Mapping Carbon Emissions & Removals for the Land Use, Land Use Change & Forestry Sector

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

The Department of Energy and Climate Change (DECC) takes the lead in the UK in preparing the annual Inventory of Greenhouse Gas Emissions for the United Nations Framework Convention on Climate Change. The Inventory is prepared in 6 main sections, or Sectors. DECC contract Ricardo-AEA to prepare the main greenhouse gas emissions inventory but contract the Centre for Ecology and Hydrology to prepare the data for the Sector 5 tables relating to Land Use, Land Use Change and Forestry in the UK.

In addition to the National Greenhouse Gas Inventory, the UK is required to provide reports to both the EU and the UNFCCC on its progress towards its Kyoto Protocol target. Article 3.3 of the Kyoto Protocol requires Parties in meeting their emissions reduction commitments to account for Afforestation, Reforestation and Deforestation (ARD) since 1990. Accounting for ARD under Article 3.3 requires i) a definition of forest, ii) knowledge of forest type and planting/deforestation date, iii) geographical location, and iv) a method to distinguish deforestation from areas harvested and replanted. Also, Article 3.4 of the Kyoto Protocol allows Parties flexibility to choose Forest Management, Cropland Management, Grazing Land Management and Revegetation towards meeting commitments, but this is not mandatory. The UK elects Forest Management as an activity under Article 3.4, but does not elect Cropland Management, Grazing Land Management or Revegetation (Defra 2006). The activities of afforestation, reforestation and deforestation are covered by Sector 5, the Land Use, Land Use change and Forestry Sector (LULUCF).

The Centre for Ecology and Hydrology annually prepares Sector 5 estimates for inclusion in the UK GHG Inventory. These estimates are made using dynamic models of changes in stored carbon driven by land use change data. For forestry, the model deals with plant carbon, dead organic matter, soil and harvested wood products and is driven by the area of land newly afforested each year. Changes in soil carbon are driven by estimated time series of land use transitions between semi-natural, cultivated (farm), woodland and urban land uses. The models, and those for other LULUCF activities, are run for each of the four devolved administrative regions of the UK. Until the 1990-2004 inventory (submitted in 2006) no data was reported in map format at a scale below the devolved administrations (England, Scotland, Wales and Northern Ireland); here we report results from methods to provide estimates of LULUCF emissions and removals at the scale of Local Authority within the UK for the 2011 inventory year.

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.

Categories

The IPCC Good Practice Guidance (GPG) for Land Use, Land Use Change and Forestry (IPCC 2003) 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. Category G: Other is used for LULUCF activities that do not fall within any of the other categories.

The GPG allows modification of the basic set of six land classes to match national databases. In the UK, areas of wetlands will either be saturated land (e.g. bogs, marshes) or open water. Emissions from specific peat extraction sites have been allocated to their respective local authorities in Great Britain. Spatially disaggregated data is not available for Northern Ireland.. The Other land category includes lakes, rivers, reservoirs and rocky coastal land etc 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'. Thus, for practical uses, the UK land use change matrix can be simplified to that shown in Figure 1, including only Forest Land (A), Cropland (B), Grassland (C) and Settlements (E) (shown clockwise from top left). 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 Figure 1, each arrow represents the possible change for an area of land between two time points showing the corresponding category designation; '1' refers to land that has not changed use (e.g. 5A1 is for Forest Land remaining Forest Land) , '2' refers to land that has undergone change (e.g. 5A2.1 is for Cropland converted to Forest Land).

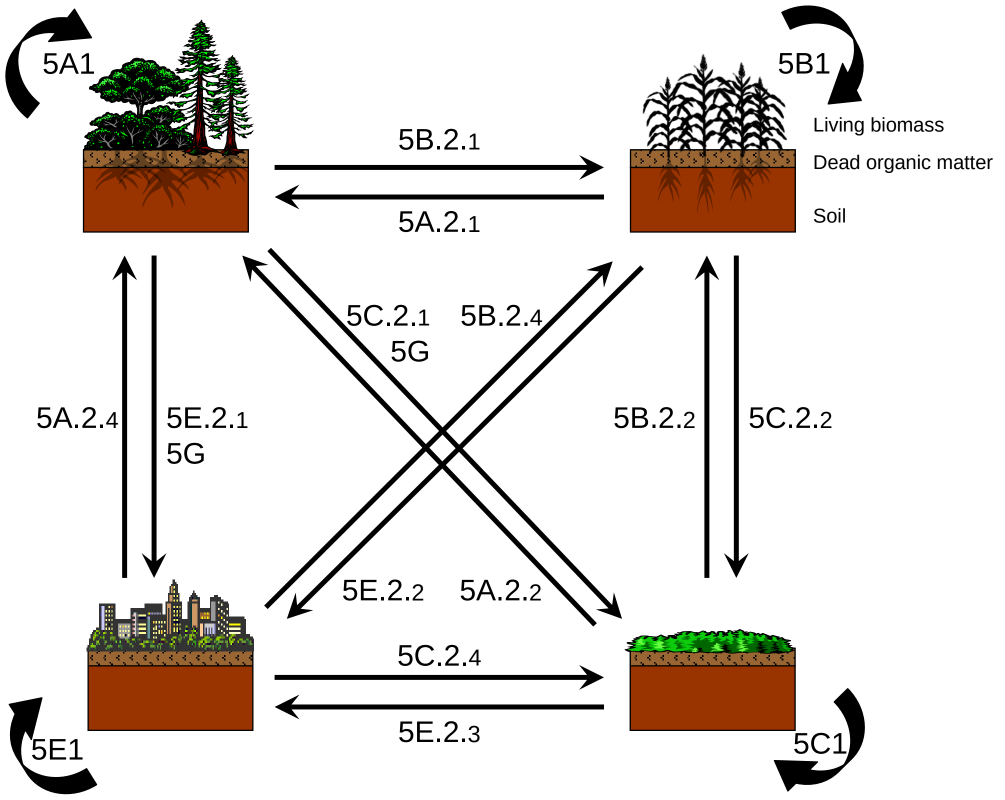


Figure 1: UK Sector 5 land use transitions showing categories for carbon stock change. See text for details.

Different activities are associated with each land use or land use change. For example, 'afforestation' refers to all land use change *to* Forest Land, 'liming' activity can relate to both Cropland and Grassland and 'peat extraction' affects Wetlands remaining Wetlands. 'However, there are no transitions *to* or *from* Wetlands and therefore this category is not shown in Figure 1. The change in carbon stocks of living biomass, dead biomass and soil organic matter must be reported for each activity together with other relevant non-carbon changes.

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 is currently subdivided into England, Scotland, Wales and Northern Ireland where possible and some categories are further disaggregated into time periods relating to the effects of forest planting before or after 1990. Subdivision into smaller units, such as 20kmx20km regions, is appropriate for modelling purposes and the development of estimates at Local Authority scale are described in this report.

Activities

The activities relevant to LULUCF are listed in Table 1. The main category designations are listed with the activity description and the UK total emissions/removals (Gg C) for 2011 as reported in the 1990-2011 Inventory. The activities are sorted in order of magnitude and divided into four groups; afforestation, emissions from soils due to land use change, minor emissions and categories assumed to have zero emissions/removals for the UK. Full details are given in the report "Inventory and projections of UK emissions by sources and removals by sinks due to land use, land use change and forestry" (CEH 2010).

Table 1: The UK carbon emissions and removals in Sector 5 (Land Use, Land Use change and Forestry) for 2011 sorted in order of magnitude.

Category	Activity	2011 UK total GgC emission (+) or removal (-)
5A	Forest Land	**-2876.49**
5C2	Grassland (soil)	**-2426.70**
5B2	Cropland (soil)	**2867.54**
5E2	Settlements (soil)	**1672.85**
5B1	Cropland remaining Cropland (lowland drainage)	**288.00**
5B1	Cropland remaining Cropland (Yield improvement)	**-174.65**
5B	Liming of Cropland	**131.60**
5D1	Wetlands remaining Wetlands	**109.82**
5C	Wildfires	**99.50**
5C	Liming of Grassland	**88.29**
5C2	Land converted to Grassland (deforestation to grass)	**56.32**
5E	Land converted to Settlements (deforestation to settlements)	**25.18**
5B2	Settlements (non-forest biomass)	**16.52**
5B2	Land converted to Cropland (deforestation to Cropland)	**1.89**
5B2	Cropland (non-forest biomass)	**1.71**
5C2	Grassland (Non-forest biomass)	**-0.07**

Each of the three (non-zero) groups of activities is described below. Emissions and removals from the LULUCF Sector are predominantly of CO_2. Emissions of other greenhouse gases are produced by biomass burning during wildfires or the conversion of Forest Land to Grassland or to Settlements (CH_4, N_2O, NO_x and CO), or by N fertilisation of new forests. Estimates of N_2O and CH_4 emissions and removals from other land use change activities are included in the 2011 inventory but these are small quantities (1.3 Gg CH_4 or 7.6 Gg Ce for methane and 0.01 Gg N_2O or 0.8 Gg Ce for nitrous oxide across the UK). Emissions of these non-CO_2 gases from agricultural land (e.g. due to fertilization) are already reported in the Agriculture sector of the Greenhouse Gas Inventory. Only carbon (for CO_2) is included in this report.

Forestry – Afforestation

For the National Inventory, the carbon uptake by forests planted since 1920 is calculated by a carbon accounting model, C-Flow, as the net change in pools of carbon in standing trees, litter and soil for conifer and broadleaf forests and in products (Dewar and Cannell 1992; Milne, Brown *et al*. 1998). Forests accumulate carbon (removing it from the atmosphere) in their biomass and soils as they grow, but timber harvesting and planting activities disturb this accumulation and result in emissions of carbon 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 time scales (50 years+) so the rate of carbon removal *now* is driven by the rate of forest planting in previous decades. Two types of input data are required for the model; a) areas of new forest planted in each year in the past, and b) the stemwood growth rate and harvesting pattern.

For the National estimates we use the combined area of new private and state planting from 1922 to 2000 for England, Scotland, Wales and Northern Ireland sub-divided into conifers and broadleaves. For mapping at LA scale, the C-Flow model was applied to 20km x 20km grid squares across the UK by estimating the required input planting data at this scale. The planting data was also extended to 2011. The model output per grid square was then combined to provide estimates per Local Authority (LA). This is achieved by taking the grid square data and assigning appropriate values to every 1km square in the UK. These smaller units can then be combined according to the LA boundaries (see Figure 2).

