7. Methodology for incorporating effects of variability in forest characteristics (WP 2.3)

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7.1 Introduction

The Forest Land category (5A) is the largest net sink in the UK's LULUCF sector and flux estimates under Articles 3.3 and 3.4 of the Kyoto Protocol are also derived from this category. The LULUCF GHG inventory and projections for forest carbon stocks currently make a range of broad assumptions relating to species composition, productivity and forest management. The aim of this work package is to investigate these assumptions in more detail. CEH's work in the first phase of the project has concentrated on the investigation of spatial variation in planting patterns under different ownership types since 1990. This has particular relevance for the estimation of carbon fluxes from Afforestation under Article 3.3 of the Kyoto Protocol. For this work package Forest Research have developed draft scenarios of forest management in the devolved regions. These include taking account of revised assumptions abut restocking of existing forests to diversify composition, improved estimates of yield class distribution by species and better representation of new forest management regimes, notably "Low Impact Silvicultural Systems".

7.2 Data sources for spatial modelling work

The activity data for estimating afforestation fluxes up to now have been annual planting statistics for each country. More detailed data sources have now become available from the various forestry agencies and can be combined together to construct forest planting time series from 1990 to 2005 at the 20km grid cell scale. Data is reported by planting year, which runs from 1st April to 31st March of the following year, i.e. a planting year of 1995 corresponds to the period 1st April 1994 to 31st March 1995.

7.2.1 Forestry Commission Sub-Compartment Database

The Forestry Commission Sub-Compartment Database (FC SCDB) contains management information (species, stocking, age etc.) for each forest compartment in the public forest estate. The Forestry Commission provided an extract of this database (actually two separate databases) with all compartment records with a planting date of 1995 onwards, identified by the 20km grid cell reference (the SQUID). The relevant attributes for this work package are the species, the planting year, the yield class, the area of the forest compartment and the rotation (whether new planting or restocking).

7.2.2 Woodland Grant Scheme

The Forestry Commission Grants and Licences section supplied annual data on planting funded by the Woodland Grant Scheme (England, Scotland and Wales 1995-2006) and the Scottish Forestry Grant Scheme (Scotland only 2003-2006). These schemes cover new planting and restocking in private woodland funded by the Forestry Commission. Grants are only paid once planting has been completed. Data is

split by coniferous and broadleaf planting (no species split available) and by NUTS4 administrative region (local authority regions).

The Northern Ireland Forest Service supplied figures for areas planted under the Northern Ireland Woodland Grant Scheme since 1996. This data on private woodland planting has only recently been transferred into GIS and there are still some teething problems with the data set. Data was split by the old county regions (Antrim, Armagh, Down, Fermanagh, Derry and Tyrone) but was not split by conifer/broadleaf planting. Data split by NUTS4 administrative region and conifer/broadleaf is being sought but has not yet become available.

7.2.3 National Inventory of Woodland and Trees

The National Inventory of Woodland and Trees (NIWT) is the most recent forest survey undertaken in Great Britain. The NIWT consists of two surveys: the Main Woodland Survey (MWS) of woods ≥2 hectares, and the Survey of Small Woodland and Trees (<2 ha). The MWS is composed of a digital woodland map (derived from 1:25 000 aerial photographs) and a ground sample survey to evaluate woodland information, such as species, age and stocking (Forestry Commission 2003). Survey fieldwork was undertaken between 1994 and 2000. A second forest inventory (NIWT2) is being developed.

The Forestry Commission supplied a version of the NIWT database that had been analysed by 20km grid cell and split by ownership into Forestry Commission and non-Forestry Commission woodland. This dataset contained woodland over 2 hectares in extent and had been updated to 2001 (J. Gilbert, pers. comm.). (The area of 1990s planting will therefore be different from those published in the original NIWT reports, which did not include the full decade of planting). There is not complete coverage of the country because some cells (coastal and parts of the Northern and Western Isles) contain no woodland and therefore have no NIWT record. There is no equivalent woodland inventory for Northern Ireland.

A distinction must be made between the establishment date and the afforestation date when using the NIWT dataset (Thomson 2006). The establishment 'date' (within a decade) for a woodland stand is inferred from the average age of its trees recorded by the NIWT sample survey. For newly planted ('afforested') woodland the establishment dates and the planting dates should be equivalent. However, it should be noted that: (1) not all woodland established within a certain decade will appear in the equivalent age class in the NIWT, due to deforestation or disturbance, and (2) the NIWT does not distinguish between new planting and restocking of woodland.

7.2.4 Comparison of data sources

The reported areas of planting in the different datasets were compared with the national new planting statistics (Table 7-1 and Figure 7-1).

