Section 5

Mapping of carbon emissions and removals in the UK due to changes in stocks of soil carbon driven by land use change other than afforestation

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5.1. Introduction

5.1.1. Background

CEH (Edinburgh) annually prepares estimates of the uptake (removal from atmosphere) of carbon dioxide by afforestation and net loss or gain of carbon dioxide from soils (emissions to or removals from the atmosphere) for inclusion in the UK GHG Inventory. These estimates are made using dynamic models of change in stored carbon driven by land use change data. For forestry the model deals primarily with plant carbon and is driven by the area of land newly afforested each year. The changes in soil carbon are driven by estimated time series of land use transitions between semi-natural, cultivated (farm), woodland and urban. The models are run for each of the four devolved administrative regions of the UK and the data included in the annual national Greenhouse Gas Inventory. Until now no data has been reported in a map format.

In a previous contract between AEAT and CEH (Edinburgh) on mapping LUCF fluxes a disaggregation of removals for the three devolved regions of Great Britain was made for the plant carbon (afforestation) flux in 400 km^2 grid-cells for 1990 and 1995.

The work described here extends the LUCF mapping work by: i) preparing maps of net emissions in 1990 and other years from soils due to land use change in United Kingdom prior to that date.

Devolved region estimates of gains or losses of soil carbon due to land use change are estimated by CEH (Edinburgh) for the UK GHG Inventory using a model of change in soil carbon that follows an exponential pattern with time after a change in land use. The difference in mean soil carbon density between different land use for each devolved region is estimated and the rate of transition from one density to another is set for each type of transition between land use types. The land use change data is derived from transition matrices developed from Measuring Landscape Change (MLC), (see MLC, 1986) and Countryside Survey (CS) programmes carried out in 1947, 1980, 1984 and 1990 and summarised at the scale of the devolved regions.

Work has been undertaken in a separate project in CEH (Edinburgh) to build land use change matrices between 1990 and 1998 from the Land Cover Maps of Great Britain developed by ITE/CEH for those two years and the results could also be applied to disaggregating net emissions from soils. This work also showed that, although CS data on land use change at scales smaller than 10,000 km^2 had previously been considered to be unreliable, a good correlation with information from the land cover maps was achieved at much smaller scales.

Here we develop time series of land use change in 20 x 20 km grid-cells (to match those used for the afforestation fluxes) for the period from using the Countryside Surveys covering periods1984 to 1990 and 1990 to 1998. 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 can then be used for each grid-cell in a model analogous to that presently used for the full devolved area.

5.2. Method

5.2.1. Dividing the UK into 20km by 20km grid squares

The basic resolution for mapping of emissions and removals has been set to the 1km by 1km squares covering Great Britain and the Isle of Man. There are a total of 240243 1km points. Land use change information from the Countryside Surveys would not be reliable at this scale. A grid of 20 km by 20 km was used for analysis of afforestation fluxes (Milne & Brown, 2003) and is used here for compatibility.

These 240243 1km points have been assigned to the 804 larger grid squares of 20km by 20km (see Figure 5-1). Each large square can contain between 1 and 400 1km points depending whether the region is entirely land or contains sea or other bodies of water. The centre of each circle in Figure 5-1 shows the location of the SW corner of a 20km square and the area of each circle indicates the amount of land (1km squares) enclosed by the larger square. Each 20km by 20km grid square is also assigned to England, Scotland or Wales according to the dominant country out of the 400 smaller points, as indicated by the colour of each point shown on the map. This approximation allocates 127887km^2 to England, 86983km^2 to Scotland and 24715km^2 to Wales. The Isle of Man accounts for 7 of the grid squares and these have been discarded, as no land use information is currently available. The axes in Figure 5-1 show the Easting and Northing coordinates of the National Grid used to identify each square.

Similarly, Northern Ireland contains 13466 1km squares that can be allocated to 55 20km by 20km squares (Figure 5-2). Note that the National Grid coordinate system for Northern Ireland is not the same as that used for Great Britain. The Easting and Northing coordinates shown in Figure 5-1 and Figure 5-2 cannot be used directly to plot the full UK data on one map without further calculations.

In total, there are 852 grid squares across the UK that will be used to map carbon flux due to land use change.

