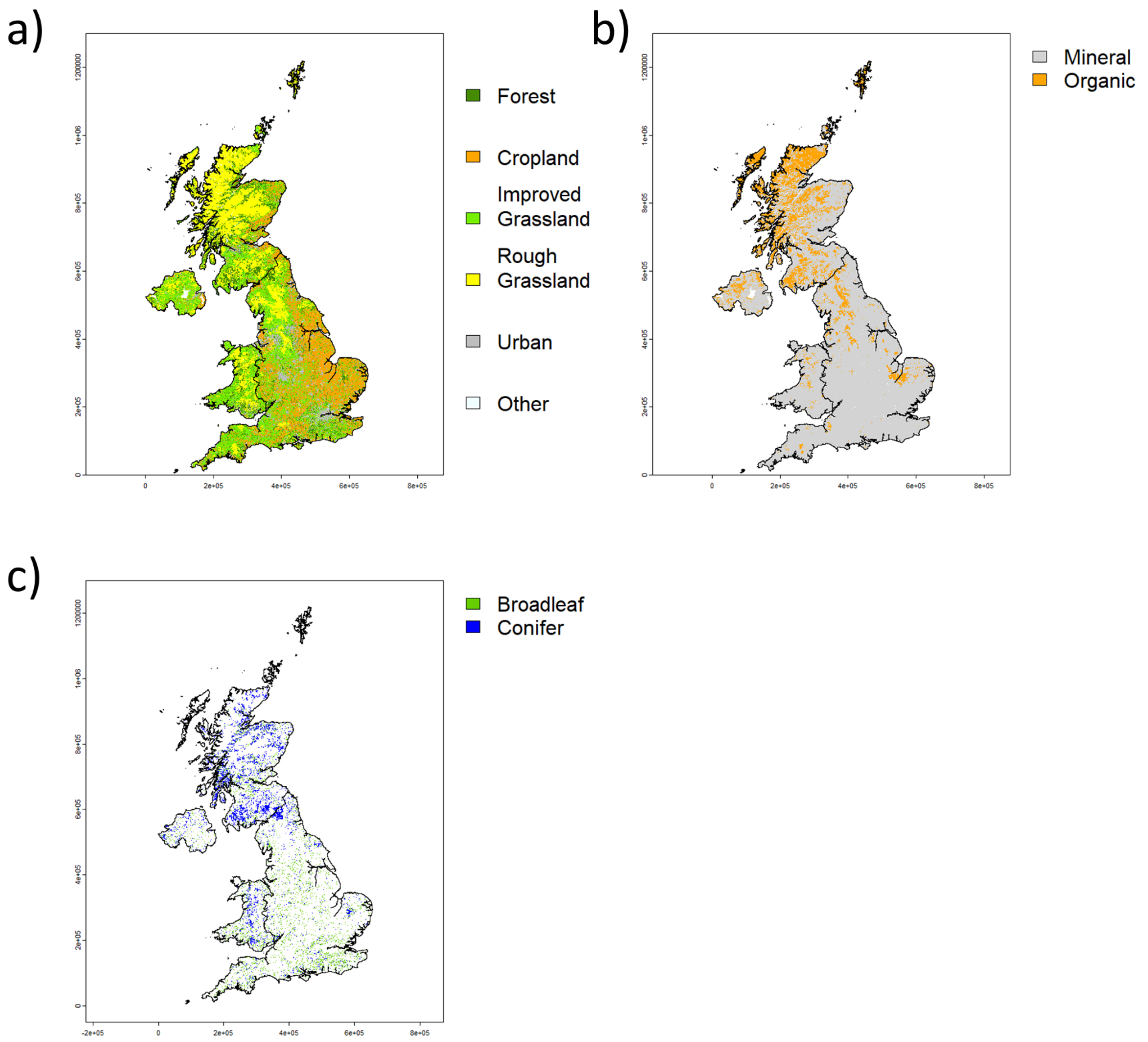
This methodology uses land use change (LUC) variables calculated from the Land Use Change Tracking project (LUC-T) spatial maps (Levy et al. 2020, 2021; Rowland et al. 2021). Outputs from this project include land use classification maps at 100m x 100m spatial resolution and an annual temporal resolution. Land is classified as Forest, Cropland, Grassland (Improved Pasture), Rough Grassland, Urban and Other land. This data is produced using a Bayesian data assimilation approach, with full details provided in the project reports (Levy et al. 2020, 2021; Rowland et al. 2021). An example of the gridded data is shown in Figure 2a.

This data is then supplemented with soil and forest type data.

A raster soil type map (showing locations of mineral and organic soils) at 100m grid scale is produced from the organic soil basemaps in England, Scotland, Wales and Northern Ireland (see **Error! Reference source not found.**). The gridded data is shown in Figure 2b.

Maps of forest type are produced for each year, assigning each 100m x 100m forest grid cell in the LUC-T land use maps as either broadleaf or conifer. Forest type data for 2005, 2010, 2015, 2018 and 2020 for GB, and 2020 for NI (produced for the LUC-T project as described in Rowland et al. 2021), are re-categorised to broadleaf and conifer, with an ‘unspecified’ category assigned to useful remaining data, such as that classified as ‘woodland’ or ‘unknown’. This unspecified data is then reassigned to broadleaf or conifer based on the nearest neighbour. Subsequently, for each LUC-T land use map from 1985-current inventory year, the forest type data from the closest year available is used, and forest grid cells are categorised as broadleaf or conifer based the value from the forest type map intersecting the grid cell location. As the LUC-T land use maps are produced from a probabilistic model, plus forest type data does not have 100% coverage, not all forest grid cells will align with forest inventory data. In this case, if the grid cell location from the land use map does not intersect forest on the forest type map, the closest broadleaf/conifer value to the grid cell is used. Figure 2c shows an example of the gridded data output.

**Figure 2: Raster files used as inputs for calculating spatial variables. (a) Land use categories from LUC-T in 2020; (b) Soil types; (c) Forest types in 2020**



## Calculating Spatial LUC Variables

The spatial LUC variables are calculated based on the three sets of maps: land use, soil type and forest type. The spatial variables to be calculated fall into five categories:

- **Current land use**
  Grid cells where the land use in the year being considered (2005-current inventory year) and the soil type matches the condition.
  e.g. Current Cropland on mineral soil
- **Land use changes in the last year**
  Grid cells where the current land use and the land use in the previous year (for 2005-current inventory year, so requires data 2004-current inventory year), as well as the soil type match the conditions.
  e.g. Settlement to Cropland in the last year on all soils
- **Land use changes in the last three years**
  Grid cells where the current land use and the most recent land use change in the previous three years, as well as the soil type, match the conditions (requires data 2002-current inventory year)
  e.g. Grassland to Forest Organic in the previous three years
- **Land use changes in the last 20 years**
  Grid cells where the current land use and the most recent land use change in the previous 20 years, as well as the soil type, match the conditions. In some cases the land use prior to the change is specified and in others it can be any land use. (requires data 1985-current inventory year)
  e.g. Cropland to Forest Mineral < 20 years
- **Land remaining the same land use for at least the last 20 years**
  Grid cells where the current land use, soil type and forest type (for forest land use cells) match the condition and the grid cell has remained in the same land use for at least the last 20 years (requires data 1985-current inventory year)
  e.g. Broadleaf Forest on Mineral >= 20 years

A full list of the spatial variables required are in Annex 1, matched to the emissions/removals they are used to disaggregate. The columns “Group”, “From Land Use”, “To Land Use” and “Soil Type” specify how the variable is defined.

The spatial LUC variables are calculated for each year in the disaggregation time series (2005-current inventory year), by looking back over the 20 years prior to each year. Where a grid cell has undergone multiple land use changes within the previous 20-year period, only the most recent land use change is considered when categorising it into the variables.

This produces 100m x 100m spatially gridded data for each year covering the whole UK for each spatial variable.

## Disaggregating Emissions / Removals

LULUCF Inventory totals are disaggregated to LAs according to the spatial LUC variables. Each inventory emissions/removal total is disaggregated based on the number of grid cells from the relevant spatial LUC variable within the LA polygons. Inventory emissions are matched with spatial variables to be used for disaggregation as in Table A1. The number of grid cells from the relevant spatial LUC variable in each polygon is divided by the total number in the DA. The proportions are calculated for each year (2005-current inventory year). When calculating how many grid cells are in each polygon, grid cells are assigned to polygons based on whether the midpoint of the cell lies within the polygon. To apportion the emissions/removals DA totals for each year from the inventory are multiplied by the spatial LUC variable proportions for the year associated with each polygon. In cases where, for a given spatial LUC variable and year, a DA contains no grid cells for that spatial variable but there is a non-zero emission/removal total to disaggregate, the proportions from the most recent year with grid cells in the DA are used. In cases where the LUC-T data has not been produced for the current inventory year, proportions from the previous year are used for all spatial LUC variables.

## Organic Soil Maps

This methodology utilises organic soil base maps of peatland condition and Google Earth data of active peat extraction. Firstly, using point location data for organic soil rewetting sites, annual areas of peatland rewetting are added to the polygon organic soil base maps to create an annual timeseries of peatland condition category which includes accounting of rewetting activity. Secondly, annual peat extraction polygon areas derived from Google Earth imagery are used to calculate annual maps of active peat extraction and rewetted peat extraction. The peatland condition category and peat extraction timeseries can then be intersected with LA boundaries. See Table 2 below for details on input data.

**Table 2:** Details of data inputs used in organic soil rewetting and peat extraction calculations.

| Layer | Year | Description | Reference |
|---|---|---|---|
| England base map | 2013 | Organic soil vector polygon data covering England, including peatland condition category | Evans et al. (2017) |
| Scotland base map | 1990 | Organic soil vector polygon data covering Scotland, including peatland condition category | Evans et al. (2017) |
| Wales base map | 1990 | Organic soil vector polygon data covering Wales, including peatland condition category | Evans et al. (2017) |
| NI base map | 2007 | Organic soil vector polygon data covering Northern Ireland, including peatland condition category | Evans et al. (2017) |
| Rewetting sites | 2000 - 2012 | Rewetting site data covering E/S/W/NI. Includes XY location, total area and peatland condition category. Rewetting is known to occur between 2000-2012 but no specific year given | Evans et al. (2017) |

| | | | |
|---|---|---|---|
| Scotland rewetting sites post 2012 | 2013 - current year | Scotland year-specific rewetting data from 2013 onwards. Includes XY location and peatland condition category | Peatland Action |
| Peat Extraction annual shapefiles | 2002, 2005, 2010, 2014 - current year | Peat extraction extent shapefiles created from Google Earth imagery. Covering E/S/W/NI | Brown et al. *2023* |
| Local Authority boundaries E/S/W | 2021 | Local authority boundary vector polygon shapefile for E/S/W | statistics.gov.uk |
| Local Authority Boundaries NI | 2012 | Local authority boundary vector polygon shapefile for NI. NI is a separate shapefile due to different coordinate system | opendatani.gov.uk |

## Data Preparation

Due to some non-spatial (e.g. DA level) data used in the main LULUCF inventory, preparation of the organic base maps and rewetting site data is required before they can be used for spatial disaggregation.

Drainage and bare peat assumptions for mapped areas of 'Eroded' Bog are applied to LAs by splitting 'Eroded' polygons proportionally between four peatland condition categories (Eroding Drained, Eroding Undrained, Modified Bog Drained, Modified Bog Undrained). For each DA the Eroded polygons from the organic base map are selected and split based on DA specific proportions. Each polygon is split individually into the four categories to ensure equal distribution across the DA.

Rewetting site data is given as point location data with peatland condition category and total area rewetted for each site. In the main LULUCF inventory, Modified Bog sites are rewetted from three different peatland condition categories (Modified Bog, Extensive Grassland and Eroding Modified Bog, based on DA specific proportions). In order to calculate spatially explicit rewetting from the correct peatland condition category all Modified Bog rewetting sites are split into three with areas calculated based on DA specific proportions.

Further, additional site information is required and calculated for each site prior to running rewetting calculations, including:

- Average rewetting (2000 – 2012): Rewetting is known to occur between 2000 – 2012 but as no specific year is given the 2000 – 2012 average is removed annually (note that for Scotland post-2012 year specific rewetting is given and therefore averages are not required).
- Site minimum and maximum: rewetting site calculations are unlikely to find an area of the exact average rewetting area. The site minimum and maximum provide upper and lower thresholds in which to calculate area that still rounds to the correct area in hectares.

- Peatland condition match variable: peatland condition category names vary slightly between data inputs; this variable ensures rewetting site soil categories can be matched to the organic base maps.

## Calculation Methodology

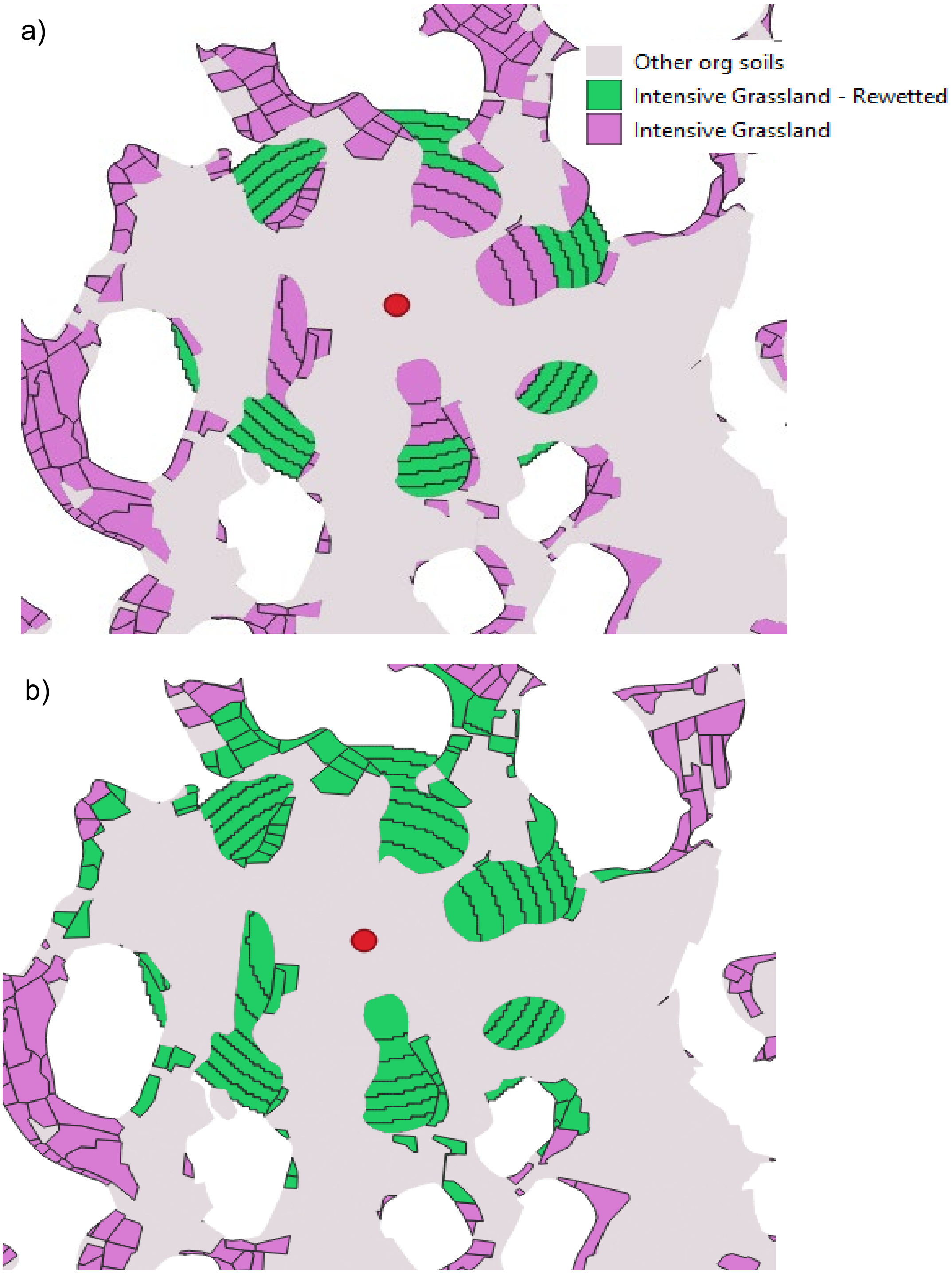
The following methodology is used to create a timeseries of organic soil maps for each DA.

