SECTION 6

Mapping of carbon uptake in British woodlands and forests using EuroBiota and C-Flow.

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Introduction

In Milne & Brown (2001) the forest ecosystem model "EuroBiota" was introduced (Kramer & Mohren 2001). This model primarily describes the effect of changing temperature and atmospheric carbon dioxide concentration on productivity. The model is based on the work of Wang & Polglase (1995). Extensive modification of the original model has taken place to allow the influence of geographical variation in weather and the presence of evergreen and deciduous forest at different locations to be taken into account. The model was paramaterised using results from site-specific process models which had been calibrated against field data at a range of locations across Europe. Conifer and deciduous forests were distinguished. The effect of changing air temperature was described using a version of the CRU 1901 - 1995 climate data but regridded to the 0.5^{o} cell size. Changes in carbon dioxide concentration throughout Europe followed the IS92a emission scenario and were as estimated by University of Berne for the IPCC Second Assessment Report.

The C-Flow model is that used to prepare estimates on carbon uptake by forest at the scale of the UK devolved regions for use in the various GHG Inventories. The coding of C-Flow has now been altered so that it can be run for any chosen location in the UK where a time series of forest planting data is available.

The Woodlands Surveys Branch of the Forestry Commission has now provided forest age data for each 20 km x 20 km square in Great Britain. This data has been prepared specifically for this project from the National Inventory of Woodlands and Trees (NIWT) using information from 1 ha sample squares.

This report describes the results from running EuroBiota and C-Flow for broadleaf and conifer forests in each 20 km square in Great Britain.

NIWT data

The data from National Inventory of Woodlands and Trees summarises the 1 hectare sample squares that fall within each 20km square. The squares are allocated by their grid reference. Some 20km squares may contain woodland map but may not contain any sample squares.

Each data file contains tables of areas per species by planting year class for one 20km square. The species reported are those present within each 20km square by the standard species grouping as used in the National Inventory reports (see below). Any species that is not present in that particular 20km square is omitted from the table. In addition the area of any area not stocked with trees (the area by default goes into the Pre 1860 planting year class) i.e. felled, integral open space and some land found in other uses not differentiated from woodland are given. The total mapped forest area in the square is also provided.

The data takes the format in Table 1 where each entry is the area in hectares of that planting date/species in the square appropriately scaled to the known forest area from the information from the sample squares.

Table 1 Example of data for one 20 km square.

species	1860	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	Total
SP	0	0	0	0	0	88	216	4	0	44	0	0	351
CP	0	0	0	0	0	62	0	0	0	0	0	0	62
NS	0	0	0	0	0	0	0	0	6	0	0	6	
EL	0	0	0	0	5	108	13	4	0	0	0	0	129
OK	0	93	0	32	6	6	18	0	0	0	0	0	155
BE	0	24	0	6	0	0	0	0	0	0	0	0	30
SY	0	0	0	9	67	0	186	0	23	10	0	0	296
AH	0	23	0	6	32	0	0	0	5	0	0	0	66
BI	0	0	0	5	4	291	42	5	126	0	0	0	472
PO	0	0	0	0	0	0	0	0	0	5	0	0	5
SC	0	0	0	0	0	0	25	0	70	44	0	0	140
EM	0	0	0	0	0	0	0	0	69	18	0	0	86
XB	0	32	0	77	33	6	55	0	51	66	0	0	320
MB	0	0	0	0	5	0	6	0	0	5	5	0	22
ZZ	316	0	0	0	0	0	0	0	0	0	0	0	316
TT	316	171	0	136	152	561	561	13	343	199	5	0	2456

The planting year classes for the data are as follows**:**

Class	**Label**	**Assumed age at 1995**
Pre 1860	1860	200
1860 – 1900	1900	115
1901 – 1910	1910	90
1911 – 1920	1920	80
1921 – 1930	1930	70
1931 – 1940	1940	60
1941 – 1950	1950	50
1951 – 1960	1960	40
1961 – 1970	1970	30
1971 – 1980	1980	20
1981 – 1990	1990	10
1991 -	2000	2

The last class, 1991 – extends to the planting year of the most recently planted trees in the 20km square at the time of survey.