It can be seen that the area of 1990s-established woodland in the NIWT exceeds that reporting in the new planting statistics for the most part, because the NIWT figures include restocking. However, the new planting statistics exceed the NIWT estimates for all private woodland planting in Scotland and private broadleaf woodland planting in England and Wales. The explanation for these differences is unknown but may be related to the different sampling dates of the NIWT in the different countries.

The FC SCDB shows similarities to the annual patterns in the new planting statistics 1995-2006 but large discrepancies during certain periods (England 2002-03, conifer planting in Scotland and Wales). Forestry Commission planting in Wales is reported as zero in the new planting statistics for much of the period.

Table 7-1: Comparison of woodland established 1991-2000 recorded in the NIWT and new forest planting 1991-2000 recorded in the national statistics. Units in hectares.

		Forestry Commission (public)		**Non-Forestry Commission (private)**	
		Broadleaf	*Conifer*	*Broadleaf*	*Conifer*
England	*NIWT*	3 680	13 541	22 395	10 091
	NP statistics	165	290	41 165	6 403
Scotland	*NIWT*	1 709	24 071	7 754	18 533
	NP statistics	987	10 770	43 607	61 835
Wales	*NIWT*	1 282	15 082	1 877	2 675
	NP statistics	18	82	3 911	1 275

The WGS database matches well with the new planting statistics for England and Wales for 1996-2006. There are differences between the WGS and new planting statistics for Scotland during the earlier part of the period (although the pattern of planting is the same) but the areas agree from 2004 onwards.

7.3 Methods for spatial modelling work

The woodland planting datasets were harmonised so that they all had the same 20km cell reference system. The FC SCDB and NIWT data were already in this format, and the WGS data was converted into 20km grid cell data by proportional assignment and summation in ArcGIS. The Northern Ireland data will be re-analysed in the same way when the geographic data becomes available. A Matlab script was written to extract all records of planting between 1990 and 2000 from the NIWT dataset.

The proportion of new planting within the total NIWT planting area had to be estimated. The split between new planting and restocking in broadleaf woodland is similar for all woodland and for private woodland alone for England, Scotland and Wales. However, there is a difference in the split for conifer woodland between all woodland and private woodland alone. The proportional splits also vary over time. The estimated split by species type and ownership type for the NIWT 1990/91-1994/95 data was assumed to be the same as the average proportional split 1995/96-1999/2000 for the FC SCDB and WGS data (Table 7-2).

Table 7-2: Ratios between new planting and restocking 1995/96-1999/2000

	FC forest, New planting: Restocking		**Non-FC forest, New planting: Restocking**		**All forest New planting: Restocking**	
	Broadleaf	*Conifer*	*Broadleaf*	*Conifer*	*Broadleaf*	*Conifer*
England	16:84	2:98	77:23	45:55	75:25	18:82
Scotland	20:80	9:91	83:17	71:29	80:20	51:49
Wales	11:89	6:94	61:39	20:80	56:44	5:95
N.Ireland					76:24	47:53