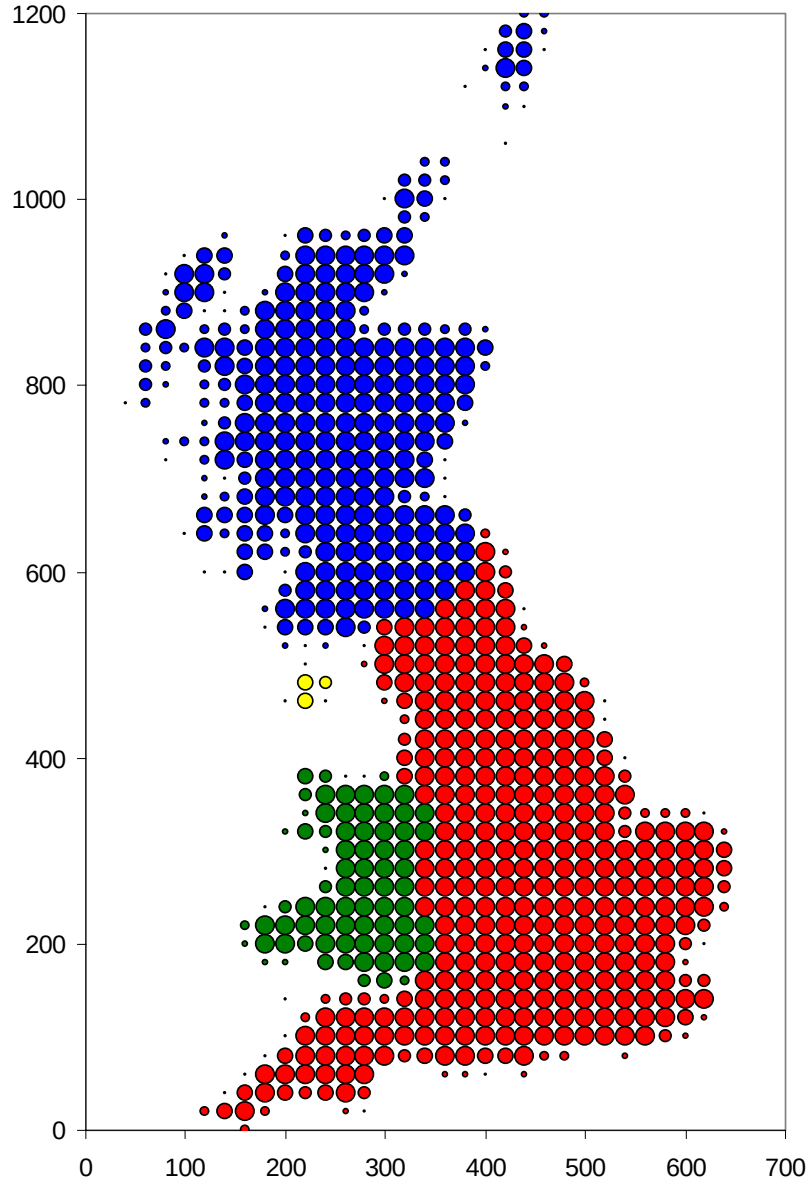

Figure 5-1: Scotland, England, Wales and the Isle of Man showing the location of the 804 20km by 20km grid squares. The relative size of each circle indicates the number of 1km points contained within the square (1 to 400).

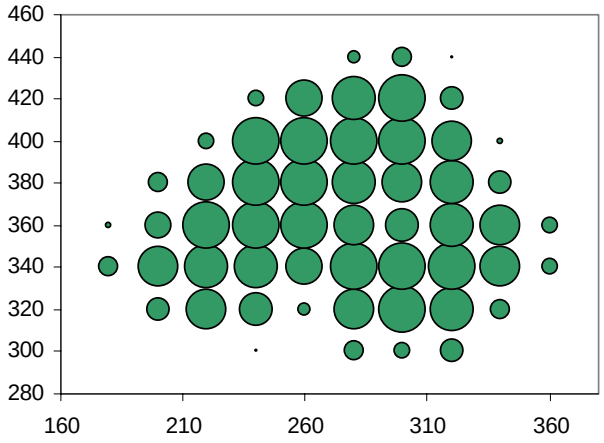

Figure 5-2: Northern Ireland showing the location of the 55 20km by 20km grid squares.

5.2.2. Land Use Change Matrices

For this exercise six basic land use types were used

- Woodland
- Natural
- Farm, Pasture (grassland)
- Farm, Arable (cropland)
- Urban
- Other

and the rate at which areas of land change from one use to another within these categories for the seven decades 1950's to 2010's. A typical land use change (LUC) matrix is shown in Table 5-1, in this example the data are 1000s ha change for England between 1950 and 1959. For this exercise we do not use data for land areas that do not change use within these categories.

Table 5-1: An example of a land use change matrix (England, 1950 to 1959). Data are 1000 ha.

From \ ***To***	***Woods***	***Natural***	***Farm (Pasture)***	***Farm (Arable)***	***Urban***	***Other***
Woods		3.83	3.63	0.87	0.16	0.0
Natural	0.08		0.2	0.0	0.0	0.0
Farm (Pasture)	3.36	4.62		19.79	0.75	0.0
Farm (Arable)	2.01	0.95	51.34		1.34	0.0
Urban	0.51	0.12	10.15	5.96		0.0
Other	0.0	0.0	0.0	0.0	0.0	

The Countryside Survey contains information on land class for Great Britain on a 1km scale and sampled data relating land use change between 1984 and 1990 and between 1990 and 1998 to the land class. By querying this data we can draw up land use change matrices showing the total area of land changing from one use to another within each of the 797 squares (20 km by 20 km) of Great Britain, between the years given above.