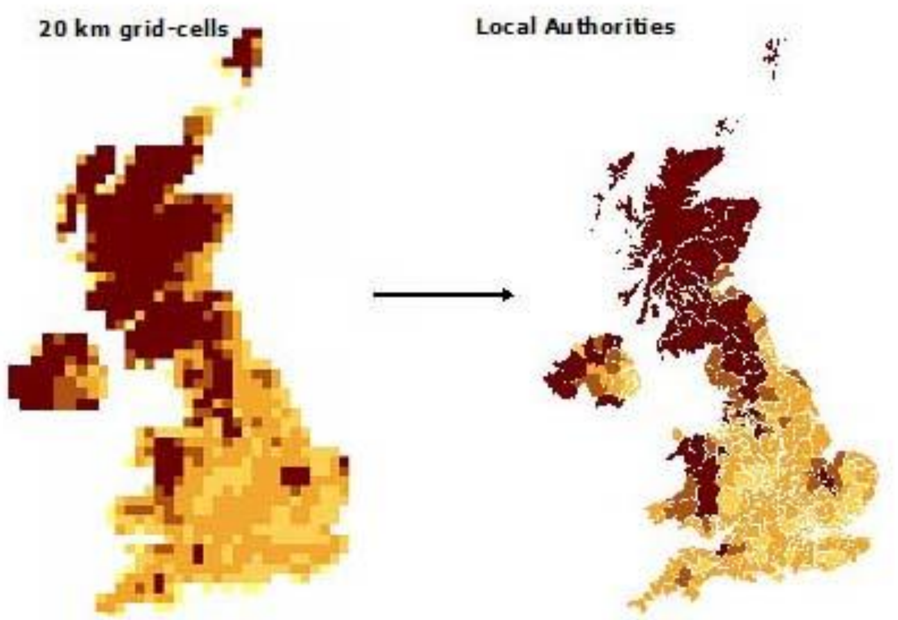


Figure 2: Model output is generated for 852 squares across the UK. Data are combined to provide estimates for each Local Authority (data for illustration only).

Figure 3 shows the distribution of carbon removals due to afforestation across the UK expressed as tonnes of Carbon per square kilometre (tC per km^2). Maps of total carbon emissions/removals per LA can be misleading due to the wide range of areas across authorities – maps tend to be dominated by the Highlands region of Scotland.

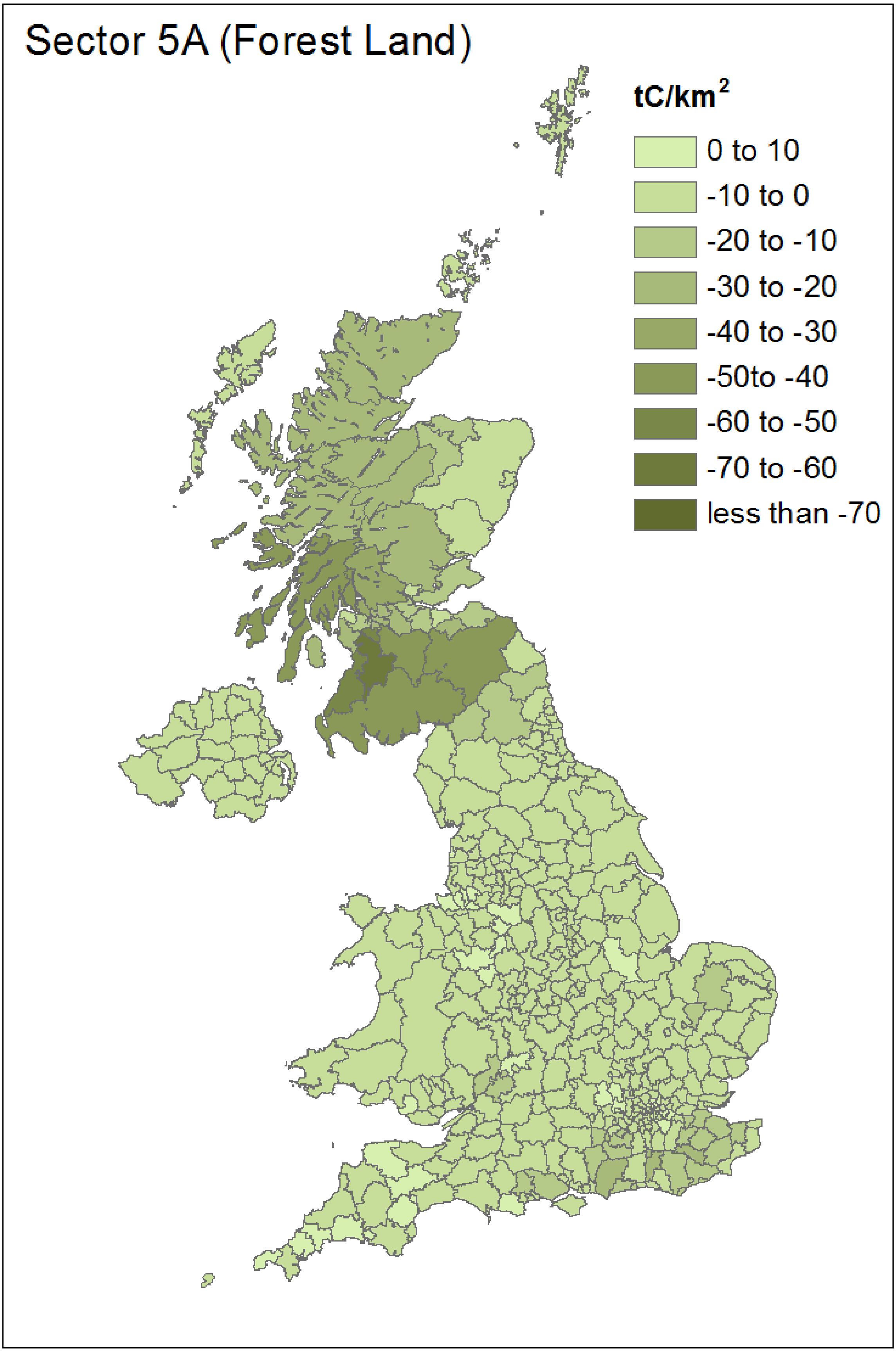


Figure 3: Distribution of carbon removals from the atmosphere due to afforestation across the UK expressed as tC per km^2.

Cropland, Grassland, Settlements – Emissions from Soils due to land use change

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. Also, the initial disturbance of the soil will release carbon to the atmosphere.

For the National Inventory, the method for assessing changes in soil carbon stock due to land use change links a matrix of change from land surveys to a dynamic model of carbon stock change. For Great Britain, matrices from the Monitoring Landscape Change data from 1947 & 1980 (MLC 1986) and the Countryside Surveys (CS) of 1984, 1990,1998 and 2007 are used.

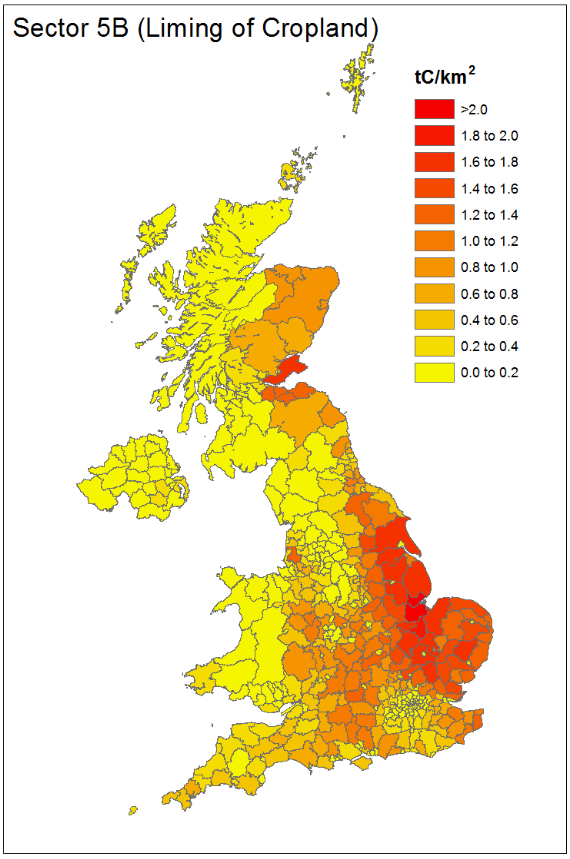
In Northern Ireland, for 1990 to 1998 and 1998 to 2007, a matrix for the whole of Northern Ireland was available from the Northern Ireland Countryside Survey (Cooper and McCann and Rogers 2007). The only data available pre-1990 for Northern Ireland are land use areas from the Agricultural Census and the Forest Service (Cruickshank and Tomlinson 2000). Matrices of land use change were then estimated for 1970-80 and 1980-90 using area data. The basis of the method devised assumed that the relationship between the matrix of land use transitions for 1990-1998 and the area data for 1990 is the same as the relationship between the matrix and area data for each of two earlier periods – 1970-79 and 1980-89. The matrices developed by this approach were used to extrapolate areas of land use transition back to 1950 to match the start year in the rest of the UK.

We have developed time series of land use change in 20 x 20 km grid-cells (to match those used for the afforestation fluxes) using the Countryside Surveys covering periods 1984 to 1990,1990 to 1998 and 1998 to 2007. The land use change matrices for the 20 x 20 km grid-cells are scaled to match those used in estimates of emissions and removals for the devolved administration areas in the United Kingdom. These matrices are then used for each grid-cell in a model analogous to that presently used for the full devolved area. The data are then combined to give estimates per Local authority region (see Figure 5 overleaf).

Estimates of various minor emissions

Liming of Cropland and Grassland

The National Inventory estimate of carbon flux due to liming of agricultural land (Grassland and Cropland) uses land use data from the Agricultural Census for the four devolved administrations, England, Scotland, Wales and Northern Ireland. Similar land use data is also available from the Census at a smaller scale, at local authority or regional groupings, so the flux can be estimated for each LA using the same method as used nationally (see Figure 4). For the local authority scale data we have assumed the same distribution as given for 2004. Due to non-disclosure and confidentiality issues the sum of the LA land use data from the Census does not exactly equal the published national totals; the estimated carbon flux data from the LA calculations do not exactly equal that submitted in the National inventory. We have assumed that the difference in published areas applies to all LAs in proportion to their area and have adjusted the flux estimates so that the sum is equal to the submitted inventory value (5B liming and 5C liming).