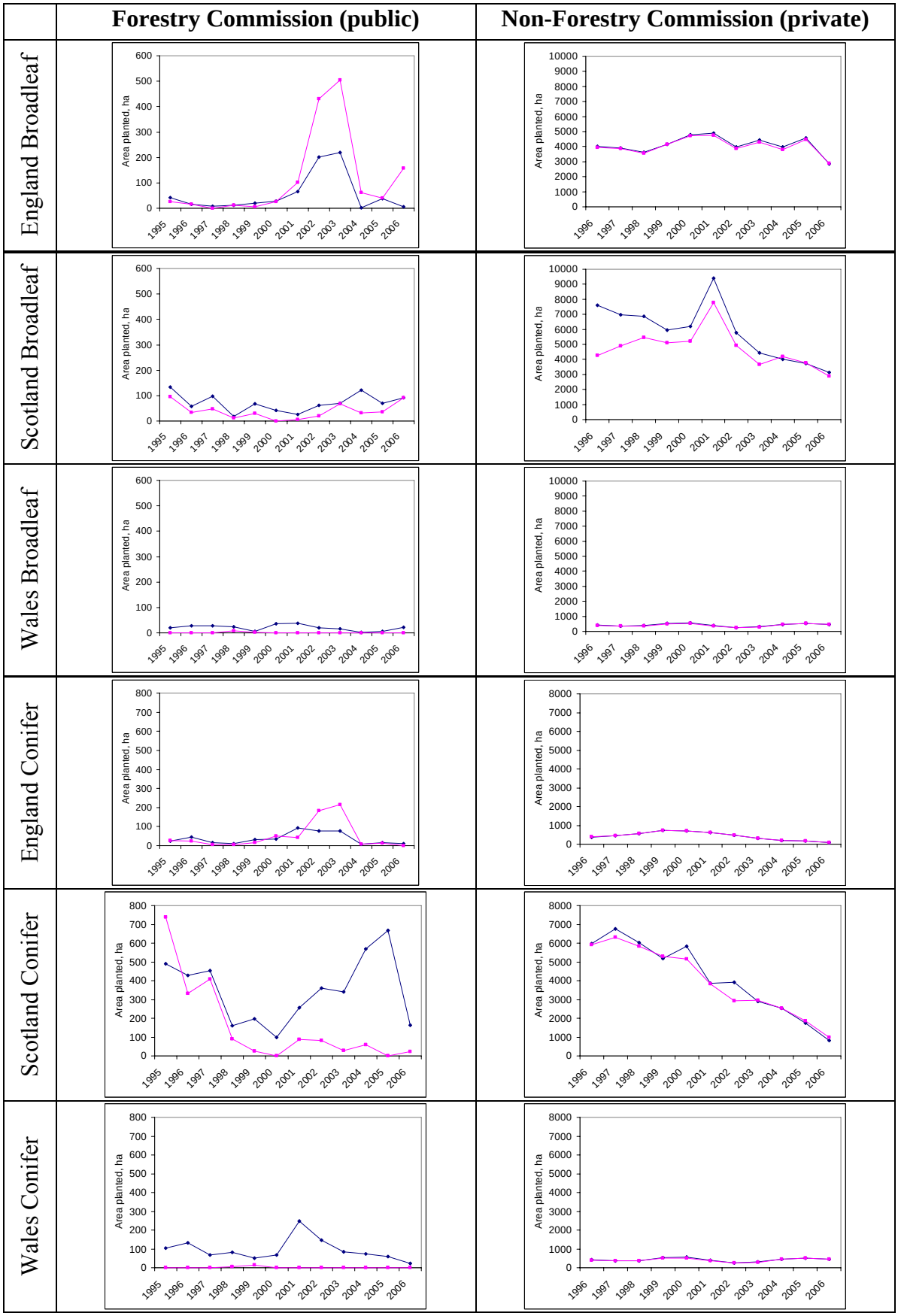

Figure 7-1: Area of new planting from FC SCDB and WGS databases (blue) vs. national afforestation statistics (pink).

There is insufficient confidence in the NIWT absolute values for planting at this time to justify their replacing of the national planting statistics for 1990-1995. However, the NIWT does give the distribution of forest planting and the relative proportions of broadleaf and coniferous planting, and of FC and non-FC planting in each square (but not the relative proportion of new planting and restocking). The FC SCDB and WGS give the species and ownership distribution of new planting and restocking from 1995 onwards. The reported numbers are in reasonable agreement with the national FC planting statistics but there are still some areas of concern. Until these data issues have been resolved the planting areas from each data set will be weighted by country so that they match the country reported total in the FC national statistics.

Separate tables of new planting were created for each year and species type (coniferous or broadleaf). Two sets of tables were produced: one for results by planting year (1st April-31st March), as used in the UNFCCC GHG inventory, and the other for results by calendar year (1st January -31st December).). This is to take account of the fact that the Kyoto Protocol strictly runs from 1st January 1990. The adjusted values for calendar year planting for 1990 for example are calculated by

*(Area in planting year 1990 * 0.25) + (Area in planting year 1991 * 0.75)*

There are minimal differences between the two datasets. The datasets were formatted so that they could be used in the ArcGIS geographic information system using the SQUID as the common attribute for joining datasets.

7.4 Results of spatial modelling work

Planting datasets for new planting in Great Britain split by ownership and broadleaf/conifer for 1990 to 2005 are now available. Example maps of planting in 1990 by ownership and cumulative planting 1990-2005 are shown in Figure 7-2 and Figure 7-3. These datasets can be used in the C-Flow model to produce estimates of carbon fluxes from afforestation at the 20km grid scale. This will help to achieve the UK's aim of reporting activities under Article 3.3 of the Kyoto Protocol at the 20km grid scale.

7.5 Future objectives of spatial modelling work

- Adaptation of the C-Flow model to use spatially disaggregated inputs
- Estimation of split in conifer planting between organic and mineral soils at the 20km grid cell scale
- Harmonisation of the Northern Ireland planting data with the other datasets
- Further analysis of the differences in planting patterns under public and private ownership and an investigation of the impact that this has on carbon fluxes
- Development of the methodology for pre-1990 planting (for estimation of carbon fluxes from Forest Management activities under Article 3.4 of the Kyoto Protocol).