The species / species groups are as follows:

SP Scots pine
CP Corsican pine
LP Lodgepole pine
SS Sitka spruce
NS Norway spruce
EL European larch
JL Japanese and hybrid larches
DF Douglas fir
XC Other conifers, minor species not separately reported upon
MC Mixed conifers, complex mixtures not distinguished

OK Pedunculate and sessile oaks
BE Beech
SY Sycamore
AH Ash
BI Birch
PO Poplars
SC Sweet chestnut
EM Elm
XB Other broadleaves, minor species not separately reported upon
MB Mixed broadleaves, complex mixtures not distinguished

ZZ Area within woodland not stocked with tree species

TT Total mapped woodland area.

In the initial testing of the application of these data to the EuroBiota and C-Flow models 1995 was assumed as the year of most recent planting. Each age class was assigned the specific age noted above on the assumption the data was recorded in 1995. An average conifer and broadleaf woodland age for each 20 km square was calculated based on this assumption. For use with C-Flow the recorded planting was assumed to have occurred equally across the class period (usually a decade).

EuroBiota.

The EuroBiota model has now been tested for use with both conifer and broadleaf woodland in Great Britain. The forest areas were taken from the NIWT for each 20 km square as described above.

The model was run for GB woodlands in 3 stages. 1: The carbon pools were initialised with effectively zero value and 1901 weather and carbon dioxide conditions assumed for each subsequent year and the model run to equilibrium carbon stocks. 2: Using these equilibrium tree and soil carbon stocks as new starting values, the model was rerun with changing temperature and carbon dioxide for the years from 1901 to 2100 3: To assess the effect on productivity of the specific age structure in the GB this transient run was recalculated, but all forests had a simulated felling and replanting in the year indicated by the average age of forest for the year. A prior felling and replanting was also included at 50 years for conifers or 90 years for broadleaves where this was possible. This felling and replanting was modelled by removing in the appropriate year all stem carbon from the model and transferring leaf and root carbon to the litter pools. The forest was then forced to re-established. The result of this approach is that productivities will depend, not only due to local weather conditions, but on the stage of recovery which the model forest has reached since the simulated felling/regrowth. Fluxes of carbon for the year 1990 were extracted from the output of the models for comparisons with C-Flow 20 km and national data. EuroBiota functions on a per unit area basis. Broadleaf and conifer woodland area in each square in 1990 was used to convert these output to a per woodland or national basis.

C-Flow

A time series of planting for each 20 km square from 1920 to 2000 was generated for broadleaf and conifer woodlands using the NIWT data. This period was chosen to be

similar to that used in the regional/national applications of C-Flow. The model was run separately for conifer and broadleaves for each square using these time series and the uptake per square, and nationally, extracted for 1990.

Results

From Tables 1 2 & 3 general agreement between the three approaches to estimating uptake of carbon by British forests can be seen. Table 1 presents the national run results for 1990 for Great Britain. Note the usual assumption that uptake by conifer soils is excluded. The data in Table 2 shows the sum of the equivalent outputs from C-Flow run for each 20 km square. The forest areas appropriate to each calculation are also included and go some way to explaining the differences in the results of the different ways of running C-Flow. The two sources agree well for conifer woodlands but the national scale run of C-Flow (Table 1) included much less broadleaf forest, even although the 20 km scale woodland data was limited to planting in a similar time span starting in 1920. It is likely therefore that the NIWT includes many broadleaved woodlands that fall outside of those reported in Forestry Commission planting statistics, upon which the national C-Flow runs are based. Figure 1 shows these differences in more detail. These woodlands may be smaller in size or have been planted without grant aid. Amenity and other small private woodlands would appear to fit this description but further investigation is required. This area of woodland, with those planted before 1920, have been taken to be "in equilibrium" with no net uptake in compilation of data for the UNFCCC GHG Inventory. The main purpose of the study reported here is to map these national data and although the use of C-Flow at the 20 km scale appears promising it is not yet possible to carry out calculations for just those broadleaf woodlands in the national scale planting data. The total difference in area can be calculated but the needed geographical distributions for various woodlands are not known. The results from EuroBiota are of similar magnitude to those from C-Flow but the comparative uptake of carbon between conifers and broadleaves is reversed. The forest areas in Table 4 are smaller, although the same source, than those in Table 3 for two reasons. EuroBiota failed for some 20 km squares due to incompatible climate/parameter combinations and many 20 km squares did not have climate data as this was generated from the 0.5^{o} x 0.5^{o} grid squares of the Global Climate Model data. These only cover areas where the majority of the area is land, which for a small island like Britain means strips of land around the coast do not have this coverage. However the relative magnitude of the NEP for conifers and broadleaves will be due to the structure and parameters of EuroBiota and these will require further investigation and comparison with C-Flow.