The land use change matrix for the data 1984 to 1990 is assumed to be representative of the full decade 1980 to 1989, and the change of use of the land is assumed to be constant throughout the decade. Thus one sixth of the total change is assumed to take place for each year 1980 to 1989.

Similarly, the land use change matrix for the data 1990 to 1998 is assumed to be representative of the full decade 1990 to 1999, and the change of use of the land is assumed to be constant throughout the decade. Thus one eighth of the total change is assumed to take place for each year 1990 to 1999.

We assume that the land use change recorded between 1990 and 1999 also applies for years following 1999, thus the same rate of change is applied to each year in the decades 2000 to 2009 and 2010 to 2019.

For earlier decades 1950 to 1979, the land use change information is only available (from the Monitoring Landscape Change data) as country totals for England, Scotland and Wales. To disaggregate the land use change across the countries, we assume the pattern of change is uniform across the region and will therefore be distributed across 20km by 20km squares in proportion to the number of 1km land squares in each grid square (see Figure 5-1).

An adjustment is applied to the data for all decades to align the values for afforestation and deforestation with those reported by Forestry Commission and use in modeling of removals and emissions for these activities.

The Countryside Survey data does not cover Northern Ireland. For the 55 grid squares covering this region we use the full regional information, distributed in proportion to the number of $1km^2$ land squares as shown in Figure 5-2. See Chapter 2 Section 2.2.3 for further information on sources of data for Northern Ireland.

5.2.3. Calculating the Carbon flux

Each change of land use results in an exchange of carbon with the atmosphere. This may be due to changes in the soil as well as changes in the type of vegetation that defines the land type.

Milne (Chapter 2, Section 2.2.3 of this report) describes the method used to calculate the total carbon flux associated with each of the 30 possible land use changes, previously applied at the national scale. The convergence rates and C change for each land use change for each country calculated by Milne are applied at the 20km x 20km scale. Table 5-2 gives typical values for a C change matrix.

Table 5-2: An example of the estimated C change (England).

From \ *To*	***Woods***	***Natural***	***Farm (Pasture)***	***Farm (Arable)***	***Urban***	***Other***
Woods		24.6	24.6	32.0	83.5	0.0
Natural	-21.2		0.0	22.8	78.6	0.0
Farm (Pasture)	-21.2	0.0		22.8	78.6	0.0
Farm (Arable)	-31.2	-23.0	-23.0		52.3	0.0
Urban	-87.0	-76.1	-76.1	-53.6		0.0
Other	0.0	0.0	0.0	0.0	0.0	

5.2.3.(a) Midpoint estimates

For each of the 852 grid squares across the UK the main calculations, for each year from 1990 onwards, give

1. ‘Old flux’ - Flux of carbon due to land use changes between 1950 and 1979
2. ‘New flux’ – Flux of carbon from due to land use changes between 1980 to 2020
3. ‘ToGrass’ - the total C flux (old and new) associated with changes to grassland (natural + farm pasture).
4. ‘To Crop‘ - the total C flux (old and new) associated with changes to cropland (farm arable).
5. ‘To Settle‘ - the total C flux (old and new) associated with changes to urban (settlements).
6. ‘To Other‘ - the total C flux (old and new) associated with changes to other land types.
7. ‘Net‘ – the net carbon change

Sample output is mapped and shown in section 5.3.

5.2.3.(b) Monte Carlo estimates

There are uncertainties associated with the land use change data and carbon flux calculations. The mid-point estimates described above do not include these errors. In addition to the LUC

matrices used above we can calculate upper and lower bound matrices assuming a given error, say 30%. If we assume these and other parameters (rate of change, equilibrium change in soil carbon density) are uniformly distributed between lower and upper bounds, we can use Monte Carlo methods to select values and repeat the calculation many times to produce uncertainty estimate for the total carbon flux.

The Matlab program required to carry out the Monte-Carlo runs has been prepared but not yet used.

5.3. Results

Results for 1990 and 2003 are presented in Figure 5-3 to Figure 5-8. In each case a comparison is made with the emission or removal calculated for each of the devolved regions as part of the 2003 UK GHG Inventory (2005 submission) described in Chapter 2 of this report.

The results for each region of Great Britain for each land type show good agreement between the national estimate and the sum of the 20 km by 20 km grid cells. There is exact agreement for Northern Ireland as expected because the national rates of land use change data was applied to each grid cell but the agreement is a useful check of the programme coding.

