SECTION 2

Land Use Change and Forestry: The 2000 UK Greenhouse Gas Inventory and projections to 2020

Land Use Change and Forestry: The 2000 UK Greenhouse Gas Inventory and projections to 2020

R. Milne[1], R. Tomlinson[2], M. Cruickshank[2] & T. Murray[1]
[1]*Centre for Ecology & Hydrology, Bush Estate, Penicuik.* [2] *Queen's University, Belfast.*

1. Introduction

This chapter expands the descriptions of methods for estimating removals and emissions of carbon dioxide due to Land Use Change and Forestry (LUCF) in the UK National GHG Inventory for 1990 to 2000 (Salway et al. 2002a) and in the 1990 to 2000 Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland (Salway et al. 2002b). Projections of LUCF removals and emissions from 2001 to 2020 area also presented. These projections are in line with those used in the Third National Communication under the United Nations Convention on Climate Change (DEFRA 2001) but updated using information for 2000.

The estimates for Land Use Change and Forestry are from work carried out by the Centre for Ecology & Hydrology and described in the scientific literature (Cannell et al 1999, Milne and Brown 1999) and in Contract Reports to DETR (Milne et al. 1999, 2000, Cruickshank & Tomlinson 2000). The data is reported under IPCC categories 5A (Changes in Forests and Other Woody Biomass, 5C (CO_2 Emissions from Soils) and 5E (Other). No data is included for Categories 5B (Forest and Grassland Conversion) or 5C (Abandonment of Managed Lands) as these are considered to be negligible, or not occurring, in the UK.

Here some further detail on the methods used, and recent changes to estimates, are described to further the adoption of "Good Practice". IPCC (2000) provides guidance related to Sectors other than LUCF and similar recommendations are being developed for LUCF.

2. Changes in Forests and Other Woody Biomass Stocks (5A)

The UK GHG estimates for carbon uptake related to changes in forests are based on data for the areas of forest plantation published by the UK Forestry Commission and the Northern Ireland Department of Agriculture (for 2000 data see Forestry Commission 2001, Forest Service 2000). The carbon uptake is calculated by a carbon accounting model (Dewar and Cannell 1992, Cannell and Dewar 1995, Milne et al. 1998) as the net change in pools of carbon in standing trees, litter, soil in broadleaf forests and products. It is assumed that all commercial forest is restocked. It should be noted that for consistency with previous reports those parts of the net uptake by litter, soils and products are included in the data reported in this category for the national and devolved inventories (Salway et al. 2002a, Salway et al. 2002b), but are included as a removals under the Soils category in the Common Reporting Format tables submitted to the UNFCCC. The differences made to the reported data by these alternatives is detailed in subsidiary tables here and in the UK National Report (Salway et al. 2002a) to allow comparison with data from countries which report only changes in woody biomass and exclude soils etc.

The carbon accounting model of Dewar and Cannell (1992) calculated the mass of carbon in trees, litter, soil and wood products from harvested material in new even-aged plantations that were clear-felled and then replanted at the time of Maximum Area Increment (MAI). Two types of input data and two parameter sets were required for the model (Cannell and Dewar, 1995). The input data are a) areas of new forest planted in each year in the past and b) the stemwood growth rate and harvesting pattern. Parameter values were required to estimate i) stemwood, foliage, branch and root masses from the stemwood volume and ii) the decomposition rates of litter, soil carbon and wood products.

For the estimates described here we used the combined area of new private and state planting from 1921 to 1999 for England, Scotland, Wales and Northern Ireland sub-divided into conifers and broadleaves. Restocking was dealt with in the model through the second and subsequent rotations for the 'new' areas and hence areas restocked each year did not need to be considered separately.

The carbon flow model uses Forestry Commission Yield Tables (Edwards and Christie, 1981) to describe forest growth. It was assumed that all new conifer plantations have the same growth characteristics as Sitka spruce (*Picea sitchensis* (Bong.) Carr.) under an intermediate thinning management. Milne et al. (1998) have shown that mean Yield Class for Sitka spruce varied across Great Britain from 10 to 16 m^3 ha^{-1} a^{-1} but with no obvious geographical pattern and that this variation had a less than 10% effect on estimated carbon uptake. The Inventory data has therefore been estimated by assuming all conifers in Great Britain followed the growth pattern of Yield Class 12 m^3 ha^{-1} a^{-1}, but in Northern Ireland Yield Class 14 m^3 ha^{-1} a^{-1} , Sitka spruce. Milne at al. (1998) also showed little effect of different assumptions on broadleaf species. Hence it was assumed here, that broadleaf forests had the characteristics of beech (*Fagus sylvatica* L.) of Yield Class 6 m^3 ha^{-1} a^{-1} .

Increases in stemwood volume were based on standard Yield Tables, as in Dewar and Cannell (1992) and Cannell and Dewar (1995), and the mass of carbon in a forest was calculated from this volume by multiplying by wood density, stem to branch and root mass ratios and the fraction of carbon in wood (0.5 assumed). The values used for these parameters for conifers and broadleaves are given in Table 1.

Table 1: Main parameters for forest carbon flow model for species used to estimates carbon uptake by planting of forests of Sitka spruce (*P. sitchensis*)and beech (*F. sylvatica*) in United Kingdom (data from Dewar & Cannell, 1992).

	P. sitchensis	***P. sitchensis***	***F. sylvatica***
	YC12	**YC14**	**YC6**
Rotation (years)	59	57	92
Initial spacing (m)	2	2	1.2
Year of first thinning	25	23	30
Stemwood density (t m^{-3})	0.36	0.35	0.55
Max. carbon in foliage (t ha^{-1})	5.4	6.3	1.8
Max. carbon in fine roots (t ha^{-1})	2.7	2.7	2.7
Fraction of wood in branches	0.09	0.09	0.18
Fraction of wood in woody roots	0.19	0.19	0.16
Max. foliage litterfall (t ha^{-1} a^{-1})	1.1	1.3	2
Max. fine root litter loss (t ha^{-1} a^{-1})	2.7	2.7	2.7
Foliage decay rate (a^{-1})	1	1	3
Wood decay rate (a^{-1})	0.06	0.06	0.04
Fine root decay rate (a^{-1})	1.5	1.5	1.5
Soil organic carbon decay rate (a^{-1})	0.03	0.03	0.03
Fraction of litter lost to soil organic matter	0.5	0.5	0.5

The parameters controlling the transfer of carbon into the litter pools and its subsequent decay are given in Table 1. Litter transfer rate from foliage and fine roots increased to a maximum at canopy closure. A fraction of the litter was assumed to decay each year, half of which added to the soil organic matter pool which then decayed at a slower rate. The decay of litter and soil matter was assumed to be controlled only by tree species and Yield Class and unaffected by other factors which varied with location. Additional litter was generated at times of thinning and felling. As in Cannell and Dewar (1995) it was assumed that conifer forests increased the amount of organic carbon in litter but did not increase the net amount of carbon in soil due to gains from the new forest being balanced by loss due to the disturbance at planting. Further data on these changes has been analyzed and is discussed in paper submitted to *Forestry* (Hargreaves et al. 2002). The effect of incorporating this new information on changes in soil carbon under recently established conifer forests on national inventory estimates I discussed in another Chapter of this report. Broadleaved forests were assumed to increase the net amount of carbon in litter and soil. Harvested material from thinning and felling, which is made into wood products, was assumed to decay over a period equal to the rotation of the forest, conifer or broadleaf as appropriate, since products from broadleaves (e.g. furniture) will decay more slowly than those from conifers (e.g. paper, building timber). A detailed description of all the assumptions in the model was given by Dewar and Cannell (1992) and Cannell and Dewar (1995) and the effect of assuming all forests to be of either Sitka spruce or beech in Milne et al. (1998).

3 CO_2 Emissions and Removals from Soils (5D)

Three processes are reported in this category: changes in soil stocks due to land use change, change in soil stocks due specifically to the change in land use from arable in Set Aside schemes and emissions due to the application of lime and dolomite.

3.1.1 Land Use Change in Great Britain

The basic method for assessing changes in soil carbon due to land use change is to use a matrix of change from surveys of land linked to a dynamic model of gain or loss of carbon. A database of soil carbon density for the UK has been constructed (Milne and Brown 1995, Cruickshank *et al.* 1998) from information provided by the Soil Survey and Land Research Centre, the Macaulay Land Use Research Institute and Queen’s University Belfast on soil type, land cover and carbon content of soil cores. These densities include carbon to a depth of 1 m or to bedrock whichever is the shallower, for mineral and peaty/mineral soils. Deep peats in the North of Scotland are identified separately and depths to 5 m are included but these play a minor role in relation to land use change. MLURI reviewed and revised downwards the values of soil carbon density for some peaty soils types in Scotland for the 1999 Inventory (Milne et al 2001).

Table 2a shows average values of soils carbon density for different land covers in the four devolved areas of the UK. The data of Table 2a shows no strong evidence of a major difference in the soil carbon density of tilled cropland or actively managed grass hence the inclusion of both uses within the Farm category in the flux calculations described below.

Table 2a. Average soil carbon density (t C ha^{-1}) for different land cover in the UK

Cover \ Region	England	Scotland	Wales	N. Ireland
Natural	487	1048	305	551
Woodland	217	580	228	563
Arable	153	156	93	151
Pasture	170	192	200	178
Other	33	141	43	102

Areas of land changing use are described by matrices from the Monitoring Landscape Change (MLC) data from 1947 & 1980 and the DETR/ITE Countryside Surveys (CS) of 1984 & 1990. Land use in the UK can be placed into 4 broad groups – (Semi) Natural, Farming, Woodland and Urban – and hence the more detailed categories for the two surveys were combined as shown in Table 3a for MLC and 3b for CS. In both cases only unimproved grassland is included in the Natural category. For the CS the different types of grass are shown in Table 4.

Table 3a: Grouping of MLC land cover types for soil carbon change modelling.

FARM	**NATURAL**	**WOODLAND**	**URBAN**
Crops	Upland heath	Broadleaved wood	Built up
Market garden	Upland smooth grass	Conifer wood	Urban open
Improved grassland	Upland coarse grass	Mixed wood	Transport
Rough pasture	Blanket bog		Mineral workings
	Bracken		Derelict
	Lowland rough grass		
	Lowland heather		
	Neglected grassland		
	Marsh		

Table 3b: Grouping of CS land cover types for soil carbon change modelling. For Managed grass (I) signifies "Improved", usually by ploughing and seeding, (U) signifies "Unimproved" by such means.

FARM	**NATURAL**	**WOODLAND**	**URBAN**
Tilled land	Rough grass/marsh	Broadleaved/mixed	Communications
Managed grass(I)	Managed grass (U)	Coniferous	Built up
	Dense bracken		Inland bare (Hard areas)
	Moorland grass		
	Dense heath		
	Open heath		

Table 4: Different types of CS land cover included in the "Improved" and "Unimproved" groups for soil carbon modelling.