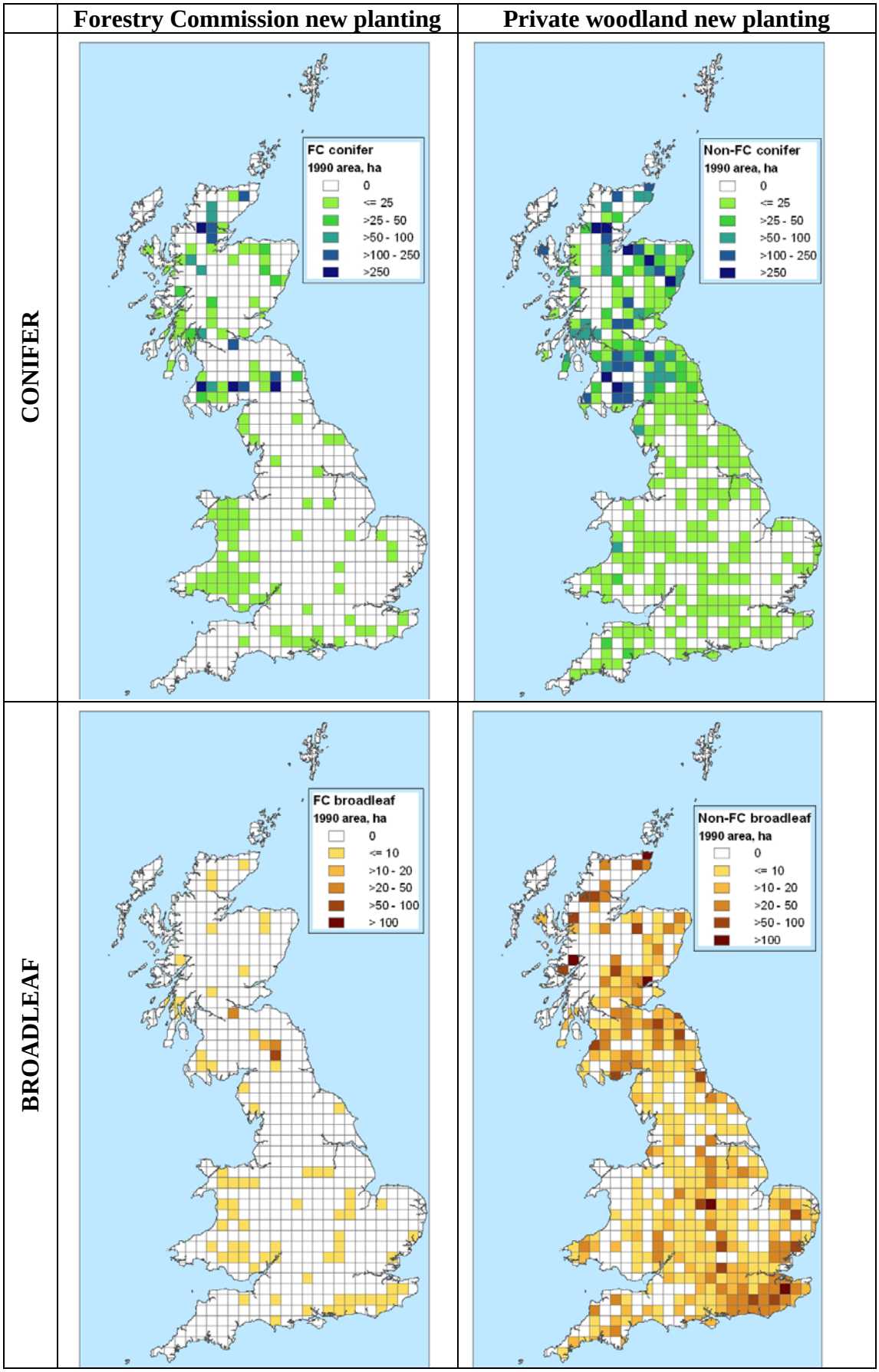

Figure 7-2: New planting in 1990 split by ownership and broadleaf/conifer

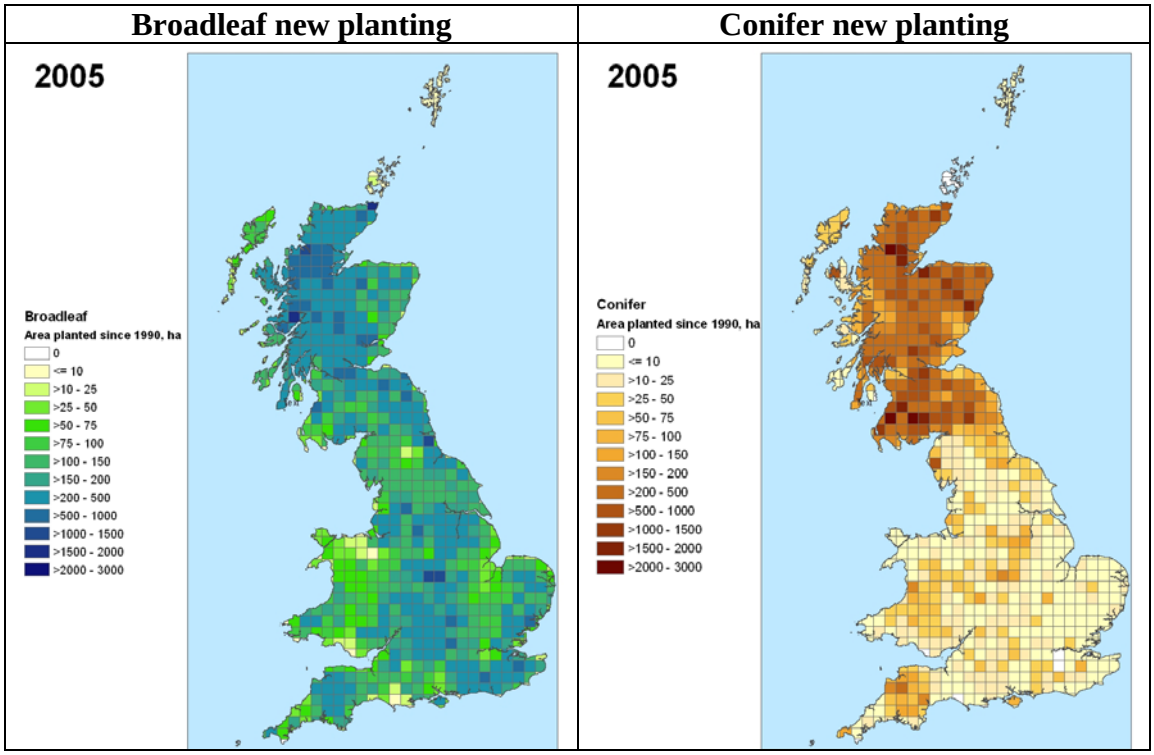

Figure 7-3: Cumulative new planting in Great Britain 1990-2005

7.6 The Production Forecasting Exercise in the Forestry Commission

Forests represent a significant carbon stock. If carbon sequestered within forests is to be estimated accurately (see chapter 8, WP2.4), then there is a fundamental requirement for a database of forest areas and stand composition, and a reliable approach to forecasting how forest species and composition may change over time.

The UK Forestry Commission (FC) uses a methodology for Production Forecasting (PF) (Forestry Commission, 2004), which is calculated every year, and formally published for softwoods every 5 years [PFs for private estates are calculated and published on a 5-yearly basis]. Currently about 57% of UK forest is softwood, accounting for 94% of production (Forestry Commission, 2006). The most recently published (2005) PF covers softwood availability from the Forestry Commission (Great Britain), the Forest Service (Northern Ireland) and potential softwood availability from the Private Sector (United Kingdom). The 2005 PF and a comparison with the 2000 PF forms the basis of milestone WP2.3:II and contributes to a