1. Using peat extraction spatial data create an annual timeseries of peat extraction areas (including rewetted peat extraction sites where peat extraction areas decrease). Peat extraction areas are not available for all years in the timeseries - the missing years are filled in linearly with the difference between available years. Land to peat extraction is calculated in the LULUCF from three grassland categories based on DA specific proportions. The underlying peatland condition categories in the organic base maps are not necessarily consistent with this assumption. Therefore, the peat extraction timeseries is not combined into the organic soil maps. However, to ensure spatially consistent cumulative areas the merged peat extraction areas are intersected with the organic base layer to identify organic areas that should not be used in rewetting calculations.
2. For each site in the rewetting site dataset (point location datasets with variable fixed - point uncertainties) the aim is to reassign areas of relevant initial peatland condition to rewetted. Where no year specific data for rewetting exists the average annual rewetting area is used. Rewetting is assumed to be spatially correlated to the site (i.e. rewetting occurs in soils closest to the point identifying the site location). When every site in the year has been calculated, this map is used as the input for the next year of calculations.
3. The baseline year for England and NI are in the middle of the timeseries. To deal with this, areas are retrospectively added in to the timeseries from baseline year to 2000 using the same assumptions as the main rewetting calculations. Although the final disaggregation is only required from 2005, rewetting must be calculated back to 2000 to ensure consistent cumulative areas.
4. Intersect the peat extraction timeseries and organic rewetting timeseries with LA boundary data.

Examples of rewetted calculations are given in Figure 3 which shows rewetting in Northern Ireland in 2003 for an Intensive Grassland rewetting site. As the baseline for Northern Ireland is 2007, retrospective areas were added in to 2000 – the concentric circles in Figure 3a. There are 4 years of rewetting shown in green (i.e. 2000 – 2003), with the non-rewetted Intensive grassland shown in purple.

Figure 3b below shows the same site in NI in the year 2010. As the figure shows, the entirety of the retrospectively added areas have been rewetted, and rewetting areas after the baseline year are being summed from the base map polygons. Restoration activity data supplied as polygon features rather than point-locations would improve this representation.

**Figure 3: Organic soil rewetting calculations for an intensive grassland rewetting site in Northern Ireland (red dot). Where: (a) demonstrates retrospective area addition for 2000-2003; (b) demonstrates cumulative rewetting in 2010.**




## Disaggregating Emissions / Removals

The analysis described above produces tables with the area of each peatland condition category in each LA in each year, for each DA. These areas are converted to proportions of the DA total for each peatland category in each LA. These proportions are then used to disaggregate the DA emissions/removals totals by multiplying the DA totals by the peatland category area proportions. The emission/removal totals are disaggregated according to peatland condition category. The current peatland condition category (for each year) is used to disaggregate the emissions (e.g. Cropland Drained Remaining Cropland Drained and Forest Drained to Cropland Drained emissions are both disaggregated based Cropland Drained area).

# Forest Land

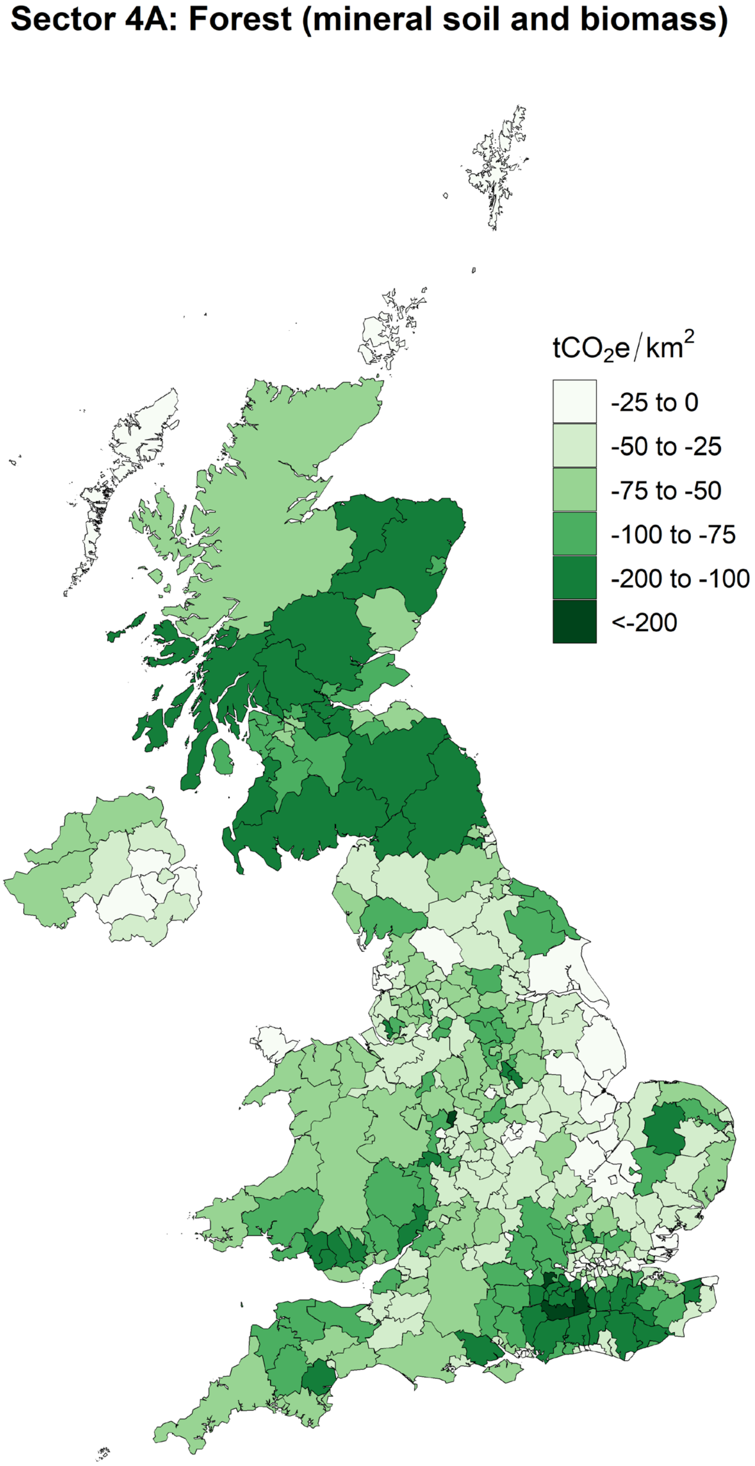
## Mineral Soil and Biomass

For the National Inventory, the carbon uptake by forests planted in the UK is calculated by a carbon accounting model, CARBINE, as gains and losses in pools of carbon in standing trees, litter and soil in conifer and broadleaf forests and in harvested wood products. Forests accumulate carbon (by removing $CO_2$ from the atmosphere) in their biomass and soils as they grow, but timber harvesting, planting activities and drainage disturb this accumulation and result in loss of carbon via emissions of carbon dioxide, and other greenhouse gases to the atmosphere. The net carbon stock change at any one time depends on the balance between these different activities. Forestry management cycles operate over long timescales (40+ years), so the rate of carbon dioxide removal *now* is driven by the rate of forest planting in previous decades. Three parameters are required for the model; a) areas of new forest planted in each year in the past, b) areas deforested each year and c) management/harvesting pattern.

For mapping at LA scale, the mineral soil and biomass (living biomass, dead wood and litter) carbon stock change from the CARBINE model for England, Scotland, Wales and Northern Ireland were disaggregated using the LUC-T methodology.

Figure 4 shows the distribution of carbon removals due to forest land per local authority area expressed as tonnes of carbon dioxide per square kilometre ($tCO_2$ per $km^2$). Maps of total $CO_2$ emissions/removals per LA can be misleading due to the wide range of areas across authorities – maps tend to be dominated by the Highland region of Scotland. The distribution of forest carbon removals is directly linked to the location of forests, for example close to half of the forest land in England is in the north, which is clearly visible from the large sink in that area.

**Figure 4: Distribution of forest carbon dioxide removals from the atmosphere in 2021 per local authority area expressed as $tCO_2$ per $km^2$.**

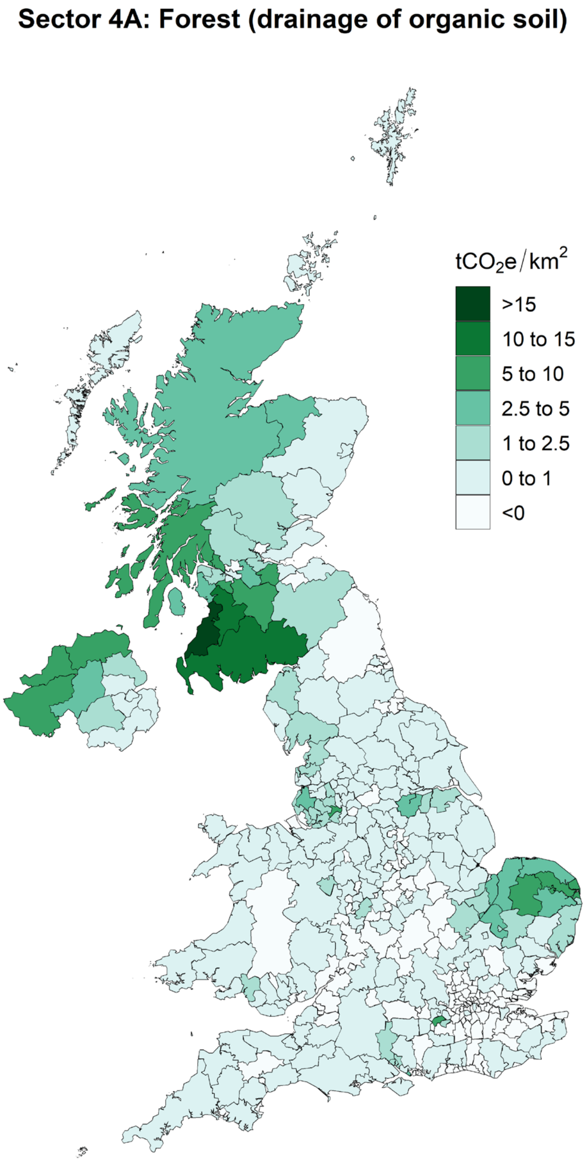


# Drainage

## Organic Soil

Direct soil carbon stock change due to drainage of forest soils is included in the CARBINE modelling and hence in the data behind Figure 4. $CO_2$ emissions from indirect fluvial export of particulate organic carbon (POC) and dissolved organic carbon (DOC), and emissions of direct $CH_4$, $CH_4$ from ditches, and $N_2O$ emissions as a result of forest drainage of organic soils are disaggregated to LA scale using the organic soil map methodology. The distribution of emissions from drained organic soils under Forest is focused in Scotland where peat extent and the location of forests are both high (Figure 5)

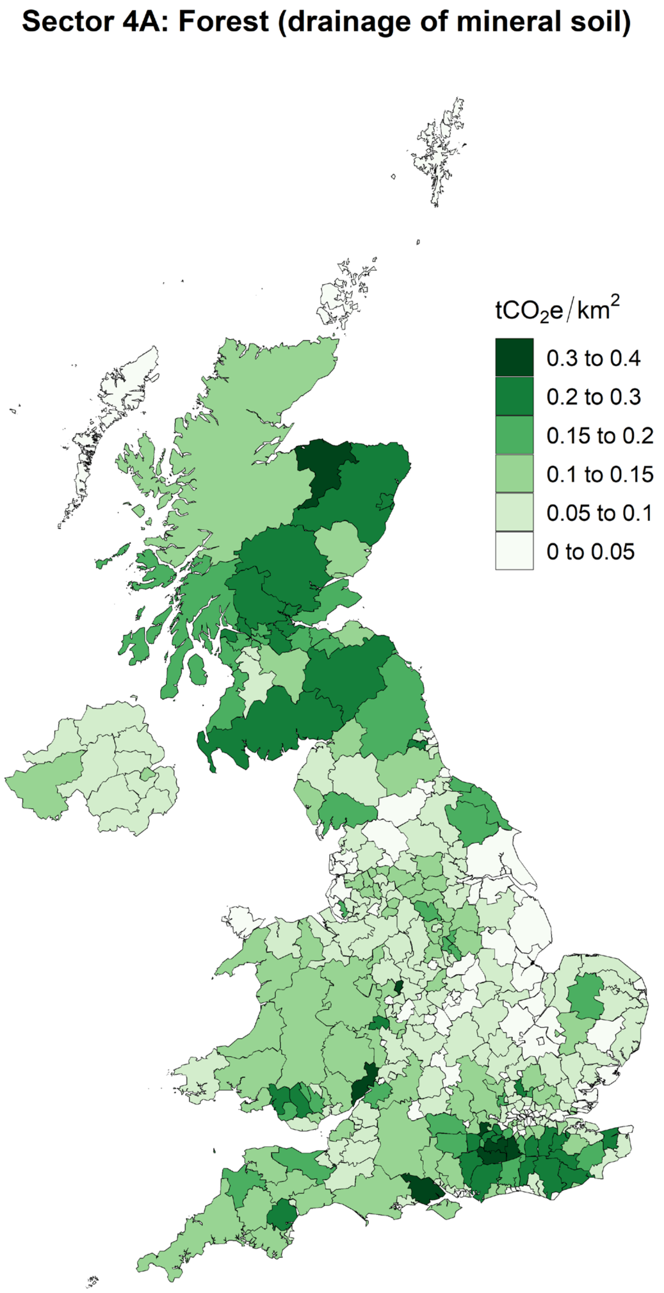
**Figure 5: Indirect carbon dioxide (from POC and DOC), methane and nitrous oxide emissions due to drainage of organic soils under Forests per local authority area ($tCO_2e/km^2$) in 2021.**



## Mineral Soil

Forests planted on mineral or organo-mineral soils which have slow natural drainage and are prone to waterlogging are assumed to be artificially drained and $N_2O$ emissions are reported for this drainage. These emissions are disaggregated to LA scale using the LUC-T methodology (Figure 5).