Managed grass (I)	**Managed grass (U)**
Recreational	Non-agricultural improved
Recently sown	Calcareous
Pure rye	Upland
Well managed	
Weedy swards	

Table 5: Area and change data sources for different periods in estimation of changes in soil carbon. (1) Stamp (1962), (2) MLC (1986), (3) Barr *et al*. (1993).

Year or Period	**Area data**	**Change matrix or data**
1930	Land use Survey (1)	
1930 – 1947	*Interpolated*	MLC 1947->MLC1980
1947	MLC (2)	
1947-1980	*Interpolated*	MLC 1947->MLC1980
1980	MLC (2)	
1980-1984	*Interpolated*	*Interpolated*
1984	CS1984 (3)	
1984-1990	*Interpolated*	CS1984->CS1990
1990	CS1990 (3)	
1990-2010	*Extrapolated from 84->90*	CS1984->CS1990

Area data exist for the period 1930 to 1990 and those from 1984 to 1990 are used to extrapolate forward for the years 1991 to 1998 with a small adjustment taking into account general trends in farmed areas.. Land use change matrices for the periods 1947 to 1980 and 1984 to 1990 are used. See Table 5 for the sources of information for land use and matrices of change.

The core equation describing changes in soil carbon with time for any land use transition is

$$C_t = C_f - (C_f - C_0)e^{-kt}$$

C_t is carbon density at time t
C_0 is carbon density initially
C_f carbon density after change to new land use
k is time constant of change

If the inventory year is 1990 and A_T is area in a particular land use transition in year T considered from 1930 onwards then total carbon lost or gained from 1930 to 1990 (X_{1990}) and from 1930 to 1989 (X_{1989}) is given by

$$X_{1990} = \sum_{T=1930}^{t=1990} A_T (C_0 - C_f)(1 - e^{-k(1990-T)})$$

$$X_{1989} = \sum_{T=1930}^{T=1989} A_T (C_0 - C_f)(1 - e^{-k(1989-T)})$$

Hence flux of carbon in 1990 is given by difference:

$$F_{1990} = X_{1990} - X_{1989}$$

The land use transitions considered are each of those between the (Semi) Natural, Farm, Woodland and Urban categories. Scotland, England and Wales are treated separately. Northern Ireland does not have a matrix of land use change and changes in soil carbon are calculated by a method based on that recommended by the IPCC (1997b, c) and is described in Chap 2.x.x of this report. The area data for Great Britain are shown in Table 6. The data from the CS has had a small adjustment applied to account for one of the detailed land types (Non-cropped arable) actually bridging the main Natural and Farm categories.

Table 6a:Area of land in England for each use category from field and area surveys (1) Stamp (1962), (2) MLC (1986), (3) Barr *et al*. (1993).

		Area(ha)			
Source	**Year**	**Farm**	**Natural**	**Urban**	**Woodland**
lus (1)	***1930***	9,542,340	1,543,000	1,034,858	843,800
mlc (2)	***1947***	9,242,777	1,639,511	823,665	865,370
mlc (2)	***1980***	9,013,401	1,307,178	1,301,965	948,779
cis (3)	***1984***	8,670,815	1,908,436	1,249,383	1,303,455
cis (3)	***1990***	8,336,428	2,120,609	1,323,084	1,353,399

Table 6b: Area of land in Wales for each use category from field and area surveys (1) Stamp (1962), (2) MLC (1986), (3) Barr *et al*. (1993).

		Area(ha)			
Source	**Year**	**Farm**	**Natural**	**Urban**	**Woodland**
lus (1)	***1930***	1,094,187	771,520	77,298	120,439
mlc (2)	***1947***	1,061,571	701,347	71,422	160,077
mlc (2)	***1980***	1,148,150	521,131	121,459	203,677
cis (3)	***1984***	1,155,174	585,248	176,112	221,521
cis (3)	***1990***	1,132,768	593,918	188,628	222,953

Table 6c: Area of land in Scotland for each use category from field and area surveys (1) Stamp (1962), (2) MLC (1986), (3) Barr *et al.* (1993).

		Area(ha)			
Source	**Year**	**Farm**	**Natural**	**Urban**	**Woodland**
lus (1)	***1930***	1,861,215	5,265,673	146,906	443,187
mlc (2)	***1947***	2,037,860	5,209,630	260,313	447,753
mlc (2)	***1980***	2,100,125	4,667,711	297,076	890,644
cis (3)	***1984***	2,109,333	4,940,892	287,471	1,019,931
cis (3)	***1990***	2,059,553	4,935,184	294,291	1,068,543

In the model, the change, from the initial to the final land use, in equilibrium carbon density is required. Here, these are calculated for each land use category as averages for Scotland, England and Wales. In order to account for variation in carbon density and Land Use Change in different soil types these averages are weighted by the area of soil groups used by IPCC (1997c). They define five groups, which are represented in Great Britain, on the basis of their carbon content and activity namely; aquic, high activity clay, low activity clay, sandy and organic. In Great Britain few clay soils truly fall into the 'high activity' class so the *total clay content* is used to divide these soils into 'high' and 'low' groups. For Great Britain all soil types not falling into these five types an 'undefined' groups is used. Mean soil carbon density change are calculated as.

$$\overline{C}_{ijc} = \frac{\sum_{s=1}^{6}(C_{sijc}L_{sijc})}{\sum_{s=1}^{6}L_{sijc}}$$

which is the weighted mean, for each country, of change in equilibrium soil carbon when land use changes and

i = initial land use (Natural, Farm, Woods, Urban)
j = new land use (Natural, Farm, Woods, Urban)
c = country (Scotland, England & Wales)
s = soil group (High clay, low clay, aquic, organic, sandy, undefined)
C_{sijc} is change in equilibrium soil carbon for a specific land use transition within a soil group region in a specific country
L_{sijc} is area change (1984 to 1990) for a specific land use transition within a soil group region in a specific country.

The weighted mean change in equilibrium soil carbon calculated for England, Scotland and Wales are shown in Table 7 a-c.

Table 7a. LUC area weighted mean change in equilibrium soil carbon (tC ha^{-1})for England

Final \ Initial	Farm	Natural	Urban	Woods
Farm		-79	-8	-39
Natural	78		71	-20
Urban	9	-63		-24
Woods	38	20	31	

Table 7b LUC area weighted mean change in equilibrium soil carbon (tC ha^{-1}) for Scotland

Final \ Initial	Farm	Natural	Urban	Woods
Farm		-410	85	-260
Natural	279		324	-30
Urban	-63	-286		-551
Woods	204	30	396	

Table 7c LUC area weighted mean change in equilibrium soil carbon (tC ha^{-1}) for Wales

Final \ Initial	Farm	Natural	Urban	Woods
Farm		-30	40	-23
Natural	31		78	-10
Urban	-38	-72		-53
Woods	25	10	89	

The rate of loss or gain of carbon is dependent on the type of land use transition (Table 8). For transitions where carbon is lost e.g. transition from Natural to Farm land, a 'fast' rate is applied whilst a transition which gains carbon occurs much more slowly. This 'slow' rate had in the 1998, and earlier, GHG Inventories been set such that 99% of the change occurred in 100 years throughout GB as had been observed at the Highfield field site at Rothamsted (Howard *et al.* 1994). However, this site is thought to respond to change much more quickly than most (P. Smith pers. comm.) and that using the 100 year change parameter produced uptake rates of carbon in Scotland that were unreasonably large in the situation where land moved to the Natural class from the Farm class. The rate of uptake has therefore been reduced until the uptake of soil carbon in such transitions is less than the order of net primary productivity for cold temperate grasslands (about 300 g m^{-2} a^{-1}). Thus, a rate of soil carbon accumulation in Scotland equivalent to taking 800 years to reach 99% of a new value is used. In addition to this assumption account is taken of the uncertainty in such rates of transition. A literature search for information on measured rates of changes of soil carbon due to land use was carried out and, in combination with expert judgement, ranges of possible times for completion of different transitions were selected. These are shown in Table 8.

Table 8: Range of times for soil carbon to reach 99% of a new value after a change in land use in England (E), Scotland (S) and Wales (W).

	Low (years)	**High (years)**
Carbon loss ("fast") E, S, W.	50	150
Carbon gain ("slow") E, W.	100	300
Carbon gain("slow") S.	300	750

Table 9: Rates of change of soil carbon for land use change transitions. ("Fast" & "Slow" refer to 99% of change occurring in times shown in Table 7.

		1984			
		Farm	**Natural**	**Urban**	**Woods**
1990	**Farm**		*fast*	*slow*	*fast*
	Natural	*slow*		*slow*	*fast*
	Urban	*fast*	*fast*		*fast*
	Woods	*slow*	*slow*	*slow*	

The model of change was then run 500 times with the time constant for change in soil carbon being selected separately, using a Monte Carlo approach, for England, Scotland and Wales from within the ranges of Table 8. The mean carbon flux for each region resulting from this imposed random variation was then reported as the estimate for the Inventory. An adjustment was made after these calculations for each country to remove increases in soil carbon due to afforestation, because the value for this was considered to be better estimated by the C-Flow model used for the Changes in Forests and Other Woody Biomass Stocks (5A) category. Histograms of the variation in estimated changes in soil carbon are shown in Figure 1 and the ranges for each country in Table 10.

Figure 1a: Histogram of estimates of annual changes in soil carbon due variation in variation in rate parameter in soil carbon change model for England.
Removals are –ve, Emissions are +ve.

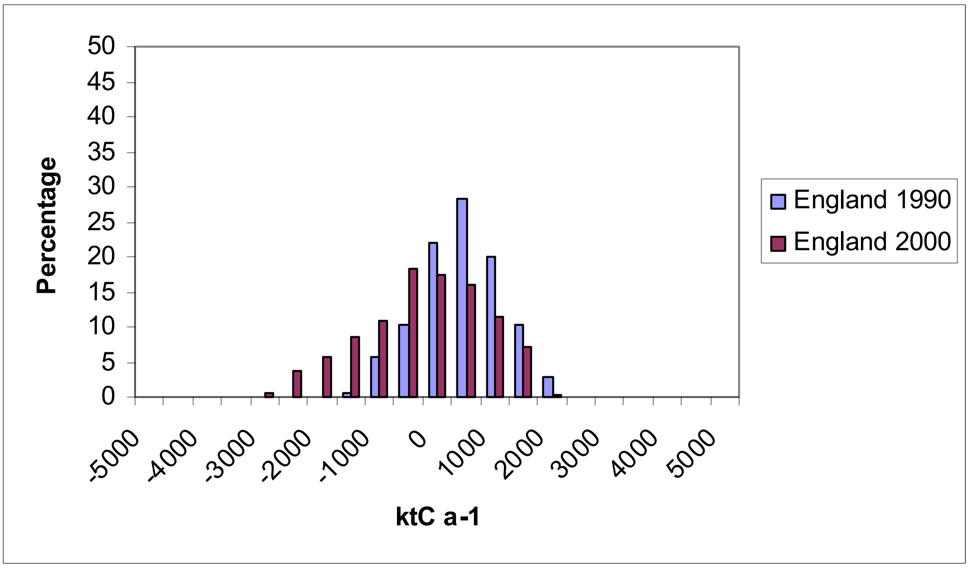


Figure 1b: Histogram of estimates of annual changes in soil carbon due variation in variation in rate parameter in soil carbon change model for Scotland.
Removals are –ve, Emissions are +ve.