better understanding of potential impacts of uncertainty in inventory data and management information on estimates of carbon stocks. Longer term scenarios may be used, incorporating changes in management, species and composition (WP2.3). PFs for hardwoods are also carried out, though these are not published so formally.

7.6.1 Developments in the 2005 PF

The PF in 2005 represented a major revision of 2000 improving representation of the forest estate and its management through:

- More complete and accurate stand data
- More comprehensive management plans
- Appropriate representation of intended management

More complete and accurate stand data.

An example from the Private Sector forecast for Scotland can be used to demonstrate how this has been achieved. The distribution of yield classes has changed substantially between the 2000 and 2005 exercise. The primary reason for this change is largely due improved assumptions about the yield class distribution in private woodlands (Figure 7-4), as discussed in Halsall *et al* (2006).

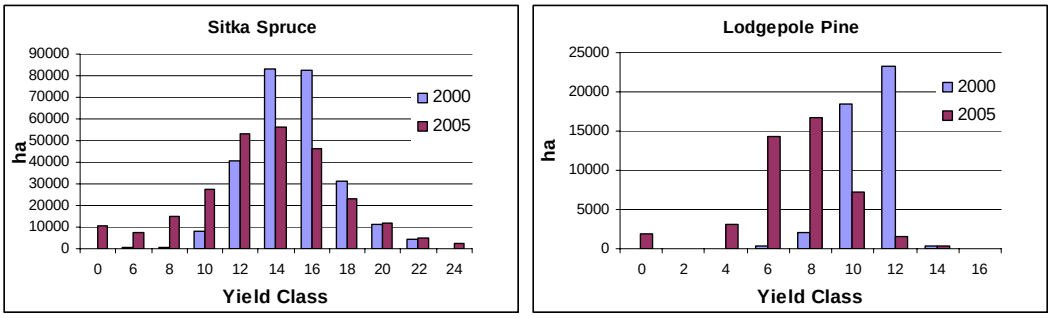

Figure 7-4: Comparison of yield class distribution in the Scottish Private Sector PFs in 2000 and 2005. The two example species (Sitka spruce Lodgepole pine) represent about 58% and 10% respectively of the Private Sector PF woodland in Scotland.