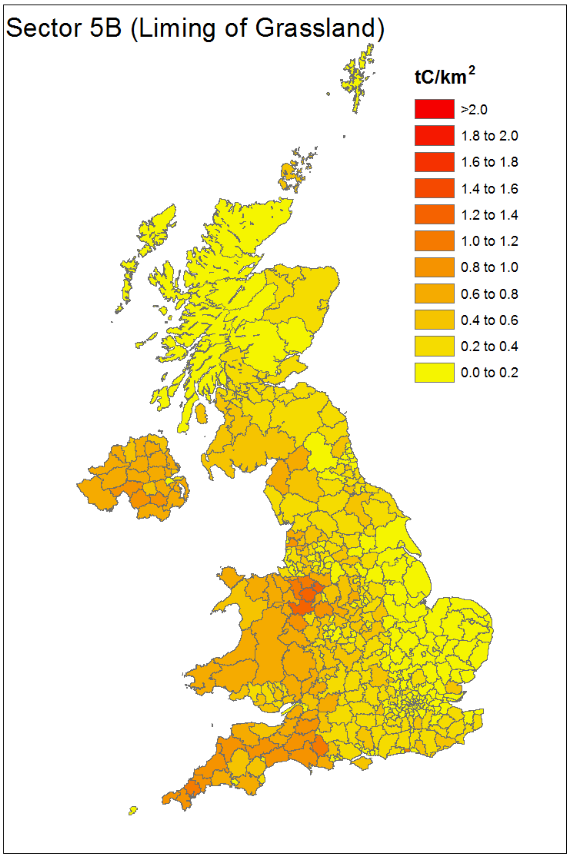


Figure 4: Carbon emissions due to liming of agricultural land, (a) Cropland and (b) Grassland.

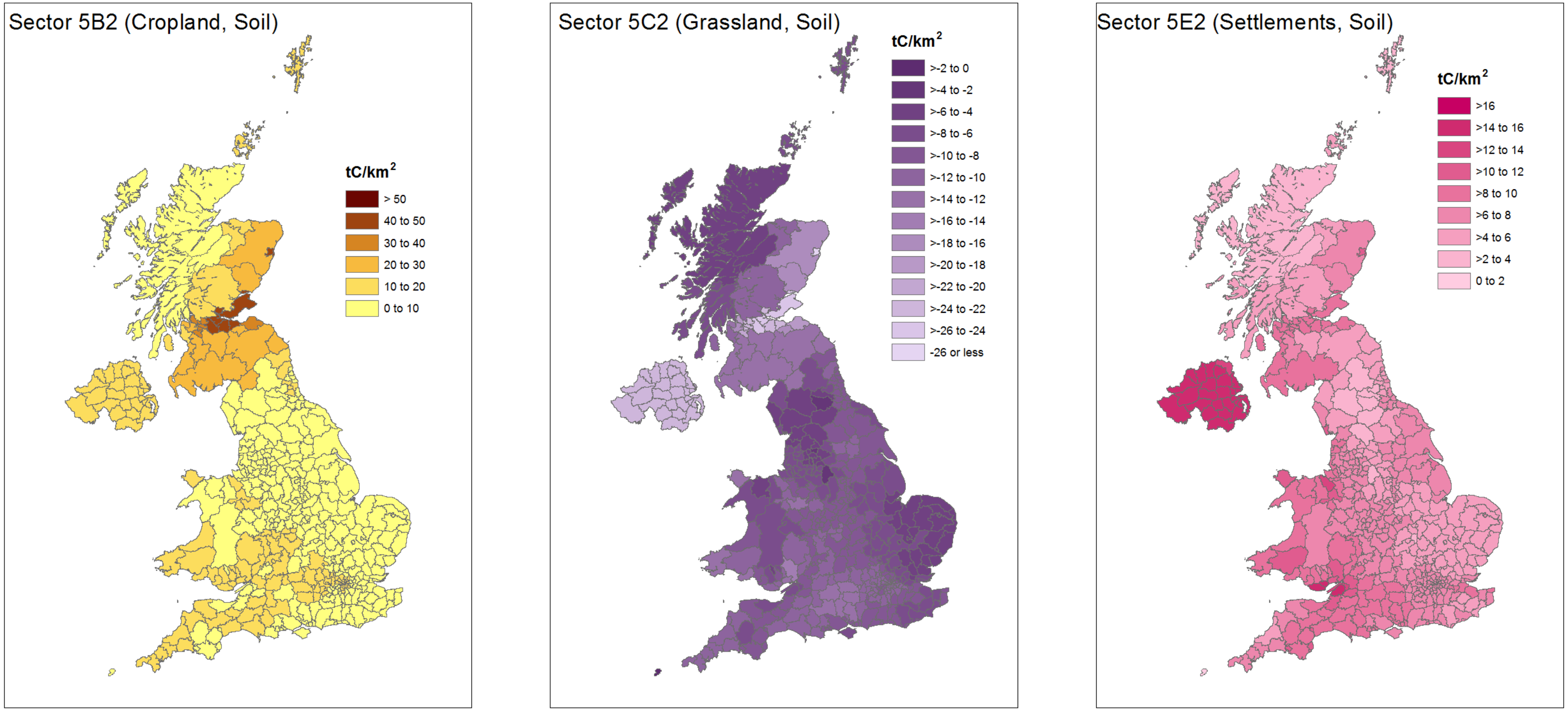


Figure 5: Emissions from soil due to land use change (tC/km^2) for conversion of all land type to (a) Cropland (b) Grassland and (c) Settlements.

Other Biomass Changes

Non-forest Biomass

The different land use types have different biomass carbon densities at equilibrium. Change from one land use type to another can result in an increase or decrease in biomass carbon density. 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 National Inventory, estimates of emissions and removals for this category are made using the Countryside Survey Land Use Change matrix approach, with biomass densities weighted by expert judgment. Changes in carbon stocks in biomass due to land use change are now based on the same area matrices used for estimating changes in carbon stocks in soils. The biomass carbon density for each land type is assigned by expert judgement based on the work of Milne and Brown (1997). Five basic land uses were assigned initial biomass carbon densities, then the relative occurrence of these land uses in the four countries of the UK were used to calculate mean biomass carbon densities for each of the IPCC types, Cropland, Grassland and Settlements. The mean biomass carbon densities 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. Changes between these equilibrium biomass carbon densities were assumed to happen in a single year.

This matrix approach was extended and applied to each 20km x 20km grid square across the UK, and the results combined to give estimates for each Local Authority (see Figure 6).

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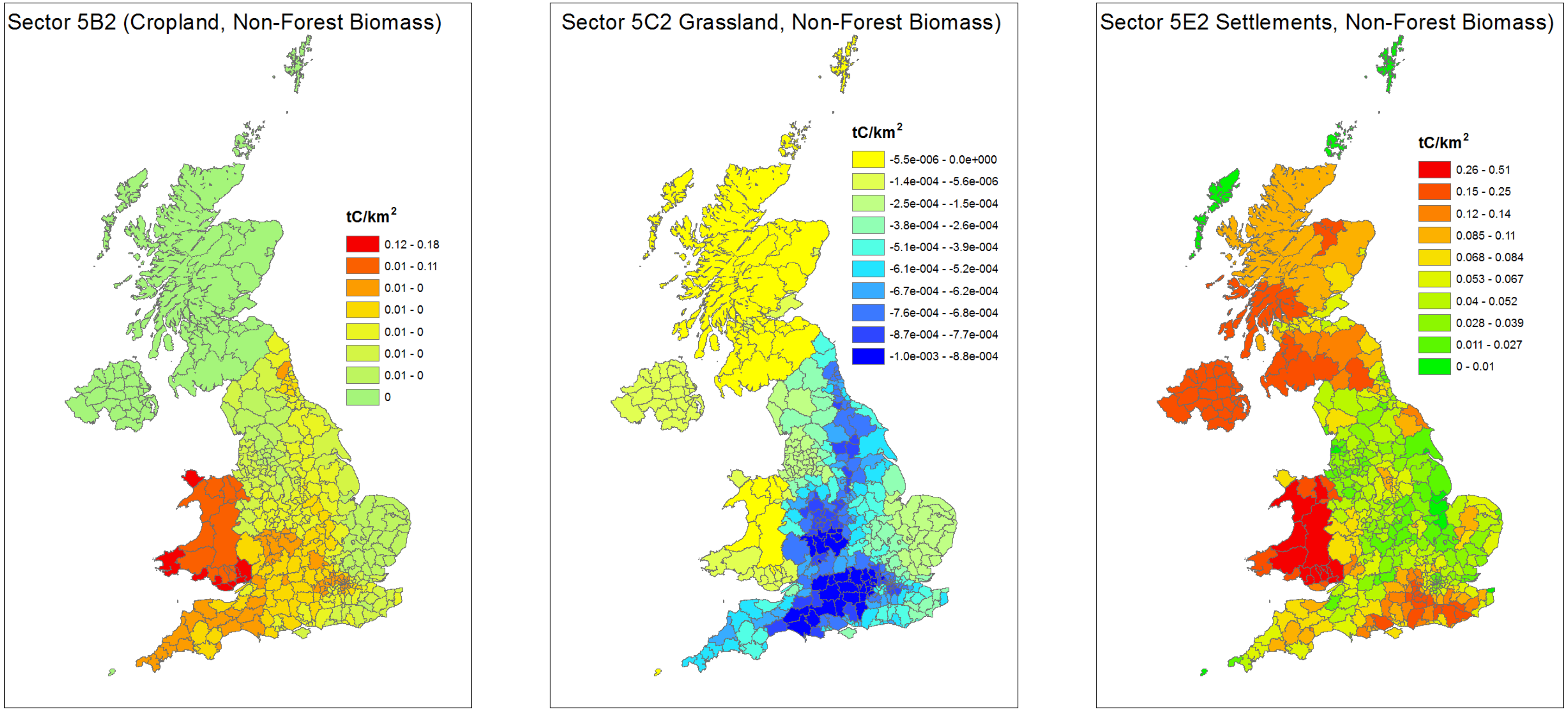

Figure 6: Carbon emissions and removals across the UK due to changes in living biomass following land use change to Cropland (5B2), Grassland (5C2) or Settlements (5E2).

Crop Yield Improvement

There is an annual increase in the biomass of cropland vegetation in the UK that is due to yield improvements (from improved species strains or management, rather than fertilization or nitrogen deposition). The increases in crop yield are calculated separately from those resulting from land use change. The method used for the national figures has been repeated separately for each Local Authority as the required cropland area data are available (see Figure 7).