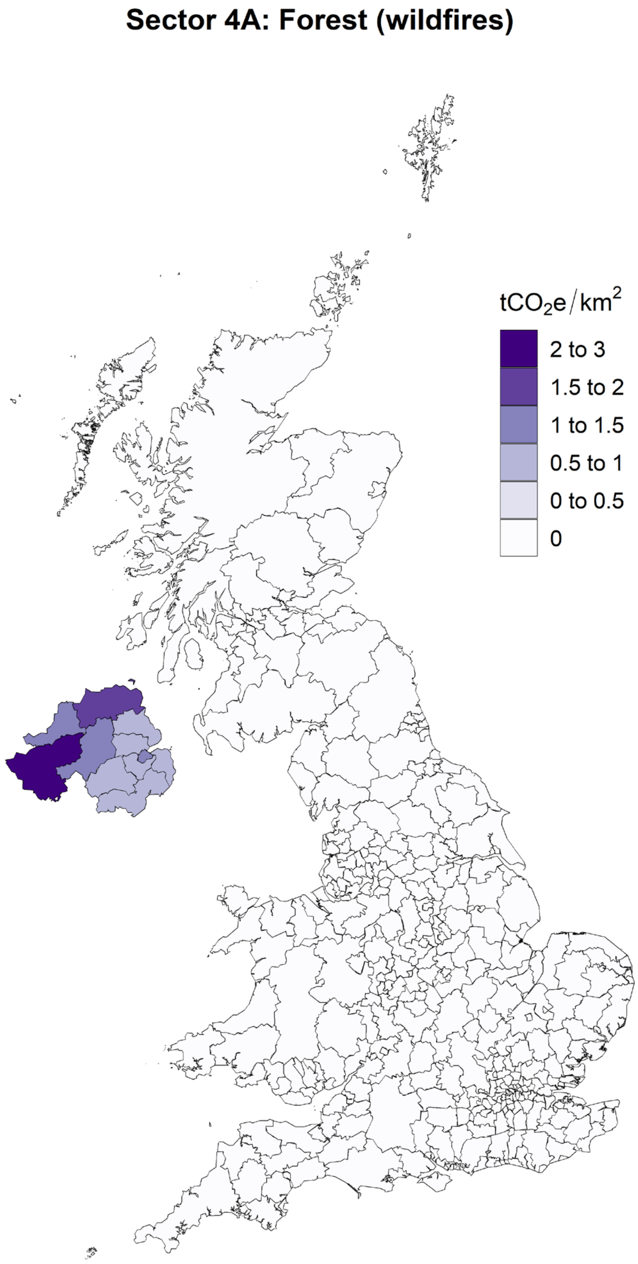
**Figure 6: Nitrous oxide emissions due to drainage of organic soils under Forests per local authority area ($tCO_2e/km^2$) in 2021.**



# Forest Wildfires

Information on areas of wildfires on forest land in Great Britain and in Northern Ireland is available from the Fire Service Incident Response System (IRS). This dataset is available at individual grid referenced fire level for Great Britain and as a national total for Northern Ireland. Hence, in Great Britain fires can be assigned to the LA in which they occurred, and in Northern Ireland the emissions are assigned to LAs in proportion to the total area of forest land in each LA. Forest wildfires occurred only in Northern Ireland in 2021 as shown in Figure 7.

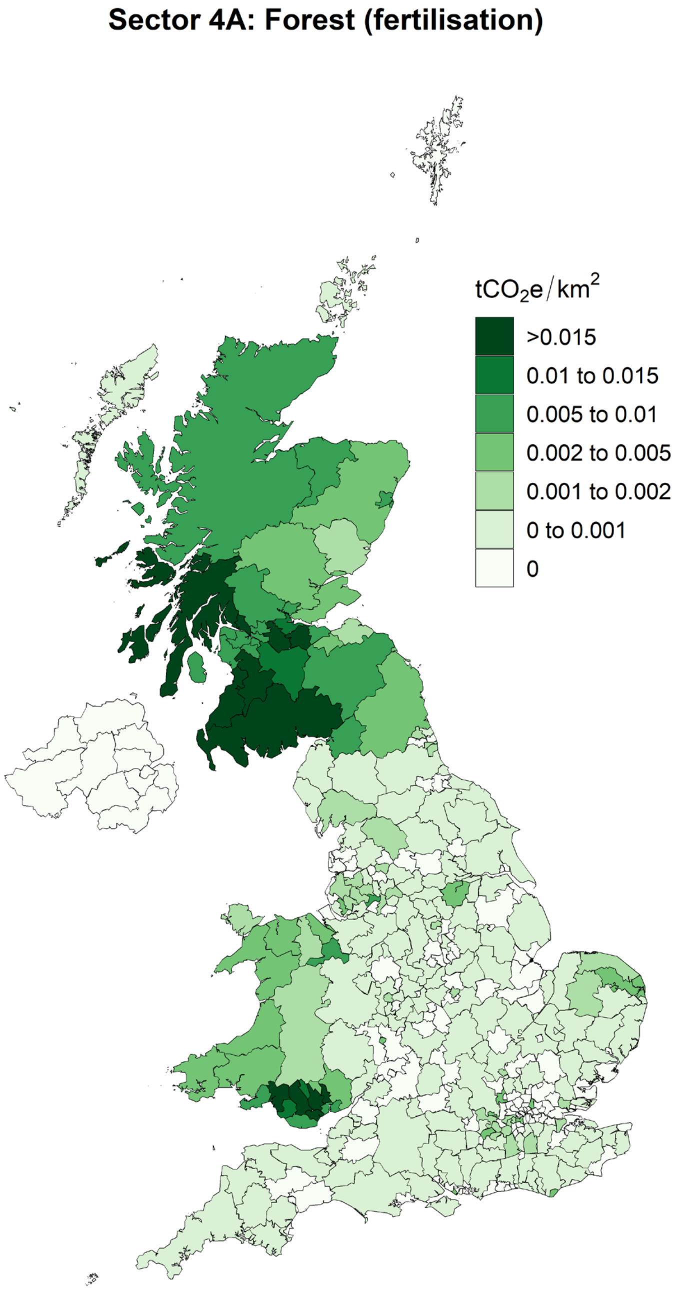
**Figure 7: Emissions of carbon dioxide, methane and nitrous oxide due to forest wildfires per local authority area ($tCO_2e/km^2$) in 2021.**



# Forest Fertilisation

Fertilisation, leading to emissions of $N_2O$, occurs on the first rotation of forests planted on nutrient poor soils and is applied in the years of planting and again three years later. These emissions are disaggregated to LA scale using the LUC-T methodology. Forest fertilisation is highest in Scotland in 2021, particularly in the South West, followed by Northern Ireland (Figure 8).

**Figure 8: Emissions/removals of nitrous oxide arising from Forest fertilisation per local authority area ($tCO_2e/km^2$) in 2021**



# Emissions from mineral soils due to land-use change: cropland, grassland, settlements

Changes from one land use type to another will result in a change in soil carbon stocks over time. The change in vegetation cover and management will affect the amount of carbon that goes into the soil from biomass decomposition. This is represented by emissions or removals which continue for decades after the change in land use until equilibrium carbon stocks characteristic of the new land use are reached. Also, any initial disturbance of the soil is represented by a release of carbon from soils to the atmosphere as $CO_2$.

For the LULUCF inventory, the method for assessing changes in soil carbon stock due to land-use change on mineral soil links a matrix of area changes at country level to a dynamic model of carbon stock change. In the 1990-2020 inventory a major improvement was made to the land use change matrices which are now derived annually using a Bayesian data assimilation approach combining data from Earth Observation, land cover surveys and agricultural land statistics (Brown et al 2023, Annex section A 3.4.2).

The LUC-T methodology is used to disaggregate to LA scale (see Figure 2). The pattern of emissions and removals across the UK for each land-use type is dependent on the ratio of land-use change in each LA in relation to the total for that devolved administration. For example, the majority of land-use change to both Cropland and Grassland in Scotland occurs in the south and east of the country. $N_2O$ from soil mineralisation from land use change are presented in  Figure 9.

**Figure 9: Carbon dioxide emissions from mineral soil due to land-use change per local authority area ($tCO_2/km^2$) in 2021. This covers the conversion of all land types to (a) Cropland (b) Grassland and (c) Settlements**

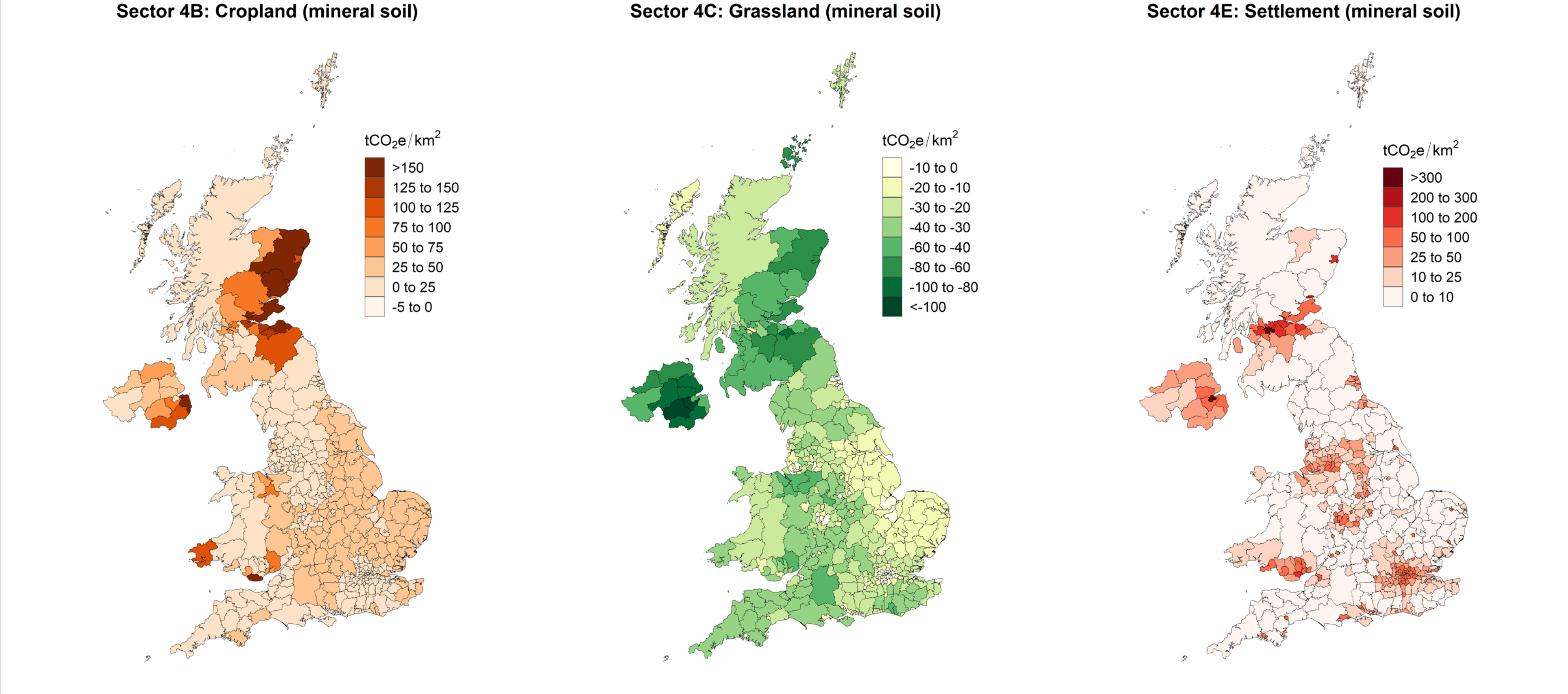
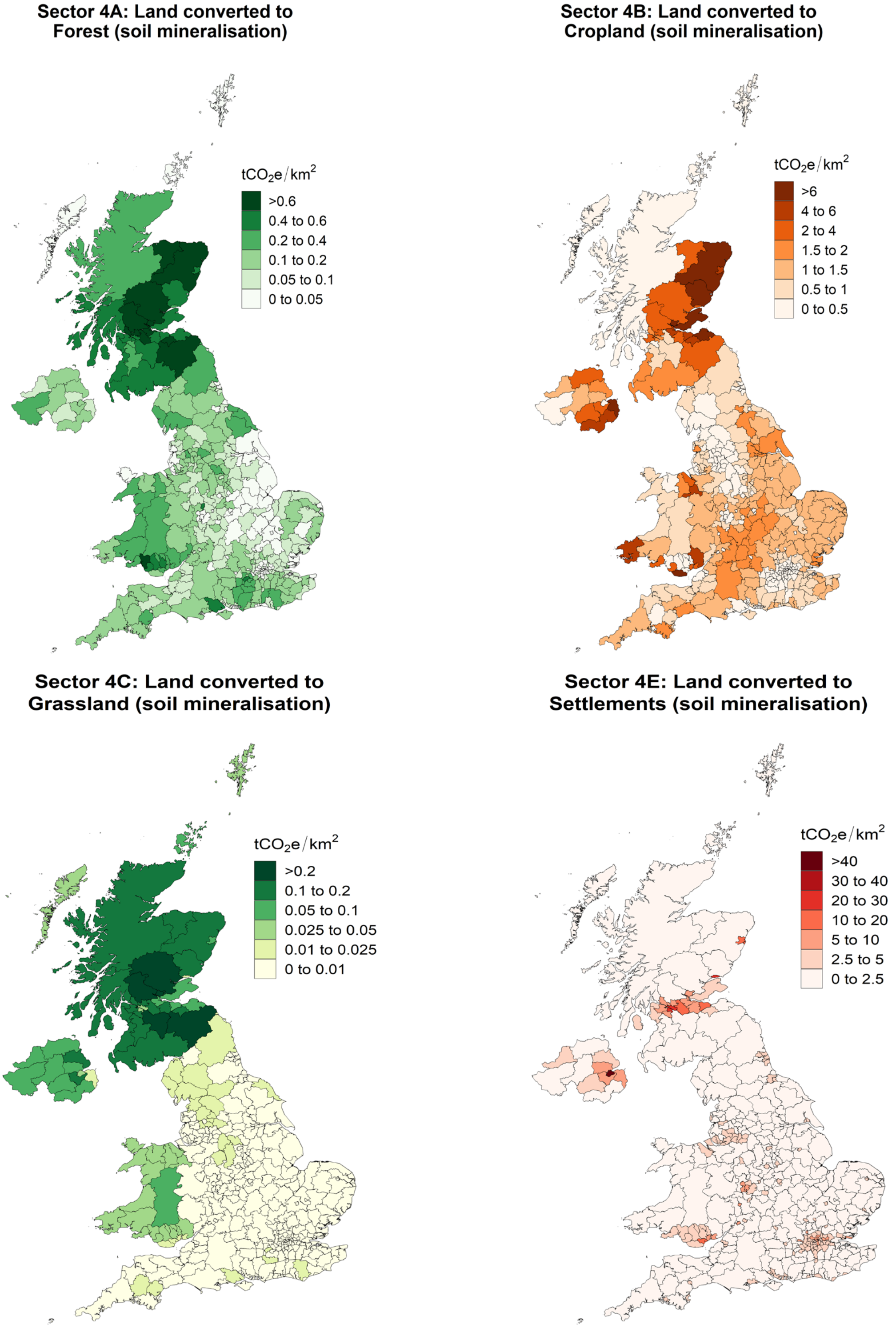