More comprehensive management plans - Restocking species changes

Tree species being selected for restocking felled areas are undergoing major changes. Much of the coniferous forest is being diversified. In the case of England, the diversification involves significant emphasis on broadleaf species. Table 7-3 shows the indicative re-stocking prescription in North England. In the Private Sector these prescriptions are encouraged by the use of planting grants. PFs can be run to account for replacing the current coniferous forest with the broadleaf trees, and also to account for management involving greater areas of open ground.

Evolving forest management

Increasingly, the management of forests is changing to address new policy-driven, commercial and environmental objectives. In practice many areas of forest are now being managed according to “Low Impact Silvicultural Systems” (LISS). These low impact systems include shelterwood and selection silviculture, minimum intervention and ‘biological retentions’.

For example, The Welsh Assembly has directed the Forestry Commission to change its restocking policy and to accelerate the delivery of LISS in FC woodlands throughout Wales (FC Wales National Committee, 2003). Table 7-4 summarises the position in the Assembly Woodlands in 2005. In future years, the amount of woodland managed under LISS will increase. Note that the PF area is not the same as the land area; it includes High forest, understorey and windblow areas where production is deemed practical and economic, but does not include felled, coppice or intruded broadleaves.

Table 7-3: Indicative re-stocking prescription for coniferous forests in North England (as assumed in the 2005 PF)

Species felled	YC felled	Restock prescription
SP	<= 8	10% to open ground, 45% to broadleaves, remainder as SP
SP	>= 10	10% to open ground, 27% to broadleaves, 18% to JL/HL, 18% to CP, remainder stays as SP
CP		10% to open ground, 27% to broadleaves, remainder as CP
LP		50% to not restocked/broadleaves, remainder convert to SS
SS	<= 8	10% to open ground, 90% BI
SS	>= 10	10% to open ground, 18% broadleaves, remainder as SS
NS		10% to open ground, 25% broadleaves, 27% to SS, 9% to DF, remainder stays as NS
EL		10% to open ground, 45% broadleaves, 23% to SP, 22% to JL/HL
JL/HL	4, 6, 8	10% to open ground, 50% broadleaves, 18% to SS
JL/HL	>= 10	10% to open ground, 36% broadleaves, 18% to DF, 18% to SS, remainder stays as JL/HL
DF	<= 10	10% to open ground, 60%broadleaves, 15% to SS, remainder stays as DF
DF	>= 12	10% to open ground, 18% broadleaves, remainder stays as DF
XC		10% to open ground, 54% broadleaves, 18% to SP, 18% to SS
MC		10% to open ground, 45% broadleaves, 9% to SS, 18% to SP, 18% to JL/HL

SP: Scots pine; JL/HL: Japanese larch/Hybrid larch; CP: Corsican pine; LP: Lodgepole pine; SS: Sitka spruce; BI: Birch; NS: Norway spruce; DF: Douglas fir; EL: European larch; XC: other conifers; MC: mixed conifers.

Table 7-4: Summary of areas in Welsh Assembly Woodlands managed according to traditional and LISS regimes

	District Area (ha)	PF area (ha)	LISS area (ha)	LISS of PF (ha)
Coed y Cymoedd	30430.9	18930.5	7645.8	5471.4 (28.9%)
Coed y Mynydd	38862.8	22984.6	8518.6	5512.9 (24.0%)
Coed y Gororau	22730.9	16398.2	6427.0	5289.4 (32.1%)
Llanymddfri	35987.8	25359.7	9581.6	6422.5 (25.3%)
Total	128012.4	83673.0 (65.4%)	32173.0	22676.2 (27.1%)

Note that the PF area is not the same as the land area; it includes High forest, understorey and windblow areas where production is deemed practical and economic, but does not include felled, coppice or intruded broadleaves.

The Forestry Commission PF system permits Forest Districts to make detailed descriptions of the composition of woodlands and intended management. The 2005 PF system recognises all the major types of LISS regime and makes appropriate adjustments to forecasts.

Appropriate representation of intended management

Changing management away from the traditional to LISS regimes may have a large effect on the volumes (and carbon) produced by a forest (Figure 7-5). Managing woodland under a LISS regime may reduce or increase the carbon-stock, particularly as woodland develops over time.