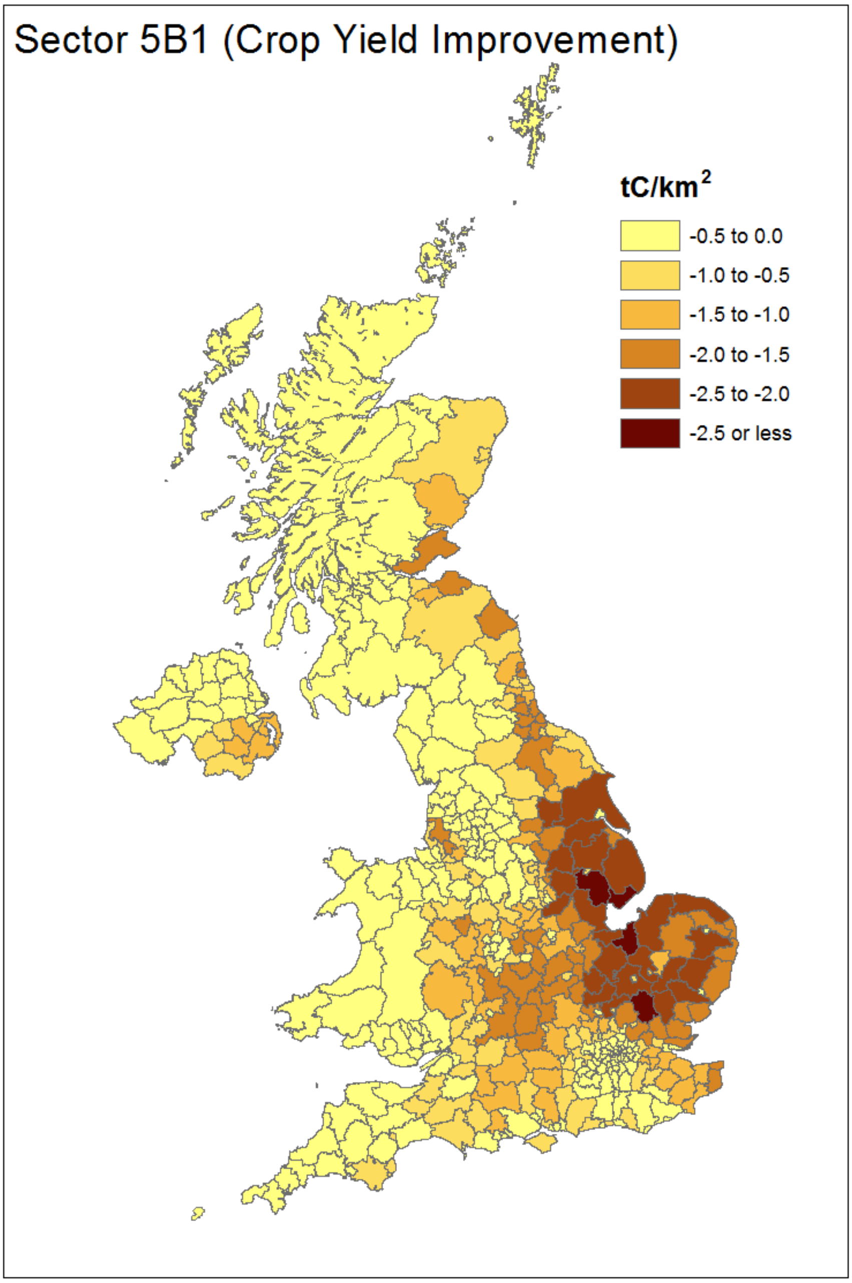

Figure 7: Carbon removals due to increases in Crop yield. This is part of the Cropland remaining Cropland category.

Peat Extraction

Carbon emission from peat extraction is calculated for the National Inventory based on data published in the *Mineral Extraction in Great Britain Business Monitor PA1007.* Historically, the data were available for smaller regions, e.g. North East England, but not at the LA level. It was then assumed that the data applied to all the LAs within the region in proportion to their area. For 2009 and 2010, we have peat extraction data at Local Authority scale. 2011 peat extraction data were not received in time to be included in the 1990 – 2011 inventory calculations. he peat extraction data gives the area of origin of the peat and we have assumed that the carbon emission applies to this area (see Figure 8). Due to rounding errors in the published figures, the sum of the extraction areas for the regions does not exactly equal the national totals. The emissions per LA have been adjusted in proportion to their area so that the total equals the submitted national emission. Peat extraction is now reported in 5D (Wetlands).

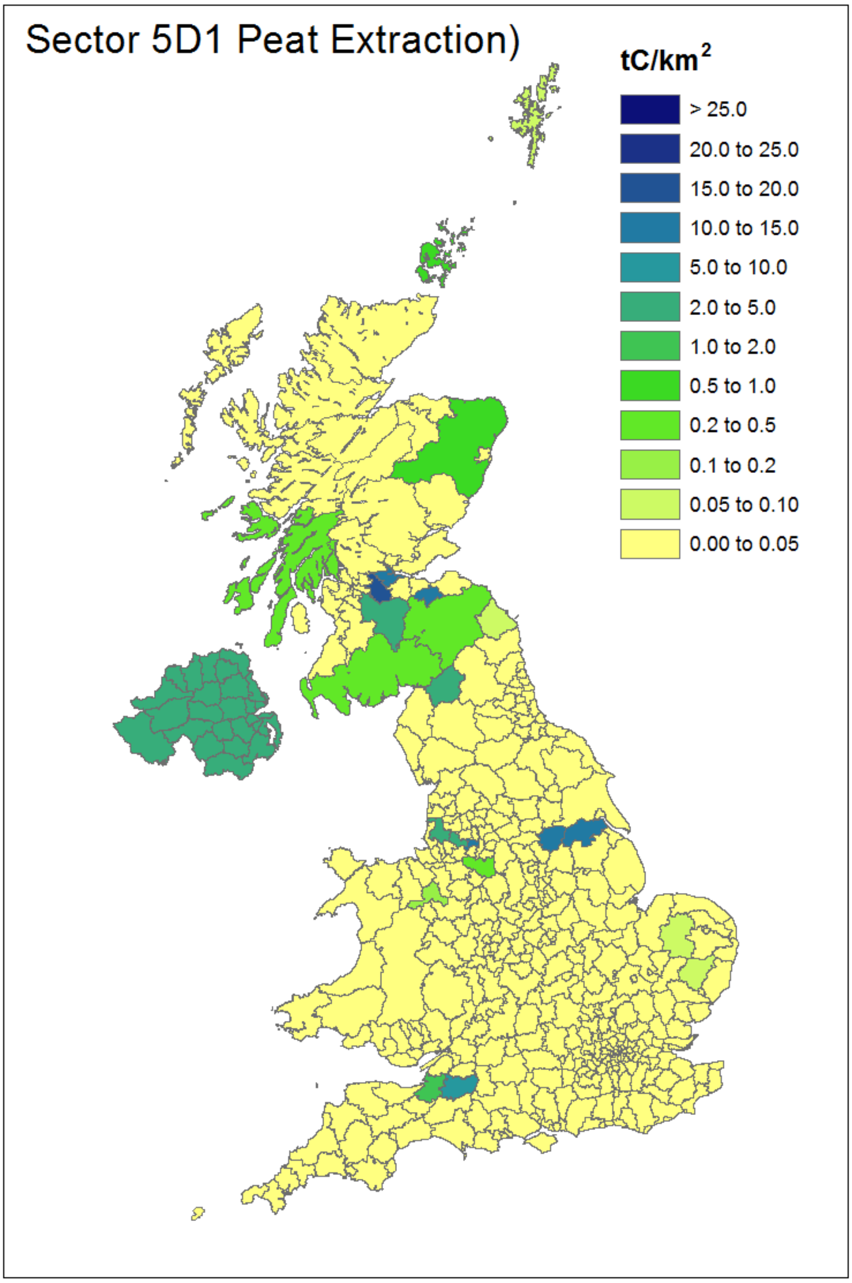

Figure 8: Carbon emissions, tC/km^2, resulting from the extraction of peat for horticultural use. This is part of the Grassland remaining Grassland category.

Lowland Drainage

Lowland wetlands in England were drained many years ago for agricultural purposes and continue to emit carbon from the soil. Bradley (1997) has estimated that there is 1500 km^2 of lowland fen or peatland that has been drained in the past and is still emitting carbon dioxide. He states that the drained area is mostly in the East Anglian Fen and Skirtland with limited areas in the rest of England.

To estimate emissions at Local Authority scale, we compared existing areas of lowland peat with the areas of GB below sea level (this is assumed to have resulted from past drainage). This area was split by local authority and the individual areas calculated. Areas of lowland drainage (excluding the area below sea level) were assigned in proportion to the area of peatland still existing within local authority areas. Based on comments by Bradley and in Burton and Hodgson (1987) areas of peatland in the Norfolk broads, the south of England and on ground above 50m were excluded from the analysis. The remaining areas of lowland peat occurred in the northwest and east of England, and in the Somerset levels area. Of the 1500km^2, 860km^2 is estimated to occur in the 6 fenland LAs, or 979km^2 in the wider "fenland and skirtland" area. Figure 9 shows the estimated distribution and emissions (tC/km^2).

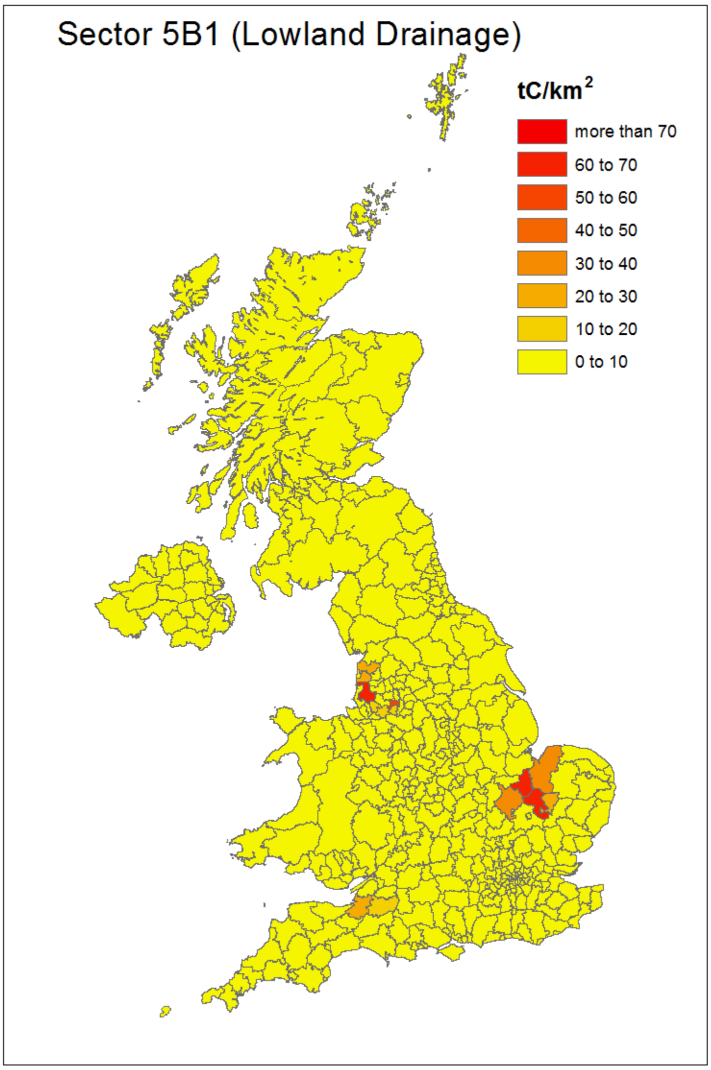

Figure 9: Carbon emissions due to lowland drainage in previous years.