**Figure 10: Nitrous oxide emissions from soil mineralisation resulting from land use change to Forest, Cropland, Grassland and Settlement per local authority area $tCO_2e/km^2$) in 2021.**



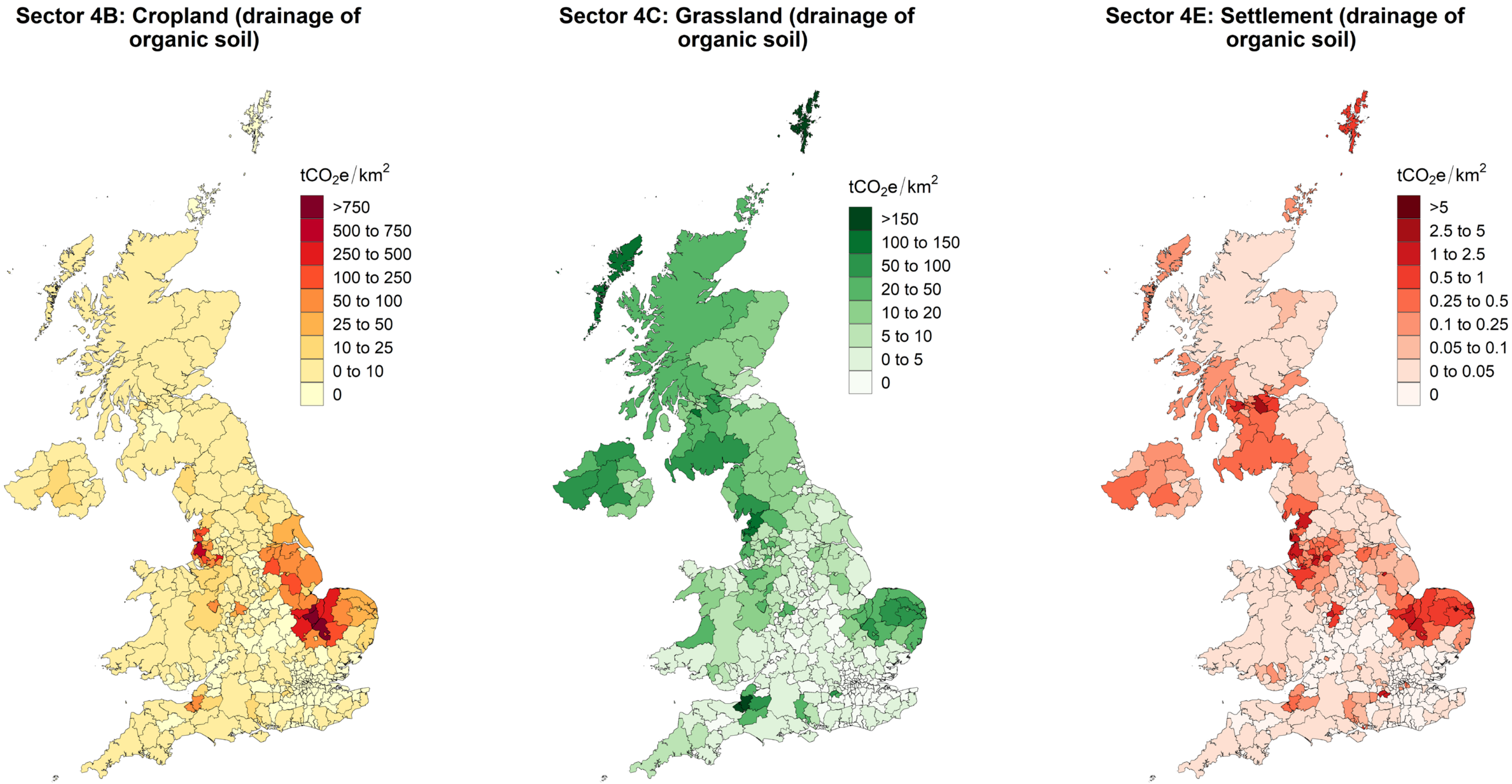
# Emissions from soils due to drainage, rewetting and management of organic soils: forest, cropland, grassland, wetland, settlement

## Drainage

The majority of peatlands in the UK were drained many decades ago for agricultural purposes and continue to lose carbon from the soil as $CO_2$, as well as emit significant amounts of $N_2O$ associated with organic matter decomposition. In a natural state, peatlands are important long-term sinks for carbon, which is counterbalanced by similar emissions of methane in $CO_2$ equivalent terms. Using the more recent GWP values from AR5 has increased the contribution of methane, resulting in a net emission from near natural bog and reduced net sink from near natural fen, however near-natural peatland remain close to carbon neutral (see section on undrained organic soils below). The emissions / removals are disaggregated using the organic soil map methodology.

Figure 11 shows the estimated distribution of emissions ($tCO_2e/km^2$). Emissions from drained organic soils under Cropland are largely concentrated in the East and North Midlands of England and are associated with deep (>40cm depth) and wasted peat (organic soils that were previously deep peat, and now mapped as retaining less than 40 cm of peat). Emissions from drained organic soils under Grassland are driven by different proportions of peatland condition categories reported together in the Grassland sector. Like Cropland, intensive and extensive grasslands have high GHG emissions per unit area (and also occur on wasted peat in England), and LAs with emissions from these grasslands are distinguishable in dark green in Figure 11. Emissions from Settlement on organic soils mostly occur in lowland regions where population density is higher.

**Figure 11: Carbon dioxide, methane and nitrous oxide emissions due to drainage of organic soils under Cropland and Grassland (intensive, extensive, modified bog), and Settlement per local authority area ($tCO_2/km^2$) in 2021.**

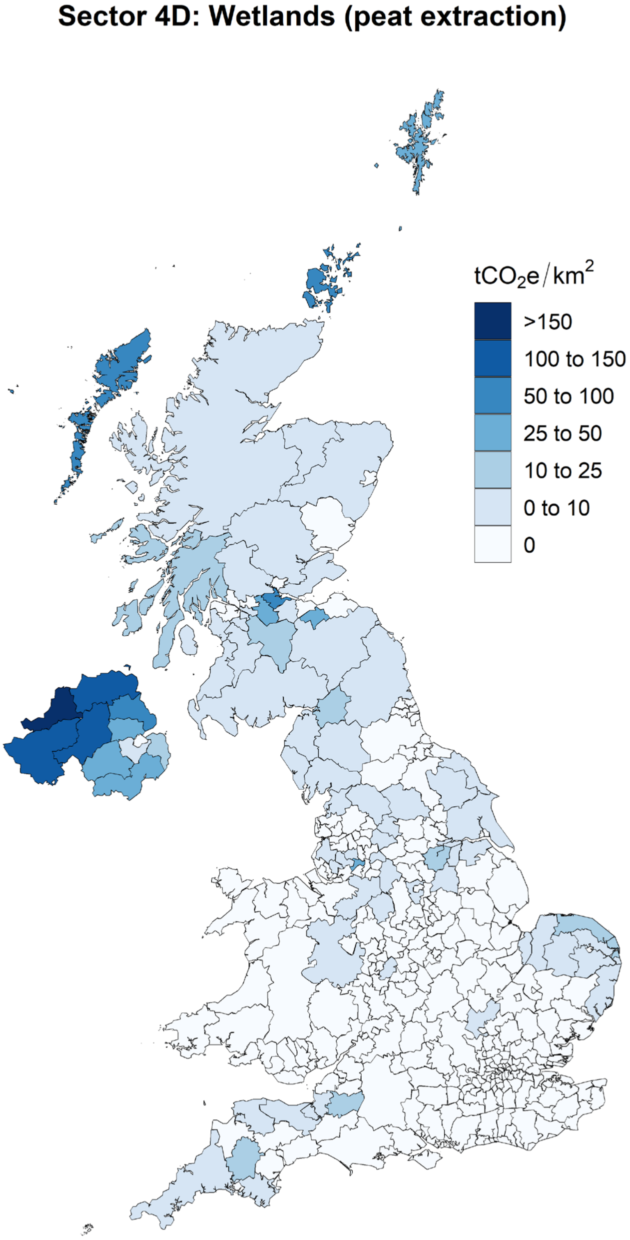


# Peat Extraction

On-site $CO_2$, $CH_4$ and $N_2O$ emissions and off-site $CO_2$ emissions from peat extraction are calculated for the LULUCF inventory based on data published in the *Mineral Extraction in Great Britain Business Monitor PA1007 and Growing Media Association report* (GMA 2021) which gives data on volumes of peat sold, the BGS *Directory of Mines and Quarries (DMQ)* and BritPits database, and peat condition mapping outputs from Evans et al. (2017) which gives the location of peat extraction sites, and the UKCEH Google Earth dataset which provides information on the area and activity of peat extraction sites. The DMQ and BritPits data give the location of origin of active peat extraction, and mapping outputs from the BEIS-funded Wetlands Supplement project (Evans et al. 2017) also provide areas of historical domestic and industrial extraction, we have assumed that the carbon emission applies to this combined area (see **Error! Reference source not found.**12).

Emissions are disaggregated using the organic soil maps methodology. Local authorities with no peatland extraction activities have zero emissions from peat extraction. Emissions from peat extraction are reported in category 4D (Wetlands).

**Figure 12: Carbon dioxide, methane and nitrous oxide emissions from active and historical extraction of peat for horticultural and domestic use per local authority area ($tCO_2e/km^2$) in 2021. This is part of the Wetlands category.**

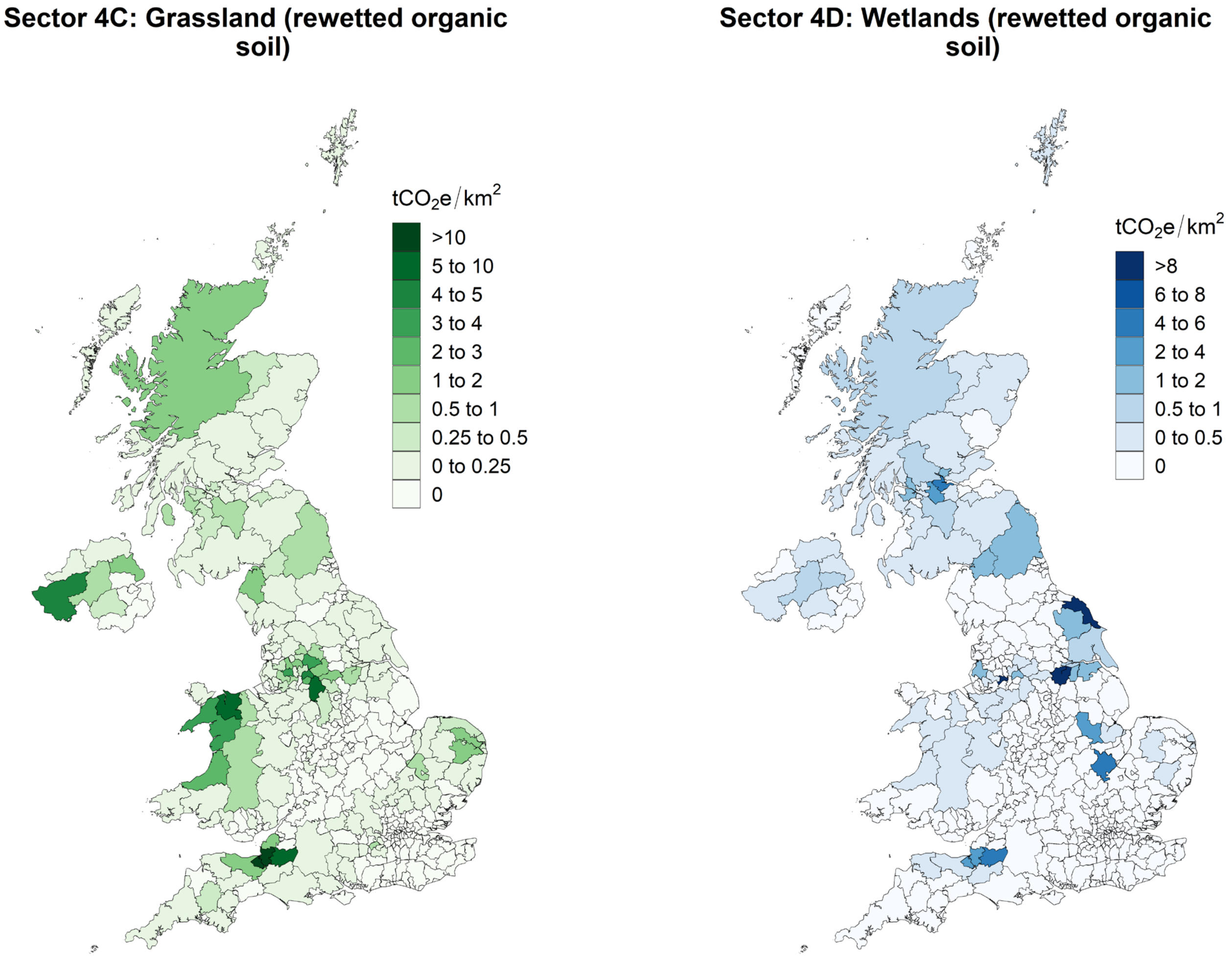



# Rewetting

Rewetted peatlands are reported under Grassland and Wetland categories (see LULUCF category description in the Categories section). Rewetting has largely occurred from 2000 onwards, and is increasing in practice as regions attempt to restore natural functioning of peatlands and long-term sinks for carbon. Disaggregation is carried out using the organic soil maps methodology. LAs with lands that have undergone peatland restoration (rewetting) are shown in Figure 12 as those exhibiting either a net sink or source of $CO_2e$ emissions. Separate emissions factors are applied to rewetted peatlands depending on the starting condition of the restored lands (see Section A3.4.6.3 of the NIR, Brown et al. 2022), with rewetted semi-natural habitats reported under Grassland having the lowest emission factors.