Having calculated carbon fluxes at the 20 km scale maps can then be drawn of their distribution. Figure 2 shows the distribution of woodlands with ages indicating they were planted since 1920 from the NIWT data and the resulting fluxes from C-Flow and EuroBiota. Figure 3 shows the equivalent broadleaf data. The distributions of broadleaf woodland plated prior to 1920 according to the NIWT are shown in Figure 4. Figure 5a and 5a show digital based maps of woodlands in Great Britain which may later me used for presentational purposes in relation to mapping of fluxes

C-Flow GB 1990						
(MtC)	Trees	Products	Litter	Soil	Total uptake	Area (kha)
Conifer	1.24	0.41	0.38	-	2.03	1,185
Broadleaf	0.21	0.01	0.04	0.14	0.40	144
ALL	**1.45**	**0.41**	**0.41**	**0.14**	**2.42**	1,328

Table 1 Results from national scale run of C-Flow showing total carbon uptake for woodlands in Great Britain.

C-Flow Sum of 20 km GB 1990						
(MtC)	Trees	Products	Litter	Soil	Total uptake	Area (kha)
Conifer	1.98	0.19	0.32	-	2.49	1,268
Broadleaf	0.90	0.00	0.14	0.57	1.62	578
ALL	**2.88**	**0.19**	**0.46**	**0.57**	**4.10**	1,846

Table 2 Results from 20 km scale run of C-Flow showing total carbon uptake for woodlands in Great Britain.

EuroBiota Sum of 20 km GB 1990			
	NEP (g/m2)	Total uptake (MtC)	Area (kha)
Conifer	60.2	0.92	1,106
Broadleaf	43.3	1.09	507
ALL		2.02	1,613

Table 3 results from 20 km scale run of EuroBiota showing net ecosystem productivity and total carbon uptake for woodlands in Great Britain

Future work on mapping LUCF fluxes for UK

- Investigation of EuroBiota parameter values to consider relative NEP of broadleaf and conifer woodland.
- Consideration of how pre-1920 and "missing" broadleaf woodlands might be included in national C-Flow estimates or excluded from 20 km C-Flow estimates
- Extension of present work on woodlands to Northern Ireland
- Further development of methods for estimating at 20 km scale carbon gains and losses for soils due to land use change.

References

Kramer, K. & Mohren G.M.J. (2001) *Long-term effects of climate change on carbon budgets of forests in Europe.* Final report of EU-funded project "Long-term regional effects of climate change on European forests: impact assessment and consequences for carbon budgets (LTEEF-II, ENV4-CT97-0577)"

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Wang, Y-P. & Polglase, P.J. (1995) Carbon balance in the tundra, boreal forest and humid tropical forest during climate change: scaling up from leaf physiology and soil carbon dynamics. *Plant, Cell and Environment*, **18**, 1226-1244.