5.3.1. Land Converted to Grassland

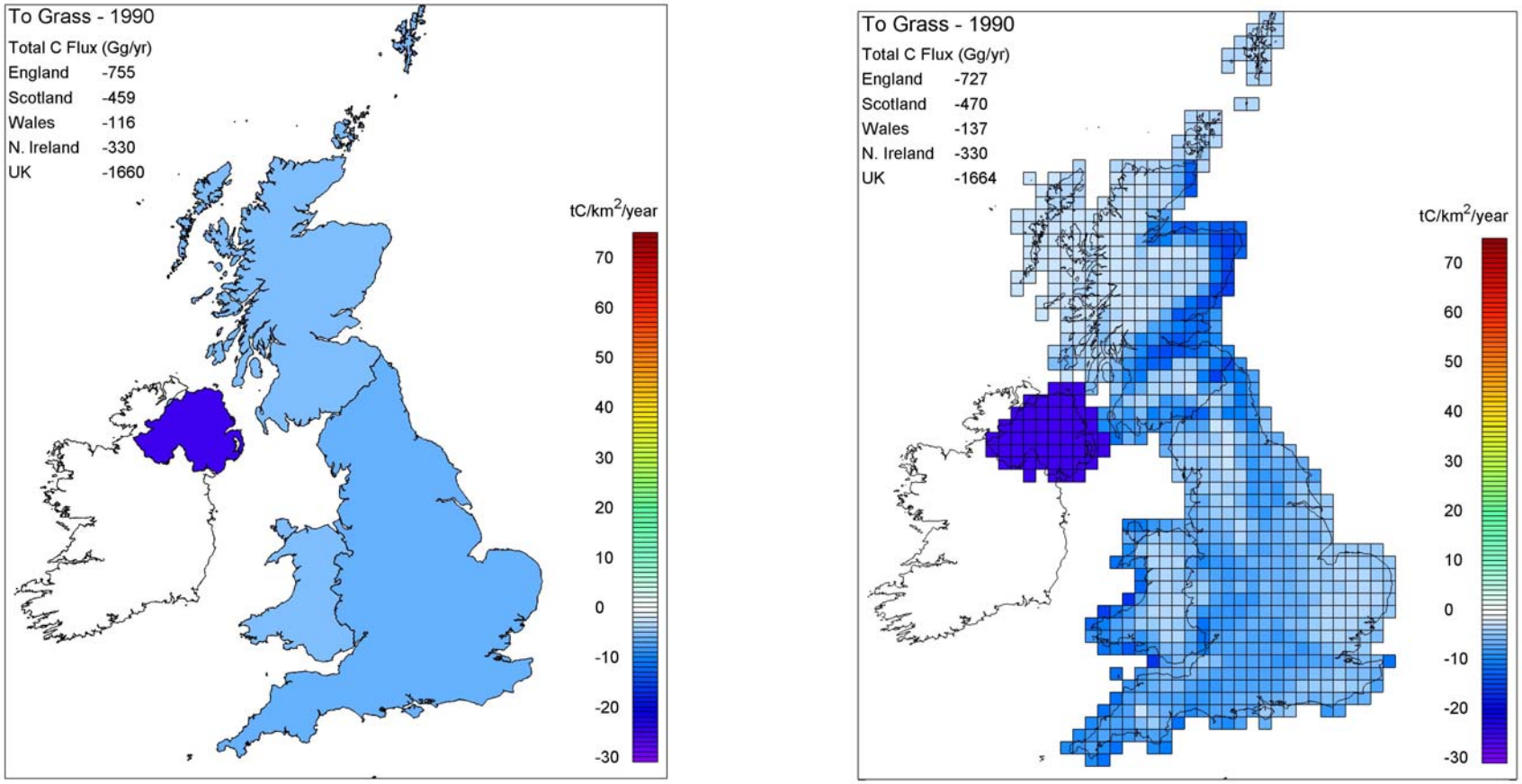

Figure 5-3: Carbon flux associated with land use change to grassland for 1990. National totals compared with 20km by 20km scale data.