The mitigation impacts of peatland restoration are largely from avoided soil emissions due to the conversion of drained organic soils to rewetted peatlands, which are accounted for in the final emissions from remaining drained peatlands in Figures 11 and 12 using the organic soil maps methodology.

**Figure 13: Net carbon dioxide, methane and nitrous oxide emissions from rewetted organic soils per local authority area ($tCO_2e/km^2$) in 2021. This is part of the Grassland and Wetlands categories.**

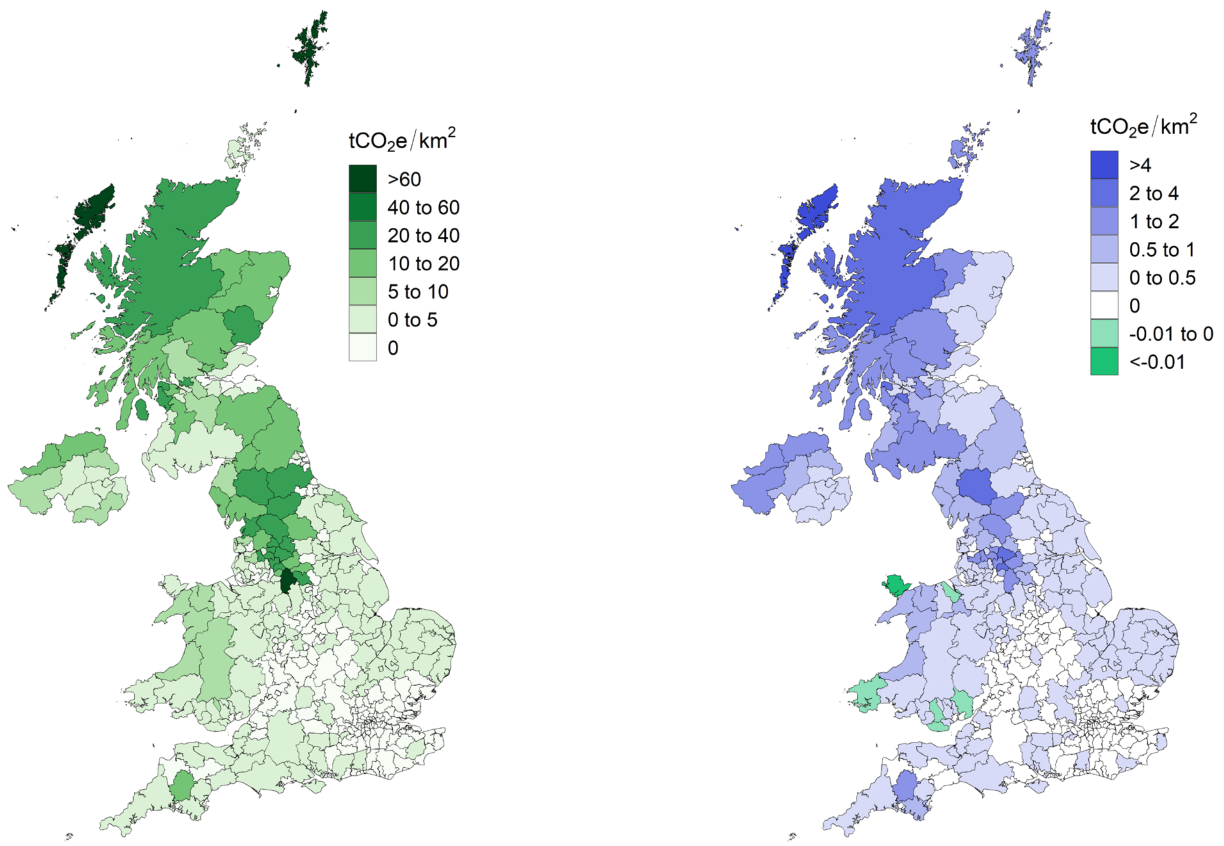



# Emissions from undrained organic soils: grassland, wetland

Large areas of UK peatlands are undrained, predominantly semi-natural heather- and grass-dominated bog that are modified by grazing and burning-management practices, reported under Grassland, and near-natural bog or fen which have suitable conditions for carbon sequestration and are reported under Wetlands (Figure 14). Emissions of $CH_4$ and removals of $CO_2$ ($N_2O$ emissions from undrained soils are assumed to be negligible) from undrained peatlands were disaggregated to the LA level using the organic soil maps methodology. The emissions and removals from these peatland habitats are distributed similarly across the UK, with patterns of highest emissions (for Grasslands) and removals (for Wetlands) in the Highlands and Islands of Scotland, the Pennines in Northern England, North West and Mid Wales, and North and West Northern Ireland (Figure 13).

**Figure 14: Net carbon dioxide and methane emissions and removals from undrained semi-natural and near natural peatlands per local authority area ($tCO_2e/km^2$) in 2021, which are part of the Grassland and Wetlands categories, respectively.**

**Sector 4C: Grassland (undrained organic soil)** **Sector 4D: Wetlands (near-natural organic soil)**




# Estimates of various minor emissions

## Non-Forest Biomass

The different land-use types have different biomass carbon densities per area at equilibrium. Change from one land use type to another can result in an increase or decrease in biomass carbon density per area. This category describes the annual change in the carbon stock in vegetation biomass due to all land-use change to Grassland, Cropland or Settlements, excluding forests and woodland.

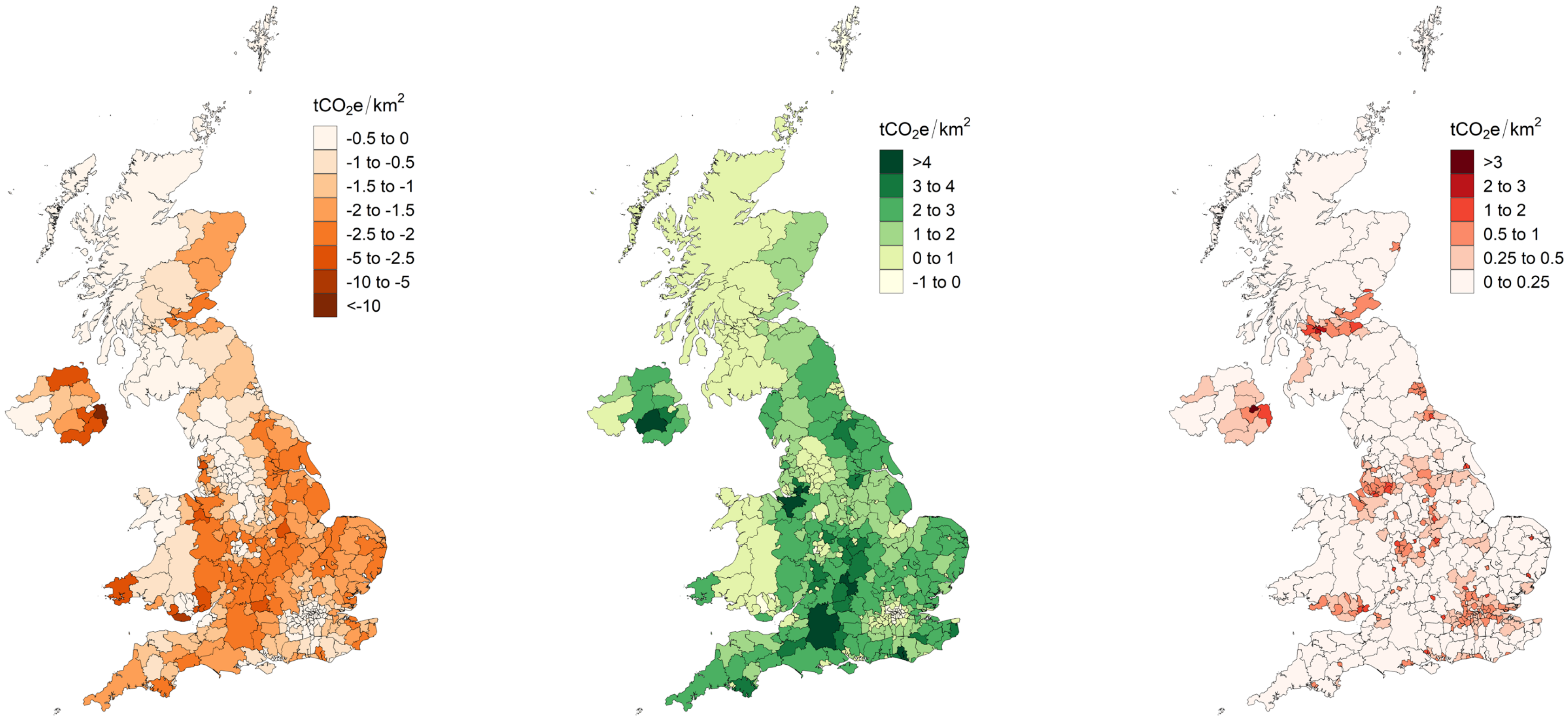
For the LULUCF inventory, estimates of emissions and removals for this category are made using the Countryside Survey Land-Use Change matrix approach. Changes in carbon stocks in biomass due to land-use change are based on the same area matrices used for estimating changes in carbon stocks in soils. The biomass carbon density per area for Wetlands and Settlement were assigned by expert judgement based on the work of Milne and Brown (1997). Average biomass densities per area for Cropland and Grassland used in the non-forest biomass LUC model are the same as those used in the cropland and grassland management calculations, based on a UK-relevant literature review in Moxley et al. (2014). Five basic land uses were assigned initial biomass carbon densities per area, then the relative occurrence of these land uses in the four countries of the UK were used to calculate mean biomass carbon densities per area for each of the IPCC types, Cropland, Grassland and Settlements. The mean biomass carbon densities per area for each land type were then weighted by the relative proportions of change occurring between land types in the same way as the calculations for changes in soil carbon densities per area. Changes between these equilibrium biomass carbon densities per area were assumed to happen in a single year. The emissions / removals are disaggregated to LA using the LUC-T methodology (see Figure 15).

**Figure 15: Changes in living biomass following land-use change from Grassland and Settlements to Cropland (4B2), from Cropland, Settlements and Wetlands to Grassland (4C2) and Cropland, Grassland and Wetlands to Settlements (4E2) in 2021, expressed as carbon dioxide emissions or removals per local authority area ($tCO_2/km^2$).**

**Sector 4B: Land converted to Cropland (non-forest biomass)**

**Sector 4C: Land converted to Grassland (non-forest biomass)**

**Sector 4E: Land converted to Settlements (non-forest biomass)**



# Deforestation

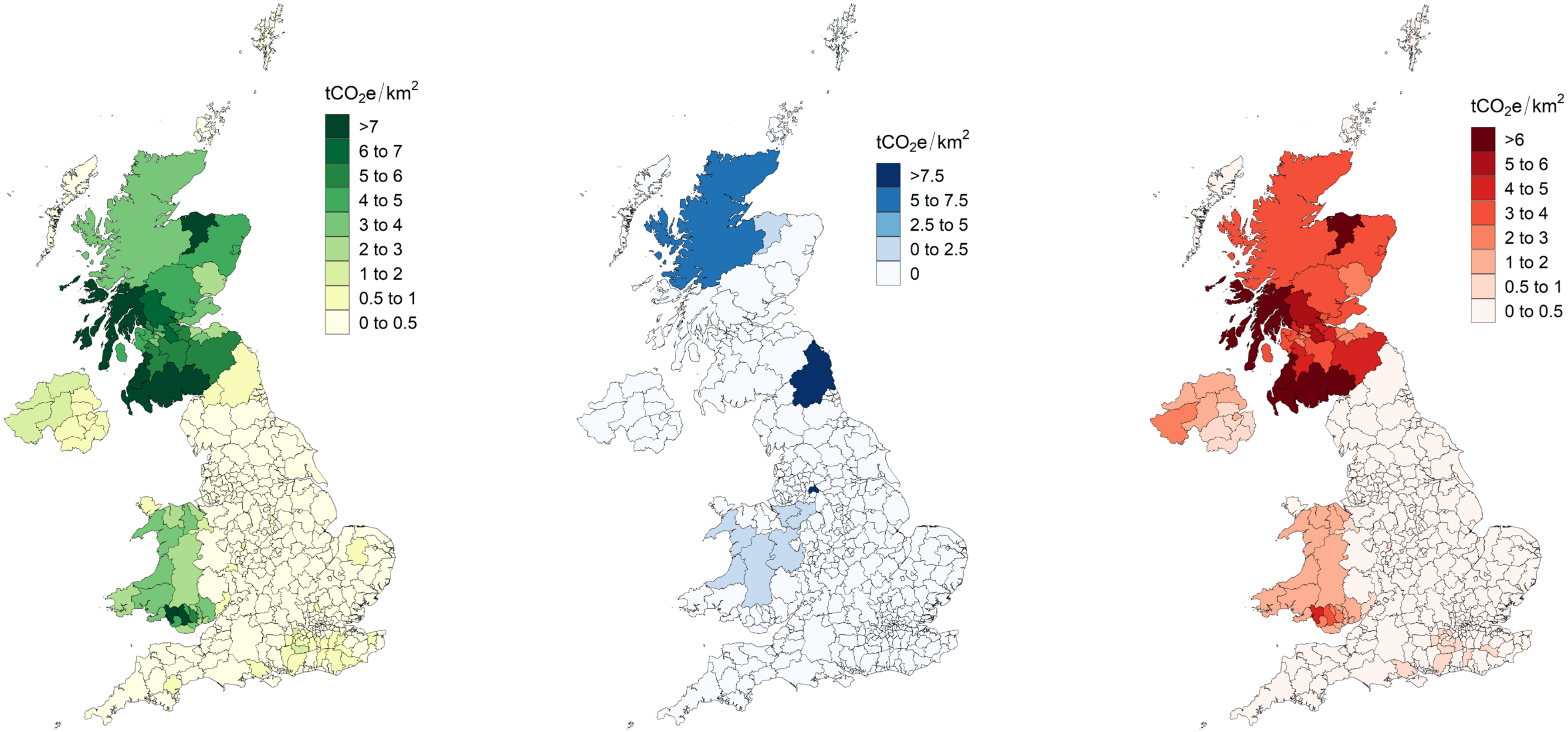
Emissions due to deforestation are disaggregated into deforestation to Cropland (reported in 4B, and only occurring in England and Scotland up to 2006), Grassland (4C), Wetlands 4D, and Settlements (4E). This includes emissions from loss of living biomass, decay of dead organic matter and controlled burning, but excludes emissions from soils as these are presented separately, see the emissions from mineral soils due to land-use change and emissions from soils due to drainage, rewetting and management of organic soils sections.