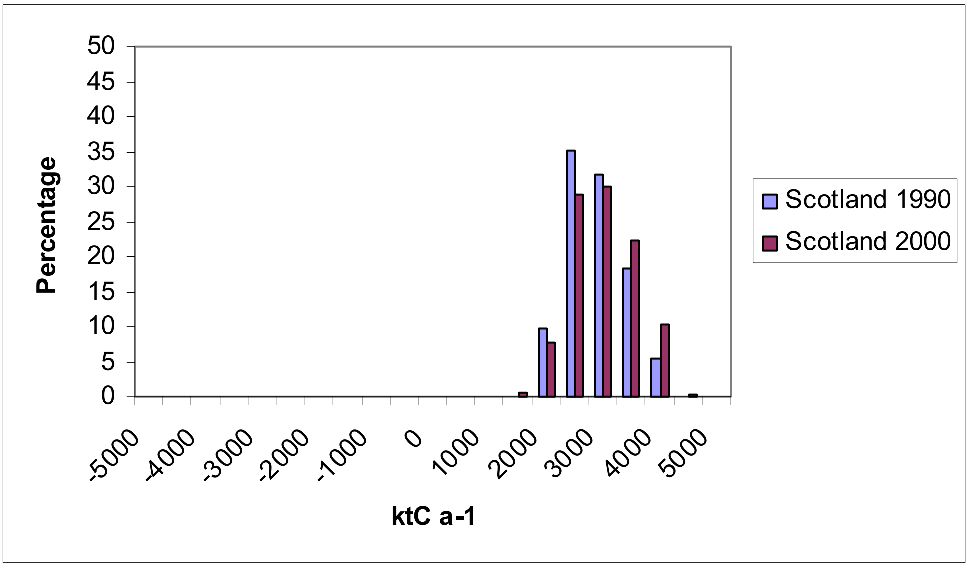
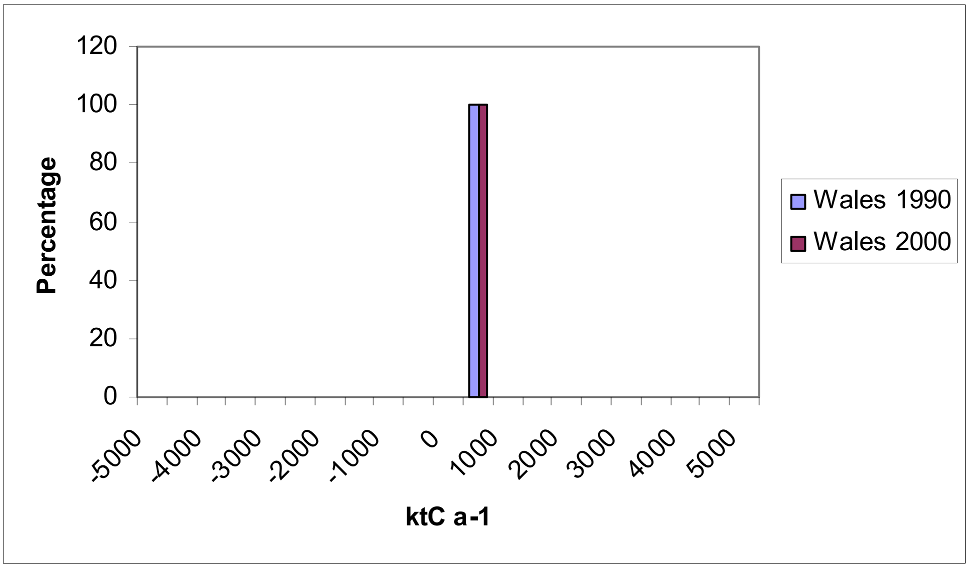


Figure 1c: Histogram of estimates of annual changes in soil carbon due variation in variation in rate parameter in soil carbon change model for Wales.
Removals are –ve, Emissions are +ve.



		Minimum	**Mean**	**Maximum**
Scotland	**1990**	1546	2616	3785
	2000	1462	2729	3947
England	**1990**	-1541	186	1818
	2000	-3138	-509	1570
Wales	**1990**	36	159	270
	2000	-5	149	266
N Ireland	**1990**	353	353	353
	2000	259	259	259

Table 10 Summary of range of emissions from Monte Carlo variation of rate parameters for effect of land use change on soil carbon.

3.1.2 Land use change in Northern Ireland

For this region the default method of the IPCC Guidelines (IPCC 1997) continues to be used. Cruickshank & Tomlinson (2000) provides a general description of the method as applied to Northern Ireland.

Points relevant to preparation of the 2000 Inventory are given in an Appendix to this chapter but awareness of problems associated with this default method – (the statistics are really not good enough, and in some respects getting worse) has not abated. A summary of the changes in land uses and the resulting changes in stored soil carbon are shown in Table 9. The estimate for 1999 has been revised upwards since the 1999 Inventory submission due to inclusion of data for Minor Holdings in 1979 which has only recently become available.

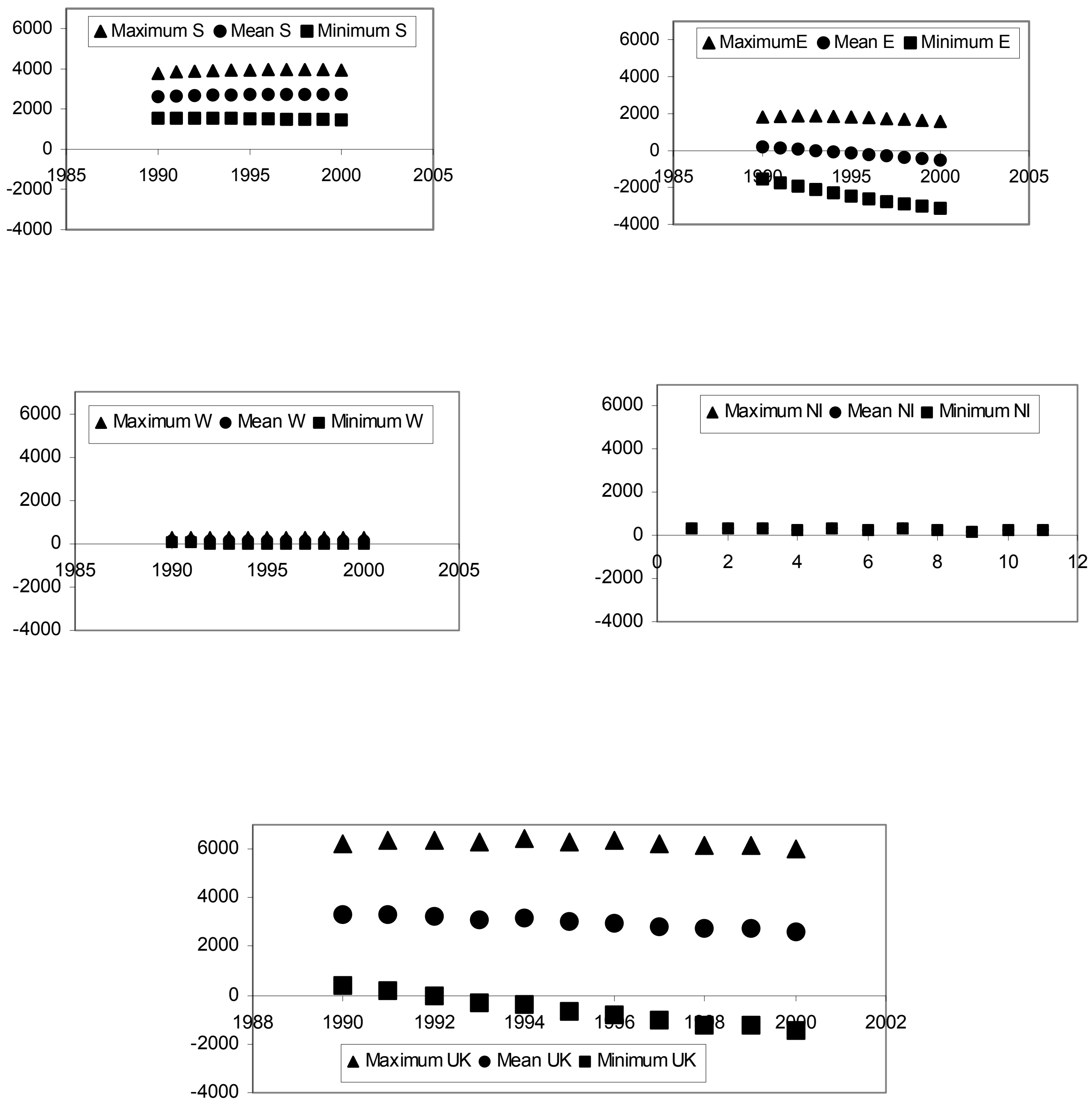
Table 11: Summary of changes in areas of land use and resulting changes in soil carbon in Northern Ireland using the IPCC "default" method.

kha	Arable	Grass	Semi-natural (not peat)	Semi-natural (peat/bog)	Urban	Carbon loss kt/yr
1970	96.9	740.3	249.9	149.0	40.4	
1971	94.4	745.2	248.0	148.4	40.6	
1972	84.2	759.5	233.5	147.8	47.7	
1973	77.6	754.5	227.8	147.1	65.2	
1974	74.8	761.1	239.1	146.5	49.6	
1975	73.4	758.5	226.5	145.9	65.7	
1976	79.2	773.9	226.1	145.3	44.6	
1977	82.9	772.5	214.8	144.7	53.3	
1978	79.9	776.1	210.1	144.1	57.4	
1979	76.8	777.1	219.0	143.5	50.4	
1980	77.5	791.2	212.9	142.9	43.1	
1990	61.5	797.9	212.6	136.9	67.7	-353
1991	62.8	806.1	210.9	135.5	61.2	-361
1992	64.0	800.3	202.6	134.9	70.9	-351
1993	63.0	817.2	199.9	134.9	57.2	-245
1994	57.6	814.8	197.2	134.9	66.6	-366
1995	56.4	819.1	191.0	134.9	68.7	-278
1996	56.5	821.0	188.9	134.9	67.8	-310
1997	58.1	826.7	184.2	134.9	64.4	-222
1998	57.4	832.3	177.7	134.9	65.3	-290
1999	54.8	835.2	177.3	134.9	64.7	~~-262~~ -288
2000	52.5	831.0	175.0	134.9	74.1	-259

3.1.3 Changes in soil carbon in the UK

UK time series of changes in soil carbon we calculated by adding the mean, maximum and minimum data from each region together to provide aggregate, mean, maximum and minimum series for the UK. It was assumed that the mean, maximum and minimum values for Northern Ireland were each equal to the data from the default method. The adjustment to remove uptake of carbon into afforestation was made prior to aggregation for each region, except Northern Ireland where the default method did not include afforestation. The UK aggregate mean value was used for GHG Inventory purposes. The time series for each region and the UK are shown in Fig. 2.