Deforestation

Emissions due to deforestation are disaggregated into deforestation to Cropland (reported in 5B), Grassland (5C) and deforestation to Settlements (5E).

The area of land deforested in each Local Authority is not currently available so we assume that the area deforested is proportional to the total area of forest in each LA, and that the relative conversion of forest to either Settlement or Grassland is the same for each LA (see Figure 10).

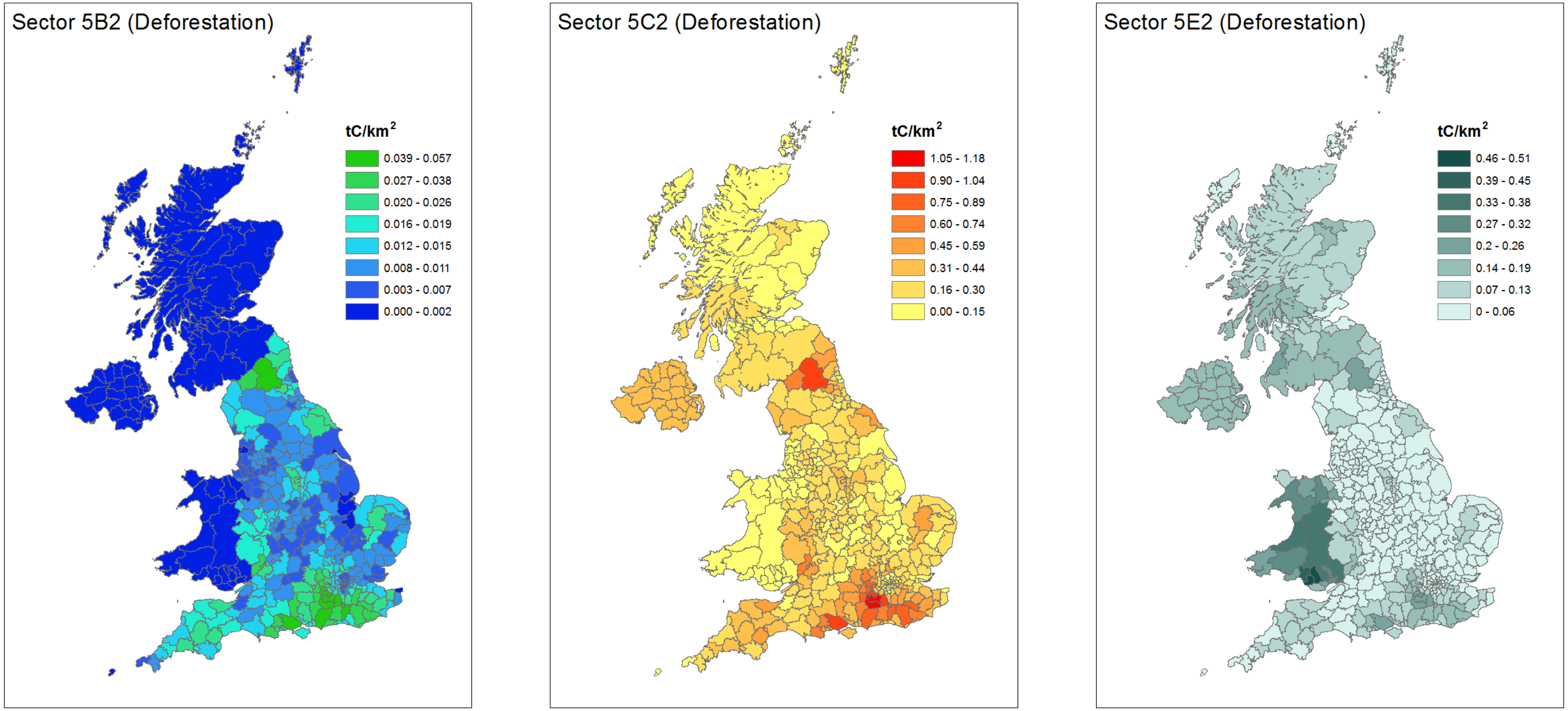

Figure 10: Emissions of carbon resulting from deforestation to Grassland or Settlements.

Wildfires

Information on areas of wildfires in Great Britain and in Northern Ireland is available. As areas of wildfires by Local Authority are not collected, the emissions are assigned between LAs in proportion to the total area of forest land in each LA. The results of this assignment can be seen in Figure 11.

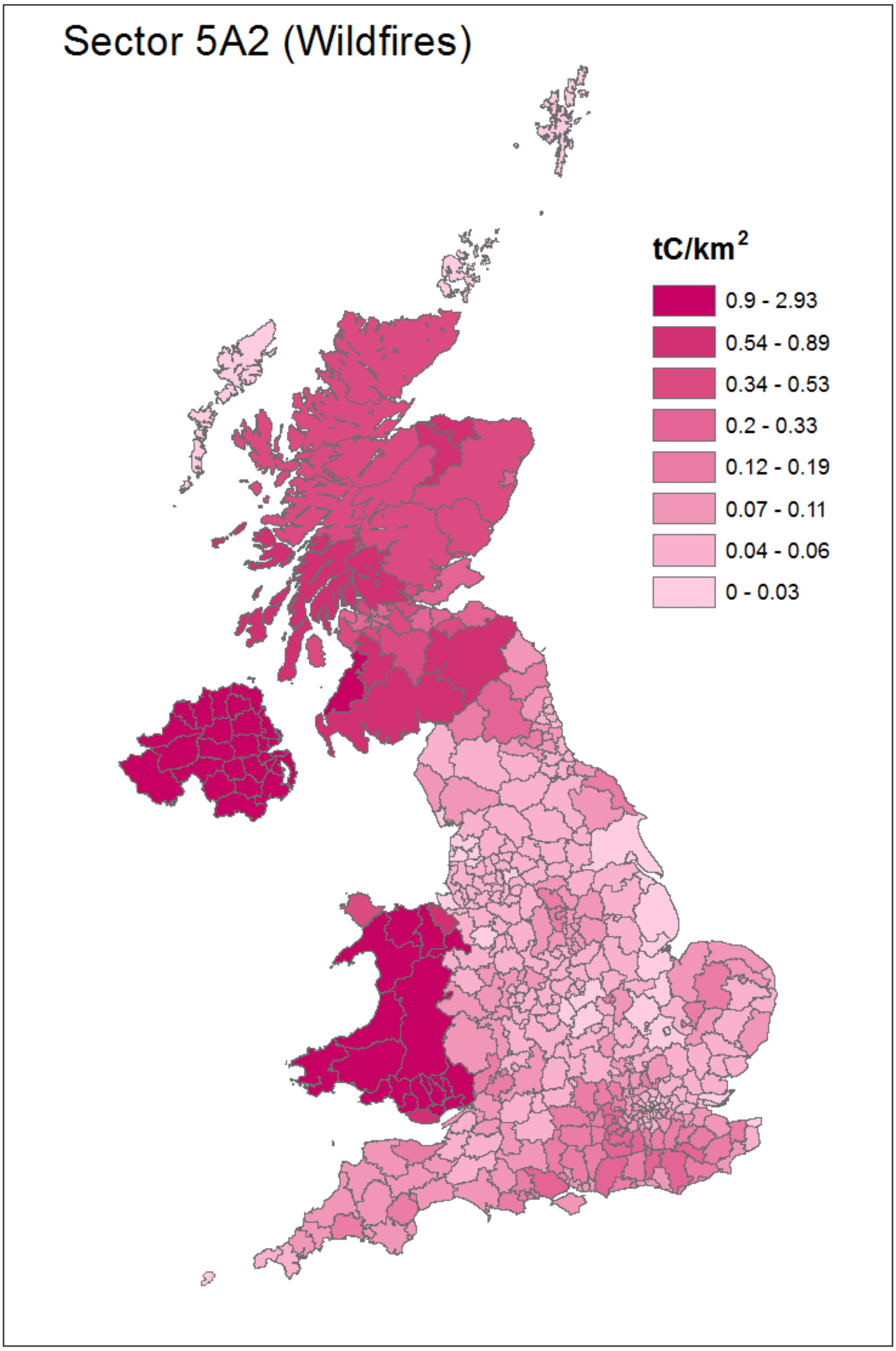

Figure 11: Emissions of carbon resulting from wildfires on Forest Land

Sector 5 Totals Summary

The total carbon emissions for the UK land use, land use change and forestry sector (excluding harvested wood products which cannot be mapped) are shown in Figure 12.