As the LUC-T disaggregation methodology is based on probabilistic LUC data and deforestation is both rare and difficult to distinguish from felled forest areas awaiting replanting, the deforestation to Cropland, Grassland and Settlement emissions are disaggregated using the LUC-T variable for Forest remaining Forest. (see Figure 16, this does not show Deforestation to Cropland as this was zero in 2021).

Deforestation on organic soil areas are known through rewetting projects and the methodology for disaggregating deforestation to Wetlands is similar to the organic soil maps methodology whilst retaining the information on previous land use (in this case forest).

**Figure 16: Emissions of carbon dioxide, methane and nitrous oxide from deforestation to Grassland, Wetlands, or Settlements per local authority area ($tCO_2e/km^2$) in 2021.**

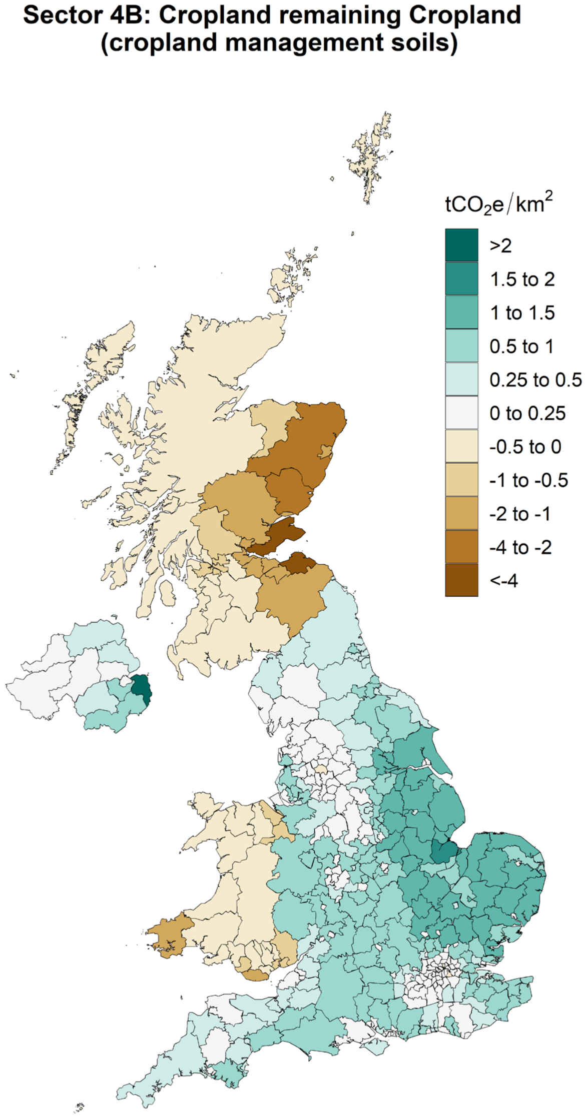
**Sector 4C: Land converted to Grassland (deforestation to Grassland)** | **Sector 4D: Land converted to Wetland (deforestation to Wetland)** | **Sector 4E: Land converted to Settlement (deforestation to Settlement)**



# Cropland Management Soil

Cropland management activities including inputs of fertiliser, manure and crop residues have an impact on soil carbon stocks. Data on the areas under the main crop types are obtained from the annual June Agricultural Censuses carried out by each UK administration (Defra, 2020; Welsh Government, 2020; Scottish Government, 2020; DAERA, 2020). Data on the areas of Cropland receiving inputs of manure, fertiliser and crop residues are obtained from the annual British Survey of Fertiliser Practice (Defra, 2021 and previous editions). The emissions were disaggregated to the LA level using the LUC-T methodology. The resulting assignment by LA is shown in Figure 17.

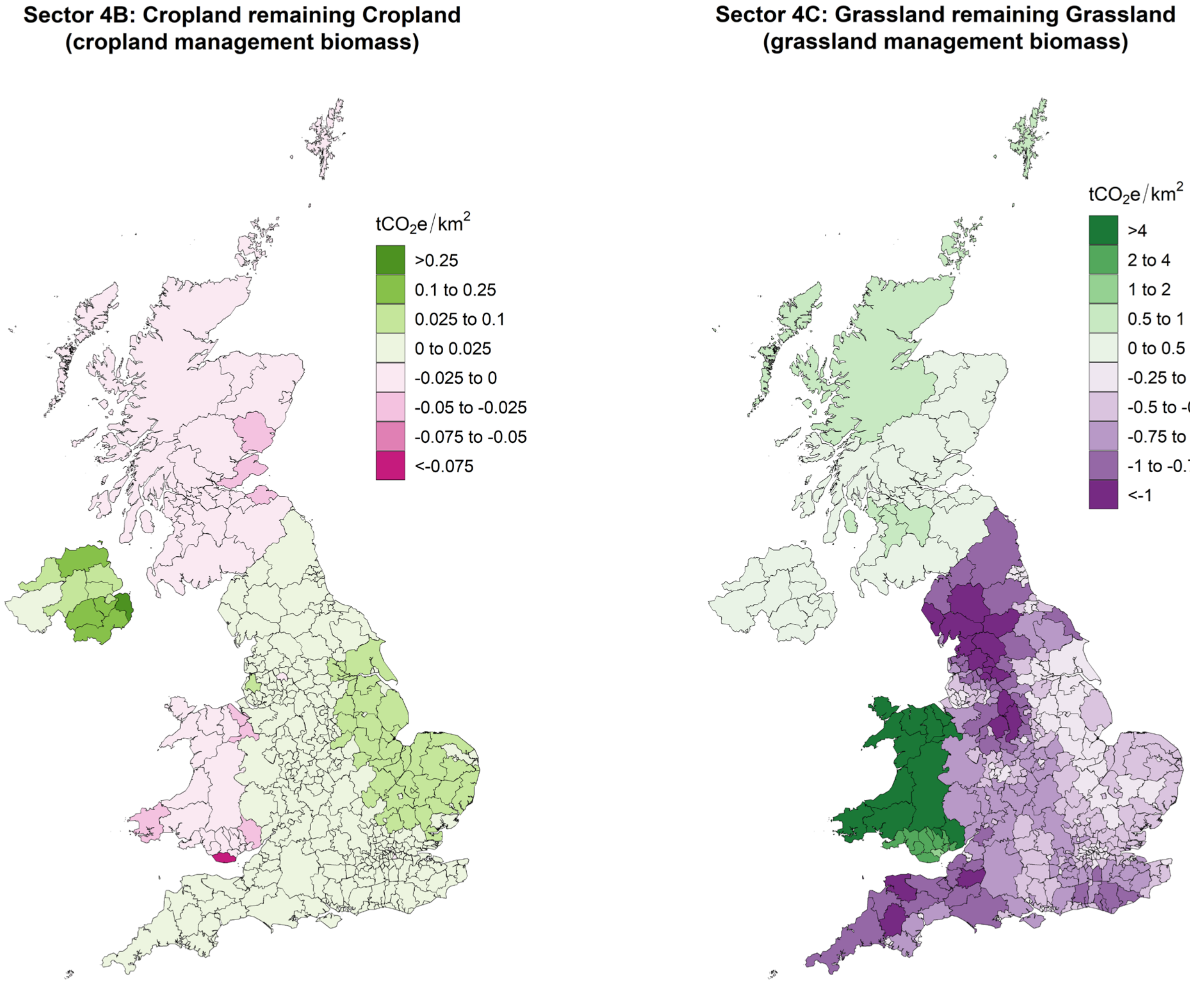
**Figure 17: Emissions / removals of carbon dioxide from Cropland Management soil activities per local authority area ($tCO_2/km^2$) in 2021.**



# Cropland and Grassland Management Biomass

Changes in biomass carbon stocks arising from Cropland and Grassland management activities are reported in the inventory. These include change between annual crops, orchards, short rotation coppice, set aside and fallow for Cropland and change between shrubby and non-shrubby grassland types and hedge creation and removal for Grassland. Data on the areas under the main crop types are obtained from the annual June Agricultural Censuses carried out by each UK administration (Defra, 2020; Welsh Government, 2020; Scottish Government, 2020; DAERA, 2021). Data on areas of grassland types are derived from the Countryside Surveys of 1990, 1998 and 2007. Information on emission factors were derived from a literature review described in Moxley et al. (2014). The emissions and removals are disaggregated to the LA level using the LUC-T methodology. The resulting assignment by LA is shown in Figure 18.

**Figure** 18**: Emissions / removals of carbon dioxide from Cropland and Grassland Management biomass activities per local authority area ($tCO_2/km^2$) in 2021.**

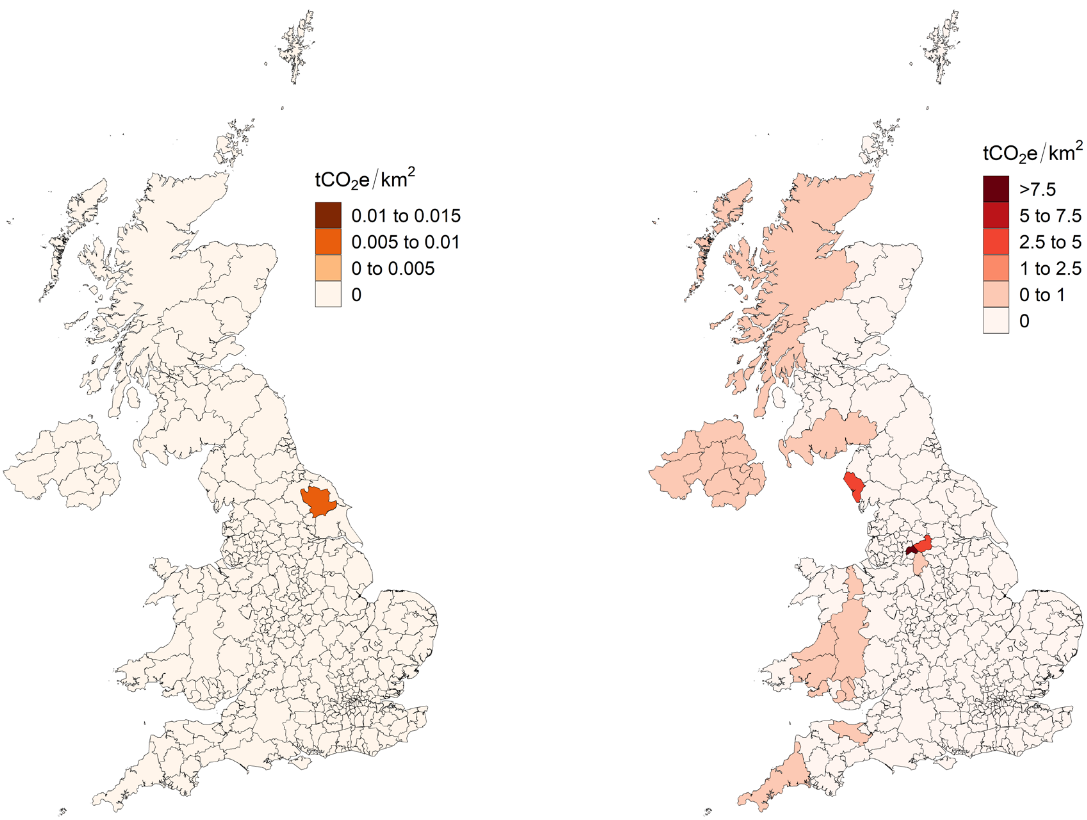


# Non-Forest Wildfires

Information on areas of wildfires on cropland and grassland in Great Britain and in Northern Ireland are available from the Fire Service Incident Response System (IRS). As is the case with forest wildfires, the non-forest wildfire dataset is spatially explicit, available at individual grid referenced fire level for Great Britain and as a national total for Northern Ireland. Hence, in Great Britain wildfires on cropland and grassland can be assigned to the LA in which they occurred, and in Northern Ireland the emissions are assigned to LAs in proportion to the total area of crop or grassland in each LA. Data for non-forest wildfires in England from 2015-2017 were not supplied with coordinates. For these incidents emissions were assigned proportionally between the LAs within the fire service boundary in which the incident occurred. Wildfires on cropland only occurred in England in 2021, whereas wildfires on grassland occurred in each DA in 2021 (Figure 19).