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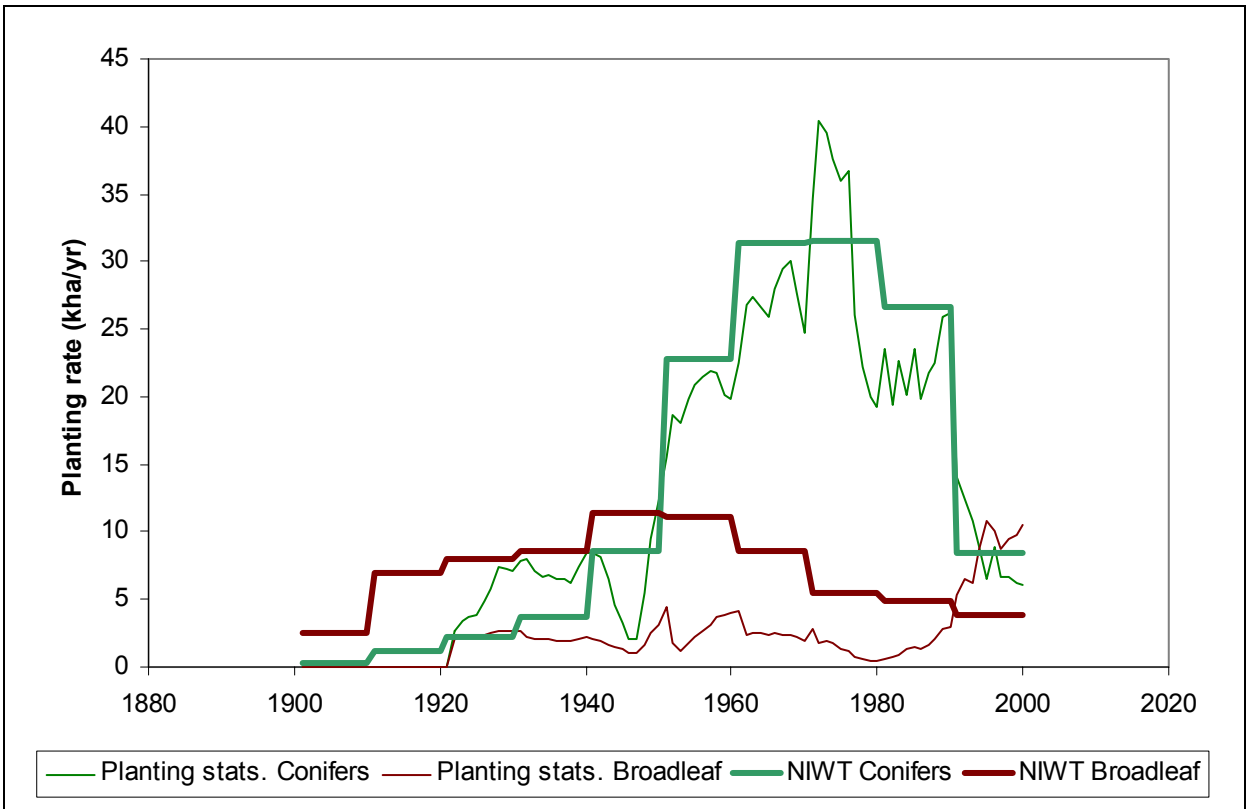

Figure 1 Comparison of woodland planting in Great Britain as indicated by FC new planting statistics and NIWT age data from samples.