Figure 2. Range of estimates for changes in soil carbon in England (E), Scotland (S), Wales (W) and Northern Ireland (N) and the aggregates for the United Kingdom (UK).



3.2 Set Aside

The estimation of changes in soil carbon calculated by the matrix method for all transitions does not fully include the effects of the policy of Set Aside from production of arable areas. This is the case because although the schemes were introduced in 1988 there was a slow rate of acceptance by farmers and it was not until after 1990 that significant areas were recorded in the Annual Farm Census. In this post-1990 period the matrix method uses an extrapolation of the CS field data from 1984 to 1990 therefore a separate estimate of the effect of Set Aside on soil carbon for these later years has been made. Data reported in inventories prior to 1997 were based on the observation from the Annual Farm Census that Set Aside was continuing to increase in total area. Recent Census data shows considerable variation in the amount of Set Aside and this is included in the estimates of carbon emissions for this 2000 GHG Inventory account is also taken of not only the effect of soil carbon increasing in areas where land is not used for arable purposes but the subsequent loss of the extra accumulated carbon from the soil when land is returned to arable use.

Set Aside areas are taken from the Annual Farm Census for Scotland and England & Wales separately. Scottish soils coming out of arable use are assumed to be able to take up 300 t/ha but that this happens at a rate that would only allow 99% of that change to occur in 500 years. For English & Welsh soils it is assumed that the change in equilibrium soil carbon density would be 60 t/ha and that 99% of this change would occur in 200 years. These times fall in the middle of the ranges used in the main calculation for the effect of land use change causing an increase in soil carbon. The new areas of land in Set Aside are calculated from the increases in area up to the maximum total recorded area (in 1995 throughout GB). The emission of carbon from these areas are calculated for years up until 2000. To compensate for any losses in area, two assumptions were made: a) the area lost in each year from 1995 onwards was assumed to have been in Set Aside for 3 years and b) the carbon gained in these years would be lost at a rate which would cause 99% of the change to occur in 20 years. The 3 year assumption is made as there is no clear indication of how long any area does remain in Set Aside. This value is not unreasonable but may be low given that some Set Aside could have existed from 1988. Prior to the 1998 GHG Inventory it was assumed that all Set Aside was simply abandoned but between 30 and 50% is actually managed by cutting etc. Such areas will not be very different from other rotational pasture situations that we have already shown to have similar soil carbon to arable areas. Hence such areas have been excluded from estimates of the effect of Set Aside reported here.

Thus for the estimates reported here the assumptions are: Set Aside area rises to a maximum in 1995, uptake occurs slowly in Scotland and 50% of areas in the Agricultural Census are in rotational form of management are excluded. Northern Ireland has negligible change in soil carbon due to Set Aside

3.3 Emissions of CO_2 from soil due to liming

Emissions of carbon dioxide from the application of limestone, chalk and dolomite to agricultural soils were estimated using the IPCC (1997a, b, c) default method. Data on the use of limestone, chalk and dolomite for agricultural purposes is reported in BGS (2002). It is assumed that all the carbon contained in the lime is released in the year of use. For limestone and chalk, a factor of 120 t C/kt is used, and for dolomite application, 130 t C/kt. These factors are based on the stoichiometry of the reaction and assume pure limestone and dolomite.

4 Other sources and sinks (5E)

These are:
Sources

- Drainage of deep peat
- Drainage of lowland wetlands
- Peat extraction

and sink

- Changes in crop biomass
-

The activity data and carbon fluxes are based on data from (Bradley 1997, Cannell *et al.* 1993, Cruickshank et al. 1997, Hargreaves and Fowler 1997) for sources and from (Adger and Subak 1995) for the sink.

4.1 Changes in Crop Biomass

Adger & Subak (1995) originally derived this value using Agricultural Census and other data up to 1992. From the 1998 Inventory onwards more recent data from the Agricultural Census were considered but did not support any change to the existing estimate. This rate is therefore reported for all years from 1990 to 2000.

4.2 Peat Extraction

Trends in peat extraction in Scotland and England over period 1990 to 2000 are included. In Northern Ireland no recent data on use of peat for horticultural use was available but a recent survey of extraction for fuel use suggested that there is no significant trend for this purpose. The contribution of emissions due to peat extraction is therefore incorporated as constant from 1990 to 2000. Peat extraction is negligible in Wales.

4.3 Lowland (fen) peat drainage

The trend in emissions due to changing areas of drainage is based on the work of Bradley (1997).

4.4 Upland (forestry) peat drainage

The area of forestry on peat is unlikely to change significantly under present afforestation policies. Emissions from planted areas tend to exist for considerable periods due to the large stock of carbon that is available for decomposition and hence the emissions included under this heading are reported as constant from 1990 to 2000. Emission factors are summarised in Tables 12 and 13.

Table 12 Summary of Emission Factor Data for Deep Peat Drainage and Lowland Wetland Drainage

	Emission Factor g $C/m^2/y$
Deep Peat Drainage	200
Lowland Wetland Drainage	297

Table 13 Summary of Emission Factor Data for Peat Extraction (GB Great Britain, NI Northern Ireland)

	Emission Factor	
	kg C m^{-3}	Gg C/Gg
GB Horticultural Peat	55.7	-
GB Fuel Peat	55.7	-
NI Horticultural Peat	44.1	-
NI Fuel Peat	-	0.3

5 Summary Tables

The basic data for the each flux relevant to the Land Use Change and Forestry Sector of the UK GHG Inventory for 2000 are presented in Table A1.1A. These data are used for several different submissions and reports and 2 main formats have been used to summarise them.. Originally a format derived from submissions to the UNFCCC prior to the introduction of the Common Reporting Format was used for all purposes. This is still used for the UK Digest of Environmental Statistics. This style if often referred to as the "IPCC" format and for LUCF Removals of carbon to soils due to Set Aside were combined with other changes in soils to provide a figure for net soil emission. In the Common Reporting Format (CRF) the Set Aside Removal is entered separately and in the 2000 submission to the UNFCCC the Emissions from drainage of upland and lowland soils are included under Category 5D Soils (Emissions) rather than 5E Other (Emissions). The "IPCC" and "CRF" styles of summary for the 2000 submissions are presented for the UK in Table A1.1B & A1.1C.
The constituent data for the devolved administrative regions of England, Scotland, Wales and Northern Ireland are presented in Tables 14,15,16 & 17 in "IPCC" format as used in Salway et al (In prep). The UK data in units of Gg of CO_2 as used in the National Report are presented in Table A1.6.

6 Results

The data for the 2000 Inventory and equivalent values for 1990 to 1999 can be summarised from Table A1.6A and the IPCC Format in Table A1.6B. The same data is also presented in an Appendix in the Common Reporting Format Table 5 Sectoral Report style for each year separately.

6.1 Changes in Forest and Other Woody Biomass Stocks

6.1.1 Temperate Forest

The Removal of atmospheric CO_2 to Woody Biomass Stocks caused by expanding UK forests in 2000 was estimated to be 7157 Gg with an additional sink of 1151 Gg due to an increase in the stock of carbon in undecayed forest products from these forests. The latter is a small increase compared to the downward trend in Removals to Woody Biomass that began in 1995, but wood products are showing a small decrease in uptake for 2000. Thus Removals to Woody Biomass increased from 5731 Gg in 1990 to a peak of 7605 Gg in 1995 and in 2000 are now at 7157Gg. Removals to products fell from 1573 Gg in 1990 to 913 Gg in 1995 but are now in 2000 at 1151 Gg. These changes reflect variation in planting rates in past decades which feed through growth and felling to the carbon uptake trends reported here. Changes in forest soils are reported with other processes related to changes in soils.

6.2 CO_2 Emissions and Removals from Soil

6.2.1 Land use change

Estimates of changes in stored soil carbon due to land use change (excluding afforestation) continue to indicate large emissions to the atmosphere although the trend continues downwards. For 2000 the Emission of CO_2 is estimated to be 11744 Gg compared to 14187 Gg in 1990. Emissions from Scotland continue to be the primary source, with additional small source contributions from Wales and Northern Ireland being balanced by a sink in England. The estimate for 1999 in Northern Ireland has been revised upwards due to new information on minor farm holdings resulting in the UK figure being revised from 12102 Gg to 12199 Gg. Land use changes on both mineral and organic soils are included in these estimates but those transitory fluxes due to changes involving new forest planting or continuous emissions due to drainage of organic soils for forestry or agriculture are reported elsewhere.

6.2.2 Liming of Agricultural Soils

Emissions due to liming of agricultural soils fell to 770 Gg in 2000 from 859 Gg in 1999. This reduction continues a downward trend that started in 1997. No information is presently available to explain this trend but it may be related to present poor economic conditions in farming.

6.2.3 Forest Soils

Forest soil carbon stocks were estimated to have increased due to a sink of 2244 Gg for 2000. As in previous Inventories this estimate comes from the C-FLOW forest carbon accounting model and it is assumed that soils under new conifer forest do not change their original pre-forest carbon stock due to a balance of losses from the disturbance of the typically high carbon content soils by the addition of new carbon from the litter of high productivity plantations. Removals of atmospheric carbon dioxide to the soils of the new broadleaf soils have not varied much over the period 1990 to 2000 but have shown a small increasing trend from a low of 1991 Gg in 1993 which reflects planting in the past now working through the slowly responding soil turnover system.

6.2.4 Set Aside

In general, the Set Aside sink strength had fallen from 1995, as fewer new areas now being brought into this type of scheme but an increase was recorded for 2000. In 2000 it is estimated that the Removal was 1071 Gg having increased from 298 Gg in 1999. The maximum Removal of 2007 Gg occurred in 1995 after when many arable areas were taken out of annual ploughing and sequestered carbon. The areas Set Aside now appear to be increasing again and this trend is considered to be likely to continue.