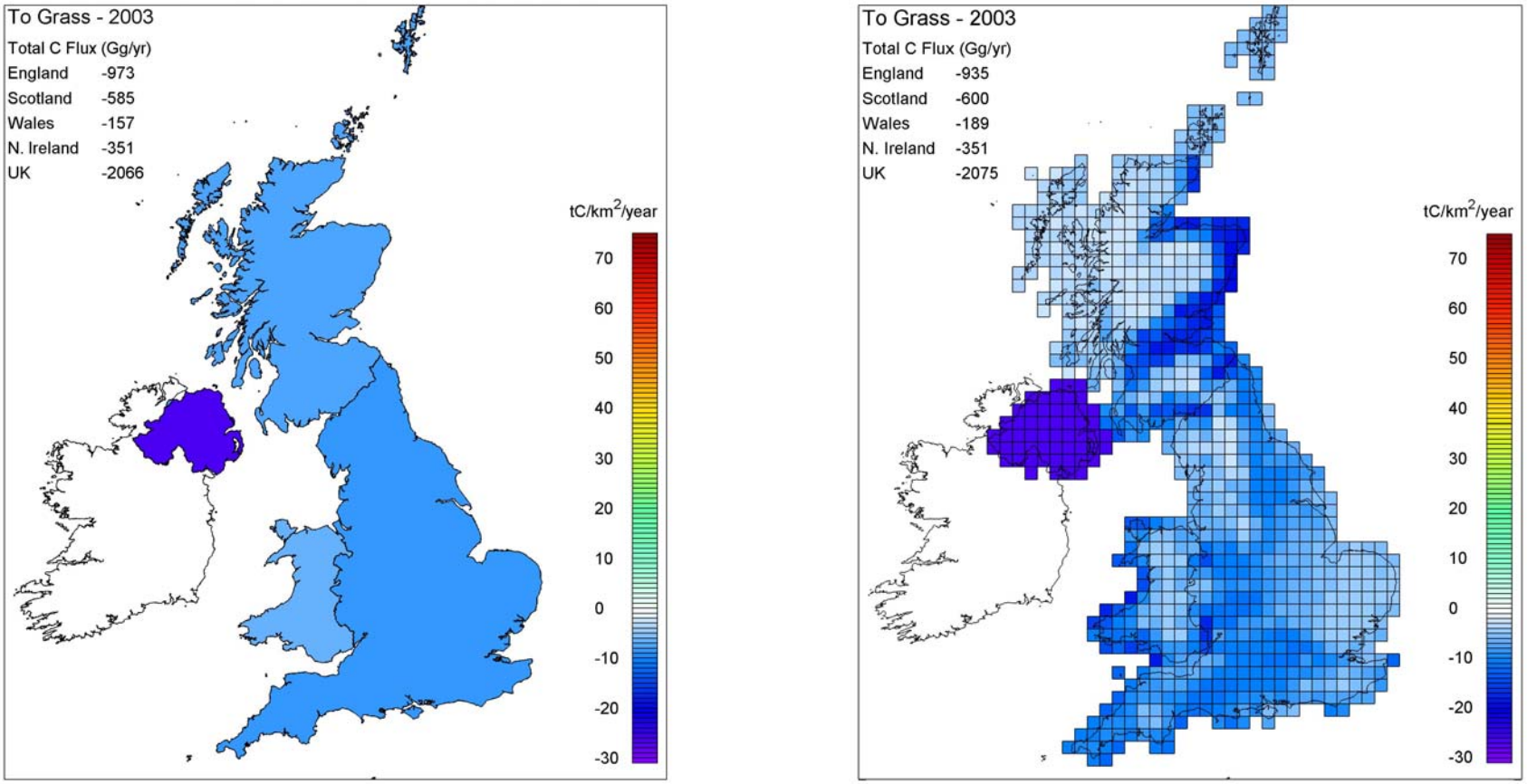

Figure 5-4: Carbon flux associated with land use change to grassland for 2003. National totals compared with 20km by 20km scale data.