For example in the 2005 PF fore the Private Sector woodlands in Wales, special yield models were developed to reflect the changes in stand management occurring as a result of the introduction of LISS. Although the primary objective was to understand potential impacts on timber production, the models also describe potential impacts on the growing stock. In Figure 7-5, the changes in carbon in merchantable stem wood is illustrated for two yield models; one based on a traditional management regime and the other on LISS. In this example, the long term average carbon stock in standing stem wood in the stand managed under LISS is more than twice the stock in the stand under traditional management.

It must be emphasised that this is just one scenario. Better understanding is needed of the potential impacts of evolving management on forest carbon stocks.

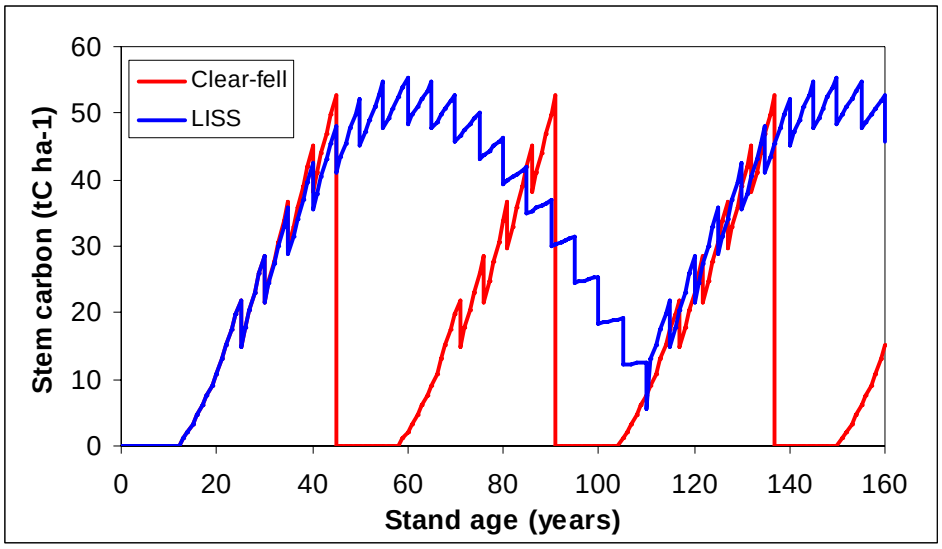

Figure 7-5: Differences in standing stem carbon in a Sitka spruce stand, Yield class 12, 2.0m spacing, managed according to a traditional thin and clearfell regime.

7.6.2 Effects of improved management and data.

The many improvements and changed assumptions in the 2005 PF have resulted in some notable changes in forecasts of timber volume availability compared to the 2000 PF, as illustrated in the results for the Private Sector in Figure 7-6.

Impacts on estimates of the growing (carbon) stock in the GB forests are likely to mirror these changes in estimates of production. The potential sensitivity of the forecast results to uncertainties in these data and assumptions about future management emphasises the requirement for a robust, verifiable forecast methodology.