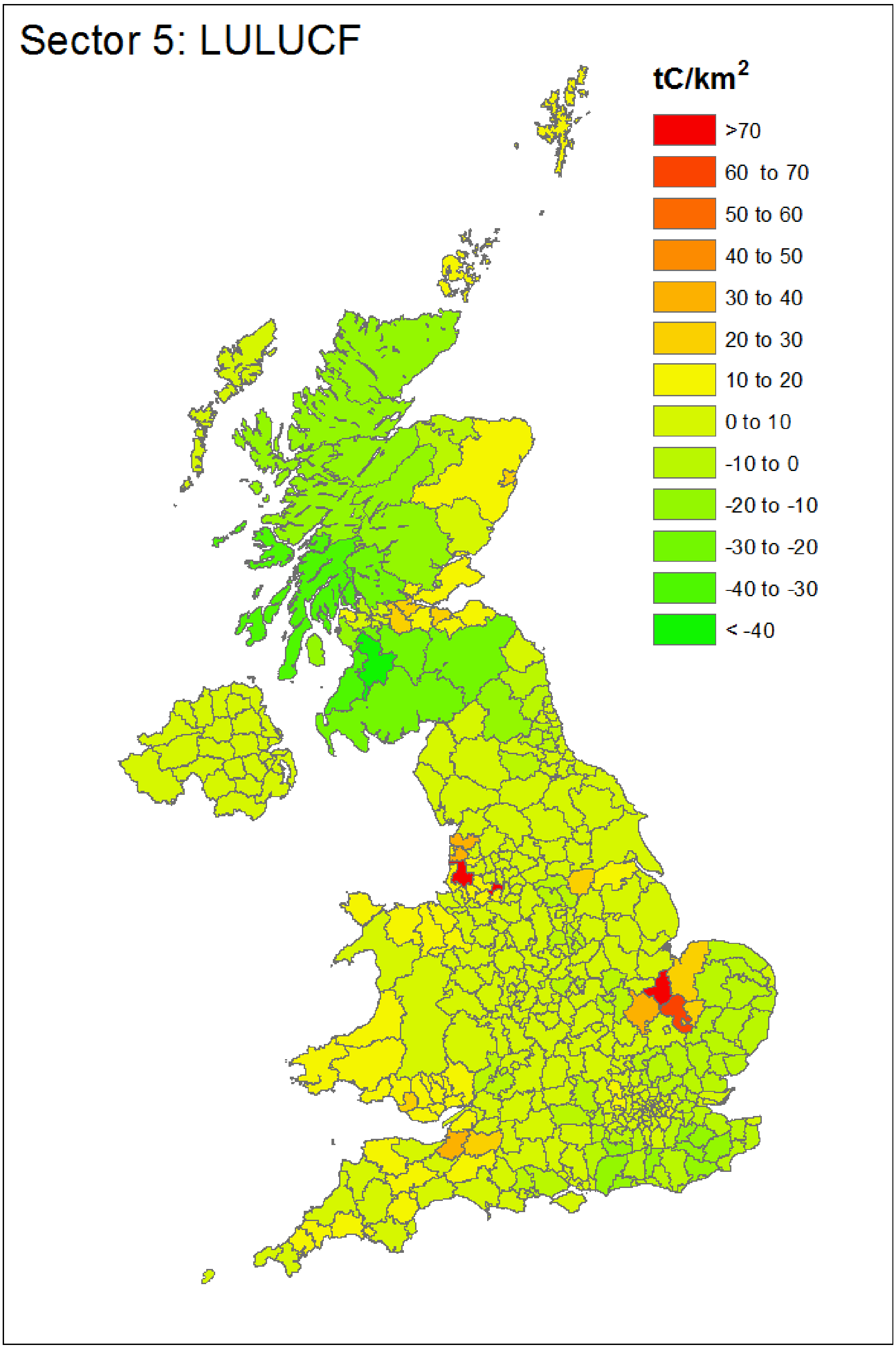

Figure 12: The total carbon emissions or removals for Sector 5 across the UK.

Recalculations of Previous Years' Data.

Previous years' emissions and sequestrations have been recalculated to include improved data. The main reasons for change are:

a) Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage
b) New data on wildfires
c) Biomass and DOM losses following deforestation are now estimated using country-specific biomass densities
d) Peat Extraction sites that are no longer active are assumed to be still producing on-site emissions. 2009-2010: new activity data published
e) Adjustment of grass/cropland area split for liming

Table 2 Reasons for the main changes between the 2010 and 2011 inventory

Year	Local Authority	DA	Nature of Overall Change	Reason for change
2005	Aberdeenshire	Scotland	Increased emission	a, b
2005	Highland	Scotland	Increased emission	a,b,c
2005	Fermanagh	Ni	Increased emission	a,d
2005	Limavady	NI	Increased emission	a
2006	Aberdeenshire	Scotland	Increased emission	a,b
2006	Dumfries and Galloway	Scotland	Increased sequestration	a,c
2006	Highland	Scotland	Reduced sequestration	a,b,c
2006	Scottish Borders	Scotland	Increased sequestration	a
2006	Gwynedd	Wales	Increased sequestration	a
2006	Powys	Wales	Increased sequestration	a
2006	Fermanagh	NI	Increased emission	a
2006	Tynedale	England	Increased sequestration	a
2007	Aberdeenshire	Scotland	Increased emission	a,b
2007	Dumfries and Galloway	Scotland	Increased sequestration	a
2007	Highland	Scotland	Reduced sequestration	a,b
2007	Scottish Borders	Scotland	Increased sequestration	a
2007	Carmarthenshire	Wales	Increased sequestration	a
2007	Gwynedd	Wales	Increased sequestration	a
2007	Powys	Wales	Increased sequestration	a
2007	Fermanagh	NI	Increased emission	a
2008	Dumfries and Galloway	Scotland	Increased sequestration	a
2008	Highland	Scotland	Reduced sequestration	a,b,c
2008	Scottish Borders	Scotland	Increased sequestration	a
2008	Carmarthenshire	Wales	Increased sequestration	a
2008	Gwynedd	Wales	Increased sequestration	a
2008	Monmouth	Wales	Increased sequestration	a
2008	Pembrokeshire	Wales	Increased sequestration	a
2008	Powys	Wales	Increased sequestration	a
2008	Fermanagh	NI	Increased emission	a
2008	Tynedale	England	Increased sequestration	a

2009	Doncaster	England	Increased emission	d
2009	Mendip	England	Increased emission	d
2009	North Lincolnshire	England	Increased emission	d
2009	Dumfries and Galloway	Scotland	Increased sequestration	a
2009	Highland	Scotland	Reduced sequestration	a,b,c
2009	Scottish Borders	Scotland	Increased sequestration	a
2009	Carmarthenshire	Wales	Increased sequestration	a
2009	Gwynedd	Wales	Increased sequestration	a
2009	Monmouth	Wales	Increased sequestration	a
2009	Pembrokeshire	Wales	Increased sequestration	a
2009	Powys	Wales	Increased sequestration	a
2009	Fermanagh	NI	Reduced sequestration	a,d
2010	Doncaster	England	Increased emission	d
2010	North Lincolnshire	England	Increased emission	d
2010	Dumfries and Galloway	Scotland	Increased sequestration	a
2010	Highland	Scotland	Reduced sequestration	a,c
2010	Scottish Borders	Scotland	Increased sequestration	a
2010	Ceredigion	Wales	Increased emission	b
2010	Gwynedd	Wales	Increased emission	b
2010	Powys	Wales	Increased emission	b,e
2010	Fermanagh	NI	Increased emission	a,d
2010	Tynedale	England	Increased sequestration	a

Trend Analysis

For the trend analysis, we have examined seven years of Local Authority (LA) scale emissions and removals (2005-2011) for sector 5 (as calculated for the 2011 inventory year). We calculated the "maximum minus minimum" Sector 5 annual totals within the seven year period. We sorted the Local Authorities on these differences to find those with the greatest changes. The top ten, based on gigagrams of carbon per local authority (Gg C per LA) are shown in Figure 13. Highland has the largest change within the seven year period; with the area becoming less of a sink for carbon between 2005 and 2011 but the large change happened between 2009 and 2010. The area has been sequestering carbon between 2005 and 2011.

We see that by using the measure, Gg C per LA, the large changes tend to be associated with the largest local authorities. The average area of LAs in the UK is 566 km^2, see **Error! Reference source not found.**. We also note that the large changes presented in Figure 13, are usually associated with forest land, see Figure 14. Soil carbon fluxes due to conversion take many decades to reach equilibrium and the trends observed are a consequence of a fall off in the sequestration potential of forest land planted many years ago. Large changes carbon stock in forest living biomass for some local authorities are due to forest management. The forest carbon model assumes standard forest management practice where plantations are harvested and replanted once they reach a certain age. Many conifer plantations in Scotland were planted in the mid-20th century and are now starting to come to maturity and being harvested. This loses a large stock of living biomass in the mature trees which is replaced with a much smaller stock in the young tree. C stocks in dead organic matter and harvested wood products (reported under 5G not 5A) increase at the same time.

The deforestation method is integrated with the forest carbon model, in that area losses are taken into account

Since areas across authorities differ widely, we have mapped emissions and removals in this report as tonnes of carbon per square kilometre (tC per km^2), otherwise maps tend to be dominated by the Highlands region of Scotland and other large LAs. The ten local authorities with the largest changes (in tonnes of carbon per square kilometre) over the six year period as are shown in Figure 15. These LAs are not the largest in area and forest land (sector 5A) is less frequently the main reason for the large changes, see Figure 16. With this measure (tC per km^2), forest land is the largest contribution to the changes for those LAs in Wales whereas for the LAs in England and Scotland, it is Land Use Change, see Figure 17 to Figure 19.

Table 3 The top ten LAs with the greatest changes within the six year period based on gigagrams of carbon per local authority (Gg C per LA).

Local Authority	DA	Area of LA (km^2)	Largest change between any 2 years in a 6 year period (GgC/LA/year)
Highland	**Scotland**	26277	124.61
Powys	**Wales**	5160	110.63
Argyll and Bute	**Scotland**	7153	92.45
Aberdeenshire	**Scotland**	6337	83.63
Dumfries and Galloway	**Scotland**	6455	82.63
Gwynedd	**Wales**	2595	64.39
Moray	**Scotland**	2244	48.28
Carmarthenshire	**Wales**	2393	38.62
Tynedale	**England**	2246	38.10
Ceredigion	**Wales**	1803	37.85

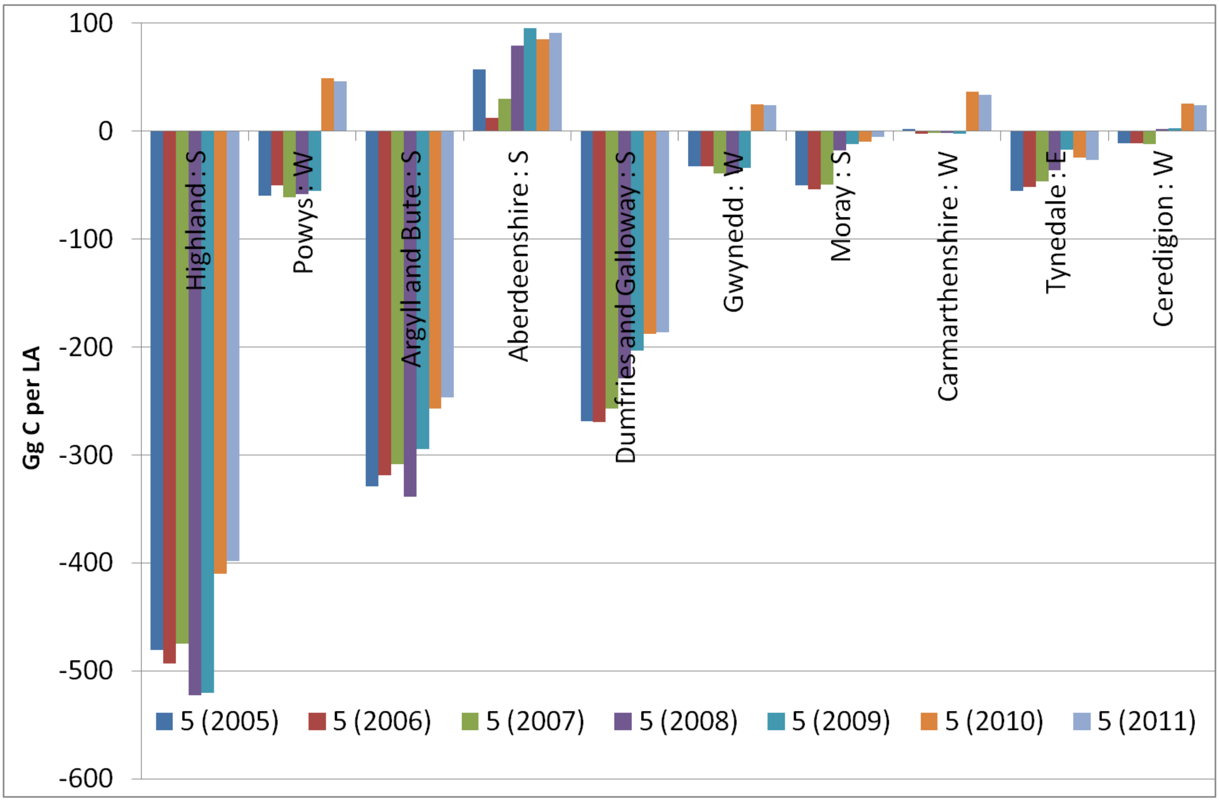

Figure 13: Sector 5 total emissions and removals for the ten local authorities with the largest changes within the period 2005 to 2011 as calculated in the 2011 inventory (Gg C per LA). Of these ten, Dumfries and Galloway in Scotland has the largest changes with changes diminishing in magnitude for each LA from left to right until Ceredigion in Wales.