**Figure 19: Emissions of methane and nitrous oxide from non-forest wildfires per local authority area ($tCO_2e/km^2$) in 2021.**

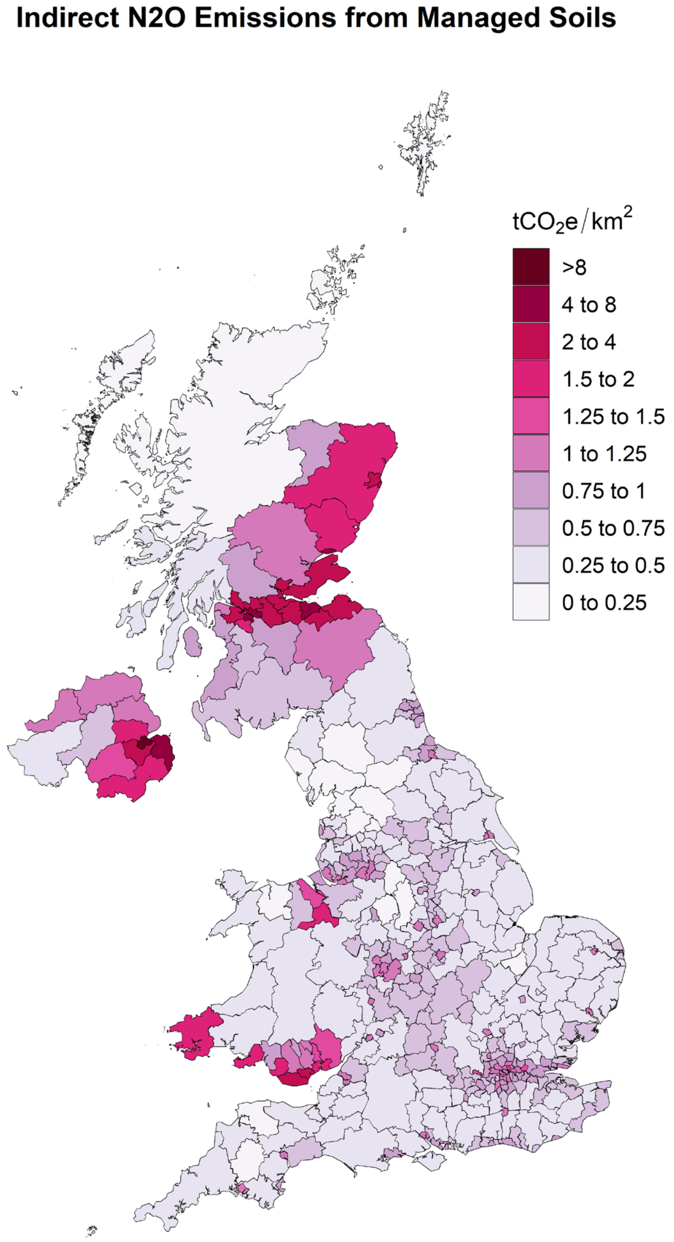
**Sector 4B: Cropland (wildfires)** **Sector 4C: Grassland (wildfires)**



# Indirect $N_2O$

Indirect emissions of $N_2O$ from atmospheric deposition and leaching are reported collectively for all LULUCF sectors (as set out in inventory reporting rules). Indirect $N_2O$ from atmospheric deposition arises from forest fertilisation and indirect emissions from leaching arise from both forest fertilisation and $N_2O$ mineralisation as a result of land use change. These emissions are disaggregated to LA scale using the LUC-T methodology (Figure 20).

**Figure 20: Indirect nitrous oxide emissions from managed soil per local authority area ($tCO_2e/km^2$) in 2021.**



# LULUCF Totals

The total greenhouse gas emissions and removals for the UK land use, land-use change and forestry sector (excluding harvested wood products which cannot be mapped) are shown in Figure 21. Maps of emissions and removals of individual gases, $CO_2$, $CH_4$, and $N_2O$ are shown in Figures 22-24.

**Figure 21: Emissions or removals of GHGs from land use, land-use change and forestry per local authority area ($tCO_2e/km^2$) in 2021.**

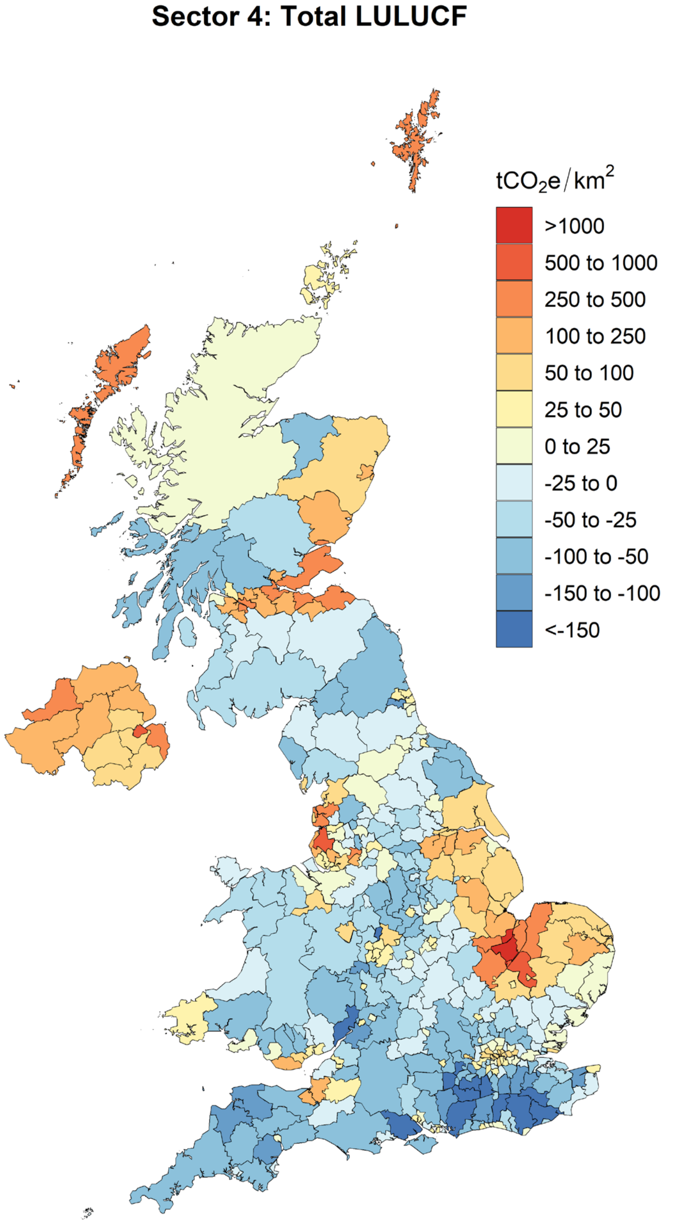


**Figure 22: Emissions or removals of carbon from land use, land-use change and forestry per local authority area ($tCO_2e/km^2$) in 2021.**

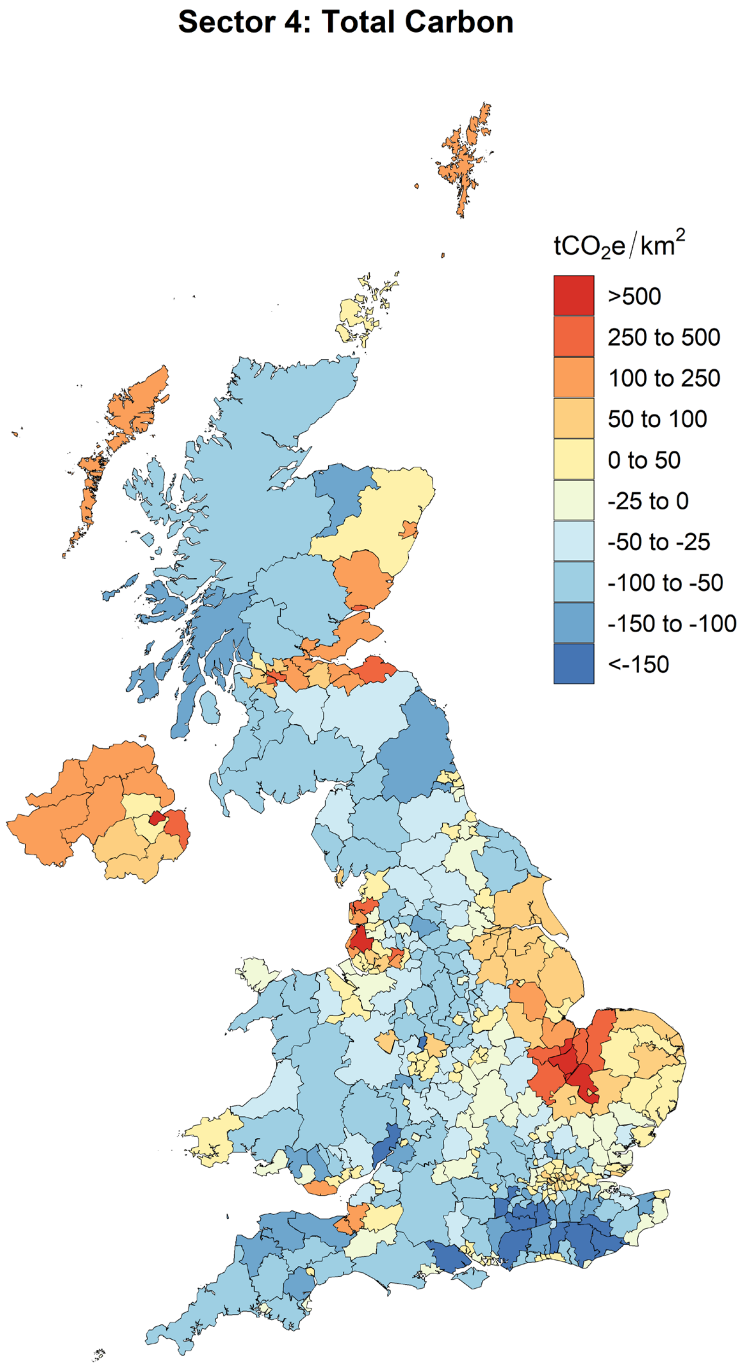


**Figure 23: Emissions or removals of methane from land use, land-use change and forestry per local authority area ($tCO_2e/km^2$) in 2021.**

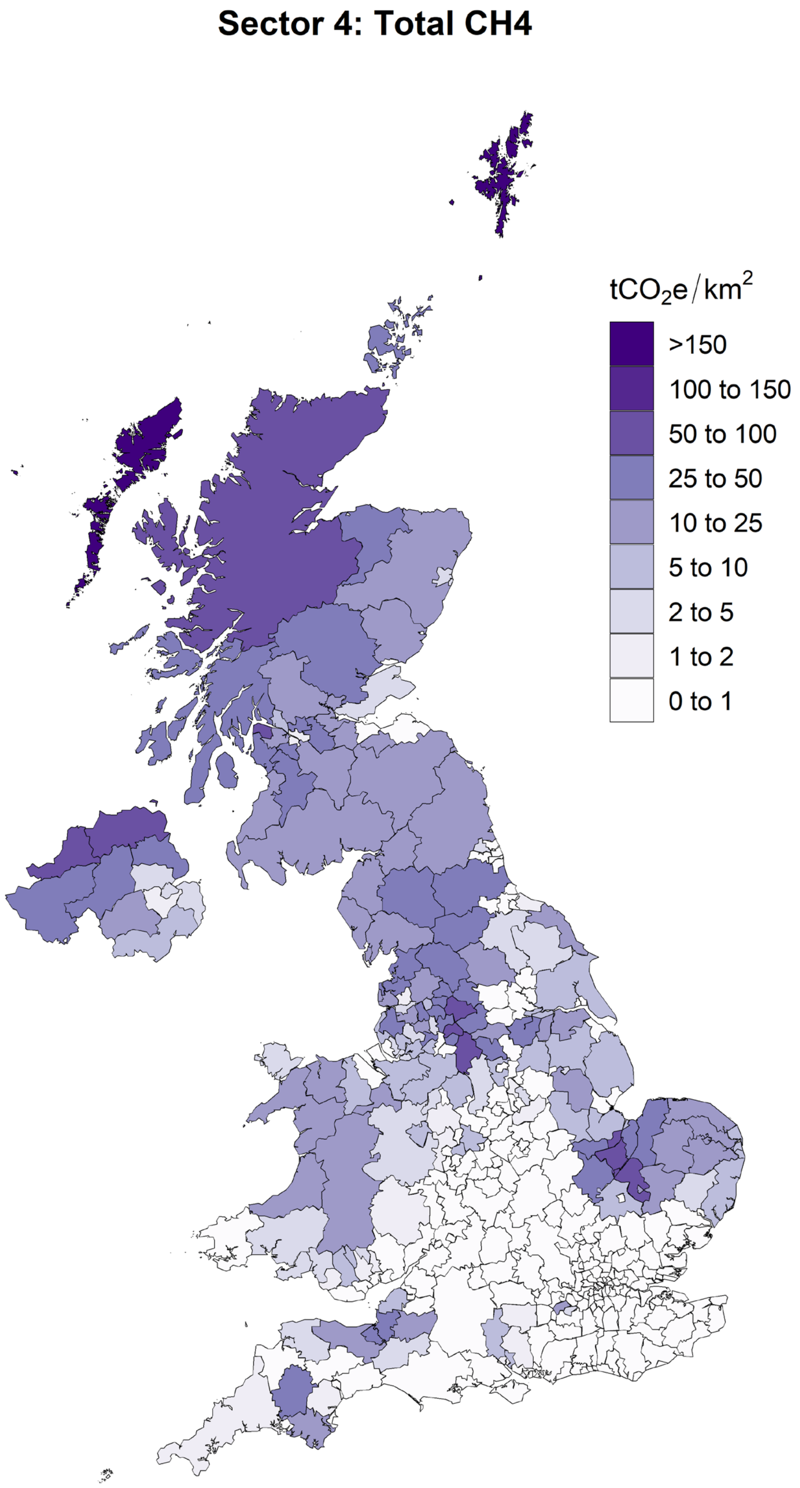
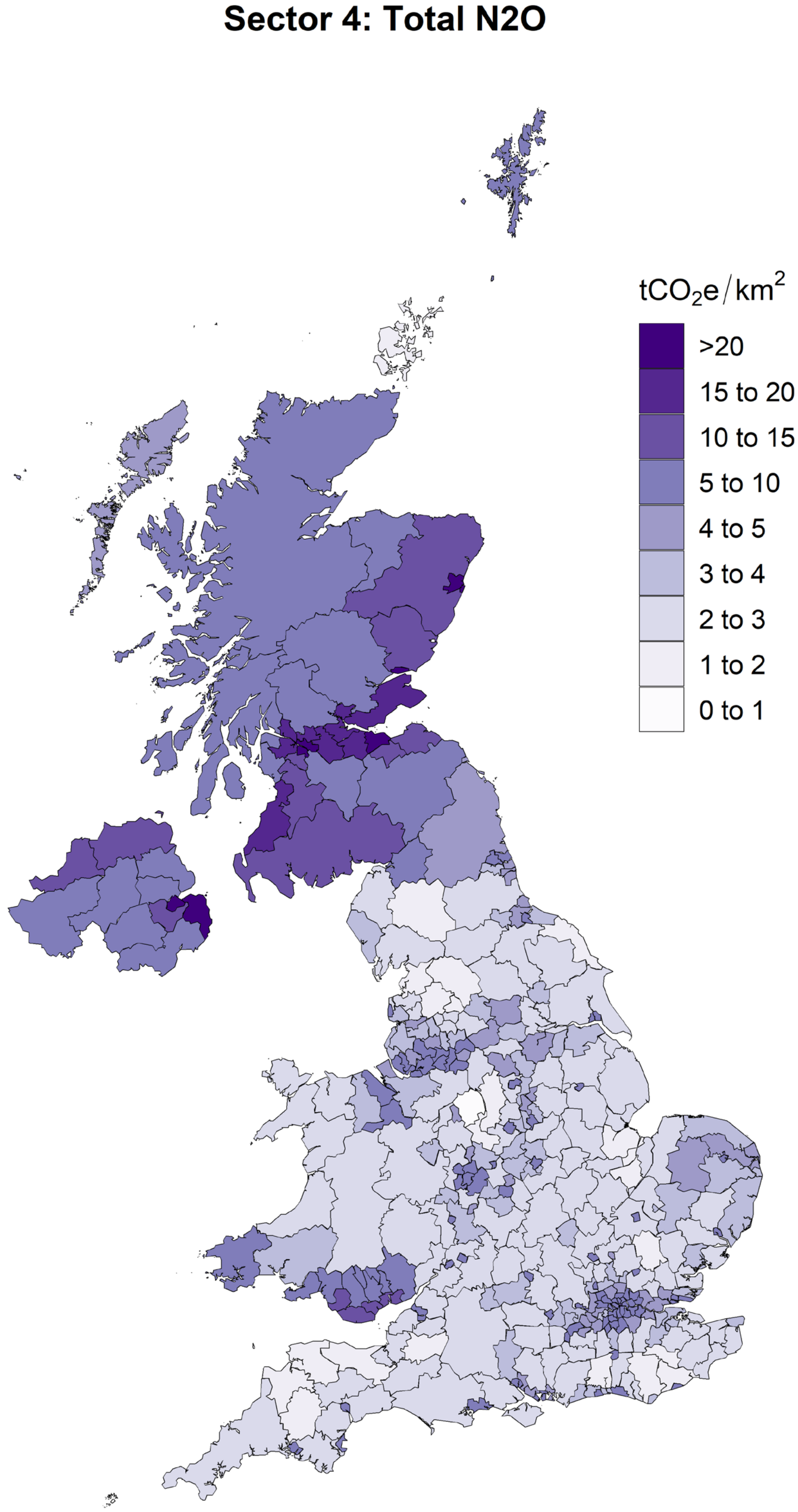