6.3 Other

6.3.1 Changes in Crop Biomass

The uptake of carbon due to improvements in the productivity and area of crops is estimated in 2000 to be unchanged from previous years at 1100 Gg.

6.3.2 Peat Extraction

The estimated emission of carbon due to peat extraction shows variation both upwards and downwards over the 11 reported years with the latest year of 2000 showing an emission of 818 Gg compared to the lowest of the 11 years of 704 Gg estimated for 1998. Emissions were greatest at 950 Gg in 1995 and around 800 Gg in the early part of the decade.

6.3.3 Lowland (fen) peat drainage

The downward trend in Emissions from drainage of organic soils in the lowlands (primarily English fens) firstly entered into the Inventory in 1998 continues for 1999. The Emissions are estimated to have fallen from 1650 Gg in 1990 to 1283 Gg in 2000 reflecting fewer new areas of drainage and stabilisation of changes in older drained areas.

6.3.4 Upland (forestry) peat drainage

No new areas of organic soil have been ploughed for forestry recently due to government policy and hence the estimated Emission due to this process is assumed to remain constant 1467 Gg over the period 1990 to 2000.

6.4 Net UK Emissions/Removals

The Land Use Change and Forestry Sector of the UK is estimated, in 2000, to have continued to be an overall emitter of carbon dioxide with a value of 3355 Gg. This net figure is made up from Emissions of 15008 Gg offset by 11633 Gg of Removals. The equivalent values for 1990 were a net emission of 8791 Gg due to 19348 Gg of Emissions offset by 10556 Gg of Removals.

6.5 Projections of Emissions and Removals to 2020

Estimates have been made of Emissions and Removals over the period 2001 to 2020 base on the 1990 to 2000 Inventory data. These estimates are based on the same scenarios for forest and agricultural management used for the projections in the UK Third National Communication (3NC)- (DEFRA 2001) but with some minor changes due to the inclusion of the recorded data for 2000.

Three scenarios for projections were used: “High” emission scenario to consider situation where emissions would tend to be greater and Removals lesser than in 2000, “Mid” following a “business-as usual” approach to management issues and “Low” where management which would cause greater Removals or lesser Emissions were considered. The assumptions for each LUCF process where a linear trend in emission flux was applied are summarised in Tables 14 to 18 for each scenario. Forestry projections were made using contrasting assumptions on areas of new planting in the future. The “Mid” scenario assumed that forest planting would continue at the annual rate recorded in 2000. The “Low” emissions scenario assumed that planting in each year from 2001 would be of 10 kha of conifers and 20 kha of broadleaves. The “High” emission scenario assumed there would be no new planting from 2001. The removal of carbon dioxide from the atmosphere by these projections was then estimated using the C-Flow model. The range of future forest removals presented in 3NC (DEFRA 2001) was based on the “Low” and “Mid” scenarios. The projections of fluxes associated post-1990 afforestation was calculated in a similar way but omitting all earlier planted areas from the model runs.

The trend in the effect of land use change on emissions from soils was estimated by considering the trends which had occurred not only in the data used for the 2000 GHG Inventory (the mean estimates from the Monte Carlo study on parameter uncertainty) but also the trends in the maximum and minimum estimates from the Monte Carlo study.

Trends in Set Aside were based on combinations of assumptions of activity (area) data and trends in fluxes based on calculations from the model used for that process in the GHG Inventory. The “Mid” scenario assumed that the area of land set aside would double between 2000 and 2010 but then remain constant until 2020. For the “Low” scenario this data was used for the period 2001 to 2010 but the trend in the flux was then assumed to continue until 2020 at the mean rate between 2001 and 2010 without defining how this would be achieved in area terms. The “High” scenario assumed that the area set aside would remain constant at the amount in 2000 but the flux would therefore equilibrate to zero.

	Scenario assumption		
Category	**LOW Emission**	**MID Emission**	**HIGH Emission**
Forestry	UK Conifer planting from 2001 assumed to be 10 kha/yr allocated to each country in proportions of 2000. UK Broadleaf planting from 2001 assumed to be 20 kha/yr yr allocated to each country in proportions of 2000.	Conifer planting from 2001 assumed to be as in 2000. Broadleaf planting from 2001 assumed to be as in 2000.	Conifer planting from 2001 assumed to be 0 kha/yr. Broadleaf planting from 2001 assumed to be 0 kha/yr.
Land Use Change (Soils)	Flux (including forest soils) changes at maximum rate of from model for fall from 1990 to 2000	Flux (including forest soils) changes at average rate of change from model for 1990 to 2000	Flux (including forest soils) changes at average MODEL rate of change for 1990 to 2000
Set Aside	Flux sink rate becomes greater due to SA doubling by 2010. Flux continues to increase at 2000-2010 slope	Flux sink rate becomes greater due to SA area doubling by 2010 then staying fixed	Flux increases from 2000 value to become emission due to areas returning to arable (SA area fixed after 2000)
Peat extraction	Flux reduces at possible rate from data for 1990 to 2000	Flux remains at 2000 value	Flux increases at possible rate from data for 1990 to 2000
Liming	Flux reduces at possible rate from data for 1990 to 2000	Flux remains at 2000 value	Flux increases at possible rate from data for 1990 to 2000
Upland drainage	Flux remains at 2000 value	Flux remains at 2000 value	Flux remains at 2000 value
Lowland drainage	Flux reduces at mean rate from data for 1990 to 2000	Flux remains at 2000 value	Flux increases at rate opposite to loss rate from data for 1990 to 2000
Crop biomass	Flux remains at 2000 value	Flux remains at 2000 value	Flux remains at 2000 value

Table 14 Assumptions in scenarios for projection of LUCF Emissions and Removals from 1990 to 2000 data to 2001 onwards.

England	"Low" emissions	"Mid" emissions	"High" emissions
Land Use Change	-100	-70	-20
Peat extraction	-5	0	+14
Liming	-40	0	+40
Lowland drainage	-10	0	+10

Table 15 Assumed rates of change of emissions fluxes (kTC/year/year) in England after 2000.

Scotland	"Low" emissions	"Mid" emissions	"High" emissions
Land Use Change	-20	-11	+14
Peat extraction	-10	0	+10
Liming	-7	0	-7
Lowland drainage	NA	NA	NA

Table 16 Assumed rates of change of emissions fluxes (kTC/year/year) in Scotland after 2000

Wales	"Low" emissions	"Mid" emissions	"High" emissions
Land Use Change	-1	-1	0
Peat extraction	NA	NA	NA
Liming	-5	0	+5
Lowland drainage	NA	NA	NA

Table 17 Assumed rates of change of emissions fluxes (kTC/year/year) in Wales after 2000

Northern Ireland	"Low" emissions	"Mid" emissions	"High" emissions
Land Use Change	-20	-10	0
Peat extraction	0	0	0
Liming	-4	0	+4
Lowland drainage	NA	NA	NA

Table 18 Assumed rates of change of emissions fluxes (kTC/year/year) in Northern Ireland after 2000

Figure 3 shows the UK projections for Emissions and Removals using the "IPCC" form of grouping the processes.
The data from each country in the UK used to prepare the "Mid" scenario are given in Tables A1.2 to A1.5 and for the UK in Table A1.1. The "Low", "Mid" and "High" scenario data at 5 year intervals are given in Table 19. Remvals associated with post-1990 afforestation are presented in Appendix 4.

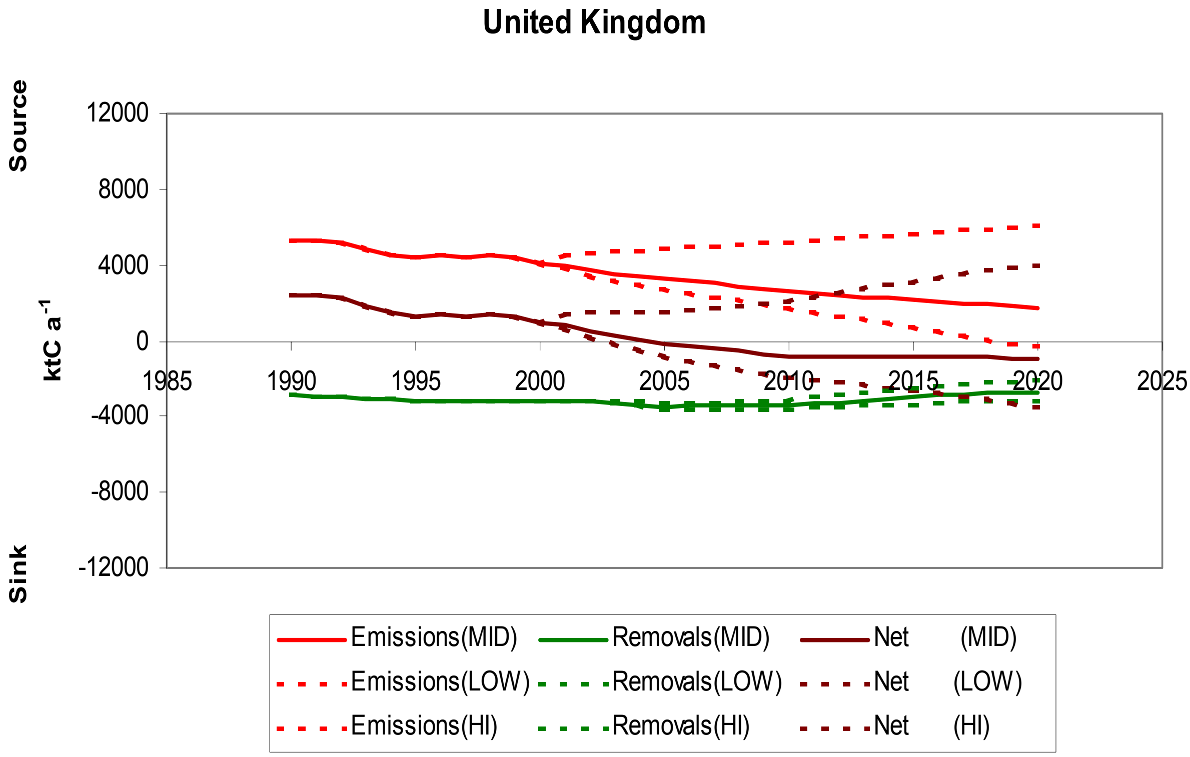


Figure 3 Projections to 2020 of Emissions and Removals of carbon from atmosphere by UK land use change and forestry.