5.3.2. Land Converted to Cropland

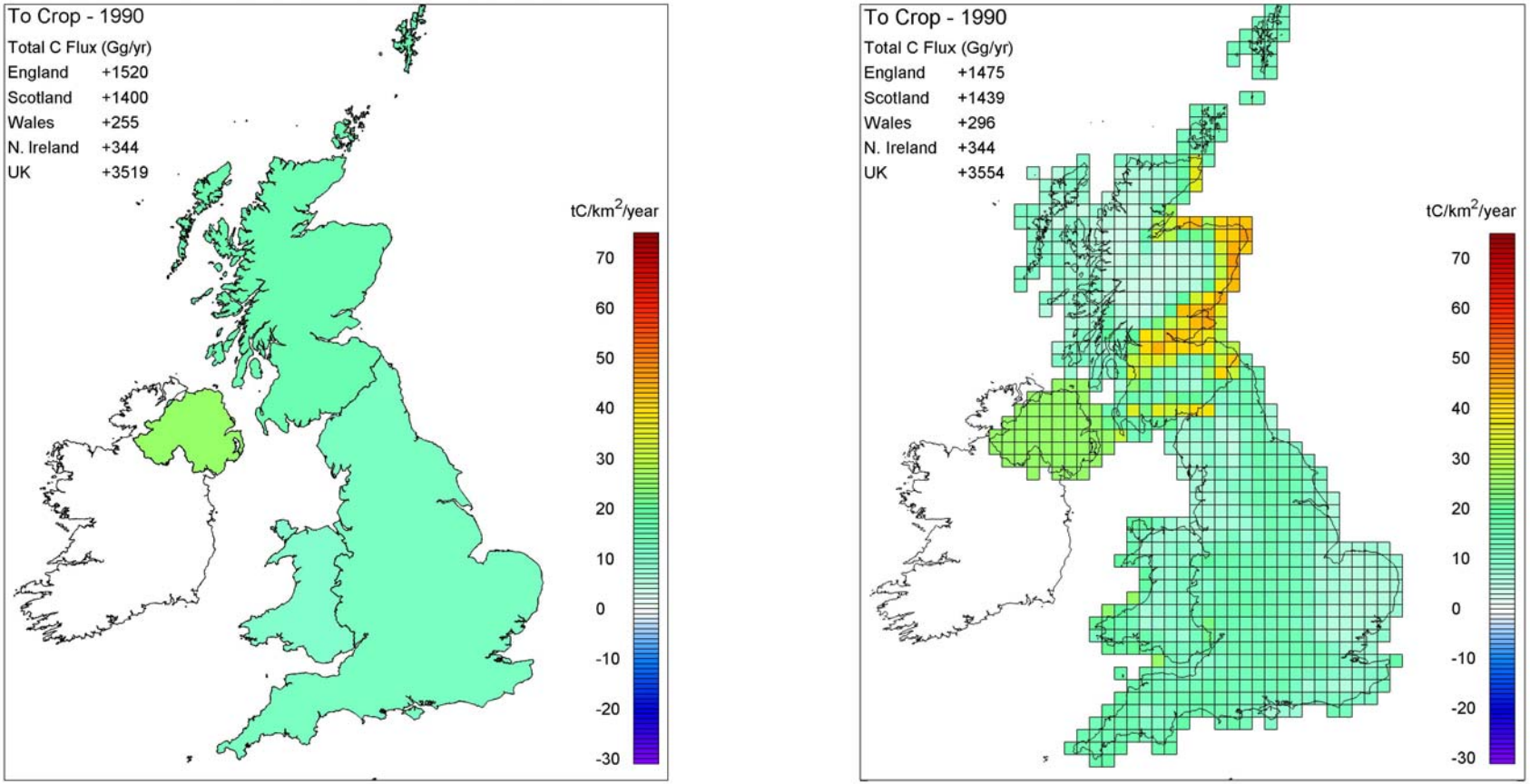

Figure 5-5: Carbon flux associated with land use change to cropland for 1990. National totals compared with 20km by 20km scale data.