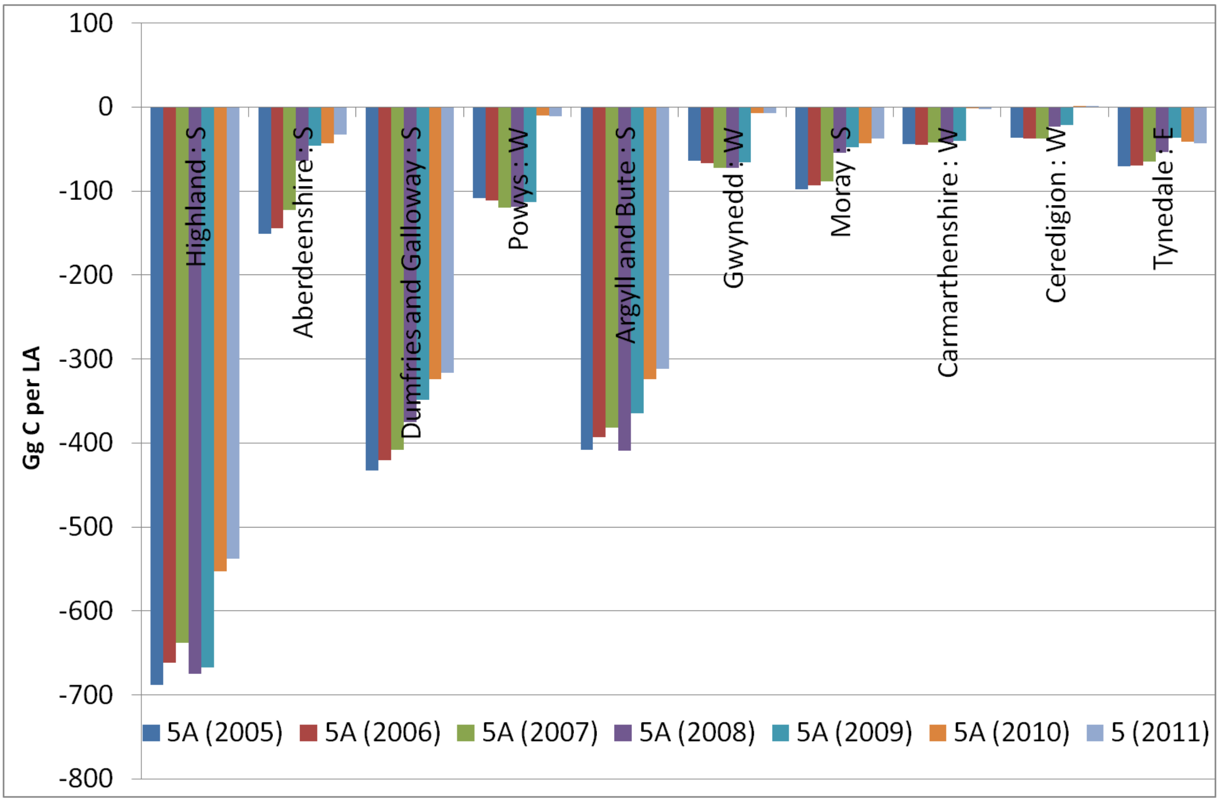

Figure 14: Sector 5A, forest land, emissions and removals in GgC per LA for the ten local authorities with the largest changes in Sector 5 totals, within the period 2005 to 2011.

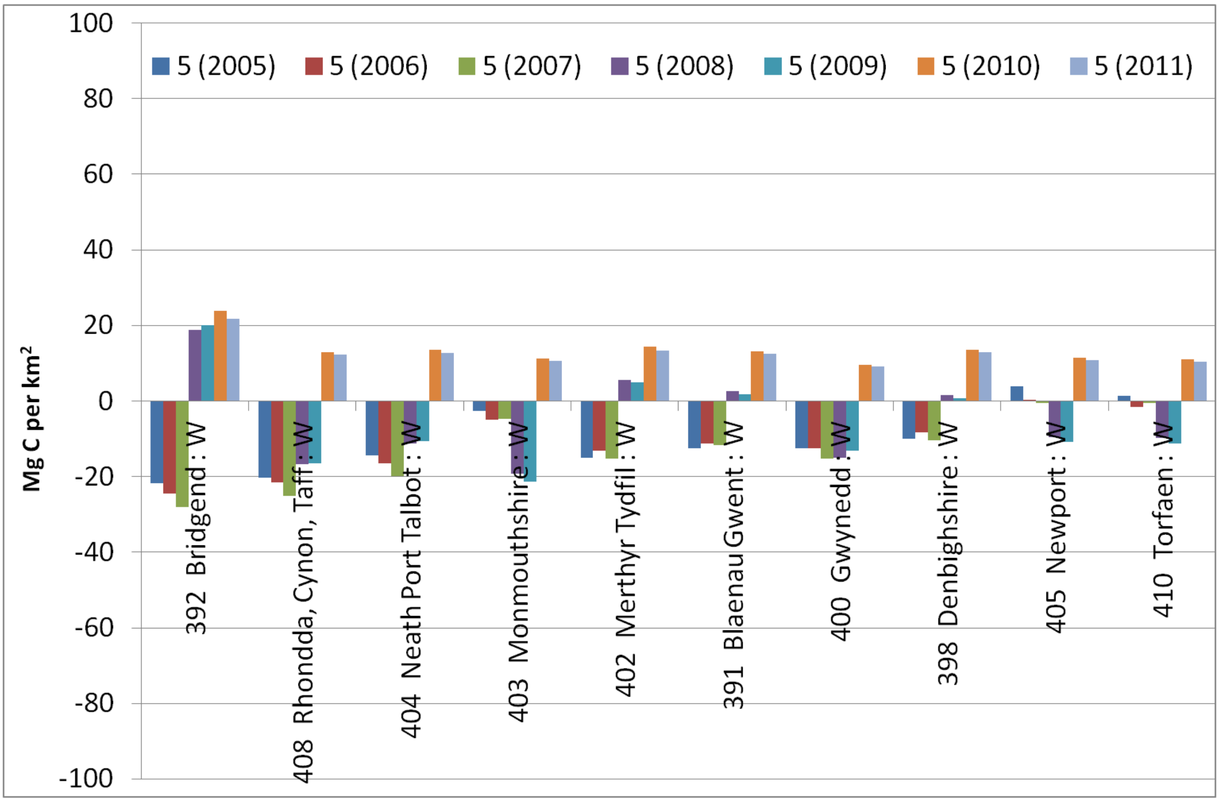

Figure 15. Sector 5 total emissions and removals for the ten local authorities with the largest changes within the period 2005 to 2011 as calculated in the 2011 inventory in tC per km^2. Of these ten, Bridgend in Wales has the largest changes with changes diminishing in magnitude for each LA from left to right until Torfaen in Wales.

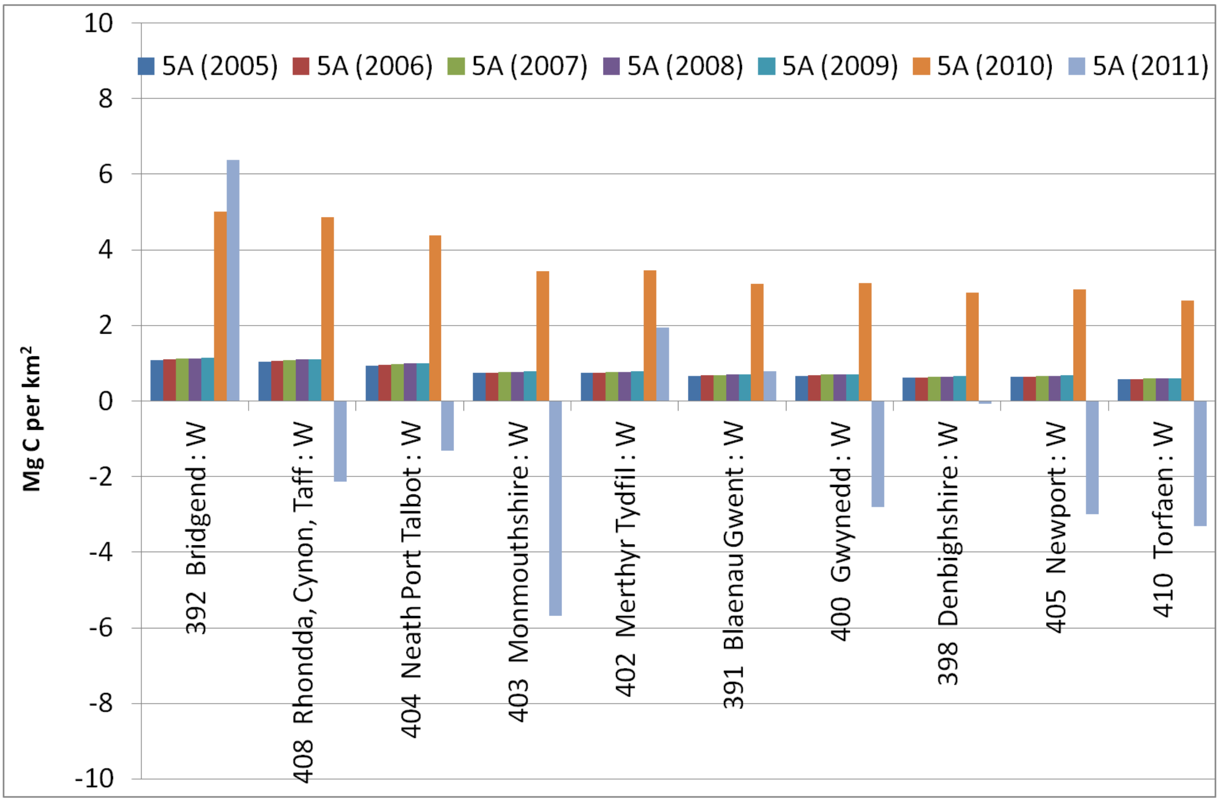

Figure 16. Sector 5A, forest land, emissions and removals in tC per km^2 for the ten local authorities with the largest changes in Sector 5 totals, within the period 2005 to 2011.