Year	Emissions (LOW)	Removals LOW)	Net (LOW)	Emissions (MID)	Removals (MID)	Net (MID)	Emissions (HIGH)	Removals (HIGH)	Net (HIGH)
1990	5277	-2879	2398	5277	-2879	2398	5277	-2879	2398
1995	4422	-3144	1278	4422	-3144	1278	4422	-3144	1278
2000	4093	-3178	915	4093	-3178	915	4093	-3178	915
2005	2734	-3574	-840	3285	-3466	-181	4838	-3315	1523
2010	1755	-3674	-1919	2625	-3449	-824	5234	-3139	2095
2015	705	-3352	-2647	2163	-3007	-844	5648	-2542	3106
2020	-324	-3147	-3471	1745	-2686	-941	6066	-2066	4000

Table 19. Inventory (1990 to 2000) and projected (2005 to 2020) Emissions and Removals data (kTC/year) for three scenarios (See text) (-ve sign indicates Removal)

7 References

Adger, N. & Subak, S. (1995) Carbon fluxes resulting from Land Use Change: Land Use Data and Policy. In: Carbon Sequestration in Vegetation and Soils (Ed. by MGR Cannell), DOE/ITE Contract EPG 1/1/3. Interim Report March 1995. Department of Environment, London.

Barr, CJ, Bunce, RGH, Clarke, RT, Fuller, RM., Furse, MT, Gillespie, MK., Groom, GB, Hallam, C.J, Hornung, M, Howard, DC, Ness, MJ, (1993) Countryside Survey 1990, Main Report. London, Department of the Environment.

BGS (2002), United Kingdom Minerals Yearbook 1, British Geological Survey, Natural Environment Research Council

Bradley, I, (1997) Carbon loss from drained lowland fens. In: Carbon Sequestration in Vegetation and Soils (Ed. by MGR Cannell), DOE/ITE Contract EPG 1/1/3. Final Report March 1997. Department of Environment, London.

Cannell, MGR, Dewar, RC, (1995), The carbon sink provided by plantation forests and their products in Britain, Forestry, Vol. 68, No. 1, pp 35-48.

Cannell, MGR, Milne, R, Hargreaves, KJ, Brown, TAW, Cruickshank, MM, Bradley, RI, Spencer, T, Hope, D, Billett, MF, Adger, WN & Subak, S (1999) National inventories of terrestrial carbon sources and sinks: the UK experience. Climatic Change 42, 505-530

Cruickshank, MM, Tomlinson, RW, Devine, PM, Milne, R (1997) Effects of agricultural, management on carbon storage in Northern Ireland. In: *Carbon Sequestration in Vegetation and Soil*s (Ed. by MGR Cannell), DOE Contract EPG 1/1/3. Final Report March 1997. Department of Environment, London.

Cruickshank, MM, Tomlinson, RW (1997) Carbon loss from UK peatlands for fuel and horticulture. In: Carbon Sequestration in Vegetation and Soils (Ed. by MGR Cannell), DOE, Contract EPG 1/1/3. Final Report March 1997. Department of Environment, London.

Cruickshank, MM, Tomlinson, RW, Devine, PM and Milne, R (1998) Carbon in the vegetation and soils of Northern Ireland. Proceedings of the Royal Irish Academy, 98B, 9 - 21.

Cruickshank, MM, and Tomlinson, RW, (2000) Change in soil carbon storage in Northern Ireland: estimated by the IPCC default and matrix methods. DETR Contract EPG 1/1/39. Final Report April 2000. (Ed. by R. Milne),

Dewar, RC, Cannell, MGR, (1992) Carbon sequestration in the trees, products and soils of forest plantations: an analysis using UK examples. Tree Physiology Vol. 11, pp49 - 72.

DOE, (1997), Climate Change: The UK Programme; United Kingdom's Second Report under the Framework Convention on Climate Change, The Stationary Office, London.

Forestry Commission (2001), Annual Report and Accounts of the Forestry Commission 1999-2000. The Stationery Office: Edinburgh. (In press).

Forest Service (2000), Annual Report 1999/2000 of Forest Service, Dept. of Agriculture for Northern Ireland.

Hargreaves, K and Fowler, D (1997) Short-term CO_2 fluxes over peatland. In: Carbon Sequestration in Vegetation and Soils (Ed. by MGR Cannell), DOE Contract EPG 1/1/3. Final Report March 1997. Department of Environment, London

Howard, PJA and Howard, DM (1994) Modelling the effects of land use change and climate change on soil organic carbon stores. In: Carbon sequestration by soils in the UK, Report to the Department of the Environment, Contract No. PECD 7/12/80, March 1994.

IPCC, (1997a), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 1, Greenhouse Gas Inventory Reporting Instructions, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC, (1997b), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 2, Greenhouse Gas Inventory Workbook, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC, (1997c), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 3, Greenhouse Gas Inventory Reference Manual, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC, (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC Technical Support Unit, IGES, Kanagawa, Japan. ISBN 4-88788-000-6.

Milne, R and Brown, TA (1997) Carbon in the vegetation and soils of Great Britain. Journal of Environmental Management, 49, 413 - 433.

Milne, R, and Brown, TA (1999) Methods and data for Land Use Change and Forestry Sector in the 1997 IPCC Greenhouse Gas Inventory. In.: *Carbon Sequestration in Vegetation and Soils* (Ed. by R. Milne), DETR Contract EPG 1/1/39. Interim Report April 1999.

Milne, R, Brown, TAW and Murray, TD (1998) The effect of geographical variation in planting rate on the uptake of carbon by new forests of Great Britain. Forestry, 71, 298 – 309.

Milne, R., Murray, T.D. and Brown, T.A.W. (2000) The Land Use Change and Forestry Sector in the 1998 UK Greenhouse Gas Inventory using the Common Reporting Format. DETR Contract EPG 1/1/39. Final Report April 2000. (Ed. by R. Milne), MLC (1986) *Monitoring Landscape Change* Vols. 1, 1A & 10. Report prepared by Hunting Surveys & Consultants Ltd for Department of the Environment and the Countryside Commission.

Salway, A.G., (2001). *UK Greenhouse Gas Inventory, 1990 to 1999 Annual Report for submission under Framework Convention on Climate Change.* National Environmental Technology Centre, AEA Technology Centre. (In preparation)

Stamp, LD (1962) *The Land of Britain: Its Use and Misuse.* London, Longman.

Appendix 1
Data Tables

Table A1.1. United Kingdom data for 1999 UK GHG Inventory: A: component fluxes, B: "IPCC" summary, C: "CRF" summary. (Italics are "Mid" projections – see text)

A Gg carbon	Forest biomass	Forest soils & litter	Forest products	Land Use Change	Set Aside	Liming	Upland drainage	Lowland drainage	Peat extraction	Crop biomass
1990	-1563	-587	-429	3869	-48	390	400	450	216	-300
1991	-1587	-592	-430	3858	-72	483	400	440	219	-300
1992	-1724	-566	-368	3785	-96	494	400	430	216	-300
1993	-1872	-543	-305	3609	-127	308	400	420	213	-300
1994	-1935	-544	-299	3665	-517	346	400	410	242	-300
1995	-2074	-521	-249	3494	-547	417	400	400	259	-300
1996	-1983	-569	-315	3503	-421	413	400	390	237	-300
1997	-1965	-584	-303	3359	-275	367	400	380	222	-300
1998	-1905	-612	-327	3302	-37	280	400	370	192	-300
1999	-1862	-632	-353	3327	-81	234	400	360	224	-300
2000	-1952	-612	-314	3203	-292	210	400	350	223	-300
2001	*-1869*	*-647*	*-354*	*3111*	*-309*	*210*	*400*	*350*	*223*	*-300*
2002	*-2113*	*-584*	*-197*	*3019*	*-487*	*210*	*400*	*350*	*223*	*-300*
2003	*-2405*	*-520*	*-41*	*2927*	*-542*	*210*	*400*	*350*	*223*	*-300*
2004	*-2634*	*-480*	*60*	*2835*	*-593*	*210*	*400*	*350*	*223*	*-300*
2005	*-2880*	*-438*	*152*	*2743*	*-640*	*210*	*400*	*350*	*223*	*-300*
2006	*-2635*	*-536*	*11*	*2651*	*-685*	*210*	*400*	*350*	*223*	*-300*
2007	*-2364*	*-636*	*-155*	*2559*	*-727*	*210*	*400*	*350*	*223*	*-300*
2008	*-1975*	*-760*	*-400*	*2467*	*-766*	*210*	*400*	*350*	*223*	*-300*
2009	*-1811*	*-814*	*-527*	*2375*	*-804*	*210*	*400*	*350*	*223*	*-300*
2010	*-1529*	*-899*	*-721*	*2283*	*-840*	*210*	*400*	*350*	*223*	*-300*
2011	*-1026*	*-1027*	*-961*	*2191*	*-875*	*210*	*400*	*350*	*223*	*-300*
2012	*-1121*	*-975*	*-844*	*2099*	*-867*	*210*	*400*	*350*	*223*	*-300*
2013	*-923*	*-1019*	*-914*	*2007*	*-859*	*210*	*400*	*350*	*223*	*-300*
2014	*-609*	*-1111*	*-1059*	*1915*	*-851*	*210*	*400*	*350*	*223*	*-300*
2015	*-554*	*-1100*	*-1053*	*1823*	*-842*	*210*	*400*	*350*	*223*	*-300*
2016	*-387*	*-1122*	*-1086*	*1731*	*-834*	*210*	*400*	*350*	*223*	*-300*
2017	*-456*	*-1072*	*-995*	*1639*	*-825*	*210*	*400*	*350*	*223*	*-300*
2018	*-565*	*-1018*	*-888*	*1547*	*-817*	*210*	*400*	*350*	*223*	*-300*
2019	*-655*	*-980*	*-812*	*1455*	*-808*	*210*	*400*	*350*	*223*	*-300*
2020	*-366*	*-1054*	*-966*	*1363*	*-800*	*210*	*400*	*350*	*223*	*-300*

B Gg Carbon	Changes in woody biomass		Soils	Other	Other	NET Emission (+) Removal (-)
1990	-2579		4211	1066	-300	2398
1991	-2609		4269	1059	-300	2419
1992	-2658		4183	1046	-300	2271
1993	-2720		3790	1033	-300	1803
1994	-2778		3494	1052	-300	1468
1995	-2844		3363	1059	-300	1278
1996	-2867		3495	1027	-300	1355
1997	-2852		3451	1002	-300	1302
1998	-2844		3545	962	-300	1362
1999	-2847		3481	984	-300	1317
2000	-2878		3120	973	-300	915
IPCC Format Tables	5A (Removal s)		5D (Emissions)	5E (Emission s)	5E (Remo vals)	
	Forest biomass, soils, litter, products		*Effect of LUC (Net), Set Aside soils (Removal), liming of soils*	*Drainage of soils, peat extraction*	*Crop biomass*	