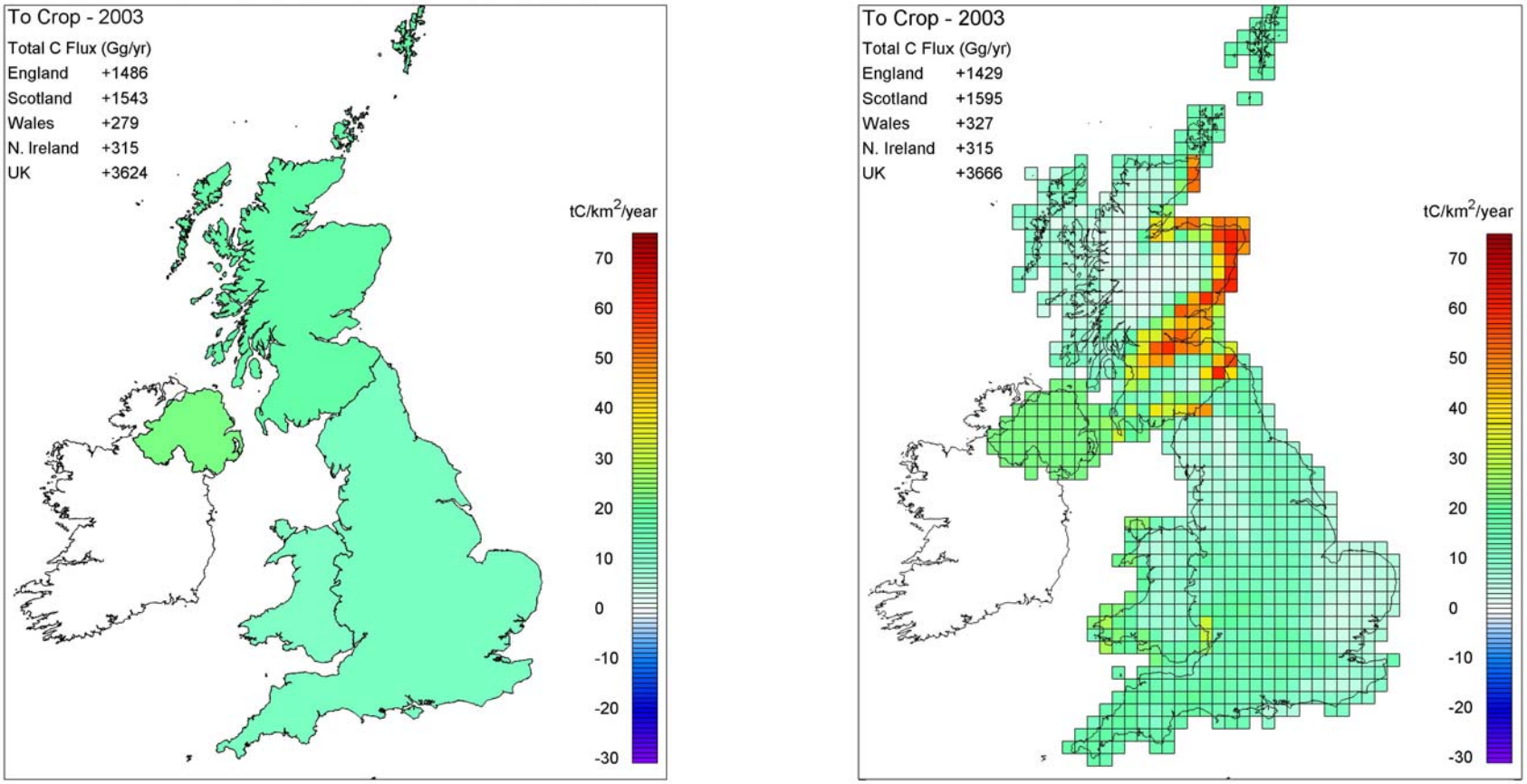

Figure 5-6: Carbon flux associated with land use change to cropland for 2003. National totals compared with 20km by 20km scale data.

5.3.3. Land Converted to Settlement

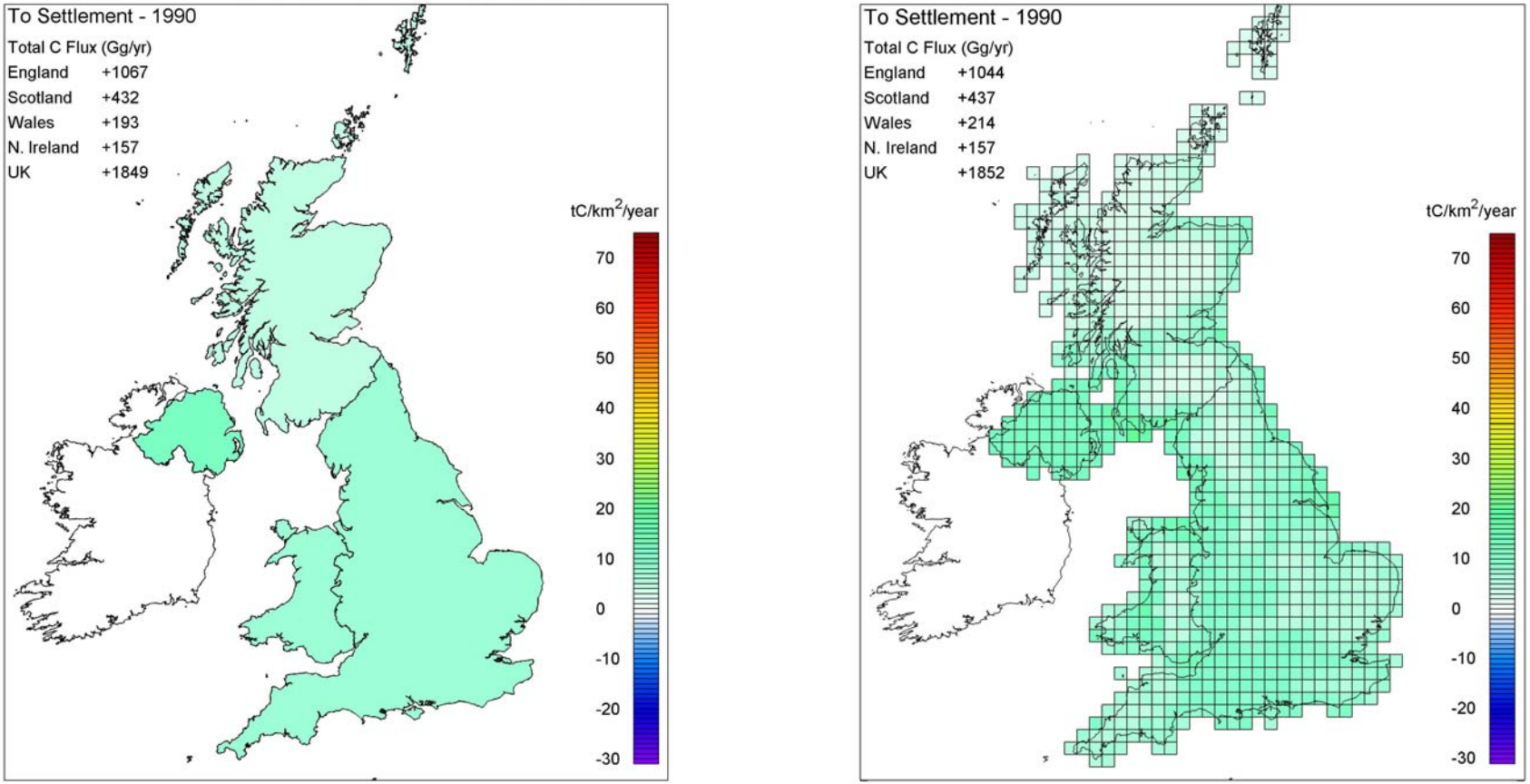

Figure 5-7: Carbon flux associated with land use change to settlements for 1990. National totals compared with 20km by 20km scale data.