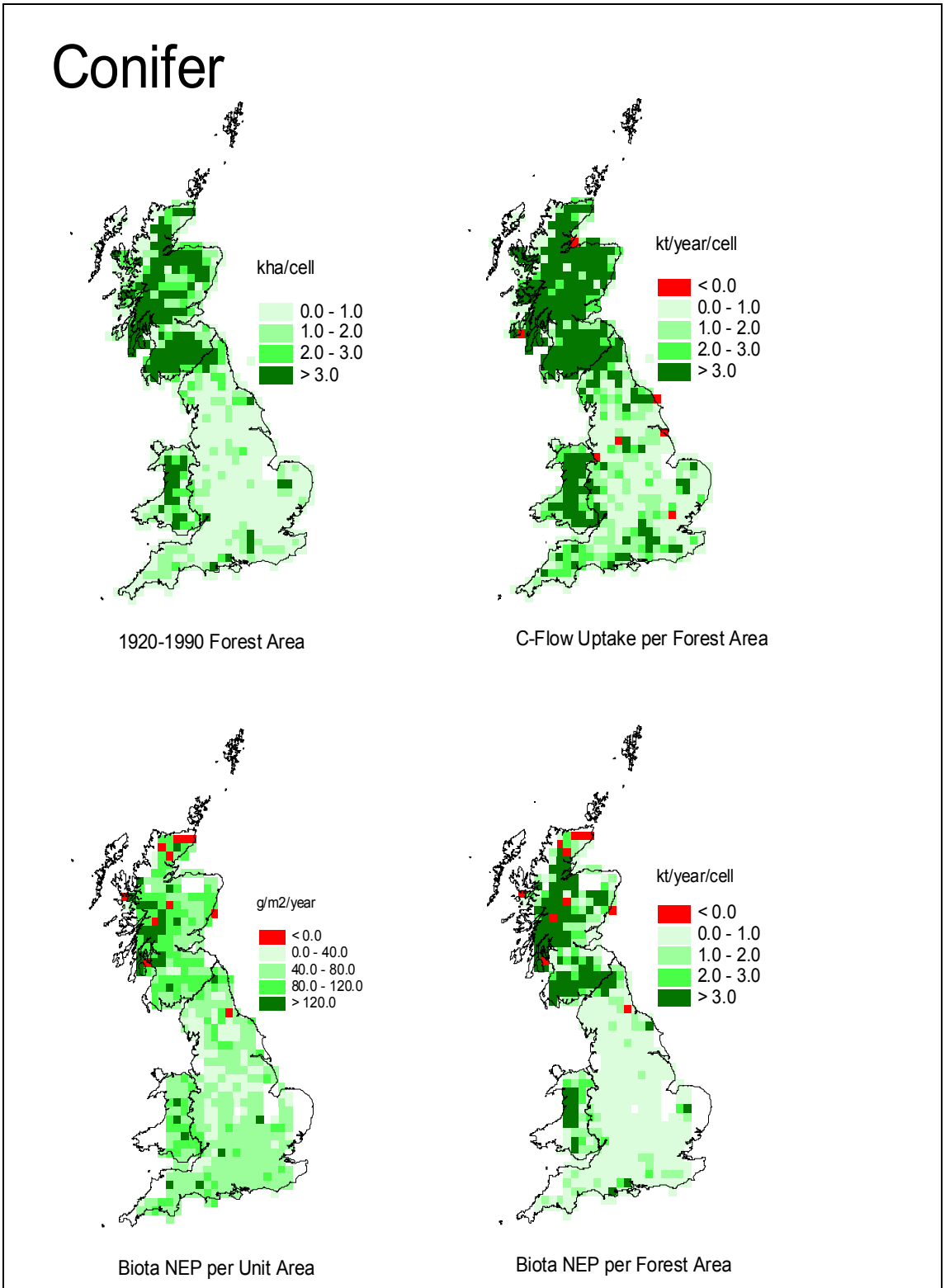

Figure 2. Conifer woodlands, C-Flow carbon uptake and EuroBiota carbon fluxes for 1990 at 20 km scale.