C Gg Carbon	Changes in woody biomass	Soils	Soils	Other	Other	NET Emission (+) Removal (-)
1990	-1992	-635	5109	216	-300	2398
1991	-2017	-664	5181	219	-300	2419
1992	-2092	-662	5109	216	-300	2271
1993	-2177	-670	4737	213	-300	1803
1994	-2234	-1061	4821	242	-300	1468
1995	-2323	-1068	4711	259	-300	1278
1996	-2298	-990	4706	237	-300	1355
1997	-2268	-859	4506	222	-300	1302
1998	-2232	-649	4352	192	-300	1362
1999	-2215	-713	4321	224	-300	1317
2000	-2266	-904	4162	223	-300	915
CRF Format Tables	5A (Removals)	5D (Removals)	5D (Emissions)	5E (Emissions)	5E (Rem ovals)	5 Net
	Forest biomass, forest products	*Forest soils, forest litter, Set aside soils*	*Effect on soils of LUC(Net), liming, drainage.*	*Peat extraction*	*Crop biomass*	

Table A1.2 England data for 2000 UK GHG Inventory: A: component fluxes, B: "IPCC" summary. (Italics are "Mid" projections – see text)

AGg carbon	Forest biomass	Forest soils & litter	Forest products	Land Use Change	Set Aside	Liming	Upland drainage	Lowland drainage	Peat extraction	Crop biomass
1990	-174	-250	-202	436	-35	287	40	450	62	-255
1991	-288	-215	-128	344	-52	355	40	440	67	-255
1992	-324	-206	-105	271	-69	362	40	430	60	-255
1993	-364	-198	-82	195	-92	226	40	420	60	-255
1994	-366	-200	-83	125	-404	254	40	410	77	-255
1995	-383	-197	-72	49	-431	306	40	400	88	-255
1996	-361	-206	-80	-15	-331	304	40	390	73	-255
1997	-382	-201	-63	-93	-205	270	40	380	68	-255
1998	-357	-210	-77	-156	-24	206	40	370	52	-255
1999	-323	-221	-96	-217	-57	172	40	360	68	-255
2000	-336	-217	-87	-292	-228	154	40	350	70	-255
2001	*-332*	*-220*	*-84*	*-362*	*-242*	*154*	*40*	*350*	*70*	*-255*
2002	*-408*	*-199*	*-35*	*-432*	*-380*	*154*	*40*	*350*	*70*	*-255*
2003	*-491*	*-180*	*12*	*-502*	*-423*	*154*	*40*	*350*	*70*	*-255*
2004	*-545*	*-172*	*40*	*-572*	*-463*	*154*	*40*	*350*	*70*	*-255*
2005	*-614*	*-159*	*72*	*-642*	*-499*	*154*	*40*	*350*	*70*	*-255*
2006	*-562*	*-183*	*43*	*-712*	*-533*	*154*	*40*	*350*	*70*	*-255*
2007	*-503*	*-205*	*6*	*-782*	*-565*	*154*	*40*	*350*	*70*	*-255*
2008	*-363*	*-250*	*-80*	*-852*	*-595*	*154*	*40*	*350*	*70*	*-255*
2009	*-276*	*-276*	*-132*	*-922*	*-624*	*154*	*40*	*350*	*70*	*-255*
2010	*-217*	*-292*	*-169*	*-992*	*-651*	*154*	*40*	*350*	*70*	*-255*
2011	*-151*	*-309*	*-195*	*-1062*	*-677*	*154*	*40*	*350*	*70*	*-255*
2012	*-219*	*-286*	*-143*	*-1132*	*-670*	*154*	*40*	*350*	*70*	*-255*
2013	*-155*	*-306*	*-172*	*-1202*	*-663*	*154*	*40*	*350*	*70*	*-255*
2014	*117*	*-398*	*-322*	*-1272*	*-655*	*154*	*40*	*350*	*70*	*-255*
2015	*113*	*-389*	*-310*	*-1342*	*-648*	*154*	*40*	*350*	*70*	*-255*
2016	*166*	*-398*	*-324*	*-1412*	*-640*	*154*	*40*	*350*	*70*	*-255*
2017	*148*	*-385*	*-303*	*-1482*	*-632*	*154*	*40*	*350*	*70*	*-255*
2018	*93*	*-365*	*-262*	*-1552*	*-625*	*154*	*40*	*350*	*70*	*-255*
2019	*45*	*-352*	*-229*	*-1622*	*-617*	*154*	*40*	*350*	*70*	*-255*
2020	*47*	*-355*	*-231*	*-1692*	*-610*	*154*	*40*	*350*	*70*	*-255*

B Gg Carbon	Changes in woody biomass		Soils	Other	Other	NET Emission (+) Removal (-)
1990	-626		688	552	-255	359
1991	-631		647	547	-255	308
1992	-635		565	530	-255	205
1993	-644		330	520	-255	-49
1994	-649		-25	527	-255	-402
1995	-652		-75	528	-255	-454
1996	-647		-42	503	-255	-441
1997	-646		-28	488	-255	-440
1998	-644		26	462	-255	-411
1999	-640		-102	468	-255	-529
	-640		-367	460	-255	-801
IPCC Format Tables	5A (Removals)		5D (Emissions)	5E (Emissions)	5E (Remo vals)	
	Forest biomass, soils, litter, products		*Effect of LUC (Net), Set Aside soils (Removal), liming of soils*	*Drainage of soils, peat extraction*	*Crop biomass*	

Table A1.3 Scotland data for 2000 UK GHG Inventory: A: component fluxes, B: "IPCC" summary. (Italics are "Mid" projections – see text)

AGg carbon	Forest biomass	Forest soils & litter	Forest products	Land Use Change	Set Aside	Liming	Upland drainage	Lowland drainage	Peat extraction	Crop biomass
1990	-1070	-242	-170	2858	-13	47	320	0	22	-37
1991	-1060	-257	-195	2907	-20	58	320	0	20	-37
1992	-1132	-251	-173	2927	-27	59	320	0	24	-37
1993	-1214	-244	-149	2940	-33	37	320	0	21	-37
1994	-1287	-239	-135	2949	-109	42	320	0	34	-37
1995	-1385	-226	-111	2946	-112	50	320	0	39	-37
1996	-1346	-257	-155	2984	-86	50	320	0	32	-37
1997	-1305	-280	-166	3011	-66	44	320	0	22	-37
1998	-1287	-296	-168	3029	-11	34	320	0	8	-37
1999	-1299	-302	-166	3034	-22	28	320	0	24	-37
2000	-1372	-290	-141	3019	-61	25	320	0	20	-37
2001	*-1292*	*-325*	*-191*	*3008*	*-65*	*25*	*320*	*0*	*20*	*-37*
2002	*-1408*	*-301*	*-118*	*2997*	*-102*	*25*	*320*	*0*	*20*	*-37*
2003	*-1579*	*-268*	*-33*	*2986*	*-114*	*25*	*320*	*0*	*20*	*-37*
2004	*-1727*	*-243*	*25*	*2975*	*-125*	*25*	*320*	*0*	*20*	*-37*
2005	*-1872*	*-223*	*67*	*2964*	*-135*	*25*	*320*	*0*	*20*	*-37*
2006	*-1730*	*-282*	*-19*	*2953*	*-145*	*25*	*320*	*0*	*20*	*-37*
2007	*-1600*	*-338*	*-103*	*2942*	*-155*	*25*	*320*	*0*	*20*	*-37*
2008	*-1457*	*-391*	*-202*	*2931*	*-164*	*25*	*320*	*0*	*20*	*-37*
2009	*-1446*	*-406*	*-242*	*2920*	*-173*	*25*	*320*	*0*	*20*	*-37*
2010	*-1322*	*-452*	*-346*	*2909*	*-181*	*25*	*320*	*0*	*20*	*-37*
2011	*-954*	*-553*	*-534*	*2898*	*-190*	*25*	*320*	*0*	*20*	*-37*
2012	*-990*	*-530*	*-477*	*2887*	*-189*	*25*	*320*	*0*	*20*	*-37*
2013	*-824*	*-571*	*-547*	*2876*	*-188*	*25*	*320*	*0*	*20*	*-37*
2014	*-771*	*-578*	*-559*	*2865*	*-188*	*25*	*320*	*0*	*20*	*-37*
2015	*-711*	*-582*	*-574*	*2854*	*-187*	*25*	*320*	*0*	*20*	*-37*
2016	*-646*	*-587*	*-580*	*2843*	*-186*	*25*	*320*	*0*	*20*	*-37*
2017	*-713*	*-552*	*-511*	*2832*	*-185*	*25*	*320*	*0*	*20*	*-37*
2018	*-826*	*-507*	*-419*	*2821*	*-184*	*25*	*320*	*0*	*20*	*-37*
2019	*-877*	*-487*	*-379*	*2810*	*-183*	*25*	*320*	*0*	*20*	*-37*
2020	*-664*	*-543*	*-496*	*2799*	*-183*	*25*	*320*	*0*	*20*	*-37*

B Gg Carbon	Changes in woody biomass		Soils	Other	Other	NET Emission (+) Removal (-)
1990	-1482		2891	342	-37	1714
1991	-1512		2945	340	-37	1736
1992	-1556		2960	344	-37	1711
1993	-1607		2944	341	-37	1642
1994	-1661		2881	354	-37	1537
1995	-1722		2884	359	-37	1484
1996	-1758		2948	352	-37	1504
1997	-1751		2990	342	-37	1543
1998	-1751		3052	328	-37	1592
1999	-1767		3040	344	-37	1580
2000	-1803		2983	340	-37	1483
IPCC Format Tables	5A (Removals)		5D (Emissions)	5E (Emissions)	5E (Removals)	
	Forest biomass, soils, litter, products		*Effect of LUC (Net), Set Aside soils (Removal), liming of soils*	*Drainage of soils, peat extraction*	*Crop biomass*	

Table A1.4 Wales data for 2000 UK GHG Inventory: A: component, B: “IPCC” summary. (Italics are “Mid” projections – see text)