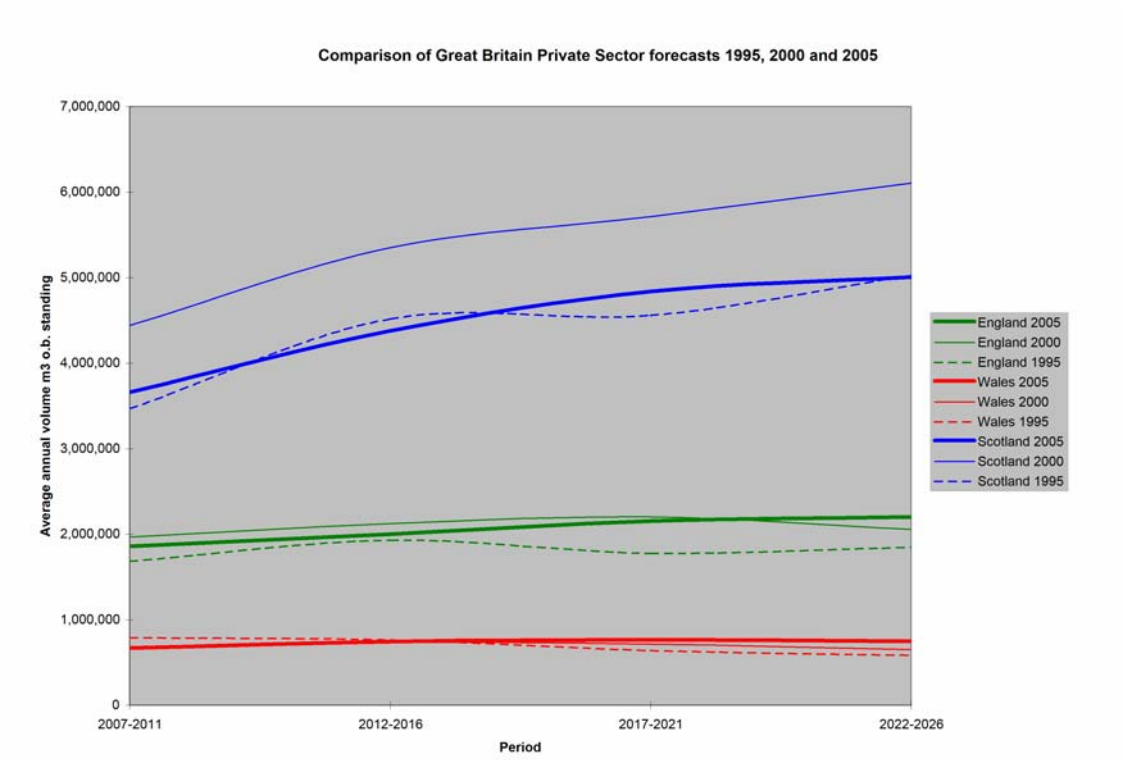

Figure 7-6: Availability of softwood timber volume in the Private Sector as forecast in 1995, 2000 and 2005 for the GB mainland.

7.6.3 Future developments

Forecasts are likely to undergo further changes as new research findings are accounted for. For example, Forest Research has recently completed the development of a new dynamic growth and yield model for Sitka spruce stands, know as M3. This model is capable of representing a much wider range of stand management regimes than was previously possible. The M3 model also suggests that estimates of stand yield class based on top height may need to be revised, although the adjustments required depends on the age of the stand when the height assessment is made. Table 7-5 give the suggested adjustments to yield classes based on the existing published yield models for Sitka spruce (Edwards and Christie, 1981) when top height is assessed at age 50.

Table 7-5: Percentage allocations of Booklet 48 ('old') General Yield Classes for Sitka spruce to M3 yield classes at a reference age of 50 years. Mean equivalent ('new') .yield classes are also shown.

Old	Allocation to M3 yield classes (per cent)													Mean new
	4	6	8	10	12	14	16	18	20	22	24	26	28	
6	8	92												5.8
8		7	93											7.9
10			25	75										9.5
12				41	59									11.2
14					41	59								13.2
16						36	64							15.3
18							24	76						17.5
20								29	54	17				19.8
22										55	45			22.9
24											34	66		25.3

The Forestry Commission has recognised a requirement to develop a more comprehensive, robust, transparent and verifiable methodology for forecasting and scenario analysis in British woodlands. Work has begun on specifying this system, beginning at a high level in terms of inputs and associated outputs. Hierarchical levels of input can be defined, in terms of the level of detail provided, with more information permitting a wider range of forecast outputs, greater detail and estimates in confidence. Four major levels, 'minimal', 'basic', 'partial' and 'complete' have been specified. The specification for 'basic' level information is summarised in Table 7-6.

There is an opportunity to achieve convergence of the FC forecast system development work with the methodology for estimating and reporting LULUCF carbon.

Table 7-6: High level specification of the forecast system for the 2010 PF exercise in terms of inputs and associated outputs (Basic level). Matthews (2006)

Inputs				**Outputs**
Basic inventory	**Prescription**	**Area change**	**Forecast variables**	
Total forest area for region of interest (conifer, broadleaf, mixed) in combination with: (%) Species distribution (%) Age class distribution [by species] (%) Yield class distribution [by species and age class].	Basic management prescription (initial spacing + non-thin, standard thin, [line thin, LISS, etc.]) in combination with fell age distribution (where appropriate) [by species, age class and yield class].	[Rules for: Restocking forest area (ha or %) in terms of species, yield class, basic management prescription and fell age (where appropriate) as areas are felled or regenerated under LISS. Loss of forest area (i.e. conversion to other land cover/uses, ha or %) [in terms of species, yield class, basic management prescription and fell age] as areas are felled or regenerated under LISS. Additions to forest area (i.e. conversion from other land cover/uses, ha or % per period) in terms of species, yield class, basic management prescription and fell age (where appropriate).]	Forecast period and intervals for reporting Availability of: [Numbers of trees Stem volume Volume of specified products Total biomass Woodfuel (to specification)]. Growing stock: [Numbers of trees Basal area (Mean) dbh Stem volume Total biomass Total carbon 'Increment' 'stand Structure'].	Totals/means of specified forecast variables for complete area and by species (groups). Forecasts based on tabular calculations. Values reported over forecast period at specified intervals. No confidence intervals.

7.7 References

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7.8 Acknowledgements

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