**Figure 24: Emissions or removals of nitrous oxide from land use, land-use change and forestry per local authority area ($tCO_2e/km^2$) in 2021**



# Uncertainties

The uncertainties in calculating the LULUCF inventory are described in an annex of the National Inventory Report (see Table A 3.4.32 in Brown et al. 2023) and range from 12-197% for $CO_2$, 34-95% for $CH_4$ and 36-240% in 2021 depending on the LULUCF sector activity. Additional uncertainty is associated with disaggregating the dataset to LA scale. It is estimated that the uncertainty in the disaggregation process is in the range of 20-30% on decadal timescales, though probably higher for annual estimates. There is low uncertainty in the LA mapping of emissions associated with wildfire occurrence and emissions from organic soils due to fine-scale spatial input data. Moderate uncertainty in the disaggregation process is attributed to emissions from soils due the land-use change, soils due to drainage, and the minor categories where the LUC-T disaggregation methods were employed. The LUC-T methodology is probabilistic, therefore although spatial location of unchanged land and the trend in land use change is well constrained, the spatial location and timing of land use change is less certain. There is higher uncertainty in the mapping of deforestation than the other land use changes which use the LUC-T methodology, due to challenges in identifying deforestation rather than land felled and awaiting restocking. Hence, the area of land remaining forest is used to disaggregate deforestation emissions. Similarly, the yearly evolution of the forest sink at LA level is assumed to follow the country level estimates relatively closely, but without explicit representation of forest management operations (including clear-fell operations) this introduces high uncertainty associated with the forest sink reported at LA scale for specific years.

**Table 2: Summary of source data and estimated uncertainty associated with the disaggregation of emissions to the local authority level.**

| Category | Source data used for disaggregation | Uncertainty |
|---|---|---|
| Forest Land | LUC-T methodology | Moderate for decadal average, high for annual average |
| Emissions from soils due to land-use change - Cropland, Grassland, Settlements | LUC-T methodology | Moderate |
| Emissions from soils due to drainage and rewetting of organic soils – Forest, Cropland, Grassland, Wetland, Settlement | Organic soil maps methodology | Low |
| Peat Extraction | Organic soil maps methodology | Low |
| *Minor estimates:* | | |
| Non-Forest Biomass | LUC-T methodology | Moderate |
| Deforestation | LUC-T methodology for deforestation to Cropland, Grassland and Settlement. Spatial organic soil restoration data for deforestation to Wetland. | High |

| | | |
|---|---|---|
| Wildfires | Fire and Rescue Service Incident Response System for Scotland, England and Wales from 2009 onwards. Proportion of the burnt area land use for all other fires. | Low |
| Cropland Management Soil | LUC-T methodology | Moderate |
| Cropland and Grassland Management Biomass | LUC-T methodology | Moderate |

# Recalculations

The National Inventory is often updated to include improved, or new, datasets and modelling techniques. More detailed descriptions of the changes can be found in the UK National Inventory Report and annexes (Brown et al. 2023).

**Table 3: Details of the major changes to emissions / removals between the 2020 and 2021 LULUCF inventories.**

| Description of Change | Reason for Change | Categories Affected | 1990-2020 Inventory<br><br>2020 UK Value ($GgCO_2e$) | 1990-2021 Inventory<br><br>2020 UK Value ($GgCO_2e$) | 1990-2021 Inventory<br><br>2021 UK Value ($GgCO_2e$) |
|---|---|---|---|---|---|
| Major change due to the incorporation of a new (lower) $CO_2$ EF for Cropland on wasted peat in England of 15.98 t $CO_2$ $ha^{-1}$ $yr^{-1}$ (compared to 28.60 t $CO_2$ $ha^{-1}$ $yr^{-1}$ for Cropland on deep peat used in the previous inventory for wasted peat) | Inclusion of new flux tower data collected as part of an ongoing BEIS-funded study to support the development of Tier 2 EFs for Cropland and Intensive Grassland on wasted peat. | 4B Cropland (drainage of organic soil) | 4,189.81 | 2,553.27 | 2,553.27 |
| Large change due to the incorporation of an updated (2022) Tier 2 analysis of organic soil emission factors (EFs) from the Defra Peatland Code Project SP0822. This update incorporates new UK datasets, including data from the UK flux tower network, as well as international data from | Inclusion of updated information from UK and international studies. | 4A Forest (drainage of organic soil), 4B Cropland (drainage of organic soil), 4C Grassland (drainage of organic soil), 4C Grassland | 14,116.52 | 13,258.15 | 13,216.22 |

| Description of Change | Reason for Change | Categories Affected | 1990-2020 Inventory<br><br>2020 UK Value ($GgCO_2e$) | 1990-2021 Inventory<br><br>2020 UK Value ($GgCO_2e$) | 1990-2021 Inventory<br><br>2021 UK Value ($GgCO_2e$) |
|---|---|---|---|---|---|
| climatically similar regions. Existing data and classifications used in EF database were also reviewed and revised, with the exclusion of several cropland and grassland flux data for methodological reasons. Particulate organic carbon (POC) EFs were updated for all soil categories using an IPCC Tier 1 methodology (IPCC 2014 Appendix Eq.2A.1). | | (rewetted organic soil), 4C Grassland (undrained organic soil), 4D Wetlands (near-natural organic soil), 4D Wetlands (peat extraction), 4D Wetlands (rewetted organic soil), 4E Settlement (drainage of organic soil) | | | |
| | | **LULUCF Total[2]** | 6,176.14 | 3,171.55 | 3,120.60 |

[2] This is the total emissions / removals for all LA categories both recalculated and unchanged (excludes Harvested Wood Products as this is not disaggregated to LA scale).

# References

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# Annex 1

## Inventory categories and spatial variables used for LUC-T disaggregation

| Inventory emission category | Gas | Spatial Variable | Group | From Land Use | To Land Use | Soil Type |
|---|---|---|---|---|---|---|
| Remaining broadleaf forest on mineral soil & biomass CSC | Carbon | Broadleaf Mineral >= 20 years | Remaining Land | NA | Forest Broadleaf | Mineral |
| To broadleaf forest on mineral soil & biomass CSC | Carbon | Broadleaf Mineral < 20 years | 20 year LUC | Any | Forest Broadleaf | Mineral |
| Remaining conifer forest on mineral soil & biomass CSC | Carbon | Conifer Mineral >= 20 years | Remaining Land | NA | Forest Conifer | Mineral |
| To conifer forest on mineral soil & biomass CSC | Carbon | Conifer Mineral < 20 years | 20 year LUC | Any | Forest Conifer | Mineral |
| Remaining broadleaf forest on organic soil & biomass CSC | Carbon | Broadleaf Organic >= 20 years | Remaining Land | NA | Forest Broadleaf | Organic |
| To broadleaf forest on organic soil & biomass CSC | Carbon | Broadleaf Organic < 20 years | 20 year LUC | Any | Forest Broadleaf | Organic |

| | | | | | | |
|---|---|---|---|---|---|---|
| Remaining conifer forest on organic soil & biomass CSC | Carbon | Conifer Organic >= 20 years | Remaining Land | NA | Forest Conifer | Organic |
| To conifer forest on organic soil & biomass CSC | Carbon | Conifer Organic < 20 years | 20 year LUC | Any | Forest Conifer | Organic |
| Remaining forest on mineral soil draining and rewetting | N2O | Current Forest Mineral | Current Land Use | NA | Forest | Mineral |
| To forest inorganic fertiliser application and indirect N2O (deposition and leaching) | N2O | Grassland to Forest Organic in previous three years and Settlement to Forest in previous three years | Change in previous three years | Grassland<br>Settlement | Forest<br>Forest | Organic<br>All |
| Cropland to forest land use change soils direct N2O and indirect N2O (leaching) | N2O | Cropland to Forest Mineral < 20 years | 20 year LUC | Cropland | Forest | Mineral |
| Grassland to forest land use change soils direct N2O and indirect N2O (leaching) | N2O | Grassland to Forest Mineral < 20 years | 20 year LUC | Grassland | Forest | Mineral |
| Settlement to forest land use change soils direct N2O and indirect N2O (leaching) | N2O | Settlement to Forest Mineral < 20 years | 20 year LUC | Settlement | Forest | Mineral |
| Cropland management soil | Carbon | Current Cropland Mineral | Current Land Use | NA | Cropland | Mineral |
| Cropland management biomass | Carbon | Current Cropland | Current Land Use | NA | Cropland | All |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cropland remaining Cropland CSC | Carbon | Cropland Mineral >= 20 years | Remaining Land | NA | Cropland | Mineral |
| Grassland to Cropland Non-forest Biomass | Carbon | Grassland to Cropland in the last year | Change in previous year | Grassland | Cropland | All |
| Settlement to Cropland Non-forest Biomass | Carbon | Settlement to Cropland in the last year | Change in previous year | Settlement | Cropland | All |
| Forest to Cropland land use change soils: CSC, direct N2O and indirect N2O (leaching) | Carbon, N2O | Forest to Cropland Mineral < 20 years | 20 year LUC | Forest | Cropland | Mineral |
| Grassland to Cropland land use change soils: CSC, direct N2O and indirect N2O (leaching) | Carbon, N2O | Grassland to Cropland Mineral < 20 years | 20 year LUC | Grassland | Cropland | Mineral |
| Settlement to Cropland land use change soils CSC | Carbon | Settlement to Cropland Mineral < 20 years | 20 year LUC | Settlement | Cropland | Mineral |
| Deforestation to Cropland: Dead Organic Matter, Living Biomass, Burning | Carbon, N2O, CH4 | Forest to Cropland in the last year | Change in previous year | Forest | Cropland | All |
| Grassland management biomass | Carbon | Current Grassland | Current land use | NA | Grassland | All |

| | | | | | | |
|---|---|---|---|---|---|---|
| Grassland remaining Grassland: CSC, direct N2O and indirect N2O (leaching) | Carbon, N2O | Grassland Mineral >= 20 years | Remaining land | NA | Grassland | Mineral |
| Cropland to Grassland Non-forest Biomass | Carbon | Cropland to Grassland in the last year | Change in previous year | Cropland | Grassland | All |
| Settlement to Grassland Non-forest Biomass | Carbon | Settlement to Grassland in the last year | Change in previous year | Settlement | Grassland | All |
| Deforestation to Grassland: Dead Organic Matter, Living Biomass, Burning | Carbon, N2O, CH4 | Forest to Grassland in the last year | Change in previous year | Forest | Grassland | All |
| Forest to Grassland Land Use Change soils: CSC, direct N2O and indirect N2O (leaching) | Carbon, N2O | Forest to Grassland Mineral < 20 years | 20 year LUC | Forest | Grassland | Mineral |
| Cropland to Grassland Land Use Change soils: CSC | Carbon | Cropland to Grassland Mineral < 20 years | 20 year LUC | Cropland | Grassland | Mineral |
| Settlement to Grassland Land Use Change soils CSC | Carbon | Settlement to Grassland Mineral < 20 years | 20 year LUC | Settlement | Grassland | Mineral |
| Settlement remaining Settlement: CSC, direct N2O and indirect N2O (leaching) | Carbon, N2O | Settlement Mineral >= 20 years | Remaining land | NA | Settlement | Mineral |

| | | | | | | |
|---|---|---|---|---|---|---|
| Deforestation to Settlement: Dead Organic Matter, Living Biomass, Burning | Carbon, N2O, CH4 | Forest to Settlement in the last year | Change in previous year | Forest | Settlement | All |
| Forest to Settlement Land Use Change soils: CSC, direct N2O and indirect N2O (leaching) | Carbon, N2O | Forest to Settlement Mineral < 20 years | 20 year LUC | Forest | Settlement | Mineral |
| Cropland to Settlement Land Use Change soils: CSC, direct N2O and indirect N2O (leaching) | Carbon, N2O | Cropland to Settlement Mineral < 20 years | 20 year LUC | Cropland | Settlement | Mineral |
| Grassland to Settlement Land Use Change soils: CSC, direct N2O and indirect N2O (leaching) | Carbon, N2O | Grassland to Settlement Mineral < 20 years | 20 year LUC | Grassland | Settlement | Mineral |
| Cropland to Settlement Non-forest Biomass | Carbon | Cropland to Settlement in last year | Change in previous year | Cropland | Settlement | All |
| Grassland to Settlement Non-forest Biomass | Carbon | Grassland to Settlement in last year | Change in previous year | Grassland | Settlement | All |
| Forest Wildfires | Carbon, N2O, CH4 | Current Forest | Current Land Use | NA | Forest | All |
| Cropland Wildfires | N2O, CH4 | Current Cropland | Current Land Use | NA | Cropland | All |

| | | | | | | |
|---|---|---|---|---|---|---|
| Grassland Wildfires | N2O, CH4 | Current Grassland | Current Land Use | NA | Grassland | All |

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