AGg carbon	Forest biomass	Forest soils & litter	Forest products	Land Use Change	Set Aside	Liming	Upland drainage	Lowland drainage	Peat extraction	Crop biomass
1990	-209	-63	-43	222	0	33	20	0	0	-4
1991	-120	-89	-95	247	0	40	20	0	0	-4
1992	-145	-78	-77	236	0	41	20	0	0	-4
1993	-164	-71	-64	228	-2	26	20	0	0	-4
1994	-169	-69	-61	225	-4	29	20	0	0	-4
1995	-180	-65	-54	220	-4	35	20	0	0	-4
1996	-163	-69	-60	223	-4	34	20	0	0	-4
1997	-168	-65	-52	218	-4	31	20	0	0	-4
1998	-151	-68	-59	220	-3	23	20	0	0	-4
1999	-135	-71	-67	222	-1	20	20	0	0	-4
2000	-136	-68	-65	217	-3	17	20	0	0	-4
2001	*-129*	*-67*	*-63*	*216*	*-3*	*17*	*20*	*0*	*0*	*-4*
2002	*-170*	*-53*	*-34*	*215*	*-5*	*17*	*20*	*0*	*0*	*-4*
2003	*-214*	*-39*	*-6*	*214*	*-5*	*17*	*20*	*0*	*0*	*-4*
2004	*-256*	*-28*	*17*	*213*	*-6*	*17*	*20*	*0*	*0*	*-4*
2005	*-284*	*-21*	*31*	*212*	*-6*	*17*	*20*	*0*	*0*	*-4*
2006	*-254*	*-30*	*16*	*211*	*-6*	*17*	*20*	*0*	*0*	*-4*
2007	*-177*	*-52*	*-27*	*210*	*-7*	*17*	*20*	*0*	*0*	*-4*
2008	*-95*	*-72*	*-73*	*209*	*-7*	*17*	*20*	*0*	*0*	*-4*
2009	*-42*	*-83*	*-102*	*208*	*-7*	*17*	*20*	*0*	*0*	*-4*
2010	*57*	*-107*	*-158*	*207*	*-8*	*17*	*20*	*0*	*0*	*-4*
2011	*155*	*-127*	*-204*	*206*	*-8*	*17*	*20*	*0*	*0*	*-4*
2012	*147*	*-116*	*-187*	*205*	*-8*	*17*	*20*	*0*	*0*	*-4*
2013	*101*	*-96*	*-150*	*204*	*-8*	*17*	*20*	*0*	*0*	*-4*
2014	*80*	*-87*	*-131*	*203*	*-8*	*17*	*20*	*0*	*0*	*-4*
2015	*84*	*-84*	*-127*	*202*	*-8*	*17*	*20*	*0*	*0*	*-4*
2016	*108*	*-86*	*-128*	*201*	*-8*	*17*	*20*	*0*	*0*	*-4*
2017	*103*	*-80*	*-118*	*200*	*-8*	*17*	*20*	*0*	*0*	*-4*
2018	*116*	*-79*	*-119*	*199*	*-7*	*17*	*20*	*0*	*0*	*-4*
2019	*113*	*-75*	*-114*	*198*	*-7*	*17*	*20*	*0*	*0*	*-4*
2020	*190*	*-94*	*-155*	*197*	*-7*	*17*	*20*	*0*	*0*	*-4*

B Gg Carbon	Changes in woody biomass		Soils	Other	Other	NET Emission (+) Removal (-)
1990	-315		255	20	-4	-44
1991	-304		288	20	-4	0
1992	-300		277	20	-4	-7
1993	-299		251	20	-4	-32
1994	-299		250	20	-4	-33
1995	-299		251	20	-4	-32
1996	-292		254	20	-4	-22
1997	-285		245	20	-4	-24
1998	-278		241	20	-4	-21
1999	-273		240	20	-4	-17
	-269		232	20	-4	-21
IPCC Format Tables	5A (Removals)		5D (Emissions)	5E (Emissions)	5E (Removals)	
	Forest biomass, soils, litter, products		*Effect of LUC (Net), Set Aside soils (Removal), liming of soils*	*Drainage of soils, peat extraction*	*Crop biomass*	

Table A1.5 Northern Ireland data for 2000 UK GHG Inventory: A: component fluxes, B: "IPCC" summary. (Italics are "Mid" projections – see text)

AGg carbon	Forest biomass	Forest soils & litter	Forest products	Land Use Change	Set Aside	Liming	Upland drainage	Lowland drainage	Peat extraction	Crop biomass
1990	-110	-32	-14	353	0	24	20	0	132	-4
1991	-119	-31	-12	360	0	30	20	0	132	-4
1992	-123	-31	-13	351	0	31	20	0	132	-4
1993	-130	-30	-10	245	0	19	20	0	132	-4
1994	-113	-36	-20	366	0	22	20	0	132	-4
1995	-126	-33	-12	278	0	26	20	0	132	-4
1996	-113	-37	-20	310	0	26	20	0	132	-4
1997	-110	-38	-22	222	0	23	20	0	132	-4
1998	-110	-38	-23	209	0	17	20	0	132	-4
1999	-105	-38	-24	288	0	15	20	0	132	-4
2000	-108	-37	-21	259	0	13	20	0	132	-4
2001	*-116*	*-35*	*-16*	*249*	*0*	*13*	*20*	*0*	*132*	*-4*
2002	*-127*	*-31*	*-10*	*239*	*0*	*13*	*20*	*0*	*132*	*-4*
2003	*-121*	*-33*	*-14*	*229*	*0*	*13*	*20*	*0*	*132*	*-4*
2004	*-106*	*-37*	*-22*	*219*	*0*	*13*	*20*	*0*	*132*	*-4*
2005	*-110*	*-35*	*-18*	*209*	*0*	*13*	*20*	*0*	*132*	*-4*
2006	*-89*	*-41*	*-29*	*199*	*0*	*13*	*20*	*0*	*132*	*-4*
2007	*-84*	*-41*	*-31*	*189*	*0*	*13*	*20*	*0*	*132*	*-4*
2008	*-60*	*-47*	*-45*	*179*	*0*	*13*	*20*	*0*	*132*	*-4*
2009	*-47*	*-49*	*-51*	*169*	*0*	*13*	*20*	*0*	*132*	*-4*
2010	*-47*	*-48*	*-48*	*159*	*0*	*13*	*20*	*0*	*132*	*-4*
2011	*-76*	*-38*	*-28*	*149*	*0*	*13*	*20*	*0*	*132*	*-4*
2012	*-59*	*-43*	*-37*	*139*	*0*	*13*	*20*	*0*	*132*	*-4*
2013	*-45*	*-46*	*-45*	*129*	*0*	*13*	*20*	*0*	*132*	*-4*
2014	*-35*	*-48*	*-47*	*119*	*0*	*13*	*20*	*0*	*132*	*-4*
2015	*-40*	*-45*	*-42*	*109*	*0*	*13*	*20*	*0*	*132*	*-4*
2016	*-15*	*-51*	*-54*	*99*	*0*	*13*	*20*	*0*	*132*	*-4*
2017	*6*	*-55*	*-63*	*89*	*0*	*13*	*20*	*0*	*132*	*-4*
2018	*52*	*-67*	*-88*	*79*	*0*	*13*	*20*	*0*	*132*	*-4*
2019	*64*	*-66*	*-90*	*69*	*0*	*13*	*20*	*0*	*132*	*-4*
2020	*61*	*-62*	*-84*	*59*	*0*	*13*	*20*	*0*	*132*	*-4*

B Gg Carbon	Changes in woody biomass		Soils	Other	Other	NET Emission (+) Removal (-)
1990	-156		377	152	-4	369
1991	-162		390	152	-4	376
1992	-167		382	152	-4	363
1993	-170		264	152	-4	242
1994	-169		388	152	-4	367
1995	-171		304	152	-4	281
1996	-170		336	152	-4	314
1997	-170		245	152	-4	223
1998	-171		226	152	-4	203
1999	-167		303	152	-4	284
2000	-166		272	152	-4	254
IPCC Format Tables	5A (Removals)		5D (Emissions)	5E (Emissions)	5E (Removals)	
	Forest biomass, soils, litter, products		*Effect of LUC (Net), Set Aside soils (Removal), liming of soils*	*Drainage of soils, peat extraction*	*Crop biomass*	

Table A1.6. UK Data for 2000 UK GHG Inventory expressed in units of Gg of CO_2:
A: component fluxes, B: “IPCC” summary, C: “CRF” summary.

A Gg Carbon dioxide	Forest biomass	Forest soils & litter	Forest products	Land Use Change	Set Aside	Liming	Upland drainage	Lowland drainage	Peat extraction	Crop biomass
1990	-5731	-2152	-1573	14187	-178	1430	1467	1650	792	-1100
1991	-5819	-2171	-1577	14145	-264	1772	1467	1613	803	-1100
1992	-6321	-2075	-1349	13880	-351	1810	1467	1577	792	-1100
1993	-6864	-1991	-1118	13231	-465	1130	1467	1540	781	-1100
1994	-7095	-1995	-1096	13439	-1897	1270	1467	1503	889	-1100
1995	-7605	-1910	-913	12810	-2007	1529	1467	1467	950	-1100
1996	-7271	-2086	-1155	12843	-1542	1515	1467	1430	869	-1100
1997	-7205	-2141	-1111	12316	-1007	1346	1467	1393	815	-1100
1998	-6985	-2244	-1199	12106	-136	1027	1467	1357	704	-1100
1999	-6827	-2317	-1294	12199	-298	859	1467	1320	821	-1100
2000	-7157	-2244	-1151	11744	-1071	770	1457	1283	818	-1100

B Gg Carbon dioxide	Changes in woody biomass		Soils	Other	Other	NET Emission (+) Removal (-)
1990	-9456		15439	3908	-1100	8791
1991	-9566		15653	3883	-1100	8869
1992	-9746		15338	3835	-1100	8327
1993	-9973		13897	3787	-1100	6610
1994	-10186		12811	3859	-1100	5384
1995	-10428		12332	3883	-1100	4687
1996	-10512		12816	3766	-1100	4969
1997	-10457		12655	3675	-1100	4773
1998	-10428		12997	3527	-1100	4995
1999	-10439		12764	3608	-1100	4829
2000	-10533		11440	3568	-1100	3355
IPCC Format Tables	5A (Removals)		5D (Emissions)	5E (Emissions)	5E (Removals)	
	Forest biomass soils, litter, & products		*Effect of LUC (Net), Set Aside soils (Removal), liming of soils*	*Drainage of soils, peat extraction*	*Crop biomass*	

C Gg Carbon dioxide	Changes in woody biomass	Soils	Soils	Other	Other	NET Emission (+) Removal (-)
1990	-7304	-2328	18733	792	-1100	8791
1991	-7396	-2435	18997	803	-1100	8869
1992	-7671	-2427	18733	792	-1100	8327
1993	-7982	-2457	17369	781	-1100	6610
1994	-8191	-3890	17677	887	-1100	5384
1995	-8518	-3916	17274	950	-1100	4687
1996	-8426	-3630	17255	869	-1100	4969
1997	-8316	-3150	16522	814	-1100	4773
1998	-8184	-2380	15957	704	-1100	4995
1999	-8122	-2614	15844	821	-1100	4829
2000	-8309	-3315	15261	818	-1100	3355
CRF Format Tables	5A (Removals)	5D (Removals)	5D (Emissions)	5E (Emissions)	5E (Removals)	5 Net
	Forest biomass, forest products	*Forest soils, forest litter, Set aside soils*	*Effect on soils of LUC(Net), liming, drainage.*	*Peat extraction*	*Crop biomass*	