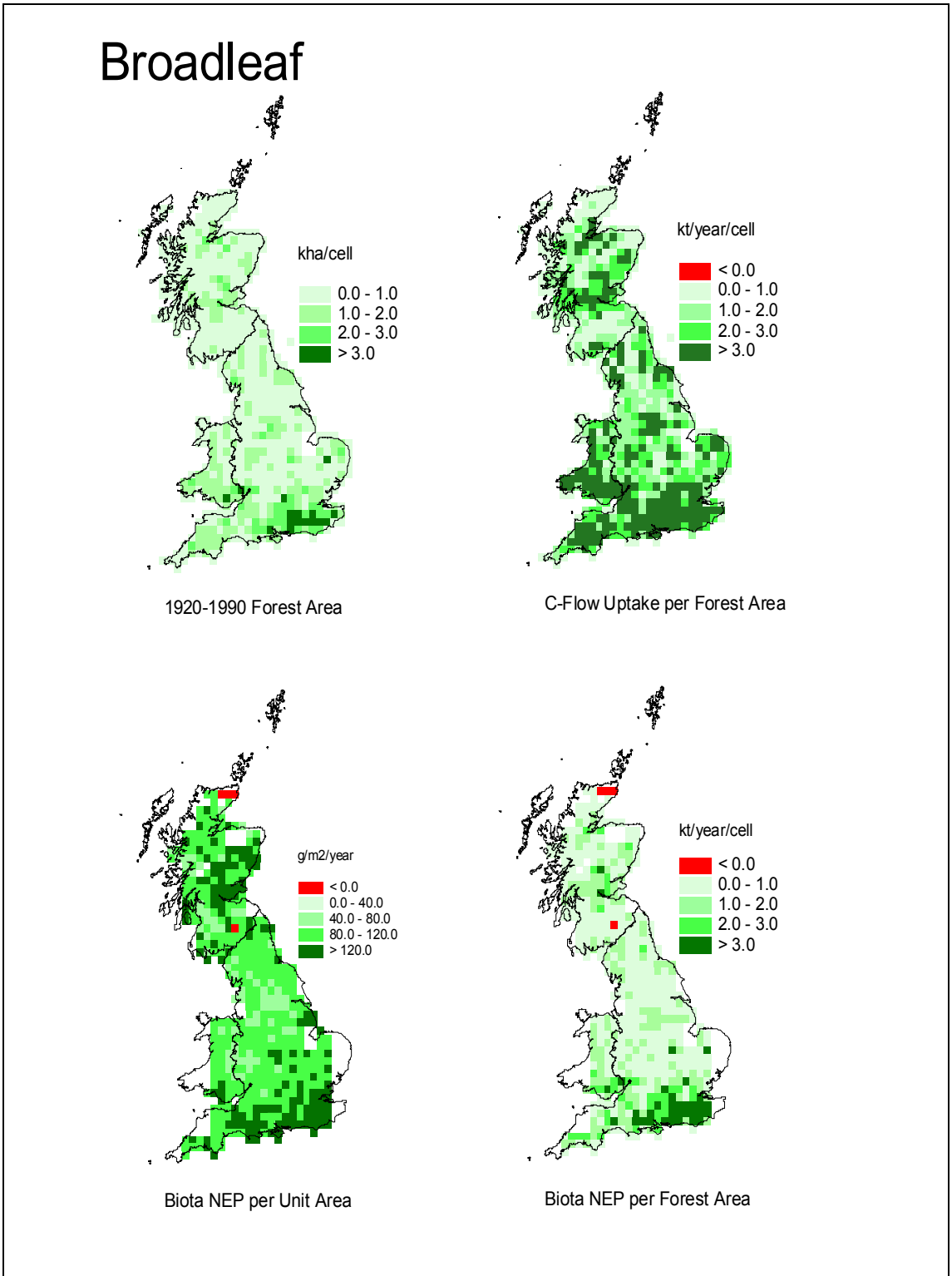

Figure 3. Broadleaf woodlands, C-Flow carbon uptake and EuroBiota carbon fluxes for 1990 at 20 km scale.