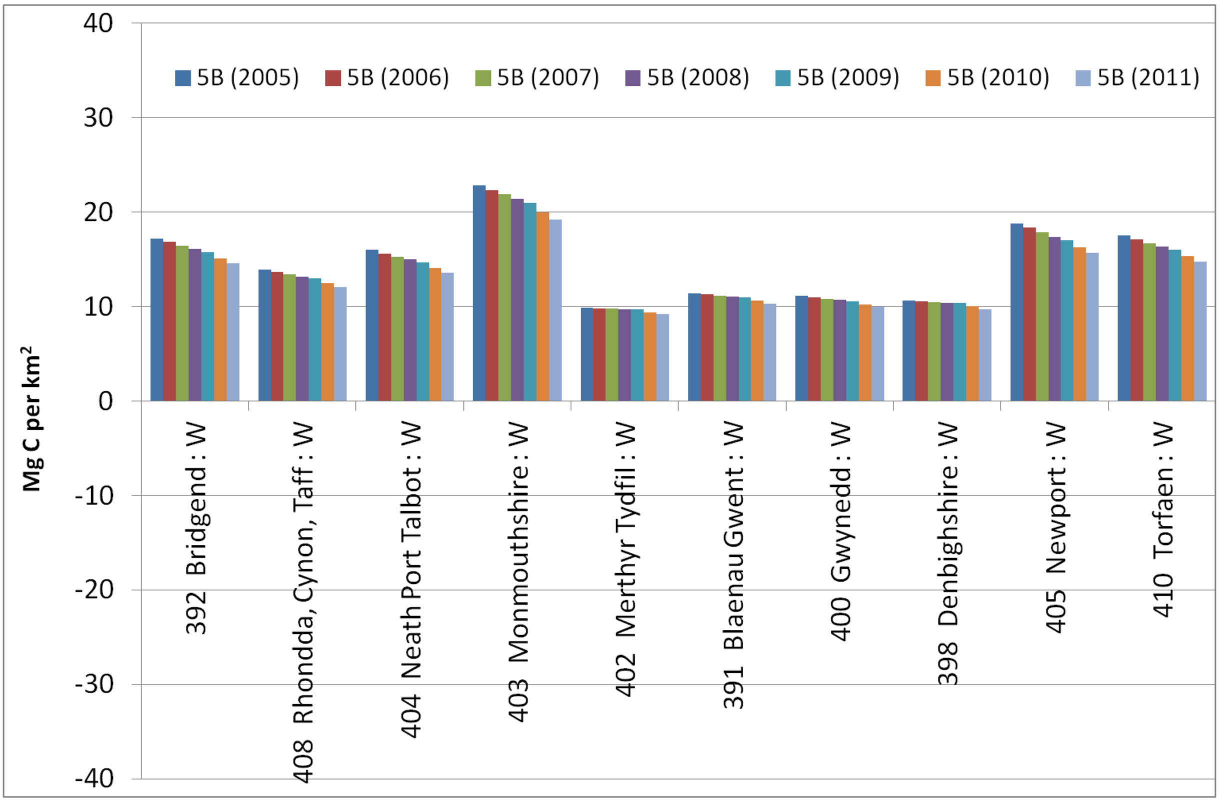

Figure 17. Sector 5B, cropland (soil), emissions and removals in tC per km^2 for the ten local authorities with the largest changes in Sector 5B totals, within the period 2005 to 2011

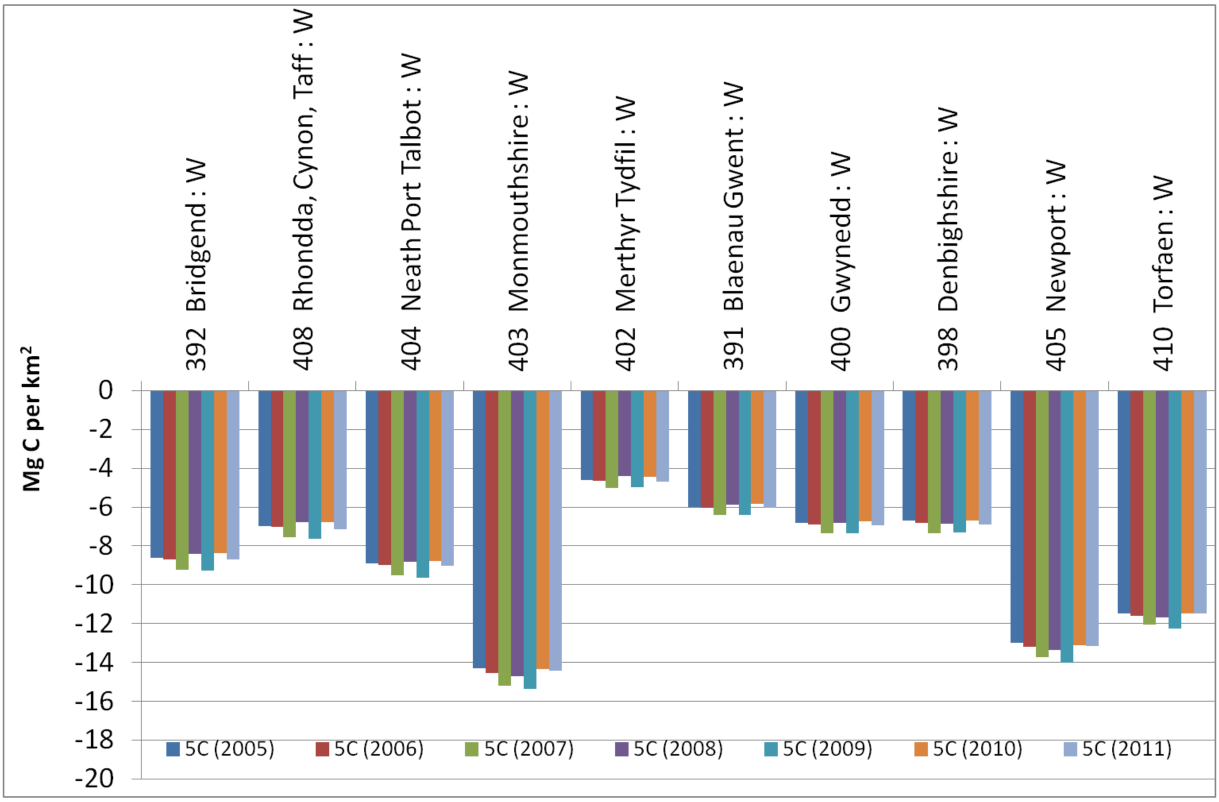

Figure 18. Sector 5C, grassland (soil), emissions and removals in tC per km^2 for the ten local authorities with the largest changes in Sector 5 totals, within the period 2005 to 2011

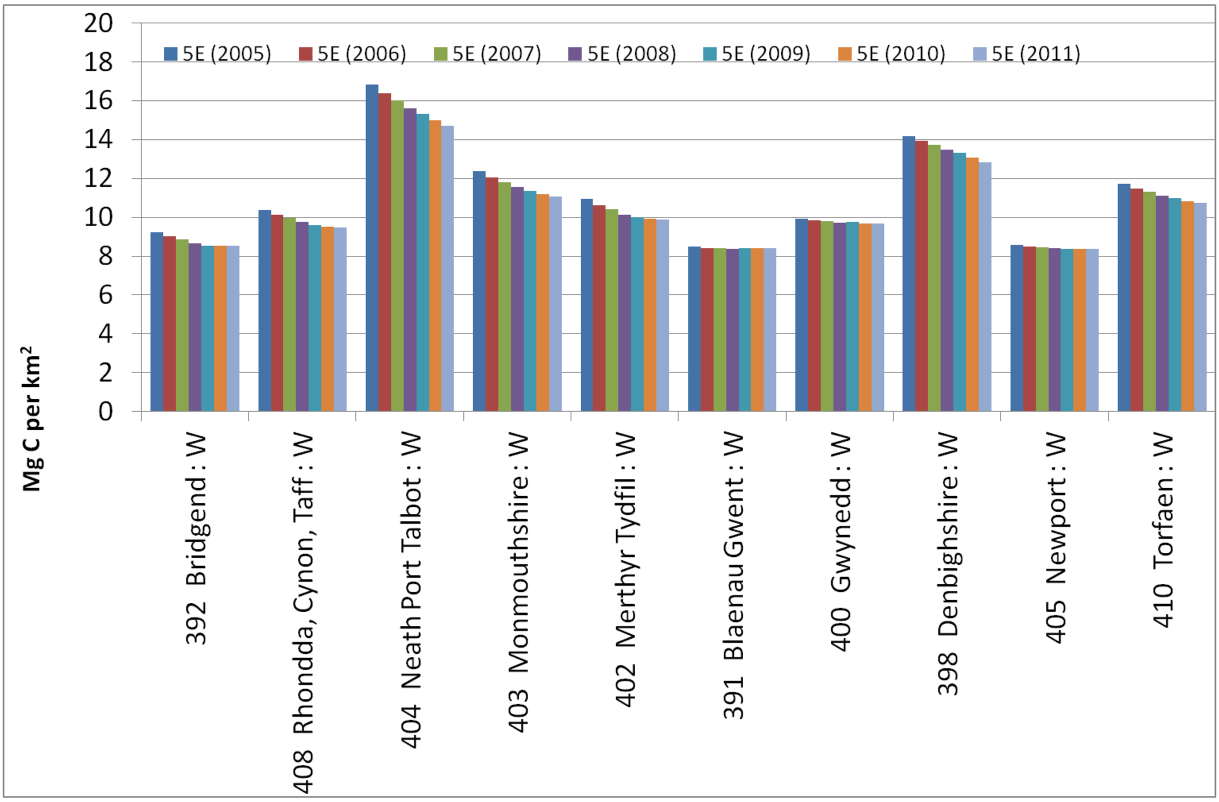

Figure 19. Sector 5E2, settlements (soil), emissions and removals in tC per km^2 for the ten local authorities with the largest changes in Sector 5 totals, within the period 2005 to 2011

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