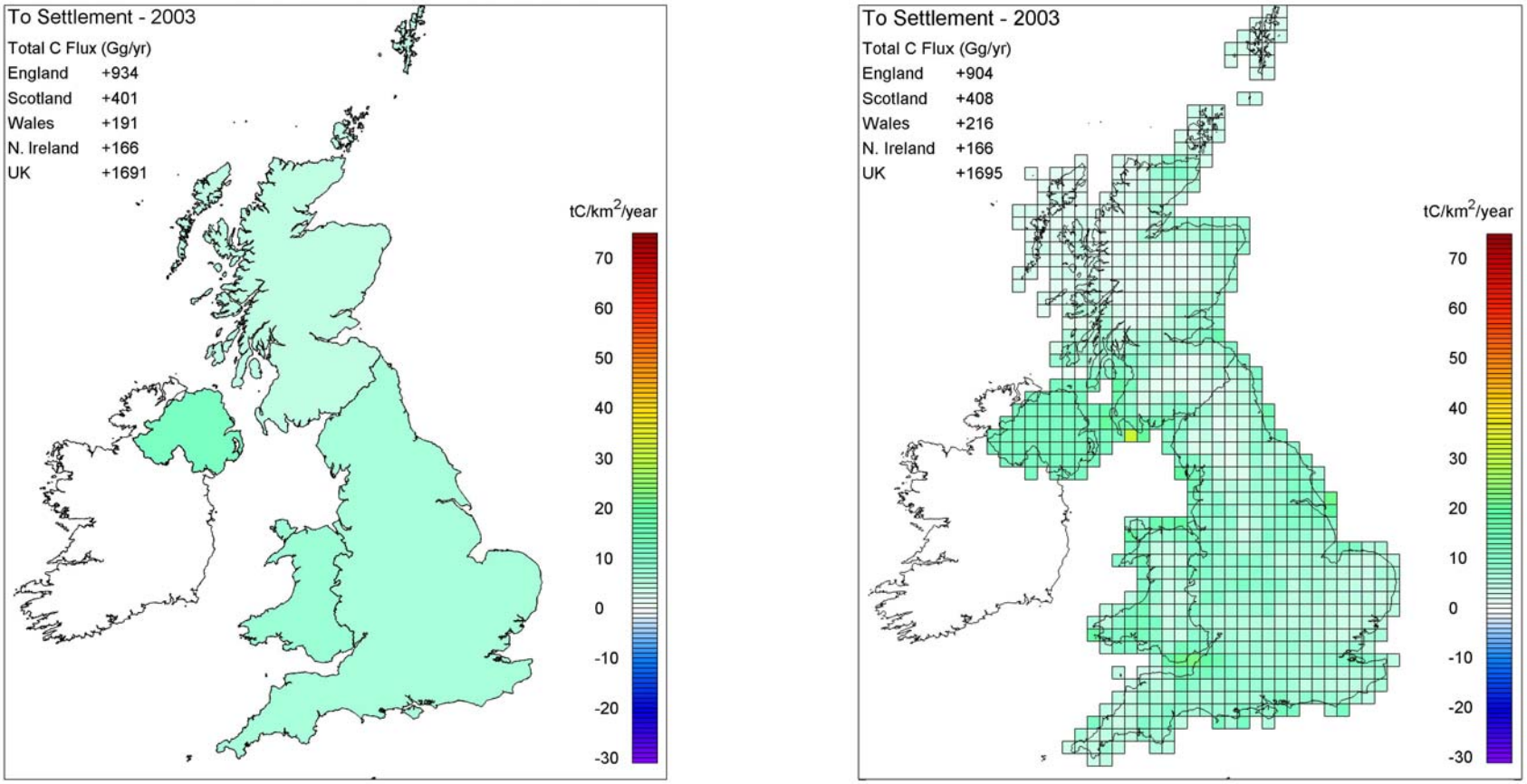

Figure 5-8 : Carbon flux associated with land use change to settlements for 2003. National totals compared with 20km by 20km scale data.

5.4. Future work

Topics for further work are:

- Use land cover maps for 1990 and 1998 as source of land use change for 1990 onward
- Investigate use of county level MLC data for better spatial resolution on land use change in England and Wales before 1980.
- Discussion with AEAT on exact needs for maps suitable for the GHG Emissions Inventory website etc.
- Decide on geographical resolution to be used by UK for reporting emissions and removals by LULUCF under Kyoto Protocol

5.5. References

Milne, R., Brown, T. A. W., (2003). Mapping of carbon uptake in British afforestation and land use change. *UK Emissions by Sources and Removals by Sinks due to Land Use, Land Use Change and Forestry Activities*, (ed Milne, R.). Annual report (2003) for DEFRA Contract EPG1/1/160.

MLC (1986). *Monitoring Landscape Change.* Report prepared by Hunting Surveys & Consultants Ltd for Department of the Environment and the Countryside Commission.