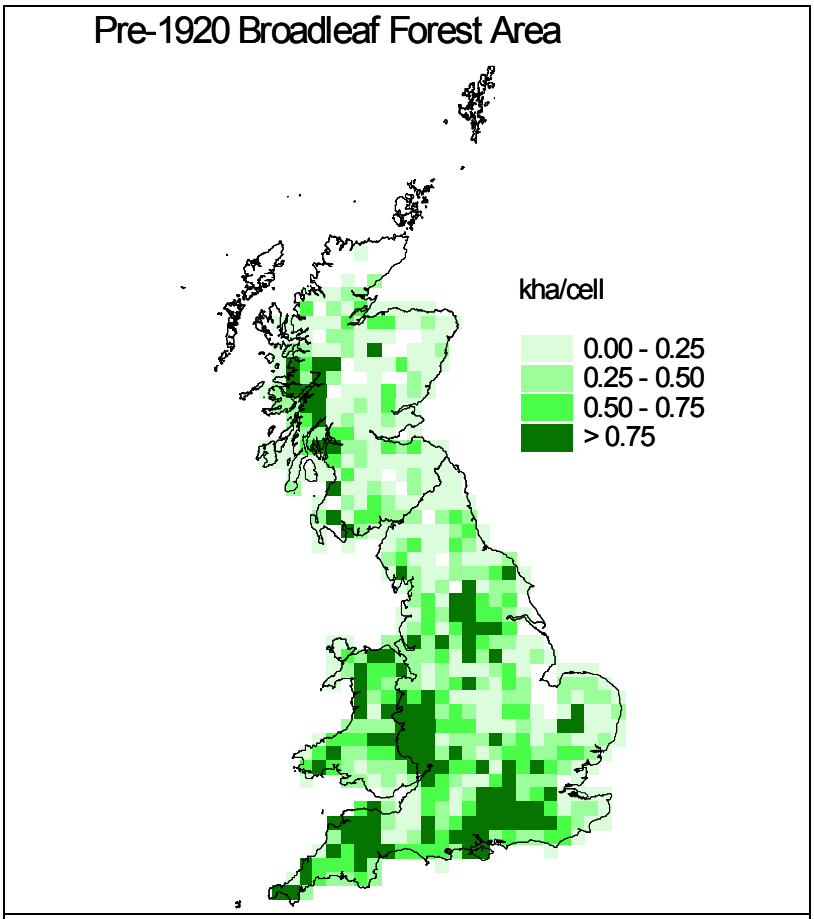

Figure 4. Distribution of broadleaf forest planted before 1920 as indicated from age data of NIWT samples.

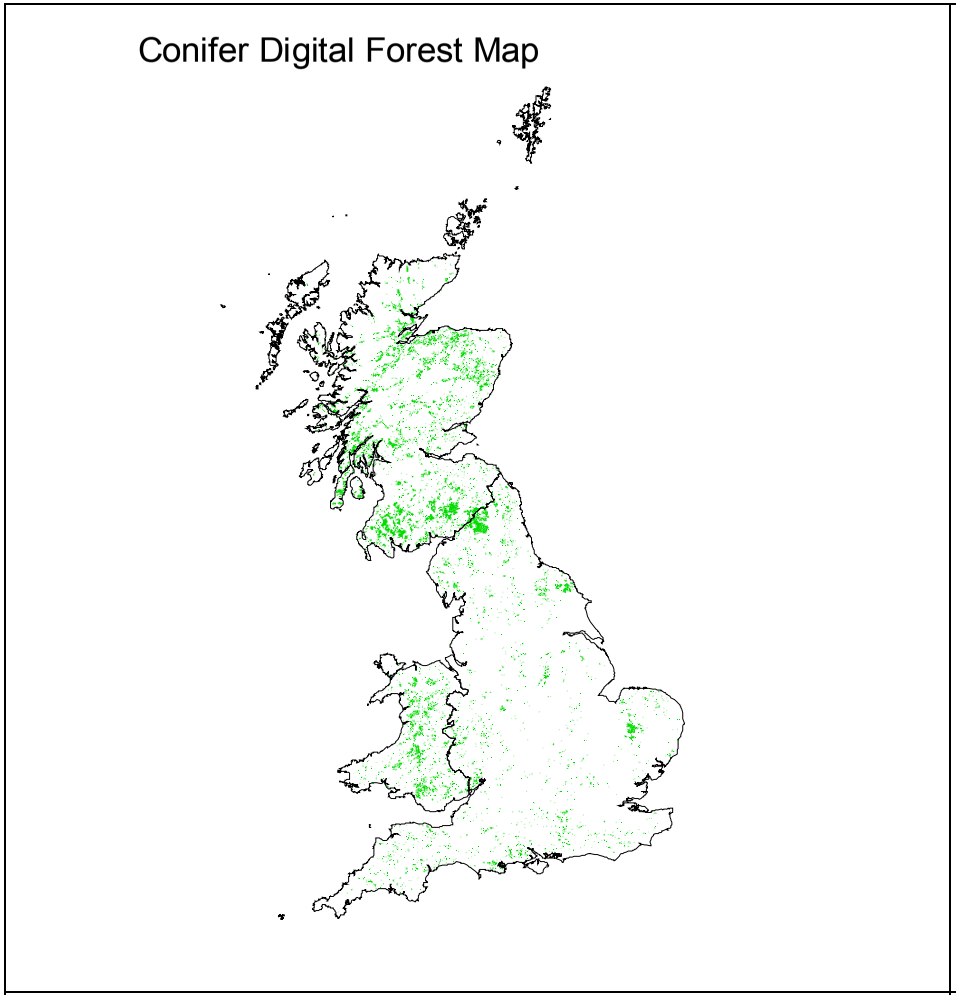

Figure 5a Forestry Commission digital map of conifer woodlands (1995)

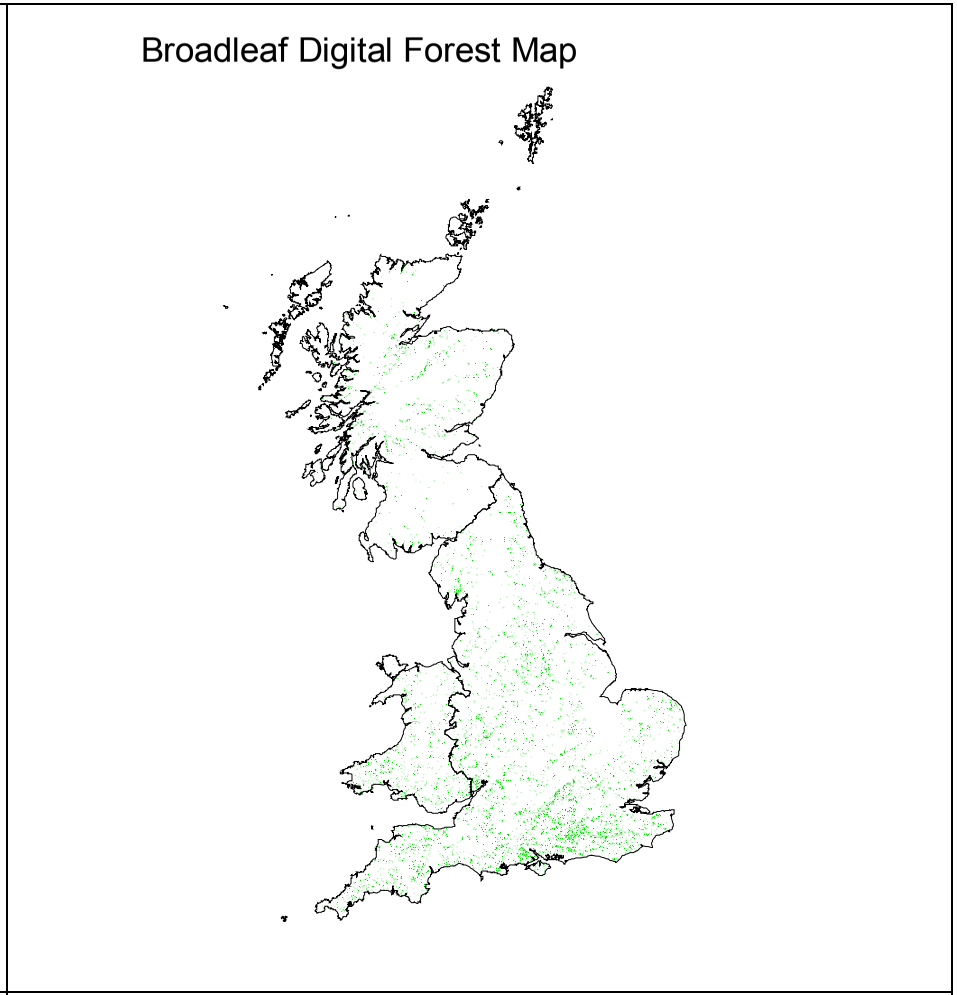

Figure 5b Forestry Commission digital map of broadleaf woodlands (1995)